Engineering Design Criteria

February 2, 2023

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LIST OF APPENDICES

Record of Revisions

The following are the effective date(s) of the City of Norman Engineering Design Criteria and all approved amendments:

Amendment	Description	Effective Date

Introduction

The Engineering Design Criteria, together with the City of Norman's Standard Specifications and Construction Drawings, regulate both public improvements and private work, which will either be dedicated to or accepted by the City. In addition, all work within the public right-of-way is governed by these regulations. They are intended to provide for coordinated development with adequate facilities to serve and protect the users.

These documents are meant to provide minimum criteria and to apply rigidly to new developments which are not constrained by already existing improvements. Designers are encouraged to exceed these criteria whenever possible to provide designs that enhance the community in the future. Infill development in an urban area is often constrained when matching existing improvements. To the extent deemed possible by the City Engineer, infill developments shall be completed in accordance with these Engineering Design Criteria. However, the City Engineer may allow modification of these requirements when necessary to allow private and public construction that is compatible with surrounding in-place improvements.

These design criteria, standard specifications, and construction standards shall also be used in conjunction with the City's zoning regulations and subdivision ordinances for site development work on private property.

Definitions

Agricultural Stormwater Runoff shall mean any stormwater runoff from orchards, cultivated crops, pastures, range lands, and other non-point source agricultural activities, but not discharges from concentrated animal feeding operations as defined in 40 CFR Section 122.23 or discharges from concentrated aquatic animal production facilities as defined in 40 CFR Section 122.24 and any addition or amendment thereto.

Best Management Practice (BMP) shall mean the best available practices or devices used singly or in combination to eliminate or reduce pollution entering the MS4.

Bridge shall mean a construction with abutments and superstructures, which are typically concrete, steel, or other materials. Since the superstructures are generally not an integral structural part of the abutments, and are therefore free to move, the hydraulic criteria for bridges is different than for culverts. Bridges shall also include multi-barrel culvert structures with a span length of greater than 20 feet meeting national standards. Bridges are also usually constructed with earth or rock inverts, whereas culverts are typically the same material throughout the waterway opening.

Collector Sewer shall mean sewer pipelines with a nominal diameter of 12-inches or less and may have sewer service taps.

Commercial shall mean property devoted in whole or in part to commerce, that is, the exchange and buying and selling of commodities or services. The term shall include, by way of example but not of limitation, the following business: amusement establishments, animal clinics or hospitals, automobile service stations, new or used automobile dealerships, automobile car washes, automobile and vehicular repair shops, banking establishments, beauty and barber shops, bowling alleys, bus terminals and repair shops, camera shops, dental offices or clinics, day care centers, department stores, drug stores, funeral homes, furniture stores, gift shops, grocery stores, hardware stores, hotels, jewelry stores, laboratories, laundries and dry cleaning establishments, liquor stores, medical offices and clinics, motels, movie theaters, offices buildings, paint stores or shops, parking lots, produce markets, or professional offices, radio stations, repair establishments, retail stores, restaurants and similar establishments serving prepared food and beverages, rooming houses, shopping centers, stationary stores, television stations and production facilities, and theaters.

Confidential Information shall mean a document or information regarding or describing a process, product or information which has been determined by the City to be confidential or has been declared by a court of competent jurisdiction to be exempt from disclosure to third parties under the Oklahoma Open Records Act and any amendment or supplement thereto.

Construction Activity shall mean, but not be limited, to clearing, grading, excavation, paving, building, and other ground disturbance activities associated with the construction of public assets. Construction does not include routine maintenance performed by public agencies, or their agents to maintain original line grade, hydraulic capacity, or original purpose of facility.

Culvert shall mean a closed conduit for the passage of water under an embankment, such as a road, railroad, or driveway. Culverts are most commonly used to relieve roadside drainage ditches and to convey stormwater beneath roadways at natural stream and creek crossings.

Detention Pond shall mean the flood-control features that temporarily hold water before gradually releasing flow to a river or stream, often referred to as “Dry Ponds”. Most of the year, these structures do not contain water and only collect water during and immediately following a precipitation event. The temporary storage provided by these structures reduce peak runoff rates experienced during a precipitation event.

Discharge shall mean to cause or allow to release, spill, drain, dump, throw, empty, emit, blow or pour of any pollutants into the MS4.

Earth Change is defined as excavation, grading, regrading, landfilling, berming or diking of land.

Erosion and Sediment Control Plan shall mean a written plan, including drawings or other graphic representations, for the control of soil erosion and sedimentation resulting from a land disturbing activity.

Flood Fringe shall mean the area between the floodway boundary and limit of the 100-year floodplain. The Flood Fringe encompasses the portion of the floodplain that could be completely obstructed without increasing the water surface elevation of a 100-year flood event more than 1-foot at any point.

Floodplain Area shall mean the area defined by the 1% chance of a regulatory flood event.

Floodway shall mean the channel of a river or other watercourse and the adjacent land areas that must be reserved in order to discharge the base flood without cumulatively increasing the water surface elevation more than a designated height.

Full Urbanization shall mean the total anticipated development within the project boundaries.

Hazardous Substance shall mean any substance listed in Table 3002.4 of 40 CFR Part 302 and any amendment or addition thereto.

Hazardous Waste shall mean any substance identified or listed as a hazardous waste by the EPA pursuant to 40 CFR Part 261.

Illicit Discharge shall mean any discharge to the MS4 not composed entirely of stormwater, except discharges authorized under an OPDES or NPDES permit (other than the OPDES permit for discharges from the MS4) and discharges resulting from firefighting activities.

Illicit Connection shall mean any drain or conveyance, either surface or subsurface which allows an illicit discharge to enter the MS4.

Industrial shall mean a business engaged in manufacturing or productive enterprise or a related service business. This term shall include, by way of example but not of limitation, the following: salvage yards, wrecker services, apparel and fabric finishers, blast furnace, boiler works, cold storage plants, contractors plants and storage facilities, foundries, furniture and household good manufacturing, forge plants, greenhouses, junk yards, manufacturing plants, metal fabricating shops, ore reduction facilities, planning mills, rock crushers, rolling mills, saw mills, smelting operations, stockyards, stone mills or quarries, textile production, utility transmission or storage facilities, warehousing, and wholesaling facilities.

Industrial Activity shall mean any activity which is directly related to manufacturing, processing, or raw materials storage areas at an industrial facility. The term includes, but is not limited to, industrial plant yards; immediate access roads and rail lines used or traveled by carriers of raw materials, manufactured products, waste material, or by-products used or created by the industrial facility; sites where material handling activities are performed; refuse sites; sites used for the applications or disposal of process wastewaters; sites used for the storage and maintenance of material handling equipment; sites used for residual treatment, storage or disposal; shipping and receiving areas; manufacturing buildings; storage areas (including tank farms) for raw materials, and immediate and finished products.

Industrial Facility or Industry shall mean a premise(s) whose function is classified in the latest edition of Standard Industrial Classification Manual, (United States Office of Management and Budget).

Industrial Stormwater Discharge Permit shall mean a permit regulating regular discharges from facilities who may control any conveyance which is used for collecting and conveying stormwater and which is directly related to material storage, fueling, handling, and processing areas at an industrial plant.

Industrial Waste shall mean any airborne particulates, waterborne liquid or solid substance that results from any process of industrial, manufacturing, mining, production, trade, or business activities, including concrete washout.

Institutional shall mean an established organization, especially of a charitable or public character. This term shall include, by way of example but not of limitation, the following: churches, community buildings, colleges, day care facilities, dormitories, drug or alcohol rehabilitation facilities, fire halls, fraternal organizations, golf courses and driving ranges, government buildings, hospitals, libraries, kindergartens or preschools, nursing homes, mortuaries, schools, social agencies, synagogues, parks, and playgrounds.

Interceptor Sewers shall mean sewer pipelines with a nominal diameter of greater than 12-inch and may not have sewer services taps.

Manufactured Systems shall mean commercial products that typically aim at providing stormwater treatment in space-limited applications.

Material Handling Activities shall mean the storage, loading and unloading, transportation or conveyance of any raw material, immediate product, finished product, by-product or waste product.

Monitoring shall mean the performance of stormwater flow measurements, stormwater sampling, sample analysis, and like procedures necessary to determine compliance with stormwater discharge activity.

Motor Vehicle Fluid shall mean any vehicle crankcase oil, antifreeze, transmission fluid, brake fluid, differential lubricant, gasoline, diesel fuel, gasoline/alcohol blend, and any other fluid used in, or from within, a motor vehicle.

Multi-family Residential shall mean an apartment building or other residential structure built for three or more family units, mobile home parks with three or more units or lots under common ownership, and condominiums of three or more units.

Municipal Separate Storm Sewer System (MS4) shall mean a conveyance or system of conveyances (including streets, curbs, gutters, storm drains, catch basins, natural and man-made channels and ditches) owned by the City of Norman and designed for collecting and conveying stormwater.

National Pollutant Discharge Elimination System (NPDES) Permit shall mean a permit issued by EPA (or by the State under authority delegated pursuant to 33 U.S.C. § 1342 (b)) that authorizes the discharge of pollutants to waters of the United States, whether the permit is applicable on an individual, group, or general area-wide basis.

Non-point Source shall mean any source of any discharge of a pollutant that is not a "point source."

"Notice of Intent" (NOI) shall mean a written notice by a discharger or potential discharger to the Director, or his designee, that the person wishes his discharge to be authorized under a general permit authorized by State law or regulation.

"Notice of Termination" (NOT) shall mean a written notice by a discharger to the Director of the Department of Public Works, or his designee, that the project permitted has 70 percent re-vegetation of all bare areas and all soil disturbing activities are concluded, allowing the termination of the permit issued under this section, or the discharger is no longer the operator of the facility and another has assumed the responsibility and filed a NOI.

Person shall mean any individual, partnership, co-partnership, firm. Company, corporation, association, joint stock company, trust, estate, governmental entity or any other legal entity or their legal representatives, agents or assigns.

Pipe depth or depth of cover shall mean the difference between the finished grade elevation and the top of the pipe.

Point Source shall mean any discernible, confined and discrete conveyance including, but not limited, to any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation, landfill leachate collection system, vessel or other floating craft from which pollutants are or may be discharged.

Pollutant shall mean any dredged spoil, solid waste, incinerator residue, sewage, garbage, sewage sludge, munitions, chemical wastes, biological materials, radioactive materials, wrecked or discharged equipment, rock, sand, cellar dirt, soil, sediment, building materials, industrial or agricultural waste.

Pollution shall mean the presence in or introduction into the environment of a substance or thing that has harmful or poisonous effects.

Pollution Prevention Plan shall mean a written site-specific plan to eliminate or reduce and control the pollution of stormwater through designed facilities, sedimentation ponds, natural or constructed wetlands, and Best Management Practices.

Premises shall mean any plot or tract of property, regardless of size or plat, owned or used by any person.

Release shall mean any spilling, leaking, pumping, pouring, emitting, emptying, discharging, injecting, escaping, leaching, dumping, or disposing into the Municipal Separate Storm Sewer System (MS4), Waters of the State, or the Waters of the United States.

Retention Pond shall mean the flood-control features that maintain a volume of water year-round. Retention ponds are often referred to as “Wet Ponds”. The amount of water within these ponds fluctuates based on the amount of precipitation and runoff that an area experiences.

SIC Code shall mean Standard Industrial Classification Code of Executive Office of the President of the United States, Office of Management and Budget.

Significant Spills shall mean the inclusion of but not limited to releases of oil or hazardous substances in excess of reportable quantities under section 311 of the Clean Water Act (see 40 CFR 110.10 and CFR 117.21) or section 102 of CERCLA (see 40 CFR 302.4) and any amendment or addition thereto.

Solid Waste shall mean any garbage, rubbish, refuse, municipal solid waste, sludge from a waste treatment plant, water supply treatment plant, or air pollution control facility, and other discarded material, including solid, liquid, semi-solid, or contained gaseous material resulting from industrial, municipal, commercial, mining, agricultural operations, community and institutional activities, including metal shavings, plastic pellets, paint chips, carpet fibers, wood chips, sawdust, grass clippings and leaves.

Spills shall mean any release that, in the opinion of the Director of Public Works or their Designee, negatively impacts the quality of water within or discharges from the City's municipal separate storm sewer system or causes damaging or deleterious effects to the City's municipal separate storm sewer system including all structures or appurtenances, and/or the waters to the storm sewers.

State shall mean the State of Oklahoma.

Stormwater shall mean any flow occurring during or following any form of natural precipitation and resulting therefrom.

Stormwater Control Measures shall mean stormwater runoff treatment systems. SCMs are also commonly known as best management practices (BMPs). These are engineered facilities designed to reduce and/or treat stormwater runoff, which mitigate the effects of increased stormwater runoff peak rate, volume, and velocity due to urbanization.

Stormwater discharge associated with industrial activity shall mean stormwater from areas of industrial activity or areas where industrial activity has taken place in the past and significant materials remain and are exposed to stormwater.

Stormwater Management shall mean the collection, conveyance, storage, treatment and disposal of stormwater runoff in a manner to meet the objectives of this article and its terms, including, but not limited to measures that control the increased volume and rate of stormwater runoff and water quality impacts caused by man-made changes to the land.

Stormwater Management Program or SMP shall mean the set of drawings and other documents that comprise all of the information and specifications for the programs, drainage systems, structures, SCMs, concepts, and techniques for the control of stormwater and which is incorporated as part of the NPDES permit for the City, and as part of this article.

Streets shall mean earthwork, subgrade, base course(s), wearing surface, concrete curb and gutters, proper backfill, and proper drainage structures, including storm sewers, stormwater control measures (SCMs) and inlets that work as a system to support the design traffic loading over the prescribed design life.

Toxic Pollutant shall mean any pollutant or combination of pollutants listed as toxic in 40 CFR Part 401 promulgated by the Administrator of the Environmental Protection Agency under the provisions of 33 U.S.C. § 1317 and any amendment or addition thereto.

Uncontaminated shall mean not containing a harmful quantity of any substance.

User shall mean any source of direct or indirect discharge to the City of Norman Municipal Separate Storm Sewer.

Water of the State (or water) shall mean any groundwater, percolating or otherwise, lakes, bays, ponds, impounding reservoirs, springs, rivers, streams, creeks, estuaries, marshes, inlets, canals, inside the territorial limits of the State, and all other bodies of surface water, natural or artificial, navigable or non-navigable, and including the beds and banks of all water courses and bodies of surface water, that are wholly or partially inside or bordering the State or inside the jurisdiction of the State.

Waters of the United States shall mean all waters which are currently used, were used in the past, or may be susceptible to use in interstate or foreign commerce including all waters which are subject to the ebb and flow of the tide; all interstate waters, including interstate wetlands; all other waters the use, degradation, or destruction of which would affect interstate or foreign commerce; all impoundments of waters otherwise defined as Waters of the United States under this definition; all tributaries of waters identified in this definition; all wetlands adjacent to waters identified in this definition; and any waters within the Federal definition of "Waters of the United States" at 40 CFR § 122.2; but not including any waste treatment systems, treatment ponds, or lagoons designed to meet the requirements of the Federal Clean Water Act.

Water Quality Protection Zone (WQPZ) shall mean a vegetated strip of land in the Lake Thunderbird watershed and its adjacent wetlands, floodplains, or slopes that is comprised of the stream bed and areas adjacent to the stream bed and the distance of which is determined by the Water Quality Protection Zone Design Standards found in Section 19-411(B), (C), and (D) of the Code of the City of Norman.

Water Quality Volume (WQV) shall mean the minimum volume of stormwater runoff from the contributing drainage area to the control for treatment

Design Criteria

1000: GENERAL

1001 STANDARDS AND SPECIFICATIONS

1001.1 All plans are reviewed to determine the future effect on the proposed site and adjacent area development. During the plan review, the impact on City and City-operated facilities will be considered.

1001.2 All criteria within the specifications shall be met unless the Engineer of Record submits the proposed changes and justification to the City Engineer for approval.

1001.3 Any work not covered by the adopted engineering design criteria or standard specifications shall be submitted for approval. The Engineer of Record shall submit the design, specifications, and/or special provision with his first submittal for review and acceptance by the City Engineer.

1001.4 Review and acceptance of plans by the City does not release the Consulting Engineer, Architect, or Contractor from his professional responsibility as stated within the by-laws of the Oklahoma State Board of Licensure for Professional Engineers and Land Surveyors

1001.5 The Contractor must keep a set of approved construction plans on the job site at all times.

1001.6 All construction plans and reports shall be signed, sealed and dated by a Professional Engineer registered in the State of Oklahoma prior to plan submittal.

1001.7 All pay items shall be increased to the next full unit, and the method of measurement listed in the proposal as the basis for payment.

1002 DRAFTING AND GIS

1002.1 Submittals to the City shall be completed in an electronic and paper format. The electronic format shall include pdf files and CAD files in a format compatible with the City's GIS system. The paper format shall be submitted per the requirements defined in the subdivision regulations.

1002.2 Standard sheets shall be 24" x 36", having a margin of 1.5" along the left border and 0.5" along the top, bottom, and right borders.

1002.3 All project drawing packages shall have a cover sheet containing the project title, project location with location map, project owner's name, address, telephone number, and contact person, if not the owner, Engineer of Record name, address, and telephone number, drawing index and legend.

1002.4 The cover sheet shall not be used for a plan sheet. The package must also include an overall plan sheet showing proposed improvements with sufficient labeling for reference to plan and/or profile sheets.

1002.5 The cover sheet shall be sealed. The CA number and the expiration dates must be shown on the cover sheet.

1002.6 North shall be oriented to the top or right-hand side of all plan sheets. The north arrow shall not be pointed down.

1002.7 A Title Block shall be located in the lower right-hand corner or right side of each sheet and shall include the project title, Owner's and Engineer's name, drawing description, page number, project number (if required), and date.

1002.8 The scale shall not be less than 1": 50' horizontal and 1": 5' vertical on plan and profile sheets. The minimum scale shall be 1" = 100' on plan sheets. Larger scales may be required where conditions warrant. Plans must include a scale bar so they may be scaled if not reproduced at the exact size as the original.

1002.9 All line work and text shall be of sufficient density to be reproducible by current reproduction processes. Any line work which does not reproduce satisfactorily may be cause for rejection of the plans by the City.

1002.10 Proposed improvements shall be shown darker to be distinguished from existing improvements.

1002.11 All lettering shall be at least 0.12” high and 0.10” width per letter except mechanical lettering on plats or records reproduced in the plans may be 0.10” high and 0.10” width. All lettering must be legible at half size.

1002.12 All base maps shall be referenced to existing land lines (section corners, etc.). Property lines, right-of-way, easements, building lines, etc. shall be located and dimensioned.

1002.13 No public improvements shall be installed without the dedication of right-of-way or appropriate easements. These easements shall be submitted for review and acceptance prior to filing. Easements will be filed by the City.

1002.14 All structures (manholes, junction boxes, etc.) shall be numbered and labeled both in plan and in profile and detailed on plans.

1002.15 Waterlines, sanitary sewer mains, and storm sewer lines shall be identified on both plan and profile sheets.

1002.16 Drawings shall show all obstructions existing and proposed, above and below ground. These shall be located vertically and horizontally. The Engineer of

Record shall be responsible for contacting ALL utilities to obtain locations of their facilities. This also applies to various affected pipeline companies. The City is not responsible for the location and depth of buried obstructions. "Potholing" or excavation should be performed to verify depth or location of obstructions at no expense to the City.

1002.17 Drawings shall show existing and proposed elevations of the proposed site improvements and alterations after construction.

1002.18 A list of construction pay items and an estimate of quantities shall be shown on the plans.

1002.19 Upon completion of construction, the Engineer of Record will furnish the City Engineer's office as-built drawings incorporating changes made during the construction process. The Contractor is responsible for maintaining an as-built drawing on-site at all times to be verified by the Engineer of Record and city personnel. The as-built drawings are to be certified and sealed by a Professional Engineer. The as-built drawings shall include the following:

A. Retaining Walls, and other physical site improvements (cross-sections may be necessary to detail these features).

B. Driveway grades.

C. Existing grade elevations at: the rear lot corners, the top of curb at the front lot line extension, the center of the lot at the building line or set-back line.

D. All drainage features within the lots shall be surveyed.

E. Lot drainage arrows.

F. Existing pad and proposed finished floor elevations. Grade breaks and slopes 3:1 or greater.

1002.20 Deviations from the approved Site Grading Plan must be reviewed and accepted by the City Engineer or designee to:

A. Revise pad elevation.

B. Revise finished floor elevation.

C. Change drainage flow direction.

D. Revise other significant proposed features.

1002.21 The Engineer of Record will submit as-built drawings in electronic format to the City. The format will be in PDF and CAD files compatible with the city GIS requirements.

1003 BENCHMARKS

1003.1 All development must be tied to two City of Norman control points. The City of Norman control point locations and information can be found at: **https://www.arcgis.com/apps/webappviewer/index.html?id=700e9d6a402f4772aa750d6d72e928b4**

1003.2 All elevations shown on the plans shall be based on NAVD 88 level datum.

1003.3 Horizontal coordinates shall be on the basis of the NGS Oklahoma State Plane Coordinate System, South Zone (3502) NAD 83, latest revision.

1003.4 The permanent benchmark location and description used to extend level datum to the projects shall be noted on the plans.

1003.5 All temporary benchmarks used for control of the project shall be designated on the plans stating elevation, location, and description. The nearest such benchmark shall be shown on each sheet.

1003.6 A permanent benchmark shall be established on the project. This permanent benchmark will meet the Oklahoma State Board of Engineers and Land Surveyors' requirements for a permanent benchmark. The cap shall read "City of Norman Benchmark" together with a letter and/or numerical designation assigned it by the City Engineer's office from the master file of benchmarks maintained by the City Engineer's office. The location, description, and elevation of the permanent benchmarks shall be shown on the front sheet of the plans and final plats.

1003.7 Permanent benchmark data shall be provided in electronic format to be incorporated within the City's GIS system.

1004 INITIAL SITE GRADING PLAN

1004.1 Present site conditions:

A. Existing site topography extending a minimum of 50 feet past property limits with contour lines (1' maximum interval) shall be provided. In some cases 0.5' intervals may be necessary.

B. Existing features:

1. Easements and rights-of-way.
2. All utilities.
3. Drainage ways with 1% chance floodplain and floodway limits.
4. Buildings, fences, retaining walls, and other physical features .
5. Spot elevations at perimeter lot lines.
6. Storm drainage structures and off-site drainage.

7. All existing above ground features.

1004.2 Proposed site conditions:

A. Drainage flow arrows.

B. Proposed topography at a maximum of one (1) foot contour intervals.

C. Proposed improvements:

1. Sidewalks, bike paths, and other public improvements.
2. Storm drainage structures and off-site drainage.
3. Top of curb elevation at each 100-foot station.
4. Retaining walls that are 3 feet high or higher.
5. Pad and proposed finished floor elevations.
6. All ADA site features.
7. Any other significant improvements/site features that are not otherwise listed above.

D. The stormwater runoff from no more than 3 lots or ½ acre (whichever is less) shall be allowed onto another lot or between 2 lots. If more lots or area needs to be drained, then an underground storm sewer shall be required.

E. Maximum slopes.

1. For utility easements 6:1.
2. For lots in urban areas 3.5:1.

F. All drainage areas shall be clearly marked on the drainage area plan sheet; showing acreage, runoff and off site pickup points.

1004.3 Erosion Control: A Sediment and Erosion Control Plan shall include plans for both pre- and post-construction. These plans shall be prepared and submitted for review and approval by the Stormwater Program Manager or City designee.

1005 EARTH CHANGE PERMIT

1005.1 A written permit shall be issued by the Stormwater Program Manager, City Engineer, or designee prior to any person, firm, or corporation initiating an earth change.

1005.2 The permit fee shall be submitted as part of the Earth Change Permit application. Please see **APPENDIX D Fee Schedule**.

1006 RURAL REQUIREMENTS

1006.1 Mailboxes: Mailboxes shall be located along the edge of the roadway, so that mail can be delivered to the box without leaving the paved surface. Mailbox supports shall be painted or reflectorized so as to be clearly visible in accordance with U.S. Postal Service regulations.

No brick, masonry or other structurally rigid mail boxes shall be allowed on rural roads with a speed limit greater than 40 mph. The type of mail box support that will be allowed is a light weight (18 gauge) l½ inch diameter metal post, 4"x4" wooden post or approved equal. Posts may be set in concrete. Equivalent supports shall be approved by the City Engineer or City Transportation Engineer.

1006.2 Right-of-Way Maintenance: All owners of property abutting a street or road in those areas zoned A-1, A-2, and R-E, and which has been platted and subdivided in accordance with City of Norman Regulations and Ordinances, shall maintain the rights-of-way of said streets and roads.

1007 RETAINING WALL DESIGN

1007.1 All retaining walls 3 feet and more in height or those supporting 2 feet of soil or more, measured from the top of footing to top of wall, shall be required to obtain a retaining wall permit prior to construction. All retaining wall designs greater than 3 feet in height shall be prepared and sealed by a registered professional engineer. The height of a retaining wall is measured from the top of the wall to the top of the foundation (footing).

A. The permit application shall include:

1. A plan view drawing showing the location of the proposed retaining wall, all existing or proposed structures and all easements.
2. A cross-section drawing showing exactly how the retaining wall will be constructed (i.e., concrete, rebar, blocks, etc.).

1007.2 Retaining Wall Permit Fees shall be submitted with the retaining wall design. Fees shall follow **APPENDIX D Fee Schedule**..

1007.3 Penalties:

A. If a retaining wall is constructed without a permit, fees will be doubled.

B. If the Builder/Contractor obtained a retaining wall permit, but the retaining wall was constructed without contacting the City for inspections, the penalty established in **APPENDIX D Fee Schedule** shall be assessed for each missed inspection. The Builder/Contractor will be required to provide certification from the Design Engineer that the retaining wall was constructed per the permit.

1008 SOLID WASTE CONTAINER ENCLOSURE

1008.1 The location of a solid waste container enclosure shall be shown on the site plan and approved by the Utilities Engineer and City Engineer. The configuration and components of the enclosure shall be in accordance with the City standards.

1008.2 Access to the solid waste containers shall be made easy for sanitation vehicles. Backing into a street or parking way in order to egress the waste container is prohibited. Any backing requirement of greater than 50-feet shall be approved by the City.

1008.3 Solid waste container enclosure location shall be shown on the site plan and approved by the City.

1008.4 Access to a solid waste container enclosure must be by paved surface meeting City requirements. For private paving, the City will not be responsible for any damage as the result of solid waste service.

1008.5 For rural subdivisions, trash receptacles must be brought to the nearest through City street.

1008.6 All non-residential developments shall be required to utilize a dumpster unless polycart service is approved by the City due to the property's location and adjacent service area type.

1009 ENCROACHMENT OF PUBLIC PROPERTY

1009.1 Temporary encroachment permits

A. Temporary Encroachment Permits are required for the use of public property for construction or demolition. Construction or demolition by a City of Norman contractor, developer of a commercial or residential subdivision, or franchise Utility Company is exempt from paying a fee but is required to obtain a permit. When said developer encroaches onto public property longer than the initially agreed upon time, then he shall pay a penalty (see the schedule of fees).

B. Requirements for Temporary Encroachment Permits

1. Liability of public property. The amount of liability insurance to be set by the City Engineer and/or Public Works Director.

2. Pedestrian protection. The applicant must provide for pedestrian protection from construction and/or demolition by the use of railings, fences, walkways, and canopies as required by the City Engineer and/or Public Works Director.

3. Plans. The applicant must supply plans showing the location and amount of public property to be occupied: the location of all railings, fences, canopies and construction offices, sheds and other appurtenances: and the nature and location of all warning devices necessary to protect pedestrian and vehicular traffic. These plans must be approved by the City Engineer and/or Public Works Director.

4. Any pedestrian or traffic detours must be submitted to the Transportation Engineer for approval prior to commencing any work. All detour routes must be ADA compliant.

5. Permit Fee. Please see **APPENDIX D Fee Schedule**.

6. Inspections - An inspection must be obtained after all barricades, fences, railings and other forms of pedestrian and vehicular protection are in place. A final inspection must be obtained after all such items are removed.

1009.2 Consent to Encroach

A. Private improvements may not be constructed over an existing utility easement without written City approval for the proposed encroachment. All costs of applying, obtaining, and filing a consent to encroach to be borne by the requesting entity.

END OF SECTION 1000

2000: WATER LINES

2001 GENERAL REQUIREMENTS

2001.1 The minimum design criteria for all public water facilities shall be the most current edition of Title 252: Oklahoma Administrative Code, Chapter 626, Public Water Supply Construction Standards, Oklahoma Department of Environmental Quality (ODEQ).

2001.2 The City of Norman is authorized to self-permit water lines 12-inch and less in diameter by ODEQ. The Design Engineer or Developer is responsible for acquiring ODEQ authorizations and permits for pump stations and pipe lines greater than 12-inch. The Developer shall be required to submit the required documentation for approval and the ODEQ required application, engineering report, and fee.

2001.3 A Maintenance Bond or Irrevocable Letter of Credit shall be posted in an amount based on a percent of the determined amount of construction costs for a period after the completion and acceptance of the project work, defined as follows:

A. Privately Financed Projects: 50% for one (1) year period

B. Publicly Financed Projects: 100% for the first year plus 15% for the second year

Should repairs on either privately or publicly financed projects be necessary during the maintenance bond period, the repairs made shall also be fully bonded for an additional one-year period from the date of completion and acceptance of the repair work by the City.

2001.4 In accordance with ODEQ regulations, the City provides water at a minimum pressure of 25 psi. The Developer is responsible for designing and constructing all fixtures and systems to provide adequate domestic and fire protection under minimum pressure conditions. The Developer shall be responsible for any failure of domestic and fire protection systems which require water in excess of 25 psi.

2002 WATER SERVICE REQUIREMENTS

2002.1 Water lines shall be separated from a sanitary sewer at least 10-feet horizontally and 2-feet vertically per ODEQ separation requirements.

2002.2 Water lines shall be installed along the entire frontage of the subdivision or development adjacent to a street or thoroughfare. If the subdivision is not adjacent to a thoroughfare, the extension of utilities shall be accomplished in such a manner as to allow future connections to said utilities by future developments, unless otherwise approved by the Utilities Engineer.

2002.3 Generally, water lines shall be on the south or east side of right-of-way. Water lines shall be at least 10 feet from any proposed or existing structure, measured from the edge of the outermost wall, unless otherwise approved by the Utilities Engineer. When properties are rezoned or when the building setback lines are changed, the Developer shall be responsible for relocating the water main if the existing water main will be less than 10-feet from a proposed structure. Water lines shall not be installed within an Oklahoma Department of Transportation (ODOT) right-of-way, except in permitted crossings or approved by the Utilities Engineer. Water lines not in street right-of-way shall be centered in a waterline easement with a minimum width of 15-feet, unless otherwise approved by the Utilities Engineer.

2002.4 The minimum size of water line on all section lines and arterial streets shall be 12-inch diameter and 8-inch diameter on half-section lines and all collector streets. The minimum size of all other lines shall be 6-inch diameter. Proposed water lines and service lines shall be sized to accommodate the domestic supply, fire flow, irrigation, industrial demands appropriate for the property(-ies) they serve. Water mains may be required to be upsized in compliance with the latest City of Norman Water System Hydraulic Model. The additional cost for the upsize shall be determined by the Utilities Engineer and may request the developer to participate in cost sharing of the additional construction costs.

2002.5 Water lines shall be designed to have a standard depth of cover of 3.5-feet and maximum depth of cover of 8-feet, unless approved by the Utilities Engineer. Final grading activities, either cut or fill, may warrant the replacement of the existing water line to maintain the required depth of cover.

2002.6 Existing and proposed centerline grade above water lines and proposed curb grade, or proposed centerline of street grade, shall be shown on profile.

2002.7 Isolation valves shall be installed on a minimum of each branch minus one of a tee or a cross fitting such that no more than one block is out of service at a time and a maximum four valve shutout. For instance, on a cross, valves shall be required on at least three branches from the cross. Spacing between valves shall not exceed 1,320-feet or in accordance with ODEQ regulations. Additional valves will be required at stream, ODOT right-of-way, and railroad crossings. Type of isolation valve used on water lines shall be as follows:

A. Gate Valve for diameters 12-inch or smaller.

B. Butterfly valve for diameters larger than 12-inch.

2002.8 Dead ends shall be avoided whenever practicable. Where a dead end is necessary, a fire hydrant must be installed at the end of the water line. The hydrant shall be located such that the flushed water is discharged on the ground and not directly connected to any sanitary or storm sewer. The Utilities Engineer may require the installation of an automatic flushing device in lieu of a fire hydrant in areas that may be difficult to access or as deemed necessary. If a dead end is planned to be temporary and will be looped in the near future, a flushing device (auto-flusher or blow-off hydrant) may be installed with approval of the Utilities Engineer.

2002.9 Water lines installed under existing or proposed driving surfaces shall have aggregate backfill material which conforms to ODOT 703.01, Type A Aggregate Base or flowable fill which conforms to ODOT 501.02.

2002.10 Fire Hydrants:

A. All fire hydrants shall be located in street right-of-way or easement. In a platted subdivision all fire hydrants shall be located at the lot line, or lot line extension, and at the elevation shown on the plans based on the finished grade.

B. Except as herein provided, a fire hydrant shall be located between 3-feet and 6-feet from the back of curb (or edge of pavement) to the centerline of the barrel unless otherwise approved by the Utilities Engineer.

C. Fire hydrants may be located more than 6-feet from the back of curb (or edge of pavement) only if all of the following conditions are met:

1. In no case shall the fire hydrant be located greater than 15 ft. from the back of curb (or edge of pavement).

2. A blue reflective indicator shall be placed in the center of the street at the fire hydrant.

D. Fire hydrants in residential, unsprinklered commercial, and industrial areas shall be placed at each street intersection, water line termination in cul-de-sacs, and other locations so that the distance between them does not exceed 300 feet. This distance shall be measured in the street as fire hose laid down from a fire vehicle. Fire hydrants shall be located such that all proposed or existing structures are within 300-feet and in direct line from another fire hydrant. Hydrant placement near sprinkled structures must be approved by the City of Norman Fire Chief.

E. All fire hydrants located outside of the right-of-way to provide fire suppression for a commercial or industrial structure shall be fully accessible from paved driveways, streets, parking lots, and fire lanes.

F. The fire hydrants connection to the water line shall be in accordance with the City's "Standard Specifications and Details".

G. All fire hydrant assemblies shall include gate valves on the branch pipe to isolate the fire hydrant from the water main. Pipes branching from the water main serving fire hydrants shall not be a plastic pipe material, unless approved by the Utilities Engineer.

H. A tamper resistant operating mechanism shall be installed on all fire hydrants install east of 48th Avenue NE or as directed by the Utilities Engineer.

2002.11 All water pipes shall conform to the current American Water Works Association (AWWA) specifications. The allowable materials include:

Material	Specifications[1]	Application
Polyvinyl Chloride (PVC)	AWWA C900, DR-018 (231 psi) minimum	All Water Mains
High Density Polyethylene (HDPE)	AWWA C906, DR-11 (200 psi) minimum, DIPS sizing	Trenchless Installation only
Ductile Iron Pipe (DIP)	AWWA C151, Pressure Class 200 minimum	Only where potential for contact with hydrocarbons exist[2]

[1] Pressure class or DR rating to conform with expected hydraulic conditions of pipe.
[2] Or as approved by Utilities Engineer.

A. The following nominal pipe diameters are acceptable: 6, 8, 12, 16, 20, or 24 inches. For service lines only, 4-inch nominal diameter pipe will also be acceptable. Diameters larger than 24-inch to be approved by the Utilities Engineer.

B. For HDPE piping, pipe shall only be used for trenchless directional drilling applications where no service connections are proposed. Additionally, HDPE wall thickness shall be considered when selecting the appropriate pipe size for hydraulic conditions.

C. For DIP piping and fittings, the exterior of the pipe shall have a layer of arc-sprayed zinc under the bituminous coating or asphaltic top coating. All buried ductile iron pipe and fittings shall have a tube type polyethylene encasement treated with V-Bio in accordance with manufacturers recommendations.

2002.12 PVC pipe installed by open cut shall have one #12 copper tracer wire with HDPE coating attached to the top of it. Wire shall connect to a weatherhead or fire hydrant per the current City Standard Specifications and Details. For trenchless installations, the tracer wire shall be #8 Copper Head Solo Shot Extra-High Strength Tracer Wire or approved equal.

2002.13 Cover over water lines at creek crossings shall be 4-feet minimum. Water lines shall be restrained joint pipe through the creek area. The restraint length shall begin and end at least 10-feet horizontally from the top of the creek bank or the next pipe joint, whichever is greater.

2002.14 Where a rural roadway section is allowed, a separate easement, a minimum of 15-feet wide, shall be granted adjacent to the street right-of-way, in which the proposed water line shall be placed.

2002.15 For private fire lines, the backflow prevention device shall be installed in a concrete vault and shall be constructed in accordance with the current Standard Specifications and Construction Drawings. During installation, the fire line shall be pressure tested and chlorinated by the Contractor under the observation of the City of Norman staff. Public service taps will not be allowed on the public line between the main distribution line and the isolation (gate) valve or the backflow prevention device.

2002.16 Fire department connections (FDC) shall be installed per City of Norman's Fire Code.

END OF SECTION 2000

3000: SANITARY SEWER

3001 GENERAL REQUIREMENTS

3001.1 Minimum design criteria for all Sanitary Sewer Collection and Treatment Facilities shall be the Title 252. Oklahoma Administrative Code, Chapter 656. Water Pollution Control Construction Standards, most current edition, Oklahoma Department of Environmental Quality (ODEQ).

3001.2 The Developer shall be required to submit the required documentation for approval and the ODEQ required application, engineering report, and fee.

3001.3 A Maintenance Bond or Irrevocable Letter of Credit shall be posted in an amount based on a percent of the determined amount of construction costs for a period after the completion and acceptance of the project work, defined as follows:

A. Privately Financed Projects: 50% for one (1) year period

B. Publicly Financed Projects: 100% for the first year plus 15% for the second year

Should repairs on either privately or publicly financed projects be necessary during the maintenance bond period, the repairs made shall also be fully bonded for an additional one-year period from the date of completion and acceptance of the repair work by the City.

3002 SEWER LINES

3002.1 Sanitary sewers shall be installed and separated from an existing or proposed water line at least 10-feet horizontally and 2-feet vertically, per ODEQ separation requirements.

3002.2 New sewer laterals shall be installed in the front of the lot to the sewer collection main in the right-of-way or easement, unless approved by the Utilities Engineer.

3002.3 Side lot easement widths will be based upon other utilities in the easement and the location and depth of the sewer with a minimum width of 15-feet.

3002.4 No public gravity sewer shall be less than 8-inches in diameter. Sewer pipe shall be PVC (SDR 35 or better) in only the following sizes: 8,12, 15, 18, 24, 30, 36, or 42-inches. Pipe in larger sizes, or constructed of different materials, shall be approved by the Utilities Engineer.

3002.5 For dead-end sewers, the sewer line shall be extended across the last lot and terminate with a manhole within the street ROW. Greater distances may be approved to locate manholes adjacent to streets.

3002.6 Alignment, size, and grade of sewer lines and private laterals shall be designed by the Developer or Design Engineer and are subject to review by the Utilities Engineer. The minimum design grade for sanitary sewer is shown in the following table:

Minimum Pipe Grade	
Pipe Diameter	**Design Grade**
6 in	0.750%
8 in	0.500%
12 in	0.290%
15 in	0.220%
18 in	0.170%
21 in	0.140%
24 in	0.120%

3002.7 All sewer pipes shall conform to the City's current Standard Specifications and Construction Drawings. All installations in excess of 12-feet deep shall require approval of the Utilities Engineer.

3002.8 Concrete encasement shall be required where the depth of cut from the ground elevation to the top of pipe is 4-feet or less. Unless otherwise approved by the Utilities Engineer, concrete cradle shall be used when sewer depth exceeds 16-feet with approval by the Utilities Engineer.

3002.9 The depth of cover over sewers at channel or creek crossings shall be 4-feet minimum. Steel conduit surrounding the sewer as per Norman Standard Specifications and Construction Drawings shall be used at crossings with less than 4-feet of cover. The steel conduit shall extend a minimum of 10-feet past the top of the bank. Sewers at or above the channel or creek flow line are not recommended and if allowed will require written approval of the Utilities Engineer. Concrete piers for above grade sewers shall, at a minimum, comply with the City's "Standard Specifications and Construction Drawings".

3002.10 The following table illustrates the range of sewer easement width for sewers at various depths. Sewer depth is defined as the difference between the finished grade elevation and the pipe invert. Collector sewers are sewers with a nominal diameter of 12-inches or less and may have sewer service taps. Interceptor sewers are sewers with a nominal diameter of greater than 12-inches and may not have sewer service taps.

Easement Width (feet)	Range of Collector Sewer Depth (feet)	Range of Interceptor Sewer Depth (feet)
10	0.0 to 10.0	0.0 to 10.0
15	10.1 to 11.7	10.1 to 11.7
20	11.8 to 13.3	11.8 to 13.3
25	13.4 to 15.0	13.4 to 15.0
30	15.1 to 16.0	15.1 to 16.7

Notes: The easement widths noted above assume the following:

1. For side lot easements, the minimum sewer easement width must be increased to account for the allowable roof overhang(s). No service lines greater than 24-inches will be allowed inside lots.
2. Storm sewers shall not be located within the sewer easement unless approved by the Utilities Engineer.
3. Type C soils and trench side slopes of 1.5 horizontal to 1.0 vertical are assumed above trench shoring of 8-feet. Differing site conditions may require the easement to be larger and subject to approval of the Utilities Engineer.
4. For sewers located adjacent to rights-of-way, the easement width reflected above may be reduced by 5-feet (10-feet minimum width required).

3003 MANHOLES

3003.1 The distance between manholes shall be consistent with the most current edition of ODEQ regulations or up to 500-feet with authorization by the Utilities Engineer. Lampholes are not allowed.

3003.2 Manholes shall be 4-feet deep minimum, or a special structure will be required. Rim elevation shall be 1-feet minimum, above 100-year flood (1% annual chance of a flood) or high-water level in these areas, and watertight manhole lids shall be installed. Exact manhole rim elevations shall be shown on profile and staked in field. Unless otherwise approved by the Utilities Engineer, all manholes shall have at least 0.10 feet drop across the manhole. Internal drop manholes may be allowed only by authorization by the Utilities Engineer.

3004 CONNECTIONS

3004.1 When making new sanitary sewer service connections for all platted lots and at any point where a sanitary sewer service connection is anticipated., the method for connection shall be made by the following in order of descending preference:

A. Sanitary sewer connections shall be made directly to a manhole in accordance with the City Standard Specifications and Details.

B. If connection to a manhole is not possible, an in-line tee shall be installed on a proposed sewer connection line or an ADS Inserta Tee lateral connection fitting, or approved equal on an existing sewer collection line. Looking upstream, all taps to the left shall be installed 10-feet upstream from the property corner and all taps to the right shall be installed 15-feet upstream from the property corner. Fitting size and location or distance from the downstream manhole shall be shown on the plan and profile.

C. For long sewer service connections, the Developer or Design Engineer shall have the option to install a single 6-inch public service line with a double 4-inch wye and termination manhole or two 4-inch private service lines. The property line or easement boundary shall demarcate the public and private ownership of the pipe, per City's Standard Specifications and Construction Drawings.

3004.2 Design depth shall be based on service line stub-out 1.5-feet below surface, 1 percent minimum grade, and minimum 26-inches from finished floor elevation to top of sewer line service.

3004.3 For private sewer service connections to a main with only one size difference, a connection at the manhole is required or a tee fitting must be installed on the existing collector sewer pipe and conform to the City's Standard Specifications and Details.

3004.4 Non-standard sewer taps shall be removed, the sewer main repaired, and the tap installed in accordance with the City's Standard Specifications and Construction Drawings.

3005 WASTE STABILIZATION LAGOONS

3005.1 Waste stabilization lagoons are not allowed within Norman City limits, unless otherwise approved by the Utilities Engineer.

END OF SECTION 3000

4000: STREETS

4001 GENERAL REQUIREMENTS

4001.1 A Maintenance Bond or Irrevocable Letter of Credit shall be posted in an amount based on a percent of the determined amount of construction costs for a period, following completion and acceptance of all improvements, defined as follows:

A. Privately financed projects: 25% for a three-year period.

B. Publicly financed projects: 100% for one-year plus 15% for the succeeding four-year period.

C. Should repairs on the either privately or publicly financed projects be necessary during the maintenance bond period, the repairs made shall also be bonded for an additional one-year period from the date of completion and acceptance of the repair work by the City.

4001.2 When invasive subsurface investigatory methods, such as “pot holing” operations, are performed to locate existing utilities under an existing street, the following will be required:

A. Right-of-way permit

B. The maximum size of a drilled “pothole” shall be 6 inches in diameter.

C. The operations will be performed in locations out of wheel paths.

D. A traffic control plan shall be submitted and approved by the City Transportation Engineer, prior to beginning work. Traffic control plans shall comply with City of Norman Standards and the most current version of the Manual on Uniform Traffic Control Devices (MUTCD).

E. Holes will be backfilled with 6 inches of sand immediately above the utility and 3000 psi concrete to the street surface. These repairs must be completed within 24 hours.

4001.3 Variances and exceptions to the criteria defined herein will be at the discretion of the City Engineer or their designee. Variance or exception requests shall be made to the City Engineer for consideration and determination prior to completion of related design work or execution of work in the field.

4002 TRAFFIC IMPACT OF DEVELOPMENTS

When a development will have a significant impact on the traffic pattern (100 vph increase or as deemed necessary by the City Transportation Engineer) of the adjacent streets, driveways, and intersections, the developer shall provide a traffic impact analysis. The developer shall provide additional traffic lanes and right-of-way width to the streets or other improvements to mitigate the impact of the development. The City Transportation Engineer shall determine the exact type and quantity of construction required. Each development will be evaluated based on the traffic into and out of the development, the traffic load on the arterial, and current and planned configuration of the arterial, as shown in the City's Comprehensive Transportation Plan and the trip generation rates for the proposed development, including future phases. Traffic Impact Studies shall be prepared in accordance with the guidelines located in APPENDIX A.

All improvements shall be constructed according to the applicable sections within this document.

4003 STREET FUNCTIONAL CLASSIFICATION

4003.1 Highways

Highways are all roadways for which the primary responsibility for maintenance is other than the City of Norman. The function of these roadways is primarily to accommodate long trips between parts of Norman and to connect areas outside of Norman. Highways will, in some instances, serve as both Urban and Rural Arterials. The right-of-way requirements, number of lanes, and shoulder requirements will vary greatly within the highway system.

A. Freeway: A divided highway with full control of access. The Federal Interstate System is included in this classification.

B. Turnpike: A divided highway with full control of access, on which a *user fee* or toll is charged for each trip. In Oklahoma, all turnpikes are owned and operated by the Oklahoma Turnpike Authority and are outside the purview of both the Federal Highway Administration and the Oklahoma Department of Transportation.

C. Expressway: A divided highway with partial control of access.

D. Gateway/Boulevard/Parkway Scenic Zones: Any highway, generally divided, where special setbacks are imposed, signs are restricted, uniformity of street trees is required and extensive landscaping is encouraged, to enhance the park like setting along the street

E. Conventional: Any non-divided road, maintained by the Oklahoma Department of Transportation.

4003.2 Urban Streets

Urban streets are all roadways within urbanized Norman. Urbanized Norman includes all currently developed land and all land designated to be served by central utility systems in the most recently adopted land use plan. The right-of-way requirements, number of lanes, and turn lane and median requirements vary widely. Appropriate cross-sections for all classification of urban roadways are contained within the most current version of the City's Comprehensive Transportation Plan.

A. Principal Arterial (Urban): Urban principal arterial roadways provide the predominant passageways through the urbanized portions of the community and connect to the regional freeway network, typically providing for curb and gutter drainage. Intersections are provided at all arterial, collector and local roadways and as needed allowing for local land access directly to the facility. Intersections with arterial roadways are typically signalized and provisions made for one or more left turn lanes and occasionally right turn lanes to facilitate the through movements along the arterial. Principal urban arterial roadways are to provide at least two travel lanes in each direction plus a center median area for separations of traffic. The median area may be used to provide channelized left turn lanes, continuous left turn lanes, and/or streetscape. Where traffic operational analyses support the need for greater throughput capacity, a six-lane section may be considered. Access management practices should be employed to minimize the impacts of property access (i.e., driveways) on the principal arterial facility. When transit routes run along urban principal arterials, consideration should be given to providing a bus pullover bay for service at the bus stops to reduce the traffic delay and potential safety implications of buses stopping in the rightmost travel lane to serve passengers. Street lighting should be provided, or provisions for future installation of street lighting, unless adjacent facility lighting exists. Sidewalks, 5 to 10 feet in width, should be provided along both sides of the roadway. With concurrence by the city's Bicycle Advisory Committee (BAC), principal arterials may also incorporate bike lanes within the roadway pavements to enhance the bicycle transportation network, in which case, sidewalks would be limited to 5 feet in width.

1. Includes ALL Highways within or passing through urbanized Norman, and

2. All non-highway, principal arterials require a minimum of four travel lanes with curb and gutter and a minimum of 100' of right-of-way. Additional lanes, turn lanes, medians and right-of-way may be required based upon traffic generation or unique conditions.

B. Minor Arterial (Urban): Urban minor arterial roadways provide passageways across segments of the urbanized portions of the community and connect to the regional arterial network, typically providing for curb and gutter drainage. Intersections, signalized as warranted, are provided at all arterial, collector and local roadways and the minor arterial allows for local land access directly to the facility. Intersections with other arterial roadways are typically signalized, as warranted. Minor arterial streets typically have significant local access needs or closely spaced intersecting local streets, and thus two optional cross sections may be applied:

1. A three-lane section to allow a continuous left turn lane or raised median with left turn lane pockets to facilitate the through movements along the arterial. A special version of this three-lane section would have a reversible center lane that can be allocated to the peak direction of travel by special lane markings and overhead signs.
2. A four-lane section that can accommodate multiple left turns and right turns into adjacent property driveways. At street intersections, the left or right lanes can be dedicated to through lanes or turning lanes as needed for intersection capacity.
3. Bike lanes would be provided on either typical section. Street lighting should be provided, or provisions for future installation of street lighting, unless adjacent facility lighting exists. Sidewalks, 5 to 8 feet in width, would be provided along both sides of the roadway.

C. <u>Collector (Urban)</u>: Collector streets are an important part of the urban street network. Collector roadways tie neighborhoods together, within the one-mile grid of development blocks and across the arterial roadways. In industrial and commercial areas, collector streets serve local industrial and commercial streets and would have a thicker pavement section. The network of collectors provides numerous benefits to the transportation system:

1. Focus the entry and crossing of traffic on the arterials, thus minimizing total delay;
2. Allow lower speed/lower volume roadways for shorter-distance local traffic circulation; and
3. Provide bicycle and pedestrian friendly connections between the one-mile grid blocks.

Collector streets should be sufficiently wide to allow for one lane of traffic in each direction and either curbside parking or bike lanes (typically not both), suitable to the needs of the neighborhood and the transportation network. An alternative section for one-way collector roadways would allow for one lane of traffic and both parking and a bike lane. Street lighting, or provisions for future lighting, may be required at the discretion of the City Transportation Engineer or their designee. A minimum 5-foot-wide sidewalk will be provided along both sides of the roadway.

D. <u>Local (Urban)</u>: The primary function of local streets is to provide access to and from properties. Local streets feed to and from the collector street network, but occasionally may tie directly to arterial streets. The urban local street will be a 26-foot pavement width, with curb and gutter drainage and minimum 4-foot-wide sidewalks on each side of the street. Street lighting, or provisions for future lighting, may be required at the discretion of the City Transportation Engineer or their designee.

4003.3 Rural Roads

Rural Roads include all roadways outside of urbanized Norman. The right-of-way requirements, width of lanes, width and types of shoulders, and requirements for turn lanes vary widely. Appropriate cross-sections for all classification of rural roadways are contained within the most current version of the City's Comprehensive Transportation Plan

A. Principal Arterials (Rural): Rural principal arterial roadways provide the predominant passageways through the rural portions of the community and connect to the regional arterial and freeway network, typically providing for open ditch drainage. Intersections are provided at all arterial, collector and local roadways. Local land access is permissible directly to the rural principal arterial facility. Intersections with arterial roadways may be signalized or stop controlled and provisions should be made for left turn lanes to facilitate the through movements along the arterial. Principal rural arterial roadways are to provide at least one and no more than two travel lanes in each direction plus a center median area for separations of traffic, provision of channelized left turn lanes, sections of continuous two-way left turn lane, and/or streetscape. Access management practices should be employed to minimize the impacts of property access in the rural principal arterial facility. The roadway is to be provided with 10-foot-wide paved shoulders. Rights-of-way should be provided to allow a 10-foot trail along one or both sides of the roadway for urban trail and side path connections to the rural recreational trail network. Street lighting will be located at intersections only. Additional street lighting, or provisions for future lighting, may be required at the discretion of the City Transportation Engineer or their designee.

B. Minor Arterial (Rural): Rural minor arterial roadways provide passageways across segments of the rural portions of the community and connect to the regional arterial network, typically providing for open ditch drainage. Intersections are provided at all arterial, collector and local roadways and the minor arterial allows for local land access directly to the facility. Intersections with arterial roadways may be signalized or stop controlled and provisions should be made for left turn lanes to facilitate the through movements along the arterial. Minor rural arterial roadways are to provide one travel lane and a 6-foot-wide shoulder in each direction. Access management practices should be employed to minimize the impacts of property access in the rural minor arterial facility. Street lighting will be located at intersections only. Additional street lighting, or provisions for future lighting, may be required at the discretion of the City Transportation Engineer or their designee.

C. Collector (Rural): Collector streets in the rural areas of Norman can serve as the one-mile grid of streets in the sparsely developed areas near Lake Thunderbird and the Canadian River. Due to the very low traffic volumes, the roadway will consist of the minimal 26-foot width of paved roadway plus a gently graded shoulder area, for safety, that would be unpaved. Sidewalks are typically not provided along rural collector roads. Street lighting, or provisions for future lighting, may be required at the discretion of the City Transportation Engineer or their designee.

D. Local (Rural): Local streets in the rural areas of Norman serve access to development in the sparsely developed areas near Lake Thunderbird and the Canadian River. Due to the very low traffic volumes, the roadway would consist of the minimal 22-foot width of paved roadway plus a gently graded shoulder area, for safety, that would be unpaved. In a rural estate setting, the 22 feet of pavement may be framed by curb and gutter. Sidewalks are typically not provided along local rural streets. Street lighting, or provisions for future lighting, may be required at the discretion of the City Transportation Engineer or their designee.

4004 PLAN REQUIREMENTS

4004.1 All intersections, cul-de-sacs, and other critical locations shall be shown in plan detail at a minimum scale of 1" = 40', including direction of drainage, top of curb elevation at PC's, PT's and high or low points. All curve information and drainage structures shall be shown in detail.

4004.2 Where cul-de-sac radii varies so that the distance from face of curb to the right-of-way line is less than 12-feet, an additional easement will be granted to accommodate sidewalks and/or utilities of the necessary width to achieve 12-feet.

4004.3 A site plan showing proposed locations and elevations of all utilities shall accompany the street and storm sewer plans.

4004.4 The profile may be either three separate profiles or one single profile.

A. Three separate profiles: When using three separate profiles, the top and bottom shall show existing property line and proposed top of curb. The middle profile shall show only existing center line profile. Stationing shall be along center line.

B. One single profile: When using one single profile both property lines shall be shown along with the proposed top of curb. The center line profile shall not be shown. Stationing shall be along center line. A typical section shall show cross slopes.

4004.5 All fill areas within the street right-of-way shall be cross hatched on the profile and notation shall be made that the fill area shall be compacted to a minimum of 95 percent standard proctor density. When storm sewer pipes are located in fill area, the fill shall be made and compacted to finish grade, then trenched before storm drain excavation.

4004.6 Curb returns with elevations shall be clearly labeled on profile.

4004.7 Vertical curves in profile shall give the top of curb elevation at the PC, PI, PT and high or low point, at a minimum of interval of 60 feet.

4004.8 Storm sewer mains shall be located outside of the proposed street pavement footprint where possible. If through preliminary investigations and driven by limited right-of-way or design constraints such as SCM, it is deemed not feasible to place the storm sewer outside of pavement, the alternative storm sewer line placement shall be in accordance with **Section 5008.2** or as approved by the City Engineer.

4004.9 Utility lines (i.e., Petroleum lines, gas lines, franchise utility lines, etc.) shall not be located under street pavement except at crossings. They are not permitted longitudinally down a street or within 3 feet per foot of depth with a minimum of 10 feet of the edge of pavement, unless approved by the City Engineer.

4004.10 Cross Sections

A. Cross sections shall be required as a part of the construction plans for Capital Projects and when necessary, or as required by the City Engineer, for development plans to reflect more clearly the intent of the design.

B. All cross sections for street rights-of-way shall be labeled by station and be drawn to a scale of (1:1, without exaggeration), showing existing ground, existing and proposed utilities, existing and proposed right-of-way and easements, proposed curbs, paving limits, and proposed construction from building line to building line.

C. The beginning and ending points of a project shall be stationed and cross sections for both the stations shall be drawn.

D. Typical interval between cross sections shall be 50 feet. Additional cross sections shall be included as needed to show driveway slopes and other pertinent information.

E. Sufficient roadside information shall be furnished to show that water is not ponded behind curbs or in ditches.

F. Scale for cross section sheets shall not be less than:

Cross Section Sheet Scale		
Type	**Horizontal**	**Vertical**
Channels	1" = 10'	1" = 5'
Streets	1" = 5'	1" = 5'

4005 TYPICAL SECTIONS

4005.1 Typical sections are to be based on the roadway functional classification as defined in **Section 4003** and detailed in the Comprehensive Transportation Plan. For Development plans, the City Standard Specifications and Construction Drawings may be used.

4005.2 Typical sections shall be drawn at the same horizontal and vertical scale (1:1).

4005.3 Typical sections shall show dimensions, type of materials, layer details, reserve topsoil, temporary and permanent erosion control, compacted thickness, etc.

4005.4 All typical sections or notes that are necessary to clearly reflect the design shall be included.

4005.5 If not using City Standard typical sections a geotechnical study/investigations shall be required as detailed in **Section 4017**. The developer shall provide geotechnical study/investigation for all areas to be paved. Soil tests during construction shall be submitted to the City Engineer for review. Density tests are required from right-of-way to right-of-way and within easements, if extending beyond right-of-way, during construction.

4005.6 If not using City Standard typical sections pavement thickness shall be designed according to **Section 4017**; however, industrial, and commercial pavement sections shall have a minimum thickness of 8 inch asphaltic concrete or 7 inch Portland cement concrete. Residential pavement sections shall have a minimum thickness of 6-inch asphaltic concrete or 6 inch Portland cement concrete.

4005.7 Portland cement concrete streets shall have an integrally placed curb of the same mix design as the street paving. If required due to construction sequencing or other outside factors, variance can be requested for placing the curb separate. Curbs shall be in accordance with the *Standard Specifications and Construction Drawings.*

4005.8 Joints in Portland cement concrete shall be located in accordance with the American Concrete Institute (ACI) Standards. If deemed appropriate and approved by the City Engineer, the Oklahoma Department of Transportation Pavement Joint Standards may be used on arterial roadways. A joint layout plan shall be provided for concrete roadways for review and approval by the City Engineer or their designee.

4005.9 Joints in Portland cement concrete paving, curbs and gutters shall be constructed in accordance with ODOT and the American Concrete Institute (ACI) Standards unless otherwise accepted by the City Engineer.

4005.10 All concrete shall be in accordance with Sections 414 and 701 of the ODOT "Standard Specifications for Highway Construction" 2019 or the applicable Portland Cement Concrete Pavement and materials spec in the latest edition.

Class	Description	Concrete Uses
AA	4000 PSI, Min. cement 564 LBS/CY	Superstructures
A	3000 PSI, Min. cement 517 LBS/CY	Pavements (all functional classifications) and substructures (pier caps, columns, abutments, retaining walls, and reinforced concrete not requiring Class AA concrete).
AP	3000 PSI, Min. cement 470 LBS/CY	Use Class AP concrete in shoulders, merge areas, and gore areas for Portland cement concrete (PCC) pavements.
C	2400 PSI, Min. cement 395 LBS/CY	Soil Erosion Control Structures.
P	As required by the Contract, Min. cement 564 LBS/CY	Use Class P concrete for precast prestressed concrete members.

4005.11 Asphaltic concrete streets shall have a Portland cement concrete curb and gutter. The curb shall be in accordance with the Standard Specifications and Construction Drawings.

4005.12 All curb sections shall be vertical curb. Mountable type curbs will not be allowed unless accepted for specific sites by the City Engineer.

4005.13 If not using City Standard typical sections Asphaltic Concrete shall be provided in accordance with the geotechnical evaluation as detailed in **Section 4017**. Asphalt shall, where designated by the pavement design, shall be provided as Superpave Types S 3,4, 5 & 6 per the latest edition of the Oklahoma Department of Transportation Standard Specifications for Highway Construction.

4005.14 Where Residential Estate (RE) zoning has been allowed the typical roadway section shall be designed and constructed in accordance with the Standard Specifications and Construction Drawings.

4006 ROADWAY DESIGN

4006.1 Minimum Street Width: Width of streets shall be according to the classifications as provided for in the Norman Comprehensive Transportation plan and the currently adopted Comprehensive Transportation Plan. Width shall be measured from curb face to curb face or from edge of design strength pavement.

Roadway Widths			
Type	**R/W***	**Pavement**	**Shoulder**
Urban			
Principal Arterial	100'	64' (4-lanes w/ median)	C & G
Minor Arterial	Varies	Varies	C & G
Collector	60'	34' (3-lanes)	C & G
Local	50'	26' (2-lanes)	C & G
Rural			
Principal Arterial	100'	56' (2-lanes)	10' Paved
Minor Arterial	100'	48' (2-lanes)	6' Paved
Collector	100'	26' (2-lanes)	6' Earthen
Local (Section Line)	80'	22' (2-lanes)	4' Earthen
Local (Interior)	50' w/ 25' UE/DE	22' (2-lanes)	4' Earthen

* Roadside ditches and their backslopes should be captured within right-of-way. See section 4006.3.

4006.2 All minor and principal arterial street designs planned within a proposed development, shall be designed, and coordinated under the authority of the City Engineer.

4006.3 Where Residential Estate (RE) zoning has been allowed, the typical pavement section shall be a minimum width of 22 feet with 4 feet earthen shoulders on each side. Additional easements or right-of-way shall be dedicated such that the roadside ditch, including the back slope, can be maintained from within the street right-of-way. Roadside ditches shall be constructed in accordance with the City's Standard Specifications and Construction Drawings.

4006.4 All urban streets shall be constructed with concrete curbs, except as provided for in **Section 4003.2**, in accordance with the Standard Specifications and Construction Drawings.

4006.5 The centerline of paving shall be the centerline of right-of-way where dedication has been made according to the major street plan. All other cases shall be determined by the City Engineer.

4006.6 The minimum longitudinal design grade for streets and gutter lines shall be 0.6 percent. The maximum grade for non-arterial streets shall be limited to 8 percent. Where the topography is hilly, steeper grades may be permitted if approved by the City Engineer, up to a maximum of 12 percent, providing they do not exceed 500 feet in length from PT to PC, except in areas near intersections, where the 8% maximum will apply. Longitudinal roadway grades through crosswalks at intersections shall comply with the most current version of the ADA Standards for Accessible Design and by reference, the Public Rights of Way Accessibility Guidelines (PROWAG) for best practice, for allowable cross-slope.

4006.7 All vertical and horizontal curves shall be designed according to the current AASHTO Specifications using the criteria of safe stopping sight distance, with the minimum centerline radius on street alignments to be 200 feet.

4006.8 Vertical sag curves shall be the minimum length available for the two intersecting grades as defined by the AASHTO publication titled, A Policy on Geometric Design of Highways and Streets (Green Book), current revision. For residential streets, no sag vertical curve shall be used if the algebraic difference between the two intersecting grades does not exceed 1%. For collector streets, sag vertical curve length shall be determined by the "comfort equation" contained in the referenced AASHTO publication.

4006.9 Design and posted speed shall be 25 mph on all residential and collector streets and 45 mph on arterial streets. Posted speed shall only be modified by a commissioned speed study through the corridor or as approved by the City Transportation Engineer.

4006.10 The minimum radius on roadway functional classification types shall be as defined in the below table:

Minimum Intersection Radii (ft)			
Type	**Local**	**Collector**	**Arterial**
Local	30	30	40
Collector	30	30	40
Arterial	30	30	40

Note: Radii denoted in the table are minimum values only. Truck turning templates should be applied to intersections and larger radii used to avoid curb over-tracking.

Minimum radius on the returns for industrial districts shall be 40 feet, independent of roadway functional classification. Larger radii may be required for industrial districts if approved by the City Engineer.

4006.11 A proposed and existing profile shall be shown beyond the end of all dead-end streets for a minimum of 200 feet to determine a satisfactory grade for future development if applicable.

4006.12 Roadway cross slope shall be 2% (1/4" per foot) on all roadways unless otherwise approved by the City Engineer.

4006.13 Where proposed development is adjacent to an existing arterial street not constructed to the approved width and pavement dimensions of the current edition of the City's Comprehensive Transportation Plan and "*Standard Specifications and Construction Drawings"*, the City shall be provided with a geotechnical report detailing the existing condition of the roadway. Information to be provided, at a minimum, will include the type of pavement, thickness of pavement, estimated age of the pavement, type of subgrade, and CBR for the subgrade material. This report will be used to determine if full replacement to centerline will be required as a part of the public improvements for the development. The proposed design shall be approved by the City Engineer or their designee.

4006.14 Temporary End-of-Pavement Sections

A. A gravel turn-around area will be provided at the temporary end of any street length in excess of 150 feet. The gravel turn-around will consist of either a gravel circle or a T shaped turn-around. The radius of the turn-around will be a minimum of 38-feet, and the gravel thickness will be a minimum of 6-inches. The T turn-around will be as per City Standard ST-35.

B. Where a temporary end of street is less than 150 feet in length, one of the following shall be installed at the end of the pavement section: either a 12-inch-wide concrete header curb, or an additional 5-feet of asphaltic pavement. In both cases, this end of pavement material shall be removed prior to extending the pavement section.

4007 INTERSECTION DESIGN

4007.1 General

A. Streets shall intersect one another at right angles (90º) unless topography and other design factors require a waiver by the City Transportation Engineer. Intersections that cannot be at right angles require review and approval by the City Transportation Engineer.

B. Grades at collector/arterial intersections and 50 foot back of radius points shall not exceed 3% unless greater slopes are deemed necessary and approved by the City Engineer.

C. For residential and collector streets the portion of the street from the gutter line of the street being intersected to the P.C. (point of curvature) of the curb return (typically 30 feet) shall have a maximum longitudinal grade of 2%. This will allow the crosswalk to meet the requirements of the Americans with Disabilities Act, which has a maximum sidewalk cross slope of 2%. (See Drawing ST-12)

4007.2 Sight Distance Triangle (Vision Triangle)

A. The intersection sight distance provisions contained in 'A Policy on Geometric Design of Highways and Streets' published by the American Association of State Highway and Transportation Officials (the AASHTO Green Book referenced in **Section 4006**: Roadway Design) are adopted as the presumptive standard applicable to all intersections within the City provided, however, that the Director of Public Works or his designee may, where consistent with public safety, specify greater or lesser intersection sight distances. Unless otherwise required by the Director of Public Works or his designee, all intersections shall be designed, constructed, and maintained in accordance with such sight distance provision. Additionally, no landscaping, fence, utility equipment, wall, or other structure shall be constructed or maintained in the area identified as the sight triangle, nor shall any parking be allowed within the area of the sight triangle unless a sight distance study designates the desired item not to conflict with required visibility. Sight distance variance shall only be granted at the Director of Public Works or his designee's discretion.

B. Streets shall not be designed with intersections on the inside of horizontal curves or at any location in general where sight distance will be inadequate for drivers to safely enter the traffic flow or cross the street. The minimum distance from an intersection to a curve shall be the applicable minimum sight distance listed below. The Director of Public Works or his designee may make exceptions for especially difficult design circumstances only if visibility easements to provide adequate sight distance are established. In lieu of visibility easements, additional street right-of-way may be dedicated. Minimum intersection design sight distance standards and design procedures shall be as defined in the most current version of the AASHTO "A Policy on Geometric Design of Highways and Streets".

C. Where stop control is not used, the corner sight distance for residential streets shall be a minimum of 200 feet [300 feet recommended].

D. To maintain the minimum sight distance, restrictions on height of embankment, locations of buildings, and screening fences may be necessary. Landscaping in the sight distance triangle shall be low-growing and shall not be higher than 3 feet, or lower as needed to satisfy the calculated required sight distance, above the level of the intersecting street pavements. Tree overhang shall be trimmed to a line at least 8 foot above the level of the intersections.

4007.3 Right-of-Way

A. Intersections containing principal and minor arterials as classified by the Major Streets and Highways Map of the "Comprehensive Transportation Plan" shall provide a width of one hundred twenty (120) feet of public right-of-way for a distance of two hundred (200) feet from the intersecting right-of-way. Said right-of-way shall then have a one hundred fifty-foot transition from the one hundred twenty-foot width to a one-hundred-foot standard width.

B. Variations to this right-of-way requirement shall be granted in accordance with the procedure for plat variations contained in the *Subdivision Regulations of the City of Norman, Oklahoma.*

4008 ARTERIAL ACCESS

A. Direct access to arterial roadways must be avoided wherever possible. For instance, if the development is adjacent to a minor roadway or interior development road, primary access should be to the minor roadway. Direct arterial access shall only be allowed after review and approval by the City Engineer or their designee.

B. Whenever possible, cross access with an adjoining property must be sought.

If the City Engineer is satisfied that sufficient attempts to secure cross access have been made and that cross access is not possible, and access cannot be provided via another street, driveway access to the arterial may be granted if the minimum corner clearance is met. However, this access will be limited to right turns in and out.

C. Adequate sight distances will be required at every driveway connecting to an arterial, consistent with Intersection Sight Distance as defined in **Section 4007**: Intersection Design. Any movement for which inadequate sight distance is available will not be permitted.

D. Each lot will be permitted to have one access driveway, either on the parcel or as part of cross access. Where side streets abut the parcel, the access will be provided from the side street. Additional driveways may be needed and provided under the following conditions:

1. If the daily traffic volume using the driveway exceeds 2,000 vehicles per day.

2. If traffic using one driveway exceeds the capacity of a single stop-controlled intersection during one peak street traffic hour or the peak site traffic hour.

3. If an approved traffic analysis shows that traffic conditions warrant additional driveways.

E. In all cases, minimum spacing and clearances shall be provided.

F. Driveways along arterial roadways must satisfy the following minimum spacing requirements:

Posted Speed	Small Generator	Medium Generator	Large Generator
	0 to 100 peak hour trips	101 to 200 peak hour trips	201 or more peak hour trips
</= 40 MPH	220 Feet	330 Feet	550 Feet
> 40 MPH	330 Feet	440 Feet	660 Feet

Distances are from centerline to centerline of driveway. The Director of Public Works or their designee may, where consistent with public safety, specify greater distances when considering future development and/or future changes to traffic control in order to keep driveways away from queuing areas and thus assure adequate traffic flow through the intersection.

G. The corner clearance for driveways next to public road intersections, as measured from the edge of pavement of the intersecting roadway to the centerline of the driveway, shall meet the following criteria:

Speeds < 40 MPH		Speeds >/= 40 MPH	
Signal Control	Stop Control	Signal Control	Stop Control
175 Feet *	100 Feet	350 Feet*	200 Feet

**The Director of Public Works or his designee may, where consistent with public safety, specify greater distances when considering future development and/or future changes to traffic control in order to keep driveways away from queuing areas and thus assure adequate traffic flow through the intersection.*

4009 DRIVEWAY APPROACH STANDARDS

4009.1 General

A. A driveway approach sketch shall be submitted with the driveway permit application for review by the Engineering Division.

B. A variance from the driveway approach standards described in this section and contained in the City's Standard Specifications and Construction Drawings may be granted upon review by the Director of Public Works and City Engineer. During the absence of either the Director of Public Works or

City Engineer, the City Transportation Engineer shall replace the absent party.

C. A driveway approach installation and/or maintenance not meeting the requirements of the driveway approach standards may be corrected by the City if deemed necessary by the Public Works Department, at the expense of the property owner and after notice to the property owner to correct the problem.

D. Specifications for all materials used in constructing a driveway approach shall be reviewed by the City Engineer.

E. All subgrades shall be compacted to 95% standard proctor density *before* any paving material shall be placed.

F. At the intersection of public roads, driveways shall be located so that the dimension measured along the edge of the travel way between the frontage boundary line (F.B.L.), and the tangent projection of the nearest edge of the driveway is greater than 100 feet (for commercial and industrial driveways) or 30 feet Type I Driveway and 38 feet for Type II Driveway (for residential driveways). (Refer to the *Standard Specifications and Construction Drawings ST-25 & ST-27 respectively*).

G. All private roads, driveways, or streets serving all development types within the City, shall be constructed to specifications required for local streets unless otherwise directed by the City Transportation Engineer.

H. All concrete driveway approaches shall use concrete as defined in **Section 4005.10** Class A (3000 psi) concrete and be a minimum of 6 inches thick. All commercial driveways shall be concrete and may be thicker than 6 inches if required by the City Engineer or as indicated by the site-generated traffic and vehicle classification using said drive.

I. The expansion joint at the right-of-way line may be silicone sealant with backer rod or hot poured joint sealant.

J. Residential lots with access either to a collector or local street shall not have driveway access to an arterial street. A residential lot at the corner of a local and collector street shall not have driveway access to the collector without the approval of the Director of Public Works.

K. Every driveway approach shall be connected to a parking pad/drive of the same width or larger than the approach and a minimum of 20 feet deep beyond the Right of Way (ROW) Line (limited by: Zoning Ordinance 22:421.1.3.g. - concerning paving coverage of yard, drainage impact on surrounding properties, utility easement accessibility, collector access or Historic District Impact).

L. In the Historic District, the minimum driveway width shall be 8 feet and the maximum 10 feet. Also, two strips of concrete, 18 inches wide shall be allowed.

4009.2 Approach Grades

A. Minimum approach width is 10 feet.

B. Grades suggested for driveway conditions are as follows:

Driveway Grades				
Element	**Driveway Type**	**Functional Classification**		
		Arterial	**Collector/ Distributor**	**Local**
Recommended Grades	Residential	Desirable: 0-10% Maximum: 10%		
	Commercial/Industrial	Desirable: 0-5% Maximum: 8%		
Change in Grade without Vertical Curve	All	8% or Less	9% or Less	12% or less

C. The maximum difference between the downward cross slope of the street (usually 2.0% or less) and the upward slope of the driveway approach shall not exceed 12.0% as noted above. Special conditions outside of the above criteria must have approval from the City Engineer.

4009.3 Special Conditions

For specific design considerations, driveway approaches are separated below into two Approach types.

Driveway Approach Types	
Type	**Description**
I	Driveway approach on street located in agricultural or residential estate zoning
II	Driveway approach on street or areas other than agricultural or residential estate zoning (urban areas)

A. Type I Driveway Approaches (streets located in agricultural or residential estate zoning)

1. Neither the intersection point of the driveway approach with the edge of pavement or the end of drainage culvert pipe shall extend past the projected side property line, unless written permission is given by the affected property owner.

2. The driveway approach shall be constructed using materials listed in the following chart:

Minimum Material Standards

Type I Driveway Materials		
Existing Street	**Material**	**Thickness**
Concrete	Concrete	6"
Asphalt	Type S5 Asphalt	7.5”

3. Drainage pipe may be constructed of corrugated metal, HP, or reinforced concrete. The minimum pipe diameter shall be 18" or equivalent.

4. A drainage culvert pipe may not be required if the proposed driveway is located in an area with little to no contributing drainage area and a shallow ditch, 12" depth or less. The City Engineer shall determine if a drainage culvert pipe is not required.

B. Type II Driveway Approaches (streets located in areas other than agricultural or residential estates)

1. All driveway approaches shall consist of concrete (ODOT Class A, 6 sack, 3000 psi, water/cement ratio of 0.48, 1” to 3” Slump), 6" minimum thickness. For driveway thickness of 8" or greater, dowels are required at contraction joints and at joint connection with the street per **Section 2304.4.A.4** of the City's Standard Specifications and Construction Drawings.

2. Connections to the existing curb will meet and match the old curb.

3. Between driveways, construct a minimum 10' width pedestrian safety island at and parallel to the property line.

4. Where the existing pavement is asphalt or concrete with a separate concrete curb and gutter, remove both curb and gutter, then construct drive approach and gutter as one unit.

5. Immediately after finishing operations, curing shall be accomplished by either wetted earth, cotton mats, wet burlap bags, membrane curing compounds, or other methods accepted by the City Engineer.

6. Sawed contraction joints shall be made as soon as the concrete has set firmly enough to support the concrete saw without tracking. The joints shall be filled with rubberized asphalt or other material accepted by the City Engineer.

7. All exposed edges shall be tooled to no less than 1/4" radius (curb backs and slabs).

8. Neither the intersection points of the driveway approach with the edge of pavement or the end of drainage culvert pipe shall extend past the projected side property line unless written permission is given by the affected property owner.

4010 SIDEWALKS

4010.1 All sidewalks, pedestrian signalization, or other pedestrian related infrastructure shall be designed to comply with the most current version of the 2010 ADA Standards for Accessible Design and by reference, the Public Rights of Way Accessibility Guidelines (PROWAG), for best practice.

4010.2 All sidewalk layouts and designs must be reviewed and approved by the City Engineer or designee. Sidewalk widths shall be 4 feet minimum for local streets and 5 feet for arterial and collector streets. When sidewalk is at the back of curb an additional 1 foot of width shall be added for all roadway classifications. Sidewalks parallel to arterial roads that are designated bike paths shall be 8-10 feet wide.

4010.3 Sidewalks shall be required on both sides of local, collector, and arterial streets.

4010.4 All sidewalks shall consist of concrete compliant with **Section 4005.10** Sidewalks shall include pedestrian bridges across creeks, flumes, and streams, where applicable.

4010.5 The finished thickness of Portland cement concrete sidewalks shall not be less than 4 inches. Sidewalks across driveways shall not be less than 6 inches.

4010.6 Immediately after finishing operations, curing shall be accomplished by either wetted earth, cotton mats, wet burlap bags, membrane curing compounds, or other methods accepted by the City Engineer.

4010.7 Plans for sidewalks or trails, within right-of-way, with a decorative or “special” finish shall be submitted to the City Engineer for approval.

4010.8 In general for residential streets, sidewalks shall be constructed within the dedicated right-of-way at a distance no less than 1 foot from the abutting property lines, and except at intersections or as reviewed by the City, shall be no less than 3 feet from the outside curb line of the street pavement. However, at the home builders’ option with approval from the City Engineer, they may construct the sidewalk where it crosses the driveway approach adjacent to the street to allow more space for parking between the garage and the sidewalk. Sidewalks shall be designed such that they meet future street sections, SCM criteria, and tree requirements.

4010.9 Sidewalks must provide access for the safe and convenient movement throughout the corridor, maintaining a consistent “accessible path”. Construction of wheelchair ramps shall be in accordance with the City's Standard Specifications and Construction Drawings and compliant with the most current version of the 2010 ADA Standards for Accessible Design and by reference, the Public Rights of Way Accessibility Guidelines (PROWAG) for best practice.

4010.10 To accommodate wheelchair passing space, sidewalks less than 5 feet wide shall have at least 5 foot by 5 foot passing spaces located at intervals not to exceed 200 feet. Driveway crossing may be utilized as the 5-foot by 5-foot passing spaces as appropriate, provided that the cross-slope of the driveway on each side of the sidewalk does not exceed 2%.

4010.11 Transverse crack control joints shall be placed at intervals not to exceed 5 feet, unless otherwise approved by the City Engineer for specialty designs. Joints shall be tooled or sawed to a depth of 1 inch.

4010.12 Expansion joints shall be placed at curbs, driveways, or abutting structures.

4010.13 Where sidewalks intersect drainage flumes, the sidewalks shall span the flume per the applicable standard ST-34.

4010.14 Detectable warnings shall be required on the end of curb ramps at roadways and major drives or as required by current ADA standards. The detectable warnings shall consist of raised truncated domes with a nominal diameter 0.9-1.4 inches, a nominal height of 0.2 inches and a nominal center-to-center spacing of 1.6-2.4 inches, shall be the full width of the ramp walking surface, 24 inches in length from the end of ramp and shall contrast visually with adjoining surfaces, either light-on-dark, or dark-on-light. The specifications listed here-in shall meet current ADA standards if said standards are revised in the future. The material used to provide contrast should contrast by at least 70%. The City Engineer shall approve the detectable warning material and method of installation or request a pre-approved style of detectable surface to maintain consistency.

4010.15 Changes in horizontal alignment of a sidewalk shall be as noted in Standard Drawing No. ST-14b.

4010.16 Meandering or undulating sidewalk shall remain in conformance with current ADA standards and should be designed as follows:

A. Meandering Sidewalk: Sidewalks shall be constructed to be generally parallel to the curb of the roadway or the adjacent property line. If a meandering sidewalk is constructed, it shall be constructed such that a continual travel path parallel to the curb or the property line is maintained unless deviation is required to avoid an existing obstacle. The change in horizontal alignment must be consistent with **Section 4010.15**.

4011 SIGNAGE

4011.1 Street and traffic control sign plans shall be prepared by the developer and submitted to the City Transportation Engineer for approval.

4011.2 The developer shall be responsible for street name and other traffic control signage in all developments. For public streets, the city will furnish and install these signs for the developer on the basis of the City's current Sign Expense Chart. For private streets, the developer may, at his option, pay the city for the installation of the signs or hire a private contractor to do the work. Either way, the signs shall meet the requirements outlined in the Manual on Uniform Traffic Control Devices, latest edition and be approved by the City Transportation Engineer.

4011.3 Payment for public street signs shall be made to the City after the final plat is filed. In the case of private streets, either payment to the City or installation of the signs by a private contractor will be required prior to the filing of the final plat.

4011.4 A Work Zone Traffic Control Plan shall be provided to the City Transportation Engineer for review before any work is done on existing streets.

4012 STRIPING

4012.1 Plans for marking of streets requiring striping shall be reviewed by the City Transportation Engineer for approval. The Contractor performing the work shall be approved by City Transportation Engineer.

4012.2 Striping materials shall be in accordance with **Section 2304.7** of the City's Standard Specifications and Construction Drawings and as noted below. Variations or alternative material use requests shall be submitted to the City Transportation Engineer for approval prior to application.

Striping Schedule Of Materials		
Vehicles per Day	**Striping Material by Roadway Type**	
	Concrete*	**Asphalt**
Over 4,000	Paint (Multipolymer)	Thermoplastic (90 mil)
1,000 - 4,000	Paint (Multipolymer)	Thermoplastic (50 mil)
Under 1,000	No Striping unless required by the City Transportation Engineer	

* When applying striping to an existing concrete surface, that surface shall be cleaned thoroughly, and paint shall be applied as a surface prime coat before placing Thermoplastic.

4013 LIGHTING

4013.1 General

A. Streetlights shall be installed by the franchised vendor providing the electrical service.

B. Street lighting determination shall be based on the roadways functional classification, as defined in **Section 4003**, or as required by the City

Engineer or their designee.

C. Four basic objectives shall be considered in providing street lighting: aesthetics, traffic safety, security, and public street intersection identification. The objectives to be considered are directly related to the function of the street to be lighted.

1. For principal and minor arterials, the primary objectives are aesthetics and traffic safety.

2. For collector and local roads, the primary objectives are security and intersection identification.

D. Light poles shall be located a minimum of 5' back of curb or future curb, including left and right turn lanes.

4013.2 Scheduling

Street lighting shall be chronologically integrated with development. Street lighting shall not be installed until all required offsite improvements such as water mains, sanitary sewer mains, paving, and drainage structures are completed and accepted by the City, to avoid conflicts. However, it shall be installed prior to extensive development to avoid interference with private landscaping. A good rule to follow is to order street lighting at the same time that street name signs are ordered. Close coordination with the developer is required for lights to be installed in time to avoid interference with private landscaping.

4013.3 Location and Design

A. Street light fixtures shall be full cut-off. LED, 3000 Kelvin.

B. Generally, street lighting shall be installed in all zones except A-1, A-2, and R-E, as development occurs. However, street lighting may be considered in A-1, A-2, and R-E zones if they are bordered or traversed by a major thoroughfare, and if that major thoroughfare has been improved to current City standards.

C. The following guidelines shall be followed in providing lighting on minor streets and local collectors:

1. One 4,000 lumen streetlight at each street or alley intersection. Streetlights shall not be placed at individual driveways.

2. One 4,000 lumen streetlight at each end of each cul-de-sac or other permanently dead ended street.

3. One 4,000 lumen streetlight at the approximate midpoint of curvilinear streets that prohibit visual contact between intersections.

4. One 4,000 lumen streetlight midway between intersections that are spaced 300' or more apart. Closer spacing would be allowed on curves as approved by the City Transportation Engineer.

5. The intention of lighting to be installed is for maintenance to be addressed by the utility provider. For this to occur, all fixtures and lighting components, including the poles, must meet the utility providers standards. Failure to do so could result in a situation where the utility provider refuses to maintain the installation(s).

D. The spacing and sizing of thoroughfare lighting shall be in accordance with the criteria of *Roadway Lighting Handbook*, U.S. Department of Transportation, Federal Highway Administration, current revision.

4013.4 Approvals

A. Requests for street lighting shall be submitted to the office of the City Transportation Engineer. Lighting for minor streets and local collectors shall be reviewed by the City Transportation Engineer and forwarded to the franchised vendor on forms provided by the vendor. Lighting for minor streets and collectors which are not as specified herein shall require the review of the City Transportation Engineer and the Director of Public Works.

B. Proposals for thoroughfare lighting shall be submitted in letter or email to the franchised vendor by the City Transportation Engineer, with final allowance to proceed with installation by the Director of Public Works.

C. The City Transportation Engineer will document in writing reasons for denying a request for lighting.

4014 STRUCTURES AND SPECIFIC DETAILS

4014.1 All special structures (those to which a construction standard detail does not exist or a variation from standard is required) shall be sufficiently detailed.

4014.2 Special structures shall be drawn to scale unless otherwise specifically noted, for the purpose of information clarification.

4014.3 Sufficient details, dimensions and related notes shall be provided for all structures.

4014.4 All structures subject to vehicular traffic shall be designed for HS-20 loading.

4014.5 All bridge design shall meet the requirements in the latest edition of Standard Specifications for Highway Bridges prepared by AASHTO.

4015 PARKING

4015.1 When on-street parking is required, it shall operate as parallel parking unless otherwise approved by the City Engineer. Where on-street angled parking is used, the street shall provide a travel section that is no less than 24-feet wide, the angled parking shall be no closer than 20-feet from the curb return of an upstream or downstream intersection, and the angled parking shall be no closer than 20-feet from the downstream edge of a pedestrian crossing (regardless of whether it is striped with a crosswalk) or within 30 feet of a stop sign.

4015.2 New cut back parking areas will be allowed only on roadways carrying less than an average of 1,000 vehicles per day. Where allowed, sufficient maneuvering space for safe backing must be provided. The minimum width of the parking area, measured perpendicularly from the edge of the travel lane, shall be as follows:

Parking Angle	Minimum Width
0 Degrees (Parallel)	10 Feet or 8' CCFBC
30 Degrees	17 Feet
45 Degrees	19 Feet
60 Degrees	20 Feet
90 Degrees (Perpendicular)	18 Feet

Cut back parking areas shall be paved in accordance with the applicable adopted City paving standard. Curb shall be constructed to prevent parked vehicles from encroaching into unpaved areas or sidewalks.

4016 EASEMENT AND RIGHT-OF-WAY

4016.1 Easements and rights-of-way shall be clearly dimensioned on the plans. For curved roadways, additional right-of-way may be required to maintain adequate sight distance.

4017 PAVING DESIGN

4017.1 Geotechnical Investigation Report

A. All pavement designs not per the standard drawings shall be supported by a geotechnical investigation report that is performed by a geotechnical engineer that is licensed as a professional engineer in the State of

Oklahoma. Proposed pavement sections that are less than the minimum thickness required by the standards shall be approved by the City Engineer.

B. The geotechnical investigation shall include a subsurface exploration with adequate sample location coverage that is developed by the geotechnical engineer-of-record for the project. The field investigation shall include test borings, test pits, geophysical soundings, field testing, or other industry-accepted methods to evaluate the subsurface conditions, as appropriate to meet the needs of the project. Test borings shall extend at least 5 feet below the proposed top of pavement.

C. Laboratory testing shall be included to characterize the United States Soil Classification for each major strata and any substrata that could influence pavement performance. This shall include index testing to characterize moisture, density, plasticity, and grain size. Strength and modulus determination testing shall also be performed, as noted in **Section 4017**.

D. The results of the geotechnical investigation shall be summarized in a geotechnical report. A copy of the geotechnical report shall be provided to the City.

E. The report(s) shall provide the recommended pavement thickness and supporting thickness calculation documentation, including the process used to determine the Equivalent Single Axle Load (ESAL) for each load case.

4017.2 AASHTO Method

Street pavements shall be designed based on *Guide for the Design of Pavement Structures,* American Association of State Transportation Officials (AASHTO), 1993 edition and current amendments. Computations shall be performed on an up-to-date version of the computer software program *Pavement Analysis Software*, developed by the American Concrete Pavement Association.

4017.3 Design Parameters

A. Traffic Volumes:

Street Class	ADT	No. Lots
Residential	300-700	50-120
Residential Collector	2,000-6,000	350-1025

Arterial traffic volumes shall be based on the current City Transportation Plan.

B. Truck Traffic Volumes

Truck traffic for various axle loads, accounting for truck traffic during construction, shall be estimated from Table 4017.1.

Table 4017.1: Truck Traffic for Residential & Residential Collector Streets

(1) Axle Load (K)	(2) Construction (Per Lot)	(3) Occasional (Per Lot Per Yr)	(4) Regular (Per Year)
Tandem:			
18/23/23	36	0.503	104
Single:			
12/22	42	0.123	348
10/18	38	2.68	1456

Note: Traffic volumes are total vehicles per year. Values for each truck category, for input to the paving design software are calculated as follows:
Trucks per year = [Col. (2) * No. Lots / Design Period] + [Col. 3 * No. Lots] + Col. (4)

C. Design Period:

Pavement Type	Design Period
Asphalt pavements	20 years
Concrete pavements	30 years

D. Reliability Factor:

Street Class	Reliability Factor
Residential	65
Collector	85
Arterial	90

E. Drainage Coefficient: Except as accepted by the City Engineer for specific conditions, either supported by geotechnical testing or by the inclusion of subgrade drainage, the coefficient of drainage shall be no greater than 1.00

F. Geotechnical Data: AASHTO-based pavement design software utilizes the subgrade resilient modulus (M_R) as the basis of its computations. In cases where existing California Bearing Ratio (CBR) or subgrade modulus (*k*) test data is available, they may be used with prior written approval by the City Engineer. The *Simplified Guide for the Design of Concrete Pavements* (1993) by the American Concrete Pavement Association provides approximate correlations between CBR or *k* and M_R. Table 4017.2 contains the approximate correlated values but they must be applied with judgement by the engineer-of-record for the project using site-specific data. All geotechnical parameters used for the pavement design are subject to the approval of the City Engineer.

Table 4017.2: Relationships of Soil Types & Strength Parameters				
Type of Soil	**Subgrade Strength**	***k* Value Range (pci)**	**M_R (psi)**	**CBR**
Silts & clays of high compressibility[1] natural density	Very Low	50-100	1000-1900	$\leq$ 3
Fine grain soils in which silt & clay size particles predominate (low compressibility)[2]	Low	100-150	1900-2900	3-5.5
Poorly graded sands & soils that are predominately sandy with moderate amounts of silts and clays	Medium	150-220	2900-4300	5.5-12
Gravely soils, well-graded sands, and sand gravel mixtures relatively free of plastic fines	High	220-250+	4300-4850	>12
Source: *Simplified Guide for the Design of Concrete Pavements*, American Concrete Pavement Association, 1993.				

G. Material Coefficients: Acceptable coefficients for conversion of depth of various types of materials are presented in Table 4017.3.

Table 4017.3: Layer Coefficients by Layer Type			
Flexible Pavement Layer Type			**Layer Coefficient Per Inch of Depth**
Surface Course – "S 4 & 5" HMAC			0.44
Base – "S3" HMAC			0.40
Subbase – Modified Subgrade,	CKD	(CBR 24)	0.10
" ,	Fly Ash	(CBR 40)	0.12
" ,	Cement	(CBR 100)	0.14
" ,	Lime	(CBR 24)	0.10
Type A Aggregate		(CBR 100)	0.14
Prepared Roadbed – Compacted Subgrade			0.04

Note: The layer coefficient values in Table 4017.3 are those that are commonly used for these material types. These are values that may be used in the absence of project and/or material specific test data, and the design engineer may consider adjustment of the values based on experience as approved by the City Engineer.

4017.4 Construction Materials Quality Control Inspection & Testing

A. All street construction projects shall include quality control inspection and testing of materials used for the construction of the subgrade, curb and gutter, and pavement.

B. The construction materials quality control inspection and testing requirements/frequency shall be as defined by the geotechnical engineer-of-record or as stated in **Section 2300** of the Standard Specifications and Construction Drawings. In cases where the requirements are in dispute, the City Engineer shall make the final determination of the requirements.

C. Construction materials testing will be performed by an AASHTO accredited testing laboratory. Test results will be stamped and sealed by a Professional Engineer and provided to the City prior to project acceptance. The construction materials quality control program for streets shall include:

1. Moisture-density relationship (Proctor curve)
2. Atterberg limits
3. Particle size gradation/percent passing No. 200 sieve
4. In place nuclear density determination with moisture
5. California Bearing Ratio (CBR)
6. Concrete strength testing of samples
7. Slump and entrained air determination
8. Inspection and verification of reinforcing steel
9. Inspection/documentation of concrete placement
10. Inspection/documentation of subgrade stabilization and density
11. Soundness testing of aggregate materials
12. Verification testing of asphalt materials and placement

D. All moisture-density relationship tests shall be based on a five (5) point curve and include at least one index test to document the plasticity (if appropriate) and the percent passing the No. 200 sieve size (for subgrade materials without significant material above the No. 4 sieve) or a particle size gradation curve (for gravelly subgrade soil or granular paving layers).

END OF SECTION 4000

5000: STORMWATER

5001 GENERAL REQUIREMENTS

5001.1 If a Stormwater Master Drainage Plan has been adopted for the area under consideration, proposed stormwater drainage systems shall comply with the provisions of the plan.

5001.2 A Maintenance Bond, Certificate of Deposit, or cash shall be posted in an amount equal to 25 percent of the determined amount of construction costs for a 3-year period after completion and acceptance of all improvements.

5001.3 It shall be the responsibility of all owners of property, whether undeveloped, developed, or undergoing development to:

A. Mow and provide maintenance of drainage channels and their slopes for that portion of the channel lying within their property line.

B. Keep clear all drainage channels within the boundaries of their properties in accordance with the requirements of this article.

C. Control all storm water runoff and drainage, erosion and sedimentation from points and surfaces on the property.

D. Prevent any and all drainage interferences, obstructions, blockages, or other adverse effects upon drainage, into, through, or out of the property.

E. Not alter or otherwise change designed and installed storm water management control systems and not take any action on existing property that shall adversely affect stormwater runoff in any manner contrary to the provisions of this Section, whether temporary, permanent, or a combination thereof.

5001.4 Provision of Improvements

A. The City may require provision of drainage easements, and for provision of improvements, agreements, and/or easements beyond the boundaries of the subdivision, development, or property improvement to facilitate flow of stormwater from or through the property, to avoid damage from changed runoff conditions, to provide continuous improvement of the overall storm drainage system, and to accommodate all drainage conditions or requirements. Where stormwater runoff flows require the logical extension of any street or its associated drainage in order to prevent flooding, ponding, or uncontrolled runoff, the extension shall be provided by the developer.

B. During all construction activity and all other non-construction activity developers, property owners, and contractors shall be required to keep streets, gutters, inlets, drainage pipes, swales, ditches, drainage channels, and all drainage devices and structures clean and free from debris, sedimentation, soil, and any materials. Any failure to meet this requirement shall, upon notice and failure to immediately correct the notified condition, constitute sufficient grounds for initiation of enforcement action, including, but not limited to, stopping all work until correction is completed.

C. Property owners, developers, or their legal agents, upon receipt of notice by the City of Norman that repair or maintenance is required of privately owned stormwater infrastructure, shall be responsible for effecting such repairs or maintenance within the time specified, or the City shall have repairs and maintenance performed at the expense of the property owner.

5001.5 It shall be the responsibility of the City of Norman to:

A. Repair and maintain stormwater infrastructure located within or upon rights-of-way and drainage easements dedicated to the City of Norman. However, this does not pertain to platted parcels or subdivisions which shall be maintained by the developer or HOA.

B. Design, periodically update, and implement a Stormwater Master Plan for drainage, storm water management, and flood control.

C. Make such necessary improvements of primary and secondary drainage channels that cannot or will not be improved through private development.

D. Maintain floodway and flood fringe areas that are dedicated public areas, rights-of-way, park lands, or publicly owned buildings or properties.

E. Maintain all publicly owned drainage channels or systems outside the flood fringe area.

5002 EASEMENTS

5002.1 All drainage easements will be shown detailed on the Construction Plans and Final Plat, as well as described in the covenants and restrictions of the development.

5002.2 The City may accept dedication of the entire floodplain area for an unimproved channel.

5002.3 Adequate restrictive easements or dedicated right-of-way must be provided for access and maintenance of channels and detention ponds.

5002.4 The minimum width for all closed storm sewer easements shall be 15 ft or the outside diameter of pipe plus 10 ft, whichever is greater, and the pipe shall be laid in the center of easement.

5002.5 Drainage easements for channels or flumes will extend, at a minimum, from left top of bank to right top of bank and require necessary vehicular access to perform maintenance.

5003 DRAINAGE SYSTEM REQUIREMENTS

5003.1 All stormwater runoff systems shall be reviewed and accepted by the City Engineer with regard to analysis, design, and construction of drainage facilities. The appropriate public authority shall have the right to maintain or to cause to be maintained the drainage system for its intended purposes. All proposed development within a floodplain must be reviewed and accepted by the Floodplain Permit Committee.

5003.2 Drainage facilities, both public and private, shall consist of all elements necessary to convey stormwater runoff from its contact with the earth to its disposition in the Little River, Canadian River, or Lake Thunderbird.

5003.3 The stormwater drainage system, both public and private, may consist of storm sewers (which are closed conduits); improved channels constructed in conformity with adopted City Standards; unimproved drainageways left in their natural condition; areas identified within the Water Quality Protection Zone (WQPZ), covered by restricted drainage easements for the purpose of providing overland flow; and all appurtenances to the above including inlets, manholes, junction boxes, headwalls, dissipators, culverts, etc. All portions of the drainage system that exist within dedicated rights-of-way or restricted drainage easements shall be maintained by the the City, unless provided otherwise by agreement or covenant.

5003.4 The stormwater drainage system shall be designed to receive and pass the runoff from a 100-year frequency rainstorm within dedicated easements under full urbanization. Full urbanization is defined as the total anticipated development within the project boundaries. The entire flow shall be confined within the stormwater drainage system. The currently adopted Stormwater Master Plan and/or Comprehensive Plan shall be used to identify future land uses to determine Full Urbanization conditions. Other terms such as “fully developed” and “full build-out” are considered interchangeable with “fully urbanized”.

5003.5 The stormwater drainage system shall be designed for either of the following conditions:

A. Convey:

1. A minimum of overland flow capacities to pass the runoff from a 100-year frequency rainstorm under fully urbanized conditions; or

2. The entire runoff from a 100-year frequency rainstorm under fully urbanized conditions shall be contained within the rights-of way. The network of pipes and inlets must be designed to convey the runoff even in the event of blockage or bypass and must be approved by the City Engineer.

3. The overland flow and bypass system mentioned in **Section 5003.5A.1** and **Section 5003.5A.2** above shall be placed at sump locations and consist of a concrete flume or equivalent product which provides a permanent flowline (i.e., articulated block, turf reinforcement) that can handle design velocities and must be approved by the City Engineer.

B. When inlets are placed in a sump, an emergency overland drainage easement shall be provided and an overflow route designed to convey the 100-year flows based on 100% clogging of the sump inlet.

C. Runoff from areas greater that one half (1/2) acre outside the roadway shall be collected before it reaches the roadway. Parking lots shall have internal drainage systems to reduce concentrated flows into streets. This item does not apply to single family residential lots on local streets.

D. Inlets shall be located at intersections to prevent the flow from crossing the intersection. Inlets at intersections shall be located so they do not encroach upon the curb return. The City Engineer may approve alternative designs.

E. No storm sewer inlet (as defined in **Section 5007**) shall be permitted at a wheelchair ramp. Stormwater Control Measures (SCMs) such as permeable pavers are not considered storm sewer inlets and may be permitted at a wheelchair ramp with the approval of the City Engineer provided that they meet ADA requirements.

F. Drainage areas, runoff from 10-year and 100-year frequency rainstorms, time of concentration, and inlet design for each inlet shall be summarized and tabulated on the plans. This summary table shall also be a part of the drainage report calculations.

G. No flumes will be allowed to discharge onto arterials. Flumes discharging onto collectors and local streets are strongly discouraged and shall be allowed by the City Engineer only if there is no other reasonable solution.

5003.6 The overland flow portion of the collector system shall be confined to dedicated rights-of-way, or restricted drainage easements to assure that stormwater can pass through the development without inundating the lowest level of any building, dwelling, or structure. Restricted drainage easements shall be shown on the plat. The stormwater runoff from no more than 3 lots or ½ acre (whichever is less) shall be allowed to drain onto another lot or between 2 lots. If more lots or areas need to be drained, then an underground storm sewer shall be required.

5004 RAINFALL

5004.1 Introduction

Presented in this section is the design rainfall data to be used for runoff hydrograph calculations and the Rational Method. All hydrological analyses for the City of Norman shall utilize the rainfall data presented herein for calculation of storm runoff.

5004.2 Total Rainfall

NOAA Atlas 14, Precipitation-Frequency Atlas of the United States, Volume 8, Version 2.0 (2013), provides total rainfall depths for 100% (1-year) through 0.2% (500-year) storms with storm durations of 5-minutes to 24-hours for the City of Norman and are presented in **Table 5004.1**. These rainfall depth-duration values are for the NORMAN Station ID: 34-6386 and shall be used in all HEC-HMS or other approved models to calculate existing and future development discharges for all frequency storms. NOAA Atlas 14, Precipitation-Frequency Atlas of the United States, Volume 8 is updated every 5-10 years. The most current version of this data or its equivalent shall be used. The latest version adopted by NOAA can be obtained on the NOAA website for the NORMAN Station.

Table 5004.1: Total Rainfall Depths
Noaa Atlas 14, Volume 8, Version 2 (2013)
Norman Station Id: 34-6386

Duration	Total Rainfall Depths for Norman, Oklahoma - Inches							
	Frequency (Return Period)							
	100% (1-year)	50% (2-year)	20% (5-year)	10% (10-year)	4% (25-year)	2% (50-year)	1% (100-year)	0.2% (500-year)
5-minute	0.43	0.50	0.61	0.71	0.86	0.98	1.10	1.41
10-minute	0.63	0.72	0.89	1.04	1.25	1.43	1.61	2.06
15-minute	0.76	0.88	1.09	1.27	1.53	1.74	1.96	2.51
30-minute	1.11	1.30	1.61	1.88	2.26	2.58	2.90	3.70
1-hour	1.47	1.72	2.15	2.53	3.08	3.54	4.02	5.23
2-hour	1.82	2.14	2.69	3.18	3.91	4.50	5.14	6.76
3-hour	2.04	2.39	3.02	3.59	4.44	5.15	5.91	7.90
6-hour	2.44	2.84	3.57	4.24	5.29	6.18	7.15	9.73
12-hour	2.87	3.29	4.09	4.84	6.03	7.07	8.20	11.30
24 hour	3.30	3.77	4.66	5.52	6.87	8.04	9.33	12.80

Reference Online NOAA Atlas 14, Volume 8, Version 2 Point Precipitation Frequency Estimates for Norman Station ID: 34-6386

5005 RUNOFF

5005.1 Approved Methods

Table 5005.1 contains methods of runoff which analysis may be used for the design of components of the storm drainage system as applicable.

5005.2 Rational Method

A. Formula: The Rational Method is based on the formula: Q = CIA

"Q" is defined as the maximum rate of runoff in cubic feet per second. "C" is a runoff coefficient of the area. "I" is the average intensity of rainfall in inches per hour for a duration equal to the time of concentration. The time of concentration is the time required for water to flow from the most remote point of the basin to the point being investigated and to reach a steady state condition. "A" is the contributing watershed area in acres.

Table 5005.1

Methodology	Applicable For			Minimum Drainage Area	Maximum Drainage Area
	Peak Q (Pipe, Inlet, Culvert)	Pond/Detention Calculations	Volume/Floodplain Calculations		
Rational Method	Yes	No	No	No Min	200 acres
NRCS (SCS) Method	Yes	Yes	Yes	No Min	No Max*
USGS Regression Equations	Yes**	No	No	2 sq. miles	2,000 sq. miles

*Drainage areas should be delineated so that homogenity of the watershed is maintained and time of concentration flow paths are not wrongfully skewed due to the creation of a "long/skinny" watershed.

**USGS Regression Equations should only be used for Estimating Peak Flows along the Canadian River and any unregulated stream within Norman, Oklahoma.

B. Time of Concentration:

1. One of the basic assumptions underlying the Rational Method is that runoff is a function of the average rainfall rate during the time required for water to flow from the most remote part of the drainage area to the point under consideration.

2. The time of concentration consists of overland flow time, To plus the time of travel, Tf, in the storm sewer, paved gutter, roadside drainage ditch, or drainage channel. For non-urban areas, the time of concentration consists of an overland flow time, To, plus the time of travel in a combined form, such as a small swale, channel, or drainage. The latter portion, Tf, of the time of concentration can be estimated from the hydraulic properties of the storm sewer, gutter, swale, ditch, or drainage. Overland flow time, on the other hand, will vary with surface slope, surface cover, and distance of

surface flow. The infiltration rate of the soil, the presence of depression storage areas, and the amount of antecedent rainfall will also affect the inlet time, since the rainfall must first overcome these losses before a steady state runoff condition will be achieved. Thus, the time of concentration can be calculated using the following equation:

$$T_C = T_0 + T_f$$

Where,

T_C = time of concentration (minutes)

T_0 = initial, or overland flow time (minutes)

T_f = travel time in the ditch, channel, gutter, storm sewer, etc. (minutes)

Minimum time of concentration, T_c, shall be 5 minutes.

3. The overland flow time, T_o, in non-urbanized watersheds may be calculated as follows:

$$T_0 = \frac{1.8(1.1 - C)({L_0}^{0.5})}{{S_0}^{0.333}}$$

Where,

C = Runoff coefficient

L_o = Length of overland flow (feet, 150 feet maximum)

S_o = Average basin slope (percent)

In lieu of the foregoing, formulas may be used as contained in the ODOT *Roadway Design Manual,* Section 15.3.2.1.

4. The equation for overland flow time, T_o, is generally adequate for distances up to 150 feet. For longer basin lengths, the runoff will combine, and the sheet flow assumption is no longer valid. The time of concentration would then be overland flow in combination with the travel time, T_f, which is calculated using the hydraulic properties of the swale, ditch, or channel. The time of concentration is then the sum of the initial flow time, T_o, and the travel time, T_f.

C. Runoff Coefficient: The runoff coefficient, C, represents the integrated effects of infiltration, evaporation, retention, flow routing, and interception, all of which affect the time distribution and peak rate of runoff. Determination of the runoff coefficient requires judgment and understanding on the part of the engineer. Table 5005.2 presents the recommended range of C values for different surface characteristics as well as for different aggregate land uses. Coefficient values selected from the range available shall be consistent with the urbanized percent imperviousness (i.e. minimum percent imperviousness requires minimum runoff coefficient value). Also, for flat slopes and permeable soils, use the lower values. For steep slopes and impermeable soils use the higher values. A copy of NRCS Soil Survey Map should be included in the drainage report showing soil type(s) and soil hydrologic group.

D. Intensity: The intensity, I, is the average rainfall rate in inches per hour for the period of maximum rainfall of a given frequency having a duration equal to the time of concentration. For a given time of concentration, T_c, and a given design storm frequency, the rainfall intensity, I, can be obtained using the following equation:

$$I = \frac{d}{(T_C + e)^f}$$

Where,

I = Rainfall Intensity (inches per hour)

T_C = Time of Concentration (minutes)

d, e, f = Parameters defined in Table 5005.3.

TABLE 5005.2 – Runoff Coefficients and Percent Imperviousness for the Rational Method

Land Use or Surface Characteristic	Percent Imperviousness	Runoff Coefficients
BUSINESS:		
Commercial Areas	70 to 95	0.70 - 0.90
Neighborhood Areas	60 to 80	0.50 - 0.70
RESIDENTIAL:		Use percent impervious for runoff coefficient or calculate composite runoff coefficient (0.40 minimum)
Single Family	40 to 60	
Multi-unit (detached)	45 to 55	
Multi-unit (attached)	65 to 75	
1/2 acre lot or larger	20 to 40	
Apartments	65 to 75	
INDUSTRIAL:		
Light Uses	70 to 80	0.50 - 0.80
Heavy Uses	80 to 90	0.60 - 0.90
PARKS, CEMETERIES	4 to 8	0.40 - 0.60
PLAYGROUNDS	10 to 20	0.40 - 0.50
SCHOOLS	40 to 60	0.40 - 0.60
RAILROAD YARDS	35 to 45	0.40 - 0.60
UNDEVELOPED AREAS:		
Cultivated	30 to 70	0.40 - 0.60
Pasture	20 to 60	0.40 - 0.50
Woodland	5 to 40	0.40 - 0.50
Offsite Flow (land use not defined)	35 to 55	0.40 - 0.90
STREETS:		
Paved	90 to 100	0.70 - 0.95
DRIVES AND WALKS	90 to 100	0.75 - 0.90
ROOFS	85 to 95	0.75 - 0.95

** Runoff coefficient to be calculated using actual impervious area and soil type.*

Table 5005.3 - Rainfall Intensity Parameters			
Design Storm	**Parameter**		
	d	**e**	**f**
2-Year	53	10	0.82
5-Year	64	12	0.79
10-Year	74	12	0.79
25-Year	93	15	0.79
50-Year	104	15	0.79
100-Year	108	15	0.77
500-Year	130	15	0.75

Source: Drainage Design Manual, ODOT, November 2014

5005.3 Unit Hydrograph Methods

A. Introduction: Unit hydrograph computations are required for all hydrologic studies when the time of concentration for the entire watershed draining to the point of discharge from the project is greater than 10 minutes. The Soil Conservation Service (SCS) Unit Hydrograph Method is the preferred method. HEC-HMS is the preferred computer program for performing these computations. HEC-HMS is a hydrologic simulation model developed by the US Army Corps of Engineers Hydrologic Engineering Center in Davis, California and is the successor to HEC-1. Other models may be used with the approval of the City Engineer. Table 5005.1 indicates methods applicable to various scenarios and watersheds. This section contains brief explanations of the various hydrograph methods; however, the design engineer is assumed to be familiar with the basic assumptions and limitations regarding the applicability of the method used.

B. Design Storm Precipitation:

1. The design storm for the Norman area shall consists of a 24-hour storm and have a 1-minute unit duration for peak flow calculations.

2. A precipitation hyetograph shall be used as the input for all runoff calculations. The specified precipitation is assumed to be uniformly distributed over the watershed. The hyetograph represents average precipitation depths over a computation interval.

5005.4 SCS Unit Hydrograph Method

A. Introduction

The SCS Unit Hydrograph methodology combines the effect that specific soils and soil cover (i.e., vegetation) have on the runoff from a storm into one parameter called the Soil-Cover Complex Number (CN). For a specific type of land use, soil type, and cover condition in a watershed, a CN value can be determined. Then, utilizing the total rainfall value and the CN value, the storm runoff volume is calculated from a given total rainfall. Next, the peak flow rate and hydrograph shape are determined by applying the runoff to the SCS dimensionless unit hydrograph which is defined by calculating the lag time of the basin.

When using the SCS unit hydrograph method for a sub basin, the SCS basin lag time shall be used in conjunction with the CN value to determine runoff.

B. Curve Number (CN) Determination

The soil type and vegetative covers of a watershed are generally classified separately. A combination of a specific soil type and a specific cover is referred to as a Soil-Cover Complex Number (CN) and a measure of this complex can be used as a watershed parameter in estimating runoff. The CN for each sub area in the hydrologic analysis can be derived by first determining the classification of the soil, and then choosing the CN value from **Table 5005.4** for the applicable cover type and hydrologic condition.

The local Natural Resources Conservation Service (NRCS) office has soil survey data for Cleveland County. This data was mapped with soil series and complexes and can be obtained on the NRCS website. Generalized soils maps, on a county basis, can also be obtained from the NRCS website. Once the soil series is known, the soil can be placed into the proper hydrologic soil group.

The Soil Conservation Service (SCS) method is presented in detail in Section 4 of the U.S. Department of Agriculture Soil Conservation Service Engineering Handbook and Model Drainage Manual, American Association of State Highway and Transportation Officials, 1991. The SCS publication TR55 may be used for areas up to 2,000 acres.

Proposed Table 5005.4 – Runoff Curve Numbers – SCS Method

Cover Type and Hydrologic Condition	Percent Impervious	Curve Numbers for Hydrologic Soil Group A	B	C	D
Fully Dev. Urban Areas (Vegetation Established)					
Open space (lawns, parks, golf courses, cemeteries, etc.):					
Poor condition (grass cover < 50%)	0	68	79	86	89
Fair condition (grass cover 50% to 75%)	0	49	69	79	84
Good condition (grass cover > 75%)	0	39	61	74	80
Impervious areas:					
Paved parking lots, roofs, driveways, etc.	100	98	98	98	98
Streets and roads:					
Paved with curbs and storm sewers	100	98	98	98	98
Paved with open ditches	80	83	89	92	93
Gravel	100	98	98	98	98
Dirt	80	72	82	87	89
Urban districts:					
Commercial and business	85	89	92	94	95
Industrial	72	81	88	91	93
Residential districts by average lot size:					
1/8 acre or less (town houses)	65	77	85	90	92
1/4 acre	38	61	75	83	87
1/3 acre	30	57	72	81	86
1/2 acre	25	54	70	80	85
1 acre	20	51	68	79	84
2 acres	12	46	65	77	82
Developing Urban Areas (No Vegetation)					
Newly graded areas - no vegetation	0	77	86	91	94

C. Routing of Hydrographs

For all hydrologic studies submitted to the City of Norman which involve routing of sub basin hydrographs, the following routing methods shall be used as indicated and are also provided in **Table 5005.5**:

1. The Kinematic Wave method may be used in channel and storm sewer routings.
2. The Storage-Discharge (Modified Puls) routing shall be used for channel/overbank and reservoir routings.
3. The Lag method may be used for storm sewer flow.

Proposed Table 5005.5 – Approved Routing Methods	
Routing Method	**Flow Condition**
Kinematic Wave	Flow completely contained in the channel. Flow contained in storm sewer
Modified Puls (Storage-Discharge)	Flow completely contained in the channel. Flow contained in storm sewer
Lag Method	Flow contained in full storm sewer

5005.5 USGS Regression Equations: The United States Geological Survey (USGS) regression equations for ungauged streams can be found in the USGS publication, *"Techniques for Estimating Flood Discharges for Oklahoma Streams",* Water Resources Investigation 77-54, U.S. Geological Survey, Water Resources Division, June 1977.

5006 STREET DRAINAGE

5006.1 Criteria for Street Drainage

When the drainage in the street exceeds allowable limits, a storm sewer system is required to convey the stormwater runoff. Use of streets for conveyance of stormwater runoff shall be within the following limitations:

A. The 100-year fully urbanized flow shall be contained within the right-of-way.

B. For arterial and collector streets, the depth of street flow is limited to inundation of the outside lane (typically 0.38 feet) during a 100-year frequency rainstorm under fully urbanized conditions.

C. For residential streets, the depth of street flow is limited to 0.50 feet (6-inches) during a 100-year frequency rainstorm under fully urbanized conditions.

D. Where sump collection systems are used, an overflow route shall be established in the event of complete blockage of the sump in accordance with **Section 5003.5B**. Additional criteria for storm sewer inlets are in **Section 5007**.

5006.2 Drainage Impact on Streets

A. Sheet Flow: To minimize the effects of hydroplaning and splashing of sheet flow, the streets of Norman are designed with a 2% (1/4" per foot) cross slope. In addition, for arterial streets, the amount of flow spread permitted in the street is limited to the outside lane before a storm sewer inlet is required (Refer to **Section 5006.1A**). Flow spread (T) is calculated as follows:

$$T = \left[\frac{Qn}{K_u S_x^{5/3} S_l^{1/2}}\right]^{0.375}$$

Where,

T = Width of flow or spread, (ft)

Q = Discharge (cfs)

N = Manning's roughness coefficient

Ku = 0.56

Sx = Cross slope, (ft/ft)

Sl = Longitudinal slope (ft/ft)

B. Cross Flow: The depth of cross flow permitted in non-arterial streets, where it cannot be avoided, is limited to the top of curb. Cross flow in arterial streets is not permitted and is strongly discouraged for collectors and residential streets. The cross-flow limitations for freeways are determined by the Oklahoma Department of Transportation.

C. Valley Gutters: Concrete valley gutters are required in asphalt streets when the longitudinal grade is 1% or less. The width of the valley gutter will be determined by the depth required. The maximum slope of the lateral grade shall be 5% when the valley gutter is located at or near a stop sign. When the valley gutter is in mid-block with a speed limit of 25 mph the cross slope shall be a maximum of 3%. No mid-block valley gutters shall be allowed if the speed limit is greater than 25 mph. If a bird bath exists on an asphalt valley greater than 1%, then a concrete valley gutter shall be constructed.

5006.3 Hydraulic Evaluation

A. Curb and Gutter Capacity:

1. The allowable storm capacity of each street section with curb and gutter shall be calculated using the modified Manning's formula:

$$Q = 0.56(\frac{Z}{N})S^{\frac{1}{2}}Y_T^{\frac{8}{3}}$$

Where,

Q = Discharge (cfs)

Z = Reciprocal of the street cross slope (S_x, ft/ft)

Y_T = Depth of flow at the gutter (feet)

S = Longitudinal grade of street (ft/ft)

N = Manning's roughness coefficient

2. Manning's roughness coefficient, N, shall be used according to the applicable construction condition from **Table 5006.1**.

3. When the street cross section has different cross slopes, capacity computation shall take into account the various cross slopes.

B. Roadside Ditch Capacity: The capacity of a roadside ditch shall be computed using Manning's equation. The allowable flow over the paved portion of the street is computed according to **Section 5006.3A**. This capacity of the roadside ditch and street capacity are combined to determine the entire street section capacity. The paved street portion contributes to the total capacity only when the depth of flow in the roadside ditch is exceeded for the design storm. For streets with curb and gutter, the maximum allowable depth at the pavement edge shall not exceed the limits set in **Section 5006.1**.

Table 5006.1: Manning's N Values

	CHANNEL/SURFACE TYPE	N VALUE RANGE	RECOMMENDED VALUE
A.	Earth Lined (ditches/canals)		
	1. Clean, weathered	0.018 to 0.025	0.022
	2. Clean, gravel	0.022 to 0.030	0.025
	3. Some weeds	0.022 to 0.033	0.027
	4. Not maintained	0.30 to 0.40	0.035
B.	Grass Lined (manmade)		
	1. Well maintained	0.03 to 0.05	0.03
	2. Poorly maintained	0.05 to 0.10	0.05
C.	Natural Streams	0.025 to 0.10	Note 1
	Overbank Areas	0.03 to 0.20	
D.	Rock Lined		
	1. Ordinary rip rap	0.02 to 0.03	0.02
	2. Gabions	0.02 to 0.03	0.02
	3. Grouted rip rap	0.023 to 0.03	0.027
	4. Slope mattress	0.025 to 0.033	0.028
E.	Concrete		
	1. Float finished/wood forms	0.013 to 0.016	0.015
	2. Slip formed	0.016 to 0.016	0.015
	3. Gunite	0.016 to 0.025	0.015

Note 1 Refer to Chow, V.T., Open Channel Hydraulics, McGraw-Hill Book Company, 1959, Table 5-6

5007 STORM SEWER INLETS

5007.1 Design Criteria

A. Inlet Types:

1. Grated inlets without a curb opening are not permitted within the City of Norman streets unless approved by the City Engineer.
2. Inlet types shall be in accordance with the City's Standard Drawings.
3. Allowable inlet types, standards, and clogging factors are shown in **Table 5007.1**.
4. The bicycle safe grates (in combination with a curb opening) are the only grates approved by the City of Norman within the street right-of-way. The Neenah R-3076 Vane Grate, or approved equal, shall be used in the City of Norman.
5. Minimum size shall be 2 hoods and 2 grates.

Table 5007.1 – Allowable Inlet Types and Clogging Factors

Standard No.	Description	Allowable Locations	Inlet Location on Street	On-Grade Clogging Factor	Inlet Location on Street	Sump Clogging Factor
SD 21A SD21B	Recessed 6" Metal Frame Inlet w/Access Manhole Back of Curb - 4' and 8' length	Residential Neighborhood	Continuous Grade	1.0	Sump	0.8
SD21ASD21B	Recessed 10" Metal Frame Inlet w/Access Manhole Back of Curb - 4' and 8' length	Collector or Arterial Streets, Commercial and Industrial Areas	Continuous Grade	1.0	Sump	0.8
SD 11	Non-Recessed Standard Inlets and Grates w/Access Manhole Back of Curb	Street Rehabilitation Projects	Continuous Grade	1.0	Sump	0.7
SD 13	Non-Recessed Standard Reinforced Concrete Storm Sewer Inlets with Cast Iron Curb Openings and Grates	Street Rehabilitation Projects	Continuous Grade	1.0	Sump	0.7
SD 16	Recessed Cast Iron Curb Inlets with grates (no access manhole back of curb)	Residential, Collector or Arterial Streets	Continuous Grade	1.0	Sump	0.7
SD 16	Recessed Concrete Curb Inlets	Residential, Collector or Arterial Streets, outside of a ___' radius	Continuous Grade	1.0	Sump	0.8

Table 5007.1 – Allowable Inlet Types and Clogging Factors						
Standard No.	Description	Allowable Locations	Inlet Location on Street	On-Grade Clogging Factor	Inlet Location on Street	Sump Clogging Factor
	without grates with access manhole back of curb					
SD 17, SD 18, SD 19	Standard Drop Inlets (15-inch through 48-inch pipes)	Sump areas in Medians, R/W, drainage easements and reserves			Sump	0.8
SD 20	Standard Three Way Drop Inlet (48-inch pipe)	Sump areas in Medians, R/W, drainage easements and reserves			Sump	0.8
ODOT Standard SMD-4 (R-29)	ODOT Standard Median Drain with Type 1 or Type 2 Grate	Sump areas in Medians, R/W, drainage easements and reserves			Sump	0.6

5007.2 Location of Inlets:

1. Inlets shall be located at all low points in the gutter grade, on side streets at intersections where runoff would flow onto an arterial street or highway, and upgrade of bridges to prevent runoff from flowing onto the bridge deck. Inlets are also required when the allowable depth of flow in the gutter is exceeded.

2. Inlets at intersections shall be located in such a manner that no part of the inlet will encroach upon the curb return. Inlets on a continuous grade in the interior of a block should be placed upstream of a nearby driveway, if possible. The flowline and top of curb elevations shall be shown on all inlets.

3. For residential & non-residential streets, the first inlet shall be located no more than 400 feet from the high point in the street profile or at the point where the outside lane would be inundated, whichever is less.

A. Spacing Between Inlets: The spacing between inlets shall be such that depths of flow and widths of spread requirements are not violated. Flow spread equations and street design is in **Section 5006.**

B. Interception and Bypass:

1. Attempting to intercept all the flow on a street at every inlet leads to a costly storm sewer system. It is more cost effective to allow some portion of the runoff to bypass an inlet and intercept the runoff at the next inlet. Another cost-effective method is to design as many of the inlets as possible to be sump inlets.

2. The type of inlet to be used and the percent of flow to be intercepted at a particular location is left to the judgment of the designer. The objective is to minimize the cost of the storm sewer system while satisfying all of the design criteria.

3. On-grade inlets are required to capture 70 percent of the local flow; allowing no more than 30 percent bypass.

4. Hydraulic design of inlets shall be in accordance with **Section 5007.2**and **Section 5007.3**.

C. Inlets in Sump Condition: When inlets are placed in a sump, emergency overflow shall be provided as described in **Section 5006.3**.

5007.3 Hydraulic Evaluation of On-Grade Inlets

A. Recessed 6-inch and 10-inch Metal Frame Curb Opening On-Grade:

1. First determine street cross slope, longitudinal slope, and curb opening height to determine which coefficient values to use.

2. Calculate the flow rate for 100% efficiency as follows:

$$Q_0 = (a + b * Lo)(So)^x$$

Where,

Q_0 = Largest flow that is captured completely

a = -0.35 (for 3/8 per inch or 3% cross slope, 6-inch curb opening), or

a = -0.4 (for 1/4 per inch or 2% cross slope, 6-inch curb opening)

a = 1.25 (for 3/8 per inch or 3% cross slope, 10-inch curb opening), or

a = 1.0 (for 1/4 per inch or 2% cross slope, 10-inch curb opening)

b = 0.2 (for 3/8 per inch or 3% cross slope, 6-inch curb opening), or

b = 0.1 (for 1/4 per inch or 2% cross slope, 6-inch curb opening)

b = 0.25 (for 3/8 per inch or 3% cross slope, 10-inch curb opening), or

b = 0 (for 1/4 per inch or 2% cross slope, 10-inch curb opening)

x = -0.78 (for 3/8 per inch or 3% cross slope, 6-inch curb opening), or

x	=	-0.7 (for 1/4 per inch or 2% cross slope, 6-inch curb opening)
x	=	-0.5 (for either cross slope, 10-inch curb opening)
Lo	=	Length of opening in feet (4 feet or 8 feet)
So	=	Longitudinal Street grade in percent

3. If Qt is equal to or less than Qo, Q_t = Qo

   Where,

   Q_t = Total approach flow

4. If Q_t is greater than than Qo, Qc is calculated as follows:

$$Q_a = (c + d * Lo)(So)^x$$

$$Qc = Qo + (Qa - Qo)[1 - \exp\left\{-\left(\frac{Qt-Qo}{Qa-Qo}\right)\right\}]$$

   Where,

   Qa = The upper limit constant on the captured discharge

c	=	3.9 (for 3/8 per inch or 3% cross slope, 6-inch opening), **or**
c	=	3.5 (for 1/4 per inch or 2% cross slope, 6-inch opening)
c	=	2.9 (for 3/8 per inch or 3% cross slope, 10-inch opening), **or**
c	=	3.2 (for 1/4 per inch or 2% cross slope, 10-inch opening)
d	=	1.65 (for 3/8 per inch or 3% cross slope, 6-inch opening), **or**
d	=	0.8 (for 1/4 per inch or 2% cross slope, 6-inch opening)
d	=	1.8 (for 3/8 per inch or 3% cross slope, 10-inch opening), **or**
d	=	1.7 (for 1/4 per inch or 2% cross slope, 10-inch opening)

   Where,

   Qc = Total capture flow

5. The bypassed flow (Qb) is that flow greater than Qc, or

   Qb = $Qt - Qc$

B. Non-Recessed & Recessed Cast Iron Curb Opening Inlets with Grates On-Grade

1. First calculate the Curb Opening Inlet Capacity.
2. Calculate the length of curb opening (Lt) required for total interception using the following formula:

$$Lt = 0.6Q^{0.42}S^{0.3} * \left[\frac{1}{nSx}\right]^{0.6}$$

3. The inlet efficiency (E) of curb-opening inlets shorter than the length required for total interception is expressed by the following formula:

$$E = 1 - \left[1 - \left(\frac{L}{Lt}\right)\right]^{1.8}$$

Where,

L = Length of curb-opening (ft)

4. The flow captured (Qi) by the curb inlet is calculated using the following formula:

$$Qi = E\ x\ Qt$$

5. <u>Second calculate the Grate Inlet Capacity</u>. Using the flow bypassing the curb opening inlets as Q, the flow spread T, is calculated as follows:

$$\mathrm{T} = \left[\frac{Q * N}{(Ku * Sx^{\frac{5}{3}} * Sl\hat{}(\frac{1}{2})}\right]^{0.375}$$

Where,

T = Width of flow or spread, (ft)

Q = Discharge (cfs)

N = Manning's roughness coefficient

Ku = 0.56

Sx = Cross slope, (ft/ft)

Sl = Longitudinal slope (ft/ft)

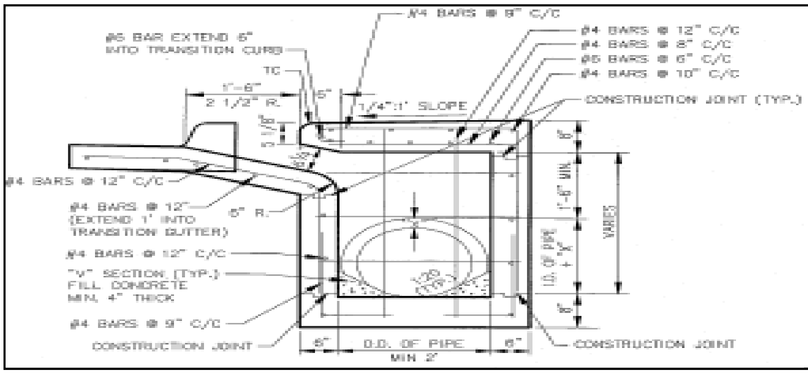
The ratio of frontal flow to total gutter flow (Eo) is computed using the following equation:

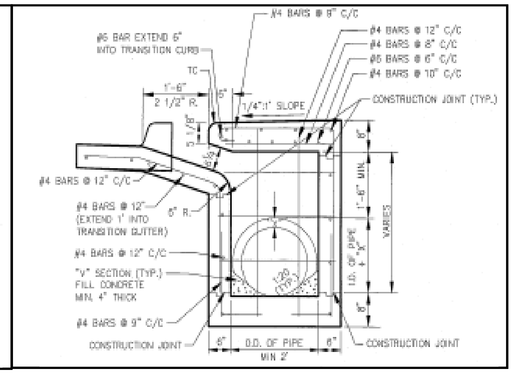
$$Eo = 1 - \left[1 - \left(\frac{1.33}{T}\right)\right]^{2.67}$$

The interception capacity of a grate inlet on grade (Qi) is equal to the efficiency of the grate multiplied by the total gutter flow:

$$Qi = Eo * Q$$

C. Recessed Concrete Curb Opening Inlets On-Grade – Only to be used in Rehabilitation Project





1. First calculate ($Q100$) the flow rate for 100% efficiency using the following formula:

$$Q100 = Leff * 0.70 * Yt$$

Where,

$Q100$ = Captured flow for 100% efficiency at $Leff$

$Leff$ = 26 feet (10 foot actual opening)

Yt = Approach depth in the gutter

2. If the approach flow (Qa) is equal to or less than Q100, captured flow (Qc) = Qa

3. If Qa is greater than Q100, Qc is calculated as follows:

$$Lt = \frac{Qa}{0.70 * Yt}$$

Where,

Lt = Effective Length that would be required for 100% capture

$$Qc = Qa\left[0.0526\left(\frac{Leff}{Lt}\right) + 2.86\left(\frac{Leff}{Lt}\right) - 1.92\left(\frac{Leff}{Lt}\right)^3\right]$$

The bypassed flow (Qb) is that flow greater than Q100, or

$$Qb = Qa - Qc$$

5007.4 Hydraulic Evaluation of Sump Inlets

A. Recessed 6-inch and 10-inch Metal Frame Curb Opening in a Sump:

1. First determine the curb opening capacity which starts in weir flow as follows:

$$Q = 3.1 * L * d^{1.5}$$

Where,

L = Length of curb opening (4' or 8')

d = Depth of flow (ft)

2. At a depth approximately equal to the height of the opening, the flow changes to orifice control and is calculated as follows:

$$Q = 0.65 * A * (2 * g * d)^{0.5}$$

Where,

A = Area of opening (ft^2)

g = Gravity = 32.2 ft/sec^2

d = Depth of flow above centroid of area (ft)

In the transition zone between weir flow and orifice flow, 1.0-1.4 times the opening height, the smaller of the flow calculations will control.

B. Non-Recessed & Recessed Cast Iron Curb Opening Inlets with Grates in a Sump:

1. To determine the flow intercepted by a single cast iron curb opening with grate in a sump is as follows:

$$Q = 7.22 * d^{0.5}$$

Where,

d = Depth of flow above the grate (ft)

2. To determine the flow intercepted by an additional curb opening can be calculated as follows:

$$Q = 3.1 * L * d^{1.5}$$

Where,

L = Length of curb opening (ft)

d = Depth of flow (ft)

3. Combining the two equations, the total flow intercepted by a cast iron curb inlet with grates in a sump can be estimated by:

$$Q = G(7.22 * d^{0.5}) + T(8.34 * d^{1.5})$$

Where,

Q = Design Flow (cfs)

G = Number of Grates

T = Number of Throats or Additional Hoods

d = Ponding Depth (ft)

C. Drop Inlets in a Sump:

1. First determine the capacity which starts in weir flow as follows:

$$Q = 3.1 * L * d^{1.5}$$

Where,

L = Length of curb opening (ft)

d = Depth of flow (ft)

2. At a depth approximately equal to the height of the opening, the flow changes to orifice control and is calculated as follows:

$$Q = 0.65 * A * (2 * g * d)^{0.5}$$

Where,

A = Area of opening (ft^2)

g = Gravity = 32.2 ft/sec^2

d = Depth of flow above centroid of area (ft)

In the transition zone between weir flow and orifice flow, 1.0-1.4 times the opening height, the smaller of the flow calculations will control.

5008 STORM SEWER PIPE SYSTEM

5008.1 Introduction

A "storm sewer system" refers to a system of inlets, pipes, manholes, junctions, outlets, and other appurtenant structures designed to collect and convey storm runoff to a defined drainageway. A "drainage system" also includes curbs and gutters, roadside ditches, swales, channels, and detention systems for the control of overland runoff. In general, a storm sewer system is required when other parts of the drainage system no longer have the capacity for additional runoff without exceeding the design criteria.

5008.2 Location of Storm Sewers

Storm sewer shall not be placed within the wheel path of any driving lane of the pavement. The preferred location of the storm sewer is according to the following order of priority listed.

A. Behind the Curb

B. Down the Center of the Traffic Lane

C. On Centerline

The traffic lane is defined as the normal width provided for each lane and delineated by pavement stripes.

5008.3 Design Criteria

A. Design Storm Frequency:

1. The storm sewer system, beginning at the upstream end with inlets, is required when the allowable street capacity (see **Section 5006.1**) or overflow capacity is exceeded for the design storm. The "design storm" for the storm sewer system is the 100-year storm under fully urbanized conditions. Thus, the storm sewer system should be designed to convey flow equal to the difference between the design storm and the capacity within the ROW, to prevent violation of the criteria in **Section 5006.1A.**

B. Construction Materials: Storm sewers within the City of Norman may be constructed using materials, pipes, and appurtenances that meet the requirements of the City's Standard Specifications **Section 2300** and are shown in **Table 5008.1**.

1. Corrugated Polypropylene Pipe (PP): Polypropylene pipe and fittings from 18- through 60-inch shall be of a dual wall configuration and shall meet ASTM F-2881 or AASHTO M-330. Pipe shall be joined using a bell and spigot joint meeting the requirements of ASTM F-2881. The joint shall be watertight according to the requirements of ASTM D-3212. Gaskets shall meet the requirements of ASTM F-477. 18- through 60-inch diameters shall have a reinforced bell with a polymer composite band installed by the manufacturer. Polypropylene pipe is allowed inall storm sewer applications. PP can only be used outside of the roadway limits or perpendicular to the travel way for crossings.

2. Storm sewers within the City of Norman shall be constructed using pipe materials that meet or exceed the Oklahoma Department of Transportation Specifications for Highway Construction, latest edition. All pipe systems shall have joints that meet or exceed ASTM D3212 for water tightness. Manholes and junction boxes shall have watertight connections meeting a field testing of ASTM F2487 and ASTM F1417.

3. Approved pipe material shall meet or exceed ASTM C 443, ASTM C 76, AASHTO M 170. Precast Concrete Boxes shall meet or exceed ASTM C 789 or ASTM C 850. Installation shall be in accordance with ASTM F3212 or AASHTO M330. Pipe cover shall be in accordance with the manufacturer’s guidelines.

4. Alternate pipe materials for special applications may be approved if the above specifications are met or exceeded. Watertight pipe joints are highly important as is pipe strength.

5. Minimum Pipe Sizes are provided in **Table 5008.2**

6. Approved Manning’s N Values are provided in **Table 5008.3**

7. Approved Manhole spacing and sizes are provided in **Table 5008.4**

Table 5008.1 – Approved Pipe Material and Standards	
Pipe Material	**Standard**
Reinforced Concrete Pipe	
Round	ASTM C-76 or AASHTO M-170
Elliptical	ASTM C-507 or AASHTO M-207
Joints	ASTM C-443 or AASHTO M-198
Arch	ASTM C-506 or AASHTO M-206
Pre-Cast Concrete Manholes	ASTM C-478 or AASHTO M-199
Pre-Cast Concrete Box	ASTM C-789/C-850, AASHTO M-259/273, ODOT
Concrete Cast-in-Place pipe	ODOT Standard
PVC Pipe	ASTM D-3034 or
Corrugated Polypropylene Pipe	ASTM F-2881 & AASHTO M330

Table 5008.2 – Approved Pipe Size and Standards		
Type	**Minimum Equivalent Pipe Diameter**	**Minimum Cross-Sectional Area**
Main Trunk	18-inch	1.77 sq. ft.
Lateral from inlet	18-inch	1.77 sq. ft.

Table 5008.3 – Approved Manning's N Value	
Material	**N Value**
Concrete	
Pre-Cast (Public)	0.013
Cast-in-Place (Public)	
Steel forms	0.013
Wood forms	0.015
Plastic	
Corrugated Polypropylene	0.022
Corrugated Polypropylene (smooth interior)	0.012
Polyvinyl chloride (smooth interior)	0.011

Table 5008.4 – Manhole Spacing		
Pipe Size	**Maximum Spacing for Manholes**	**Minimum Manhole Size**
18" to 24"	300 ft	4 ft
27" to 36"	400 ft	5 ft
42”	400 ft	6 ft
48"	500 ft	6 ft
54" to 60"	500 ft	8 ft
> 60"	500 ft	Junction Structure

C. Vertical Alignment:

1. The sewer grade shall be such that a minimum cover is maintained to withstand AASHTO HS-20 loading on the pipe. The minimum cover depends upon the pipe size, type and class, and soil bedding condition, but shall not be less than two (2) feet from the top of pipe to the finished grade at any point along the pipe. If the pipe encroaches into the street sub-grade, a variance must be granted by the City Engineer.
2. Manholes will be required whenever there is a change in size, alignment, elevation grade and slope, or where there is a junction of two or more sewers. For sewers equal to or larger than 60" diameter, pre-formed smooth transitions shall be approved by the City Engineer. The maximum spacing between manholes for various pipe sizes shall be in accordance with **Table 5008.4**.
3. The minimum clearance between storm sewer and water main (for new construction), either above or below shall be 24". Steel pipe encasing (with proper bedding) of the water line will be required for clearances of 24" or less when the clearance between existing water mains and storm sewer cannot be maintained.
4. The minimum clearance between storm sewer and sanitary sewer (for new construction), either above or below, shall be 24”. In addition, when an existing sanitary sewer main lies above a storm sewer, or within 24" below, the sanitary sewer shall have impervious encasement or be constructed of ductile iron pipe for a minimum of 10' on each side of the storm sewer crossing.
5. Siphons or inverted siphons are not allowed in the storm sewer system

D. Horizontal Alignment

1. Storm sewer alignment between manholes shall be straight except when accepted in writing by the City Engineer. Approved curvilinear storm sewers may be constructed using pipe bends or radius pipes.

2. A minimum horizontal clearance of six (6) feet is required between sanitary and water utilities and the storm sewer.

E. Storm Sewer Capacity and Velocity

1. Storm sewer shall be designed to convey the difference between the capacity of the street and the design storm (10-year) flood peaks without surcharging the storm sewer. The sewer may be surcharged during larger floods and under special conditions when approved by the City Engineer.

2. The conduit capacity and velocity shall be based on the Manning's n-values presented in Table 5008.3. The maximum full flow velocity shall be less than 20 fps. Higher velocities may be accepted by the City Engineer if the design includes adequate provisions for uplift forces, dynamic impact forces and abrasion. The minimum velocity in a pipe based on full flow shall be 2.5 fps to avoid excessive accumulations of sediment.

3. The energy grade line (EGL) for the design flow shall be no more than 1-foot above the final grade at manholes, inlets, or other junctions. To ensure that this objective is achieved, the hydraulic grade line (HGL) and the EGL shall be calculated by accounting for pipe friction losses and pipe form losses. Total hydraulic losses will include friction, expansion, contraction, bend, manhole, and junction losses.

F. Storm Sewer Inlets and Outlets

1. Before discharging the runoff from a parking lot of area larger than 0.5 acres, the runoff must first be collected in a storm sewer inlet and connected to the sewer within the street right-of-way, roadway ditch, or drainage conduit. Accordingly, the flow in the street shall be reduced by the amount intercepted by the inlet.

2. All storm sewer outlets into open channels shall be constructed with a headwall and wingwalls or a flared-end-section. When the outlet velocity exceeds six (6) feet per second, erosion control measures shall be taken. If required to prevent erosion, energy dissipaters shall be provided.

3. All storm sewer inlets and outlet structures for detention facilities, will have protective grates, trash racks, screens, or other approved systems utilized to prevent debris and people from entering the system and must be approved by the City Engineer.

G. Riprap Energy Dissipaters

1. Riprap energy dissipaters shall be sized to control erosion at outlets of storm sewer and/or flumes. These energy dissipaters shall be sized accordingly:

   a. Calculate the mean diameter of riprap required with the following equation:

$$D_{50} = \sqrt{\frac{V}{c\left[2g\left(\frac{\gamma_s - \gamma_w}{\gamma_w}\right)\right]^{\frac{1}{2}}}} = \left(\frac{V}{18}\right)^{\left(\frac{1}{2}\right)}$$

Where,

D50 = mean diameter of riprap required (ft)

V = water velocity at outlet (fps)

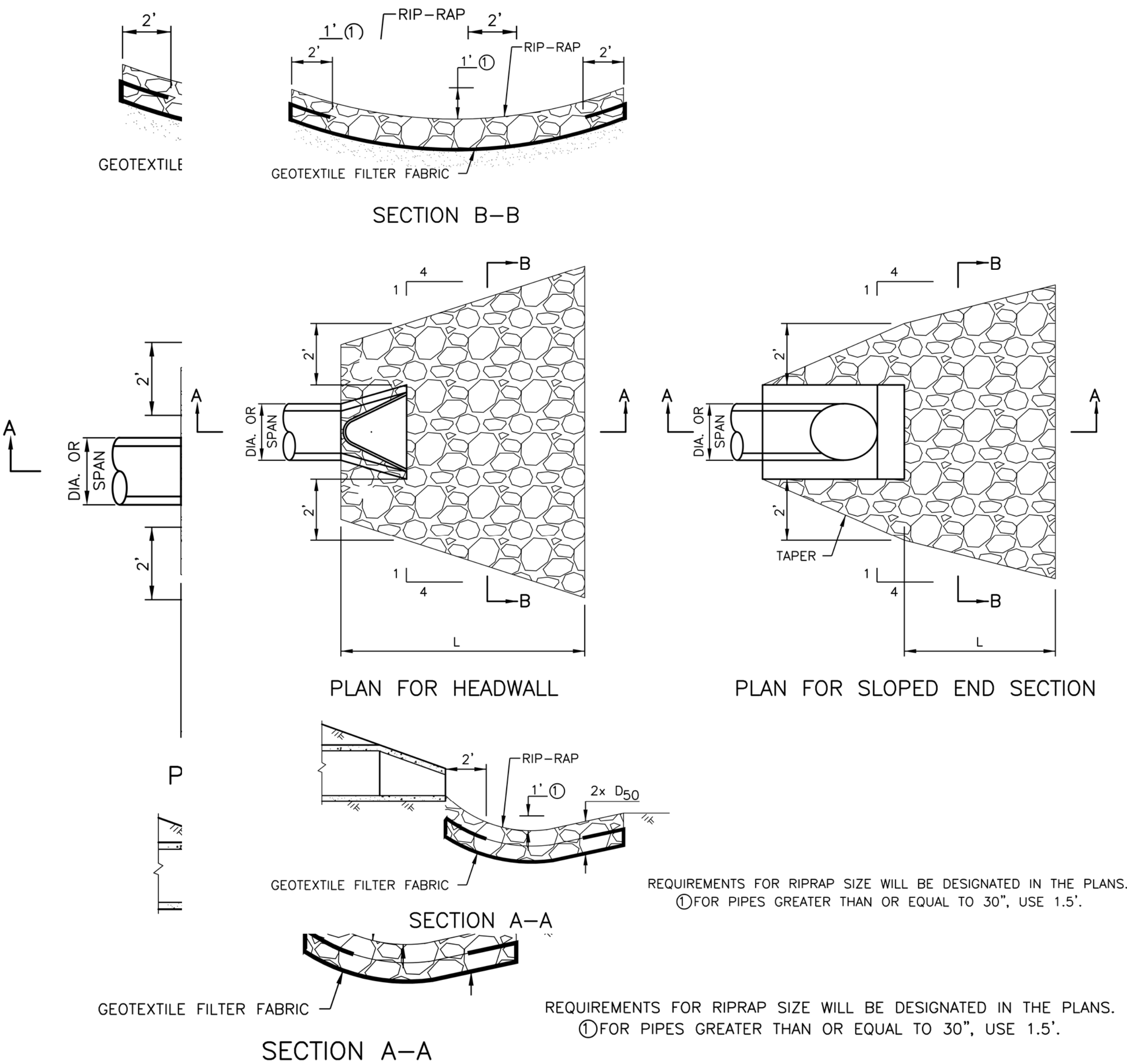
c = stability coefficient (1.8)

g = acceleration of gravity (32.174 ft/s2)

γ_s = saturated surface dry specific weight of stone (165 lb/ft3)

γ_w = unit weight of water (62.4 lb/cf)

b. For riprap design at Reinforced Concrete pipe outlets, Reinforced Concrete Arch Pipe outlets, or reinforced concrete boxes, the following Figure can be used:



c. Using the previously calculated D50, the riprap thickness and bedding can be determined using grain size curves found from Figures 3.12 to Figure 3.17 within the Integrated Stormwater Management (iSWM) Technical Manual, Hydraulics, 2014.

d. Gradations for riprap are located in Table 5008.5 and gradation tables for bedding are located in Table 5008.6.

Table 5008.5 – Riprap Gradation Table	
8" D_{50} of Riprap	
Sieve Size Square Mesh	Precent Passing
10 Inch	100
8 Inch	70 – 100
6 Inch	50 – 75
3 Inch	20 – 40
1 – ½ Inch	0 – 15
12" D_{50} of Riprap	
Sieve Size Square Mesh	Precent Passing
15 Inch	100
12 Inch	70 – 100
8 Inch	45 – 75
6 Inch	30 – 55
3 Inch	10 – 30
1 – ½ Inch	0 – 10
18" D_{50} of Riprap	
Sieve Size Square Mesh	Precent Passing
21 Inch	100
18 Inch	65 – 100
12 Inch	35 – 65
8 Inch	15 – 40
6 Inch	5 – 25
4 Inch	0 – 15
24" D_{50} of Riprap	
Sieve Size Square Mesh	Precent Passing
30 Inch	100
24 Inch	65 – 100
18 Inch	45 – 75
12 Inch	25 – 50
8 Inch	10 – 30
6 Inch	0 – 15
30" D_{50} of Riprap	
Sieve Size Square Mesh	Precent Passing
36 Inch	100
30 Inch	65 – 100
24 Inch	45 – 75
18 Inch	25 – 50
12 Inch	10 – 25
8 Inch	0 – 10
36" D_{50} of Riprap	
Sieve Size Square Mesh	Precent Passing
44 Inch	100
36 Inch	65 – 100
30 Inch	50 – 80
18 Inch	25 – 45
12 Inch	10 – 25
8 Inch	0 – 10

Table 5008.6 – Bedding Gradation Table	
Bedding Gradations	
9” D_{50} of Bedding	
Sieve Size Square Mesh	Precent Passing
6 Inch	100
3 Inch	65 – 100
1 – ½ Inch	40 – 60
¾ Inch	25 – 40
No. 4	0 – 12
6” D_{50} of Bedding	
Sieve Size Square Mesh	Precent Passing
3 Inch	100
1 – ½ Inch	55 – 100
¾ Inch	25 – 60
3/8 Inch	5 – 30
No. 4	0 – 10

e. For the following:

L = Length of riprap apron (ft)

D_{50} = Mean diameter of riprap required (ft)

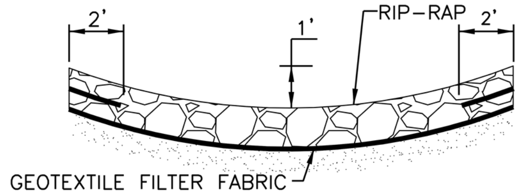
f. For discharges from round Reinforced Concrete Pipe outlets, the following Table can be used for riprap dimensions.

Table 5008.7 – RIP-RAP AT RCP OUTLETS					
		CLASS II D_{50} = 6”	**CLASS III D_{50} = 9”**	**CLASS IV D_{50} = 12”**	**CLASS V D_{50} = 15”**
DIA. OF ROUND PIPE (IN.)	**L (FT.)**	**12” DEPTH RIP-RAP (CU. YDS.)**	**18” DEPTH RIP-RAP (CU. YDS.)**	**24” DEPTH RIP-RAP (CU. YDS.)**	**30” DEPTH RIP-RAP (CU. YDS.)**
12	8	2.8	4.1	5.5	—
15	8	2.9	4.4	5.8	—
18	10	3.9	5.9	7.8	—
21	10	4.2	6.3	8.4	—
24	12	5.5	8.3	11.0	—
27	12	5.8	8.7	11.6	—
30	14	7.3	10.9	14.5	—
36	16	9.2	13.8	18.3	—
42	18	10.9	16.3	21.7	—
48	20	12.9	19.4	25.8	—
60	25	—	—	—	36.8

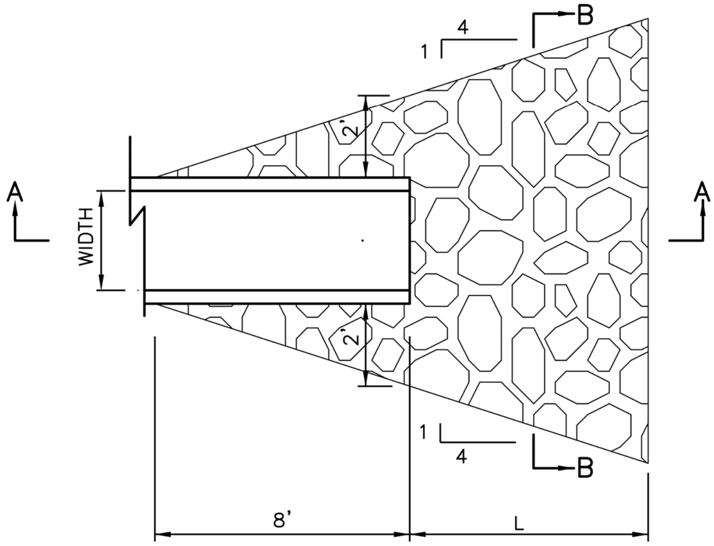
g. For discharges from Reinforced Concrete Arch Pipe outlets or reinforced concrete boxes of equivalent span, the following Table can be used for riprap dimensions.

Table 5008.8 – RIP-RAP AT RCP-A OUTLETS OR BOXES OF EQUIVALENT SPAN WIDTH				
		CLASS II D_{50} = 6"	CLASS III D_{50} = 9"	CLASS IV D_{50} = 12"
SPAN OF PIPE ARCH (IN.)	L (FT.)	12" DEPTH RIP-RAP (CU. YDS.)	18" DEPTH RIP-RAP (CU. YDS.)	24" DEPTH RIP-RAP (CU. YDS.)
22	10	3.9	5.9	7.8
28	12	5.5	8.2	10.9
36	14	7.2	10.8	14.3
43	16	9.2	13.7	18.3
51	18	10.9	16.3	21.7
58	20	12.7	19.0	25.4

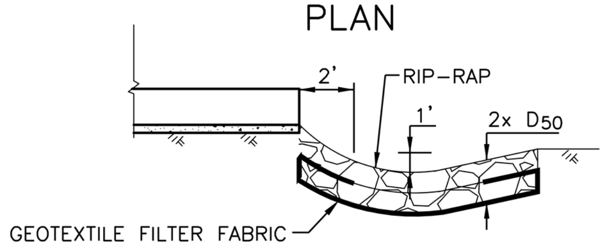
h. For discharges from concrete flumes, the following Figure and Table can be used for riprap dimensions.



SECTION B–B



PLAN



SECTION A–A

REQUIREMENTS FOR RIPRAP SIZE WILL BE DESIGNATED IN THE PLANS.

TABLE OF QUANTITIES
RIP–RAP AT CONCRETE FLUMES

		CLASS II D_{50} = 6"	CLASS III D_{50} = 9"	CLASS IV D_{50} = 12"	CLASS V D_{50} = 15"
WIDTH OF CONC. FLUME (FT.)	L (FT.)	12" DEPTH RIP–RAP (CU. YDS.)	18" DEPTH RIP–RAP (CU. YDS.)	24" DEPTH RIP–RAP (CU. YDS.)	30" DEPTH RIP–RAP (CU. YDS.)
4	15	5.9	8.9	12.1	–
6	18	8.8	13.2	17.7	–
7	20	10.7	16.1	21.5	–

5009 OPEN CHANNELS

5009.1 Channel Design

A. Design: Channels shall be designed in accordance with sound engineering principles.

B. Channel Geometry: For trapezoidal channels, the minimum bottom width shall be 4' with side slopes of not steeper than 3.5 to 1 for sodded sections and a minimum bottom width of 3' with side slopes of not steeper than 1:1 for paved or rocklined sections. Where the public may be exposed to hazards and nuisances of open channels, appropriate measures shall be taken to exclude the public from the perilous area.

C. Manning's N - Value: Manning’s Equation in the calculations of hydraulic characteristics of channels will be acceptable. The "N" value used for channels shall be based on the individual channel characteristics, according to **Table 5009.1**. Designers should anticipate growth of trees as a natural maturation process of the channel.

Table 5009.1 Manning's N Value for Open Channels

	CHANNEL/SURFACE TYPE	N VALUE RANGE	RECOMMENDED VALUE
A.	Earth Lined (ditches/canals)		
	1. Clean, weathered	0.018 to 0.025	0.022
	2. Clean, gravel	0.022 to 0.030	0.025
	3. Some weeds	0.022 to 0.033	0.027
	4. Not maintained	0.30 to 0.40	0.035
B.	Grass Lined (manmade)		
	1. Well maintained	0.03 to 0.05	0.03
	2. Poorly maintained	0.05 to 0.10	0.05
C.	Natural Streams	0.025 to 0.10	Note 1
	Overbank Areas	0.03 to 0.20	
D.	Rock Lined		
	1. Ordinary rip rap	0.02 to 0.03	0.02
	2. Gabions	0.02 to 0.03	0.02
	3. Grouted rip rap	0.023 to 0.03	0.027
	4. Slope mattress	0.025 to 0.033	0.028
E.	Concrete		
	1. Float finished/wood forms	0.013 to 0.016	0.015
	2. Slip formed	0.016 to 0.016	0.015
	3. Gunite	0.016 to 0.025	0.015

Note 1 Refer to Chow, V.T., Open Channel Hydraulics, McGraw-Hill Book Company, 1959, Table 5-6

D. Minimum Slope: Channels shall have minimum slopes of 0.5% for concrete-lined channels and 1.0% for grass-lined channels. The City Engineer's acceptance is required for channels with a flatter slope.

E. Minimum Velocity: Minimum velocity in a drainageway system, having a roughness co-efficient less than or equal to 0.015, shall be 2.5 fps to avoid sedimentation.

F. Maximum Velocities: Maximum velocities in channels shall be based on allowable shear stress for channel lining (See K. below). Velocities in concrete-lined or paved sections shall not exceed 15 fps. The dissipation of energy shall be required at the confluence of improved channels with natural channels through the use of dissipaters, stilling basins and etc. which shall be designed in accordance with FHWA HEC #14 Hydraulic Design of Energy Dissipators for Culverts and Channels Drainage Manual.

G. Freeboard: Where practical, the design water surface elevation shall be kept below the level of natural ground. A 1' freeboard above the energy grade line should be added to calculated flow depths to determine minimum channel depths.

H. Trickle Channels: All channels altered or improved from the natural state will require a paved trickle channel unless a variance is granted by the City Engineer. Sodding, or other methods of erosion control shall be required adjacent to the paved channel.

I. Concrete Flumes: Concrete flumes are not allowed to drain onto arterial streets. Concrete flumes in lieu of enclosed pipe shall be allowed as overflow protection for storm sewer systems if no other options are available for residential and collector streets, and to drain areas not exceeding five (5) acres in size. All concrete flumes shall extend to the rear of adjacent lots and shall discharge into a dedicated drainage facility or channel. There are no special freeboard requirements for concrete flumes.

J. Roadside Ditches: Roadside ditches shall conform with requirements of this section.

K. Maximum Shear Stress: the maximum shear stress for a straight channel occurs on the channel bed and is less than or equal to the shear stress at maximum depth. The permissible shear stresses can be found in **Table 5009.2**. The maximum shear Stress is computed as follows:

$$t = \gamma d S$$

Where,

t = Maximum shear stress (lb/ft2)

γ = Unit weight of water (62.4 lb/ft3)

d = Maximum depth of flow

S = Average bed slope or energy slope (ft/ft)

Table 5009.2 - Permissible Shear Stresses for Lining Materials		
Lining Category	**Lining Type**	**Permissible Shear Stress**
Temporary	Woven Paper Net	0.15 lb/sf
	Jute Net	0.45 lb/sf
	Fiberglass Roving:	0.15 lb/sf
	Single	0.6 lb/sf
	Double	0.85 lb/sf
	Straw with Net	1.45 lb/sf
	Curled Wood Mat	1.55 lb/sf
	Synthetic Mat	2.00 lb/sf
Vegetative	Class A	3.70 lb/sf
	Class B	2.10 lb/sf
	Class C	1.00 lb/sf
	Class D	0.60 lb/sf
	Class E	0.35 lb/sf
Gravel Riprap	1 in	0.33 lb/sf
	2 in	0.67 lb/sf
Rock Riprap	6 in	2.00 lb/sf
	12 in	4.00 lb/sf

5010 HYDRAULIC STRUCTURES

5010.1 Definitions

A. **Culvert**: A culvert is defined as a closed conduit for the passage of water under an embankment, such as a road, railroad, or driveway. Culverts are most commonly used to relieve roadside drainage ditches and to convey stormwater beneath roadways at natural stream and creek crossings.

B. **Bridge**: A bridge is constructed with abutments and superstructures, which are typically concrete, steel, or other materials. Since the superstructures are generally not an integral structural part of the abutments, and are therefore free to move, the hydraulic criteria for bridges is different than for culverts. Bridges are also usually constructed with earth or rock inverts, whereas culverts are typically the same material throughout the waterway opening.

5010.2 Culverts

A. Construction Materials: Culverts shall be constructed with the approved materials identified in Table 5008.1 Other materials may be used on a case-by-case basis if approved by the City Engineer.

B. Sizing Method: Culvert design shall follow the methodology presented in *Hydraulic Design of Highway* Culverts, Hydraulic Design Series HDS No. 5, FHWA, U.S. Department of Transportation and *Drainage Manual,* Oklahoma Department of Transportation, 2014.

C. Design Frequency:

Minimum design frequency for culverts shall be 100-year fully developed conditions within project boundaries.

D. Culvert Freeboard Requirement:

The calculated hydraulic grade line (HGL) for a culvert must be 1-foot below the subgrade of the road during the 100-year storm event under fully developed conditions.

E. Culvert Backwater Requirement:

Backwater is defined as the rise in the flood water surface due to the restrictions created by the construction of the culvert. Analysis must be performed to verify no adverse impacts are created due to a backwater condition. The maximum backwater shall be 1-foot with the exception of a FEMA crossing defined in **Section 5010.2G**.

F. Minimum Sizes:

1. Pipe Culverts - 18" equivalent
2. Box Culverts - no less than 3' in height
3. Other pipe sizes could be approved by the City Engineer.

G. Culverts contained within FEMA Regulatory Floodway and/or Floodplain must meet FEMA requirements for the following two scenarios:

1. The first situation is for a project on a stream or river that has been studied using detailed hydrologic and hydraulic analyses and for which Base (1-percent-annual-chance) Flood Elevations (BFEs) have been specified, but a regulatory floodway has not been designated. If the community proposes to allow development that would result in more than a 0.05-foot increase in the BFE, a CLOMR must first be obtained from FEMA.

2. The second situation requiring a CLOMR is for a project on a stream or river for which detailed analyses have been conducted and both BFEs and a regulatory floodway have been designated. If the community proposes to allow development totally or partially within the regulatory floodway that would result in any (greater than 0.0 foot) increase in the BFE, a CLOMR must be obtained.

H. Velocity Limitations:

1. In design of culverts both the minimum and maximum velocities must be considered. A minimum velocity of three (3) feet per second at the outlet is required to assure a self-cleaning condition of the culvert.

2. The outlet area shall include a headwall with wingwalls or an end-section in addition to riprap protection. Where outlet velocities exceed six (6) feet per second, erosion control measures and energy dissipators shall be provided as required.

I. Structural Design: Culverts shall be designed to withstand an HS-20 loading in accordance with the design procedures of AASHTO *Standard Specifications for Highway Bridges* and with the pipe manufacturers recommendations. The minimum cover over top of the pipe shall be 12" unless otherwise accepted by the City Engineer.

J. Driveway Crossings: Driveway culverts shall be sized to pass the 10-year ditch flow capacity without overtopping the driveway. The minimum size culvert shall be a 18" round pipe, or equivalent, for all streets. Sloped headwalls are required per the City's Standard Specifications and Construction Drawings.

5011 BRIDGES

A. Bridge Freeboard Requirement:

Freeboard for a bridge is defined as the vertical clearance of the lowest structural member of the bridge superstructure above the water surface elevation of the design frequency flood. The minimum freeboard shall be 1-foot for the 100-year frequency flood, unless accepted by the City Engineer.

B. Bridge Backwater Requirement:

Backwater is defined as the rise in the flood water surface due to the restrictions created by the construction of the bridge. The maximum backwater shall be 1-foot as required by the City floodplain regulations with the exception of a FEMA bridge defined in **Section 5011C**.

C. Bridges contained within FEMA Regulatory Floodway and/or Floodplain must meet FEMA requirements for the following two scenarios:

1. The first situation is for a project on a stream or river that has been studied using detailed hydrologic and hydraulic analyses and for which Base (1-percent-annual-chance) Flood Elevations (BFEs) have been specified, but a regulatory floodway has not been designated. If the community proposes to allow development that would result in more than a 0.05-foot increase in the BFE, a CLOMR must first be obtained from FEMA.

2. The second situation requiring a CLOMR is for a project on a stream or river for which detailed analyses have been conducted and both BFEs and a regulatory floodway have been designated. If the community proposes to allow development totally or partially within the regulatory floodway that would result in any (greater than 0.0 foot) increase in the BFE, a CLOMR must be obtained.

D. Velocity Limitations: The velocity limitations through the bridge opening are controlled by the potential abutment scour and subsequent erosion protection provided. Using riprap for the channel lining and/or protection of the abutments and wingwalls, the maximum channel velocity is limited to 15 fps.

E. Hydraulic Analysis: The hydraulic design of bridge crossings shall be in accordance with *Drainage Manual*, Oklahoma Department of Transportation, 2014.

F. Inlet and Outlet Configuration: The design of bridges shall include adequate wingwalls of sufficient length to prevent abutment erosion and to provide slope stabilization from the embankment to the channel. Erosion protection on the inlet and outlet transition slopes shall be provided to protect from the erosive forces of eddy current.

G. Bridges shall be designed in accordance with AASHTO/ODOT criteria. Rails shall comply with ODOT Standard Details.

5012 STORAGE AND INFILTRATION

5012.1 General

A. Generally, urbanization results in more impervious areas and a reduction in floodplain storage, both of which contribute to increased flow rates. The development plan shall incorporate permanent, post-construction means (such as basins, ponds, infiltration trenches, dry wells, and porous paving as detailed in **Section 7000:**) to provide for storm water storage, promote storm water infiltration, and reduce erosion and sediment transport.

B. Peak release rates from developments shall not exceed the existing runoff that occurred before development for all storm frequencies up to and including the 100-year frequency storm. Releases for 2, 5,10, 25, 50 and 100-year storms shall not exceed the existing rate. If improvements are made to any natural channel, the existing floodplain storage must be maintained.

C. The detention storage shall accommodate the excess runoff from a 100-year frequency storm. The excess runoff is that runoff generated due to urbanization which is greater than the runoff historically generated under existing conditions, for a given frequency storm. Detention facilities shall be designed so that the peak rate of discharge does not exceed that of the pre-development conditions for all storm events up to and including 100-year.

D. Detention facilities can be designed as a “dry pond” which is referred to as a “detention pond” or can be designed as a “wet pond” which is referred to as a “retention pond”.

E. Detention facilities shall be designed using a unit hydrograph method and in accordance with **Section 5005.3** to assure that there are no adverse impacts to adjacent properties.

F. Detention facilities can be effective in improving water quality of stormwater runoff. **Section 7000:** details green stormwater control measures (SCM) that can be incorporated into on-site detention facilities.

G. A fee in lieu of detention may be allowed by the City Engineer under certain conditions in accordance with **Section 5012.4**.

5012.2 Design Criteria

A. For the design of storage facilities, the methods contained in **Section 5005.3** are approved.

B. The design storm for detention shall be a 24-hour storm. Rainfall depths shall be in accordance with **Section 5004**.

C. The time increment used in developing the rainfall distribution and in reading off the ordinates of the unit hydrograph may be rounded off to the nearest whole-time interval or to the nearest time increment.

D. Rainfall patterns shall be consistent with the modeling technique used.

E. All calculations for detention facilities shall be submitted for review by the City Engineer. The submittal shall include hydrographs for both existing and developed conditions, detention facility stage-area-volume relationships, outlet structure details, and a stage versus time analysis through the facility.

F. Floodplain areas and detention facility locations shall be identified at the preliminary plat stage to illustrate how these areas will be managed during and after construction.

G. If a tract of land under development has a floodplain area within its boundary, the information that must be furnished with the preliminary plat and shall include:

1. A 100-year storm backwater analysis on the existing drainage system.
2. A 100-year storm backwater analysis on the proposed drainageway system
3. No detention volumes will be allowed that are below the 100-year floodplain or calculated backwater elevations.

H. Detention facilities should be located in areas acceptable to the City. Each facility shall incorporate methods to minimize erosion and other maintenance reducing designs.

I. A minimum number of detention facilities is encouraged for each development. Regional detention facilities are encouraged for phased or cooperative development in a drainage basin.

J. If runoff has a natural tendency to drain in several directions for a given tract of land where detention is required, then detention storage shall be provided for the biggest drainage area. Additionally, a detention storage may be provided, at the same facility, to satisfy detention requirements for a separate drainage area on the same development, provided that;

1. The whole developmental tract of land is in the same watershed.
2. The smaller drainage area(s) that, has/have been compensated for does/do not, either singly or in combination, adversely impact the health, welfare and safety of the general public downstream.
3. The smaller drainage area(s) cannot increase peak flow rates for all storm events up to and including the 100-year event when compared to existing conditions at the same comparison point(s).

K. If a tract of land being developed is located in more than one watershed, grading work to divert flows from one watershed to another will not be permitted.

L. The detention area shall be identified as a separate platted area; as appropriate, it may consist of one or more platted lots, a separate block and shall be designated as a drainage easement.

M. An accessway at least fifteen(15) feet wide for regional detention and ten (10) feet wide for subregional detention shall be provided to any required detention area. Access may be provided by frontage on a dedicated public street or by a dedicated access easement from a dedicated public street to the detention area.

N. If the detention facility is approved by the City to serve areas outside the subdivision in which it is located, such additional areas shall be specifically identified in the provision for detention.

O. Any dam or berm shall be designed in accordance with the dam safety criteria of the Oklahoma Water Resources Board.

P. The maintenance responsibility for on-site detention facilities shall remain with the private sector and appropriate covenants shall be obtained to secure such maintenance.

Q. All detention facilities utilizing closed conduit systems for the main discharge will be required to have an emergency overflow structure capable of passing the 100-year frequency storm with one (1) foot of freeboard unless more stringent OWRB dam safety requirements control, as outlined in title 785:25-3-3.

R. Maximum retention or "draw-down" time for detention ponds shall not exceed 24 hours from the time of peak storage to the time of complete emptying ***or the return to static elevation*** of the pond, as determined by hydrograph routing or other calculations acceptable to the City. This requirement does not apply to facilities in which retention or "draw-down" time is required to be greater than 24 hours such as an SCM from **Section 7000:**. However, only the portion of the volume within a water quality control available after 24 hours of drawdown time may be used or credited towards detention requirements.

5012.3 Physical Features

A. Detention dams or dikes shall be constructed as earth filled and non-overflow type dams. Embankment slopes shall not be steeper than 4:1 (horizontal: vertical).

B. Side slopes on detention and retention facilities shall not be steeper than 4:1.

C. For retention ponds, the main pool must have a depth from six to eight feet. Areas deeper than eight feet may result in the pond becoming anaerobic, possibly resulting in odors, and are prohibited unless approved by the City Engineer.

D. For retention ponds, all grading below the static water surface elevation shall not be flatter than 3:1 (horizontal: vertical). Retention ponds shall also consider the use of erosion control measures to further reduce the risk of bank erosion and sloughing. (i.e. Flexamat, Articulated Block)

E. Storm sewer outlets in the slope of the detention pond shall be protected by a reinforced concrete slopewall.

F. All earth slopes and earth areas subject to erosion, such as areas adjacent to low flow channels, inlet structures, and outlet structures shall be slab sodded with bermuda sod or protected with other erosion control measures. All other earth surfaces, within the area designated for detention facility site, shall have an established growth of bermuda grass. All covered areas shall be fertilized, watered and in an established growing condition prior to completion and acceptance of the detention facility.

G. All inlet and outlet structures shall be properly grated and in compliance with **Section 5008.3F.3**.

H. Parking lot detention is discouraged and only should be used as a last resort as approved by the City Engineer.

1. Where parking lot detention is approved:

   a. Where parking spaces are designated, the maximum depth of the 100-year storm event under fully developed conditions shall not be greater than 4-inches.

   b. Where parking spaces are not designated, the maximum depth of the 100-year storm event under fully developed conditions shall not be greater than 6-inches.

   c. Outlet structure(s) must be in accordance with **Section 5003.5** which restricts the use of flumes discharging onto streets.

I. Underground Detention is encouraged and must meet the following requirements:

1. Shall be constructed using reinforced concrete pipe, reinforced concrete box culvert, concrete vaults, polypropylene chambers, or other material as approved by the City Engineer. The material thickness, cover, bedding, and backfill shall be designed to withstand HS-20 loading.

2. Inlets to the underground system can be by way of surface inlets and/or a local private storm sewer system.

3. The outlet from the underground detention shall consists of reinforced concrete pipe (RCP) with an 18-inch minimum diameter. The invert of the lower outlet pipe must be set at the lowest point in the underground system. The outlet structure(s) shall discharge into a standard manhole or into a drainage way with erosion protection provided. If an orifice plate is required

to control the release rates, the plate(s) shall be hinged to open into the underground system to facilitate back flushing of the outlet structure(s).

4. A maintenance plan shall be developed and operated by the owner. Access easements shall be provided to facilitate cleaning of the underground system.

5012.4 Fee-In-Lieu of On-Site Detention

A. Requirement**:** Detention facilities shall be designed using the City's hydrologic model and hydraulic model for the watershed, if available. All development, including infill development, may pay a fee-in-lieu of onsite stormwater detention, subject to the discretion of the City Engineer depending on its location in the watershed and the potential for adverse impacts. The developer's engineer must submit his or her recommendation for allowing a fee-in-lieu of onsite detention, along with all supporting data.

B. Also, detention will be required if there is adverse impact from the project as determined by the City Engineer and/or the City's hydrology and hydraulic models.

C. Contribution amount:

1. The contribution amount shall be charged per square foot of additional impervious surface in accordance with **APPENDIX D Fee Schedule**.

2. Fee rate shall be adjusted yearly, based on Engineering News Record Construction Cost Index and recognizing changes in land costs in the Norman area on the annual anniversary of the approval of this *Engineering Design Criteria* document.

3. Money contributed shall be paid at the following time:

   a. Prior to the issuance of the permit for paving or storm sewers, whichever is later.

   b. When the above permit is not required, prior to the issuance of an Earth Change Permit.

   c. When none of the above permits are required, prior to the issuance of a building permit.

D. Fee-in-lieu of detention monies contributed by owners as above shall be used for regional and sub-regional detention sites, facilities and maintenance thereof in the watershed in which the development is located.

E. The boundaries and acquisition of regional and subregional detention sites and construction of detention facilities and location thereof shall be established by the City Engineer and approved by City Council.

END OF SECTION 5000

6000: STORMWATER QUALITY

6001 INTRODUCTION

6001.1 Purpose

The purpose of this Section is to protect, maintain, and enhance the environment of the City of Norman by controlling discharges of pollutants to the City's municipal separate storm sewer system (MS4) and to maintain and improve the quality of the receiving waters into which the stormwater outfalls flow, including, without limitation, the lakes, rivers, streams, ponds, wetlands, sinkholes, and groundwater of Norman.

6001.2 Scope

This Section sets forth uniform requirements to regulate the direct or indirect introduction of pollutants into the MS4 in order for the City of Norman (City) to comply with all applicable state and federal laws including Oklahoma Pollutant Discharge Elimination System (OPDES) and National Pollutant Discharge Elimination System (NPDES) stormwater regulations (40CFR Part 122).

6001.3 Authority of Stormwater Division

The Stormwater Division is responsible for the protection of the health, safety and welfare of the people of Norman by reducing the impact of flooding, erosion, and water pollution through the regulation of non-stormwater discharges to the City's MS4 as well as the management, maintenance and improvement of this system.

A. With respect to the City's compliance with environmental laws, the Stormwater Division and its authorized representatives may do the following:

1. Administer the City's compliance with its OPDES MS4 permit to discharge from the municipal separate storm sewer system;
2. Carry out all inspections, surveillance, enforcement, and monitoring procedures necessary to determine compliance;
3. Inspect City and commercial (see SIC Codes) properties for the presence of hazardous substances, and develop and administer whatever remediation programs are required;
4. Audit City departments to determine whether the City is in compliance with Federal and State Clean Water Act laws; whether the City has obtained all permits required by Federal and State environmental laws; and whether the City is in compliance with the permits it has;
5. Audit use of herbicides, fertilizers, and pesticides to determine compliance and to recommend alternative solutions where practicable for the reduction of their use through education and outreach programs;

6. Control the discharge of spills and the dumping or disposal of materials other than stormwater (e.g., industrial and commercial waste, trash, motor vehicle fluids, leaf litter, grass clippings, animal waste, etc.) into the MS4; provide technical support for spill response;

7. Administer programs to identify and control pollutants from the transportation, storage, treatment, and disposal of hazardous wastes; and monitor hazardous waste facilities which receive the City's RCRA hazardous waste for treatment or disposal for compliance with NPDES MS4 permit requirements;

8. Monitor the City's compliance with all Federal, State, and local laws; except that:

   a. Administering the City's compliance with State and Federal laws relating to discharge from the POTW is the responsibility of the Utilities Department;

   b. Administering the City's compliance with State and Federal laws relating to the production and distribution of drinking water is the responsibility of the Utilities Department;

   c. Administering the City's compliance with State and Federal laws relating to the operation of the City's landfill programs are the responsibility of the Utilities Department; and

   d. Administering the City's compliance with State and Federal laws relating to risk management and safety operations training; programs are the responsibility of the Human Resources Department.

9. Perform such other administrative duties as may be assigned by the Director.

B. With respect to enforcement, the Stormwater Division and its authorized representatives may do the following:

1. Investigate violations of and enforce those aspects of the Clean Water Act which are within the authority of local governments;

2. Investigate violations of and enforce this Section;

3. Investigate violations of and enforce those provisions that relate to hazardous substances and spills although primary enforcement will remain with the Fire Chief;

4. Investigate all other violations of and enforce environmental laws within the City's jurisdiction;

5. Order the stopping of construction of any building or structure, or the alteration, repair or wrecking thereof, if such is being done in a manner that is a violation of this Section;

6. 6.Enter upon any building, structure, or premises at all reasonable times so as to ascertain the presence of pollutant generating activities;

7. Revoke a permit where it is found that there has been a misrepresentation of facts or a violation of this Section;

8. Issue citations for violations of this Section upon the direction of the Director of Public Works, or his designee.

9. Perform other environmental activities as may be required to ensure compliance of environmental regulations by City departments and others within the City of Norman's jurisdiction.

C. With respect to other programs, the Stormwater Manager and their authorized representatives may do the following:

1. Monitor and coordinate with other City departments on the City's response to releases of hazardous substances;

2. Create, promote, and publicize educational programs for environmental awareness; and

3. Provide quantitative data through field screening programs.

6001.4 Monitoring

The Stormwater Division and/or its authorized representatives shall monitor the quantity of, and the concentration of pollutants in stormwater discharges from the areas and locations as designated in the City's Stormwater Management Program (SWMP) and Lake Thunderbird Watershed Total Maximum Daily Load (TMDL) Compliance and Monitoring Plans.

6001.5 Inspections

A. The Stormwater Division and its authorized representatives, bearing proper credentials and identification, may enter and inspect all properties for regular and/or periodic inspections, investigations, monitoring, observation, measurement, enforcement, sampling, and testing, to effectuate the provisions of this article and the Stormwater Management Program. The Stormwater Division and its authorized representatives shall duly notify the owner of said property or the representative on-site and the inspection shall be conducted at reasonable times.

B. In the event the Stormwater Division and/or its authorized representatives reasonably believes that discharges from the property into the City's MS4 may cause an imminent and/or substantial threat to human health or the environment, the inspection may take place at any place at any time and without notice to the owner of the property or a representative on-site. The inspector shall present proper credentials upon reasonable request by the owner or representative.

C. Upon refusal by any property owner to permit an inspector to enter or continue an inspection, the inspector shall terminate the inspection or confine the inspection to areas concerning which no objection is raised. The inspector shall immediately report the refusal and the grounds to the City Attorney. The City Attorney may seek appropriate compulsory process.

D. At any time during the conduct of an inspection or at such other times as the Stormwater Division and its authorized representatives may request information from an owner or representative, the owner or representative may identify areas of the property, facility or establishment, material or processes which contains or might reveal confidential information. If the Stormwater Division and its authorized representatives have no clear and convincing reason to question such identification, the inspector shall none the less inspect; however, the inspection report shall note that confidential information. To the extent practicable and permitted by applicable law, the Stormwater Division and its authorized representatives shall not release information which is designated as a confidential information by the Stormwater Division and its authorized representatives. Should the owner or his representative contend certain information to be confidential which has not been so determined or deemed by the Stormwater Division and its authorized representatives, then the owner shall be obligated to seek a declaratory judgement to so protect the alleged confidential information.

6001.6 Enforcement

The Stormwater Division shall take such steps as deemed necessary against any person, business, or entity found in violation of this Section including, but not limited to, the following:

A. Administrative Enforcement

1. Notice of Violation

   Any violation of the provisions of this Section may result in the responsible party being issued a Notice of Violation (NOV). The NOV will include a description of the violation and include a reasonable time for the violation to be corrected. Failure to comply with the NOV may result in further enforcement action against the responsible party.

2. Cease and Desist Orders

   For any violation of the provisions of this Section, the Director may issue an order requiring the responsible party to cease and desist all violations, to immediately come into compliance with the ordinance and to take any necessary remedial action to reduce or eliminate pollution entering the MS4 from the violation.

3. Administrative Fines

   Notwithstanding any other section of this ordinance, any person or entity found to be in violation of this ordinance may be fined as outlined in the schedule of fees.

4. Water Service Severance

Any person, business or entity that violates the provisions of this ordinance may be subject to severance of water service from the City. Service will recommence at the violator's expense when compliance is achieved or written arrangements to correct the violation(s) is submitted to, and approved by, the City.

5. Suspension of Permit Issuance

   Any person, business or entity that violates the provisions of this ordinance will be denied the issuance of any other City permits, approvals or inspections until the violation(s) is corrected or written arrangements to correct the violation(s) is submitted to, and accepted by, the City.

B. Injunction and Criminal Prosecution

1. Injunctive Relief

   Whenever any person, business or entity violates or continues to violate the provision of this ordinance, the Director may petition the District Court for the issuance of a preliminary or permanent injunction to restrain or compel action on the part of the violator.

2. Criminal Prosecution

   Any person, business or entity which violates the provisions of this ordinance shall be liable to criminal prosecution by the City of Norman in Municipal Criminal Court for a maximum penalty of one thousand dollars ($1000.00) per violation per day and/or imprisonment for a period of not more than thirty (30) days.

3. Remedies Nonexclusive

   The provision of **Sections 6001.5 and 6001.6** are not exclusive remedies. The City reserves the right to take any, all or any combination of these actions against violators of this Section.

6001.7 Permit Administration

A. Permit Types

1. Construction Stormwater Discharge Permit

   A construction stormwater permit is required for any earth disturbing activity except those exempted in Section 6005.

2. Industrial Stormwater Discharge Permit

   An industrial stormwater permit is required for industrial activities operating under a Standard Industrial Classification (SIC) Code identified in Table 1-3 Sectors of Industrial Activity Covered by this Permit of the OKR05 Permit.

B. Permit Application

1. Permittees wishing to obtain permit coverage must submit the following at least thirty (30) calendar days prior to discharge:

   a. Complete and accurate Notice of Intent (NOI);

   b. A copy of the ODEQ authorization, if applicable;

   c. A copy of the SWP3, including a copy of the erosion and sediment control plan if applicable;

   d. Applicants for construction stormwater discharge permit must also include a map or plat of the premises showing the present contour lines and the proposed contour lines resulting from the earth disturbing activity in relation to all parts of the premises and the properties immediately adjacent thereto and in relation to all abutting street grades and elevations.

   e. Such map or plat shall show all proposed and existing drainage facilities and the proposed permanent disposition of surface waters upon completion of the land disturbing activity. Any erosion and sediment control plan must comply with the Best Management Practices Manual and shall be reviewed by the Stormwater Division prior to the issuance of the permit.

   f. The permit application fee and annual permit fee.

2. If the Stormwater Division and its authorized representatives determine that the NOI or SWP3 does not comply with the provisions of this article, the applicant will be notified of all deficiencies.

3. A request for a no exposure certification (NEC) may be made in lieu of obtaining an industrial stormwater discharge permit. Refer to Section 6006.3 for more information.

C. Permit Transfer

1. The transfer of permit coverage shall not relieve the owner/operator of any liability or criminal prosecution for any violations occurring before the transfer is completed.

2. A stormwater discharge permit may be transferred to a subsequent owner/operator only if:

   a. There are no changes in the operation of the facility which may affect the quantity or quality of the stormwater runoff.

   b. The current owner/operator is in compliance with all permit conditions at the time of transfer.

   c. The subsequent owner/operator files an amended NOI containing all of the subsequent owner/operator's required information.

3. If there are to be any changes in the operation of the facility which may affect the quantity or quality of stormwater runoff, then the subsequent owner/operator shall apply for a separate stormwater discharge permit prior to assuming operation of the facility.

D. Permit Application Fee and Annual Permit Fee

1. Permit Application Fees

   a. Earth change permit application fee shall be assessed in accordance with **APPENDIX D Fee Schedule.**

   b. Industrial stormwater discharge permit application fee shall be assessed in accordance with **APPENDIX D Fee Schedule.**

   c. The annual permit fee shall be assessed in accordance with **APPENDIX D Fee Schedule.**

2. Annual Permit Fee

   a. The permittee shall submit the required annual permit fee on an annual basis no later than July 1.

E. Permit Termination

Permittees wishing to terminate permit coverage must submit a complete and accurate Notice of Termination (NOT). The permittee's authorization to discharge will be terminated when the City's termination notification has been issued.

1. Earth Change Permit Termination

   An NOT must be submitted within 30 calendar days after one or more of the following conditions have been met:

   a. Final stabilization has been achieved on all portions of the site for which the permittee is responsible;

   b. For residential subdivision only: final stabilization has been completed and the ownership of all lots has been transferred to new owners and the permittee is no longer responsible for the construction activities for the subdivision. A Notification of Change of Ownership (NCO) has been signed, and included in the SWP3; and

   c. When another operator has assumed control over all areas of the site that have not been finally stabilized. The NOT must be submitted with the new operator's NOI.

2. Industrial Stormwater Discharge Permit Termination

   An NOT must be submitted within 30 calendar days after one or more of the following conditions have been met:

   a. A new owner or operator has assumed responsibility for the facility; or

b. Operations at the facility have ceased and there are not or no longer will be discharges of stormwater associated with industrial activity from the facility.

3. If there are any post-construction stormwater runoff controls that will be left in place, see **Sections 6006** and **7000:**, a maintenance plan must be included with the NOT.

4. In the event that any person holding a permit violates the terms of the permit or this Section, the City may revoke or suspend the permit and require a stoppage of all work on site until all violations are corrected. Any person engaged in activities regulated by this Section without first obtaining the required permit will be required to stop all work on site until a permit is obtained.

F. Signatory Requirements

1. The NOI, NOT, and NEC must be signed as follows:

a. For a corporation: by a responsible corporate officer. For the purpose of this section, a responsible corporate officer means: (i) a president, secretary, treasurer, or vice-president of the corporation in charge of a principal business function, or any other person who performs similar policy or decision making functions for the corporation, or (ii) the manager of one or more manufacturing, production or operating facilities, provided, the manager is authorized to make management decisions which govern the operation of the regulated facility including having the explicit duty of making major capital investment recommendations, and initiating and directing other comprehensive measures to assure long term environmental compliance with environmental laws and regulations; the manager can ensure that the necessary systems are established or actions taken to gather complete and accurate information for permit applications; and where authority to sign documents has been assigned or delegated to the manager in accordance with corporate procedures; or

b. For a partnership or sole proprietorship: by a general partner or the proprietor, respectively (Note: for limited liability company (LLC): by one of its owners, called managing members/partners of the company); or

c. For a municipality, State, Federal, or other public agency: by either a principal executive officer or ranking elected official. For purposes of this section, a principal executive officer of a Federal agency includes (i) the chief executive officer of the agency, or (ii) a senior executive officer having responsibility for the overall operations of a principal geographic unit of the agency (e.g., Regional Administrator of EPA).

2. All reports, including the SWP3 and any changes to the SWP3, must be signed by the person described in 6001.7.1 or their duly authorized representative. A person is a duly authorized representative only if:

   a. A signed and dated authorization completed by the person described above is included in the SWP3; and

   b. The authorization specifies either an individual or the position having responsibility for the overall operation of the regulated facility or activity.

3. Any person signing any document required by this Section shall make the following certification:

   a. "I certify under the penalty of law that I have personally examined and am familiar with the information submitted in the attached document; and, based on my inquiry of those individuals immediately responsible for obtaining the information, I believe the submitted information is true, accurate and complete, I am aware that there are significant penalties for submitting false information, including the possibility of a fine and/or civil penalty."

G. Retention of Records

Appropriate proof and records of compliance with the provisions of a stormwater discharge permit, including copies of SWP3(s), reports, and monitoring, shall maintained for a period of at least three years from the date that the permit is terminated.

6002 DISCHARGES TO IMPAIRED WATERS

Throughout the United States there are thousands of waters listed for impairments from stormwater sources. The most common pollutants coming from stormwater sources include sediment, pathogens, nutrients and metals. These impaired waters need a TMDL, which identifies the total pollutant loading that a waterbody can receive and still meet water quality standards, and specifies a pollutant allocation to specific point and nonpoint sources.

The TMDL is implemented in part via the OPDES/NPDES stormwater permitting system. States and EPA Regions have used a variety of methods to develop stormwater-source TMDLs during the past decade. With the expansion of OPDES/NDPES stormwater regulations to smaller municipalities and smaller construction activities, there has been increasing demand for more detailed quantification of stormwater allocations in TMDLs that are more useful for implementation in OPDES/NPDES permits.

6003 ILLICIT DISCHARGES AND IMPROPER DISPOSAL

The Stormwater Division shall take appropriate steps to detect and eliminate illicit connections to the MS4, including the adoption of a program to screen illicit discharges and identify their source or sources, programs to provide for public education and public information, and other appropriate activities to facilitate the proper management and disposal of used oil, toxic materials, and hazardous household waste.

6003.1 Types of Authorized Discharges

The following discharges are allowed unless they are determined by the Director of Public Works (Director) to cause contamination of stormwater, surface water or groundwater; cause overload or damage to the MS4; endanger public health and safety; or cause the City to violate its ODEQ issued stormwater permit or any applicable state or federal permit:

A. Diverted stream flows;

B. Uncontaminated discharges from riparian areas and wetlands;

C. Uncontaminated ground water or spring water;

D. Residential building wash water that does not use detergents, solvents, and/or soaps;

E. Uncontaminated pumped ground water;

F. Uncontaminated ground water infiltration;

G. Uncontaminated discharges from potable water sources, including water line flushing and fire hydrant flushing;

H. Foundation drains;

I. Air conditioning condensate;

J. Water from crawl space pumps;

K. Footing drains;

L. Residential, non-commercial, and charity car washing;

M. Landscape irrigation and lawn watering, provided all pesticides, herbicides, and fertilizers have been applied in accordance with the approved manufacturers' instructions and/or labeling;

N. Uncontaminated and dechlorinated swimming pool discharges provided the discharge is done in such a way to minimize impacts to water quality and neighboring properties;

O. Street wash water, including wash water generated from the washing of other impervious surfaces such as sidewalks and parking lots, that does not use detergents, solvents, and/or soaps;

P. Discharges in compliance with a separate OPDES or NPDES permit;

Q. Discharges of gray water from municipal splash pads (aka, spray parks or spray grounds), as defined in 27A O.S. § 2-6-107, unless otherwise permitted or regulated by DEQ, provided the discharges comply with all applicable municipal or county ordinances enacted pursuant to law (discharges from recirculating systems shall be dechlorinated); and

R. Discharges or flows from emergency firefighting activities or training activities that are not taking place at a permanent facility.

6003.2 Prohibited Discharges

It is prohibited to discharge, allow to discharge, or cause the discharge of any of the following to the MS4:

A. Non-stormwater discharges except those listed in **Section 6003.1**.

B. Any material other than stormwater, which is stored, spilled, or disposed of in such a manner that causes pollutants to be discharged, such as discarded building materials, soil, silt, sediment, vehicle wash water, litter, yard waste, chemicals or any other pollutant.

C. Any illicit discharge.

6004 CONSTRUCTION STORMWATER RUNOFF CONTROL

6004.1 Earth Disturbing Activities

All earth disturbing activities shall be in compliance with and permitted under this Section and performed in such a manner as to minimize erosion and the discharge of sediment and other pollutants into the MS4. All such activities are also subject to the requirements of the City of Norman Engineering Design Criteria and Standard Specifications and Construction Drawings as incorporated by reference in Section 16-101 of the City of Norman Code of Ordinances and may also be subject to the requirements of the Oklahoma Department of Environmental Quality's (ODEQ)General Permit for Stormwater Discharges from Construction Activities Within the State of Oklahoma, OKR10, if the earth disturbing activity occurs on an area greater than or equal to one (1) acre or is part of a larger common plan of development or sale that will disturb an acre or greater. To seek coverage under OKR10, a Notice of Intent must be submitted to ODEQ.

For the purposes of this Section, the phrase "earth disturbing activity" is defined as follows:

Any land change which may result in soil erosion from water and wind and the movement of sediments into the MS4 or Waters of the State or onto lands and roadways within the community, including, but not limited to, clearing, dredging, grading, excavating, transporting, stockpiling, mining, and filling of land, except that the term shall not include the following:

A. Such minor land disturbing activities as home gardens and individual home landscaping, home repairs, home maintenance work, and other related activities which result in minor soil erosion;

B. The construction of single-family residences when built separately on lots less than one acre not within a subdivision or which have been recorded in the Office of Stormwater Quality Management, and have been issued building permits; provided that excavation is limited to trenches for the foundation, basements, service and sewer connections, and minor grading for driveways, yard areas and sidewalks, with no offsite discharge of pollutants;

C. Individual service and sewer connections for single-or two-family residences;

D. Agricultural practices involving the establishment, cultivation or harvesting of products of the field or orchard, preparing and planting of pasture land, forestry land management practices including harvesting, farm ponds, dairy operations, and livestock and poultry management practices, and the construction of farm buildings;

E. Any project carried out under the technical supervision of the Soil Conservation Service of the United States Department of Agriculture;

F. Installation, maintenance and repair of any underground public utility lines when such activity occurs on an existing hard-surface road, street or sidewalk, provided the activity maintains pollution control and is confined to the area of the road, street or sidewalk which is hard-surfaced and a street, curb, gutter, or sidewalk permit has been obtained; and

G. Construction, repair or rebuilding of tracks of a railroad company;

H. No person may engage in any earth disturbing activities, including but not limited to land clearing, developing, grading, excavating, paving, landfilling, berming or diking without first obtaining an Earth Change Permit from the City of Norman. Such permit shall be required in addition to any building permit or other permit required by the City of Norman for the site. The permit will remain in effect until earth disturbing activities have ceased and permanent erosion control measures, including establishment of vegetative cover, are complete, and a Notice of Termination is submitted or permit coverage is transferred to a new responsible party.

6004.2 Permit Requirements

No earth disturbing activity shall be conducted within the City except in such a manner that complies with the most current OKR10 permit, in addition to the following:

A. All streets and storm sewers are kept free of sediment, discarded building material, litter, chemicals, fuels, or fluids. BMPs must be maintained in good and effective condition at all times. BMPs may not be modified or removed without first obtaining approval from the City.

B. Stripping of vegetation, re-grading and other development activities shall be conducted so as to minimize erosion. Clearing and grubbing must be held to the minimum necessary for grading and equipment operation. Pre-construction vegetative groundcover shall not be destroyed, removed or disturbed more than ten (10) days prior to grading or earth moving. Construction must be sequenced to minimize the exposure time of cleared surface area;

C. Upon completion of land disturbing activities, slopes will not be left so that they will erode. Such methods shall include re-vegetation, sodding, mulching, rip-rapping or guniting. Regardless of the method used, the objective will be to leave the site as erosion-free and maintenance-free as practicable;

D. Whenever feasible, natural vegetation shall be retained, protected and supplemented;

E. Permanent or temporary soil stabilization is applied to disturbed areas to the extent feasible within seven (7) days on areas that will remain inactive for more than fourteen (14) days. Permanent soil stabilization with perennial vegetation shall be applied immediately after final grading is reached on any portion of the site. Soil stabilization refers to measures that protect soil from the erosive forces of wind, raindrop impact and flowing water, and includes the growing of grass, sod, application of straw, mulch, fabric mats, and the early application of gravel base on areas to be paved;

F. A permanent vegetative cover shall be established on disturbed areas not otherwise permanently stabilized;

G. Sediment in stormwater runoff trapped by the use of debris basins, sediment basins, silt traps or similar measures until the disturbed area is stabilized; Any debris basins, sediment basins, silt traps, or similar 500measures shall be stabilized above water level (including all slopes, banks, areas of deposition, inlets, and outlets).

H. Neighboring persons and property are protected from damage or loss resulting from excessive stormwater runoff, soil erosion or deposition upon property or public streets of water-transported silt and debris. Adjacent property owners shall be protected from land devaluation due to exposed bare banks;

I. A controlled construction entrance/exit is maintained in a condition that will prevent tracking or flowing of sediment onto the public right-of-way. Tracked out sediment must be removed by the end of the workday;

J. Erosion and sediment control measures must be in place and functional before earth moving operations begin and must be constructed and maintained throughout the construction period. Temporary measures may be removed at the beginning of the workday, but must be replaced at the end of the workday;

K. Structural controls shall be designed and maintained as required to prevent pollution. All surface water flowing toward the construction area shall, to the extent practicable, be diverted by using berms, channels or sediment traps as necessary. Erosion and sediment control measures shall be designed according to the size and slope of disturbed or drainage areas to detain stormwater runoff and trap sediment. Discharges from sediment basins and traps must be through a pipe or lined channel so that the discharge does not cause erosion. Muddy water to be pumped from excavation and work areas must be held in settling basins or treated by filtration prior to its discharge. Waters must be discharged through a pipe or lined channel so that the discharge does not cause erosion and sedimentation;

L. All control measures are inspected, and repaired as necessary. During prolonged precipitation, daily inspections and repairing must be performed. The permittee shall maintain records of such inspections and repairs Routine facility inspections must be conducted at the following frequencies:

- once every 14 calendar days; and
- within 24 hours of the end of a storm event of 0.5 inches or greater; and
- within 24 hours of a discharge generated by snow-melt.

M. A specific individual is designated to be responsible for erosion and sediment controls on each site;

N. There shall be no distinctly visible floating scum, oil or other matter contained in the stormwater discharge. The stormwater discharge must not cause an objectionable color contrast in the receiving water. The stormwater discharge must result in no materials in concentrations sufficient to be hazardous or otherwise detrimental to humans, livestock, wildlife, plant life or fish and aquatic life in the receiving stream; and

O. When the land disturbing activity is finished and stable, perennial vegetation has been established on all remaining exposed soil.

P. Any person, business or entity that performs an activity which requires an OPDES/NPDES Stormwater Permit shall make available to the City copies of permits, applications and any other records or correspondence pertaining to the aforementioned permit. Any person, business or entity which discharges or causes to be discharged stormwater to the MS4 may be required to provide the City with copies of any records or correspondence determined to be necessary to ensure compliance with this ordinance.

Q. The developer/property owner and contractor designated by the developer are responsible for implementation of, and compliance with, the Erosion and Sedimentation Control Plan, and maintenance of erosion control devices. The developer or the designated contractor must apply for the Earth Change Permit. If no contractor is designated, the contractor having day to day operational control of the site is considered to be designated by the developer.

R. Commercial or residential construction sites less than one acre, but which are part of a common plan of development larger than one acre, such as individual residential lots in a subdivision, are required to maintain BMPs implemented during development. The BMPs may be modified or temporarily removed with approval of the City. If BMPs are absent or not effective, the property owner or designated contractor will, at a minimum, install BMPs to keep streets, drainage ways, and storm drains free from sediment or other construction material or debris.

S. Earth Change Permit and Stormwater Inspection fees shall be assessed according to the City of Norman Standard Specifications and Construction Drawings.

T. An Annual Renewal fee shall be paid per the schedule of fee.

6004.3 Best Management Practices (BMP)

The minimum standards for controlling erosion and sedimentation from earth disturbing activities shall be set forth in the Best Management Practices Manual, as adopted and amended from time to time by resolution approved by the city council.

6004.4 Termination Requirements

In the event that any person holding an Earth Change Permit violates the terms of the permit or this Section, the City may revoke or suspend the permit and require a stoppage of all work on site until all violations are corrected. Any person engaged in activities regulated by this Section without first obtaining the required permit will be required to stop all work on site until a permit is obtained.

6005 INDUSTRIAL STORMWATER RUNOFF CONTROL

6005.1 Industrial Activities

All industrial activities shall be in compliance with and permitted under this Section and performed in such a manner as to minimize the discharge of pollutants into the MS4. All such activities are also subject to the requirements of the City of Norman Engineering Design Criteria and Standard Specifications and Construction Drawings as incorporated by reference in Section 16-101 of the City of Norman Code of Ordinances and may also be subject to the requirements of ODEQ's Multi-Sector General Permit for Stormwater Discharges from Industrial Activities Within the State of Oklahoma, OKR05, if the industrial activity is covered under SICs listed in the OKR05 permit. To seek coverage under OKR05, a NOI must be submitted to ODEQ.

6005.2 Permit Requirements

A. No industrial activity shall be conducted within the City except in such a manner that complies with the most current OKR05 permit. No Exposure Certificate

B. No Exposure Certificate

1. Upon request for an NEC, an inspection of the facility may be performed by the Stormwater Division. Facilities that have been issued an NEC may be subject to an annual compliance inspection. If it is determined that the facility no longer qualifies for an NEC then an application for an industrial stormwater discharge permit must be submitted.

2. A condition of no exposure exists at an industrial facility when all industrial materials and activities are protected by a storm resistant shelter to prevent exposure to rain, snow, snowmelt, and/or runoff. Industrial materials or activities include, but are not limited to, material handling equipment or activities, industrial machinery, raw materials, intermediate products, by-products, final products, or waste products. Material handling activities include the storage, loading and unloading, transportation, or conveyance of any raw material, intermediate product, final product or waste product. A storm resistant shelter is not required for the following industrial materials and activities:

   a. drums, barrels, tanks, and similar containers that are tightly sealed, provided those containers are not deteriorated and do not leak. "Sealed" means banded or otherwise secured and without operational taps or valves;

   b. adequately maintained vehicles used in material handling; and

c. final products, other than products that would be mobilized in stormwater discharges (e.g., rock salt).

3. No Exposure Certification must be provided for each facility qualifying for the no exposure exclusion. In addition, the exclusion from NPDES permitting is available on a facility-wide basis only, not for individual.

C. If an NEC is issued, the facility will be exempt from requirements of the industrial stormwater discharge permit for a period not to exceed twelve (12) months from date of issuance. A new NEC must be submitted annually no later than July 1.

6006 POST-CONSTRUCTION STORMWATER RUNOFF CONTROL

6006.1 Post-Construction Stormwater Runoff Control Measures

Post-construction stormwater runoff control measures includes those BMPs which are typically installed during, and left in place after the completion of, a construction project. This includes detention ponds, retention ponds, rain gardens, pervious pavement, and other controls, including those described in **Section 7000:**.

6006.2 Operation and Maintenance Requirements

A. For the purposes of this section, an “owner/operator” is defined as the party with control over operational and maintenance activities of the BMP, including home owner associations, commercial, and industrial entities.

B. A maintenance plan shall be developed which defines who will conduct the maintenance, the type of maintenance necessary to ensure effective performance, and the maintenance intervals. At a minimum,

1. The owner/operator shall inspect the BMP at least annually.
2. The owner/operator shall maintain and repair the BMP:
    a. In the case of basins and other facilities where sediment collects, to preserve the storage or capacity at or above the design volume or, where no design storage volume or capacity is incorporated into the permit, the volume or capacity recommended by the manufacturer.
    b. In the case of conveyances and other structures, to preserve design hydraulic capacity.
    c. In the case of facilities relying on soils and vegetation for stormwater management or treatment, to preserve healthy vegetation and design soil permeability.
    d. In the case of all facilities, as necessary to preserve the integrity and intended function.
    e. Any other additional requirements specified in **Section 7000:**.

END OF SECTION 6000

7000: SUSTAINABLE STORMWATER DEVELOPMENT

7001 INTRODUCTION

7001.1 Background

Stormwater can have significant impact on the water quality of Norman's natural areas. To minimize the effect of non-point source pollutants in stormwater, stormwater control measures (SCMs, or controls; also referred to as “BMPs”) are encouraged to reduce the impact of development. Controls are designed to improve water quality by removing suspended particulate matter and associated constituents such as bacteria, nutrients and metals.

SCMs are in line with sustainable design practice goals and complete streets principles. As stewards for the land, Norman encourages the use of SCMs on all developments, including new, existing, and redevelopment sites. Installing such controls are incentivized through coordination with the City but are also encouraged within the Lake Thunderbird Watershed as prescribed in the Water Quality Protection Zone (WQPZ) Ordinance.

The information in this section is intended to define the technical design criteria to be used in the design of SCMs. This document provides criteria for both the design of stormwater controls to enhance water quality and for the long-term maintenance of these facilities. The criteria should be followed to provide protection of the water resources in Norman and to minimize time and effort in obtaining project review and approval.

7001.2 Site Design Credits

RESERVED

7001.3 Sustainable Development Incentives

RESERVED

7002 GENERAL DESIGN CRITERIA

7002.1 Water Quality Volume

The primary control strategy for water quality basins is to capture a minimum volume of stormwater runoff for treatment and to release the treated volume in length of time specified. The minimum volume is the amount of runoff that is produced by the first one inch (1”) of rainfall. This depth of runoff from the contributing drainage area to the control is and will be referred to as the Water Quality Volume or WQV. The WQV must be routed through the SCM as designed per this Section of the EDC.

A. The water quality volume must consist of runoff from all impervious surfaces (existing and proposed conditions) such as roadways, parking areas and roof tops, and all developed pervious areas. Water quality treatment is not required for runoff from lands left in their natural state, e.g., greenbelts and open spaces. Runoff from these areas must be routed around the water quality basin or it must be included in the water quality volume. Off-site contributing drainage should be routed around the water quality basin except in cases where untreated, off-site area can be treated.

B. Water Quality Volume Determination

$$\boldsymbol{WQV = \frac{D_S * R_v * A}{12}} \quad \textbf{(1)}$$

$$\boldsymbol{R_v = 0.05 + 0.009I} \quad \textbf{(2)}$$

Where,

WQV = Water Quality Volume (ft^3)

D_s = Target precipitation depth (1.0 inch)

R_v = Volumetric runoff coefficient

I = Percent impervious cover

A = Site area (ft^2)

7002.2 SCM Regulations

Stormwater control measures (SCMs) are engineered facilities designed to reduce and/or treat stormwater runoff, which mitigate the effects of increased stormwater runoff peak rate, volume, and velocity due to urbanization**. The following must be met as part of the incorporation of SCMs into a site.**

A. SCMs must be registered with the City and dedicated within the plat

B. Submit an operations and maintenance plan as required as part of the filed restrictive covenant

7002.3 Stormwater Controls Selection

Table 7002-1 below provides an overview of specific site conditions that must be met for a particular SCM to be suitable and other factors that go into SCM selection. SCM's are to be of the approved measures listed in the table unless otherwise approved by Public Works Director, or designee and designed based on adopted criteria from another public agency.

A. Type of Stormwater Control Measures

The SCMs are broken up into two general categories: small scale controls and large scale controls. Small scale controls are designed to be at the site scale where they are typically designed to treat runoff from one commercial building or residential parcel. Large scale controls are designed to be at the watershed or neighborhood development scale where all runoff from the site is typically routed to one SCM per drainage area.

B. Pollutant Removal

The first set of columns reference water quality treatment and provide an overview of the pollutant removal performance of each SCM option when designed, constructed, and maintained according to the criteria and specifications in this Manual.

- Total Suspended Solids (TSS) Removal – Indicates the extent an SCM can remove total suspended solids from a water volume. If not removed, suspended solids will make a water body cloudy, clog fish gills, and reduce light penetration into the water which can damage stream health and aquatic life. Hotspots with significant loadings of suspended solids include areas such as roads, parking lots, and industrial sites or eroding channel banks.
- Total Phosphorous (P) Removal – Indicates the capability of an SCM to remove phosphorus in runoff. This may be of particular concern with certain downstream receiving waters due to eutrophication, a process where a body of water is supplied with an excess of nutrients. Excess nutrients can cause algal blooms which can disrupt an ecosystem and create hypoxic zones in the water. Sources of phosphorus include plant and leaf litter, pet waste, road salt, fertilizer, and soil particles. Hotspots for phosphorus are comprised of areas such as parks, lawns, roads, and agricultural sites.
- Total Nitrogen (N) Removal – Indicates the capability of an SCM to remove nitrogen in runoff, which may also be of particular concern with certain downstream receiving waters due to eutrophication— explained in the paragraph above. Sources and hotspots for nitrogen are the same as phosphorus.
- Pathogen Removal – Indicates the capability of an SCM to remove fecal coliform and associated bacteria in runoff. Removal of these contaminants are key to keeping waters sanitary. This capability may be of particular focus in areas with pathogen hotspots like public parks and/or water quality regulatory criteria under the Total Maximum Daily Load (TMDL) program.
- Metals Removal – Indicates the capability of an SCM to remove trace metals, which may be present in stormwater runoff from designated hotspots, or where subsurface soil and/or groundwater contamination may be present. Metals are generally hazardous, highly soluble in water, and can be absorbed by living organisms. If metals are allowed to enter the food chain, they can bioaccumulate in humans and cause serious health problems. Examples of hotspots for metals include: gas stations, convenience stores, public works storage areas, vehicle

service and maintenance areas, commercial nurseries, and auto recycling facilities.

C. Site Selection

The second group of columns provides an overview of specific site conditions or criteria that must be met for a particular SCM to be suitable. In some cases, these values are recommended values or limits that can be exceeded or reduced with proper design or depending on specific circumstances. Please see the specific criteria section of each practice for more details.

- Maximum Contributing Drainage Area – Indicates the approximate maximum drainage area that is considered suitable for the SCM. If the drainage area present at a site is slightly greater than the maximum allowable drainage area for a practice, some leeway can be permitted if more than one practice is installed. The minimum drainage areas indicated for ponds and basins should not be considered inflexible limits and may be increased or decreased depending on water availability (baseflow or groundwater), the mechanisms employed to prevent outlet clogging, and/or design variations used to maintain a permanent pool (e.g., liners).
- Appropriate in Floodplain – Indicates whether an SCM is allowed to be placed inside a floodplain.
- Minimum Distance to Groundwater Table – Indicates the minimum depth to the seasonally high-water table from the bottom, or floor, of an SCM.
- Maximum Site Slope – Evaluates the effect of slope on the SCM. Specifically, the slope restrictions refer to how flat the area where the SCM is installed must be and/or how steep the contributing drainage area or flow length can be.

D. Costs

The third group of columns provides comparisons between cost estimates and maintenance requirements between SCMs.

- Construction Cost – Structural controls are ranked according to their relative construction cost per impervious acre treated, as estimated from cost surveys.
- Maintenance Cost – Assesses the relative maintenance effort needed for an SCM in terms of three criteria: frequency of scheduled maintenance, chronic maintenance problems (such as clogging), and reported failure rates. It should be noted that stormwater control measures require routine inspection and maintenance, especially after a storm event.

E. Other

The last group of columns address safety issues and other benefits that a specific SCM has.

- Safety Issues – Safety considerations for each SCM. Either 'None' or a recommendation on the design that will decrease the likelihood of an accident.
- Benefits – Miscellaneous benefits that an SCM has. Benefits include but are not limited to items like aesthetic value, adaptability, and groundwater impacts.

7002.4 Pollutant Removal and Treatment Trains

Hydrologic studies show smaller, more frequent rain events account for the majority of rain events. The runoff from these smaller events account for a large portion of the annual pollutant loadings. By treating these frequent, smaller rain events and the initial portion of the stormwater runoff from larger events, it is possible to effectively mitigate the water quality impacts from a developed area. A 1.0 inch rainfall has been identified as a reasonable target for addressing the majority of smaller, pollutant-laden runoff events referred to as the WQV.

In accordance with the Section 19-411 of Chapter 19 of the Code of the City of Norman, the WQV within the Water Quality Protection Zone (WQPZ) must be treated to a 58% phosphorus and 75% nitrogen reduction. A stormwater management system designed to meet the requirements for treating the WQV will treat the first 1.0 inch of runoff, or less for smaller storms, to the 58% phosphorus and 75% nitrogen removal standards. The following section details the phosphorus removal calculations. The same process and equations should be used to calculate the percent removal of nitrogen.

A. Calculate Percent Phosphorus Removal

As stated previously, the engineer must utilize one or more treatment facilities to achieve or exceed the minimum 58% phosphorus removal in a WQPZ. **Table 7002-1** provides the percent phosphorus removal value provided by each of the SCM's presented in this Manual. If a single SCM is used for a site the percent phosphorus removal value from **Table 7002-1** applies and no further calculations are needed. If multiple SCM's are used at a site, the resulting overall removal rate should be calculated using one of the following methods. The method selection is determined based on the design of the SCMs and whether they have been placed in parallel, series, or a flow-through set-up.

1. Controls in Parallel

For controls placed in parallel the following equation shall be used:

$$\boldsymbol{P_{parallel}} = \frac{\sum_1^n (P_1 A_1 + P_2 A_2 + \cdots + P_n A_n)}{\sum_1^n (A_1 + A_2 + \cdots + A_n)} \quad (3)$$

Where,

P_n = Phosphorus removal for each SCM on-site from **Table 7002-1** (%)

A_n = Area draining to each control (acre)

And any untreated area is to be assigned a null control with a phosphorus removal rate of 0%

a. Design Example

- A stormwater management system located on a 13 acre development site contains a treatment train that treats stormwater runoff from the site. Determine the phosphorus removal rate for site controls placed in parallel given the following information:
- Control A: Infiltration Trench treating 5 acres - 60% removal efficiency
- Control B: Wet Pond treating 4 acres - 55% removal efficiency
- Control C: Infiltration Trench treating 4 acres - 60% removal efficiency

$$P_{parallel} = \frac{\sum(60\% * 5\ acre + 55\% * 4\ acre + 60\% * 4\ acre)}{\sum(5\ acre + 4\ acre + 4\ acre)}$$

$$P_{parallel} = 58.5\%$$

- This exceeds the 58% phosphorus removal requirement. No further water quality control is required to meet the phosphorus removal requirements. The same steps should be followed to determine if the nitrogen removal requirements are met for the treatment train in parallel.

2. Controls in Series

For a site where two or more controls are implemented in series, where stormwater treated in one control is discharged directly into the next control for further treatment the following equation shall be used:

$$\boldsymbol{P_{series}} = \boldsymbol{P_A} + \boldsymbol{P_B} - \frac{P_A * P_B}{100} \quad (4)$$

Where,

P_{series} = Total phosphorus removal for series (%)

P_A = % phosphorus removal for the first (upstream) control (%)

P_B = % phosphorus removal for the second (downstream) control (%)

For more than two controls in a series, P_A shall be the combined removal for the first two controls and the removal for the third control shall be P_B. Repeat this procedure as necessary to account for all controls in the series.

a. Design Example

- A stormwater management system located on a 13 acre development site contains a treatment train that treats stormwater runoff from the site. Determine the phosphorus removal rate for site controls placed in series given the following information:
- Control A: Permeable Pavement treating 5 acres - 50% removal efficiency
- Control B: Vegetated Filter Strip treating 1 acre - 20% removal efficiency
- Control C: Wet Pond treating 4 acres - 55% removal efficiency

$$P_{AB} = 50\% + 20\% - \frac{50\% * 20\%}{100}$$

$$P_{AB} = 60\%$$

$$P_{series} = P_B + P_C - \frac{P_{AB} * P_C}{100}$$

$$P_{series} = 60\% + 55\% - \frac{60\% * 55\%}{100}$$

$$P_{series} = 82\%$$

- This exceeds the 58% phosphorus removal requirement. No further water quality control is required to meet the phosphorus removal requirements. The same steps should be followed to determine if the nitrogen removal requirements are met for the treatment train in series.

3. Flow-Through Control

A flow-through scenario occurs when runoff to be treated enters the treatment train between two other controls located in series. In these cases the following equation shall be used:

$$\boldsymbol{P_{FT} = \frac{P_A A_A + P_B A_B + \frac{P_B A_B (100 - P_A)}{100}}{A_A + A_B}} \quad \textbf{(5)}$$

a. Design Example

- A stormwater management system located on a 10 acre development site consists of a bioswale and a sedimentation basin. Four acres drain to the bioswale, which then drains to a pipe system. The pipe system drains an additional 6 acres that have not been treated for water quality. The pipe system leads to the sedimentation basin for final treatment. What is the resulting phosphorus removal efficiency if the bioswale and sedimentation basin both have a 50% phosphorus removal efficiency?

$$P_{FT} = \frac{50\% * 4\ acre + 50\% * 6\ acre + \frac{50\% * 4\ acre(100 - 50)}{100}}{4\ acre + 6\ acre}$$

$$P_{FT} = 60\%$$

- This exceeds the 58% phosphorus removal requirement. No further water quality control is required to meet the phosphorus removal requirements. The same steps should be followed to determine if the nitrogen removal requirements are met for the treatment train with a flow-through.

Table 7002-1: Stormwater Control Method Selection Guide Table

		Pollutant Removal					Site Selection				Costs		Other	
	SCM (Stormwater Control Measure)	TSS	Total P	Total N	Pathogens	Metals	Maximum Contributing Drainage Area	Appropriate in Floodplain	Minimum Distance to Groundwater Table	Max Site Slope	Construction Cost	Maintenance Cost	Safety Issues	Benefits
Small Scale	**Vegetated Filter Strip**	50%	20%	20%	60%	40%	5,000 square ft.	Yes	1-2 ft	0.5-6% (non-reinforced) or 6-15% (reinforced)	Low	Low	None	Adaptable to many site conditions
	Rainwater Harvesting	varies	varies	varies	varies	varies	House Roof-top	N/A	N/A	No Restriction	Medium	Medium	non-potable water without treatment	Water supply
	Rain Garden	85%	80%	60%	90%	95%	2 ac	No	1 ft	15%	Medium	Medium	Potential mosquito habitat if not maintained	Aesthetic, flexible geometry to fit any site
	Infiltration Trench	90%	60%	60%	100%	90%	5 ac	Yes	2 ft	6%	High	High	None	Recharge groundwater, preserve baseflow
	Green Roofs	80%	50%	50%	N/A	N/A	N/A	N/A	N/A	2%	High	Medium	None	Increased roof lifespan and insulation
	Permeable Materials	80%	50%	50%	N/A	60%	N/A	Yes	2 ft	5-10% (Grid Paver & Porous Asphalt) 6% (Pervious Concrete)	High	High	None	Reduces standing water on pavement Reduces impervious cover
	Bioswales	90%	50%	50%	N/A	40%	5 ac	Yes	Below-2 ft	4%	Medium	Low	Depth should be limited to 18 in	Slow & shallow flow, little erosion
Large Scale	**Sedimentation / Filtration**	80%	50%	30%	40%	50%	2-10 ac	No	2 ft	6%	High	High	Filters should be fenced in or locked to prevent access	Few site constraints
	Extended Detention Basin	60%	35%	25%	N/A	25%	10 ac	Yes	2 ft	15%	Low	Low	None	Simple retrofit to existing detention ponds
	Wet Ponds	80%	55%	30%	70%	50%	25 ac	No	2 ft	15%	High	High	Avoid steep slopes Avoid swimming and fishing	Can be designed and landscaped for aesthetic value Serves as a site amenity

*Infiltration practices not allowed for sites with hazardous material insitu soils

7002.5 Soil Infiltration

An evaluation of infiltration rate is necessary to determine if infiltration is feasible at a site where an infiltration based SCM is proposed and to establish design infiltration rates for SCMs.

There are three steps for evaluating the infiltration rate:

1. Desktop study: soil survey maps or existing geotechnical information
2. Field sampling: soil depth verification and textural analysis
3. In-situ testing: more rigorous in-situ infiltration or percolation testing

Design infiltration rate shall be established by applying a minimum safety factor of 2 to the estimated or measured infiltration rate. Porous pavement for pedestrian use only may be designed without additional field verification or sampling. Additional field sampling or testing is required for other infiltration-dependent controls. In-situ testing is allowed for all SCMs but only required for SCMs that use full or partial infiltration methods. For these cases, infiltration rate confirmation is required during construction to confirm design assumptions.

A. Desktop Study

1. Desktop resources such as soil survey maps, published reports, or other available data is appropriate for screening to assess the feasibility and desirability of infiltration.
2. The infiltration rate shall be derived from the hydraulic conductivity listed in the U.S. Department of Agriculture National Resources Conservation Service Soil Survey for the location and soil type reported for the site. Geotechnical data from previous site studies or nearby representative locations may also be used.
3. If a range of hydraulic conductivity values is available, the infiltration rate shall be estimated as the geometric mean.

B. Field Sampling

The purpose of field sampling is to evaluate the depth and texture of soil at the location of the proposed water quality control.

1. Field sampling activities must be conducted under the direction of a qualified professional.
2. Soil depth and texture within the proposed footprint of the control must be evaluated via test pits, probes, borings, or similar means at a minimum frequency of one test location per 500 square feet.

3. Soil samples must be collected and evaluated at a depth below the expected bottom of the infiltration SCM. The probe or hole must extend to the minimum soil depth required for the proposed control.

4. Soil texture of representative samples may be classified in the field or by laboratory methods such as sieve and hydrometer analysis.

5. Based on the soil texture in the field, a representative infiltration rate can be estimated from desktop resources. In the event that the soil textures in the field differ from published references, additional testing and analysis must be conducted to establish a representative infiltration rate.

C. In-situ Testing

1. More rigorous in-situ infiltration or percolation testing methods provide the most accurate estimate of the infiltration rate. Laboratory tests are not recommended because typical laboratory samples are less representative of field conditions. A variety of in-situ tests are available for measuring the infiltration capacity of the soil.

   a. Test pit

   b. Soil boring

   c. Double-ring infiltrometer

   d. Cased borehole infiltration test

   e. Pilot infiltration test

   f. Soil grain size analysis

   g. Well permeameter method

2. In-situ testing must be conducted under the direction of a qualified professional.

3. Testing must be conducted within the proposed footprint at a minimum frequency of one test per 2,000 square feet, although a higher testing frequency is recommended to more fully characterize the subsurface conditions.

4. When more than one infiltration test is conducted for a single control, a representative infiltration rate must be calculated as the geometric mean of the test results.

5. The infiltration test should be conducted as close as possible to the proposed bottom elevation for the water quality control.

   a. Based on observed field conditions, the designer may elect to modify the proposed bottom elevation of the control.

   b. Personnel conducting infiltration tests should be prepared to adjust test locations and depths depending on observed conditions.

6. The designer should keep in mind the difference between percolation tests and infiltration tests when determining the design infiltration rate.

a. A measured infiltration rate can be determined from a single or double ring infiltrometer test.

b. A percolation rate determined from the simple open pit percolation test is related to the infiltration rate but tends to overestimate infiltration rates due to both downward and horizontal movement of water.

c. Infiltration rates correspond only to the downward movement of water.

7. In addition to the percolation test methods discussed below, the following are acceptable methods for percolation testing:

   a. Single Ring Infiltrometer Test (ASTM D5126)

   b. Double Ring Infiltrometer Test (ASTM D3385)

   c. Guelph Permeameter

   d. Constant Head Permeameter (Amoozemeter or USBR Procedure 7300-89)

D. Percolation Test Protocol

1. The percolation test is geared towards investigation of smaller infiltration facilities (drainage areas 2 acres or less and a maximum ponding depth of 12 inches).

2. The test can be conducted using simple tools and manual labor and does not require extensive excavation.

3. Test Preparation

   a. The test hole opening shall be between 8 and 12 inches in diameter or between 7 and 11 inches on each side if square.

   b. The bottom elevation of the test hole shall correspond to the bottom elevation of the proposed control (infiltration surface).

   c. Place approximately 2 inches of gravel in the bottom of the hole to protect the soil from scouring.

   d. If horizontal infiltration is to be allowed, the sides of the test hole shall be scarified.

   e. Pre-soak the hole by carefully filling it with water. If the hole has not drained completely within 24 hours, then an infiltration design is not recommended.

   f. Testing may commence after all of the water has percolated or after 15 hours has elapsed since initiating the pre-soak.

   g. Testing must commence no later than 26 hours after all pre-soak water has percolated through the test hole.

h. Place a bar over the top of the hole or a nail near the top of the hole to serve as a datum from which depth measurements will be made.

i. Measure the depth and diameter of the test hole.

4. Test Procedure

a. Carefully fill the hole with water to a level greater than or equal to the maximum ponding depth of the rain garden. Measure this water elevation and the time it was taken.

b. Measure the water surface elevation as it drops and record the time of each measurement.

- Measurements shall be taken with a precision of 0.25 inches or better.
- Refill the hole as necessary to extend the test to at least 2 hours.

c. The test can be terminated when near steady-state conditions (when the rate of drop is approximately constant) or when the test hole is empty.

d. A general recommendation is to plan to take at least 4 measurements over at least 2 hours.

e. Calculate the percolation rate using representative data points from the latter stages of testing where the rate of drop is approximately constant.

- The percolation rate is the change in water elevation (in inches) by the corresponding time interval (in hours).

f. Convert the steady-state percolation rate to a representative infiltration rate using the reduction factor:

$$\boldsymbol{I} = \frac{\boldsymbol{p}}{\boldsymbol{R_f}} \qquad (6)$$

Where,

I = Representative infiltration rate

p = Steady-state percolation rate

R_f=Reduction factor

And:

$$\boldsymbol{R_f} = \frac{(\boldsymbol{2d_1} - \boldsymbol{\Delta d})}{\boldsymbol{D}} + \boldsymbol{1} \qquad (7)$$

Where,

R_f=Reduction Factor

d_1 = Water depth at start of representative time interval (in)

Δd = Water level drop during representative time interval (in)

D = Diameter of percolation hole (in)

g. The reduction factor accounts for the water losses through the sides of the percolation hole. It assumes the percolation rate is affected by the depth of water in the hole and the hole is located in uniform soil. If there are deviations from these assumptions, other adjustments may be necessary.

7002.6 Diversion Structures

A. Off-line SCMs are required to have a diversion structure or splitter box which will capture the water quality volume. A typical approach for achieving capture of the water quality volume is to construct a diversion weir in the stormwater channel or storm drain. For SCMs that require a diversion structure the following minimum design standards must be provided:

1. The height of the diversion weir must be equal to or greater than the surface elevation of the water quality volume in the SCM.

2. The diversion structure must be capable of passing the peak flow rate of the twenty-five (25) year storm into the SCM

3. The maximum velocity entering the SCM shall not exceed two (2) feet per second.

4. When runoff in excess of the water quality volume enters the stormwater channel it will spill over the diversion weir. The diversion weir must be designed to pass the peak flow rate of the one hundred (100) year design storm past the SCM with a head over the diversion weir of no more than one foot.

5. The SCM design shall allow enough freeboard to pass the design flow rate for the 100-year storm over the splitter/diversion structure without overtopping of any side walls of the pond, plus an additional 5% of the total fill height or three inches, whichever is greater, to allow for construction irregularities and long term soil settling.

6. As an alternative, the professional engineer can size the diversion structure for the flow rate of the twenty-five (25) year inflow hydrograph that will fill the pond. A hydraulic and hydrologic analysis must be provided that conforms with the accepted procedures, as defined in **Section 5000:**

B. SCMs may be allowed to stack the required detention volume or allow all storm events to flow through the SCM above the water quality volume. However, they can only account for volume that is available after 24-hour drawdown. These SCM are as follows:

1. Partial sedimentation with sand filtration or biofiltration controls

2. Full sedimentation with sand filtration or biofiltration controls

3. Extended detention basin with or without wet pond

4. Rainwater Harvesting controls

5. Rain Gardens

6. Infiltration Trench

7. Porous Pavement

C. In-line SCMs that propose to stack the required detention volume or allow all storm events to flow through the SCM above the water quality volume must comply with the following criteria:

1. The velocity of the flows entering the SCM for the developed 100-year peak flow must not exceed two feet per second.

2. Velocity breaks and energy dissipation should be incorporated into the design to reduce erosive impacts on the SCM and to protect the medium (sand or biofiltration) from washing out or eroding.

3. Detention pond and SCM wall elevations must meet the minimum freeboard requirements provided in **Section 5000:.**

D. Maintenance Requirements

1. Remove all check boards at the end of the irrigation season to avoid damage to the structural works due to ice flows and large debris during high runoff times.

2. Immediately repair any cracks or breaks in the concrete.

3. Investigate cause before repair and take measures to prevent reoccurrence.

4. Remove sediment, debris, or any blockage that restricts capacity.

5. Remove woody vegetation and perennials from areas adjacent to the structural works.

6. Repair spalls, cracks and weathered areas in concrete surfaces.

7. Immediately repair any vandalism, vehicular or livestock damage.

8. Eradicate or otherwise remove all rodents or burrowing animals.

9. Immediately repair any damage caused by their activity.

10. Do not operate motorized vehicles within six feet of structural works.

11. Repair any gulling to earthen areas surrounding the structural works.

7002.7 Disconnection of Rooftop Runoff

Impervious surface disconnection involves the management of runoff near its source by capturing, filtering, treating, or reusing stormwater. Runoff from roofs that would have otherwise discharged to impervious surfaces is instead routed to pervious areas.

A. Design Criteria

1. Size of the receiving area must be at least the size of 10% of the contributing area.
2. Extend at least 2 feet from simple foundations and 6 feet from basements to minimize potential interaction.
3. Do not direct water to adjacent properties.
4. Runoff must be directed to an area with well-maintained vegetation.
5. The receiving area slope must be between 1% and 5%. Steep sloped areas should consider utilizing flow-dispersion techniques, such as a splash pad or level spreaders, at the outlet.

B. Construction Considerations

1. Downspout outlets that are already constructed to discharge at the ground surface should be modified to discharge to the receiving area using appropriate elbows and extensions as needed.
2. If connected directly to a standpipe at the base of the downspout, measure up from the standpipe approximately 9 inches and cut the downspout. Remember, it is better to remove too little than too much. Remove and discard the cut piece.
3. Secure the standpipe with a commercially available cap or plug. Do not use concrete to seal standpipe.
4. Attach elbow over downspout. Crimp inside of downspout if necessary to ensure a snug fit.
5. Measure and cut downspout extension to desired length. Again, secure the extension over the elbow to ensure proper fit to prevent leaks. Length of extension is dependent on the site.
6. Secure all pieces together at each joint with sheet metal screws.
7. Place splash pad or level spreader at extension discharge to encourage sheet flow of runoff, preventing erosion.

7002.8 Basin Liners

Impermeable liners are required for wet ponds and infiltration basins located in areas where there is a karst region or hazardous material conditions.

Impermeable liners may be clay, geosynthetic clay liner (GCL), geomembrane, or other approved liner, depending on the application. Concrete liners may be used for sedimentation and filtration basins that are less than one thousand (1,000) square feet in area.

The analysis and design of the liner should entail a comprehensive review of the site-specific conditions to determine the most appropriate type of liner for the site and should include a stability assessment of the pond side slope. The criteria below is applicable to any size basin or pond. When required for sedimentation/filtration basins, the liner must underlie both the sedimentation basin and filtration basin and any separator wall areas.

Clay liners must comply with **Oklahoma Department of Environmental Quality 252:616-7-3** pre-construction and construction requirements. All liner must comply with the Liner **Specification 2106**.

A professional engineer must be involved in all aspects of the liner design. All liner studies, plans, details, specifications and other related documents must be sealed by a professional engineer. Careful attention must be paid to each of the following areas:

A. Liner Subgrade

A stable subgrade is very important in the construction of the pond or basin. Careful evaluation must be conducted to ensure the liner will be placed on a suitable base. If any voids are encountered, proper geotechnical analysis must be performed to ensure that the integrity of the liner can be maintained. Proof rolling must be conducted as necessary to determine the suitability of the subgrade, and any suspect areas must be reworked and recompacted, or the weak soils removed and replaced with suitable fill material. The subgrade for geomembrane or GCL must be smooth and contain no particles greater than 0.375 inch diameter.

B. Handling of Liner Penetrations

Detailed analysis must be performed related to the handling of all areas of liner penetrations such as pipe inlet and outlet structures, headwalls, and areas where concrete access ramps, maintenance and pump pads interface with the liner. Penetrations for wet ponds should be placed to minimize the hydraulic head over the penetration. Consideration must be given to the need for special applications such as filter diaphragms, gaskets, clay or bentonite plugs, special backfill and compaction, and other measures to prevent leakage around all these areas.

C. Submerged Inlets and Storm Sewers

Due to excessive leakage issues submerged inlets and storm sewers to SCMs are to be avoided whenever possible. In situations where site conditions require a submerged inlet or storm sewer, then the portion of the inlet pipe that is placed below the water quality elevation must be designed to store water, not simply convey it. In these situations, the pond liner must extend and surround the portion of the inlet pipe or storm sewer that is designed to be under water and all structural elements and piping below the water quality elevation shall be watertight. Acceptable watertight piping includes gasketed RCP, PVC, and wastewater grade HDPE. Leak testing of the system will be performed to verify that the system is watertight and able to perform as designed.

D. Protecting the Liner from Erosion

The integrity of the liner, particularly a clay liner, can be severely compromised by any erosion that may occur at the surface of the liner. The design must provide appropriate mechanisms to prevent erosion of the liner at all areas, including the inlet structure and the separation berm between the forebay and main pool of wet ponds. Additionally, the liner must be continuous under wet pond separation berms to minimize the potential for leakage at the equalization/interbasin pipe.

E. Protecting the Liner Against Damage and Loss of Moisture

It is imperative that the clay liner be kept moist during construction and prior to the time the basin is filled.

F. Liner Plans and Specifications

The professional engineer must prepare the necessary plans and specifications to provide the contractor clear direction for the construction of the liner and all related components. Construction details must be included for all liner cross-sections, penetrations, and any other areas requiring special attention and/or guidance to ensure proper construction. A scale drawing of the area to be lined, including a grid established across the base and side slopes of the pond or basin with target elevations shown, must also be prepared by the professional engineer. This grid will provide a basis for verification of liner thickness during construction and will be used for the purpose of recording elevation data prior to placement of the initial lift and following placement of the final lift. All required testing, standards, procedures, and material properties must be spelled out in detail in the documents. Parties who are responsible for any surveying, sampling, testing and other verification requirements must be identified in the documents.

G. Groundwater Control

Liners constructed below groundwater will require dewatering as necessary to allow construction of the liner. To prevent damage to the liner due to uplift pressures after termination of dewatering or during future maintenance, the liner must include placement of sufficient soil ballast or additional thickness of clay liner to resist any uplift pressures. Alternative designs to relieve liner uplift pressure (French drain, etc.) will be considered and must be approved by the City.

H. Construction Quality Assurance/Quality Control Plan

A construction Quality Assurance/Quality Control (QA/QC) Plan must be prepared by the professional engineer for the purpose of providing a basis for all construction/installation and testing of the liner system during the liner construction process. The QA/QC plan must be approved by the City prior to liner construction.

I. Soils and Liner Evaluation Report (SLER), Geosynthetic Clay Liner Evaluation Report (GCLER), or Geomembrane Liner Evaluation Report (GLER)

All liner construction and QA/QC activities must be under the supervision of an independent licensed engineer with experience in geotechnical engineering. The engineer or designated representative must be on site during all significant liner construction activities, including but not limited to:

1. At the beginning of liner construction to inspect subgrade acceptability. Clay liners shall have an appropriate water content-density range to assure a maximum saturated hydraulic conductivity of 1 x 10-7cm/sec, verified by an independent soil testing laboratory
2. During the processing of clay liner material for placement to ensure adequate moisture conditioning and particle size reduction.
3. During placement of clay liner lifts to ensure lifts are no more than nine inches thick uncompacted, and six inches thick compacted. Examine each lift before compaction and remove rocks, debris, or foreign matter greater than one inch in diameter. Also remove and repair lenses, cracks, channels and root holes that could adversely affect hydraulic conductivity.
4. During all geomembrane installation.
5. During clay and geomembrane liner testing.
6. Prior to placement of successive clay lifts to verify acceptability of prior lift surface.
7. During construction of penetrations and any other construction that will affect the integrity of the liner (access ramps, pump pads, etc.).
8. During placement of protective soil layer.

Following completion of the liner construction, SLER, GCLER, or GLER (as applicable for the type of liner installed) must be prepared under the direction of and sealed by the professional engineer and submitted to the City. The report is intended to provide documentation of all installation methods and testing procedures conducted during the installation of the liner and to provide evidence that the liner was constructed in accordance with the construction plans, technical specifications and QA/QC plan.

J. Water Level Monitoring for Liner Integrity Verification in Wet Ponds

After the filling and installation of aquatic vegetation in a wet pond, the water level of the permanent pool shall be measured monitored for a minimum of eight weeks. The professional engineer shall specify the method and frequency of monitoring, and the responsible party for conducting water level monitoring. The professional engineer shall perform a water balance, as specified in **7004.3C.3**, to determine that the water loss does not exceed anticipated losses from calculated liner leakage, evaporation, plant transpiration and discharge. All monitoring data and calculations must be documented and submitted to the City of Norman for review.

7002.9 Short-Circuiting and Dead Storage

All water quality controls shall be designed to minimize short-circuiting (flow reaching the outlet structure before utilizing the entire water quality volume and/or surface area) and dead storage (areas within the basin which are bypassed by the flow regime and are, therefore, ineffective in the treatment process). Irregular shapes shall be avoided or shall use baffles or other measures to achieve adequate hydraulic efficiency. Inlet and outlet structures shall be located at extreme ends of the basin. Pilot channels are discouraged in water quality ponds due to the creation of short-circuiting and standing water problems.

For sedimentation basins, sediment chambers, and filtration basins, the inflow shall be discharged into the basin uniformly across the basin width. Ideally the inlet (diversion) structure should be designed to provide this uniform flow distribution. If not, a flow spreader is required in the basin to distribute flows.

See **Figure 7002-1** for preferred configurations for different SCMs (Note: Some figures are shown as rectangular shapes for simplicity; designs are not required to have straight edges).

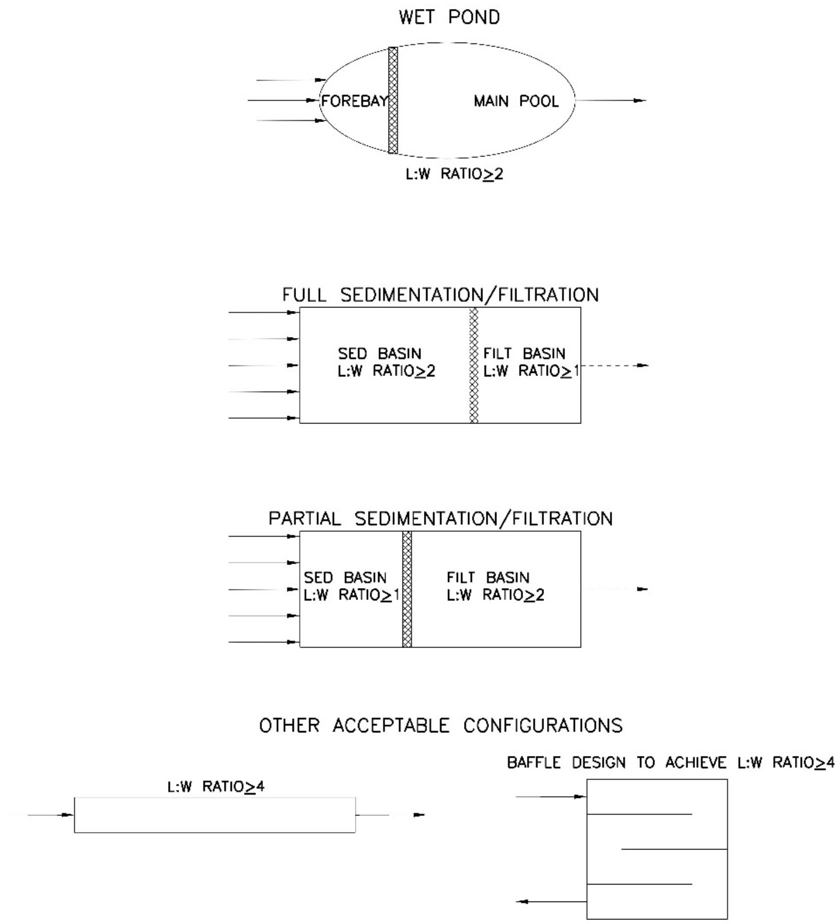


Figure 7002-1: Water Quality Control Configurations

7002.10 Integrated Pest Management Criteria

Integrated Pest Management (IPM) plans are required for all stormwater control measures outlined in this section except for permeable materials. The management of these SCMs must adhere to the techniques and control options described in this section and documented in an approved IPM plan. IPM is a continuous system of controlling pests (weeds, diseases, insects, or others) in which pests are identified, action thresholds are considered, all possible control options are evaluated, and selected control(s) are implemented. Control options which include biological, cultural, manual, mechanical and chemical methods are used to prevent or remedy unacceptable pest activity or damage. Choice of control option(s) is based on effectiveness, environmental impact, site characteristics, worker/public health and safety, and economics. The goal of an IPM system is to manage pests and the environment to balance benefits of control, costs, public health, and environmental quality. IPM takes advantage of all appropriate pest management options.

Manage the treatment system in conformance with the following criteria:

A. Applicability of Plan: These performance requirements apply to the entire SCM, as well as areas immediately adjacent to and related to the facility (including access areas, easements, irrigation, and infiltration areas, etc.).

B. Vegetation Functions: The vegetation in an SCM is integral and necessary for it to function properly. A minimum of 95% of the vegetation shall be alive and viable throughout the life of the system. No bare areas greater than 10 square feet may exist. These performance requirements apply to the entire SCM including the pond bottom, side slopes, and areas adjacent to the pond.

C. Mowing and/or Trimming: Mowing and/or trimming of herbaceous vegetation shall occur with certain restrictions.

1. Tall and Medium Herbaceous Plants: Trimming activities must not impinge on the growing tips (basal crown) of the bunchgrasses. Cutting these grasses below the basal crown will severely stress and possibly kill them. These plants shall be cut no lower than 18" from the ground. In all cases, clippings and trimmings shall be bagged and removed from the site.

2. Turf and other Short Herbaceous Plants: Sod-forming grasses may be mown or trimmed to an appropriate height. These plants shall not be scalped; cut no lower than four (4) inches from the ground. All clippings and trimmings shall be bagged and removed from the site.

D. Weed Management: A weed is generally defined as any plant in the wrong place. Refer to the original design and construction documents when uncertainty exists as to the appropriateness of a specific plant. Preventing the introduction of weeds is the most practical and cost-effective method for their management. Avoid bare soil by minimizing soil disturbance and properly managing desirable vegetation. Remove weeds early in their growth stage; before they set seed. Allow the desired vegetation to out-compete the weeds. It is necessary to allocate greater resources on landscape maintenance during the initial 3-year establishment period. During this time weed "pressure" from the drainage area will be greatest, as will availability of bare surface areas within the treatment system. These factors allow weeds to gain a foothold, especially during the first few months of the life of the SCM.

1. Cultivation: May be done with hand tools; using cultivating machines is not acceptable. Cultivation can be repeated at 2-3 week intervals during the growing season. Any bare areas must be re-seeded.

2. Biofiltration and Rain Garden SCMs: Mulching to control weeds by blocking light and air space is acceptable.

a. Wood mulch, the traditional material for minimizing weeds in ornamental landscapes, is not recommended because it will tend to float or otherwise be washed out of the system. The innovative use of non-traditional mulches will be required when ornamental beds are used in biofiltration facilities. Gravel is permitted to cover the soil surface both in the sediment basin and the filter basin.

b. Gravel or crushed recycled glass equivalent in size to gravel may be used to cover the soil surface in biofiltration.

c. Weed fabric is not permitted in biofiltration due to the potential for clogging of the pores.

E. Pesticides (includes herbicides) and Fertilizer: The use of landscape chemicals, including fertilizer and pesticides, are not allowed within the treatment system without the approval of the City. Reference the Oklahoma Department of Agriculture, Food, and Forestry (ODAFF) Oklahoma Combined Pesticide Law & Rules

F. Invasive or Noxious plants: Plant species that are invasive or noxious should not be planted or grown naturally in SCMs or their associated areas.

G. Mosquito Management: SCMs shall not be a breeding place for mosquitoes. Incidental standing water must not be present for longer than four days (96 hours). If water exists for periods longer than this, the party responsible for maintenance shall remove the water from the SCM and conduct any repairs or design flaws to ensure that this condition is not repeated.

H. Wildlife and Pet Management: In addition to water quality treatment, SCMs offer environmental benefits such as providing food and habitat for wildlife. Pets may also be attracted to them. Digging or burrowing by animals is particularly troublesome. Activities by animals within the SCM should be discouraged so to not interfere with its functions and design objectives. Where on-going problems with wildlife exist, fencing or similar exclusionary methods shall be implemented.

I. Irrigation System Performance: Not all water quality treatment facilities include an irrigation system. When an irrigation system exists, evaluate the efficiency of the system on a periodic basis, especially at the beginning of each irrigation season. The evaluation shall identify problems with the system and ensure that problems are properly addressed.

J. Erosion: Erosion damage to the treatment system shall be repaired immediately. Determine the cause of the erosion and address the situation to prevent it from recurring.

K. Restrictive Covenant: A restrictive covenant is required to be filed. The restrictive covenant is the legal document requiring the use of IPM on a given site.

7003 SMALL SCALE CONTROLS

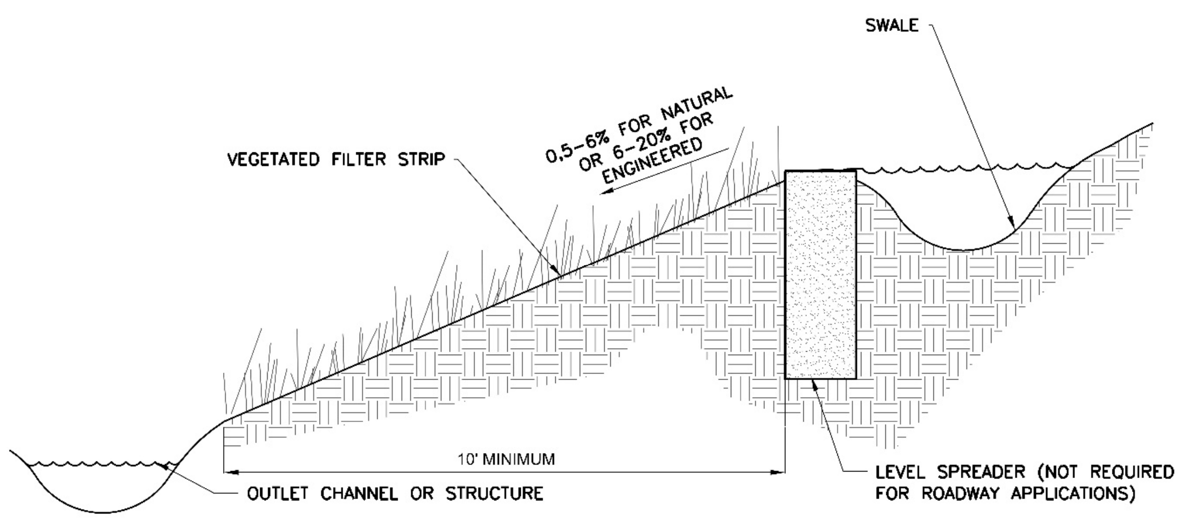
Small scale controls are designed to be at the site scale where they are typically designed to treat runoff from one commercial building or residential parcel. These SCMs generally have a contributing drainage area of less than 10 acres.

7003.1 Vegetated Filter Strip

A. Introduction

Vegetated Filter Strips (VFS) are a stormwater pre-treatment practice consisting of a densely vegetated area between a nonpoint source pollution source and a receiving body of water or stormwater conveyance system. This helps reduce the pollutant loading and stormwater volume entering the receiving body of water. They are commonly implemented next to impervious sites such as parking lots and roadways. Stormwater enters the strip as sheet flow, and as the velocity decreases the suspended sediment and pollutants can settle and/or be filtered by the dense vegetation.

An engineered level spreader should be incorporated where sheet flow cannot be attained naturally due to topography or pipes and channels to ensure sheet flow is achieved over the VFS. Depending on site characteristics and soil conditions, it is possible for infiltration to occur and



result in a minor reduction in runoff volumes. See **Figure 7003-1** below for a diagram of a vegetated filter strip utilizing a level spreader.

Figure 7003-1: Vegetative Filter Strip with Level Spreader

B. Design Criteria

1. Contributing Drainage Area
   a. Maximum 2 acres of drainage area.
   b. Receiving area shall be no smaller than 10% of the contributing imperious area.
2. Flow Path
   a. Flow path for impervious contributing drainage area shall be less than 75 feet in length.
   b. Flow path for pervious contributing drainage area shall be less than 150 feet in length.
   c. The predominant flow path between the end of the impervious contributing area adjacent to the VFS and the receiving body of water shall be at least 10 feet in length.
3. Length of vegetative filter strip in the direction of flow should equal 0.2 times the longest length of the contributing area as defined below.

$$L_{fs} \geq 0.2 * L_a \quad (8)$$

Where,

L_{fs} = Length of vegetated filter strip in direction of flow

L_a = Longest length of contributing area

4. Landscape
   a. VFS shall have a minimum overall depth of 12 inches, with at least 6 inches of topsoil at the surface and 6 inches of native or fill soil below it.
   b. The condition, type, structure, and quality of soil shall be conducive to infiltration and plant growth. Soil amendments might be warranted.
   c. Turfgrasses shall be a minimum of three (3) inches in height and bunchgrasses a minimum of eighteen (18) inches in height.
   d. Filter strip should have a minimum of 95% vegetative cover.
      - Where 95% vegetative cover cannot be achieved a minimum of 4 inches of leaf litter, mulch, or other organic matter must be placed.
      - Existing vegetation can be used as filter strips if all other design criteria are met.
5. Slope of VFS
   a. Slope shall be within the range of 0.5-6% for non-reinforced/natural vegetative filter strip.

b. Slope shall be within the range of 6-20% for reinforced/engineered vegetated filter strip.

c. Velocity of flow shall not exceed 4 feet per second.

6. Soil conditions

   a. Soil characteristics shall be evaluated using the techniques described in **Section 7002.3.**

   b. Soils draining at less than 1 inch per hour shall require an underdrain or additional surface drainage.

7. Bottom of VFS shall be at least 1 foot above the seasonal high water table elevation.

8. Level Spreader

   a. If a level spreader is implemented, it shall create a vertical drop of at least 3 inches, but no greater than 12 inches, between the contributing area and the receiving area.

   b. Level spreaders or other measures for preventing flow from becoming concentrated should be spaced throughout the length of the filter strip at intervals of no more than 25 feet.

   c. A layer of geotextile should be extended a distance of 3 feet from the level spreader lip towards the filter strip. Stone, such as ASTM No. 57 aggregate, should be placed on top of the geotextile (3 to 4 inches deep) to reduce erosion just downslope of the level spreader.

   d. Acceptable materials for construction of level spreader:

      - Concrete
      - Quarried rock
      - Earthen material (soil, clay, etc.)
      - Aggregate mix of gravel and concrete

C. Construction and Maintenance Requirements

1. Construction

   a. VFS shall not receive runoff until after the contributing drainage area has been stabilized to prevent erosion and sedimentation.

   b. Review design with contractor in the field.

   c. Restrict and/or limit vehicular and foot traffic around SCM.

   d. Install as close to the end of construction as possible.

   e. Off-line construction is preferred.

   f. Keep sediment out of the SCM as much as practical.

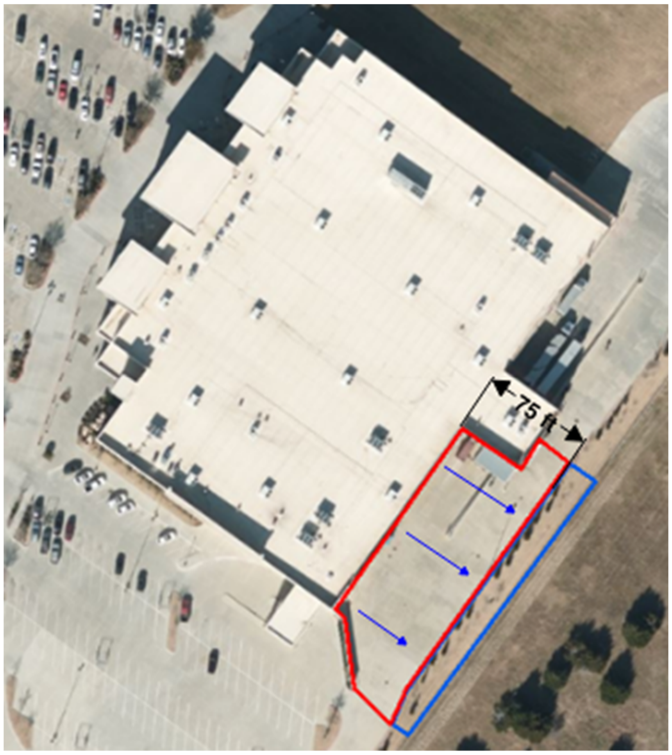
   g. Clearly mark infiltration areas before work begins to avoid soil compaction or sedimentation to preserve infiltration capacity.

h. Scarify subgrade before installing fill to loosen up native soil to promote infiltration.
i. Specify construction sequence in construction docs.

2. Maintenance
    a. Inspection shall take place after the expected drawdown period.
    b. Debris and trash shall be removed from the filter strip and level spreader.
    c. Accumulated sediment shall be inspected and removed from the filter strip and level spreader.
    d. Grass shall be mowed regularly to maintain a dense vegetative cover.
    e. Grass shall be maintained at a height of 3-12 inches.
    f. Vegetation shall be inspected for rills and gullies.
    g. Bare areas shall be seeded and sodded as needed to maintain the minimum 95% vegetative cover.

D. Design Example

A portion of the parking lot of a commercial site (outlined in red below) will be treated with a vegetated filter strip (outlined in blue below). The area of the parking lot to be treated is 18,295 square feet and the length of the longest flow path to the vegetated filter strip is 75-feet. The soil infiltration rate was measured to be greater than 1 in/hr so no underdrain will be required. What is the minimum length of the vegetated filter strip in the direction of flow?



The minimum length of vegetated filter strip required to treat this area based on **Equation 8** is:

$L_{fs} \geq 0.2 * 75\ ft$

$L_{fs} \geq 15\ ft$

Minimum proposed filter strip width = 15 ft

7003.2 Rainwater Harvesting

A. Introduction

Rainwater harvesting is a way of intercepting, diverting, and storing stormwater runoff for later use. In a typical rainwater harvesting system, rainfall is collected from a gutter and downspout system, screened, and conveyed into an above- or below-ground storage tank. Please note that barrels, tanks, and cisterns can be used interchangeably but will be referred to as storage tanks in this criterion. Once captured, stored water may be used for non-potable indoor or outdoor uses. A diagram of a simple, above ground, residential rainwater harvesting system is shown in **Figure 7003-2** below.

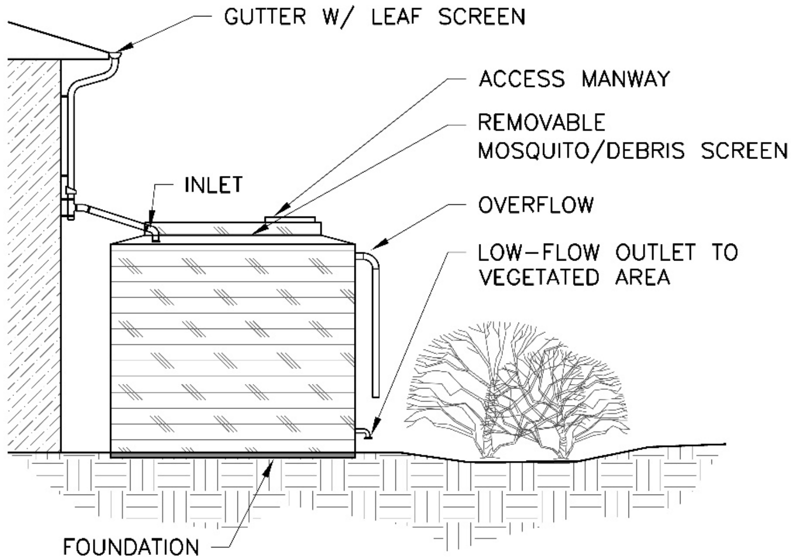


Figure 7003-2: Rainwater Harvesting System Diagram

B. General and Residential Design Criteria

Storage tanks are typically used to provide storage of rooftop runoff for small-scale residential applications. These systems are generally designed for outdoor, above ground use.

1. Rainwater Collection

a. Rainwater shall be collected only from impervious areas such as rooftops.

b. The rainwater harvesting system shall be designed to hold captured runoff for at least 12 hours after rainfall has ceased.

c. The maximum drawdown time is 120 hours and can be calculated as follows:

$$\boldsymbol{DDT = \frac{WQV}{Q_{rwh}}} \quad \textbf{(9)}$$

Where,

DDT = Drawdown time

WQV = Water quality volume

Q_{rwh} = *Rate of discharge from the rainwater harvesting system*

d. Roof Surface

- The roof surface may be constructed of any material accepted by the city.
- The roof surface shall be accessible, maintained clean and free from debris.

The catchment area shall be based upon the footprint of the roof, not the actual area of the roof surface-based on the outside dimension of the roof. See **Figure 7003-3** below.

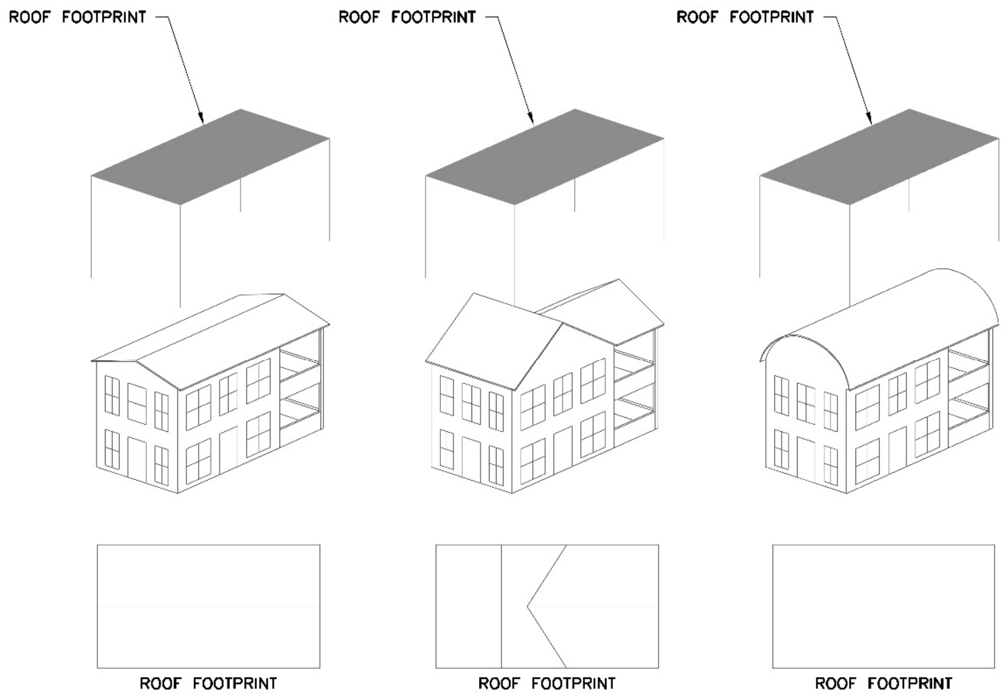


Figure 7003-3: Catchment Area Footprint

- The Catchment surface area can be determined using the following calculation:

  $$A_C = LW \quad (10)$$

  Where,

  A_C = Catchment Area

  L = Length

  W = Width

- Catchment surface area harvesting efficiency
- The relationship between the actual quantity of water that runs off the surface compared to the total amount that falls on the surface. See **Table 7003-1** below for a table of catchment water efficiencies. These efficiencies should be used when sizing the rainwater harvesting system.

Table 7003-1: Capture Water Efficiencies			
Catchment type	Simulated Rainfall Intensity (in/hr)	Theoretical Harvesting Efficiency (Farreny et al. 2011)	Average Measured Harvesting Efficiency (Ley et al. 2014)
Asphalt Shingle	2.5	0.90	0.80
Metal		0.92	0.87
Clay Tile		0.84	0.68
Asphalt Shingle	1.5	0.90	0.75
Metal		0.92	0.77
Clay Tile		0.84	0.66
Asphalt Shingle	1.1	0.90	0.79
Metal		0.92	0.81
Clay Tile		0.84	0.77

2. Gutters
    a. Gutters shall be continuous or seamless and constructed of materials approved for their intended use.
    b. Gutter outlets should be connected indirectly to the downspout with a screened leaf-protected receptor inlet.
    c. Gutters should be sized with slopes specified to contain the 1-inch storm at a rate of 1-inch/hour.
    d. Gutters should be hung at a minimum of 0.5% slope for 2/3 of the length and 1% slope for the remaining 1/3 length.
3. Downspouts
    a. Downspouts shall be continuously graded from the roof to the tank with a minimum slope of ¼ inch per 1 foot. No portion of the downspout shall be installed in a manner which will hold water.
    b. Downspouts shall be placed at a rate of 1 per 50 feet of gutter length.
    c. There shall be 1 square inch of downspout area per 100 square feet of roof area.
4. Pre-Screening
    a. Inflow must be prescreened to remove leaves, sediment, and other debris.
    b. Leaf screens and gutter guards are the minimum filtration requirement for small systems.
    c. Screens should be used on gutters, inlets, and outlets to limit debris from entering the tank.
    d. A non-corrodible screen with #24 mesh will prevent mosquito passage and be sturdy enough to keep animals out.
5. Storage Tank
    a. Adequate access for cleaning and maintenance purposes shall be provided.
    b. Storage tanks which have been previously used for other purposes are prohibited.

c. Tanks shall be opaque or painted to prohibit algae growth and protected from direct sunlight.

d. Screening for the tank may be required as per CCFBC and LDC/Zoning.

e. Cover provided by trees or other vegetation shall not constitute acceptable protection from sunlight.

f. Polypropylene tanks shall not be painted.

g. Tanks shall be watertight and designed to withstand the structural loads required for their size and shape.

h. Tank outlets shall be located at least 12 inches above the bottom of the tank.

i. Tank shall be sited up-gradient of the drainage areas or on a raised stand.

6. Overflow Pipe

a. The storage tank shall be equipped with an overflow device.

b. The device shall be located within 2 inches of the top of the tank.

c. The overflow pipe shall have a capacity equal to or greater than the inflow pipe and have a diameter and slope sufficient to drain the tank while maintaining the required freeboard.

d. The overflow pipe shall not connect to any sanitary sewer.

e. The overflow pipe should be directed away from buildings to prevent damage to building foundations.

C. Commercial and Industrial Specific Design Criteria

Larger storage tanks are used in commercial and industrial applications. These systems can use the harvested rainwater for non-potable applications such as flushing toilets or landscape irrigation. This requires additional plumbing, pressure tanks, pumps, and backflow preventers for the system.

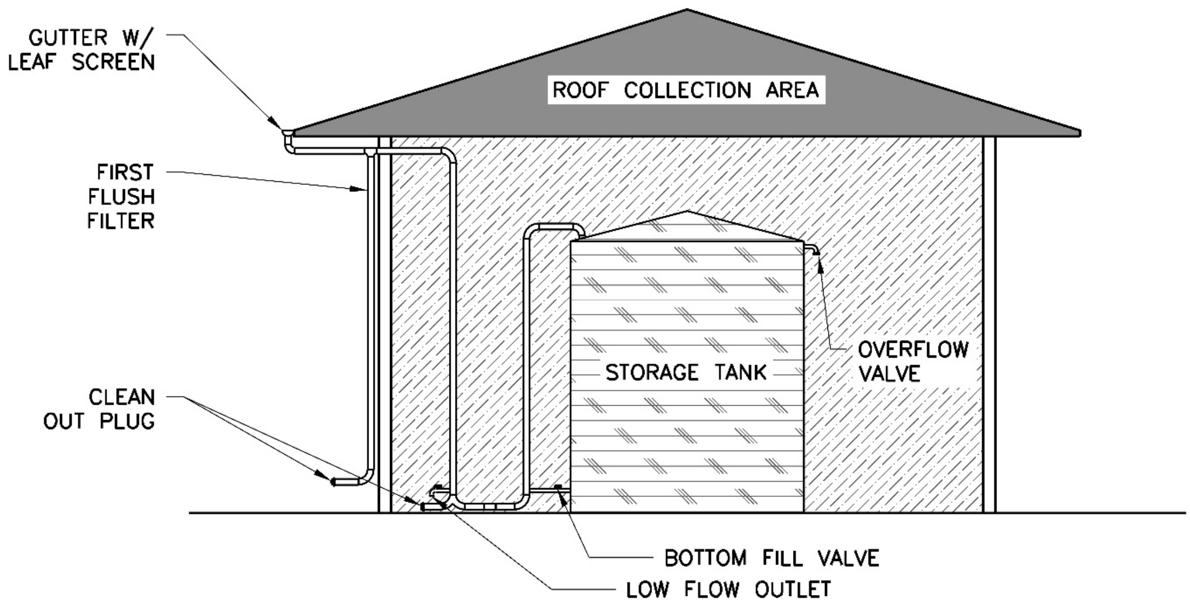


Figure 7003-4: Comm. Rainwater Harvesting System w/ Above Ground Tank

1. Gutters: In addition to the residential gutter requirements, the following should also be met:
   a. Plastic materials shall be protected from ultra-violet (UV) radiation by factory applied protective coating or painted with a compatible latex paint.
   b. Piping and solvent creams shall be approved for the intended use.
   c. Metal materials shall be seamless aluminum, galvanized steel or other approved material.
   d. All gutters leading to the tank shall be fitted with leaf screens the entire length of the gutter including the downspout opening.
   e. Leaf screen openings shall be no larger than 0.5 inches.
   f. Gutters shall have a continuous grade with a minimum slope of 1/16 inch per 1 foot to the outlet leader with no sags or flat portions where water will collect or stand.
   g. Gutter hangings shall be present every 3 feet.
2. Roof Washer

   Commercial or industrial rainwater harvesting systems using impervious roof surfaces shall have at least one roof washer. A roof washer is not required for pervious roof surfaces such as green roofs.

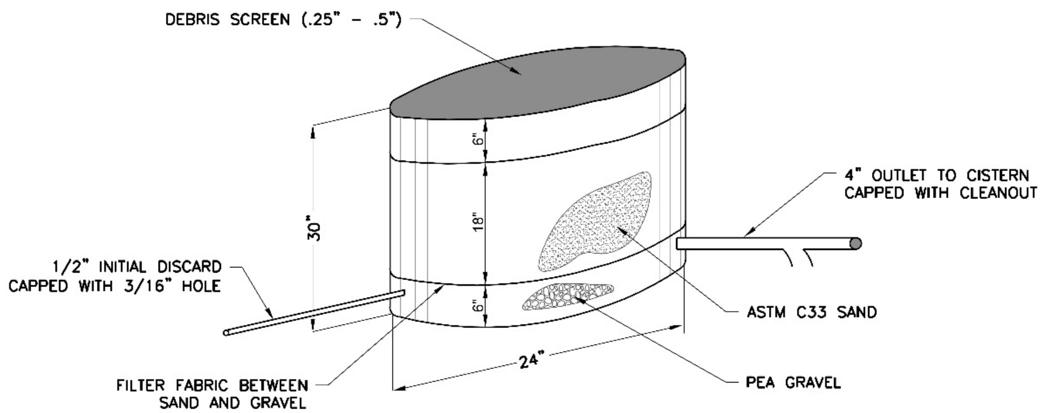


Figure 7003-5: Roof Washer Detail

a. All collected rainwater shall pass through a roof washer before the water enters the storage tank(s).

b. If more than one storage tank is used, a roof washer shall be used for each.

c. Roof washers shall be listed factory assemblies or constructed of approved materials on site.

d. The inlet to the roof washer shall be provided with a corrosion resistant debris screen with openings no larger than 1/16" to protect the roof washer from waste, animals, and mosquito breeding.

e. The roof washer shall have minimum dimensions of 30 inches tall and be 24 inches in diameter or 24 inches square. The roof washer shall contain 6 inches of pea gravel. The entire surface of the gravel shall be covered with geotextile (LINQ 125EX; LINQ TYPAR3201; TNS E040; TNS R040; AMOCO 4535; Marafi 140NL or approved equal).

f. The geotextile shall be topped with 18 inches of sand conforming to OAR 340-71- 295 (3) (e) or silica sand meeting either NSF/ANSI 61 or AWWA B100-53, Section A 2.4.

g. The outlet for the initial rainfall discharge shall be located in the side of the roof washer at or near the bottom. The outlet pipe shall be 0.5 inches nominal, capped with a 3/16 inch drain hole.

h. The outlet pipe to the storage tank shall be located in the pea gravel layer of the roof washer. The pipe shall be 4 inch nominal and fitted with an approved clean-out fitting. Access to the clean-out fitting shall be provided.

i. The outlet pipe entering the storage tank shall terminate in a return elbow a minimum of 12 inches above the tank bottom.

j. Roof washers shall have a cleanout fitting in the bottom of the device.

k. Roof washers shall have an automatic means of self-draining between rain events.

l. Roof washers shall be accessible for maintenance and service.

3. First Flush Diverter

a. For commercial and industrial systems, the first flush of rooftop runoff should be diverted to a secondary treatment practice (such as any of the small scale controls included in **Section 7003**) to prevent sediment from entering the system.

b. First flush diverter shall be designed to capture the first 1 gallon per 100 square feet of catchment area.

c. When runoff enters a storage tank through roof leaders it must pass through a first flush diverter that is self-draining with a cleanout.

d. Capacity relationship between PVC pipe diameter and length per gallon:

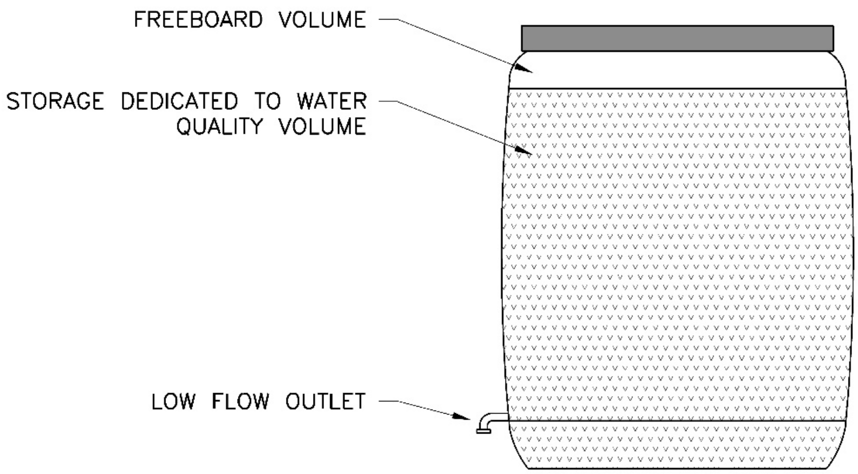
Table 7003-2: First Flush Diverter Sizing

PVC Pipe Diameter Schedule 40 (inches)	Chamber Length (inches/gallon) (*capacity*)
3	32.8
4	18.5
6	8.25
8	4.63

a. First Flush Volume

$$Vol_{ff} = A_C \left(\frac{1\,gal}{100\,ft^2}\right) \quad (11)$$

4. Storage Tank



a. The minimum internal height and width of a vault or tank shall be 3 feet.

b. The maximum water surface elevation must maintain a minimum 1 foot of freeboard in a catchment basin below the catch basin grate.

c. For tanks exerting less than 2,000 pounds per square foot: the foundation shall consist of at least 6 inches of No. 57 gravel or concrete.

d. For tanks exerting greater than 2,000 pounds per square foot: the foundation shall consist of concrete.

e. For tanks larger than 10,000 gallons the foundation shall consist of reinforced concrete.

f. Below grade tanks shall have manhole risers a minimum of 8 inches above the surrounding grade.

g. Below grade tanks made of plastic shall be reinforced and able to withstand the weight of the surrounding fill and soil and full capacity of water.

h. Below grade tanks to be used year-round shall be constructed below the frost line or inside a structure to prevent freezing.

i. A storage tank can be sized to account for additional volume to irrigate all or a portion of the property following the equations below:

- Storage volume for irrigation -

$$\boldsymbol{Vol_{other} = 0.6209 I_{deficit} A_{irr}} \quad \textbf{(12)}$$

Where,

Vol_{other} = Volume needed for irrigation (gal)

$I_{deficit}$ = Irrigation depth needed for the month with the greatest deficit (in) according to the Oklahoma Mesonet Irrigation planner, 0.97 mean inches for the month of August

A_{irr} = Area of lawn to be irrigated (ft^2)

0.6209 = Conversion factor between gallons and ft^2in

- Total tank storage volume required -

$$Vol_{STORAGE} = WQV + Vol_{other} - Vol_{ff} \qquad (13)$$

Where,

WQV = Water Quality Volume (gal)

Vol_{other} = Storage volume reserved for reuse (gal)

Vol_{ff} = First flush volume (gal)

5. Overflow Pipe
   a. The overflow device shall consist of a pipe at least equal in size to the inlet pipe, but no less than 4 inches in diameter.
6. Distribution System with Pump

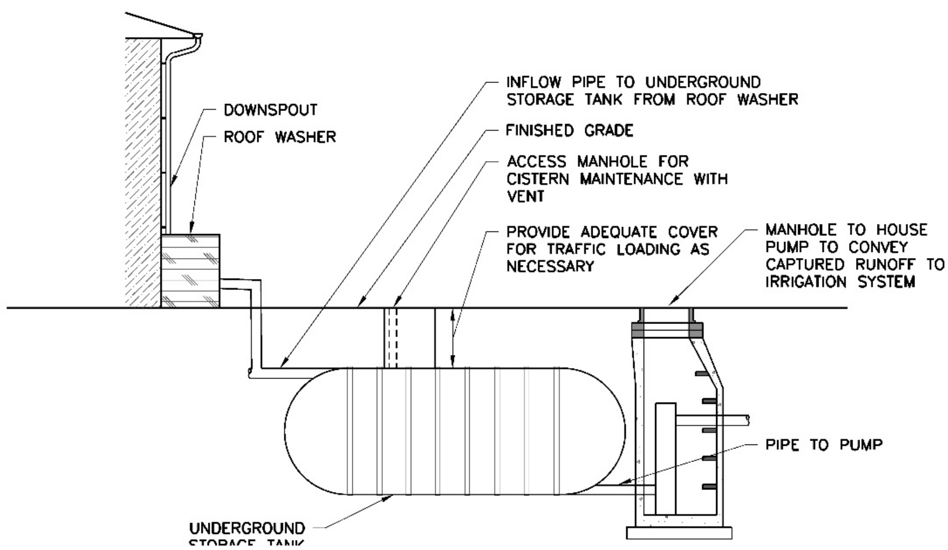


Figure 7003-6: Underground Storage Tank with Pump

a. The pump shall be capable of delivering a minimum of 15 psi residual pressure at the highest outlet served.
b. Minimum pump pressure shall allow for friction and other pressure losses.
c. Maximum pressure shall not exceed 80 psi.

d. Pressure tanks shall be of the expandable diaphragm type and sized based upon the peak flow capacity of the pump.

e. Pressure tanks shall be sized based upon the demand required for the intended use.

f. Pumps shall be a minimum of horsepower or as specified by the manufacturer.

g. A full-size check valve shall be installed between the storage tank and the pump inlet.

h. Pump inlet piping shall be a minimum of one ¾ inch or as specified by the manufacturer.

i. On-demand pump systems, which incorporate the pump, motor, controller, check valve, and pressure tank may be used.

j. Water intake supply from storage tanks to pumps shall be from a floating submerged intake pipe or equivalent.

k. Pumps shall be at an elevation as close to practical as the elevation of the tank.

l. Pumps shall be in a location which is protected from freezing, overheating or from other damage.

7. Piping

a. Piping for rainwater harvesting systems shall be separate from any domestic potable piping system.

b. There shall be no direct connection of any rainwater harvesting pipe system and any domestic potable water pipe system.

c. Pipe used to convey harvested rainwater shall be:

- Purple in color and shall conform to AWWA C901 for piping smaller than 4" diameter or AWWA C900, DR18 minimum for piping 4" diameter and larger; OR
- Meet the requirements for potable water distribution pipe and be continuously wrapped with purple mylar tape meeting the following requirements:
- Minimum nominal thickness of .0005 inches
- minimum width of 2 inches.
- made of PVC with a synthetic rubber adhesive.
- have a clear polypropylene protective coating.
- include the wording, "CAUTION: RECLAIMED WATER, DO NOT DRINK" every four feet along its length, but in no case less than once per room.
- The lettering shall be black against a purple background.

- Fittings and other system components shall be listed for use in conjunction with specified piping.
- Both piping and fittings shall be installed as required by applicable code and standards.

d. Every water closet or urinal supply, hose bibb, irrigation outlet, or other fixture shall be permanently identified with an indelibly marked placard stating: “CAUTION: RECLAIMED WATER, DO NOT DRINK”.

e. Where rainwater harvesting pipe and potable water pipe are installed in the same trench, wall cavity or other location, the potable water pipe shall be separated by a minimum distance of twelve inches above and away from the rainwater harvesting pipe.

8. Outfall Flow Control Structure

a. Weir and orifice structures must be enclosed in a catch basin, manhole, or vault and must be accessible for maintenance.

b. The control structure must be designed to pass the 100-year storm event as overflow, without causing flooding of the contributing drainage area.

c. Orifices must be protected within a manhole structure or by a minimum 18-inch-thick layer of 1½ - 3-inch evenly graded, washed rock.

d. Orifice holes must be externally protected by stainless steel or galvanized wire screen (hardware cloth) with a mesh of ¾ inch or less.

e. Orifice diameter must be greater than or equal to the thickness of the orifice plate.

f. Orifices less than 3 inches must not be made of concrete.

g. A thin material (e.g., stainless steel, HDPE, or PVC) must be used to make the orifice plate.

h. The plate must be attached to the concrete or structure.

i. The minimum allowable diameter for an orifice used to control flows in a public facility is 2 inches.

j. Private facilities may use a 1-inch-diameter orifice if additional clogging prevention measures are implemented.

k. Orifice Equations

$$Q = CA\sqrt{2gh} \quad (14)$$

Where:

Q=Orifice discharge rate (cfs)

C=Coefficient of discharge (feet), value=0.6 for plate orifices

A=Area of orifice (square feet)

h=hydraulic head (ft)

g=32.2 ft/s^2

9. Harvested rainwater can be gravity-drained to a vegetated area large enough to infiltrate all the water or used to irrigate the vegetated area.
   a. The infiltration rate of the soil is listed in the U.S. Department of Agriculture National Resources Conservation Service (NRCS) Soil Survey for the county, location, and soil type present at the irrigation site. If a range is given the lower value of the range shall be used.
   b. The design irrigation rate is not to exceed 0.20 inches/hour even if the NRCS value exceeds this rate.
   c. Irrigation must not occur on land with slopes greater than 10%.

D. Construction and Maintenance Requirements

1. Construction
   a. The roof, gutters, and downspouts shall be cleaned prior to installing the tank.
   b. Leaf screens shall be installed prior to the tank installation.
   c. Stormwater shall not be diverted to the rainwater harvesting system until the overflow path has been stabilized with vegetation.
   d. Manufacturer instructions shall be followed for the installation of the tank.
2. Maintenance
   a. Annual
      - Check system for sediment.
      - Clean out tank when sediment volume becomes greater than 5% of the volume.
   b. Semi-annually in spring and fall
      - Clean storage tank screens.
      - Inspect pretreatment devices for sediment accumulation. Remove accumulated trash and debris.
      - Inspect for tight connection at inlet and drain valve.
      - Check pumping system (if applicable) to ensure it is working properly.
      - Keep pipe clear of obstructions.

- Check for algae growth inside the tank; if found, treat water to remove the algae.
- Inspect for erosion around the overflow discharge and repair as necessary.
- Inspect gutters and downspouts. Remove any accumulated leaves or debris.
- Check tank for stability, anchor system if necessary.

c. Above freezing temperatures

- Inspect health of vegetation receiving harvested rainwater to determine watering needs.

3. Above Ground Tanks Specific Maintenance Requirements:

a. Late Fall (Before major freeze)

- Disconnect rainwater harvesting system from roof downspouts.
- Drain and clean out aboveground tanks for winter.

b. Early spring (After last major freeze)

- Connect rainwater harvesting system to roof downspouts

c. Prior to major wind-related storms

- Fill tank to at least half full.

E. Design Examples

Rainwater harvesting examples are presented below. The examples utilize different catchment areas and different storage goals.

Example 1: Residential

A rainwater catchment system is to be installed at a residential home with a roof area of 3,225 ft^2 (outlined in red below). The system shall be designed to store the WQV. Determine the number of 55-gallon storage tanks required for this system.

Step 1: Define Catchment Area.

The gutter system lines the entire perimeter of the roof and includes four downspouts; therefore the site will require four systems to capture the total water quality volume. In this example, each downspout receives an equal amount of roof area. Given the non-uniform roof shape the catchment area can be calculated by an aerial measurement as shown in **Figure 7003-7** below.

Figure 7003-7: Residential Rainwater Harvesting Example

A_C = 3,225 ft^{2}xHarvesting Efficiency

A_C = (3,225 ft^2)(0.90)

A_C = 2,902.5 ft^2

Step 2: Determine Storage Volume.

For the catchment area found above, the required WQV is calculated from **Equations 1 and 2** below.

$$WQV = \frac{D_S * R_v * A}{12}$$

$$R_v = 0.05 + 0.009I(\%)$$

$$WQV = \frac{1.0 * \left(0.05 + 0.009(100\%)\right) * 2{,}902.5\ ft^2}{12}\left(7.48\ \frac{gal}{ft^3}\right)$$

$$WQV = 1{,}719\ gal$$

Step 3: Select Tank.

Assume selected tank is a standard 55-gallon storage tank. The storage tank has a diameter of 22 inches and is 33.5 inches tall and weighs 18 pounds.

If the overflow pipe must be 2 inches from the top of the storage tank the total height for storage is

33.5 inches – 2 inches = 31.5 inches

Which equates to 52 gallons available for storage for each storage tank.

In this example the storage volume will be divided evenly between the four downspout locations since they each have the same roof area draining to them. This results in the following:

$$\frac{1{,}719\ gal}{4\ downspouts} = 430\ gal/downspout$$

$$\frac{\frac{52\ gal}{rain\ barrel}}{430\frac{gal}{downspout}} = 10\%\ of\ WQV\ treated\ by\ a\ rain\ barrel\ at\ each\ downspout$$

To treat the full WQV, a 500-gallon tank could be placed at each downspout.

Step 4: Verify drawdown time

The drawdown time in each tank must be less than or equal to 120 hours. Using **Equation 9**:

$$120\ hr = \frac{52\ gal}{Q_{rwh}}$$

The minimum rate of discharge from each tank is calculated to be

$$Q_{rwh} = 0.433\frac{gal}{hr} = 1.61x10^{-5}cfs$$

Step 5: Determine orifice size using **Equation 14**

$$Q = CA\sqrt{2gh}$$

$$A = \frac{1.61x10^{-5}cfs}{0.6\sqrt{2 * 32.2\frac{ft}{s^2} * 31.5\ in * \frac{1\ ft}{12\ in}}}$$

$$A = 2.06x10^{-6}\ ft^2 = 2.97x10^{-4}\ in^2$$

$$A = \pi(\frac{D}{2})^2$$

$$D = 2 * \sqrt{\frac{2.97x10^{-4}\ in^2}{\pi}}$$

$$D = 0.02\ in$$

Based on the required orifice diameter, a 1/16" outlet or larger shall be used for each tank at the low-flow outlet.

Example 2: Commercial and Industrial

A rainwater catchment system is to be installed at a grocery store. The system shall be designed to store the WQV for the 112,500 ft^2 roof area outlined in red below as well as an additional volume of water to be reused for irrigation of the 33,380 ft^2 area outlined in green below. Determine the size number and size of storage tanks required for this system.

Step 1: Define Catchment Area.

The gutter system lines the entire perimeter of the roof and the gutter system includes 10 downspouts, therefore the site will require 10 systems to capture the total water quality volume. In this example, each downspout receives an equal amount of roof area. Given the non-uniform roof shape the catchment area can be calculated by an aerial measurement as shown in **Figure 7003-8**, where the area outlined in red is the catchment area and the area outlined in green is the area to be irrigated.

Figure 7003-8: Commercial Rainwater Harvesting Example

A_C = 112,500 ft^2

A_{irr} = 33,380 ft^2

A_{TOTAL} = 145,880 ft^2

Step 2: Determine Storage Volume.

For the catchment area found above, the required WQV is calculated using **Equations 1 and 2** below.

$$WQV = \frac{D_S * R_v * A_C}{12}$$

$$R_v = 0.05 + 0.009I(\%)$$

$$WQV = \frac{1.0 * \left(0.05 + 0.009(100\%)\right) * 112{,}500\ ft^2}{12}\left(7.48\ \frac{gal}{ft^3}\right)$$

$$WQV = 66{,}619\ gal$$

The first flush volume is defined by **Equation 11** below.

$$Vol_{ff} = A_C\left(\frac{1\ gal}{100\ ft^2}\right)$$

$$Vol_{ff} = 112{,}500\ ft^2\left(\frac{1\ gal}{100\ ft^2}\right)$$

$$Vol_{ff} = 1{,}125\ gal$$

$$\frac{Vol_{ff}}{10\ downspouts} = 112.5\ gal/downspout$$

Refer to **Table 7003-2** to determine the proper pipe size and length for the first flush diverter. Assume a dual chamber 8" PVC schedule 40 pipe will be used for this design where:

$$2 * 8"\ PVC = \frac{4.63\ in/gal}{2} = 2.32\ in/gal$$

$$\frac{2.32\ in}{gal} * 112.5\ gal * \frac{1\ ft}{12\ in} = 21.75\ ft\ of\ dual\ chamber\ first\ flush\ diverter$$

$I_{deficit}$ can be found from the Oklahoma Mesonet Irrigation planner. Assuming a mean irrigation depth of 0.97 inches for the month of August the additional stormwater volume needed for irrigation can be defined using **Equation 12**.

$$Vol_{other} = 0.6209 I_{deficit} A_{irr}$$

$$Vol_{other} = \left(0.6209\frac{gal}{ft^2 in}\right)(0.97\ in)(33{,}380\ ft^2)$$

$$Vol_{other} = 20{,}104\ gal$$

And the total required storage volume is calculated using **Equation 13** below.

$$Vol_{STORAGE} = WQV + Vol_{other} - Vol_{ff}$$

$$Vol_{STORAGE} = 66{,}619\ gal + 20{,}104\ gal - 1{,}125\ \ gal$$

$$Vol_{STORAGE} = 85{,}598\ gal$$

Step 3: Select Tank.

The required storage volume will be divided equally between the 10 downspouts on the building.

$$\frac{85{,}598\ gal}{10\ downspouts} = 8{,}560\ gal/downspout$$

Select a 10,000-gallon tank for each downspout location. This is larger than the calculated required storage volume, but this will account for any unusable volume associated with offsets and the overflow structure. A tank of this size will have a preinstalled outlet port and the final step is to verify that the minimum required storage volume is achieved when the unusable volume is subtracted.

Step 4: Verify drawdown time

The drawdown time in each tank must be less than or equal to 120 hours.

$$120\ hr = \frac{10{,}000\ gal}{Q_{rwh}}$$

The minimum rate of discharge from each tank is calculated using **Equation 9** to be

$$Q_{rwh} = 83.33\frac{gal}{hr} = .003\ cfs$$

Step 5: Determine orifice size using **Equation 14**

$$Q = CA\sqrt{2gh}$$

$$A = \frac{.003\ cfs}{0.6\sqrt{2 * 32.2\frac{ft}{s^2} * 31.5\ in * \frac{1\ ft}{12\ in}}}$$

$$A = 3.85x10^{-4}\ ft^2$$

$$A = \pi(\frac{D}{2})^2$$

$$D = 2 * \sqrt{\frac{3.85x10^{-4}\ ft^2}{\pi}}$$

$$D = 0.02\ ft = \ 0.3\ in$$

Based on the required orifice diameter, a 1/3" outlet or larger shall be used for each tank at the low-flow outlet.

7003.3 Rain Garden

A. Introduction

A rain garden is a vegetated, depressed landscape area designed to capture and infiltrate and/or filter stormwater runoff. The growing medium for the rain garden consists of native soil or biofiltration media. If the infiltration capacity of the subgrade soils is limited, the rain garden can be underlain by an underdrain system. Rain gardens will provide removal of pollutants in stormwater runoff similar to other treatment systems. However, because they are restricted to smaller drainage areas and shallower ponding depths, which necessitate a larger surface area, infiltration, evapotranspiration, and biological uptake mechanisms may be more significant for rain gardens than other treatment SCMs.

There are three different types of rain garden designs included in this section:

- full infiltration (no underdrain);
- partial infiltration (filtration system with raised outlet or partial underdrain); and
- filtration system with little to no infiltration that includes an underdrain.

B. Design Criteria

- Rain gardens are restricted to a contributing drainage area not to exceed two acres and a ponding depth not to exceed 12 inches.
- Rain gardens may be sized to capture and treat the entire water quality volume. The storage volume provided is the combined volume of the ponded water in the basin and the effective porosity volume in the growing medium. Water quality credit is provided for 80% of the effective porosity (assumed to be 30%) of the growing medium.
- Include a minimum of 6 inches of freeboard above the overflow route.
- Drawdown time for rain gardens should not exceed 48-hours.
- Maximize the travel time from the inlet to the outlet. Consider providing pre-treatment to help reduce the extent and frequency of maintenance, especially if the contributing drainage area is expected to generate sediment, debris, or other pollutant that may cause decreased system functionality. Pre-treatment may include a sedimentation chamber, a vegetated or manufactured separator element (to functionally separate the rain garden into higher deposition and lower deposition zones), a

vegetated filter strip, or an inlet designed at a minimal slope to encourage sediment deposition prior to flows entering the rain garden.

- If pedestrian traffic is expected along a non-ADA route, provide stepping stone paths along a predefined route to discourage trampling of vegetation and compaction of soil. Planting spiny vegetation such as yucca, sotol, or agarita along the edge of the rain garden may effectively discourage pedestrian use.
- Design the rain garden depression to be as shallow as possible to facilitate mowing and reduce erosion.
- If rain garden will be installed adjacent to roadway, coordinate with professional engineer and construction services to determine appropriate garden section that will not impact integrity of road. Liner may need to be required along vertical and/or horizontal faces to protect foundations and road bases from seepage.

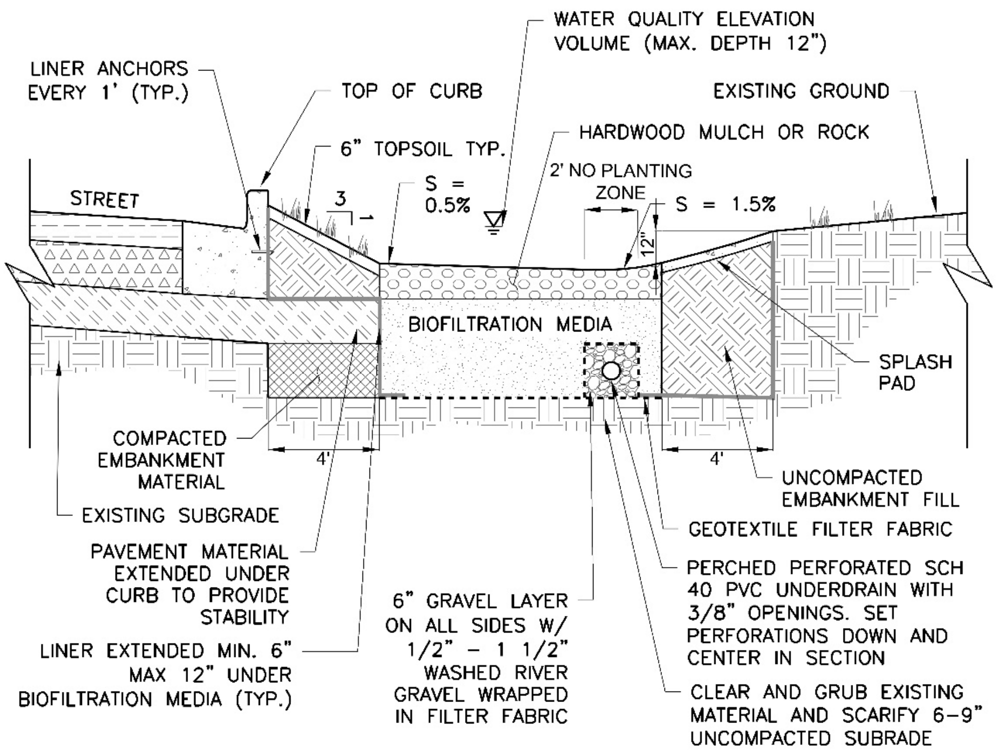


Figure 7003-9: Rain Garden Adjacent to Roadway

The type of rain garden and whether an underdrain is needed are typically dependent on the soil type. A full infiltration rain garden does not need an underdrain and has complete infiltration into native soils (typically have a greater than 2 in/hr infiltration rate). Full filtration rain gardens assume no infiltration into native soils and include an underdrain. Partial infiltration includes an underdrain and partial infiltration into native soils. Practicality of full and partial infiltration depends on the ponding depth. For example, 12” ponding depth requires 0.25 in/hr infiltration rate for a 48-hour drawdown. If the rain garden is designed such that the ponding depth will be lower, the required infiltration rate will also be lower. Partial infiltration is the preferred design if you have variable soils conditions and want to ensure adequate drawdown over time.

1. Full Infiltration

   Full infiltration rain gardens are sized to capture and fully infiltrate runoff. The infiltration area is the average surface area of the rain garden basin (i.e., the area at full ponding depth plus the area at zero ponding depth divided by two). If the side slopes of the basin are not permeable (e.g., masonry or concrete walls), then the infiltration area is the bottom permeable footprint.

   The underlying native soil must have a design infiltration rate that will draw down the full ponded depth in less than 48 hours. The design infiltration rate is based on applying at least a factor of safety of two (2) to the measured steady state saturated infiltration rate (i.e., the design infiltration rate is equal to one-half of the measured infiltration rate). For full infiltration systems the infiltration rate of the soil subgrade below the growing medium of the rain garden must be determined using in-situ testing as described in **7002.3**. If a range of values are measured then the geometric mean should be used.

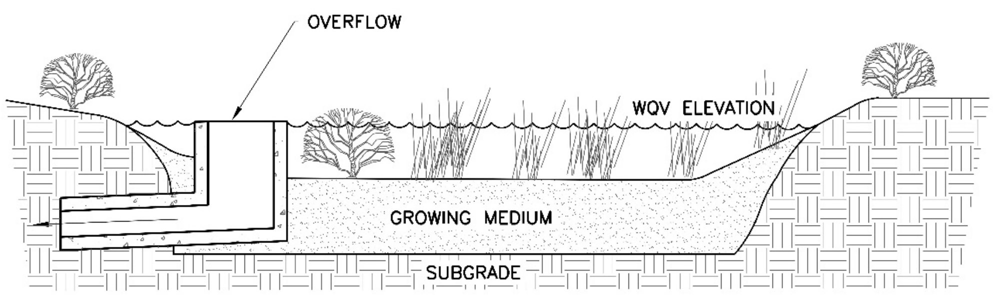


Figure 7003-10: Full Infiltration Rain Garden

$$A_i \geq 0.87 \frac{WQV}{(H+0.24L)} \quad (15)$$

Where,

A_i = Infiltration area (ft^2),

WQV = Water quality volume (ft^3),

H = Maximum head over the growing medium (ft), and

L = Depth of the growing medium (ft).

The maximum allowable head over the growing medium for a full infiltration rain garden is 12 inches provided the design infiltration rate of the subgrade soil allows for draw down of the ponded depth in at most 48 hours. Ponding depths in excess of 12 inches are not permitted.

2. Full Filtration

   Full filtration rain gardens are sized to capture and convey runoff through a biofiltration bed underlain by an underdrain system. The filtration area is the flat surface area at the bottom of the rain garden basin (i.e., the flat area above the growing medium). The maximum ponding depth for a full filtration rain garden is 12 inches.

$$A_f \geq \frac{WQV}{(H+0.24L)} \qquad (16)$$

Where,

A_f = Filtration area (ft^2),

WQV = Water quality volume (ft^3),

L = Depth of the biofiltration growing medium (ft), and

H = Maximum head over the growing medium (ft).

3. Partial Infiltration

   Partial infiltration rain gardens are sized to capture and treat runoff through a biofiltration bed. Runoff exits the biofiltration bed by discharge through a raised outlet pipe and by infiltration into the underlying soil. The filtration area is the flat surface area at the bottom of the rain garden basin (or the flat area above the growing medium). The maximum ponding depth for a partial infiltration rain garden is 12 inches.

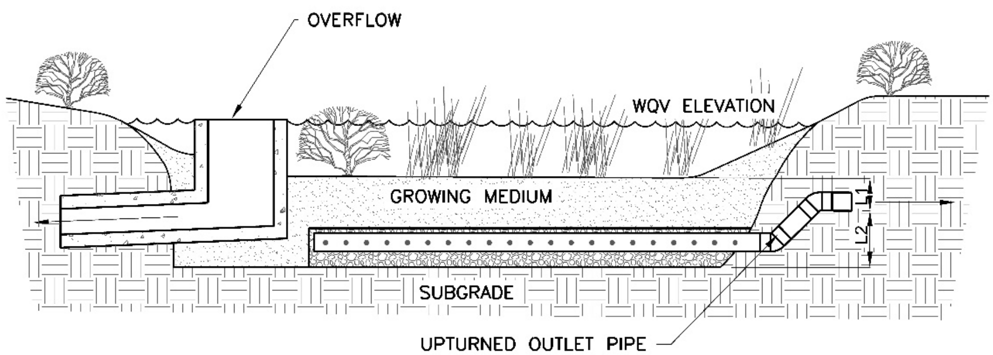


Figure 7003-11: Patrial Infiltration Rain Garden

$$A_f \geq \frac{WQV}{(H+0.24L_1+0.24I_f)} \qquad (17)$$

Where,

A_f = Filtration area (ft^2),

WQV = Water quality volume (ft^3),

H = Maximum head over the growing medium (ft) (a maximum of 12 inches),

L_1 = Depth from the top of growing medium to the invert of the raised outlet pipe (ft) (a minimum of 1.2 ft), and

I_f = Infiltration factor (ft).

Growing medium or gravel must be placed across the bottom of the rain garden below the invert of the raised outlet pipe to provide additional storage. Use of growing medium is recommended to promote greater rooting depths and biological activity. The available storage is a function of the depth below the invert of the raised outlet pipe and the porosity of the material. The ability to regenerate storage is a function of the infiltration rate of the subgrade. The infiltration factor, I_f, is based on the depth of storage below the invert of the raised outlet (L_2) and the 2-day drawdown provided by the soil subgrade design infiltration rate (i_{sub}):

- For cases where $L_2 \geq i_{sub}$ * 2 days,

$$I_F = L_2 \quad (18)$$

- For cases where $L_2 < i_{sub}$ * 2 days,

$$I_F = I_{SUB} * 2 \text{ DAYS} \quad (19)$$

Where,

I_{sub} = Design infiltration rate of subgrade (ft/day), and

L_2 = Depth from the invert of the raised outlet pipe to the subgrade surface (ft) (a minimum of 0.8 feet).

For partial infiltration rain gardens, the design infiltration rate of the soil subgrade below the growing medium may be estimated using the desktop study and field sampling methods as described in 7002.3. For design purposes, the estimated infiltration rate must be reduced by at least a factor of safety of 2 to account for uncertainty in infiltration rate estimates and potential clogging over time.

C. Design Equations

1. Drawdown time

$$t_{dd} = \frac{12D_0}{I} + 4\ hr \quad (20)$$

Where,

tdd=total drawdown time (hr)

D0=ponding depth (ft)

I=infiltration rate (in/hr)

4 hr=4 hours worth of drawdown time towards WQV (hr)

D. Basin Elements

1. Slopes

   Rain gardens should not be located on slopes exceeding 15 percent. Less than 3% is optimal as anything larger than that will be hard to achieve water quality volume without an excessive amount of cells, especially if width is limited.

   Side slopes should be 3H:1V or greater for the perimeter of the cell to prevent erosion.

2. Soil Conditions

   When siting a full or partial infiltration rain garden, appropriate soil conditions must be present. The depth to an impermeable layer must be at least 12 inches below the bottom of the rain garden.

3. Water Table

   Full and partial infiltration rain gardens are not allowed in locations where the depth from the bottom of the growing medium to the highest known groundwater table is less than 12 inches.

4. Bedrock

   Full and partial infiltration rain gardens are not allowed in locations where depth from the bottom of the growing medium to bedrock is less than 12 inches. In cases with bedrock less than 3 feet from the bottom of the growing media, soil testing should be conducted in-situ to account for the effect of this limiting horizon.

5. Groundwater and Soil Contamination

   Full and partial infiltration rain gardens are not allowed in locations where infiltration would cause or contribute to mobilization or movement of contamination in soil or groundwater or would interfere with operations to remediate groundwater contamination. If filtration rain gardens are proposed under these conditions, the potential for incidental infiltration should be evaluated to determine whether an impermeable liner must be used.

6. Growing Medium

   The rain garden growing medium should have sufficient water holding capacity to support vigorous plant growth, enhancing the ability for plants to survive during dry periods. It should also sustain a healthy microorganism population which, in concert with vegetation, should enhance biological removal of pollutants in stormwater. Requirements for the growing medium depend on the type of rain garden design being considered. For full infiltration rain gardens, the growing medium should be native soil. In the event the designer is not certain about the native soil's ability to support vegetation, a 6 inch layer of topsoil may be added to the soil. This additional depth of soil must be accounted for in the depth and volume required for the pond. For full filtration and partial infiltration rain gardens, only the biofiltration medium may be used. See **Standard Specification 2105** Biofiltration.

7. Underdrain System and Liners

    a. Full Infiltration Rain Garden

        - A full infiltration rain garden does not have an underdrain system and does not require a geotextile under the growing medium.

    b. Partial Infiltration and Full Filtration Rain Garden

        - The underdrain for a partial infiltration and full filtration rain garden consists of gravel-surrounded perforated pipes.

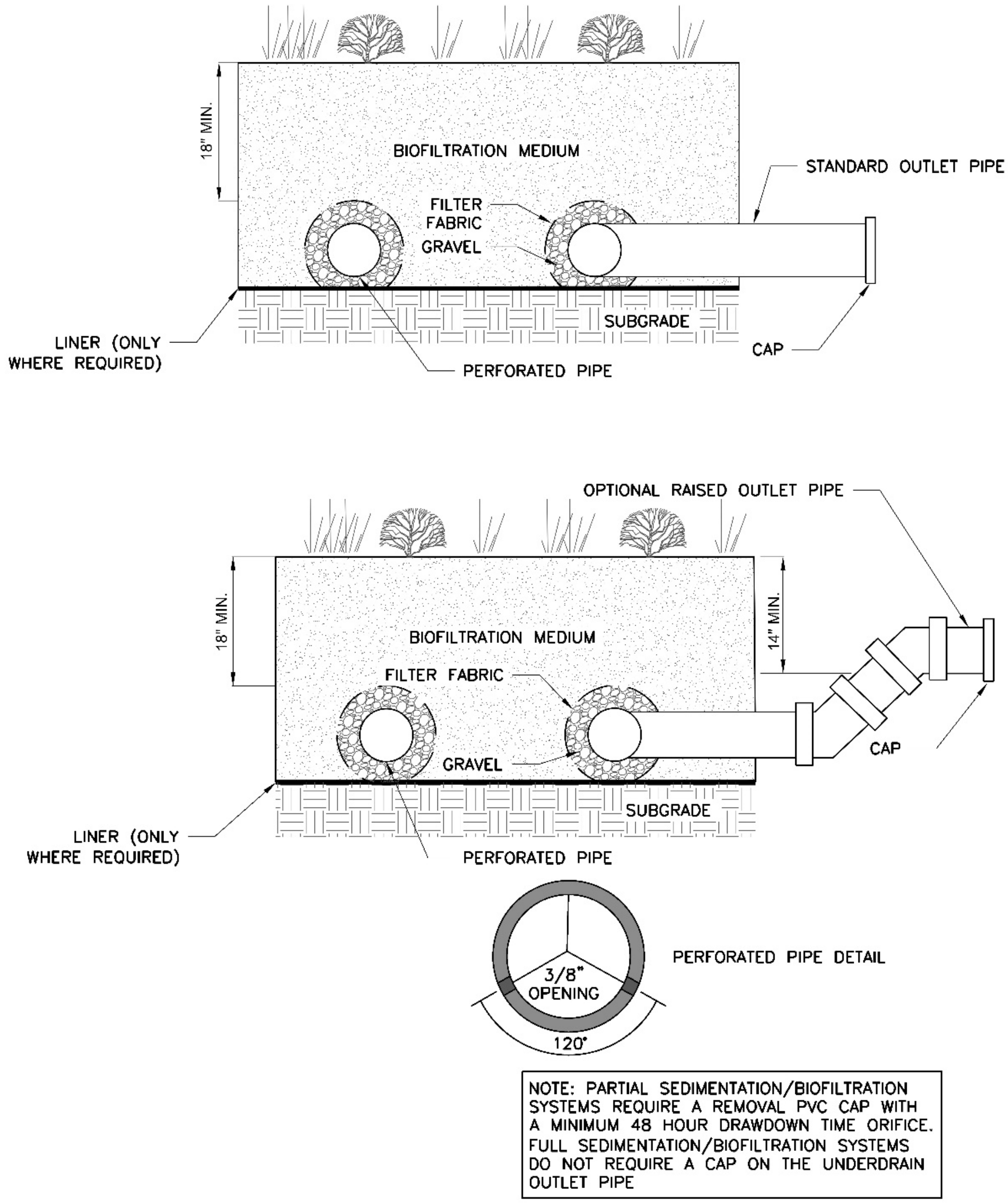


Figure 7003-12: Underdrain Design for Rain Gardens

c. The underdrain piping must comply with the criteria located in **Section 7004.1D.3**. For partial infiltration systems raised outlets are required to encourage infiltration through the native soils before flow through underdrain. The pipe does not require a slope.

d. If a rain garden is located next to a roadway then a liner is required along the sides of the measure to protect the roadway section from water infiltration. The liner shall meet the specifications given in **Specification 2106**.

8. Flow Control

a. Inflow

- How runoff enters (and for larger storms overflows or bypasses) the rain garden depends on the overall drainage configuration for the site. Runoff may enter via sheet flow from surrounding areas (for example, a parking lot with a ribbon curb), or runoff may enter as concentrated flow through a curb cut, a splitter box, or other inlet. When using a curb cut approach, ensure that inflow curb cuts have sufficient positive slope into the rain garden to prevent minor obstructions such as leaves in the curbline from obstructing flow into the system. Provide energy dissipation for rain gardens with concentrated points of inflow. The maximum velocity discharged to the rain garden should not exceed 2 feet per second.

b. Internal Flow Management

- Rain gardens located on a sloped area can be designed to pool to a specified water quality elevation and then overflow into downstream cells through a raised outlet structure or level spreader.

c. Outflow

- The preferred design to manage volume in excess of the WQV is to use an offline system configuration such that when the rain garden is full, additional runoff does not enter the system and instead flows past the inflow opening. Outflow of volume in excess of the WQV can also be managed through the use of standpipe risers, elevated catch basins, or down gradient curb cuts. When selecting the type and location of the outlet structure, incorporate enough detail in the design to prevent unintentional bypass of the rain garden before it is full. For example, when using an adjacent curb inlet to a storm drain for overflow, make sure to include sufficient grade control to establish preferential flow to the rain garden. The surface discharge from the rain garden shall be non-erosive with a maximum permissible flow velocity of 2 feet per second. Include a minimum of 6 inches of freeboard above the overflow route.

9. Landscape Design

a. Although an essential role of the vegetation is to make the rain garden attractive, the highest priority shall be to meet the water quality and soil stabilization functional requirements. Another important function of the vegetation is to help reduce clogging of the growing medium. Vegetation should be selected based on its ability to survive under alternating conditions of inundation and extended dry periods. High plant diversity is recommended and will provide resiliency to the system and help prevent a situation where all vegetation is lost. Over time, the plant species that are best suited to the unique conditions of each rain garden will naturally self-select and spread. Use of only sod is allowed and requires less long-term maintenance.

b. Vegetation quantity, size, spacing, and selection shall meet the requirements for filtration basins as provided in **Section 7004.1D.4**, Biofiltration, with the exception that rain gardens do not require a minimum of five different species (i.e., one species is acceptable), although higher diversity is recommended.

c. Select native vegetation whenever possible to reduce the need for long-term irrigation and maintenance. If rain gardens are over-irrigated and receive significant applications of fertilizers and herbicides, they can become sources of pollution rather than pollutant removal SCMs. Thus, it is essential that these rain garden systems be managed carefully and that an approved and recorded Integrated Pest Management plan be required for the drainage area up to and including the rain garden.

d. Whenever possible, vegetation should be planted throughout the entire rain garden to provide a fully stabilized surface. Containerized plants are typically grown in a looser growing medium conducive to drainage whereas grass sod is sometimes grown in more cohesive soils that may inhibit drainage. Avoid the use of wood chips because they tend to float and may clog the outlet or be washed downstream. Coarsely-shredded hardwood mulch such as that obtained from the primary run through an industrial tub grinder will be more resistant to movement and is recommended. Gravel or stone mulch is also resistant to movement but may cause sediment to build up and inhibit infiltration.

e. Designate a no planting zone in the deepest part of the garden to allow maintenance crews to remove deposited sediment over time

E. Construction and Maintenance Requirements

1. Construction

a. Review design with contractor in the field. Go over importance of meeting elevations, function of inlet location(s), and meeting specs on material.

b. Restrict and/or limit vehicular and foot traffic around infiltration basin areas.

c. Install as close to the end of construction as possible.

d. Off-line construction is preferred.

e. Keep sediment out of the infiltration device as much as practical.

f. Clearly mark infiltration areas before work begins to avoid soil compaction or sedimentation to preserve infiltration capacity.

g. Scarify subgrade before installing fill to loosen up native soil to promote infiltration.

h. Once area has been excavated, extremely important to move straight into filling with garden media to avoid leaving materials along roadways exposed to weather conditions, which will promote cracking and slides.

i. Specify in technical specs that a design survey shall be completed to confirm inlet elevations, slope of facility, outlet pipes, pond depths, overflow elevations, etc. Consider showing in the detail which locations should be surveyed. Outline allowable tolerance.

j. Inspect materials (plants, double washed gravel, media) upon delivery to the site but before install to verify it meets specs. Check watertight seals at HDPE and PVC connections.

k. Specify construction sequence in construction docs.

2. Maintenance

a. Unless damaged by unusual sediment loads, high flows, or vandalism, the biofiltration media should be left undisturbed and allowed to age naturally.

b. Biweekly during first growing season

- Inspect vegetation until 95% vegetative cover is established. Spot reseed if need be.

c. Monthly

- Check for accumulated sediments, remove as needed.

d. Quarterly

- Remove debris and accumulated sediment; replace soil media in void areas caused by settlement; repair eroded areas; re-mulch by hand any void areas.

e. Semi-annually

- Remove and replace dead or diseased vegetation that is considered beyond treatment (see planting specifications); treat all diseased trees and shrubs mechanically or by hand depending on the insect or disease infestation. If drawdown exceeds the allowable drawdown time, lightly scarify soil with hand cultivator; if standing water remains for greater than 96 hours, remove top layer of sediment, mulch, and potentially vegetation; de-compact soil by scarification, and replace mulch and disturbed vegetation.

f. Late winter

- Trim bunch grasses; mow turf grasses; harvest other types of vegetation according to recommendations in the planting specifications.

g. Spring

- Remove previous mulch layer and apply new mulch layer by hand (option) once every two to three years.

F. Design Example

Values in the examples are estimated or assumed measured values. The actual design should use field site measured data collected by trained professionals.

A portion of the parking lot of a commercial site (outlined in red below) will be treated with a rain garden (outlined in blue below). The area of the parking lot to be treated is 79,700 ft^2. This area measurement includes 1,275 ft^2 of pervious vegetated areas outlined in green below. Determine the required area for a rain garden for full infiltration, partial infiltration, and a full filtration system for an infiltration rate of 0.5 in/hr.

Figure 7003-13: Rain Garden Example

The storage provided by the rain garden should be greater than or equal to the total Water Quality Volume (WQV) calculated below using **Equations 1 and 2**.

$$WQV = \frac{D_S * R_v * A_C}{12}$$

$$R_v = 0.05 + 0.009I(\%)$$

$$WQV = \frac{1.0(0.05+0.009(98.40\%))*79{,}700\ ft^2}{12}$$

$$WQV = 6{,}214\ ft^3$$

Example 1: Full Infiltration

Next, solve for the required infiltration area using **Equation 15**. Assume the maximum ponding depth of 12 inches, a growing medium depth of 2.25 feet, and an infiltration rate of 2.0 in/hr.

$$A_i \geq 0.87(\frac{WQV}{H + 0.24\ L})$$

$$3{,}511\ ft^2 \geq 0.87(\frac{6{,}214\ ft^3}{1.0\ ft + 0.24(2.25\ ft)})$$

For this ponding depth and medium thickness, a minimum infiltration area of 3,511 ft^2 is required. If the ponding depth or media thickness are reduced, the required infiltration area will increase. If the media thickness is increased, the required infiltration area will decrease. For this example site, the available infiltration area is 4,295 ft^2 therefore this will be used for the design.

$$4{,}295\ ft^2 \geq 3{,}511\ ft^2$$

Next, verify the drawdown time using **Equation 20**.

$$t_{dd} = \frac{12D_0}{I} + 4\ hr$$

$$t_{dd} = \frac{(\frac{12\ in}{ft})(1.0\ ft)}{2.0\ \frac{in}{hr}} + 4\ hr$$

$$t_{dd} = 10\ hr\ < 48\ hr$$

Design is valid.

Example 2: Partial Infiltration

When the infiltration rate of the native soil does not allow for a full infiltration system, a partial infiltration system can be used where the addition of underdrain piping increases the infiltration rate. For this example assume a maximum ponding depth of 12 inches, a depth from the top of the growing medium to the invert of the raised outlet pipe of 2.0 ft, and an infiltration rate of 0.3 in/hr.

Calculate the infiltration factor, I_f, using **Equation 19**.

$$I_f = I_{sub} * 2\ days$$

$$I_f = 0.3\frac{in}{hr} * \frac{1\ ft}{12\ in} * \frac{24\ hr}{1\ day} * 2\ days$$

$$I_f = 1.2\ ft$$

Assuming the same filtration area used above, verify the minimum filtration area is achieved by using **Equation 17**.

$$A_i \geq (\frac{WQV}{H + 0.24\ L + 0.24 I_f})$$

$$3{,}515\ ft^2 \geq (\frac{6{,}214\ ft^3}{1.0\ ft + 0.24(2.0\ ft) + 0.24(1.2\ ft)})$$

$$4{,}295\ ft^2 \geq 3{,}515\ ft^2$$

Calculate the underdrain orifice discharge rate required to achieve a 48-hour drawdown time.

$$Q = \frac{(4{,}295\ ft^2 * 1.0\ ft)}{48\ h * \frac{3{,}600\ sec}{1\ hr}} = 0.025\ cfs$$

Size the underdrain using **Equation 14**:

$$Q = CA\sqrt{2gh}$$

$$A = \frac{Q}{C\sqrt{2gh}}$$

$$A = \frac{0.025\ cfs}{0.6\sqrt{2 * 32.2\ \frac{ft}{s^2} * (\frac{3}{2})\ ft}}$$

$$A = 0.004\ ft^2$$

$$D = 2 * \sqrt{\frac{A}{\pi}} = .07\ ft = 0.86\ in$$

Example 3: Full Filtration System

A full filtration system assumes there is no infiltration into native soils and the drawdown relies entirely on the underdrain system. For this example assume a maximum ponding depth of 12 inches, a biofiltration growing medium depth of 1.5 ft, and a native soil infiltration rate of 0.05 in/hr.

First verify the minimum infiltration area is achieved by using **Equation 16.**

$$A_i \geq (\frac{WQV}{H + 0.24\ L})$$

$$4{,}295\ ft^2 \geq 0.87(\frac{6{,}214\ ft^3}{1\ ft + 0.24(1.5\ ft)})$$

$$4{,}295\ ft^2 \geq 3{,}975\ ft^2$$

Calculate the underdrain orifice discharge rate required to achieve a 48 hour drawdown time.

$$Q = \frac{(4{,}295\ ft^2 * 1.0\ ft)}{48\ hr * \frac{3{,}600\ sec}{1\ hr}} = 0.025\ cfs$$

Size the underdrain using **Equation 14**:

$$Q = CA\sqrt{2gh}$$

$$A = \frac{Q}{C\sqrt{2gh}}$$

$$A = \frac{0.025\ cfs}{0.6\sqrt{2 * 32.2\ \frac{ft}{s^2} * (\frac{3}{2})\ ft}}$$

$$A = 0.004\ ft^2$$

$$D = 2 * \sqrt{\frac{A}{\pi}} = .07\ ft = 0.86\ in$$

7003.4 Infiltration Trench

A. Introduction

Infiltration trenches are excavations typically filled with stone to create an underground reservoir for stormwater runoff. This runoff volume gradually infiltrates through the bottom and sides of the trench into the subsoil over a set design period. By diverting runoff into the soil, an infiltration trench not only treats the water quality volume, but also helps to preserve the natural water balance on a site and can recharge groundwater and preserve baseflow. Due to this fact, infiltration systems are limited to areas with highly porous soils where the water table and/or bedrock are located well below the bottom of the trench.

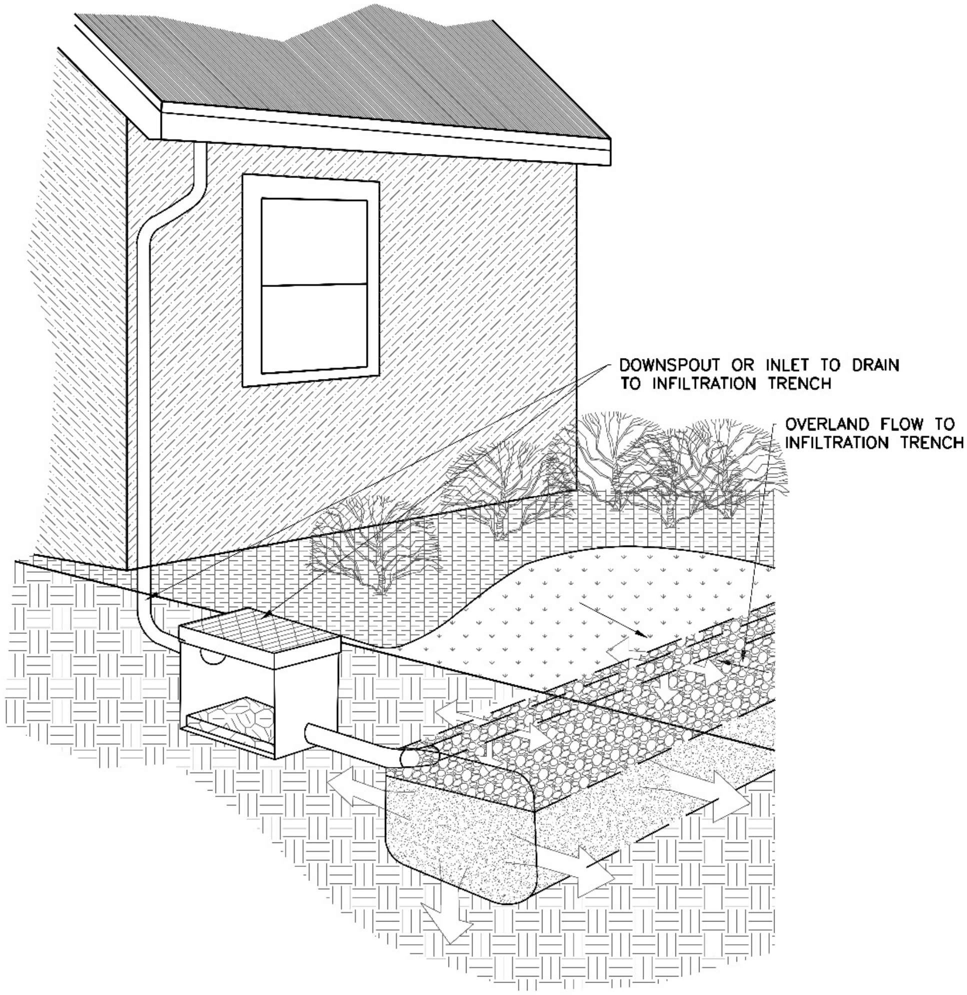


Figure 7003-14: Infiltration Trench Diagram

Infiltration trenches must be carefully sited to avoid the potential of groundwater contamination. Infiltration trenches are not intended to trap sediment and must always be designed with pretreatment measures to prevent clogging and failure. Due to their high potential for failure, these facilities must only be considered for sites where upstream sediment control can be ensured. They are applicable primarily for impervious areas where there are not high levels of fine particulates (clay/slit soils) in the runoff and should only be considered for sites where the sediment load is relatively low.

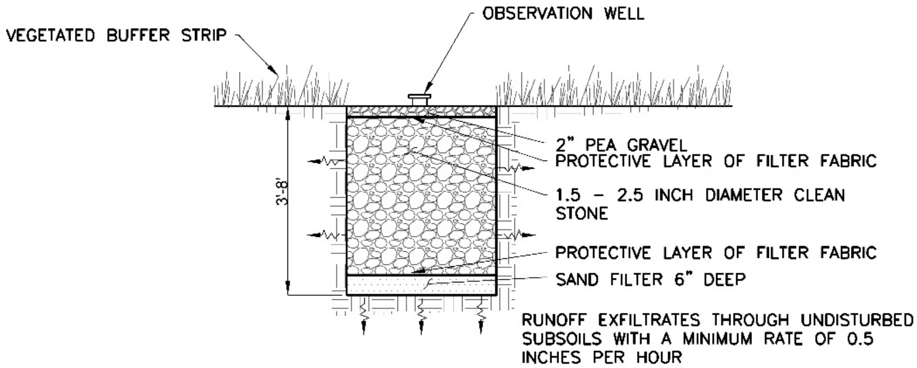


Figure 7003-15: Infiltration Trench Cross-Section

Infiltration trenches can either be used to capture sheet flow from a drainage area or function as an offline device. Due to the relatively narrow shape, infiltration trenches can be adapted to many different types of sites and can be utilized in retrofit situations. Unlike some other structural storm water controls, they can easily fit into the margin, perimeter, or other unused areas of developed sites. To protect groundwater from potential contamination, runoff from designated hotspot land uses or activities must not be infiltrated. Infiltration trenches should not be used for manufacturing and industrial sites, where there is a potential for high concentrations of soluble pollutants and heavy metals. In addition, infiltration should not be considered for areas with a high pesticide concentration.

B. Design Criteria

1. Trench Size

   a. The infiltration trench volume shall be greater than or equal to the water quality volume.

   b. The trench depth shall be between 3 and 8 feet.

   c. The trench cross sectional area shall be at least 8 square feet.

   d. The trench surface area shall be determined using the following equation:

$$\boldsymbol{A = \frac{WQV}{\left(nd + k\frac{T}{12}\right)}} \qquad \textbf{(21)}$$

Where,

A=Surface Area

WQV=Water quality volume

n=stone porosity

d=trench depth (feet)

k=percolation (inches/hour)

T=fill time (hours), (time for trench to fill with water, assume 2 hours for most designs)

2. Infiltration Trench Drainage
    a. A minimum infiltration rate of 0.5 inches/hour is required for the native soil subgrade.
    b. The trench shall have a minimum drawdown time of 10 hours, and a maximum drawdown time of 2 days.
    c. The maximum contributing drainage area shall be less than or equal to 5 acres.
    d. There shall be a minimum of 5 feet between the bottom of the infiltration trench and the seasonally high groundwater elevation.
3. Trench Elements
    a. The drainage layer shall consist of 12 to 18 inches of open graded washed 1.5-2.5 inch diameter round or crushed rock/stone with a void space of 30-40%.
        - Aggregate contaminated with soil shall not be used.
        - Unless aggregate specific data is available a porosity value of 0.32 shall be used for design calculations.
    b. A 6-inch layer of clean, washed sand shall be placed at the bottom of the trench.
    c. A vegetated buffer strip around the entire trench is required if receiving runoff from multiple directions.
    d. A trench receiving sheet flow from an adjacent area shall have a pretreatment system consisting of a vegetated filter strip meeting the requirements detailed in **Section 7003.1** of this document.
4. Geotextile Fabric
    a. Geotextile fabric shall be placed between the trench fill and the native soil.
    b. Geotextile fabric shall have greater permeability than the parent soil, but still prevent sediment from passing into the stone aggregate.
5. Pretreatment shall be included as part of the system
    a. Pretreatment shall be capable of holding 25% of the WQV.
    b. When the soil infiltration rate is greater than 2 inches per hour pretreatment shall be capable of holding 50% of the WQV.
    c. Pretreatment shall consist of a sediment forebay and grass channel or vegetated filter strip.

d. Exit velocities from pretreatment must be non-erosive.

6. Observation Well

   a. At least one observation well shall be installed in the infiltration trench.

   b. An observation well shall consist of a perforated PVC pipe extending to the bottom of the trench.

   c. Perforated PVC pipe shall be between 4 and 6 inches in diameter.

   d. The well shall be installed along the centerline of the trench, flush with the ground elevation of the trench.

   e. The top of the well shall be capped.

   f. At least 2 observation wells are required for trenches with a surface area greater than or equal to 20,000 feet.

7. Location

   a. Infiltration trenches shall not be constructed under current or future impervious surfaces.

   b. Infiltration trenches must not be used on manufacturing and industrial sites or areas with high pesticide concentrations.

   c. Minimum Offset from Facilities

Location	Offset Requirement
Property Line	10 feet
Building Foundation	25 feet
Private Water Supply Well	100 feet
Public Water Supply Well	1,200 feet
Septic System Tank/Leach Field	100 feet
Class SA Waters	30 feet
Surface Waters	30 feet
Surface Drinking Water Source	400 feet

C. Construction and Maintenance Requirements

1. Construction

   a. Infiltration trenches shall be constructed in native soil.

   b. Infiltration trenches shall not be subject to vehicular traffic or construction work that would compact the soil and reduce the permeability.

   c. Trench excavation shall be limited to the width and depth specified in the design.

   d. The trench shall be scarified before the sand is placed.

   e. The sides of the trench shall be trimmed of all large roots.

f. The sidewalls must be uniform with no voids and scarified prior to backfilling.

g. All infiltration trench facilities shall be protected during site construction and shall be constructed after upstream areas have been stabilized.

2. Maintenance

a. Sediment shall be removed after 50% of the pretreatment capacity has been lost.

b. The geotextile fabric serves as a sediment barrier and therefore will need to be replaced.

c. The observation well shall be used to determine:

- The rate of dewatering after a storm.
- Sediment levels within the trench.
- When the geotextile fabric at the top is clogged and requires maintenance.

D. Design Example

A portion of the parking lot of a commercial site (outlined in red below) will be treated with an infiltration trench (outlined in blue below). The area of the parking lot to be treated is 30,852 ft^2. This area measurement includes 1,320 ft^2 of pervious vegetated areas (outlined in green below). If the length of the infiltration trench shall be 125 ft, determine an acceptable width and depth for the trench if the infiltration rate is 0.5 in/hr.

Figure 7003-16: Infiltration Trench Example

Step 1: Calculate WQV using **Equations 1 and 2**

$$WQV = \frac{1.0 * R_v * A_C}{12}$$

$$R_v = 0.05 + 0.009I(\%)$$

$$WQV = \frac{1.0 * \left(0.05 + 0.009(95.72\%)\right) * 30{,}852\ ft^2}{12}$$

$$WQV = 2{,}343\ ft^3$$

Step 2: Determine the required surface area of the trench using **Equation 21** assuming a trench depth of 4 feet and length of 125 feet.

$$A_{BRC} = \frac{WQV}{(nd + k\frac{T}{12})}$$

$$A_{BRC} = \frac{2{,}343\ ft^3}{(0.32)d + (0.5\ \frac{in}{hr})(\frac{2\ hr}{12})}$$

The above calculations result in the following:

Trench design:

Depth=4 ft

Surface area=1,718 ft^2

Length=125 ft

Width=13.7 ft

7003.5 Green Roofs

A. Introduction

Green roofs are an alternative to traditional impervious roof surfaces. They typically consist of underlying waterproofing and drainage materials and an overlying engineered growing media that is designed to support plant growth. Stormwater runoff is captured and temporarily stored in the engineered growing media, where it is subjected to the hydrologic processes of evaporation and transpiration with any remaining stormwater conveyed back into the rooftop stormwater conveyance system. This allows green roofs to provide measurable reductions in post-construction stormwater runoff rates, volumes, and pollutant loads on development sites.

Other than the water quality component, green roofs offer an array of additional benefits, including extended roof lifespan (due to additional sealing, liners, and insulation), improved building insulation and energy use, reduction of urban heat island effects, opportunities for recreation and rooftop gardening, noise attenuation, air quality improvement, bird and insect habitat, heat reduction, value creation, and visual mitigation.

They are designed to drain stormwater runoff vertically through engineered growing media and then horizontally through a drainage layer that is sloped towards an outlet. There are two type of green roof systems:

1. Intensive system

   These green roofs have a thick layer of engineered growing media (usually 12-24 inches or more) that support a diverse understory plant community that may include trees if lightweight small geofoam fill is used.

2. Extensive system

   These green roof systems typically have a much thinner layer of engineered growing media (2-6 inches) that supports drought tolerant vegetation. Due to less media and structure loading limitations, these systems are usually lighter and less expensive.

B. Design Criteria

Green roofs are only used to replace traditional impervious roof surfaces. They should not be used to treat any stormwater generated elsewhere on the development site. All green roofs should be designed in accordance with the ASTM International Green Roof Standards (such as ASTM, 2005a, ASTM, 2005b, ASTM, 2005c, ASTM, 2005d, ASTM, 2006).

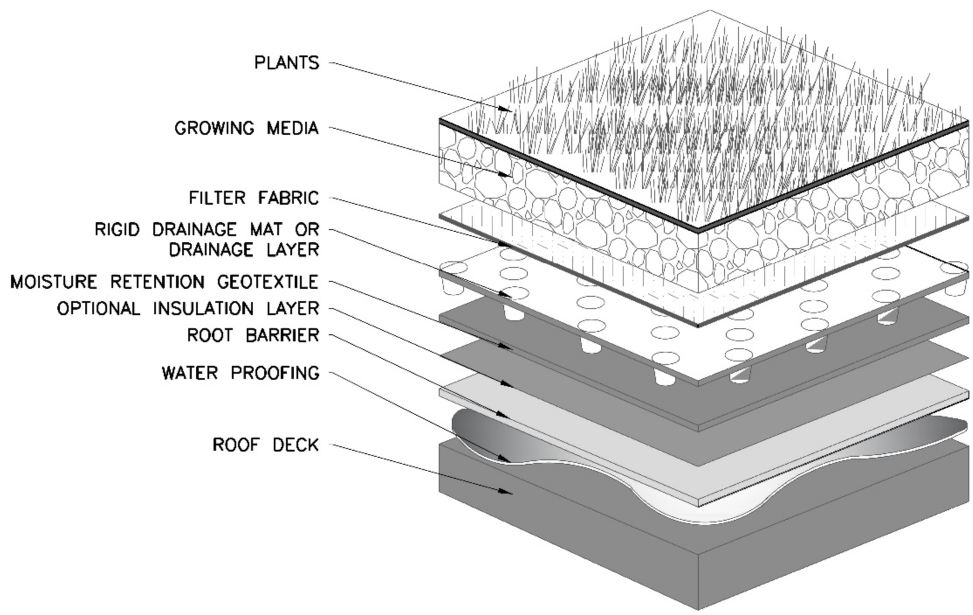


Figure 7003-17: Green Roof Layers

1. Layers

   a. Roof Deck

   - Designed to capture water quality volume flowing to the roof. Optimal slope is 1-2%. Green roofs not recommended for use on rooftops with slopes greater than 10% unless baffles are used. With baffles, 15% max.
   - Coordinate with a professional engineer to ensure rooftop is designed to support an additional load for the green roof design.

   b. Waterproofing layer

   - All green roof systems should include a waterproofing layer that will prevent stormwater runoff from damaging the underlying rooftop. Waterproofing materials typically used in green roof installation includes, but is not limited to, reinforced thermoplastic and synthetic rubber membranes.
   - Do not expose to sunlight to maximize life of the green roof.

   c. Root Barrier

   - Must extend under any gravel ballast, under the growing medium, and up the side of any vertical elements. Some waterproofing materials also contribute as a root barrier but do not suffice alone.

- Chemical root barriers or physical root barriers with pesticides, metals, or chemicals that may leach into post-construction stormwater runoff should not be used.

d. Insulation

- An optional layer (but usually required by building standard code) and can occur: under the slab/roof deck, under the waterproof membrane, or above the waterproof membrane.

e. Moisture Retention Geotextile/Protection Layer

- Synthetic material under drainage mat or drainage layer.

f. Rigid Drainage Mat or Drainage Layer

- To assist in conveying runoff to the building drainage system, a semi-rigid, plastic geocomposite drain or mat layer should be included in the design of a green roof. If the roof is flat, a perforated network may be necessary to help rainfall drain properly. Washed granular material can also be used in place of a mat. This should be a minimum 2 inch layer of clean, washed granular material, an often lightweight aggregate.

g. Geotextile

- To prevent clogging within the drainage layer, the engineered growing media should be separated from the drainage layer by a layer of permeable geotextile. The geotextile should be a non-woven geotextile with a permeability that is greater than or equal to the hydraulic conductivity of the overlying engineered growing media.

h. Growing Media

- Refer to **Specification 2105** for Biofiltration Medium makeup.
- The required depth of the drainage layer will be governed by the required storage capacity of the green roof system and by the structural capacity of the rooftop itself. The engineered growing media should have a maximum water retention capacity of approximately 30%.
- The engineered growing media should be between 4-6 inches deep or 12-24 inches deep for intensive and extensive system, respectively, unless synthetic moisture retention materials (e.g., drainage mat with moisture storage "cups") are placed directly beneath the engineered growing media layer. When synthetic moisture retention materials are

used, a less deep engineered growing media layer may be used.

i. Plants

- A landscaping plan should be prepared for all green roofs. The landscaping plan should be reviewed and approved by the City prior to construction.
- When developing a landscaping plan, site planning and design teams are required to consult with a botanist, landscape architect, or other qualified professional to identify plants that will tolerate the harsh growing conditions found on rooftops. Planting recommendations for green roofs include:
  - Drought- and sun-tolerant vegetation that requires minimal irrigation after establishment.
  - Flowering plants that may assist in adding to or maintaining habitat for pollinators.
  - Low maintenance vegetation.
  - Vegetation that is fire resistant and able to withstand heat, cold, and high winds.
  - Because sedum and succulent plants possess many of the characteristics listed above, they are recommended for use on green roof. Herbs, forbs, grasses, and other groundcovers may be used, but these plants typically have higher watering and maintenance requirements.
  - 90% native or adapted species per Section B of Appendix F of Zoning Ordinance, Trees and Plants for Oklahoma City, 2016, and/or OSU Extension’s Plant Selections for Oklahoma
  - No federal or state invasives.
  - Extend the roof flashing 6 inches above engineered growing media and protect by counter flashing.
  - Must achieve 80% vegetation coverage within 1 year.

2. Non-Green Components

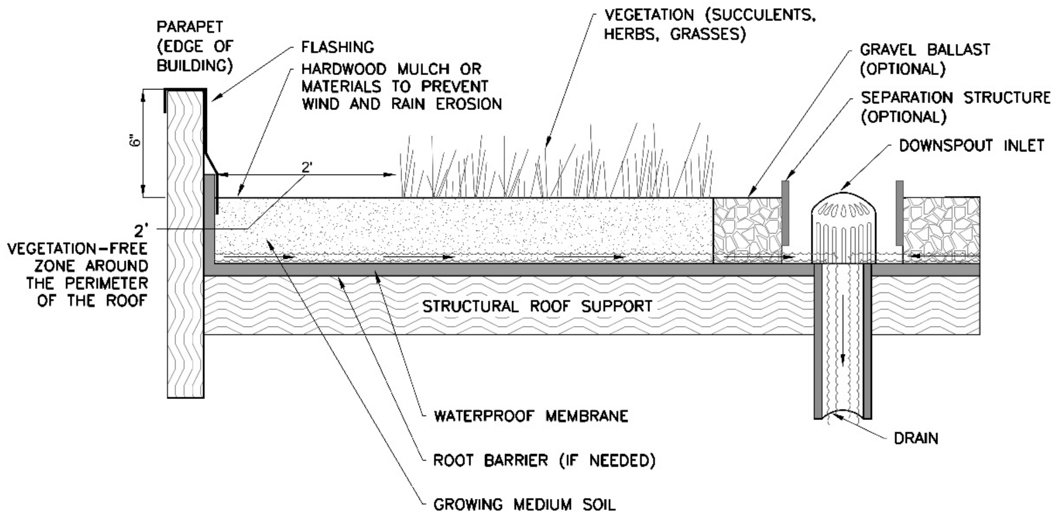


Figure 7003-18: Green Roof Cross-Section

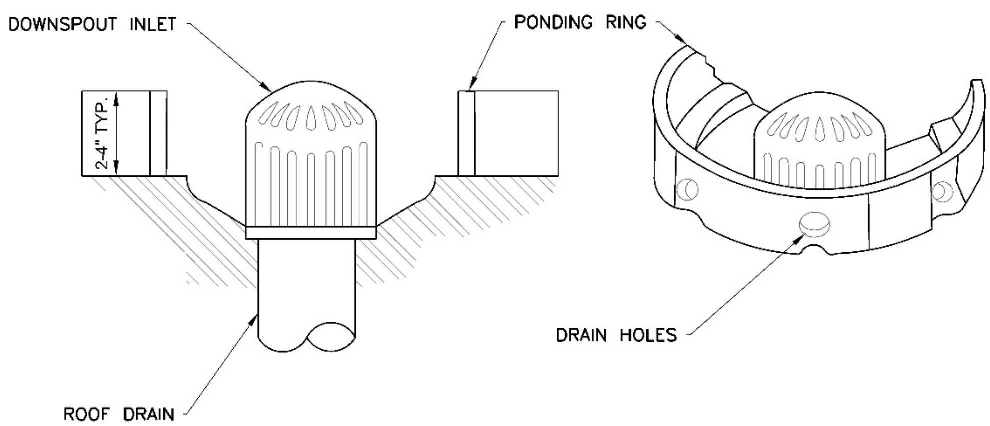


Figure 7003-19: Green Roof Downspout Inlet

a. Outlets should be provided to convey stormwater runoff out of the drainage layer and off the rooftop when the green roof becomes saturated.

b. Consideration should be given to the stormwater runoff rates and volumes generated by larger storm events to design green roofs that are able to safely convey or bypass these flows. The roof drainage system must sustain the 100-year storm and be able to handle blocked flows. An overflow system, such as a traditional rooftop drainage system with inlets set slightly above the elevation of the surface of the green roof, should be designed to convey the stormwater runoff generated by these larger storm events safely off the rooftop.

c. Minimize the use of copper of galvanized metal fittings which can introduce pollutants to the runoff.

d. Rigid pavements or gravel ballast can be placed along the perimeter of the roof and at air vents or other vertical elements for maintenance access.

e. Well-designed header or separation boards with reliable soil separators and drainage capability may be placed between gravel ballast and adjacent elements such as soil or drains.

f. A vegetation-free zone of approximately 2 feet shall be provided around the perimeter of the roof and 12 inches from any roof penetrations. The vegetation-free zone does not apply to walkways. Include in the design plan a roof layout to show all roof features and vegetated areas.

g. Extend the roof flashing 6 inches above engineered growing media and protect by counter flashing.

3. Additional Considerations

a. Direct rainfall runoff to adjacent landscape at grade and/or collect & recycle back to green roof

b. Always use drip irrigation and/or spray irrigation.

c. Meet at least 50% of green roof irrigation using non-potable sources such as HVAC condensate, rain-water collection, or other auxiliary water sources.

C. Construction and Maintenance Requirements

1. Construction

a. Avoid damage to the waterproofing membrane during installation of the green roof. If the integrity of the membrane is compromised in a manner that may cause leaks or roof damage, the area must be identified and repaired. Visually inspect for damage and test the membrane for water tightness prior to installation of the engineered growing media.

b. If the roof is sloped, stabilization measures may be required before installing the green roof to prevent soil from sliding down the roof. Some situations may allow the stabilization measures to be incorporated into the roof structure.

c. If using a proprietary system, install the green roof according to the manufacturer’s instructions, subject to approval relative to conditions herein.

d. To help prevent compaction of the engineered growing media, heavy foot traffic should be kept off of green roof surfaces during and after construction. Compaction should be anticipated – plan for remediation and ongoing replenishment.

e. Construction contracts should contain a replacement warranty that covers at least three growing seasons to help ensure adequate growth and survival of the vegetation planted on a green roof.

2. Maintenance

a. As needed

- Water to promote plant growth and survival.
- Mow and remove grass clippings.
- Remove trash, debris, and other pollutants from the rooftop.
- Observe infiltration rates after rain events, the roof should drain in 24 hours of rain event.

b. Monthly

- Inspect for weeds and conduct weeding during spring (March – May) and fall (September – November).
- Inspect green roof for dead or dying vegetation. Dead vegetation should be removed along with any woody vegetation. Plant replacement vegetation as needed.

c. Semi-annually (quarterly during first year)

- Inspect waterproof membrane for leaks. Repair as needed.
- Inspect outflow and overflow areas for trash, debris, and sediment accumulation. Remove any accumulated sediment or debris.
- Inspect vegetation for signs of stress. If vegetation begins showing signs of stress, including drought, flooding, disease, nutrient deficiency, or insect attack, treat the problem or replace the vegetation.
- Inspect irrigation system. Repair as needed.
- Weed and prune vegetation.

d. Annually

- Test the planting soils for pH levels. Consult with a qualified licensed arborist, botanist, and/or soil scientist to determine and maintain the optimal pH levels. A wireless telemetry option can be used to measure soil moisture and chemistry to assist with live information and serve as a teaching tool for the public.

D. Design Example

A portion of a commercial building's roof is to be converted to a green roof. It is assumed that the green roof will retain 100% of WQV for the roof area it covers (outlined in red below). If the total roof area is 112,878 ft^2 and the green roof will cover 40,772 ft^2, determine the resulting reduction in the WQV.

Figure 7003-20: Green Roof Example

Step 1: Calculate the total WQV for the entire roof using **Equations 1 and 2**

Total roof area=112,878 ft^2

$$WQV = \frac{1.0 * R_v * A_C}{12}$$

$$R_v = 0.05 + 0.009I(\%)$$

$$WQV = \frac{1.0 * \left(0.05 + 0.009(100\%)\right) * 112{,}878\ ft^2}{12}$$

$$WQV = 8{,}936\ ft^3$$

Step 2: Calculate the new WQV given the addition of the green roof

$$WQV = \frac{1.0 * (0.05 + 0.009(100\%)) * (112{,}878\ ft^2 - 40{,}772\ ft^2)}{12}$$

$$WQV = 5{,}706\ ft^3$$

The percent reduction in the WQV can be calculated as

$$\%Reduction = \left(\frac{8{,}936\ ft^3 - 5{,}706\ ft^3}{8{,}936\ ft^3}\right) * 100$$

$$\%Reduction = 36.1\%$$

7003.6 Permeable Materials

A. Introduction

Increasing a site's permeable surfaces allows for natural filtration and reduces the costs associated with adding stormwater management systems by reducing the amount of runoff from a site. Permeable materials can be applied to traditional impervious surfaces like roadways and sidewalks using a variety of material types.

Grid pavement systems are structural grids that are on top of a bedding layer that have space within the grid for permeable material. Aggregate and turf grass commonly fill the spaces within the grids system.

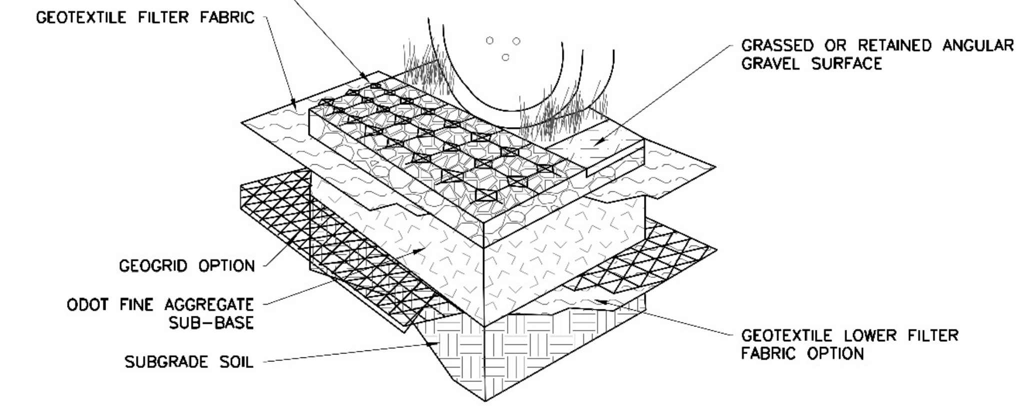


Figure 7003-21: Permeable Paver Diagram

Pavers, also referred to as Permeable Interlocking Concrete Pavers (PICPs), are blocks made from a wide variety of materials that are on top of an open graded base layer. They are typically used to provide aesthetic value to a site while being able to support the weight of a car. Water is able to drain through the openings between the blocks and naturally drain through well drained subgrade or to an underdrain system.

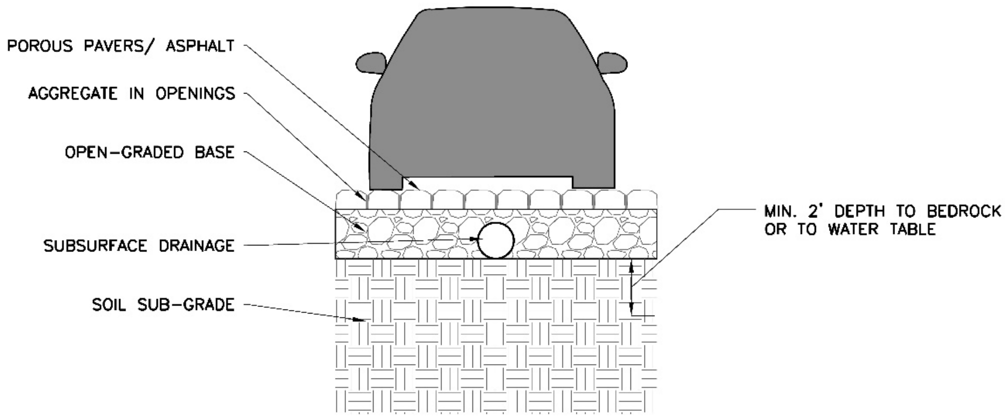


Figure 7003-22: Porous Pavers / Asphalt Cross-Section

Pervious concrete consists of a specially formulated mixture of Portland cement, uniform, open graded course aggregate, and water. The concrete layer has a high permeability, such that the underlying permeable soil layer allows rapid percolation of rainwater through the surface and into the layers beneath.

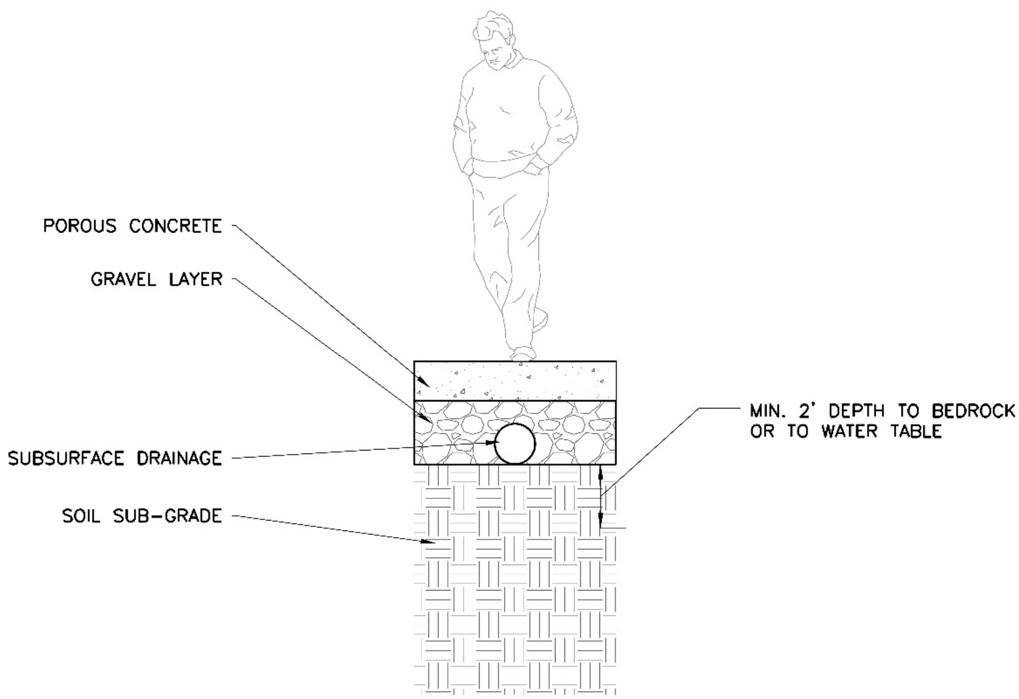


Figure 7003-23: Porous Concrete Cross-Section

Porous asphalt is asphalt with large void spaces to allow water to drain through it. Porous asphalt allows water to infiltrate into the subsoil through the paved surface and a base, aggregate layer that acts as both a structural layer and container to temporarily hold water. Porous asphalt is generally used on sidewalks, bicycle paths, or roads with low traffic volumes.

B. Design Criteria Applicable to All Permeable Materials

1. Drawdown time for the subbase storage material should not exceed 48-hours.
2. A minimum distance of 2 feet from the seasonally high groundwater elevation to the bottom of the aggregate base is required.
3. A minimum infiltration rate of 0.5 inches/hour is required for the native soil subgrade.
4. Where the infiltration rate is less than 2 inches/hour the pavement section shall sheet flow to a properly sized filter strip or the pervious pavement subsurface rock shall be sized for the required infiltration rate.
5. Surfaces shall be stable, firm, and slip resistant
6. Gravel base layer
    a. The gravel base course shall be designed to store the water quality volume at a minimum.
    b. The stone aggregate used shall be washed, bank-run gravel with a diameter of 1.5-2.5 inches.
    c. The gravel layer shall have about 40% void space.
    d. The gravel base layer shall have a minimum depth of 12 inches.
    e. Aggregate contaminated with soil shall not be used.
7. Permeable pavement system offset:

Location	Required Offset
Building	15 feet down gradient
Drinking water wells	100 feet

8. Pervious pavement must not be constructed over fill soils.
9. A subgrade geotextile layer may be used to separate the native soil subgrade and aggregate base layers but is not required.
10. If an underdrain is used for collection, the conveyance must lead to a vegetated facility sized to treat the entire pervious paved area.
11. If runoff is coming from adjacent pervious areas, the pervious areas shall be fully stabilized to reduce sediment loads and prevent clogging of the permeable pavement surface.
12. No permeable pavement system shall be installed in areas that dispense gasoline or other liquid engine fuels or where other hazardous materials are used or stored.

13. Unless otherwise approved, only porous asphalt, pervious concrete, and paver blocks may be installed in drive aisles and driveways.

14. If the pavement is a load bearing surface, the pavers must be able to support the maximum load.

15. Grid systems with turf grass cannot be used to meet minimum off-street parking.

16. Gravel based grid systems can only be used in industrial zoning districts as defined in the City of Norman Zoning Ordinance.

17. Parking spaces shall be marked with traditional striping methods or with alternative markings.

18. Pervious pavement must be designed to directly infiltrate all stormwater from the pavement surface into a crushed rock storage layer.

19. The gravel base layer must contain enough void space to store the 10-year, 24-hour storm.

20. Subsurface Drainage

   a. An underdrain shall be used when the in-situ soil cannot drain the WQV within 48 hours or if the system is lined with an impermeable barrier.

   b. An upturned elbow underdrain shall be used when the in-situ soil can meet the WQV drawdown requirements.

   c. An overdrain pipe shall be used when there is a risk of surface flooding and freeze-thaw conditions.

   d. There shall be a minimum of one cleanout per lateral line with additional cleanouts placed every 100 feet.

   e. Permeable pavement drainpipe configurations:

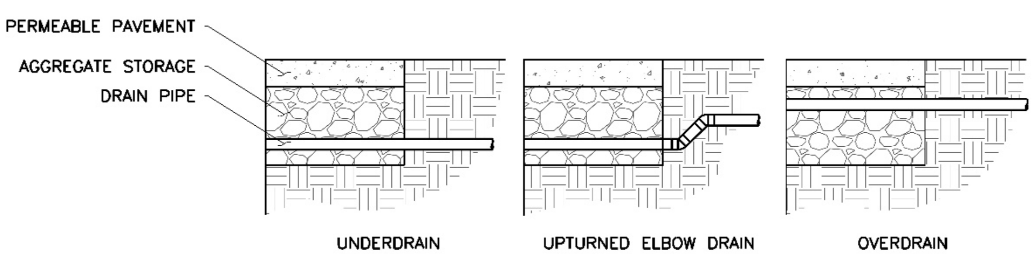


Figure 7003-24: Permeable Pavement Underdrain Diagram

C. Grid Paver System Specific Design Criteria

1. Slopes shall be between 5 and 10 percent. If used for an ADA walking surface, the max slope shall be 5 %.

2. The ratio of the contributing impervious area to the permeable paver surface area shall not exceed 3:1.

3. The entire stormwater volume must infiltrate into the subgrade.

4. A minimum of 40% of the surface area shall consist of open void spaces. Voids must be ½” or less in diameter

5. A porosity value of 0.32 shall be used for calculations unless the information is available for the manufacturer.

6. Paver blocks shall have a minimum thickness of 3.125 inches.

D. Paver Blocks Specific Design Criteria

1. The ratio of contributing impervious area to the permeable paver surface area should be no greater than 3:1.

2. Slope shall not exceed 5%.

3. Systems must conform to manufacturer specifications.

4. Pavers shall have a minimum compressive strength of 8,000 psi.

5. Pavers shall have a minimum thickness of 2.36 inches.

6. A 2-inch-thick bedding layer of ASTM No. 8 stone shall be included above the reservoir layer and below the paver blocks.

E. Pervious Concrete Specific Design Criteria

1. The maximum acceptable site slope is 6%. If used for an ADA walking surface, the max slope shall be 5 %.

2. The maximum ratio of the tributary impervious area to the area of pervious concrete is 1:1.

3. The layer of pervious concrete shall be between 6 and 12 inches thick.

4. Assume a porosity of 0.18 for the pervious concrete layer unless aggregate-specific data is available.

F. Porous Asphalt Specific Design Criteria

1. Slopes shall be between 5 and 10 percent. If used for an ADA walking surface, the max slope shall be 5 %.

2. The ratio of the contributing impervious area to the permeable paver surface area shall not exceed 3:1.

3. A minimum of 40% of the surface area shall consist of open void spaces. Voids must be ½” or less in diameter

4. A porosity value of 0.32 shall be used for calculations unless the information is available for the manufacturer.

5. Porous asphalt systems should be sized for a minimum drawdown time of 24 hours and a maximum drawdown time of 48 hours.

6. The surface of the subgrade shall be lined with an 8-inch layer of sand (ASTM C-33 concrete sand).

7. The porous asphalt layer shall be between 4 and 8 inches deep.
8. The reservoir layer shall be 2 to 4 feet deep.

G. Construction and Maintenance Requirements

1. Construction Requirements for All Permeable Pavement System Types
    a. The area to be paved shall be leveled and lightly compacted with a plate compactor to include the specified grade away from foundations.
    b. During construction the subgrade shall be protected from compaction, and sediment accumulation after installation.
    c. A pervious pavement protection plan shall be required in order to protect the surface from compaction during construction.
    d. The in-situ soil shall be scarified before the geotextile and aggregate base are installed.
    e. During construction, nearby pervious surfaces and material stockpiles shall be stabilized to prevent sediment from washing onto the surface of the pervious pavement.
2. Maintenance Requirements for All Permeable Pavement System Types
    a. Verify the porous pavement receives no off-site runoff.
    b. Sand or cinders should not be applied for winter traction over the permeable surface as it will clog the system. If applied, the materials must be removed by vacuuming in the spring.
    c. Chloride products used for deicing must not be used on permeable surfaces designed for infiltration, since the salts will be transmitted to the groundwater. Environmentally sensitive deicers are recommended. Permeable surfaces will generally require less salt application than traditional pavements.
    d. Weeds that grow in the permeable pavement shall be sprayed with pesticide. Weeds must not be pulled, as doing so can damage the fill media.
    e. Monthly
        - Ensure that paving area is clean of debris, ensure that paving dewaters between storms, and ensure that the area is clean of sediments.
    f. Semi-annually
        - Ensure that the porous pavement is protected from clogging due to runoff from landscape areas, rooftops, and other areas that may significantly reduce the long-term permeability be diverting flows away.

g. Annually

- The pervious surface should be vacuumed to restore open permeable pores and lift the sediment or other contaminants out that may reduce the long-term permeability. The frequency of this task shall be increased for areas where overhanging vegetation, excessive dirt, and pollutants are frequent.
- Inspect surface for deterioration. As necessary, repair or replace porous pavement or, for open-jointed block pavement or permeable interlocking concrete pavement, replenish aggregate within the joints.

3. Paver Block Specific Maintenance Requirements

   a. Replace bedding fill material as needed to keep fill level with the paver surface.

4. Grid Paver System Specific Maintenance Requirements

   a. If turf grass is used it shall be maintained at a height at or below 3 inches.
   b. Vegetated areas shall be inspected annually for erosion and scour.
   c. Replace bedding fill material as needed to keep fill level with the paver surface.

H. Design Example

A portion of the parking lot of a commercial site is to be converted to permeable pavement (outlined in blue below). It is assumed that the permeable pavement will retain 100% of WQV for the area it covers (outlined in red below). If the total parking lot area measured is 97,325 ft^2, including 6,380 ft^2 of pervious vegetated areas outlined in green below, and 39,410 ft^2 of this area is to be converted to permeable pavement, determine the resulting reduction in the WQV.

Figure 7003-25: Permeable Pavement Example

Step 1: Calculate the total WQV for the measured portion of the parking lot using **Equations 1 and 2**

Total parking lot area=97,325 ft^2

Vegetated area=6,380 ft^2

$$WQV = \frac{1.0 * R_v * A_C}{12}$$

$$R_v = 0.05 + 0.009I(\%)$$

$$WQV = \frac{1.0 * \left(0.05 + 0.009(93.44\%)\right) * 97{,}325\ ft^2}{12}$$

$$WQV = 7{,}227\ ft^3$$

Step 2: Calculate the new WQV given the addition of the permeable pavement

$$WQV = \frac{1.0 * (0.05 + 0.009(93.44\%)) * (97{,}325\ ft^2 - 39{,}410\ ft^2)}{12}$$

$$WQV = 4{,}300\ ft^3$$

The percent reduction in the WQV can be calculated as

$$\%Reduction = \left(\frac{7{,}227\ ft^3 - 4{,}300\ ft^3}{7{,}227\ ft^3}\right) * 100$$

$$\%Reduction = 40.5\%$$

7003.7 Bioswales

A. Introduction

A bioswale, also referred to as vegetated or enhanced swales, is a conveyance channel engineered to capture and treat the water quality volume for a given drainage area. Bioswales are designed with limited longitudinal slopes to force a slow and shallow flow, thus allowing for particulates to settle while limiting the effects of erosion. Berms and/ or check dams installed perpendicular to the flow path promote settling and infiltration.

The bioswale is a vegetated conveyance channel designed to include a filter bed of prepared soil that may overlay an underdrain system. Bioswales are sized to allow the entire WQV to be filtered or infiltrated through the bottom of the swale. Because they are dry most of the time, they are often the preferred option in residential settings.

Bioswales are not to be confused with a filter strip or grass channel. Ordinary grass channels are not engineered to provide the same treatment capability as a well-designed dry swale with filter media. Filter strips are designed to accommodate overland flow rather than channelized flow.

B. Bioswales are primarily applicable to residential and institutional areas of low to moderate density where the impervious cover in the contributing drainage area is relatively small, and along roads and highways.

C. Design Criteria

1. Bioswales shall drain completely within 48 hours of a storm, but no less than 24 hours.

2. Bioswales shall convey the 100-year storm event with a minimum of 6 inches of freeboard.

3. The peak velocity for the 2-year storm must be non-erosive for the soil and vegetative cover provided.

4. Design velocity shall not exceed 0.9 ft/s

5. Design Equations

a. Storage capacity without underdrain

$$\boldsymbol{S = A_{BSW}\left(D_0 + \frac{I}{12\frac{in}{ft}}(4\ hr)\right)} \qquad \textbf{(22)}$$

Where,

A_{BRC}=bioretention cell area (ft^2)

D_0=ponding depth (ft)

I=Infiltration rate of the bioretention media (in/hr)

4 hr=4 hours worth of drawdown time towards WQV (hr)

b. Storage capacity with underdrain

$$S = A_{BSW}\left(D_0 + (d_m - d_{rab} - D_u)\emptyset_{BRC} + (d_{rab} + D_u)\right) + \left(\frac{\pi D_u^2}{4} L_u\right)(1 - \emptyset_{BRC}) \quad (23)$$

Where,

A_{BSW}=bioswale cell area (ft^2)

D_0=ponding depth (ft)

d_m=media depth (ft)

d_{rab}=combined depth of rock above and below underdrain (ft)

D_u=underdrain diameter (ft)

$\emptyset_{BRC}$=bioretention cell media porosity

L_u=underdrain length (ft)

c. Maximum ponding depth

$$D_0 = \frac{I(24\,hr)}{12} \quad (24)$$

d. Depth of media

$$D_m = \frac{I(4\,hr)}{\emptyset_{BSW}} \quad (25)$$

e. Orifice outlet pipe diameter

$$\emptyset_o = \sqrt{\frac{8A_{BRC}}{\pi C_d t_d}}\left(\frac{h_{actual}}{2g}\right)^{0.25} \quad (26)$$

D_o=diameter for a circular orifice (ft)
A_{BRC}=bioretention cell horizontal area (ft^2)
C_d=discharge coefficient that is assumed to be 0.61 for a sharp edge orifice
t_d=design detention time (sec)
h_{actual}=actual height within the bioretention cell that is available for discharge (ft)
g=32.2 ft/sec^2

6. Swale Shape

a. Swales shall have a parabolic or trapezoidal cross-section.

b. Swales shall have a bottom width of 2 to 8 feet to achieve adequate filtration.

c. Depth of the storage volume at the downstream end shall not exceed 18 inches.

d. A 12-inch average swale depth shall be maintained.

e. Side slopes shall be no greater than 3H:1V

  - 4H:1V side slopes are recommended.

f. Channel Slope shall be no greater than 4%.

  - Channel slopes are recommended to be between 1% and 2% unless the topography necessitates a steeper slope.
  - A 6 to 12-inch drop structure can be placed to limit the slope to remain in the recommended 1 to 2% range.

g. Drop structures shall be spaced at least 50 feet apart.

h. Energy dissipation is required below the drops.

i. Wider channels shall contain berms, walls, or a multi-level cross section to prevent channel braiding or uncontrolled sub-channel formation.

7. Project Site

a. Drainage area shall be no larger than 5 acres.

b. Minimum elevation difference between inflow and outflow shall be no less than 3 feet.

c. There shall be at least 2 feet between the bottom of a swale and the elevation of the seasonally high water table.

d. Exfiltration is prohibited in hotspot areas.

8. Pretreatment

a. Pretreatment shall be provided by a sediment forebay located at the inlet of the bioswale.

b. The pretreatment volume shall equal 0.1 inches per impervious acre of drainage area.

c. The storage volume can be created by implementing one or more check dams at pipe inlets.

d. Swale systems receiving direct concentrated runoff may have a flow spreader at the upstream end of the control.

e. See **Section 7003.1**Vegetated Filter Strip for flow spreader requirements.

9. Filter Media

a. The soil media should comply with the specifications in **2105** and shall have an infiltration rate between 1 and 1.5 feet per day and be at least 18” deep.

- Underdrain
  - There shall be a permeable soil layer 30” in depth above the underdrain.
  - An underdrain collection system shall be equipped with at least a 4-inch diameter perforated PVC pipe (AASHTO M 252) longitudinal underdrain in a gravel layer.
  - A permeable geotextile shall be placed between the gravel layer and the overlying soil.

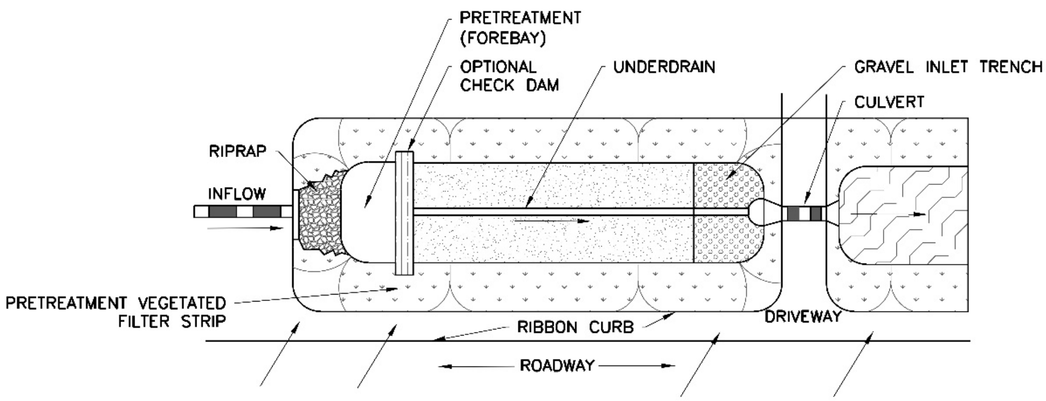


Figure 7003-26: Bioswale Plan View

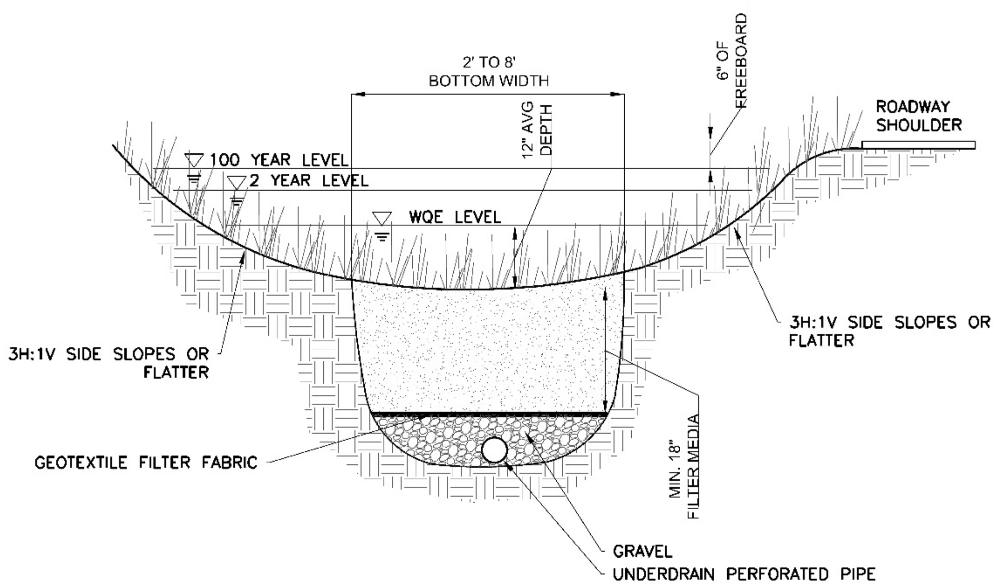


Figure 7003-27: Bioswale Cross-Section

b. Vegetation

- The maximum height of a mature plant within 30 feet of an intersection (measured from the edge of the intersecting road) shall not exceed 24 inches.
- Vegetation at driveways and midblock crossings shall not exceed 24 inches for visibility.
- Refer to Section B of Appendix F of Zoning Ordinance, Trees and Plants for Oklahoma City, 2016, and/or OSU Extension's Plant Selections for Oklahoma for native allowed sodding.

D. Construction and Maintenance Requirements

1. Construction

a. Construction equipment shall be restricted from the swale area to prevent compaction of the soil.

b. The bottom of the excavated trench for the swale shall not be loaded in a way that causes soil compaction.

c. The trench shall be scarified before the gravel and permeable soil are placed.

d. The sides of the channel shall be trimmed of all large roots.

e. The sidewalls shall be uniform with no voids and shall be scarified prior to backfilling.

f. A vegetative cover shall be established over the contributing pervious drainage area before runoff can be accepted into the facility to prevent the pores of the plant media from clogging.

2. Maintenance

a. Grass heights shall be mowed and maintained at a height of 4 to 6 inches.

b. Sediment shall be removed from the forebay and channel.

E. Design Example

Two examples at the grocery store are presented below. For each example, design a bioswale to treat the WQV for this contributing area. The examples are as follows:

1. Sandy loam soil with an infiltration rate of 2.0 in/hr. Depth of water table and restrictive layers is greater than 6 ft.
2. Clay soil with an infiltration rate of 0.25 in/hr. Depth of water table and restrictive layers is greater than 6 ft.

For these examples the bioswale will be located in the parking lot and designed to capture a portion of rainfall from the roof and parking lot (**Figure 7003-28**). Values in the examples are estimated or assumed measured values. The actual design should use field site measured data collected by trained professionals.

Figure 7003-28: Bioswale Example

The storage provided by the bioswale should be greater than or equal to the water quality volume (WQV) calculated below using **Equations 1 and 2**.

$$WQV = \frac{D_S * R_v * A}{12}$$

$$R_v = 0.05 + 0.009I(\%)$$

$$WQV = \frac{1.0(0.05+0.009(98.40\%))*79{,}700\ ft^2}{12}$$

$$WQV = 6{,}214\ ft^3$$

Example 1:

Step 1: Determine size and type of contributing area.

Total impervious area=79,700 ft^2

Step 2: Determine infiltration rate.

For this example, the infiltration rate of the native soil was measured to be 2.0 in/hr.

I=2.0 in/hr

Step 3: Select ponding depth.

The maximum pondingfi depth, D_0, is calculated using **Equation 24.**

$$D_0 = \frac{I(24\ hr)}{12}$$

$$D_0 = \frac{(2.0\ \frac{in}{hr})(24\ hr)}{12\ \frac{in}{ft}}$$

$$D_0 = 4\ ft$$

Step 4: Verify the drawdown time.

Bioswales shall drain completely within 48 hours of a storm, but no less than 24 hours. The total drawdown time is calculated using **Equation 19**

$$t_{dd} = \frac{12D_0}{I} + 4\ hr$$

$$t_{dd} = \frac{12(4\ ft)}{2\ \frac{in}{hr}} + 4\ hr$$

$$t_{dd} = 28\ hr$$

Step 5: Site selection.

Manually select area and depth then confirm design meets WQV.

Chosen spot: area in parking lot

Storage capacity without an underdrain is calculated using **Equation 22** below.

$$S = A_{BSW}(D_0 + \frac{I}{12\frac{in}{ft}}(4\ hr))$$

Where,

A_{BSW}=bioswale cell area (ft^2)

D_0=ponding depth (ft)

I=Infiltration rate of the bioretention media (in/hr)

4 hr=time that is utilized media storage calculation

Proposed bioswale area=4,295 ft^2

$$S = 4{,}295\ ft^2(4.0\ ft + \frac{2\frac{in}{hr}}{12\frac{in}{ft}}(4\ hr))$$

$$S = 20{,}043\ ft^3$$

$$S = 20{,}043\ ft^3 > 6{,}214\ ft^3 = WQV$$

Design is valid. Proposed bioswale area can be decreased if needed.

Example 2:

Step 1: Determine size and type of contributing area.

Impervious surfaces:

Total impervious area=79,700 ft^2

Step 2: Determine infiltration rate.

For this example, the infiltration rate of the native soil was measured to be 0.25 in/hr.

I=0.25 in/hr

Step 3: Manually select ponding depth.

The maximum ponding depth, D_0, is calculated using **Equation 24**

$$D_0 = \frac{I(24\ hr)}{12}$$

$$D_0 = \frac{(0.25\frac{in}{hr})(24\ hr)}{12\ \frac{in}{ft}}$$

$$D_0 = 0.5\ ft$$

Step 4: Verify the drawdown time.

Bioswales shall drain completely within 48 hours of a storm, but no less than 24 hours. The total drawdown time is calculated using **Equation 19**

$$t_{dd} = \frac{12D_0}{I} + 4\ hr$$

$$t_{dd} = \frac{12(0.5\ ft)}{0.5\frac{in}{hr}} + 4\ hr$$

$$t_{dd} = 16\ hr\ < 24\ hrs$$

Design is not valid. Repeat the design process using a deeper media section and include an underdrain.

Example 2 with Underdrain:

Step 1: Determine size and type of contributing area.

Impervious surfaces:

Total impervious area=79,700 ft^2

Step 2: Determine infiltration rate.

The infiltration rate of the native soil was measured to be 0.5 in/hr. This low infiltration rate is not suitable for a native media design, therefore a 4-in diameter underdrain pipe will be installed. Assume the installation of the underdrain will result in an infiltration rate of 1.0 in/hr where the implemented design media has a porosity of 0.3.

I=1.0 in/hr

Step 3: Manually select ponding depth.

The maximum ponding depth, D_0, is calculated using **Equation 24**

$$D_0 = \frac{I(24\ hr)}{12}$$

$$D_0 = \frac{(1.0\ \frac{in}{hr})(24\ hr)}{12\ \frac{in}{ft}}$$

$$D_0 = 2\ ft$$

Step 4: Verify the drawdown time.

Bioswales shall drain completely within 48 hours of a storm, but no less than 24 hours. The total drawdown time is calculated using **Equation 19**

$$t_{dd} = \frac{12D_0}{I} + 4\ hr$$

$$t_{dd} = \frac{12(2.0\ ft)}{1.0\frac{in}{hr}} + 4\ hr$$

$$t_{dd} = 28\ hrs$$

Step 4: Manually select the depth of media using **Equation 25.**

$$D_m = \frac{I(4\ hr)}{\emptyset_{BMP}}$$

$$D_m = \frac{\left(1\ \frac{in}{hr}\right)(4\ hr)}{(0.3)}\left(\frac{1\ ft}{12\ in}\right)$$

$$D_m = 1.1\ ft$$

Step 5: Site selection.

Manually select area and depth then confirm design meets WQV.

Chosen spot: area in parking lot

Storage capacity with an underdrain is calculated using **Equation 23**

$$S = A_{BSW}\left(D_0 + (D_m - d_{rab} - D_u)\emptyset_{BRC} + (d_{rab} + D_u)\right) + (\frac{\pi D_u^2}{4}L_u)(1 - \emptyset_{BRC})$$

$$S = 4{,}295\ ft^2(1.0\ ft + \left(1.1\ ft - 0.5\ ft - \frac{4\ in}{12\frac{in}{ft}}\right)(0.3) + \left(0.5\ ft + \frac{4\ in}{12\frac{in}{ft}}\right)) + (\frac{\pi\left(\frac{4\ in}{12\frac{in}{ft}}\right)^2}{4})(20\ ft)(1 - 0.3)$$

$$S = 11{,}155\ ft^3$$

$$S = 8{,}219\ ft^3 > 6{,}214\ ft^3 = WQV$$

Design is valid. Proposed bioswale area or media depth can be decreased if needed.

Step 6: Determine the orifice outlet diameter for the underdrain using **Equation 26.**

$$\emptyset_o = \sqrt{\frac{8A_{BSW}}{\pi C_d t_d}}(\frac{h_{actual}}{2g})^{0.25}$$

$$\emptyset_o = \sqrt{\frac{8(4{,}295\ ft^2)}{\pi(0.61)(172{,}000\ sec)}}(\frac{2\ ft}{2(32.2\ \frac{ft}{s^2})})^{0.25}$$

$$\emptyset_o = 0.14\ in$$

7004 LARGE SCALE CONTROLS

Large scale controls are designed to be at the watershed or neighborhood development scale where all runoff from the site is typically routed to one SCM per drainage area. The contributing area for these SCMs is usually 10 acres or larger.

7004.1 Sedimentation-filtration/biofiltration Basins

A. Introduction

A sedimentation-filtration SCM captures and temporarily stores stormwater runoff and passes it through a filter bed of sand. Most sand filter systems consist of two-chamber structures. The first chamber is a sediment forebay or sedimentation chamber, which removes floatables and heavy sediments. Runoff is discharged from the sedimentation chamber through a perforated standpipe into the filtration chamber, the second chamber. The filtration chamber removes additional pollutants by filtering the runoff through a sand bed. The filtered runoff is typically collected and returned to the conveyance system, though it can also be partially or fully exfiltrated into the surrounding soil in areas with porous soils.

Sedimentation-filtration basins are primarily designed as an off-line system for stormwater quality. They do not provide any runoff reduction, so they will need to be used in conjunction with another stormwater control to provide runoff reduction if necessary.

Biofiltration devices are a type of stormwater control measure that meets or exceeds treatment levels as compared to a standard sedimentation/filtration system. Similarly, stormwater is routed through a sediment forebay; however, in this control measure, flows are then directed through a biofiltration medium which removes pollutants. The biofiltration devices include plants and microorganisms that are rooted in the filter medium and provide more treatment of runoff. It is comparable to a sedimentation-filtration basin except it has a plant community that sustains the permeability of the biofiltration medium for longer periods of times without maintenance.

Full Sedimentation SCMs shall be used when all design criteria can be met. The entire water quality volume can be held in the sedimentation basin. The water from the sedimentation basin slowly discharges runoff to the filtration basin via a perforated riser pipe.

Partial Sedimentation SCMs shall be used when full sedimentation is unfeasible. Unfeasible is considered: assuming (for the purposes of this selection process only) a maximum ponding depth of three feet in the sedimentation basin, if it is not feasible to obtain an outlet for the drainage from the filtration basin within one hundred (100) feet of the crest of the filtration embankment, then the partial sedimentation/filtration configuration system may be used. Assumed smaller filtration rate due to higher sediment loading and clogging of the filter media. This design foregoes the perforated riser pipe, and distributes the water quality volume between the filtration basin and a sediment chamber. The filtration bed and sediment chamber are separated by a gabion wall or other porous structure.

Biofiltration SCMs shall be used when vegetation within the sedimentation basin is preferred.

B. Design Criteria – Full Sedimentation

1. Basin Surface Areas

For sedimentation and filtration basins, surface area is the primary design parameter for a fixed minimum draw-down time of forty-eight (48) hours.

The following equation gives the minimum surface areas required for the sedimentation and filtration basins:

The filtration basin surface area is calculated as:

$$A_f = \frac{WQV}{(7+2.33H)} \tag{26}$$

Where,

A_f=minimum surface area of the filtration media in square feet

Assumed drawdown time=48 hours

WQV=water quality volume as defined in 7002.1**.** in cubic feet

H=maximum ponding depth in the filtration basin in feet

The assumed maximum ponding depth of the sand filtration basin should be at least one (1) foot less than the maximum ponding depth in the sedimentation basin.

2. Basin Volumes

The storage capacity of the sedimentation basin shall be greater than or equal to the water quality volume. The design shall allow enough freeboard above the water quality volume to pass the design flow rate for the 100 year storm over the splitter/diversion structure without overtopping of any side walls of the pond, plus an additional 5 percent of the total fill height or 3 inches, whichever is greater, to allow for construction irregularities and long term soil settling.

The storage capacity of the filtration basin, above the surface of the filter media, should be greater than or equal to 20 percent of the water quality volume. This capacity is necessary in order to account for backwater effects resulting from partially clogged filter media.

Any pond embankment configuration meeting the criteria for dam safety requirements must follow the criteria of the Oklahoma Water Resources Board.

3. Sedimentation Basin Details

   The sedimentation basin consists of an inlet structure, flow spreader (if inlet structure does not provide flow spreading), settling area and, outlet structure. The sedimentation basin design should maximize the distance from where the heavier sediment is deposited near the inlet to where the outlet structure is located. It is recommended that the bottom of the sedimentation basin (and invert of riser pipe) be ≥ 2 inches higher than the top of the filtration bed.

   a. Inlet Structure/Flow Spreader

      - Splitter structure to separate water quality volume and discharge uniformly and low velocity to sedimentation basin.
      - Drop inlet structure is recommended to facilitate sediment removal and maintenance. Allows for heavier suspended material to drop out near the front of the basin.
      - Maximum velocity discharged to the sedimentation basin should not exceed two (2) feet per second. Flow spreader/energy dissipator will likely be necessary at the pipe outfall in order to reduce velocities and distribute flow.

   b. Outlet Structure

      - Conveys the water quality volume from the sedimentation basin to the filtration basin.
      - Designed to provide for a minimum draw-down time of forty-eight (48) hours and maximum of ninety-six (96) hours.
      - Riser pipe should be a perforated schedule forty (40) PVC riser pipe with a removable and accessible PVC cap. Drill an orifice in the cap to appropriately design drawdown time. The discharges through the perforations should not be used for draw-down time design purposes.
      - The top of the riser should extend above the elevation of the splitter weir or should be fitted with a threaded removable cap.
      - A trash rack shall be provided for the riser.

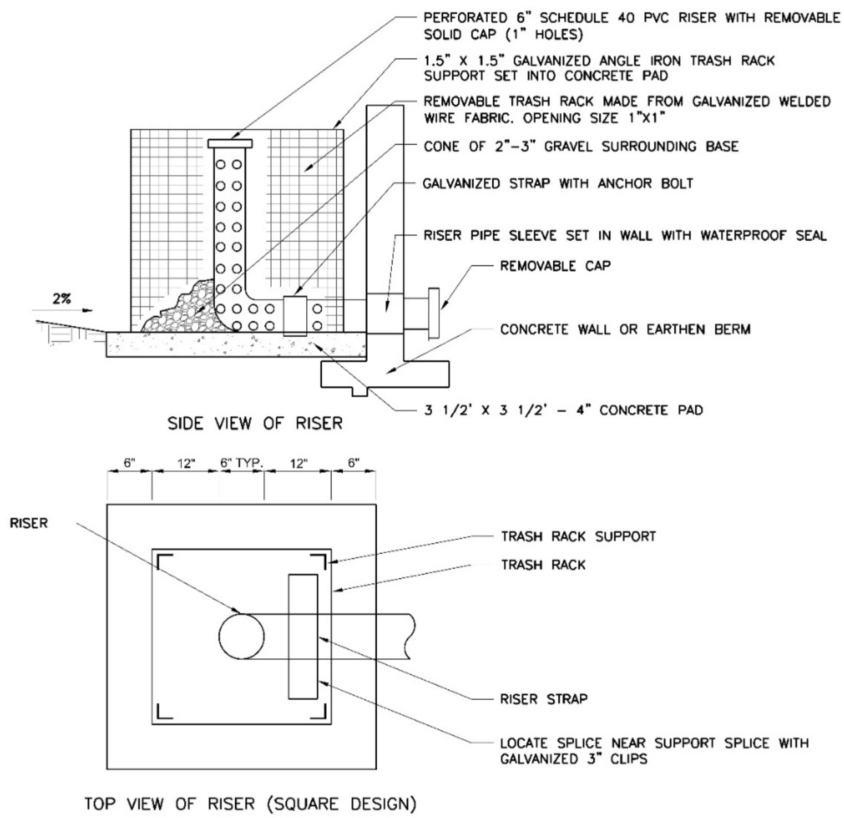


Figure 7004-1: Riser Pipe Diagram

c. Basin Geometry

- The sedimentation basin should have a minimum two (2) percent bottom slope to ensure that the pond will drain adequately even after silt accumulation.
- Water collected in the sediment basin shall be conveyed to the filtration basin to prevent standing water from occurring. The invert of the drainpipe should be above the surface of the filtration sand bed. The minimum grading of the piping to the filtration basin should be two (2) percent slope. Access for cleaning the sediment basin drain system is necessary.

4. Sand Filtration Basin Details

The sand bed filtration system consists of the inlet structure/flow spreader, sand bed, underdrain piping and basin liner.

a. Inlet Structure/Flow Spreader

- Spread the flow uniformly across the surface of the filter media. See Figure 7004-2 for flow spreader design guidance.
- A rock flow spreader is recommended. The rocks directly in the flow path of the riser pipe discharge must be sized

appropriately to prevent scour and erosion. For proper riprap sizing follow the design criteria located in riprap spec.

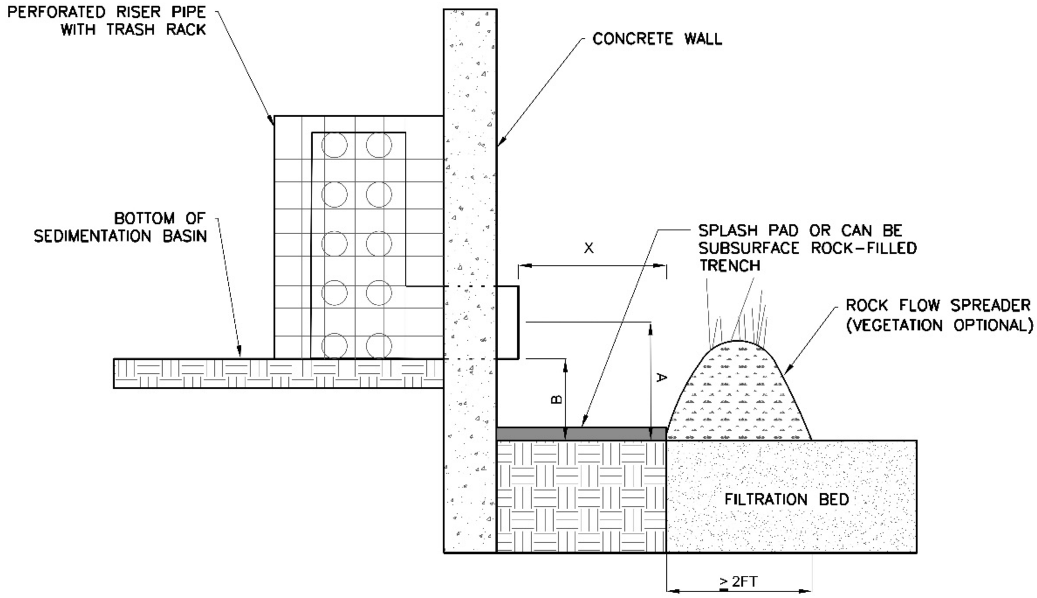


Figure 7004-2: Riser Pipe Outlet System

- Determination of Dimension X, or maximum pipe discharge travel distance:
- Given known riser pipe diameter d, calculate cross-sectional area

$$A_o = \frac{\pi d^2}{4\,ft^2} \qquad (27)$$

- Calculate maximum riser pipe discharge Q (cfs) using orifice equation
- Calculate maximum discharge velocity

$$v = \frac{Q}{A_o} \qquad (28)$$

- Calculate "fall time" for flow trajectory.

$$t = \sqrt{\frac{2(B+A)}{g}} \qquad (29)$$

Where:

t is in seconds

B = Recommended ≥ 2" differential between bottom of sedimentation basin and top of filter

A = pipe radius including thickness + any gap between riser pipe and pond bottom (ft)

g = gravitational acceleration = 32.2 ft/sec ^{2}

- Calculate

$$X \geq 1 + vt \qquad (30)$$

1 ft is added for margin of safety

b. Sand Bed

- The sand bed must be built to Figure 7004-3 configuration unless topographic constraints make this design unfeasible.
- The top surface of the sand filter bed must be horizontal, i.e., no grade is allowable.
- Sand bed depths are final, compacted depths.

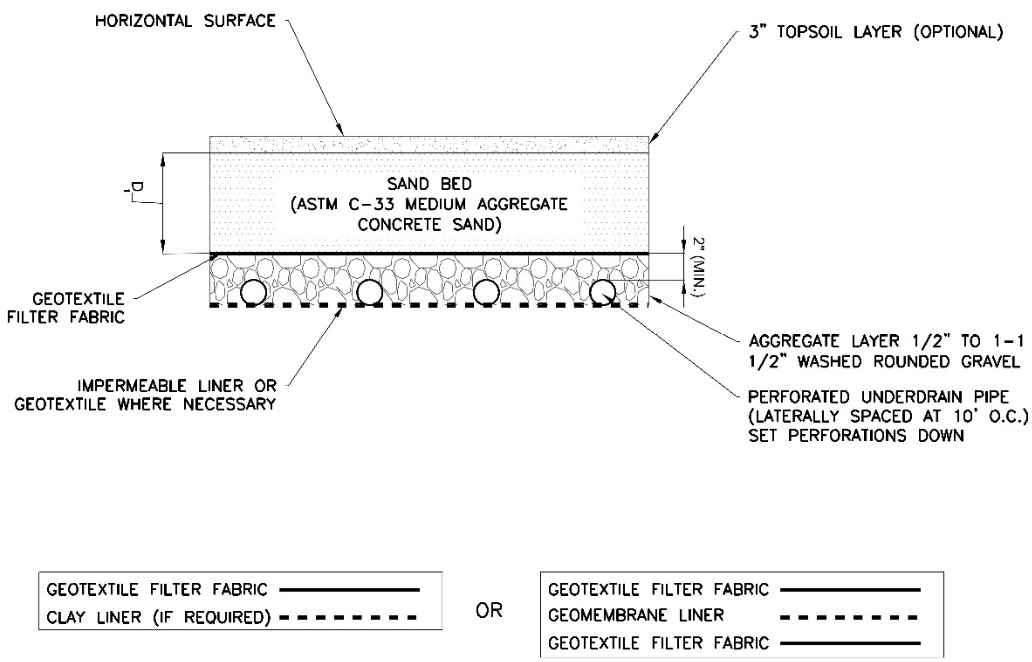


Figure 7004-3: Filtration Bed Cross-Section

c. Underdrain Piping

- The underdrain piping consists of the main collector pipe(s) and perforated lateral branch pipes. The maximum spacing for the laterals should be ten (10) feet between laterals and five (5) feet from a wall or side. The maximum spacing between rows of perforations should not exceed six (6) inches.

- The minimum grade of piping shall be one-eighth (1/8) inch per foot (one (1) percent slope).
- Access for cleaning all underdrain piping is needed. Cleanouts with a removable PVC cap are required within fifty (50) feet of every portion of lateral, at collector drain lines, and at every bend. Set the top of the cleanout flush with the top of the sand bed. At least one lateral must be accessible for cleaning when the pond is full. The full pond cleanout should extend above the water quality elevation and/or be located outside of the water quality volume ponding area. In order to minimize vandalism or other types of damage to this full pond cleanout the use of exposed piping shall be avoided or minimized.

d. Basin Liner

- Impermeable liner requirements and specifications are located in **Section 7002.5**. If basin side slopes will be installed adjacent to roadway, coordinate with professional engineer and construction services to determine appropriate basin section that will not impact integrity of road. Liner may need to be required along side slopes to protect foundations and road bases from seepage.

e. Outfall

- The surface discharge from the underdrain pipe shall be non-erosive. Where feasible the underdrain pipe should discharge to a gravel trench to diffuse the flow and promote infiltration and recharge.
- An emergency or bypass spillway must be included in the surface sand filter to safely pass flows that exceed the design storm flows. The spillway prevents filter water levels from overtopping the embankment and causing structural damage. The emergency spillway should be located so that downstream buildings and structures will not be impacted by spillway discharges.

C. Design Criteria-Partial Sedimentation

1. Basin Surface Areas and Volume

This filtration rate is less than that assumed for the filtration basin in the full sedimentation/filtration system due to higher sediment loading and consequent clogging of the filter media.

The following equation gives the minimum surface area required for the filtration basin:

$$A_f = \frac{WQV}{(4+1.33H)} \quad (31)$$

Where,

A_f=required surface area of the media in square feet

WQV=water quality volume in cubic feet

H=maximum ponding depth above the filtration media in feet

The combined volume of the sediment chamber and filtration basin exclusive of the gabion volume must be equal to the water quality volume, i.e., Vs + Vf = water quality volume where "Vs" is the sediment chamber volume and "Vf" is the filtration basin volume.

The volume of the sediment chamber, "V_s", shall be a minimum of 20 percent of the water quality volume.

2. Sediment Chamber Detail

   The sediment chamber consists of an inlet structure/flow spreader, settling area, and outlet structure. It is recommended that the bottom of the sediment chamber be ≥2 inches higher than the top of the filtration bed. The sediment chamber should have a minimum two (2) percent bottom slope to ensure that the pond will drain adequately even after silt accumulation.

   a. Inlet Structure/Flow Spreader [see **Section 7004.1B.3.a**]
   b. Outlet Structure
      - The outlet structure should be a berm or wall with multiple outlet ports or a gabion so as to discharge the flow evenly to the filtration basin. Rock gabions should be constructed using five (5) to eight (8) inch diameter rocks. The berm/wall/gabion height should not exceed six (6) feet and high flows should be allowed to overtop the structure (weir flow). Multiple outlet ports should be used in the berm/wall so as to induce flow-spreading. The outflow side should incorporate features to prevent gouging of the sand media (e.g., concrete splash pad or riprap).
      - Any pond embankment configuration meeting the criteria for dam safety requirements must follow the criteria of the Oklahoma Water Resources Board

3. Sand Filtration Basin Details (see **Section 7004.1B.4**)

   See **Figure 7004-2** for flow diffuser outlet detail. In addition, install a removable PVC cap with an appropriately sized orifice at the end of the underdrain pipe in order to provide a forty-eight (48) hour drawdown time, to account for significant uncertainties to the actual filtration media hydraulic conductivity over the life of the system.

D. Design Criteria - Biofiltration

1. Basin Surface Areas and Volumes

a. Full Sedimentation/Biofiltration Systems

- In these systems the entire water quality volume is stored in the sedimentation basin, and then discharges relatively slowly to the biofiltration basin (e.g. over a period of 48 hours). See 7004.1B. for additional design criteria and Figure 7004-4, Full Sedimentation/Biofiltration Pond, for general details. It is recommended that the bottom of the sedimentation basin be ≥ 2″ higher than the top of the filtration basin.
- Based on the equation and assumptions given above, the minimum surface area required for the biofiltration basin is:

$$A_f = \frac{WQV}{(7+2.33H)} \quad (32)$$

Where,

A_f=filtration area in square feet

WQV = water quality volume in cubic feet as defined in **Section 7002.1**

H = maximum ponding depth in the filtration basin. The assumed maximum ponding depth of the filtration basin should be at least one (1) foot less than the maximum ponding depth in the sedimentation basin, to account for tailwater effects.

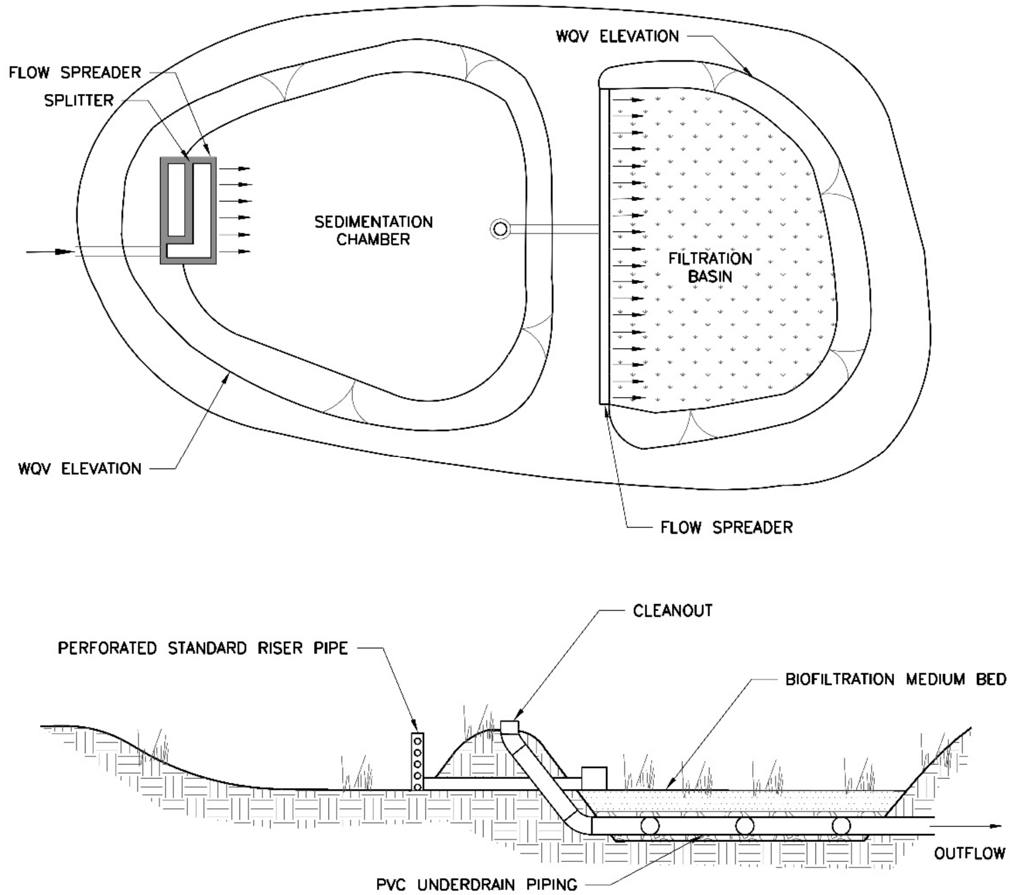
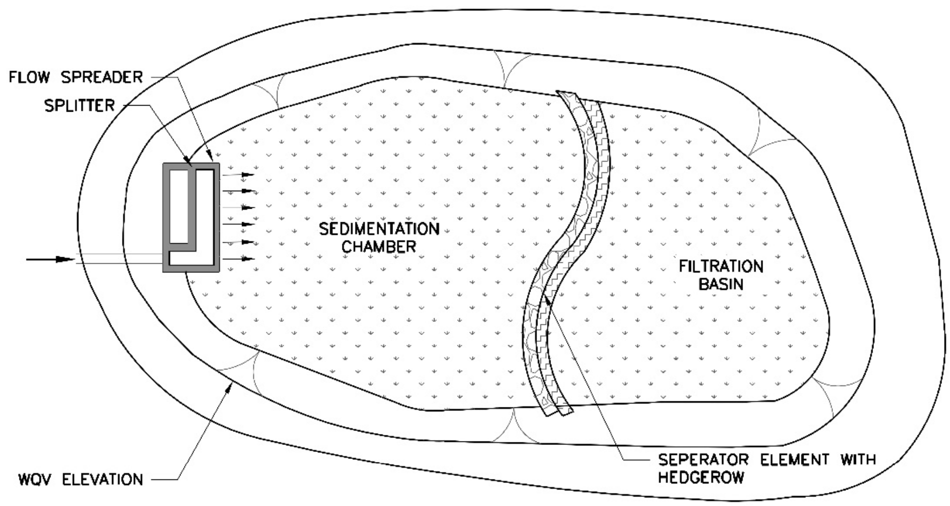


Figure 7004-4: Full Sedimentation/Biofiltration Pond

b. Partial Sedimentation/Biofiltration Systems

- System is considered partial when the sediment chamber is not large enough to store the whole water quality volume, so that volume must be stored partly over the sediment chamber and partly over the biofilter. The combined volume of the sediment chamber and filtration basin must therefore equal to the water quality volume, i.e., V s + V f = water quality volume where "V s " is the sediment chamber volume and "V f " is the filtration basin volume. The volume of the sediment chamber, "V s ", shall be no less than 20 percent of the water quality volume. For general details see Figure 7004-5 Partial Sedimentation/Biofiltration Pond, and **Section 7004.1C**, Partial Sedimentation/Filtration.



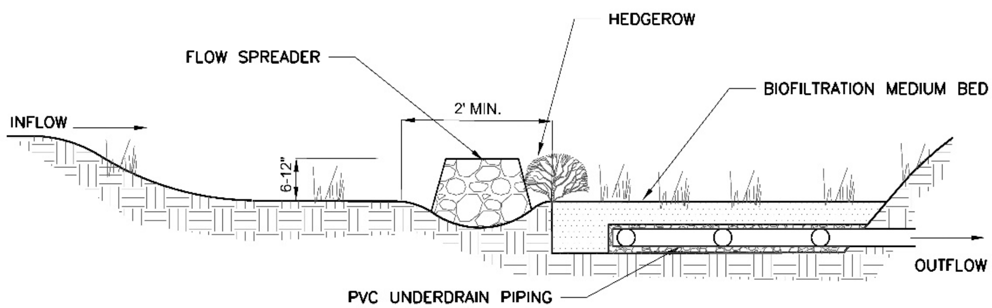


Figure 7004-5: Partial Sedimentation/Biofiltration Pond

- Based on the equation and assumptions given above, the minimum surface area required for the biofiltration basin is:

$$A_{BRC} = \frac{WQV}{(4+1.33H)} \qquad (33)$$

Where,

A_{BRC} = required surface area of the medium in square feet,

WQV = water quality volume in cubic feet as defined in **Section 7002.1**

H = maximum ponding depth above the filtration medium in feet.

2. Sedimentation Basin/Sediment Chamber Details

The system consists of an inlet structure, flow spreader, vegetative settling area, and separator element. It is recommended that the bottom of the sediment chamber be >2" higher than the top of the filtration basin to uniformly discharge flow at or above the biofiltration vegetation, and to prevent excessive drawdown times due to tailwater effects.

a. Inlet Structure/Flow Spreader

- The inflow should pass through a splitter box structure or flow spreading device. Flow spreading should be designed to restore the flows entering the SCM (i.e., after the inlet structure) to sheet flow conditions with a maximum velocity of two (2) feet per second for the peak flow rate of the twenty-five (25) year storm.
- Plantings in the sedimentation basin may provide resistance to flow and further spread the flows, thereby reducing runoff velocities further to improve settling, biological uptake, and adsorption.
- The basin should have a bottom slope of at least 2% to ensure that the pond will drain adequately even after silt accumulation.

b. Separator Element

- Designed to discharge the flow evenly across the filtration basin. This is important to avoid channelizing and destruction of the filtration medium surface. A reinforced vegetated hedgerow is recommended that uses five (5) inch by eight (8) inch rock flow spreaders or low gabion structures, two (2) feet wide and six (6) inches to twelve (12) inches deep, with hedgerows located within the structure.
- The outflow side should incorporate features to prevent gouging of the filtration medium.

3. Biofiltration Basin Details

The Biofiltration medium bed filtration system consists of the biofiltration medium bed, underdrain piping, and outlet structure.

a. Biofiltration Bed with Underdrain

- The biofiltration medium layer is to be a minimum of eighteen (18) inches meeting the specifications stated in **Specification 2105**. Required biofiltration medium bed depths should be interpreted as final consolidated values rather than as initially placed.
- Under the biofiltration medium shall be an underdrain system that consists of one-half (0.5) to one and one-half (1.5) inch diameter washed, rounded, river gravel surrounding 6 inch Schedule 40 PVC underdrain lateral pipes. The maximum spacing for the laterals should be ten (10) feet between laterals and five (5) feet from a wall or side. The minimum thickness of the gravel envelope is 3 inches. The soil

medium and gravel layer must be separated by a filter material.

- A filter can be of two (2) general forms. A fabric filter is a layer of geotextile and a granular filter is one or more graded layers of sand, gravel or stone. The geotextile filter fabric must comply with the criteria in the riprap **Specification 2200**. The gradation of a granular filter design must comply with Federal Highway Administration “Geosynthetic Design and Construction Guidelines” (FHWA-HI-95-038). In cases where the requirements cannot be met with a single gradation, multiple layers of granular filter material of varying gradations may be required to meet the criteria. The thickness of a granular filter layer should be no less than 1.5 times the maximum size in the filter gradation or four inches (102 mm) whichever is greater.

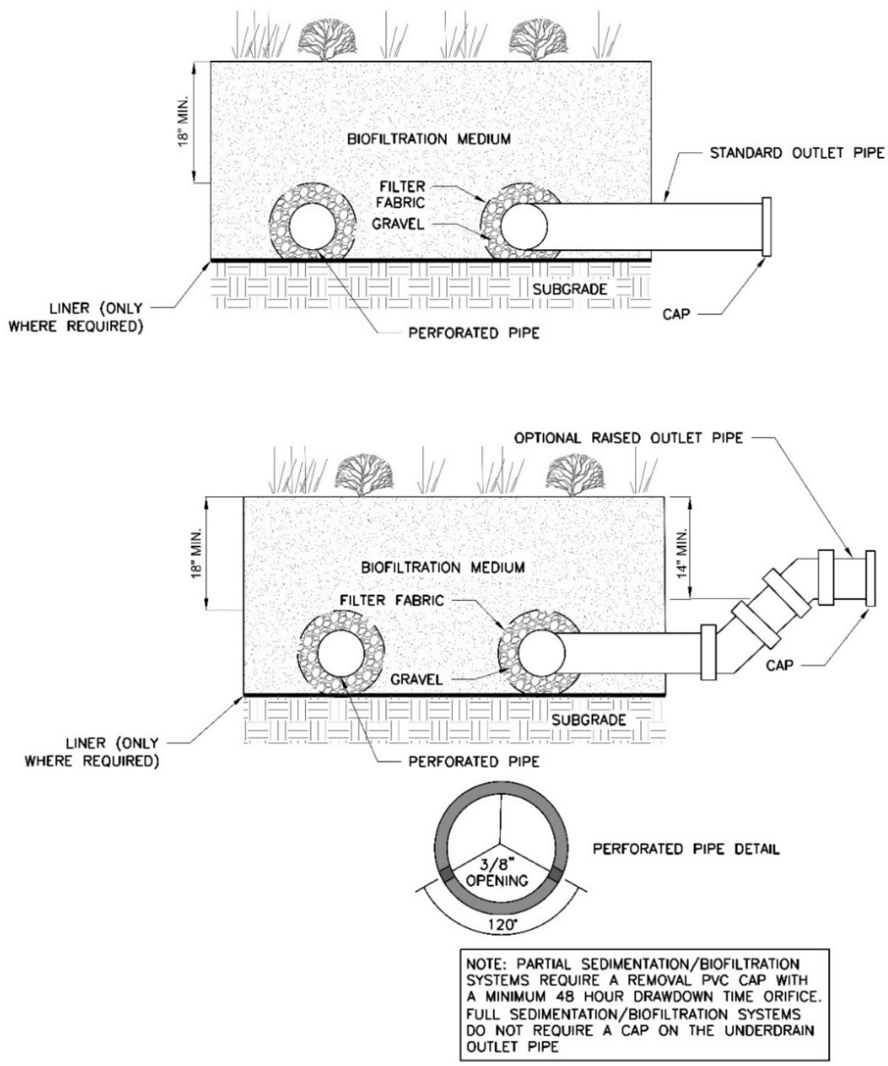


Figure 7004-6: Biofiltration Medium Bed with Underdrain System

- Access must be provided for cleaning all underdrain piping. Cleanouts with a removable PVC cap are required within fifty (50) feet of every portion of lateral, at collector drain lines, and at every bend. Top of the cleanout should be set flush with the top of the biofiltration medium bed or ground surface from which it emerges. It is recommended that cleanouts be located outside of the water quality volume ponding area and above the water quality volume elevation when feasible to reduce short circuiting caused by loss or damage to the cleanout caps. At least one lateral must be accessible for cleaning when the pond is full. The full pond cleanout must extend above the water quality elevation and/or be located outside of the water quality volume ponding area. To minimize vandalism or other types of damage, the use of exposed piping shall be avoided or minimized.
- The top surface of the biofiltration medium bed must be horizontal.

b. Outlet Structure

- The outlet structure shall be designed in accordance with design criteria for Sedimentation/Filtration Systems but may also include a raised outlet to create a saturated zone within the underdrain gravel area and part of the biofiltration medium. The advantages of a raised outlet are that the retained water is partially available to support plants in the filtration basin during extended dry periods and it reduces the total headloss across the system.
- The surface discharge from the underdrain pipe shall be non-erosive. A splash pad or other dissipation system may be necessary. Unless site conditions make it impossible, the underdrain pipe should discharge to a gravel trench in order to diffuse the discharge flow and promote infiltration and recharge.

4. Landscape Design

A diverse suite of plants should be selected based on their ability to survive under alternating conditions of inundation and extended dry periods, and in different areas within a facility (e.g., basin versus side slopes). High plant diversity will provide resiliency to the system and help prevent a situation where all vegetation is lost. Over time, the plant species that are best suited to the unique conditions of each basin will naturally self-select and spread.

The landscape elements for the sedimentation basin may be different than for the biofiltration basin, due primarily to different soil characteristics. Compared to most native soils in the Norman area, the biofiltration medium may drain more rapidly, and have less clay content.

The selection of plants for the biofiltration medium depth will also be limited because the medium depth is typically about 18-inches, thus plants with large root systems are not appropriate. Trees shall not be used in the biofiltration chamber with underdrains. The soil characteristics and depth, and soil moisture availability including groundwater, in the sedimentation basin or chamber will probably vary widely from site-to-site, and this will have a significant effect on the plant selection.

To lessen maintenance requirements, the designer has the option to specify native sod for the biofiltration basin as well, but the pollutant removal potential will be reduced due to the reduction in biological uptake in the root system.

a. Plant Selection, Quantities, and Spacing

- Vegetation shall be planted throughout the entire sedimentation and filtration basin areas as shown on a planting plan along with list of proposed plant species, container size, spacing, and quantity. The proposed vegetation must be diverse, appropriately distributed, and spaced according to the mature size of the particular plants. A landscape architect or other qualified landscape professional should be involved in the design to ensure appropriate plant species selection and layout.
- Minimum of five (5) different species planted covering 95% of basins surface areas. Annuals are not permitted. The designer can choose native plants from Section B of Appendix F of Zoning Ordinance, Trees and Plants for Oklahoma City, 2016, and/or OSU Extension’s Plant Selections for Oklahoma.
- Small trees can be incorporated in the filtration basin, around the perimeter of the filtration basin, above the water quality volume, as long as the underdrain system is protected from penetration by the tree root system.
- Small trees can be incorporated in the sedimentation basin, in the floor and side slopes within the water quality volume, if soil conditions and depth are appropriate, and measures are taken to prevent root penetration into the adjacent filtration underdrain system.
- Plants must be selected and arranged carefully so that they serve their intended functions. In addition to choosing plants for their aesthetic properties, select plants that:
    - Are adapted to the pond hydrology (i.e. both periodic flooding and drought).

- Are adapted to the soil types within the pond, whether native site soils or biofiltration media.
- Are suitable for their specific function (e.g. erosion control, filtration, etc.).
- Are durable, resilient and resistant to pests and disease.
- Are tolerant of the pollution in stormwater runoff.
- Have a root system of the desired type, mass and depth.
- Are resistant to weed invasion.
- Require minimal maintenance.
- Are not invasive.
- Are commercially available.

b. Sedimentation Basin

- To determine the minimum required quantity of rooted plants, multiply the total surface area (in square feet) of the sedimentation basin by ten percent (0.1). This number represents the minimum number of plants to be placed in the sedimentation basin.

c. Filtration Basin

- To determine the minimum required quantity of rooted plants, except turf grass, multiply the total surface area (in square feet) of the filtration basin by twenty percent (0.2). This number represents the minimum number of rooted plants to be placed in the filtration basin.

E. Construction and Maintenance Requirements

1. Construction

a. Review design with contractor in the field. Go over importance of hitting elevations, function of inlet location(s), and meeting specs on material.

b. Restrict and/or limit vehicular and foot traffic around infiltration basin areas.

c. Install as close to the end of construction as possible.

d. Off-line construction is preferred.

e. Keep sediment out of the infiltration device as much as practical.

f. Clearly mark infiltration areas before work begins to avoid soil compaction or sedimentation to preserve infiltration capacity.

g. Scarify subgrade before installing fill to loosen up native soil to promote infiltration.

h. Once area has been excavated, extremely important to move straight into filling with biofiltration media to avoid leaving materials along roadways exposed to weather conditions, which will promote cracking and slides.

i. Specify in technical specs that a design survey shall be completed to confirm inlet elevations, slope of facility, outlet pipes, pond depths, overflow elevations, etc. Consider showing in the detail which locations should be surveyed. Outline allowable tolerance.

j. Inspect materials (plants, double washed gravel, media) upon delivery to the site but before install to verify it meets specs. Check watertight seals at HDPE and PVC connections.

k. Specify construction sequence in construction docs.

2. Maintenance

a. For biofiltration basins only: unless damaged by unusual sediment loads, high flows, or vandalism, the biofiltration media should be left undisturbed and allowed to age naturally, and biofiltration pond vegetation shall be managed so that a dense, healthy vegetative cover is preserved.

b. As needed

- Inspect for clogging – rake first inch of sand.
- Remove sediment from forebay and chamber.
- Replace sand filter media.
- Inspect after large rainstorm.
- Keep drainage paths clean.
- Replace media if filter becomes clogged or over-compacted.

c. Bi-weekly during first growing season

- Inspect vegetation until 95% vegetative cover is established (if applicable).

d. Monthly

- Check to see that the filter bed is clean of sediment, and the sediment chamber is not more than 50% full or 6 inches, whichever is less, of sediment. Remove sediment as necessary.
- Make sure that there is no evidence of deterioration, spalling or cracking of concrete.
- Inspect trash rack.

- Inspect inlets, outlets and overflow spillway to ensure good condition an no evidence of erosion.
- Repair or replace any damaged structural parts.
- Stabilize any eroded areas.
- Ensure that flow is not bypassing the SCM.
- Ensure that no noticeable odors are detected outside the SCM.

e. As needed or 4 times during growing season

- Ensure that contributing area, sand filter, inlets and outlets are clear of debris.
- Weed (if applicable).
- Ensure that contributing area is stabilized.
- Ensure that activities in the drainage area minimize oil/grease and sediment entry to the system.
- Replace soil media in void areas caused by settlement; repair eroded areas; re-mulch by hand any void areas (if applicable).

f. Semi-annually

- Remove and replace dead or diseased vegetation that is considered beyond treatment; treat all diseased trees and shrubs mechanically or by hand depending on the insect or disease infestation (if applicable).
- If drawdown exceeds criteria, lightly scarify soil with hand cultivator.
- If standing water remains for greater than 96 hours, remove top layer of sediment, mulch and potentially revegetate (if applicable).
- De-compact soil by scarification and replace mulch and disturbed vegetation (if applicable).

g. Yearly

- If clogged, remove the top few inches of the sand, roto-till or otherwise cultivate the surface, and replace media with sand meeting the design specs.
- Replace any geotextile that has become clogged.

h. Every 3-5 years

- *Remove and replace the top 2-3 inches of sand in the filter*.

3. Design Example

Design a biofiltration basin in the 55,638 ft^2 area outlined in red below where the drainage area is 31.2 acres. Calculate dimensions of the basin and ponding depth required to hold the WQV.

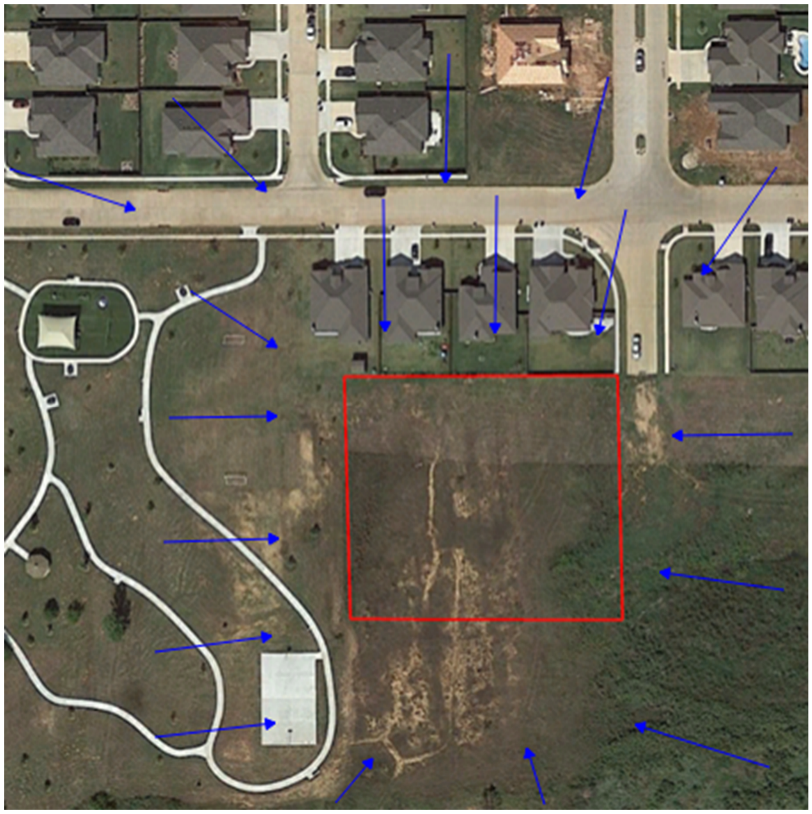


Figure 7004-7: Sedimentation-Filtration Example

Example 1: Full Sedimentation

Drainage area=31.2 acres

The water quality volume is calculated using **Equations 1 and 2**.

$$WQV = \frac{D_S * R_v * A}{12}$$

$$R_v = 0.05 + 0.009I$$

$$WQV = \frac{(1.0) * \left(0.05 + 0.009(45\%)\right) * (31.2)}{12}$$

$$WQV = 1.18\ acre - ft = 51{,}401\ ft^3$$

Calculate the minimum surface area of filtration media required using **Equation 32**. Assume a maximum ponding depth of 4 feet.

$$A_f = \frac{WQV}{(7 + 2.33H)}$$

$$A_f = \frac{1.180\ acre - ft}{(7 + 2.33(4\ ft))}$$

$$A_f = 0.072\ acre = 3{,}136\ ft^2$$

In accordance with L:W ≥ 2 for a sedimentation basin, assume a rectangular sedimentation basin containing 20% of the WQV.

$$V = H * L * W; L = 2W; V = H * 2W^2;\ 20\% * WQV = 2W^2 * H$$

$$W = \sqrt{\frac{20\% * 51{,}401\ ft^3}{4\ ft * 2}}$$

$$W = 35.8\ ft\ ; L = 71.6\ ft$$

Assume a rectangular filtration basin has the same width as sedimentation basin and L:W ≥ 1 and depth of 4.5 ft.

$$WVQ = L * W * D$$

$$L = \frac{51{,}401\ ft^3}{35.8\ ft * 4.5\ ft}$$

$$L = 320\ ft$$

Example 2: Partial Sedimentation

Drainage area=31.2 acres

The water quality volume is calculated using **Equations 1 and 2**.

$$WQV = \frac{D_S * R_v * A}{12}$$

$$R_v = 0.05 + 0.009I$$

$$WQV = \frac{(1.0) * \left(0.05 + 0.009(45\%)\right) * (31.2)}{12}$$

$$WQV = 1.18\ acre - ft = 51{,}401\ ft^3$$

Calculate the minimum surface area of filtration media required using **Equation 31**. Assume a maximum ponding depth of 4 feet.

$$A_f = \frac{WQV}{(4 + 1.33H)}$$

$$A_f = \frac{1.180\ acre - ft}{(4 + 1.33(4\ ft))}$$

$$A_f = 0.127\ acre = 5{,}532\ ft^2$$

In accordance with L:W ≥ 1 for a sedimentation basin, assume a square sedimentation basin containing 20% of the WQV.

$$V = H * L * W; L = W; V = H * W^2;\ 20\% * WQV = W^2 * H$$

$$W = \sqrt{\frac{20\% * 51{,}401\ ft^3}{4\ ft}}$$

$$W = 50.7\ ft\ ; L = 50.7\ ft$$

Assume a rectangular filtration basin has the same width as sedimentation basin and L:W ≥ 2 and depth of 4.5 ft.

$$WVQ = V_s + V_f$$

$$V_f = WQV - (20\ \% * WQV)$$

$$V_f = 80\% *\ WQV$$

$$W * L * H = 80\% *\ 51{,}401\ ft^3$$

$$L = \frac{80\% *\ 51{,}401\ ft^3}{50.7\ ft * 4.5\ ft}$$

$$L = 180.2\ ft$$

7004.2 Extended Detention Basin

A. Introduction

An extended detention (ED) basin is a surface storage basin or facility designed to provide water quality treatment and water quantity control through extended detention of stormwater runoff. Dry ED basins differ from dry detention basins in that they provide 48-hour detention of the water quality volume. It has an outlet structure that detains and attenuates runoff inflows and promotes the settlement of pollutants. The facility normally remains dry between storm events.

B. Design Criteria

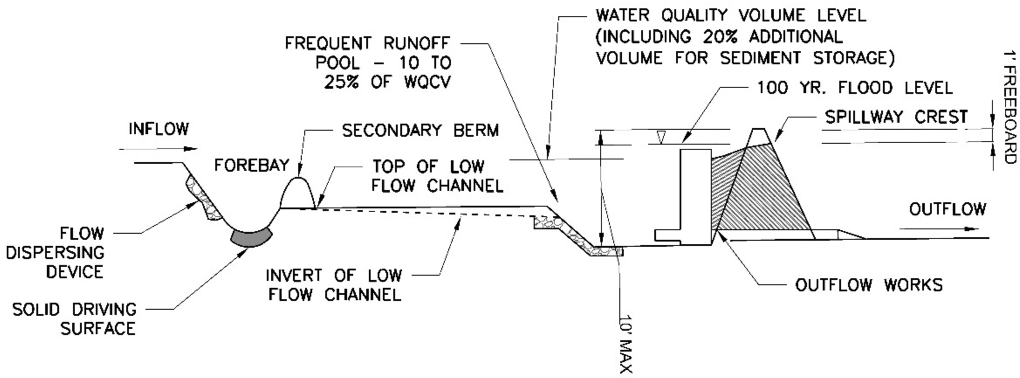


Figure 7004-8: Extended Detention Basin Cross-Section

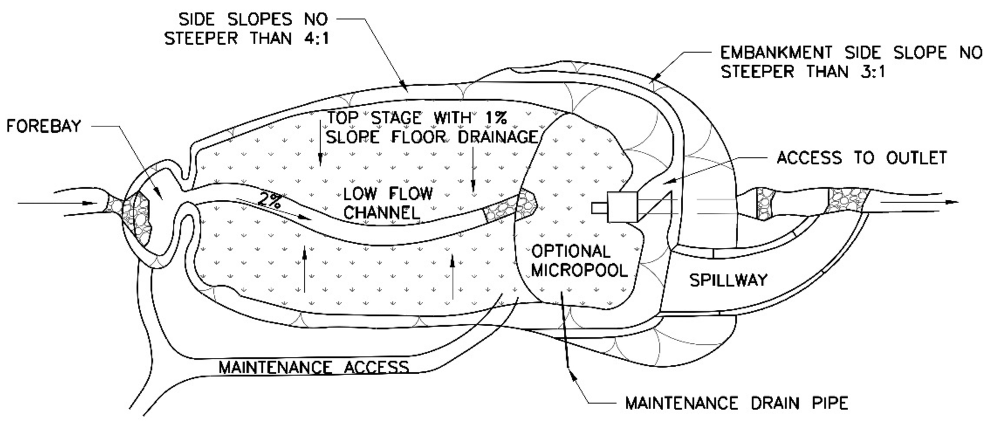


Figure 7004-9: Extended Detention Basin Plan View

1. Basin Size

   a. Design volume equal to water quality volume. Volume begins at the lowest orifice in the outlet structure.

   b. Designing dry ED basins with a high length to width ratio (i.e., at least 2:1) and incorporating other design features to maximize the flow path effectively increases the detention time in the system by eliminating the potential of flow to short circuit the basin.

   c. Drainage area less than 100 acres but large enough to use 12” or larger orifice size to prevent clogging.

   d. The depth of the basin should not exceed 10 feet. Any pond embankment configuration meeting the criteria for dam safety requirements must follow the criteria of the Oklahoma Water Resources Board.

2. Basin Elements

a. Forebay Design:

- The forebay provides an opportunity for larger particles to settle out in an area that can be easily maintained. The length of the flow path through the forebay should be maximized, and the slope minimized to encourage settling.
- The sediment forebay should be sized for 20% of the WQV.
- The forebay outlet should be sized to release 2% of the undetained peak 100-year discharge.
- For regional facilities not specific to a certain development, portions of the watershed may remain disturbed for an extended period of time. In this case, the forebay size will need to be increased due to the potentially high sediment load.
- An earthen berm with 3H:1V side slopes (or flatter) and a pipe outlet or a concrete wall with a notch outlet should be constructed between the forebay and the main basin.
- Erosion protection should be provided on the downstream side of the forebay berm/wall if the downstream grade is lower than the top of the berm or wall.

b. Basin Design

- Embankments should have side slopes no steeper than 3:1. Riprap-protected embankments should be no steeper than 2:1. Geotechnical slope stability analysis is recommended for embankments greater than 10 feet in height and is mandatory for embankment slopes steeper than those given above. All embankments must be designed to State of Oklahoma Water Resources Board criteria for dam safety.
- The bottom area of storage facilities should be graded toward the outlet to prevent standing water conditions. Minimum slope of 1% along side slopes and 2% along main flow path from inlet to outlet. Designing basins with relatively flat side slopes can also help to lengthen the effective flow path.
- Emergency spillway should be included in the basin design to safely pass the 100-year storm. The spillway prevents water levels from overtopping the embankment and causing structural damage. The emergency spillway must be located so that downstream structures will not be impacted by spillway discharges.

- A minimum of 1 foot of freeboard must be provided, measured from the top of the water surface elevation for the 100-year storm event, to the lowest point of the embankment.
- Stormwater should be conveyed to and from dry ED basins safely and to minimize erosion potential.

c. Low Flow Channel:

- Convey low flows from the forebay to the micropool with a low flow channel. The channel should have a minimum flow capacity equal to the maximum release from the forebay outlet.
- For concrete channels, a side slope between 0.4% - 1% is recommended to encourage settling while reducing the potential for low points within the section.
- To prevent stream warming, designers can place landscaping to provide shade around low flow channel and the basin outlet.

d. Micropool and Outlet Structure:

- Locate the outlet structure in the embankment and provide an optional permanent micropool directly in front of the structure. Micropools reduce shallow wet areas where mosquito breeding can happen.
- Submerge the well screen to the bottom of the micropool. This will reduce clogging of the well screen because it allows water to flow though the well screen below the elevation of the lowest orifice even when the screen above the water surface is plugged. This will prevent shallow ponding in front of the structure, which provides a breeding ground for mosquitoes (large shallow puddles tend to produce more mosquitoes than a smaller, deeper permanent pond).
- Micropool side slopes may be vertical walls or stabilized slopes of 3H:1V maximum.
- For watersheds with less than 5 impervious acres, the micropool can be located inside the outlet structure.
- The micropool should be at least 2.5 feet in depth with a a capture volume of 15-25% of the WQV.
- The bottom should be concrete unless a baseflow is present or anticipated or if groundwater is anticipated. Riprap is not recommended because it complicates maintenance operations.

- Where possible, place the outlet in an inconspicuous location.
- The outlet should be designed to release the WQV over a 48hour period. No more than 50% of the water quality volume should drain from the facility within the first 24 hours.
- Outlet structure can consist of a weir, orifice, outlet pipe, combination outlet, or other acceptable control structure. Coordinate with a professional engineer to determine if a pipe cradle through the embankment is warranted.
- A dry ED basin has a channel protection orifice with a minimum diameter of 3 inches. The orifice diameter may be reduced to 1 inch if internal orifice protection is used (e.g., an over-perforated vertical stand pipe with 0.5-inch orifices or slots that are protected by wirecloth and a stone filtering jacket). Adjustable gate valves can also be used to achieve this equivalent diameter.
- Seepage control or filter diaphragms should be provided for all outlet pipes.
- Riprap, plunge pools or pads, or other energy dissipaters are to be placed at the end of the outlet to prevent scouring and erosion. If the basin discharges to a channel with dry weather flow, care should be taken to minimize tree clearing along the downstream channel, and to reestablish a forested riparian zone in the shortest possible distance from the dry ED basin.
- The facility should have a separate drain pipe with a manual valve that can completely or partially drain the pond for maintenance purposes. To allow for possible sediment accumulation, the submerged end of the pipe should be protected, and the drain pipe should be sized one pipe schedule higher than the calculated diameter needed to drain the pond within 24 hours. The valves should be located at a point where they can be operated in a safe and convenient manner.

e. Initial Surcharge Volume

- Providing a surcharge volume above the micropool for frequently occurring runoff minimizes standing water and sediment deposition in the remainder of the basin. This is critical to turf maintenance and mosquito abatement in the basin bottom. The initial surcharge volume is not provided in the micropool nor does it include the micropool volume. It is the available storage volume that begins at the water surface elevation of the micropool and extends upward to a grade break within the basin (typically the invert of the trickle channel) The area of the initial surcharge volume, when full, is typically the same or slightly larger than that of the micropool.

- The initial surcharge volume should have a depth of at least 4 inches. For watersheds of at least 5 impervious acres, the initial surcharge volume should also be at least 0.3% of the WQV.
- The initial surcharge volume is considered a part of the WQV and does not need to be provided in addition to the WQV.

f. Trash Rack

- Provide a trash rack (or screen) of sufficient size at the outlet to provide hydraulic capacity while the rack is partially clogged. Openings should be small enough to limit clogging of the individual orifices. The trash rack should be sloped with the basin side-slopes.

g. Landscaping

- Designers should maintain a vegetated buffer around dry ED basins, selecting plants within the detention zone (i.e., the portion of the basin up to the elevation where stormwater is detained) that can withstand both wet and dry periods. The side slopes of dry ED basins should be relatively flat to reduce safety risks.
- Woody vegetation may not be planted or allowed to grow within 15 feet of the toe of the embankment nor within 25 feet from the principal spillway structure.
- Plantings should be designed not to conflict with the current drainage of the basin.
- All trees should be kept away from any drainage structures to allow for maintenance access and repairs as needed.

C. Construction and Maintenance Requirements

1. Provide appropriate maintenance access to the forebay and outlet works.
2. Monthly or as needed:

a. Remove trash, sediment, and debris from forebay and inlet and outlet structures.

b. Mow the embankment and maintenance access. Periodically mow along maintenance rights-of-ways and the embankment. Remove grass clippings.

3. As needed:

   a. Repair and re-vegetate eroded areas.

   b. Remove and dispose of vegetation that may hinder the operation of the pond.

   c. Perform structural repairs to pond, outlet structures, embankments, control gates, valves, or other mechanical devices.

   d. Remove sediment when volume of pond is reduced by 10%.

7004.3 Wet Ponds

A. Introduction

Wet ponds are stormwater basins constructed with a permanent (dead storage) pool of water equal to the water quality volume. Stormwater runoff displaces the water already present in the pool during a storm event. Temporary storage (live storage) is also provided as an extended detention volume above the permanent pool elevation. Flood detention storage can also be stacked on top of extended detention volume to detain larger flood flows.

B. Design Criteria

Minimum of 25 acres is needed for a wet pond or wet ED pond to maintain a permanent pool. Smaller drainage area may be acceptable with an adequate water supply and anti-clogging device.

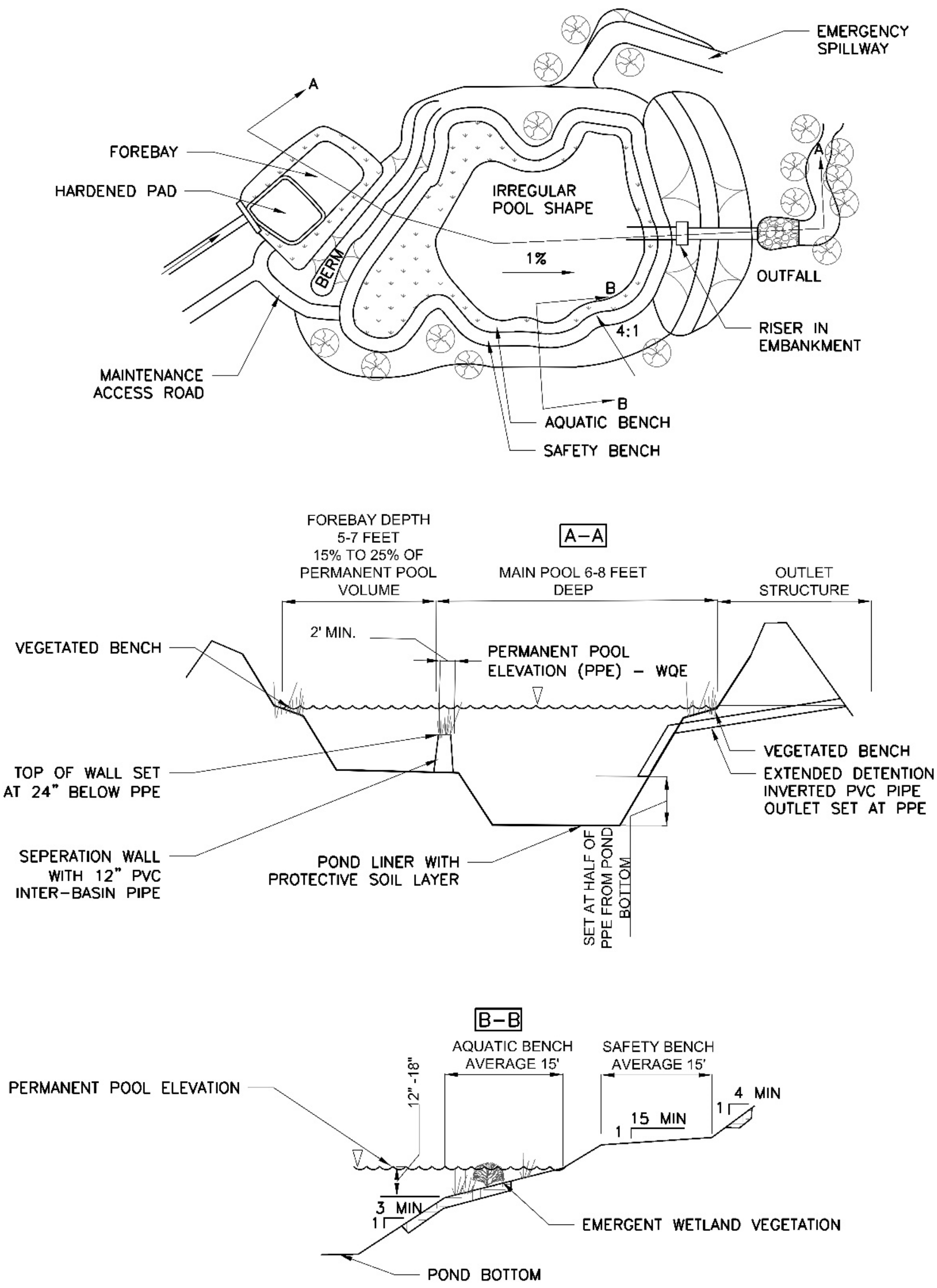


Figure 7004-10: Wet Pond Plan View and Cross-Sections

1. Capture Volume

Wet ponds in general are designed to have three stages with three corresponding volumes, which are intended to meet the water quality and detention requirements. The first two stages, permanent pool and extended detention, are required for all ponds and function primarily as a water quality control. The second stage may also serve as a streambank erosion prevention measure. The third stage, flood control detention, serves as a flood control measure and is optional to the design of the wet pond.

The permanent pool and extended detention volume shall be designed for the entire drainage area contributing to the control for which water quality controls are not already provided. Offsite areas, which are currently undeveloped, may be assumed undeveloped in the design. The primary reason to require extended detention for all of the developed drainage areas, which have not provided detention, is to prevent pond washout caused by high flow-through rates.

a. Permanent Pool

- The permanent pool, the lowest stage of the pond, is designed to hold and treat the WQV between storm events through quiescent settling and biological uptake. The permanent pool should remain nearly full at all times (maximum 12" below the permanent pool) to provide a source of water for wetland plants which are used for biological uptake and to minimize turbulence within the pond during storm events which may result in resuspension of sediment. During storm events, the pond is designed to flush out the treated water and replace it with "new" runoff. The minimum surface area of the permanent pool must be greater than ½ acre.
- The permanent pool volume should be sized to 100% of the water quality treatment volume. When the drainage area to the pond contains only uplands, an increase of volume by five percent is acceptable to account for sedimentation loss. If the pond is located where it may receive streambed loads, a more detailed analysis will be required to account for storage losses.

b. Extended Detention

- The extended detention portion of the pond minimizes turbulence in the pond by decreasing the pond flow-through rate and increasing the time in which sedimentation can occur during the storm through dynamic settling. The extended detention volume for wet ponds should be designed to detain half the water quality volume. The extended detention volume cannot include the volume provided in the permanent pool because the permanent pool is designed to be full at the start of the rainfall event.

c. Flood Control Detention (optional)

- The standard detention volume should be designed to meet the city's flood control requirement, in accordance with **Section 5000:** of the EDC and it may include the volume contained as extended detention.

2. Drainage Area

The drainage area to the pond must have the following characteristics.

a. Size Limits

- The drainage area must be large enough to allow an adequate supply of runoff. A minimum drainage area of twenty-five acres is needed. Smaller drainage areas will be considered based upon a demonstration that the wet pond can provide pond depths great enough to minimize water surface fluctuations, an adequate area for vegetation, and enough surface area to allow aeration dictates this minimum drainage area. The drainage area may not exceed 320 acres.

b. Site Slope

- There should not be more than 15% slope across the drainage area to the pond.

c. Phased Development

- A wet pond that serves a phased development may not have adequate impervious cover to generate the necessary runoff during the initial phases. In this instance, a plan must be submitted that demonstrates what accommodations will be made to address this concern.

d. Hazardous Materials Traps

- Spills of hazardous liquids can severely damage or kill the biota of a wet pond. Therefore, developments where the transportation, storage, or distribution of hazardous materials is anticipated should include hazardous material traps in the drainage system immediately upstream of the wet pond inlet.

3. Basin Elements

The permanent pool volume must be held in two compartments. The first is called the sediment forebay and the second is called the main pool. These basins must consist of deep pools and shallow vegetated benches. Other aspects of the pond include maintenance access points, maintenance pads, an outlet structure, and an impermeable liner.

a. Basin Geometry, Plug Flow, Short-Circuiting, Dead Storage, and Multiple Inlets

- Wet ponds work best when the water already in the pond is moved out in mass by incoming flows. The pond should be designed to enhance plug flow characteristics and minimize short-circuiting and dead storage. Design features that encourage plug flow and avoid dead storage are:
    - Dissipating energy at the inlet.
    - Providing a large length-to-width ratio (no less than 2:1).
    - Provide a broad surface for water exchange using a berm or island that functions as a broad-crested weir, separating the pond into two cells, a sediment forebay and the main pool.
    - Maximizing the flow path between the inlet and outlet.
    - Make pond wide enough to achieve water depth of 6'+ for more than 50% of the pond area.
- Wet ponds with multiple inlets should be avoided. If unavoidable, the professional engineer will be required to demonstrate that the proposed design will provide treatment equivalent to a design that does not have multiple inlets. This may require providing additional permanent pool volume. Each inlet must have a sediment forebay provided, as described below.

b. Sediment Forebay

- All runoff from impervious areas must discharge into a sediment forebay to capture coarse sediment and trash in a location that can be easily assessed for maintenance purposes. Sediment forebays must be designed to minimize short-circuiting and dead storage problems.
- Energy dissipation is needed at the inflow point(s) to prevent scouring of the basin floor and to quickly reduce the turbulence within the forebay.
- The forebay must hold fifteen to twenty-five percent of the permanent pool volume.
- The sediment forebay and main pool must be separated by an earthen berm (preferably utilized as a portion of the vegetated bench), or using a six inch or thicker reinforced

concrete wall. The top of the wall should be set at twenty-four (24) inches below the permanent pool water surface elevation. The submerged earth berm should have a minimum top width of two feet and meet the following conditions:

    - The material used for construction must be stable when saturated and when the maximum hydrostatic force is applied.
    - The side slope must be stable when saturated.
    - Shall be constructed to avoid damage to the liner and to prevent seepage between the berm and the liner.
    - The berm must protect against erosive forces on the top of the berm in high flow conditions. When the earth berm is used, it should also be included as part of the vegetated bench.

- The forebay and main pool must be hydraulically connected with a horizontal twelve inch or larger Schedule 40 PVC pipe called an inter-basin pipe to ensure that there will be an adequate supply of water in the forebay in dry conditions. The elevation of the inter-basin pipe should be two feet above the bottom of the forebay and a plug valve included in the line to allow independent draining (by pump) of the sediment forebay after drawing both basins down to the top of the separating wall.
- The sediment forebay must have a depth from five to seven feet.
- A maintenance pad must be provided to allow for routine removal of sediment using heavy equipment soon after the basin is drained without requiring additional time for the basin bottom to dry. The pad is to be made of reinforced concrete and be a minimum of twelve feet by sixteen feet. The pad may be located outside of and adjacent to the forebay, or at the bottom of the forebay. If the latter, the bottom of the forebay should have a minimum two percent slope towards a low point. This maintenance pad must be enlarged as needed to cover the portion of the basin which cannot be sloped inward at two percent. An examination of the hydrostatic forces on the maintenance pad when the forebay is empty and the main pool is full should be performed when designing the thickness of the pad. Pads less than four inches in thickness are prohibited. The maintenance pad should not compromise the integrity of the pond liner.

- The professional engineer should incorporate an impermeable membrane or additional liner material to prevent excess leakage at the edge of the maintenance pad. A twelve-foot-wide concrete maintenance access ramp with a maximum slope of four to one and broom finish must lead from at least twelve inches above the permanent pool elevation to the maintenance pad.

c. Main Pool

- The main pool must contain the remainder of the permanent pool volume and have a depth from six to eight feet. Areas deeper than eight feet may result in the pond becoming anaerobic, possibly resulting in odors, and are prohibited unless approved by the City. The main pool must be designed to minimize short-circuiting and dead storage problems.

d. Vegetated Bench

- A permanently submerged shallow wetland area incorporated into and/or surrounding the pond must be provided and is called the vegetated bench. The vegetated bench must be a minimum of five (5) to fifteen (15) percent of the total pond area. The slope of the vegetated bench must be in accordance with Table below.

e. Submerged Inlets

- Submerged inlets are to be avoided whenever possible. In situations where site conditions require a submerged inlet then the portion of the inlet pipe that is placed below the permanent pool elevation must be designed to store water, not simply convey it. In these situations, the pond liner must extend and surround the portion of the inlet pipe that is designed to be under water.

f. Pond Liner

- The sediment forebay and main pool must have an impermeable liner to contain the runoff and to prevent excessive seepage in accordance with 7002.5.
- Protective soil layer above the liner - All areas of the pond that are to receive and support vegetation must have a protective soil layer installed on top of the liner, regardless of the type of liner, so that plantings can be properly installed above the liner and the liner integrity can be maintained. This protective soil layer must be a minimum of 12-inches in thickness.

g. Pond Side Slopes

- Pond earthen side slopes must not be steeper than a four to one ratio, and must be designed to ensure their stability, especially when saturated. The pond liner must extend up the side slopes as high as is necessary to maintain a permanent pool volume. Where the liner extends under the separating berm, it is not necessary for the liner to extend up the side slopes of the separating berm. Utility lines may not be located within ten feet from the top of the pond side slope.

h. Dam Safety

- Any pond embankment configuration meeting the criteria for dam safety requirements must follow the criteria of the Oklahoma Water Resources Board.

4. Outlet Structures

The design of the outlet pipe is important to enhance the plug flow characteristics of the pond. This section provides criteria in designing the outlet structure. Other designs will be evaluated for their ability to provide plug flow and maintainability. In most cases, the ponds will be designed with two primary outlet structures and a maintenance drain. In all cases, the extended detention volume must drawdown within 48 hours but no less than 24 hrs. Energy dissipation is required to prevent erosion at the outfall location.

a. Extended Detention

- *The extended detention outlet structure must be constructed using an inverted PVC pipe with the soffit of the inlet set at an elevation which is one half (½) of the permanent pool depth from the bottom. The flow line of the outlet of the pipe must be set at the permanent pool elevation. No outlet other than the extended detention outlet will be permitted below the extended detention volume. In all cases, the pond will be designed so that the minimum pipe diameter is no less than six inches to minimize clogging potential; the size of the orifice at the end of the pipe may be smaller than six inches to achieve the required extended detention. If an orifice plate is used to achieve the required 48 hour drawdown, the orifice must be removable and accessible when the pond is at the extended-detention elevation in order to service blockage. It is recommended that this line discharge into the manhole required for the maintenance drain and discussed in that section.*
- If an orifice is not used to control the drawdown, the flow in the inverted discharge pipe used for extended detention must be calculated using a method that more accurately

accounts for energy losses than the orifice equation. One equation that may be used is:

$$Q = A\left(\frac{2gh}{1+k_e+k_b+k_f}\right)^{0.5} \qquad (34)$$

Where,

Q=flow (cfs)

A=cross-sectional area of the pipe (ft^2)

g=acceleration due to gravity (32.2 ft/s^2)

k_e=entrance loss coefficient

k_b=bend losses

k_f=friction loss coefficient. The friction loss coefficient can be found using the equation:

$$K_f = \frac{29Ln^2}{R^{1.33}} \qquad (35)$$

Where,

L=pipe length (ft)

n=Manning's roughness coefficient

R=hydraulic radius (ft)

b. Flood Control Detention

- EDC **Section 5000:** must be referenced for design of the outlet structure to serve for flood control. When flood control detention is not needed, an overflow spillway capable of passing the 100-year storm is required at or above the elevation at which the extended detention volume is provided. To enhance water quality, a two to one length to width ratio from the inflow to the outflow must be maintained.

c. Maintenance Drain

- A drain line, which can completely or partially drain the permanent pool, must be included where topographic relief exists. The purpose of the drain is to allow for the pond to be drained for long-term maintenance activities. A plug valve must be installed in the line, and the valve must be protected by enclosing it in a manhole set in the pond berm. If the maintenance drain cannot completely drain the pond, a 6 ft. × 6 ft. square concrete pump pad must be provided at the lowest point in the main pool to provide a base for temporary installation of a submersible pump.

C. Biological Elements

Biological elements are an important aspect to the function as well as the aesthetics of the wet pond system. The following criteria must be followed to enhance pollutant removal and minimize undesirable activity.

1. Wetland Plantings

The functions of plants in a wet pond are to physically slow the flow of water and cause suspended particles to fall out, provide a substrate on which associated microbes assimilate organics, metals, and nutrients, take up pollutants from the sediment into the roots, and oxygenate the water.

To determine the minimum requirement for wetland plant quantity, multiply the surface area (in square feet) of the permanent pool by three percent (0.03).

All wetland plants which fulfill the minimum landscape requirements shall be propagated from, or harvested from, regionally adapted stock. These are plant species or genotypes which are native to a range of within 200 miles of the project site. Wetland plants grown outside the state of Oklahoma are not acceptable. Plants not intended to meet minimum requirements do not need to be native or regionally adapted stock however under no circumstances may invasive plants be planted. Refer to Section B of Appendix F of Zoning Ordinance, Trees and Plants for Oklahoma City, 2016, and/or OSU Extension's Plant Selections for Oklahoma for native allowed plantings.

A minimum of 90% of the vegetation shall be alive and viable for one year following installation.

Wetland plants are adapted to specific water depths. These criteria identify pond planting zones based on the depth of the permanent pool. Install plants at water depths appropriate to the species. The water depths noted in the following tables show the range of depths in which these plants must be planted. The plants will often colonize deeper water than that in which they are planted. Taken together, the following zones comprise the vegetated bench.

a. Pond Bank Slopes

- Plant material must be able to withstand frequent inundation with water, as well as occasional drought. If shading is needed along the shoreline, the more rapidly-growing species such as Sycamore are preferred over the more slowly developing species, such as Swamp White Oak. Plants must be able to withstand periodic inundation of water after storms, as well as occasional drought during the warm summer months. Plants should stabilize the ground from erosion caused by runoff. In between storms, typical moisture conditions may be moist, slightly wet, or even exhibit drought conditions during the dry weather periods. Ground cover on the berms should be very low maintenance because they may be difficult to access on steep slopes or if frequency of mowing is limited. Woody vegetation may not be planted or allowed to grow within 15 feet of the toe of the embankment nor within 25 feet from the principal spillway structure.

b. Pond Edge Zone

- The pond edge zone is an area of saturated soil surrounding the perimeter of the pond. The zone extends from an elevation 3" above the permanent pool level to an elevation 3" below the permanent pool level. While a portion of this zone is above the elevation of the vegetated bench, native plants listed in Refer to Section B of Appendix F of Zoning Ordinance, Trees and Plants for Oklahoma City, 2016, and/or OSU Extension's Plant Selections for Oklahoma that are installed in this area will count towards fulfilling the required minimum number of plants.

c. Marsh Zone

- The marsh zone is the shallow water area within the pond. The zone extends from an elevation 3″ below the permanent pool level to an elevation 12″ below the permanent pool level.

d. Deep Water Zone

- The deep water zone extends from an elevation 12″ below the design pool level down to an elevation 24″ below the design pool level. This zone includes submergent plants (which grow underwater), floating-leaved aquatic plants, and tall emergent plants. Install submergent and floating-leaved aquatic plants throughout the pond to encourage colonization in a variety of locations, including the submerged earthen berm between the sediment forebay and the main pool.

2. Integrated Pest Management

As with any landscape, there is a need for pest management in wet ponds. To the extent possible, these criteria are designed to minimize the potential for pests within a wet pond.

a. Algae

- High nutrient loads in wet ponds may cause algae blooms to occur. Pungent odor is often associated with these algal blooms. However, treating with an algaecide is not recommended because blooms are usually short lived and are considered desirable for nutrient removal. The use of submergents and floating-leafed aquatics can reduce the extent of alga blooms by reducing nutrient loads and shading the water.

b. Wildlife

- Wildlife are occasionally a pest of wet ponds. Evaluation of the potential of such wildlife inhabiting or being attracted to the proposed pond site is required. When there is a potential for such activity, fencing or similar exclusionary method must be provided.

c. Mosquito Control

- Mosquitoes are problematic in urban areas. There is the potential for standing water in wet ponds to become ideal breeding localities. The wet pond should be stocked with the local native fish species Gambusia affinis to serve as a biological control for mosquitoes. Gambusia provide effective control for mosquitoes, eliminating the need for chemical control. Gambusia should be stocked at the initial density of 200 individuals per surface acre. Additionally, the City will accept the introduction of species as recommended by the OK Department of Wildlife Conservation.

d. Domestic Waterfowl

- Domestic waterfowl, including geese and swans can destroy vegetation and increase pollutant loading in wet pond systems. In addition, waterfowl can become nuisances to property owners near the pond. For these reasons, domestic waterfowl should not be introduced into these systems.

e. Fish

- Fish other than Gambusia affinis should not be introduced into a wet pond.

3. Water

a. Pond Water Losses

- While fluctuation of the permanent pool level is to be expected due to climatic conditions, type and extent of vegetation, phased developments and other factors, the minimum level acceptable at any time is 12" below the permanent pool (the lower limit of the marsh zone). This minimum water level is necessary for both aquatic plant survival and, if the liner material is clay, to keep the clay moist to prevent cracking.

- A water balance is necessary to determine if the pond is experiencing a water loss in excess of normal anticipated losses. It must be performed to develop performance criteria for the pond to be measured against upon completion of the pond construction. The professional engineer must specify criteria for acceptance testing of the pond over a specified period of time, using actual daily water level measurements, actual daily precipitation data, and other required data to determine whether the pond is losing water in excess of anticipated losses.
- One reason the permanent pool may stabilize lower than the design level is if development in the contributing watershed is phased in over a long period of time, such that the impervious cover and runoff coefficient at the early phases of construction are less than the final, build-out values. In this case the amount of water available to fill the wet pond may be lower at the earlier development phase, which would strand the vegetated bench below the permanent pool level, an unacceptable situation. The designer and contractor must ensure that the vegetated bench is submerged per the above criteria for wetland plant survival and to maintain liner integrity. It is unacceptable for the water level to remain low for an extended period of time, such that the health of the wetlands plants is threatened due to lack of moisture.

b. Aeration and Recirculation Unit (optional)

- Privately maintained wet ponds may include some type of aeration device (such as a fountain) which could enhance the dissolved oxygen concentration. Increased dissolved oxygen prevents the pond from becoming anaerobic, hence minimizing problems with odor from bacterial decomposition.

c. Make-up Water

- The water balance should use a daily time step and account for all significant inflows (rainfall, runoff, supplemental water) and outflows (evaporation of open water, evapotranspiration of wetland vegetation/vegetated bench, seepage, water withdrawals). A range of climatic conditions should be modeled, including but not limited to, average and dry years. The water balance serves two purposes. First, it is necessary to provide information for determining pond sizing requirements and any supplemental (makeup) water requirements, as applicable.
- A nearby source for non-chlorinated make-up (supplemental) water is recommended as a way to maintain an adequate permanent pool level should the level drop to a severe

drought. Potable and effluent water is not an acceptable make-up water source. Demonstrate that the quality of the make-up water is in compliance with all applicable regulations and will not harm the pond biology.

D. Construction and Maintenance Requirements

1. Construction

a. In mature ponds with abundant vegetation, aquatic plants supply the necessary litter layer and aerobic zone for microbial activity. However, since new ponds lack a sufficient source of organic matter, an appropriate amount of carbon (straw, hay, leaf clippings, soil, and other non-woody material) shall be installed during construction. After the pond liner is in place, yet prior to allowing the pond to be filled, spread the plant litter evenly on the sides of the pond (below the permanent pool level). Treat the entire shallow water bench in this manner, and all pond slopes (ranging from 3:1 to 10:1). The minimum required amount of plant litter is 45 pounds per 1,000 square feet of slope. When using coastal hay, this requirement can be expressed as 1.5 bales at 30 lb./bale. Ensure that the plant litter will not float by attaching the litter to the slopes (with staples or other appropriate methods). Cover a minimum of 40% of the slope surface area.

b. After the pond liner is completed, the basin must fill up with water within a reasonable time period, preferably within one week. Safety concerns and pond liner integrity concerns must be properly addressed during pond construction.

c. Accumulation of sediment in the basin is the primary reason the pond will require intensive maintenance. Because of this, very careful attention should be paid to adequate, well-maintained erosion and sedimentation controls in the contributing drainage area during construction. This, in combination with the sediment forebay, should prevent the requirement of maintenance of the main pool soon after the pond is put online.

d. The sediment load to the sediment forebay shall be closely monitored after every storm event. If heavy sediment loads are detected during an inspection, the source should be corrected. Sediment shall be removed from the sediment forebay when one-third of the forebay volume is lost.

e. Any sediment build-up (greater than 5% volume loss) shall be removed from the forebay upon completion of site revegetation. The sediment build-up in the main pool shall be checked and if more the ten-percent of the volume is lost, it should be cleaned at that time.

2. Maintenance

   a. Monthly

      - Inspect inlet and outlet structures for debris and illegal dumping. Remove debris as needed. Check for potential undercut or eroded areas during monthly inspection. Repair as needed.

   b. Every Three Months for the First Two Years

      - During the three month initial inspection cycle, if more than fifteen percent of the volume of the forebay is lost, it shall be cleaned at that time.

   c. Every Three Months

      - Turf areas along maintenance ROW should be mowed. Accumulated paper, trash, and debris shall be removed every three months or as necessary. Cattails, cottonwoods, and willows can quickly colonize shallow water and the edge of the pond. These species or any areas of plant overgrowth may be thinned at this time or as needed.

   d. Semiannual Inspection

      - Inspect for invasive vegetation along within the pond and along the banks. If wetland components are included in the design, inspect for wetland invasive species.

   e. Annually

      - The basin should be inspected annually for side slope erosion and deterioration or damage to the structural elements. Any damage shall be repaired. Large areas, which have dead or missing vegetation, shall be replanted.
      - Move banks and buffers once a year or every other year.
      - Check for signs of eutrophic conditions, hydrocarbon build-up, review mechanic devices, if applicable. Confirm structural integrity of the downstream face of the dam, and review wetland plant management and harvesting needs.

   f. Every Three Years

      - The sediment build-up in the sediment forebay shall be checked. The sediment forebay shall be cleaned if more than one-third of the forebay volume is lost.

   g. Every Six Years

      - The sediment build-up in the main pool shall be checked. Sediment shall be removed from the main pool when twenty percent of the main pool volume is lost.

- Consider the source of the excavated sediments during pond maintenance. If sources upstream are known to be contaminated, land application of sediment is not permitted. Contaminated sediment must be disposed of to prevent further contamination of existing site conditions. Analytical tests may be required prior to sediment disposal or reuse.

7005 MANUFACTURED SYSTEMS

7005.1 Introduction

Some manufactured systems will also be approved for usage in the City. Manufactured systems are commercial products that typically aim at providing stormwater treatment in space-limited applications. The most commonly encountered classes of proprietary stormwater management controls include hydrodynamic separation, catch basin insert technologies, cartridge filter-type controls, and proprietary biotreatment devices. Each project will require the professional engineer to work with the vendor to develop the design.

A. Hydrodynamic separation devices (alternatively, swirl concentrators)

- Remove trash, debris, and coarse sediment from incoming flows using screening, gravity settling, and centrifugal forces generated by forcing the influent into a circular motion.
- By having the water move in a circular fashion, rather than a straight line, it is possible to obtain significant removal of suspended sediments and attached pollutants with less space as compared to wet vaults and other settling devices. Hydrodynamic devices were originally developed for combined sewer overflows (CSOs), where they were used primarily to remove coarse inorganic solids. Hydrodynamic separation has been adapted for stormwater treatment by several manufacturers and is currently used to remove trash, debris, and other coarse solids down to sand-sized particles. Several types of hydrodynamic separation devices are also designed to remove floating oils and grease using sorbent media.

B. Catch basin inserts

- Manufactured filters or fabric placed in a drop inlet to remove sediment and debris and may include sorbent media to remove floating oils and grease.
- There are a multitude of inserts of various shapes and configurations, typically falling into one of three groups: socks, boxes, and trays.
- The sock-type filters are typically constructed of a fabric, usually polypropylene. The fabric may be attached to a frame, or the grate of the inlet may hold the sock. Socks are meant for vertical (drop) inlets.

- Boxes are constructed of plastic or wire mesh. Typically, a polypropylene “bag” is placed in the wire mesh box and the bag takes the form of the box. Most box products are one box; that is, settling and filtration through media occur in the same box.
- The trays may hold different types of media. Filtration media vary by manufacturer. Types include polypropylene, porous polymer, treated cellulose, and activated carbon.
- Inserts are an easy and inexpensive retrofitting option because drain inlets are already a component of most standard drainage systems. Inserts are usually only suitable for mitigating relatively small tributary areas (less than 1 acre).

C. Cartridge filter–type controls

- Typically consist of a series of vertical filters contained in a vault or catch basin that provide treatment through filtration and sedimentation.
- The vault may be divided into multiple chambers where the first chamber acts as a pre-settling basin for removal of coarse sediment while another chamber acts as the filter bay and houses the filter cartridges.
- The performance and capacity of a cartridge filter installation depends on the properties of the media contained in the cartridges. Cartridge filter manufacturers often provide an array of media types each with varying properties, targeting various pollutants and a range of particle sizes. Commonly used media include media that target solids, such as perlite, and media that target both dissolved and non-dissolved constituents, such as compost leaf media, zeolite, and iron-infused polymers.
- Manufacturers try to distinguish their products through innovative designs that aim at providing self-cleaning and draining, uniformly loaded, and clog resistant cartridges that functional properly over a wide range of hydraulic loadings and pollutant concentrations.

D. Biotreatment devices

- Manufactured to mimic natural systems such as wetlands by incorporating plants, soil, and microbes engineered to provide treatment at higher flow rates or higher volumes and with smaller footprints than their natural counterparts.
- Incoming flows are typically filtered through natural media (mulch, compost, soil, plants, microbes, etc.) and either infiltrated or collected by an underdrain and delivered to the storm system.

- Contributing drainage areas to biotreatment devices tend to be limited to 0.5 to 1.0 acres.
- The vendors of the various manufactured SCMs provide detailed documentation for device selection, sizing, and maintenance requirements. Contributing drainage area sizes are limited to the capacities of the largest available model. The latest manufacturer supplied documentation must be used for sizing and selection of all proprietary devices.

7005.2 Design Requirements

Proprietary SCM vendors are constantly updating and expanding their product lines, so refer to the latest design guidance from the vendors.

Use of any manufactured system must be approved by the City and be:

An approved best management practice listed in **Texas Commission on Environmental Quality RG-348** including Addendum Sheet, or;

An approved technology from the **State of Washington Department of Ecology Technology Assessment Protocol- Ecology table that meets either the conditional use level designation or general use level designation.**

A. General Design

- For units maintained by the City, the designer shall work with the City to determine appropriate placement such that the unit can be maintained properly.
- Hydrodynamic separation devices are effective for removal of course sediment, trash, and debris, and are useful as pretreatment in combination with other types of SCMs that target smaller particle sizes.
- Catch basin inserts come in such a wide range of configurations that it is practically impossible to generalize the expected performance. Inserts should mainly be used for catching coarse sediments and floatable trash and are effective as pretreatment in combination with other types of SCMs. Trash and large objects can greatly reduce the effectiveness of catch basin inserts with respect to sediment and hydrocarbon capture. Frequent maintenance and the use of screens and grates to keep trash out may decrease the likelihood of clogging and prevent obstruction and bypass of incoming flows.
- Cartridge filters have been proven to provide efficient removals for both dissolved and non-dissolved constituents. Cartridge filters are, however, less adept at handling high flow rates as compared to catch basin inserts and hydrodynamic devices, mainly due to the enhanced treatment provided through the filtration mechanism.

- Biotreatment devices are relatively new compared to the other types of proprietary treatment devices included in this document. Therefore, there are fewer third party studies on these devices and the available performance information is mostly vendor-supplied. According to the vendors, like their natural counterparts, biotreatment devices are highly efficient at mitigating dissolved metals, nutrients, and suspended solids.
- More detailed performance information is available from the vendors of each class of proprietary device. The performance numbers are typically presented as percent removals rather than effluent quality measurements and can be found on the vendor websites.

B. Sizing

- Hydrodynamic devices, catch basin inserts and cartridge filters are flow-based SCMs and therefore should be sized to capture and treat the flow rate based on the WQV if used as a standalone SCM.
- Proprietary biotreatment devices include both volume-based and flow-based SCMs. Volume-based proprietary devices should be sized to capture and treat the water quality design volume if used as a standalone SCM.
- Auxiliary components of proprietary devices such as sorbent media, screens, baffles, and sumps are selected based on site specific conditions such as the loading that is expected and the desired frequency of maintenance.
- Sizing of proprietary devices is reduced to a simple process whereby a model can simply be selected from a table or a chart based on a few known quantities (tributary area, location, design flow rate, design volume, etc).
- A few of the manufacturers either size the devices for potential clients or offer calculators on their websites that simplify the design process even further and lessens the possibility of using obsolete design information.
- For the latest sizing criteria, refer to the manufacturer’s website.

7005.3 Construction and Maintenance Requirements

A. Specific design, maintenance, and construction requirements will be provided by the vendor.

B. All maintenance and construction requirements should be reviewed and included in cost estimates and project documentation.

C. Hydrodynamic separators do not have any moving parts and are consequently not maintenance intensive. Maintenance is important, however, to ensure that they are operating as efficiently as possible. Proper maintenance involves frequent inspections throughout the first year of installation, especially after major storm events. The systems are considered full when the sediment level is within one foot of the unit's top, at which point it must be cleaned out. Removal of sediment can be performed with a sump vac or vactor truck. Some hydrodynamic separator systems may contribute to mosquito breeding if they hold standing water between storms. Refer to manufacturer's criteria for inspection and maintenance activities.

D. Catch basin inserts can be maintenance intensive due to their susceptibility for accumulating trash and debris. Regular maintenance activities include the cleanup and removal of accumulated trash and sediment, while major maintenance activities include replacing filter media (if used) and or repairing/replacing geotextile fabrics. There are a number of proprietary catch basin inserts and proper maintenance procedures should be determined based on manufacturer's recommendations for the selected catch-basin insert.

E. Cartridge filters maintenance activities include periodically removing captured trash, debris, and sediment from the vault floor, typically twice per year depending on the accumulation rate, using a sump vac or vactor truck. The media in media filters has to be replaced when it becomes saturated, typically about once every other year, also depending on the pollutant accumulation rate. The manufacturers of these devices typically provide contract operation and maintenance services. All stormwater vaults that contain standing water can become a breeding area for mosquitoes. Manufacturers have developed systems to completely drain the vault, such as a perforated pipe installed in the bottom of the vault that is encased in a filter sock to prevent clogging.

F. Biotreatment Devices maintenance can be provided by the manufacturers and typically consists of routine inspection and hand removal of accumulated trash and debris. As opposed to other proprietary treatment devices, no vactor trucks or mechanical maintenance is needed.

END OF SECTION 7000

APPENDIX A
Traffic Study Guidelines

1.0 INTRODUCTION

The City of Norman is responsible for providing a safe and efficient transportation system for its residents. One of the Action Items (Action P1a) defined in the City's Comprehensive Transportation Plan (adopted May 13, 2014) was to prepare guidelines for preparing and reviewing the traffic impact studies as a qualified part of the review process. The TIA procedural guidelines will address site locations, and off-site improvements necessary to permit the street system to operate at a satisfactory level-of-service. The Action Item concludes with the need to consider input from the local development community and to submit the guideline document for adoption by the City Council. This document provides the elements required for preparing and reviewing Traffic Studies. The purpose of this document is to provide guidance and encourage consistency in planning site access locations, and off-site improvements for new and modified developments through the use of Traffic Studies.

Traffic Studies are invaluable planning tools for the City of Norman by providing review staff with sufficient information concerning the transportation impacts of proposed and future projects and to determine appropriate mitigation measures so as to inform decision-makers so that they make educated decisions within the development review and approval process. The Traffic Study also helps to make the applicant aware of traffic and access conditions that may affect the use of, or benefit derived from the subject property, enabling them to make informed decisions regarding transportation system improvements that may favorably impact their project. Impacts to the transportation system may include, but are not limited to, increased congestion, diminished safety, and conflicts with site access that may require an element of access management.

The Traffic Study will provide guidance for site access and off-site improvements necessary to permit the street system to operate at a satisfactory level-of-service by addressing the following questions:

- What impact will traffic traveling to and from a proposed development have on the operation of the street system adjacent to the site?
- Will the development have safe access to the street system?
- Will the level-of-service of the adjacent street be significantly lower as a result of the proposed development?
- Will internal site traffic safely interact with external entering traffic?

The Traffic Study guidelines presented in this document will perform the following functions:

- Establish standards and consistency of study throughout the City of Norman.
- Ensure that important traffic issues are addressed.
- Ensure that roadways and intersections within the City of Norman remain safe and efficient.

- Promote increased understanding of traffic impact issues for those involved in the development process.

Once approved by the City of Norman, a Traffic Study shall be effective for a period of three years provided the layout of the site has not changed to a more intense level than was evaluated in the original study. Projects that have a multi-year build-out and have demonstrated due diligence toward completing the proposed development shall be exempt from the Traffic Study sunset requirement. Due diligence is defined as a project achieving at least 50 percent of the total project's build-out (in units or size) by the end of the three-year period. Developments seeking permits that have not demonstrated appropriate due diligence and have a Traffic Study in excess of three years old will be subject to City of Norman evaluation. This evaluation is necessary to determine the degree to which background conditions may have changed since approval of the original Traffic Study. A new Traffic Study may be required to provide information to help determine if additional mitigation measures are necessary.

A new Traffic Study will be required if significant changes are made to a development. Significant changes include, but are not limited to, the following:

- Change from a single land use to multiple land uses provided the new land uses generate an additional 100 new peak hour trips.
- Changes from one land use to another that generates an additional 100 peak hour trips.
- Changes from one land use to another where the two land uses have different peaking characteristics.

2.0 <u>TRAFFIC STUDY SCREENING THRESHOLDS</u>

Table 1 illustrates these thresholds for when a traffic study is needed. A minimum of a traffic study memo may be requested even for trip generation of less than 100 peak hour vehicle increases.

Table 1. Typical Traffic Study Screening Thresholds

Development Type	Trip Generation Threshold
Residential	100 vehicle per peak hour increase
Non-Residential	100 vehicle per peak hour increase
Residential Mixed Use (without reductions)	100 vehicle per peak hour increase

Other reasons that a Traffic Study may be required include, but are not limited to:

- An application is submitted to rezone a parcel(s) or change the use of a parcel(s) to allow a more intensive trip generating use.

- The project is located at or near a signalized intersection with traffic movement(s) operating worse than Level of Service D.
- The project will provide a through connection that links collector roadways and/or roadways of higher classification.
- The street segment serving the project does not meet current City of Norman minimum street standards and/or does not conform to acceptable geometric configurations as defined by the City of Norman and/or the Oklahoma Department of Transportation.
- The project is located near a location identified by the City of Norman as a high crash/accident location.
- The City of Norman review staff has specific concerns regarding site access and/or safety issues.

The discretion to require a traffic study relates specifically to the traffic in and out of the proposed development, the traffic load on the arterial, and current and planned configuration of the arterial.

An applicant shall not avoid the intent of this requirement by submitting piecemeal applications or approval requests for subdivision plats, preliminary or site development plans, or building permits. **Figure 1** illustrates the Traffic Study process. Section 4.0 outlines City-provided information for use in a Traffic Study.

2.1 TRANSPORTATION SYSTEM PERFORMANCE POLICY

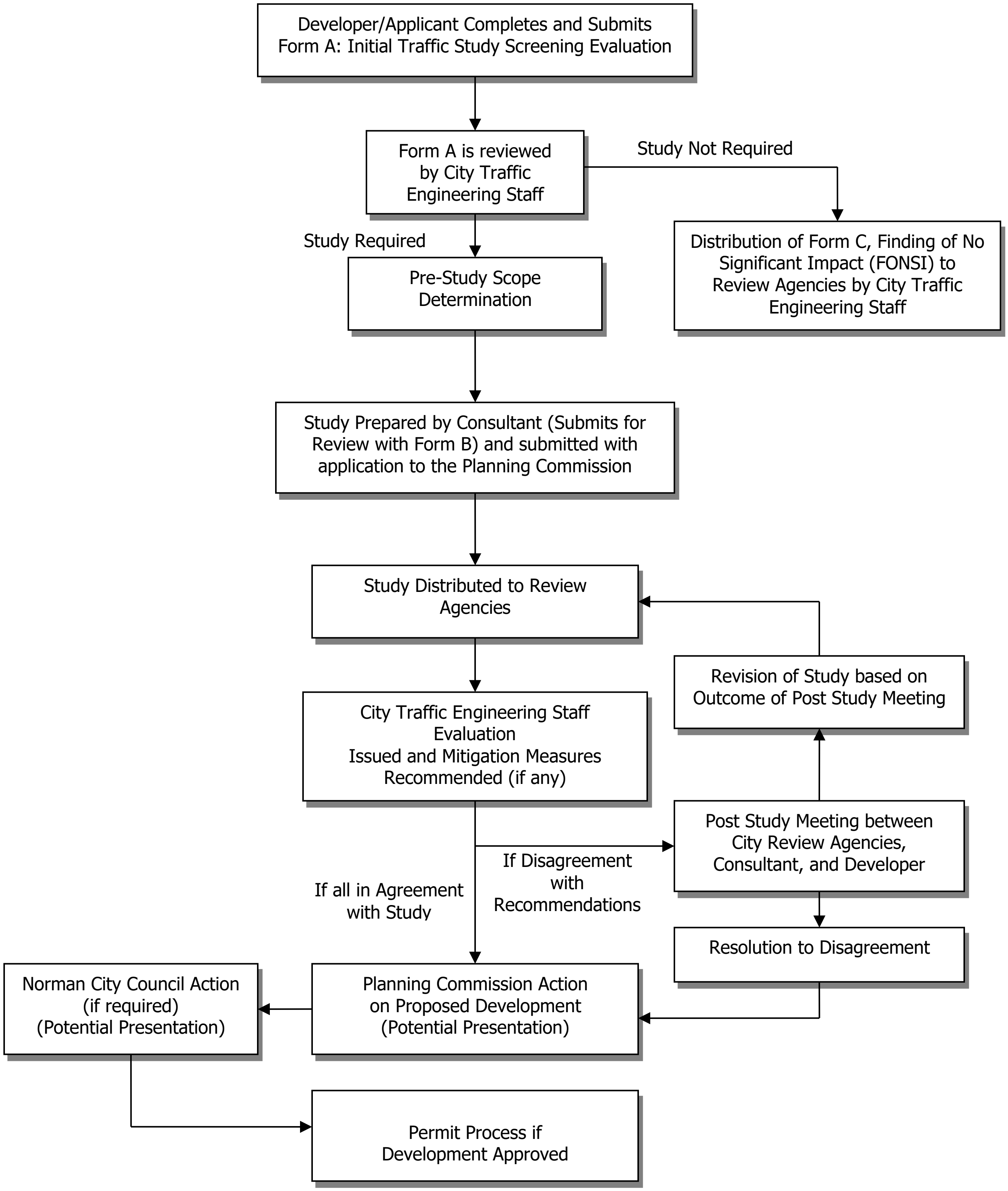
The Level of Service goals for intersections are not regulatory requirements. Instead, these goals are utilized as screening tools to assist in the determination of whether or not the impact of individual projects might be mitigated. Projects whose study area include signalized intersections with movements that operate at no worse than a Level of Service "D" under background conditions will be required to provide mitigation making sure that no movements operate worse than Level of Service "D" under post-development conditions. However, projects whose study intersections include signalized intersections with movements that operate at a Level of Service "E" or worse under background conditions will be required, with the project, to provide mitigation back to the background vehicular delay values for these critical movements.

2.2 TRAFFIC STUDY PREPARER QUALIFICATIONS

The individual completing and/or supervising the preparation of a Traffic Study shall be a registered Professional Engineer (P.E.) in good standing with the State of Oklahoma State Board of Licensure for Professional Engineers and Land Surveyors. Any elements of the Traffic Study that involve roadway or traffic signal design work shall be prepared or supervised by a registered P.E. with specific training in traffic or transportation engineering. Specific Professional Traffic Operations Engineer (PTOE) certification is desired but not required. Each Traffic

Study and/or report submitted to the City of Norman for final review will be sealed by the engineer overseeing the completion of the study(s) and/or document(s).

Figure 1. Traffic Study Review Process



Comments will be provided no later than 15 business days after receipt of a request to review a submitted study. (See Form B)

3.0 TYPES OF TRAFFIC STUDIES

There are three types of traffic studies:

- Traffic Impact Memo
- Traffic Impact Statement
- Traffic Impact Analysis

Table 2 illustrates recommended thresholds that the City of Norman review staff will use as a guide to determine the level or type of study required. The discretion of the City of Norman Public Works Department may be applied to any of the thresholds. These recommended thresholds provide for a more complete evaluation tool to assess the impact of development during the peak travel periods as this is the time of day when congestion is at its worst. Thresholds are based upon recommendations of the Institute of Transportation Engineers. A traffic impact memo may be required when no other traffic study is needed.

Table 2. Traffic Study Thresholds

Traffic Study Type	Threshold
Traffic Impact Memo	Up to 100 peak hour trips
Traffic Impact Statement (TIS)	100-249 new peak hour trips
Traffic Impact Analysis (TIA)	250+ new peak hour trips

3.1 TRAFFIC IMPACT MEMO

When the thresholds for a Traffic Study are not met, a Traffic Impact Memo may be requested. This memo should identify the trip generation potential on an average weekday, during the AM peak hour, and during the PM peak hour. In addition, the memo should address appropriateness of all connections to the public street system. Other items may be added to the requirements of the memo on a case by case basis. Once the need for a Traffic Impact Memo has been determined, the applicant shall provide additional information, identified in **Table 3**, to the City of Norman review staff.

3.2 TRAFFIC IMPACT STATEMENT

Traffic Impact Statements (TIS) evaluate impacts at the site access point(s) and appropriate nearby intersections on a case-by-case basis as determined by the City. The thresholds for conducting the TIS are between 100 and 249 new peak hour trips.

The study boundaries shall include all roadways serving the project, and all intersections up to the first collector roadway or roadway of higher functional classification. This includes those intersections that the City of Norman review staff feels are necessary to provide for an adequate review of the proposed project's impact. The City of Norman review staff, in consultation with the applicant/developer, will determine the TIS study boundaries and the scope of work for the study during the Pre-Study Scope Determination Meeting. Typical elements to be included in the TIS are identified in **Table 3**.

3.3 TRAFFIC IMPACT ANALYSIS

A traditional Traffic Impact Analysis (TIA) evaluates the impacts at site access points and appropriate nearby intersections. **Table 3** illustrates that the TIA will provide a more robust and in-depth analysis of the impacts of site-generated traffic on the transportation network than the analysis provided in a TIS. The threshold for a TIA is 250 or more new peak hour trips.

The study parameters will include an analysis of the project's access points, an analysis of all roadways serving the project, an analysis of all intersections up to the first collector roadway or the first roadway of higher functional classification, and the intersections of these roadways with arterial roadways. Intersections and roadways away from the proposed site could be in more than one direction. This includes those intersections that the City of Norman review staff feels are necessary to provide for an adequate review of the proposed project's impact. The City of Norman review staff, in consultation with the applicant/developer, will determine the TIA study boundaries and the scope of work for the study during the Pre-Study Scope Determination Meeting.

3.4 AUTHORITY FOR REQUIRING TRAFFIC STUDIES

In some instances, a Traffic Study may be required even though minimum thresholds may not be met. Level of Service screening criteria as well as evaluation of existing and background conditions may be utilized to determine the necessity for a Traffic Study. Crash rates may also be used as a screening tool to help determine the necessity for a Traffic Study. Finally, the applicant may request a Pre-Study Scope Determination Meeting if they feel that a Traffic Study is needed.

3.5 APPLICATION PROCESS

The completed traffic study is to be submitted for review by City of Norman review staff with the application to the Planning Commission. This will allow adequate time for City of Norman review staff to complete a thorough review of the submitted study and to work through any differences that might exist between the City of Norman review staff and the applicant.

4.0 ELEMENTS TO BE ADDRESSED IN A TRAFFIC STUDY

Prior to starting work on a Traffic Study, a Pre-Study Scope Determination is to be held (this can be in person, on a telephone call, or through electronic mail). At this meeting, the City of Norman review staff will determine the type of Traffic Study to be prepared. The City of Norman review staff will also consult with the developer and/or the consultant preparing the Traffic Study in order to discuss any potential issues and concerns with the project and develop an agreement about the scope of work for the Traffic Study.

The applicant shall bring to the Pre-Study Scope Determination Meeting:
- Form A—Initial Traffic Study Evaluation
- A complete description of the development. This shall include a site map that details land uses, building footprints, the number of units/unit size, access points, internal roadways (if any), streets, proposed sidewalks and bicycle facilities, and the location and number of proposed parking spaces (if applicable). The best available documentation will be sufficient to use during the Pre-Study Scope Determination Meeting. Finalized documents should be submitted, when available, for inclusion in the project file.
- If the development is to be phased, the size, location, and timing of each phase.

The applicant shall also be prepared to respond to the following questions:
- What is the relationship of the development to surrounding land uses i.e. interconnectivity with surrounding neighborhoods, pedestrian and bicycle facilities, accessibility to schools and public facilities, etc.?
- Can the proposed development be served by public transportation? If so, trip generation credits could be considered in special cases.
- Does the design provide facilities for bicycles and pedestrians who need to gain access to, pass by, or pass through the development?
- Is there any other information or material that will facilitate the preparation and accuracy of the Traffic Study?

Typical information that the City should be expected to provide includes, but may not be limited to, the following:
- Traffic signal timing
- Crash data
- Approval of anticipated growth rates

The applicant's Traffic Study preparer will include a complete and accurate analysis of the issues identified at the Pre-Study Scope Determination Meeting. Meeting notes will be prepared by the Applicant and distributed to all participants and any others identified specifically at the meeting. Once all comments from participants have been addressed, final minutes will be distributed to all.

Table 3 illustrates the typical elements that are usually included in each of the different levels/types of traffic studies.

Table 3. Elements of Typical Traffic Studies

Task	Traffic Impact Memo	Traffic Impact Statement	Traffic Impact Analysis
Pre-Study Scope Determination	√	√	√
Impact Analysis:			
Study area and road summary	√	√	√
Site plan that includes: adjacent land uses, driveways, and roadways (existing and dedicated)	√	√	√
Project description to include planned land uses, internal circulation for all modes, site access, etc.	√	√	√
Details of other projects (both approved and permitted) in study area		√	√
Existing conditions analysis (LOS) at site access locations		√	√
Existing conditions at nearby intersections		√	√
Background traffic growth		√	√
Existing conditions + Background traffic (future without project)		√	√
Trip generation for specific uses	√	√	√
Trip distribution analysis		√	√
Future + project conditions analysis at site access locations		√	√
Future + project conditions analysis for nearby intersections		√	√
Mitigation identification and evaluation		×	×
Comparison of trip generation associated with uses allowed, requested vs. current permitted uses			
Sight distance evaluation	×	√	√
Opposing driveway locations	√	√	√
Site Issues:			
Evaluate number, location, and spacing of access points	√	√	√
Access design, queue lengths, etc.		√	√
Site circulation		√	√
Other Analyses:			
Accident/Crash History		×	√
Signal coordination analysis		×	√
Signal warrant analysis		×	√
Turn lane warrant analysis	×	√	√
Consistency with City roadway standards		√	√
Segment/Link Analysis		×	×
Key: √ = required ×= may be appropriate on a case by case basis			

Note: LOS = Level of Service as determined by techniques outlined in the *Highway Capacity Manual*.

Adapted from *Evaluating Traffic Impact Studies: A Recommended Practice for Michigan Communities*. Tri-County Regional Planning Commission, 1994.

5.0 SOFTWARE AND DATA

5.1 TRAFFIC ANALYSIS SOFTWARE

The software used will be based on the Transportation Research Board's *Highway Capacity Manual* (HCM) and utilize the HCM's formulae in order to conduct capacity analysis for all transportation system scenarios. The software used must be able to analyze intersection operations including signal timing and phasing analysis, pedestrian calls, queue lengths, and analysis of street segments. The use of multiple software packages is permissible.

Software packages such as *CorSim*, *Vissim*, *Passer*, *Transyt 7*-F, and *Synchro* (not meant to be an all-inclusive list) that perform micro-simulation of traffic dynamics including simulations of transit and heavy vehicle operations, as well as provide graphic descriptions of intersection and link operations are not required but may be utilized. However, data from one of these software packages must be reported in HCM format and meet the basic criteria for exporting data as specified in this document.

Specialized software for transit operations analysis, turning templates, geometric analysis, and noise mitigation analysis may be used separately from the traffic operations analysis software. The use of these types of software packages for analysis of elements included within a Traffic Study submitted to the City of Norman must receive prior approval of the City of Norman review staff.

5.2 COLLISION REPORTS

If needed, collision reports may be obtained from the City of Norman, the Oklahoma Department of Safety, or the Oklahoma Department of Transportation. Accident data for individual roadway segments and locations not provided by one of these agencies listed above will not be accepted. If needed, data shall cover a minimum of a two-year period.

5.3 APPROVED DEVELOPMENTS

Data about properties located within the study area boundaries are available from the City of Norman. Applicants are to identify any approved development and use this information in the completion of their traffic study. Data available includes: all subdivision plats, planned unit developments, zoning, construction permits, and any conditions of approval associated with them. If available, the conditions of approval shall be included in the study analysis. In addition, the consultant may be asked to generate traffic for undeveloped tracts of land in proximity to the subject site for the purposes of determining appropriate shares for construction of recommended improvements. The City of Norman will make a copy of traffic studies for approved developments within the study area boundaries available to the consultant.

5.4 AVERAGE DAILY TRAFFIC (ADT) COUNTS

The Oklahoma Department of Transportation, the Association of Central Oklahoma Governments (ACOG), or the City of Norman Average Daily Traffic (ADT) counts may be utilized, if available, to assist in the determination of a roadway's historic annual growth rate. The consultant shall provide documentation of the methodology used to determine the growth rates within the Traffic Study document. These growth rates should be presented for approval for use in the Traffic Study.

ADT counts may also be utilized to determine the amount of traffic entering and exiting the study area and may also be used to verify counts collected by the consultant. The most recent ADT should be used. However, traffic counts that are more than two (2) years old may not be used except to determine historical trends.

5.5 INTERSECTION TRAFFIC VOLUMES

Turning movement counts must have been collected within two (2) years prior to submittal of a traffic study. Counts shall be collected on school days, and when necessary because of the land use being requested, on weekends and off-peak periods to include mid-day and evenings. If turning movement counts for the study intersections are not available through the City of Norman review staff, the consultant will be required to collect this data for at least the A.M. and P.M. peak travel periods. A printed summary of the data should be included as part of the report. The summary will include intersection drawings with lane configurations, intersection composite and individual turning movement peak hour factors, heavy vehicle percentages (if required), and traffic signal phasing (if applicable). See section 4.0 for a list of typical information to be provided by the City. Form D should be submitted as a traffic count permit.

5.6 MANUALS AND GUIDANCE DOCUMENTS

The most recent versions of the Institute of Transportation Engineers' (ITE) *Trip Generation* and the Transportation Research Board's *Highway Capacity Manual* shall be used. In some cases, a proposed land use may not be contained within *Trip Generation* and the companion *Trip Generation Handbook*. In those cases, it is acceptable for trip generation to utilize characteristics based on local data specific to a particular location or land use subject to approval by the City of Norman review staff. If these observed trip generation rates result in rates lower than predicted by *Trip Generation* for a similar use, the study must analyze the differences. For example, if observed trip rates suggest that vehicular trips will be lower because of the location of a specific site because more trips will be made as pedestrian or bicycle trips, then the study should evaluate the ability of the study area to accommodate these additional pedestrian and/or bicycle trips. *Trip Generation* contains guidelines specific to the collection of trip generation data.

The rates and formulae, intended for use in this traffic study, must have been derived using the ITE *Trip Generation* study methodology.

Other documents to be used are the City of Norman's Comprehensive Transportation Plan, the City of Norman's Zoning and Subdivision Regulations, City-adopted plans, current Major Street and/or Collector Plans, current plans for Sidewalks and/or Bicycles, the City of Norman Capital Improvements Budget, City of Norman Department of Public Works project schedules, Oklahoma Department of Transportation project schedules, and any documents identified by the City of Norman review staff as being necessary.

5.7 SIGNAL TIMING PLANS

The City of Norman, upon request, will provide the consultant with current signal timing plans for signalized intersections within the study area. In those instances where a signalized intersection is part of a coordinated system, data for the system will also be provided including the City-adopted common cycle lengths.

5.8 TRANSPORTATION IMPROVEMENT PLAN AND OCARTS PLAN

The Transportation Improvement Program and the Oklahoma City Area Regional Transportation Study (OCARTS) Plan may be obtained from the ACOG. These documents shall be consulted in order to determine what projects and/or transportation improvements are planned for an area or specific location and also to determine when the project is funded and might be completed. The City shall confirm all future projects and the schedules associated with these projects.

6.0 CAPACITY ANALYSIS

The applicant's Traffic Study preparer shall use either a generalized growth rate or a facility specific growth rate in order to derive background traffic volumes to be used in the capacity analysis. The consultant may be provided growth rates at the Pre-Study Scope Determination Meeting or instructed to derive growth rates using historic traffic volume data and linear regression techniques. If the growth rate is derived rather than provided, the consultant must document all data and calculations within the study.

A Traffic Study is basically a before and after analysis. Following are the basic scenarios of capacity analysis for study intersections and affected roadways.

6.1 EXISTING TRAFFIC

It is important to identify the existing operating conditions of the study area intersections and roadway segments in order to determine existing deficiencies in the transportation system and to allow a comparison with future conditions.

6.2 BACKGROUND TRAFFIC

A Traffic Study is not prepared in a void as existing traffic will continue to grow even if the proposed project does not develop. Projects that have an opening date at least one (1) year away will be impacted by background traffic. Background traffic consists of the natural traffic growth (traffic from approved projects or potential growth and population growth) without the proposed project. An analysis of this increased traffic shall be conducted in order to determine the future operating conditions of the roadway at the planning horizon without the project.

6.3 PROJECT TRAFFIC

An analysis of the traffic associated with the proposed development is a requirement of each of the different types of Traffic Study described in this document. A "trip generation" for the project is conducted in order to complete this analysis. A trip is defined as a single, one-way movement. Sources for trip generation are listed in Section 5.7 of this document. *Trip Generation* frequently provides more than one method for determining the number of site related trips. When provided, the Traffic Study shall utilize the fitted curve formula for determining project trip generation if the development size is within the data extremes. Otherwise, the use of the average trip rates is considered to be acceptable. During the analysis of project traffic, access and internal circulation shall be evaluated as well. Reductions in generated trips shall be conducted in good faith and shall utilize ITE approved data and methodologies for pass-by trips and internal capture.

Trip distribution and assignment methods shall be approved by the City of Norman review staff prior to distributing traffic to the roadway network and reducing the number of trips for a proposed project in a Traffic Study.

6.4 FUTURE TRAFFIC

This is the "after" portion of the Traffic Study process that was described previously. Analysis of the future traffic conditions includes examination of the background traffic for the study area increased by the project traffic volumes.

7.0 MITIGATION

Mitigation measures, if determined to be required, must be included as part of the Traffic Study. This determines if a project's impact can be eliminated or reduced to an insignificant level. It is recognized that a specific proposed development may not, by itself, create an impact, but that an inadequacy would exist regardless of whether or not the property were to be developed. In those situations where the pre-development Level of Service is not acceptable, then local participation may be necessary in order to assure that acceptable levels of service are achieved in the post development scenario. Depending on what the background Level of

Service is, this will involve mitigation back to the background Level of Service or no worse than Level of Service "D" (see Section 2.1). Identification of necessary mitigation does not determine the responsibility for such improvements only that the improvements are necessary. The mitigation criterion takes prevailing conditions into account when assessing the required level of mitigation.

The Traffic Study shall identify all impacts by lane group and evaluate suitable measures that mitigate the impact or return to projected pre-development conditions to what they would be if the proposed action were not in place or to acceptable levels. The following criteria shall apply:

- When existing plus cumulative traffic with planned and background improvements exceed established Level of Service criteria (provided in Section 2.1 of this document), the applicant shall identify mitigation necessary to offset project impacts. In this example, the total signalized intersection shall not operate at a Level of Service worse than "D" under future traffic conditions and no individual movement is allowed to operate at a Level of Service "F". In other words, the applicant is required to mitigate all impacts of the proposed project.
- When existing plus cumulative traffic with planned and background improvements do not exceed established Level of Service criteria (provided in Section 2.1 of this document), the applicant shall identify mitigation to achieve established Levels of Service. In this example, no movement at a signalized intersection under future traffic conditions would operate at a Level of Service worse than it did under background conditions. In other words, the applicant must mitigate back to the background Level of Service.
- It is important that the Traffic Study identify all mitigation measures necessary for proper mitigation regardless of responsibility.

7.1 MITIGATION MEASURES

The major benefit of a Traffic Study is to determine what, if any, mitigation measures are needed. These measures are not limited to roadway construction or other physical improvements. Mitigation can involve anything from physical or operational improvements along the roadway and site access points, to programs and incentives designed to specifically alter travel behavior, or any combination of these. They may also include alteration of the proposed development to reduce the number of peak hour trips generated or even denial of the project altogether. **Table 4** presents some examples of mitigation measures. The CMP document developed by the OCARTS also contains a list of tools and strategies that can be applied to address congestion caused by specific situations.

Table 4. Examples of Mitigation Measures

Mitigation Category	Mitigation Measure
Roadway Improvements	• Repaving/re-striping • Realignment of streets • Improve Sight Distance • Widening • Intersection Improvements • Acceleration/deceleration lanes • Traffic signals (must meet warrants) • Median crossovers • Building new roadways • Interchanges (construct or modify), etc.
Access Management Improvements	• Increase driveway spacing • Relocate driveways or intersections • Reduce the number of driveways • Install medians • Shared access, etc.
Operational Improvements	• Modify signal timing or phasing • Improve signal progression • Increase transit operations • Provide incentives for transit use, etc.
Site Plan/Land Use Improvements	• Reduce project size • Modify project phasing • Increase driveway queuing • Revise/improve internal circulation • Revise service vehicle/truck access or circulation • Improve pedestrian and bicycle access and circulation • Improve way-finding through directional signs and pavement markings, etc.
Travel Demand Management	• Staggered work hours • Car pooling • Telecommuting, etc.

Adapted from *Evaluating Traffic Impact Studies: A Recommended Practice for Michigan Communities*. Tri-County Regional Planning Commission, 1994.

7.2 <u>TURN LANES</u>

Turn lanes shall be designed to accommodate either demand or deceleration requirements, as applicable. Left-turning and right-turning movements at unsignalized intersections shall be analyzed using locally approved methodologies in order to determine the spacing needs for left-turn and/or right-turn bays. These analysis methodologies shall conform to methodologies approved and/or recommended by the most recent edition of the *Highway Capacity Manual*. Left-turn lanes shall be provided on arterial approaches at all intersections proposed for traffic signal installation. Right-turn Bays are required at driveway intersections that will serve at least 100 peak hour right-turning vehicles. The consultant shall also conduct a queue length analysis using the *Highway Capacity Manual* method in order to determine the adequacy of turn bays for both left- and right-turning movements. Turn bays shall be sized to accommodate the 95^{th} percentile confidence level and shall be designed in accordance with the most recent edition of the American Association of State Highway and Transportation Officials (AASHTO) *Policy on Geometric Design of Highways and Streets* (Green Book).

7.3 PRESENTING MITIGATION MEASURES

The consultant shall identify, analyze, and discuss mitigation measures in the Traffic Study. These mitigation measures shall be specific and feasible actions whose implementation will improve adverse transportation conditions. A mitigation measure shall adequately avoid, minimize, rectify, reduce over time, or compensate an impact. All mitigation measures that require roadway widening shall be submitted on an aerial photograph or surveyed plan. The exhibit may include a generalized drawing of the proposed mitigation and shall show existing conditions, property lines, and geographical conditions. This exhibit shall be drawn to a scale that allows the City of Norman review staff to determine the feasibility of the proposed mitigation. The mitigation measures shall consider the following:

- Scheduled improvements
- The phasing of the project's development
- A logical phasing of improvements
- Responsibility for implementation
- Generalized cost estimates (engineering design, utility relocation, right-of-way acquisition, and construction)

7.4 RESPONSIBILITY FOR MITIGATION

The City of Norman operates under the "proportionate-share" concept for implementation of mitigating improvements to offset proposed developments. The "proportionate-share" concept assigns funding responsibilities for mitigation measures based on the relative contribution of traffic generated by a given development on a specific roadway or intersection. The City of Norman is committed to providing its "proportionate-share" of traffic mitigation costs (including right-of-way acquisition costs) caused by a project, but it is not responsible for providing mitigation funding beyond its impact level. Pursuant to the U.S. Supreme Court Nollan and Dolan cases, there must not only be a link between the impact generated by a project and the mitigation required of it but there must be rough proportionality between the two as well. The City of Norman's mitigation program is designed to ensure that this link is maintained.

Improvements must be in place and/or appropriate fees paid prior to the filing of the final plat. An exception would be a development that is surrounded by undeveloped land. The development of these currently undeveloped lands also must contribute the cost of the roadway improvements to avoid a situation where the proposed development pays the way for future developments. As stated previously, mitigation costs and/or efforts must be discussed within the Traffic Study. This would include identification of the proportionate share, based on the number of peak hour trips generated by existing and background traffic conditions, of the various interests, including the City of Norman, within the study area. The City of Norman review staff, in collaboration with the consultant and the developer, will make the final recommendation of the appropriate measures including the timetable for implementation.

8.0 REPORT PRESENTATION AND CONTENTS

Any Traffic Study submitted for review shall follow a pre-determined format as shown in **Part A, Recommended Report Outline**. This format is intended to provide consistency in preparation and review of each Traffic Study. The City of Norman review staff, along with other reviewing agencies, will evaluate and comment on the initial Traffic Study over a period not to exceed fifteen (15) business days. The consultant will make any necessary revisions and submit the final Traffic Study, if necessary, to the City of Norman review staff for acceptance. It is the intent of this document to provide sufficient guidance that would minimize the number of draft versions of the Traffic Study so that comments can be provided in a timely manner allowing projects to proceed efficiently through the development review cycle.

The consultant shall provide to the City of Norman review staff an electronic copy of the Traffic Study's final documents. Only physical copies are required of draft documents. Electronic copies of the final document, including all technical appendices, shall be provided to the City of Norman review staff in Adobe portable document format (PDF).

A Civil or Traffic Engineer, who is currently registered and in good standing with the State of Oklahoma State Board of Licensure for Professional Engineers and Land Surveyors, shall seal the final report. PTOE registration is desirable but not required.

The final report will meet the following requirements:

- The report shall clearly identify the name of the development (any past names as well), the applicant, and any City of Norman case number, if applicable.
- The report shall clearly state the purpose and objective of the study.
- The report shall be presented in a clear and logical sequence. It shall lead the reader step-by-step through the various stages of the process. It will clearly state the conclusions of the study and the resulting recommendations. It shall include graphics, tables, and charts to clearly identify the project, the project location, proposed project phasing, impacts, issues, and solutions.
- All computerized analysis output sheets and supporting raw-count data, ADT, turning movements, queue length analysis, level of service calculations, intersection delay data, etc. shall be included in technical appendices to the report. All assumptions used in the calculations must be referred to in the appropriate tables, chart, or page in approved publications (e.g. volume/capacity ratios, vehicle operating speeds, trip generation rates, etc.). Calculations must be comprehensive, clear, and easy to follow.
- All maps and graphics involving improvements must be drawn to a scale that allows roadway geometrics to be approximately dimensioned (e.g. road width, lane width, 95th percentile confidence level queue length, etc.) and allows the City of Norman review staff to accurately evaluate them. Intersection geometrics must include bus stops, parking areas, pedestrian crossings, driveways, turn restrictions, existing right-of-way, etc.
- The Traffic Study shall identify traffic congestion, safety problems, and/or other deficiencies of the future transportation system across all modes, with and without the proposed development (i.e. lack of pedestrian and/or bicycle facilities, insufficient transit service, etc.). The study shall incorporate identified and/or planned transportation improvements being made by other public agencies (e.g. Oklahoma Department of Transportation, City of Norman, Cleveland County, etc.) or private organization that are funded and expected to be functional by the planning horizon of the study.
- Descriptions of on-site issues including number and location of driveways, circulation, bicycle and pedestrian facilities, truck access and operations, transit, and safety shall be presented. The City of Norman review staff may request that a discussion of parking needs and presentation of parking layout/issues be presented in the study.
- The report will address left-turn lanes and right-turn lanes utilizing local approved methodologies for analyzing the need for exclusive turn lanes. Turn bays shall be sized to accommodate either the 95th percentile confidence level queue length as determined by the current edition of the *Highway Capacity Manual* method or deceleration requirements, as applicable. Design shall be in accordance with the current edition of the AASHTO Green Book.
- The report shall evaluate potential improvement measures needed in order to mitigate the impact of the development to the background delay levels or to the Level of Service standards identified earlier in this document.

- The Traffic Study shall contain recommendations for site access and transportation improvements needed to maintain traffic flow to, from, within, and past the site at an acceptable and safe Level of Service. An evaluation of sight distance availability in accordance with AASHTO Green Book standards is to be included for each new or modified intersection. Spacing of access points shall be compared with the minimum requirements in the EDC. Discussion should focus on how the number of access points can be minimized rather than on maximizing the number allowed by the EDC based upon the site frontage. A development will be granted only as many access points as may be needed to adequately serve the proposed development.
- Description of coordination efforts with affected jurisdictions outside of the City of Norman's purview shall be included as may be necessary. Coordination efforts should minimally include correspondence with the affected jurisdiction to inform them about the Traffic Study and the proposed development. Other coordination could include providing the affected jurisdiction with a copy of the Traffic Study, providing a written invitation to the affected jurisdiction to participate in the Traffic Study review process, or providing City of Norman review staff with the contact information for their counterparts in the affected jurisdiction. Coordination efforts should be pursued when a development crosses jurisdictional boundaries or is directly adjacent to another jurisdiction and the majority of the distributed traffic from the development will impact the roadways of the adjacent jurisdiction.
- Daily trips may be reduced to account for ridesharing, transit use, and complementary land uses. However, assumptions about ridesharing, transit use, and land use must be supported with quantifiable data. Such data might include rideshare percentages for similar development, mode split percentages for the study area, demographic data, and internal capture analysis. Trip reductions shall be presented clearly and all assumptions and calculations should be included in one of the Traffic Study's technical appendices.
- The use of peak hour adjustment factors does not eliminate traffic volume. It assumes that there is less peaking in a single hour and that peaking tendencies are spread over time. Changes to peak hour adjustment factors are allowed only with the prior permission of the City of Norman review staff.
- Pass-by factors are to be used to reduce the estimated additional total daily traffic to streets serving a proposed development. They are not to be applied to directly reduce trip generation and turning movement volume at driveways or intersections serving the proposed development.

The consultant may be required to prepare and present a summary of the Traffic Study to the Planning Commission or to the City Council. If the project is deferred for action by the Commission/Council because of inquiries from Commission/Council members, elected officials, or the public, the consultant shall revise the presentation to address the identified issues and be available to offer the revised presentation.

The recommended report outline is presented in **Part A, Recommended Report Outline**.

8.1 FORMS

Part B contains the checklist of the items to be brought to the Pre-Study Scope Determination Meeting as well as the forms that are part of the traffic study process. Form A is the Initial Traffic Study Screening Evaluation that is to be submitted with each request for a Pre-Study Scope Determination Meeting. Form B is the Request for Review/Comments of a Traffic Study that the traffic study preparer can submit with each traffic study prepared for review by City of Norman review staff. Form C is the Finding of No Significant Impact form which will be issued by City of Norman review staff in the event it is determined that a traffic study is not required for a particular application. Form D is the traffic count permit form.

PART A

RECOMMENDED REPORT OUTLINE

Recommended Outline for Traffic Study Final Report

A. Executive Summary
   1. Summary of project scope
   2. A brief description of the proposed development
   3. Identification of the proposed development site
   4. Summary of the major findings of the analysis
   5. Identification of mitigation measures and recommendations

B. Background
   1. A vicinity map showing the location of the proposed development in relation to the study area’s transportation system
   2. A complete project description
   3. The proposed site plan
      a. Includes the existing land uses and
      b. Proposed site uses complete with size, land uses, and phasing
   4. The proposed location and traffic control of all proposed access points
   5. A brief description of the current (and proposed, if applicable) land uses adjacent to the site
   6. A description of the study area as defined during the Pre-Study Scope Determination Meeting
      a. All proposed site access points
      b. Roadway names, locations, and functional classifications
      c. Existing roadway conditions, intersection locations, and Levels of Service
      d. Intersection lane configurations and traffic control
      e. Pedestrian, bicycle, and transit facilities
      f. Anticipated nearby land development (approved, permitted, or under construction) and the associated traffic
      g. Overall traffic growth in the area

C. Existing Conditions Assessment
   1. Existing traffic volumes (measured within the previous two (2) years) and operational analysis for all study intersection and roadway segments
      a. Signal timing cycles
      b. Level of Service(include vehicle delay/failing approaches for unsignalized intersections)
      c. Queue length analysis
      d. Transit accessibility
      e. Identification of bicycle and pedestrian facilities
      f. High crash/accident locations
   2. Capacity analysis outputs for the existing conditions shall be included as an appendix to the report

D. Background Traffic Assessment

1. Background traffic volumes shall be forecast to the project horizon. Forecasts may utilize a straight-line regression of historical traffic volumes or apply a compound growth factor model.
2. Background traffic volumes shall incorporate existing traffic volumes that have been measured within the two (2) previous years and traffic generated from anticipated nearby land development i.e. projects approved/permitted within the last five (5) years, or currently under construction.
3. Background traffic shall be forecast to the project's horizon for completion (if the project is phased, then forecasts shall be to each of the phase horizons).
4. Operational analysis for all study intersections and roadway segments
    a. Level of Service (include vehicle delay/failing approaches for unsignalized intersections)
    b. Queue length analysis
    c. Transit accessibility (if applicable)
    d. Identification of bicycle and pedestrian facilities (if applicable)
5. Capacity analysis outputs for the background conditions shall be included as an appendix to the report

E. Trip Generation

1. Complete trip generation estimates for all phases and land uses of the proposed development
    a. Use the most recent edition of the ITE *Trip Generation* manual and the companion *Trip Generation Handbook*
    b. The specific trip generation figures that are used for calculations shall be identified in a tabular format in the report
    c. Within *Trip Generation*, some land uses utilize an average trip rate while others utilize a fitted curve equation to predict the number of trips to be generated. In the event a given land use has both options available, the consultant shall clearly identify in the report the methodology utilized.
2. If the consultant or the City of Norman review staff feels that the *Trip Generation* manual does not contain adequate data or that the land use is unique in its trip generation characteristics, a trip generation study can be conducted and its results used in place of the *Trip Generation* manual. This is subject to approval by the City of Norman review staff. *Trip Generation* contains guidelines specific to the collection of trip generation data. The rates and formulae, intended for use in this traffic study, must have been derived using the ITE *Trip Generation* study methodology.

F. Trip Distribution and Assignment Assessment
   1. Trip distribution of the trip generation information shall be performed using the existing distribution patterns. Trip distribution may be conducted using a surrogate methodology. Such methodologies could include the use of market analysis studies, population, and/or employment distributions within a buffered area around the project site. A figure of the trip distribution shall be provided.
   2. Trips shall be assigned to the roadway network based on the trip distribution. Assignment of trips to project access points shall be logical and assume that trips will take the shortest and/or most direct route to destinations within the project site and adjacent roadways and trips will seek to maximize right-turning movements. A figure of the trip assignment shall be provided.

G. Future Traffic Assessment
   1. Analysis of future traffic conditions shall include project traffic (not reduced unless approved by the City of Norman review staff) added to background project traffic
   2. Operational analysis for all study intersection and roadway segments
      a. Level of Service (include vehicle delay/failing approaches for unsignalized intersections)
      b. Queue length analysis
      c. Signal timing cycles
      d. Transit accessibility (if applicable)
      e. Identification of bicycle and pedestrian facilities (if applicable)
   3. Capacity analysis outputs for each project phase (if more than one) shall be included as an appendix to the report

H. Site Access Analysis
   1. Safety analysis of the proposed site access points including sight distance (both stopping sight distance and intersection sight triangle) and operational characteristics shall be conducted
   2. Analysis of right- and left-turn lane warrants, queue lengths, storage/throat lengths, acceleration and deceleration lanes, channelization, and other characteristics of site-access driveways, as applicable

I. Safety Analysis—High accident locations shall be evaluated when adequate information for analysis is readily available. The analysis shall include collision diagrams and accident rates and use at least two (2) years of collision data.

J. Mitigation Analysis
   1. The mitigation analysis shall evaluate the future traffic conditions with proposed mitigations to improve operations and/or deficiencies, if any
   2. Operational analysis for all study locations
      a. Level of Service (include vehicle delay/failing approaches for unsignalized intersections)

b. Identification of revised lane geometry/lane configuration (include diagram)
c. Queue length analysis
d. Signal timing cycles
e. Transit accessibility
f. Identification of bicycle and pedestrian facilities
g. Analysis of new connections opportunities/issues
h. Discussion of additional connectivity opportunities/issues

3. All mitigation measures that require roadway widening and/or additional right-of-way acquisition shall be submitted on an aerial photograph or surveyed plan showing existing conditions, property lines, geographic conditions, and the proposed mitigation. This exhibit shall be drawn to a scale that allows for determining the general feasibility of the proposed mitigation.
4. Capacity analysis outputs for each of the assessment scenarios shall be included as an appendix to the report

K. Conclusions and Recommendations

1. A summary of the existing conditions, the background conditions, and the future project conditions
2. Description and summary of mitigation measures necessary to bring the study intersections and roadway segments into compliance with acceptable Levels of Service in accordance with City of Norman transportation policies. Included in the analysis shall be the identification of signals, turn lanes, and other warrants as applicable.

PART B

FORMS

Pre-Study Scope Determination Check-List

(Please ensure that the following items are available for discussion:)

A. Complete description of the development that includes:
1. Site map detailing:
    a. Building footprints
    b. Number of units/unit size
    c. Access points
    d. Internal roadways (if any)
    e. Adjacent streets
    f. Proposed sidewalks and bicycle facilities (if applicable)
    g. Location and number of proposed parking spaces (if applicable)

The best available documentation will be sufficient to use during the Pre-Study Scope Determination Meeting. Finalized documents should be submitted, when available, for inclusion in the project file.

2. Phasing plan (if applicable) that includes:
    a. Phase size
    b. Phase location
    c. Phase timing

B. Please be prepared to respond to the following questions:
1. What is the relationship of the development to surrounding land uses (i.e. interconnectivity with surrounding neighborhoods, pedestrian and bicycle facilities (if applicable), accessibility to schools and public facilities, etc.)?
2. Can the proposed development be served by public transportation (if applicable)?
3. Does the design provide facilities for bicycles and pedestrians (if applicable) who need to gain access to, pass by, or pass through the development?
4. Are there any other items/materials that will facilitate the preparation and accuracy of the Traffic Study?

FORM A—INITIAL TRAFFIC STUDY SCREENING EVALUATION
City of Norman Traffic Study Screening

Submit this form to the City of Norman review staff in advance of requesting a Pre-Study Scope Determination Meeting. Its purpose is to help determine the need for a Traffic Study, and if so, the type of study to be conducted. The City of Norman review staff will notify the applicant if a Pre-Study Scope Determination needs to be scheduled.

Date Submitted:		**Codes or Planning Case No.:**	
City of Norman Review Staff Contact Information:		Phone:	
		E-Mail:	
Project Name and Location (specific):			
Nearest Major Cross Streets and Functional Classification:			
Applicant or Project Developer:		Phone:	
Traffic Study Preparer:		Phone:	
Has a study been prepared for this location within the past 5-years?	□ Yes / □ No	Date:	Title/Case No.:

Include the Following Materials with this Form (Unless this is a Rezoning)

Two sets of site plans showing all existing and proposed structures, parking and loading areas,
Driveways, sidewalks and bicycle paths/lanes, and on/off site circulation.

Screening Thresholds	**Traffic Impact Memo (up to 100/pkhr)**	**Traffic Impact Statement (100-249/pkhr)**	**Traffic Impact Analysis (>250/pkhr)**

Please Complete Prior to meeting

Trip Generation Calculation

	Zoning District (List Each District) Use Additional Sheet if Necessary	**Land Use** (List Each Use) Use Additional Sheet if Necessary	**Project Size** (Square Feet or Dwelling Units)	**Peak Hour Trips**		**Daily Trips**
				AM	**PM**	
Existing						
Total						
Proposed						
Total						
Net Increase/Decrease (+ or -) Above/Below Existing Trips						

City of Norman Review Staff Comments:

Recommended Traffic Study Type (circle one)	**None (Issue Form B)**	**Traffic Impact Memo**	**Traffic Impact Statement**	**Traffic Impact Analysis**

Evaluated By: ____________________ **Phone:** ____________

Signature: ______________________ **Date:** ______________

FORM B—REQUEST FOR REVIEW/COMMENTS OF TRAFFIC STUDY
City of Norman Traffic Study Review

A traffic study has been prepared. The City of Norman review staff is requested to provide a review of the attached study for the proposed project. The agreed upon study scope is also attached for verification.

Date Submitted:	**Codes or Planning Case No.:**	
City of Norman Review Staff Contact Information:		Phone: E-Mail:

Project Name and Location (specific):			
Nearest Major Cross Streets:			
Project Developer or Property Owner:		Phone:	
Traffic Study Preparer:		Phone:	
Address:		E-Mail:	

Description of Project:

The following materials are included with this Request for Review

- □ Pre-Study Scope Determination Notes (Project Scope)
- □ Completed Development Review Application (if not yet completed, provide an approximate date when applications are anticipated to be submitted)
- □ Traffic Study (studies should be sealed by a P.E.)
- □ Site plan
- □ Background information (i.e. existing conditions, adjacent land uses, recent development Activity, planned/programmed improvements, etc.)

Request Sent by:		**Phone:**	
Signature:		**Date:**	
Received by:		**Phone:**	
Signature:		**Date:**	

□ **Recommended for Approval:** □ **Recommended for Approval with Conditions:** □ **Additional Information/Revision Needed:** □ **Recommended Denial:**	**Comments:**

City of Norman Reviewer (Signature)

FORM C—FINDING OF NO SIGNIFICANT IMPACT
City of Norman Traffic Study Screening

Date Issued:		**Codes or Planning Case No.:**	
City of Norman Review Staff Contact Information:		Phone:	
		E-Mail:	
Project Name and Location (specific):			
Nearest Major Cross Streets:			
Applicant or Property Developer:		Phone:	
Traffic Study Preparer:		Phone:	
Description of Project:			
The City of Norman review staff has reviewed the Initial Traffic Study Evaluation of this project and has found that the traffic impacts will likely not significantly impact the transportation system. A traffic study will not be required.			
City of Norman Review Staff Comments:			

Evaluated by: ______________________ **Phone:** __________

City of Norman Reviewer (Print)

Signature: ______________________ **Date:** __________

Title: ______________________

- □ **Original**
- □ **Interdepartmental Copy**
- □ **Departmental Copy**
- □ **Applicant Copy**
- □ **File Copy**

This form will be returned to you by the City of Norman review staff if no traffic study is required. Additional comments, if necessary, will be provided at the earliest possible date, but not later than fifteen (15) business days after receipt of this request.

CITY OF NORMAN
Public Works Department
FORM D—PERMIT TO COUNT TRAFFIC IN CITY RIGHT-OF-WAY

Date: ________________________________

Contractor Name: ____

Address:____

City/State/Zip: ____

Telephone: ___________________________ **Fax:** ______________

E-mail: ____

Count Location: ____
____

Count Dates: ____

Type of Count (Check all that apply)

- □ **Peak Hour Turning Movement Count**
- □ **Peak Hour Pedestrian Count**
- □ **24-hour Volume Count**
- □ **Speed Study**
- □ **Gap Study**
- □ **Delay Study**

Fax to: City of Norman Traffic Control Division 405-292-9765
Additional questions please telephone 405-329-0528

Form D to be submitted one week prior to count activities with approval within 48 hours.

APPENDIX B
Complete Streets Manual

City of Norman

Complete

Streets

Design

Manual

October 2022

<u>Complete Streets Manual Review Meeting Schedule</u>

ACKNOWLEDGMENTS

Suzanne Bogert, Director of RENEW, Los Angeles County Department of Public Health.

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1. INTRODUCTION

CONTEXT

A growing number of communities are discovering the value of their streets as important public spaces for many aspects of daily life. People want streets that are safe to cross or walk along, offer places to meet people, link healthy neighborhoods, and have a vibrant mix of retail. More people are enjoying the value of farmers' markets, street festivals, and gathering places. In addition, more people want to be able to walk and ride bicycles in their neighborhoods.

Lively Street (Credit: David Riesland)

People from a wide variety of backgrounds are forming partnerships with schools, health agencies, neighborhood associations, environmental organizations, and other groups in asking their city councils to create streets and neighborhoods that fit this vision. As a result, an increasing number of cities are looking to modify the way they design their streets but are often stifled by standards and guidelines that prevent them from making the changes sought. Los Angeles County, California, created an on-line template whereby any entity could customize a Complete Streets Manual using limited resources. The authors felt that by making their work widely available, many more communities will fulfill their dreams in making and remaking their streets valuable public space that serves many needs.

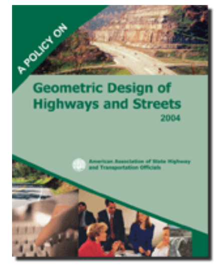
LEGAL STANDING OF STREET MANUALS

Local jurisdictions generally follow some established standards for designing streets. Much confusion exists as to what they must follow, what is merely guidance, when they can adopt their own standards, and when they can use designs that differ from existing standards. The text below untangles the myriad of accepted design documents. It is critical for cities and counties to understand how adopting this manual meshes with other standards and guides. The most important of those standards and guides are the following:

- The American Association of State Highway and Transportation Officials' (AASHTO) *A Policy on Geometric Design of Highways and Streets* (the "Green Book")
- The Oklahoma Department of Transportation Roadway Design Standards
- The City of Norman Engineering Design Criteria
- The City of Norman Comprehensive Transportation Plan
- The *Manual on Uniform Traffic Control Devices* (MUTCD)
- The Oklahoma Fire Code
- The Oklahoma State Vehicle Code

A discussion of the federal-aid roadway classification system helps to frame the requirements of each of these documents. Local governments that wish to use certain federal funds must use a street classification system based on arterials, collectors, and local streets. These funds are for streets and roads that are on the federal-aid system. Only arterials and certain collector streets are on this system. In Chapter 2, "Street Networks and Classifications," this manual recommends an alternative system. To maintain access to these federal funds, local jurisdictions can use both systems. The federal aid system encourages cities to designate more of these larger streets, and to concentrate modifications along these larger streets. Nevertheless, for the purposes of understanding design standards and guides, this is the existing system of street classification for federal funding.

AASHTO Green Book



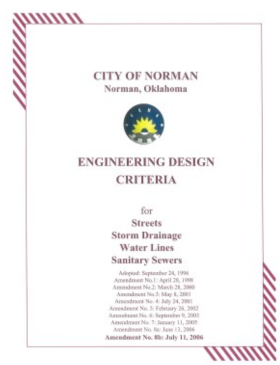
The Green Book provides guidance for designing geometric alignment, street width, lane width, shoulder width, medians, and other street features. The Green Book applies only to streets and roads that are part of the National Highway System (NHS). These are Interstate Freeways, principal routes connecting to them, and roads important to strategic defense. Although the Green Book's application is limited to these streets, some cities apply its recommendations to all streets.

Further, the Green Book provides guidance that cities often unnecessarily treat as standards. The Green Book encourages flexibility in design within certain parameters, as evidenced by the AASHTO publication *A Guide to Achieving Flexibility in Highway Design*. For example, 10-foot lanes, which cities often shun out of concerns of deviating from standards, are well within AASHTO guidelines.

Oklahoma Department of Transportation Roadway Design Standards

The Oklahoma Department of Transportation *Roadway Design Standards* applies only to State Highways and bikeways within local jurisdictions. If cities deviate from the minimum widths and geometric criteria for bikeways spelled out they are advised to follow the design exception process, as applicable. These standards do not establish legal standards for designing local streets. However, like the Green Book, some cities apply these standards as guidance to all streets.

City of Norman Engineering Design Criteria

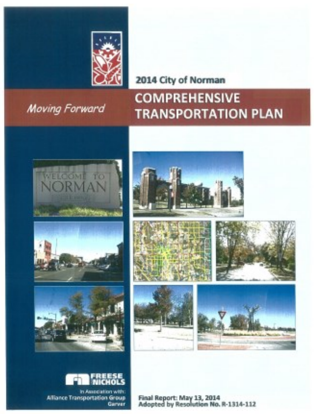


The City of Norman's Engineering Design Criteria together with the City of Norman's Standard Specifications and Construction Drawings regulate both public improvements and private work which will either be dedicated to or accepted by the City. In addition, all work within the public right-of-way is governed by these regulations. They are intended to provide for coordinated development with adequate facilities to serve and protect the users.

These documents are meant to provide minimum criteria and to apply rigidly to new developments which are not constrained by already existing improvements. Designers are encouraged to exceed these criteria whenever possible to provide better engineered facilities. Infill development in an urban area is often constrained when matching existing improvements. To the extent possible by the City Engineer, infill developments shall be completed in accordance with the Engineering Design Criteria document. The City Engineer; however, may allow modification of these requirements when necessary to allow private and public construction which is compatible with surrounding in-place improvements.

These design criteria, standard specifications, and construction standards shall also be used in conjunction with the City's zoning regulations and subdivision ordinances for site development work on private property. The adoption of this Complete Streets Program Manual will offer additional flexibility in design not offered by the City's Engineering Design Criteria.

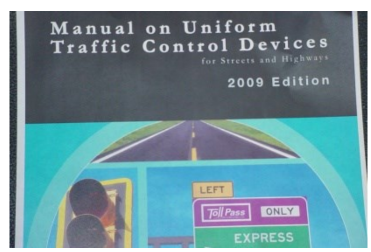
City of Norman Comprehensive Transportation Plan



The City of Norman completed a multi-year process to develop a Comprehensive Transportation Plan (CTP) for the city. This process culminated with the adoption of the City's first CTP in May, 2014. The Norman CTP identifies future transportation needs for the area, goals and policies, and short-term and long-term capital investments for improvements to existing roads, construction of new roads, bicycle, pedestrian, and transit facilities. It provides a framework for a balanced transportation system that offers choices in how people travel, supported by a realistic approach to fund improvements. One of the Action Items from the CTP was the creation and adoption of a Complete Streets Program Manual.

MUTCD

The MUTCD provides standards and guidance for the application of all allowed traffic control devices including roadway markings, traffic signs, and signals. The Federal Highway Administration oversees application of the MUTCD. In addition to the State of Oklahoma, the City of Norman has adopted and follows the federal MUTCD.



The rules and requirements for the use of traffic control devices are different than for street design criteria. Local agencies have limited flexibility to deviate from the provisions of the MUTCD in the use of traffic control devices due to the relationship between the MUTCD and state law. The MUTCD does provide flexibility within its general provisions for items such as application of standard traffic control devices, use of custom signs for unique situations, traffic sign sizes, and sign placement specifics. In contrast, agencies do not generally have the flexibility to develop signs that are similar in purpose to signs within the MUTCD while using different colors, shapes, or legends. Agencies are also not authorized to establish traffic regulations that are not specifically allowed or are in conflict with state law. The provisions of the MUTCD and related state laws thus make it difficult to deploy new traffic control devices in Oklahoma. This can result in complications, especially in the areas of speed management, pedestrian crossings, and bikeway treatments.

The Federal Highway Administration has procedures that allow local agencies to experiment with traffic control devices that are not included in the current MUTCD. Such demonstrations are not difficult to obtain from the Federal Highway Administration for testing of new devices, especially as they relate to pedestrian and bicycle facilities, but the requesting agency must agree to conduct adequate before-and-after studies, submit frequent reports on the performance of the experimental device, and remove the device if early results are not promising.

The federal MUTCD is amended through experimentation. After one or more experiments have shown benefit, the new devices are sometimes adopted into the manuals. In Oklahoma, the Vehicle Code must be changed first if the Vehicle Code prevents use of the new device.

The federal MUTCD establishes warrants for the use of some traffic control devices. For example, STOP signs, traffic signals, and flashing beacons are expected to meet minimum thresholds before application. These thresholds include such criteria as number of vehicles, number of pedestrians or other uses, distance to other devices, crash history, and more. These warrants often prevent local engineers from applying devices that, in their opinion, may improve safety. For example, trail and/or pedestrian crossings of busy, high-speed, wide arterial streets may need signals for user safety, but they may not meet the warrants.

As with street design guidelines, cities may establish their own warrants or modify those suggested by the MUTCD to suit their context in order to use some traffic control devices. In special circumstances that deviate from their own warrants, cities need to document their reasons for the exception. For example, they may say the trail crossings or school crossings qualify for certain traffic control devices.

OKLAHOMA FIRE CODE

The City of Norman recognizes three codes and/or regulations related to adequate fire protection. The first is at the state level. The 2009 International Fire Code, Section 503 addresses fire apparatus access roads. The City of Norman also recognizes the NFPA 1-2009 Fire Code which addresses fire access in Chapter 18. Finally, fire access is covered in the City of Norman's Engineering Design Criteria and Standard Specifications. The City of Norman Ordinance states that where conflicts exist between these three sources, the provisions creating the higher degree of safety will be applied.

OKLAHOMA STATE VEHICLE CODE

The Oklahoma State Vehicle Code includes laws that must be followed in street design. The Oklahoma State Vehicle Code is where you'll find all the rules, laws, regulations, requirements, penalties, and anything else having to do with motor vehicles, drivers, roads, rules of the road, and anything else vehicular. It is what gets changed when new laws are added and when old laws are updated or deleted. This is commonly referred to as Title 47 and is embodied in the MUTCD. Changes to the State Vehicle Code may create a conflict with the MUTCD.

PURPOSE OF THE MANUAL

The safety and convenience of all users of the transportation system including, but not necessarily limited to, pedestrians, bicyclists, transit users, freight, and motor vehicle drivers shall be accommodated and balanced in all types of transportation and development projects and through all phases of a project so that even the most vulnerable—children, the elderly, and persons with disabilities—can travel safely within the public right of way. The purpose and need of this Complete Streets Program Manual is:

- To create complete, safe, and sustainable streets in the City of Norman,
- To provide simple, on-point design guidance that empowers city staff,
- and To provide a clear process and direction.

HOW THIS MANUAL WAS CREATED

This template from which this manual was created was a project of the Los Angeles County Department of Public Health. The department funded the production of this manual through a federal Communities Putting Prevention to Work grant to expand opportunities for people to bicycle and walk as an obesity prevention effort. The Luskin Center for Innovation at the University of California, Los Angeles, funded Chapter 10, "Streetscape Ecosystem," to address environmental sustainability issues related to streets.

A team including many of the top street designers in the U.S. produced this manual. The team comprised experts from traffic engineering, transportation planning, land use planning, architecture, landscape architecture, public health, sociology, and other backgrounds. The team also included experts serving in leadership roles for the following national and local organizations:

- AARP Public Policy Institute
- American Society of Landscape Architects
- Association of Pedestrian and Bicycle Professionals
- California Department of Health Services
- California Strategic Growth Council
- City of Long Beach
- City of Los Angeles Planning Department
- Council for Watershed Health
- Congress for the New Urbanism
- Federal Highway Administration
- Green Los Angeles Coalition
- Institute of Transportation Engineers
- Los Angeles Chapter of the American Institute of Architects

- Los Angeles County Department of Public Health
- National Complete Streets Coalition
- Project for Public Spaces
- Safe Routes to School National Partnership
- Smart Growth America
- UCLA Luskin Center for Innovation
- US Access Board
- Walkable and Livable Communities Institute

The multidisciplinary nature of this team created concepts for streets that reflect viewpoints from various perspectives and lenses.

2. STREET NETWORKS AND CLASSIFICATIONS

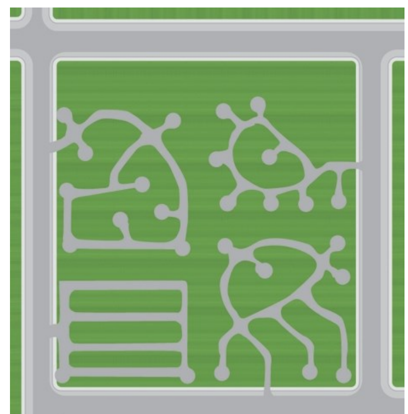
INTRODUCTION

The United States has a long and distinguished history of creating memorable and enduring cities, such as Savannah, Charleston, Washington, D.C., Boston, and San Francisco. These cities are memorable and enduring partly because of their street networks. Well-planned street networks help create sustainable cities that support the environmental, social, and economic needs of their residents.

No matter how well our streets are planned, there are still approximately 30,000 Americans killed each year in traffic crashes on the nation's highways (National Highway Traffic Safety Administration, Data Resource Website, 2013 data). Locally from 2009 to 2013, fatal collisions in Norman have averaged 7.4 per year. Of these 7.4 annual fatal collisions, 3.4 are taking place on higher speed interstate, US highway, and state highway facilities and 4.0 are taking place on generally lower speed city streets. It is important to note that these numbers have been on the decline in recent years, but there remains work to be done. For the following reasons, a good street network is a powerful tool for reducing traffic crashes and fatalities while creating beautiful places:

- **Sustainable street networks improve traffic safety**. Hierarchical street patterns (arterial-collector-local) with cul-de-sac subdivisions depending on arterials do not perform as well as sustainable street networks and cause more traffic crashes. Hierarchical street networks divert traffic to high-speed arterials that have large intersections. Most crashes occur at intersections. The speed at which motor vehicles move on these arterial streets increases the likelihood and severity of crashes.

  A 2011 study of 24 California cities found a 30 percent higher rate of severe injury and a 50 percent higher chance of dying in cities dominated by sparsely connected cul-de-sac compared with cities with dense, connected street networks (Marshall, W. and Garrick, N., "Does the Street Network Design Affect Traffic Safety?" *Accident Analysis and Prevention* 43[3]: 769-781). A 2009 study from Texas found that each additional mile of arterial roadway within a block group is associated with a 15 percent higher incidence of crashes (Dumbaugh, E.R. Rae, "Safe Urban Form: Revisiting the Relationship between Community Design and Traffic Safety," *Journal of the American Planning Association* 75[3]:309-329).



Cul-de-sac developments break up connectivity and create longer trips (Credit: Michele Weisbart)

Interconnected street network with small blocks (Credit: Marty Bruinsma)

- **Sustainable street networks increase the number of people walking and bicycling and reduce vehicle miles traveled.** Connectivity enables people to take shorter routes. It also enables them to travel on quieter streets. These shorter routes on quiet streets are more conducive to bicycling and walking. The California study cited above found that places with a dense, connected street network had three to four times more people walking, bicycling, or using transit to get to work. This in turn led to a 50 percent reduction in vehicle miles traveled per capita in these cities (Marshall, W. and Garrick, N., "The Spatial Distribution of VMT Based upon Street Network Characteristics," 90th Meeting of the Transportation Research Board, Washington, D.C., January 2011).

- **Sustainable street networks allow more effective emergency response.** Studies in Charlotte, North Carolina, found that when one connection was added between cul-de-sac subdivisions, the local fire station increased the number of addresses served by 17 percent and increased the number of households served by 12 percent. Moreover, the connection helped avoid future costs by slowing the growth of operating and capital costs; most of the cost to run a fire station is in salaries. Furthermore, Congress for the New Urbanism's report on emergency response and street design found that emergency responders favor well-connected networks with a redundancy of routes to maximize access to emergencies. Emergency responders can get stuck in cul-de-sacs and need options when streets back up ("Effect on Connectivity on Fire Station Service Area and Capital Facilities," 2009 presentation by the Charlotte, North Carolina DOT,charmeck.org/city/charlotte/citymanager/CommunicationstoCouncil/2009Communications/Documents/CNUPresentation).

These studies and others provide strong evidence that the benefits of a well-designed street network go beyond safety; they include environmental, social, and economic gains. Sustainable street networks shape land use markets and support compact development, in turn decreasing the costs of travel and providing utilities. Street networks like these are resilient over hundreds of years and accommodate changing technology, lifestyles, and travel patterns. Interconnected street networks can preserve habitat and important ecological areas by condensing development, reducing city edges, and reducing sprawl.

A sustainable and resilient street network fosters economic and social activity. It constrains traffic growth by limiting the number of lanes on each street while providing maximum travel options by collectively providing more lanes on more streets. By providing opportunities for all modes of travel, an ideal street network enhances social equity and provides an ideal setting for high quality design at all scales: building, neighborhood, and region. The resulting communities can be some of the most beautiful places with the highest values in the world.

ESSENTIAL PRINCIPLES OF SUSTAINABLE STREET NETWORKS

Sustainable street networks come in many shapes and forms, but have the following overarching principles in common:

- The sustainable street network both shapes and responds to the natural and built environment.
- The sustainable street network encourages trips by foot, bike, and transit because these are the most sustainable types of trips.
- The sustainable street network is built to walking dimensions.
- The sustainable street network works in harmony with other transportation networks, such as pedestrian, bicycle, transit, and private vehicle networks. Large parts of all of these networks are coincidental with the street network, but if any parts are separate from the street network, they must connect and interact with the network.
- The sustainable street network protects, respects, and enhances a city's natural features and ecological systems.
- The sustainable street network maximizes social and economic activity.

STREET CHARACTERISTICS AND CLASSIFICATIONS

A sustainable street network provides a pattern of multimodal streets that serves all community land uses and facilitates easy access to local, city, and regional destinations. The pattern, which may give priority to non-motorized modes, results in distribution of traffic that is consistent with the desired function of the street. One characteristic of this pattern is that it offers many route choices that connect origins with their destinations.

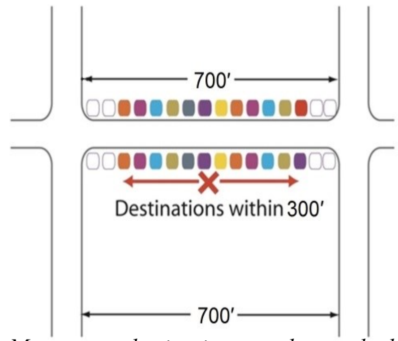
The street network works best when it provides a variety of street types. The variety is enforced by the pattern of the street network itself but also by the design of individual street segments. Natural and built features, including topography and important community destinations, should be taken into account to create unique designs.

Concept to integrate non-motorized paths into new development (Credit: Michele Weisbart)

In new subdivisions, integrating a network of shared use paths and earthen trails into the street network could be considered. Under this concept, every fourth or fifth "street" provides comfortable, quiet, access for non-motorized users along a linear parkway without motor vehicles. Where these intersect streets, they should be treated as intersections with appropriate treatments. This type of network would allow people to circulate in their new communities to schools, parks, stores, and offices while staying primarily on dedicated paths and trails. These networks can also link to paths and trails along waterways, utility corridors, rail rights-of-way, and other more common active transportation corridors. The adjacent diagram illustrates this concept.

The types of streets used in the network are described in the design standards below (see number 7). The types differ in terms of their network continuity, cross-section design, and adjoining land use. The individual streets themselves will change in character depending on their immediate land use context.

DESIGN STANDARDS



Many more destinations can be reached walking 300' within a network of short blocks than in one with long blocks (Credit: Marty Bruinsma)

1. Establish a block size maximum of 700 linear feet between intersections
    - Ensure greater accessibility within the block through alleys, service courts, and other access ways
    - Where block size is exceeded, retrofit large blocks with new street, alleys, pedestrian and/or bicycle connections
    - For existing street networks, do not allow street closures that would result in larger blocks

2. Require multiple street connections between neighborhoods and districts across the whole region. This is achieved by having boulevards and avenues that extend beyond the local area. Adjacent neighborhoods must also be connected by multiple local streets.

3. Connect streets across urban freeways so that pedestrians and bicyclists have links to neighborhoods without having to use streets with freeway on and off ramps.

4. Maintain network quality by accepting growth and the concomitant expansion of the street network (including development, revitalization, intensification, or redevelopment) while avoiding increases in street width or in number of lanes.

5. Provide on-street curbside parking on most streets. Exceptions can be made for very narrow streets, streets with bus lanes, or where there is a better use of the space.

6. Establish maximum speeds of 25 to 35 mph
    - Use design features that support lower-speed environments
    - On local streets, the speed should be 25 mph

7. Maintain network function by discouraging
    - One-way streets
    - Turn prohibitions
    - Full or partial closures (except on bike boulevards, or areas taken over for other uses of public space)

- Removal of on-street parking (except when replaced by wider sidewalks, an enhanced streetscape, bus lanes, bike lanes, etc. rather than additional vehicle lanes)
- Gated streets
- Widening of individual streets
- Conversion of city streets to limited access facilities

8. Classify major streets using the common street and context types presented in Table 2.1. However, some streets are unique and deserve a special category that lies outside the common street network types. Table 2.2 describes these special streets. Chapter 3, "Traveled Way Design," contains guidance related to cross sections of these street typologies. New street types should be welcomed as well.

TYPES AND ROLES OF STREETS

Federal Highway Function and Classification system contains the conventional classification system that is commonly accepted to define the function and operational requirements for streets. These classifications are also used as the primary basis for geometric design criteria.

Traffic volume, trip characteristics, speed and level of service, and other factors in the functional classification system relate to the mobility of motor vehicles, not bicyclists or pedestrians, and do not consider the context or land use of the surrounding environment. This approach, while appropriate for high speed rural and some suburban roadways, does not provide designers with guidance on how to design for living streets or in a context-sensitive manner.

The street types described here provide mobility for all modes of transportation with a greater focus on the pedestrian. The functional classification system can be generally applied to the street types in this document. Designers should recognize the need for greater flexibility in applying design criteria, based more heavily on context and the need to create a safe environment for pedestrians, rather than strictly following the conventional application of functional classification in determining geometric criteria.

The terms for street types for living streets are described in the following sections. Many municipalities use the terms "avenue" and "street" in combination with the street name as a way to differentiate streets running north and south from those running east and west (e.g., 1st Street, 1st Avenue); these uses differ from the definitions used in this manual.

Arterial (Boulevard)

An arterial is a street designed for high vehicular capacity and moderate speed, traversing an urbanized area. Arterials serve as primary transit routes. Arterials should have bike lanes. They may be equipped with bus lanes or side access lanes buffering sidewalks and buildings. Many arterials also have landscaped medians.

Arterial Example: Norman, OK (Credit: David Riesland)

Collector (Avenue)

A collector is a street of moderate to high vehicular capacity and low to moderate speed acting as a short distance connector between urban centers and may be equipped with a landscaped median.

Collector Example: Norman, OK (Credit: David Riesland)

Local Street (Street)

A local street is a local, multi-movement facility suitable for all urbanized transect zones and all frontages and uses. A local street is urban in character, with raised curbs (except where curbless treatments are designed), drainage inlets, sidewalks, parallel parking, and trees in individual or continuous planters aligned in an alley. Character may vary in response to the commercial or residential uses lining the local street.

Local Street Example: Norman, OK (Credit: David Riesland)

Alley

An alley is a narrow street, often without sidewalks. Alleys connect streets and can provide access to the backs of buildings and garages.

Alley example: Norman, OK (Credit: David Riesland)

Table 2.1 provides a list of common street types. The special street typologies listed in Table 2.2 have particular functions within the street network.

Table 2.1 Common Street Types

Street Type	Description	Comment
Arterial* (Boulevard)	Traverses and connects districts and cities; primary a longer distance route for all vehicles including transit	Often has a planted median
Collector* (Avenue)	Traverses and connects districts, links local streets with arterials. For all vehicles including transit.	May or may not have a median
Local Street* (Streets)	Serves neighborhood, connects to adjoining neighborhoods; serves local function for vehicles and transit	
Alley	Link between local streets; allows access to garages	Narrow and without sidewalks
*May have segments with specialized functions and features such as a Main Street segment.		

Table 2.2 Special Street Types

Street Type	Description	Comment
Main Street	Slower vehicle speeds, favors pedestrians most, contains the highest level of streetscape features, typically dominated by retail and other commercial uses	Functions differently than other streets in that it is a destination
Transit Mall	The traveled way is for exclusive use by buses or trains, typically dominated by retail and other commercial uses	Excellent pedestrian access to and along the transit mall is critical. Bicycle access may be supported.
Bike Boulevard	A through street for bicycles, but short distance travel for motor vehicles	Usually a local street with low traffic volumes
Festival Street	Contains traffic calming, flush curbs, and streetscape features that allow for easy conversion to public uses such as farmers' markets and music events	
Shared Space	Slow, curbless street where pedestrians, motor vehicles, and bicyclists share space	May support café seating, play areas, and other uses

16th Street Transit Mall: Denver, CO
(Credit: Ryan Snyder)

Shared space: Copenhagen, Denmark
(Credit: Ryan Snyder)

3. TRAVELED WAY DESIGN

INTRODUCTION

Wide Street
(Credit: David Riesland)

Streets and their geometric design have traditionally focused on the movement of motor vehicles, resulting in street environments that neglect other users. This emphasis can be seen in wide travel lanes, large corner radii, and turn lanes that severely impede the safety of pedestrians and the overall connectivity for non-automobile users. The geometric design of the traveled way and intersections has usually reflected the need to move traffic as quickly as possible. A paradigm shift needs to occur to reclaim the public right-of-way for pedestrians and bicyclists and create living streets.

Traveled way design in this chapter is defined as the part of the street right-of-way between the two faces of curbs and can include parking lanes, bicycle lanes, transit lanes, general use travel lanes, and medians. The design of the traveled way is critical to the design of the entire street right-of-way because it affects not just the users in the traveled way, but those using the entire right-of-way, including the areas adjacent to the street. As a note on terminology, "traveled way" in this document is more or less the equivalent of "roadway" in most conventional design manuals: the curb-to-curb portion of a curbed street.

ESSENTIAL PRINCIPLES OF TRAVELED WAY DESIGN

The following key principles should be kept in mind for a well-designed traveled way:

- **Design to accommodate all users.** Street design should accommodate *all* users of the street, including pedestrians, bicyclists, transit users, automobiles, and commercial vehicles. A well-designed traveled way provides appropriate space for all street users to coexist.
- **Design using the appropriate speed for the surrounding context.** The right design speed should respect the desired role and responsibility of the street, including the type and intensity of land use, urban form, the desired activities on the sidewalk, such as outdoor dining, and the overall safety and comfort of pedestrians and bicyclists. The speed of vehicles impacts all users of the street and the livability of the surrounding area. Lower speeds reduce crashes and injuries.
- **Design for safety.** The safety of all street users, especially the most vulnerable users (children, the elderly, and disabled) and modes (pedestrians and bicyclists) should be paramount in any design of the traveled way. The safety of streets can be dramatically improved through appropriate geometric design and operations.

Building on the momentum of complete streets that have been successfully implemented in different parts of the nation and around the world, there is a desire to retrofit existing streets and create new types of street environments that reflect the values and desires of all users. This chapter discusses different factors affecting traveled way design. Individual geometric design elements such as lane width and sight distance are examined in greater detail. The benefits and constraints of each element are examined and the appropriate location and correct use of each element is defined to maximize the creation of living streets. Finally, a case study of La Jolla Boulevard in San Diego demonstrates the benefits of well-designed traveled ways.

FACTORS AFFECTING STREET DESIGN

USERS

Pedestrians

Walking is the most basic mode of transportation, yet pedestrians are often ignored in roadway design. Certain areas generate high pedestrian activity, such as downtowns, residential, commercial, and entertainment areas, and schools. Yet, even in areas of low pedestrian activity, such as along commercial strip-developed arterials, pedestrian needs and safety must be addressed, as drivers usually don't expect pedestrians, who are more vulnerable if a crash occurs. Much of this is due to speed. As speeds increase, drivers are less attentive to what is happening on the side of the road, reaction time is increased, and the pedestrian has a higher chance of dying or becoming severely injured in case of a crash.

Senior citizens need more time to cross the street (Credit: Ryan Snyder)

Most pedestrian crashes occur when a person crosses the road, and the most common crash type is a conflict between a crossing pedestrian and a turning vehicle at an intersection.

However, designing for pedestrians should not focus primarily on avoiding crashes; the goal of roadway and intersection design should be to create an environment that is conducive to walking, where people can walk along and cross the road, where the roadside becomes a place where people want to be. The two most effective methods to achieve these goals are to minimize the footprint dedicated to motor vehicle traffic and to slow down the speed of moving traffic. This approach allows the designer to use many features that enhance the walking environment, such as trees, curb extensions, and street furniture, which in turn slows traffic. All urban streets should have sidewalks. All rural roads and shared-space streets should have sidewalks as practical.

See Chapter 5, "Universal Pedestrian Access," for specifics of sidewalk design and Chapter 6, "Pedestrian Crossings," for specifics of pedestrian crossings.

Bicyclists

All streets should be designed with the expectation that bicyclists will use them. This does not mean every street needs a dedicated bicycle facility, nor will every road accommodate all types of bicyclists. Minimizing the footprint dedicated to motor vehicle traffic and reducing the speed of vehicular traffic does benefit bicyclists. Chapter 7, "Bikeway Design," describes in greater detail the various types of bikeways and their application. Ideally, all multi-lane streets should have bike lanes. On multi-lane streets where bike lanes aren't feasible because of space constraints, other bikeway treatments should be applied.

Public Transportation

Designing for transit vehicles on roadways takes into consideration many factors. Buses have operational characteristics that resemble trucks - they usually operate in mixed traffic, they stop and start often for passengers, and they must be accessible to people boarding the bus. The consequences for roadway design include lane width (in most cases buses can operate safely in travel lanes designed for passenger cars), intersection design (turning radius or width of channelization lane), signal timing (often adjusted to give transit an advantage—queue jumping), pedestrian access (crossing the street at bus stops), sidewalk design (making room for bus shelters in the furniture zone), and bus stop placement and design (farside/nearside at intersections, bus pullouts, or bulb outs).

Chapter 8, "Transit Accommodations," describes in greater detail these and other design and operational considerations. Where express bus service or Bus Rapid Transit is provided, exclusive bus lanes are desirable. These have unique operating characteristics that are beyond the scope of this manual.

Design Vehicles

The design vehicle influences several geometric design features including lane width, corner radii, median nose design, and other intersection design details. Designing for a larger vehicle than necessary is undesirable, due to the potential negative impacts larger dimensions may have on pedestrian crossing distances and the speed of turning vehicles. On the other hand, designing for a vehicle that is too small can result in operational problems if larger vehicles frequently use the facility.

For design purposes, the WB-40 (wheel-base 40 feet) is appropriate unless larger vehicles are more common. On bus routes and truck routes, designing for the bus (CITY-BUS or similar) or large truck (either the WB-50 or WB-62FL design vehicle) may be appropriate, but only at intersections where these vehicles make turns. For example, for intersection geometry design features such as corner radii, different design vehicles should be used for each intersection or even each corner, rather than a "one-size-fits-all" approach, which results in larger radii than needed at most corners. The design vehicle should be accommodated without encroachment into opposing traffic lanes. It is generally acceptable to have encroachment onto multiple same-direction traffic lanes on the receiving roadway.

Furthermore, it may be inappropriate to design a facility by using a larger "control vehicle," which uses the street infrequently, or infrequently makes turns at a specific location. An example of a control vehicle is a vehicle that makes no more than one delivery per day at a business. Depending on the frequency, by under designing the control vehicle can be allowed to encroach on opposing traffic lanes or make multiple-point turns.

Traffic Volume and Composition

Traffic volume data collection is an integral part of transportation planning and decision making. Traffic volume data are collected for various periods of the day depending on the purpose for which the data is used. For most analyses it is necessary to collect peak period and daily traffic. Peak period traffic could be further divided into morning (a.m.), mid-day, and evening (p.m.) peak periods. Daily traffic data is also called average daily traffic (ADT). Other types of data collected are annual daily traffic, average annual daily traffic, average weekday traffic, hourly traffic (usually at intersections), and short-term counts as required. There are special types of traffic volume counts such as vehicle classification counts and average vehicle occupancy. The traffic volumes collected are also used for a variety of studies, including forecasting. Traffic volume on a segment of a road or at an intersection can be collected either manually or by using tubes.

The ADT volume is the most commonly collected traffic volume data. The ADT provides both the peak period traffic and the total daily traffic for analysis purposes. Typical ADT data for a central business district (CBD) will show an a.m., mid-day, and p.m. peak volume, which clearly indicates the typical usage of the CBD.

Vehicle classification counts are conducted on a daily basis to determine the types of vehicles using the roadway. The vehicle classification devices currently in use accurately record axle impulses, but do not provide consistent and accurate interpretation of axle impulses into classification of vehicles when vehicles (typically in urban areas) are traveling at speeds below 25 mph. The Federal Highway Administration (FHWA) has classified trucks into several categories based on the number of axles.

Turning movement volumes are collected at intersections to record the various turning movements. The collection of data on turning movements allows determining the level of service and making improvements to the intersection to reduce delay and idling for all vehicles. The data collected on traffic volumes and turning movements helps to determine the number of travel lanes needed.

Design Speed

The application of design speed for living streets is philosophically different than for conventional transportation practices. Traditionally, the approach for setting design speed is to use as high a design speed as practical. This has many negative effects. Speed kills places as well as people, and places efficiency over access. Because high design speeds reduce access to places on foot, they degrade the social and retail life of a street and devalue the adjacent land. Local economies thrive on attracting people.

In contrast to this approach, the goal of living streets is to establish design speeds that create a safer and more comfortable environment for motorists, pedestrians, and bicyclists. This approach increases access to adjacent land, increasing its value, and therefore is appropriate for the surrounding context. For living streets, design speeds of 25 to 35 mph are desirable. Alleys and narrow roadways intended to function as shared spaces may have design speeds as low as 15 mph. Design speed does not determine nor predict the speed motorists will travel on a roadway segment; rather, design speed determines which design features are allowable (or mandated). Features associated with high-speed designs, such as large curb radii, straight and wide travel lanes, ample clear zones (no on-street parking or street trees), guardrails, etc., degrade the walking experience and make it difficult to design living streets. A slower design speed allows use of features to enhance the walking environment, such as small curb radii, narrower sections, trees, on-street parking, curb extensions, and street furniture, which in turn slows traffic.

<u>Movement Types</u>

The following movement types describe the expected driver experience on a given street and the design speed for pedestrian safety and mobility established for each of these movement types. They are also used to establish the components and criteria for design of living streets.


High auto level of service with low multi-modal level of service (Credit: Dan Burden)

- **Yield:** Drivers must proceed slowly with extreme care and must yield in order to pass a parked car or approaching vehicle. This is equivalent to traffic calming. With lower design speeds, this type should accommodate bicycling through the use of shared lanes.
- **Slow:** Drivers can proceed carefully with an occasional stop to allow a pedestrian to cross or another car to park. Drivers should feel uncomfortable exceeding design speed due to the presence of parked cars, a feeling of enclosure, tight turn radii, and other design elements. With a design speed of 25 to 30 mph, this type should accommodate bicycling through the use of shared lanes.
- **Low:** Drivers can expect to travel generally without delay at the design speed; street design supports safe pedestrian movement at the higher design speed. This movement type is appropriate for streets designed to traverse longer distances or that connect to higher intensity locations. With a design speed of 30 to 35 mph, this type can accommodate bicycling with the use of bike lanes.


High multi-modal level of service (Credit: Ryan Snyder)

MULTI-MODAL LEVEL OF SERVICE

Municipalities use qualitative assessments to describe the perceived service a street provides to the people using the facility. The quality of service has conventionally been obtained using Level of Service (LOS) measurements. LOS assesses delay for motorists along a roadway section or at a signalized intersection. The LOS is defined using letters A to F, where LOS F denotes the greatest delay and LOS A no delay. The LOS is used to develop solutions to improve the existing system to achieve the desired LOS. This convention considers quality of service for only automobiles and other vehicles (commercial) using the roadway system. The Highway Capacity Manual (HCM) provides details of the LOS computations for roadways and intersections.

Since traveled ways are used by different modes, the multimodal level of service (MMLOS) was developed under National Cooperative Highway Research Program (NCHRP) project 3-70. The MMLOS was developed for urban streets and it is currently designed for analysis of steady state conditions during a specified analysis period. MMLOS applies to urban streets with all modes of travel (cars, pedestrians, transit, and bicycles) and assesses the impacts of facility design and operation on all users except for commercial vehicles. The MMLOS analysis provides a tool to predict travel perceptions of quality of service.

The MMLOS for the four modal usages is output as numerical ratings, which are converted into the traditional A to F letter grade system. Table 3.1 indicates the MMLOS letter grade equivalents of the numerical values obtained.

Table 3.1 MMLOS Letter Grade Equivalents

MMLOS Modal Output	MMLOS Letter Grade
Model <= 2.0	A
2.0<Model <=2.75	B
2.75<Model <=3.50	C
3.50<Model <=4.25	D
4.25<Model <=5.00	E
Model>5.0	F

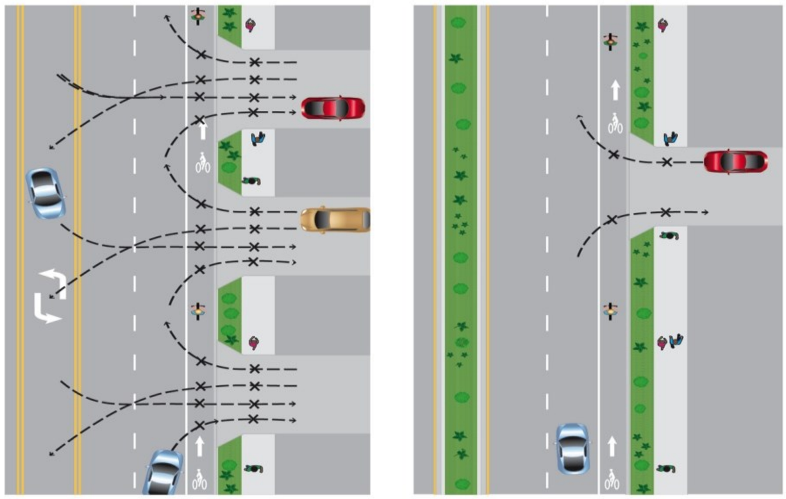
Source: NCHRP-Web Only Document 128: Multimodal level of service analysis for urban streets: User Guide, 2009.
Notes:
1. If any directional segment hourly volume/capacity ratio (v/c) exceeds 1.0 for any mode, that direction of street is considered to be operating at LOS F for that mode of travel for its entire length (regardless of the computed LOS).
2. If the movement of any mode is legally prohibited for a given direction of travel on the street, then the LOS for that mode is LOS "F" for that direction.

For conducting MMLOS it is necessary to select a roadway segment that has signalized intersections, transit usage, bicycle riders, and pedestrians. The segment could have 5 to 6 signals in the selected section. The data required for conducting MMLOS includes street geometrics, such as number of through lanes, width of lanes, median width, bike lane, shoulder width, parking lane width, sidewalk width, right turn lanes, transit stops, and signalized and un-signalized intersections. The methodology provides some basic default values for use, which can be found in the reference provided at the end of this chapter.

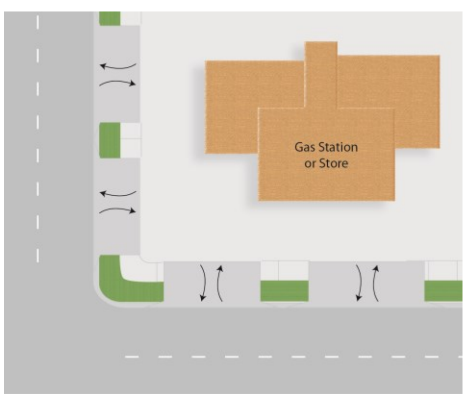
By conducting an MMLOS analysis of existing roadway segments, the agency will be able to identify the deficiency in the system for all the modes. Using the results to change the analyzed street segment will improve the system for all users. The result should lead to very different decisions than would be made under the traditional LOS assessment. Using LOS as the measurement, municipalities typically remedy low LOS by widening streets, flaring intersections, and other measures designed to improve the flow of autos. In contrast, applying MMLOS can lead to improvements for pedestrians, bicyclists, and transit users.

Access Management

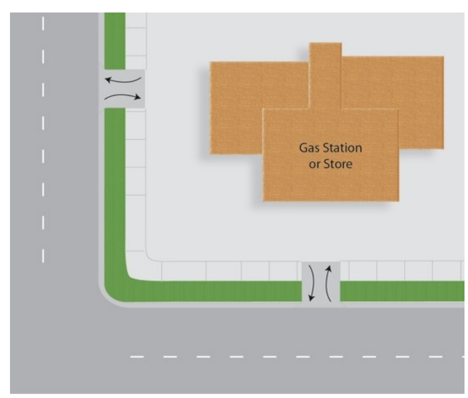
Before After



A major challenge in street design is balancing the number of access points to a street. As discussed in Chapter 2, "Street Networks and Classifications," there are many benefits of well-connected street networks. On the other hand, most conflicts between users occur at intersections and driveways. The presence of many driveways in addition to the necessary intersections creates many conflicts between vehicles entering or leaving a street and bicyclists and pedestrians riding or walking along the street. When possible, new driveways should be minimized and old driveways should be eliminated or consolidated, and raised medians should be placed to limit left turns into and out of driveways.



Adding medians and consolidating driveways to manage access (Credit: Michele Weisbart)



Corner with many wide driveways reconstructed corner with fewer, narrower driveways (Credit: Michele Weisbart)

Access management by limiting driveways and providing raised medians has many benefits:

- The number of conflict points is reduced, especially by replacing center-turn lanes with raised medians since left turns by motorists account for a high number of crashes with bicyclists and pedestrians.
- Pedestrian crossing opportunities are enhanced with a raised median.
- Universal access for pedestrians is easier, since the sidewalk is less frequently interrupted by driveway slopes.
- Fewer driveways result in more space available for higher and better uses.
- Improved traffic flow may reduce the need for road widening, allowing part of the right-of-way to be recaptured for other users.

<u>Possible Negatives of Access Management</u>

The following possible negative effects of management should be considered and addressed:

- Streamlining a street may increase motor vehicle speeds and volumes, which can be detrimental to other users.
- Reduced access to businesses may require out-of-direction travel for all users, including walkers and bicyclists.
- Concrete barriers and overly-landscaped medians act as barriers to pedestrian crossings. Medians should be designed with no more than normal curb height and with landscaping that allows pedestrians to see to the other side.
- Adjacent land uses can experience decreased access. This can impact businesses as well as residents. Careful planning of access management considers this.

CROSS SECTIONAL ELEMENTS

Living street design treats streets as part of the public realm. The street portion of the public realm is shaped by the features and cross section elements used in creating the street. Attention to what features are included, where they are placed, and how the cross section elements are assembled is necessary.

ON-STREET PARKING

On street parking can be important in the urban environment for the success of the retail businesses that line the street and to provide a buffer for pedestrians and help calm traffic speeds. On-street parking occupies about half the surface area per car compared to off-street, which requires driveways and aisles for access and maneuvering. However, cities should manage demand for on-street parking by charging market-rate prices. Free or underpriced parking encourages people to drive instead of taking transit, biking, or walking. Parking expert Donald Shoup recommends setting variable parking prices to target a 15 percent vacancy rate for curb parking. In addition to encouraging people to curtail driving, it also creates turnover that benefits retailers by making convenient parking available for short shopping trips.

Where angle parking is proposed for on-street parking, designers should consider the use of reverse-in angle (or front out) parking in lieu of front-in angled parking. Motorists pulling out of reverse-in angled parking can better see the active street they are entering. This is especially important to bicyclists. Moreover, people exiting cars do so on the curb side and aren't likely to step into an active travel lane.

Another tool for on-street parking is the park assist lane. Often when on-street parking is provided on busy roads, drivers find it difficult to enter and leave their parked vehicle. Where space is available, consideration should be given to adding a park assist lane between the parking lane and travel way to provide 3 feet of space so car doors can be opened and vehicles can enter or depart with a higher degree of safety and less delay. Bike lanes can serve this function as well. Parking assist lanes also narrow the feel of the travel lane and slow traffic. Table 3.2 below details recommended parking lane widths for slow and low movement types.

Parking assist lane
(Credit: Michael Wallwork)

Table 3.2 Parking Lane Widths

Movement Type	Design Speed	Parking Lane Width
Slow	25 mph	Angle: 16.5'(60°); 15'(45°)
Slow	25 mph	Parallel: 7 feet
Low	30-35 mph	Parallel: 7-8 feet

Bicycle Facilities

Bicycle facilities within the traveled way may include bicycle lanes, bicycle boulevards, other types of shared roadways (with or without shared lane markings), and cycle tracks. See Chapter 7, "Bikeway Design," for design recommendations for these facilities.

Transit Facilities

Transit accommodations within the traveled way may include dedicated transit lanes, bus bulbs, bus pullouts, and other features. See Chapter 8, "Transit Accommodations," for design recommendations for these features.

Travel Lanes

Travel lane widths should be provided based on the context and desired speed for the area that the street is located. Table 3.3 shows lane widths and the associated speeds that are appropriate. In low speed urban environments, lane widths are typically measured to the curb face instead of the edge of the gutter pan. Consequently, when curb sections with gutter pans are used, the vehicle, bike, and parking lane all include the width of the gutter pan.

In order for drivers to understand how fast they should drive, lane widths have to create some level of driver discomfort when driving too fast. The presence of on-street parking is important in achieving the speeds shown in Table 3.3. When designated bike lanes or multi-lane configurations are used, there is more room for large vehicles, such as buses, to operate in, but car drivers will feel more comfortable driving faster than is desired.

Wide Two-Lane Street (Credit: Angelo Lombardo)

Narrow Two-Lane Street (Credit: David Riesland)

Table 3.3 Travel Lane Widths and Associated Design Speeds

Movement Type	Design Speed	Travel Lane Width
Yield*	25 mph	N/A
Slow	25-30 mph	9**-10 feet
Low	30-35 mph	10-11*** feet

- *Yield streets are typically residential two-way streets with parking on one or both sides. When the street is parked on both sides, the remaining space between parked vehicles (12 feet minimum) is adequate for one vehicle to pass through. Minimum width for a yield street with parking on both sides should be 26 feet curb face to curb face. Minimum width for a yield street with parking on one side should be 20 feet curb face to curb face, which allows for two 10-foot lanes when the street is not parked.
- **9' requires a design exception.
- ***Generally, 10-foot lanes are preferred. Where heavy bus or truck traffic exists, 11-foot lanes may be considered.

Alleys can be designed as one-way or two-way. Right-of-way width should be a minimum of 20 feet clear with no permanent structures located within the right-of-way that would interfere with vehicle access to garages or parking spaces, access for trash collection, and other operational needs. Pavement width should be a minimum of 12 feet. Coordination with local municipalities on operational requirements is essential to ensure that trash collection and fire protection services can be completed.

Turn Lanes

The need for turn lanes for vehicle mobility should be balanced with the need to manage vehicle speeds and the potential impact on the border width such as sidewalk width. Turn lanes tend to allow higher speeds to occur through intersections, since turning vehicles can move over to the turn lane, allowing the through vehicles to maintain their speed.

Left-turn lanes are considered to be acceptable in an urban environment since there are negative impacts to roadway capacity when left turns block the through movement of vehicles. Sometimes just a left-turn pocket is sufficient, just long enough for one or two cars to wait out of traffic. The installation of a left-turn lane can be beneficial when used to perform a road diet such as reducing a four lane section to three lanes with the center lane providing for turning movements.

In urban places, normally no more than one left-turn lane should be provided. While right turns from through lanes may delay through movements, they also create a reduction in speed due to the slowing of turning vehicles. The installation of right-turn lanes increases the crossing distance for pedestrians and the speed of vehicles; therefore, exclusive right turn lanes should rarely be used except at "T" intersections. When used, they should be mitigated with raised channelization islands. See Chapter 4, "Intersection Design," for more details.

MEDIANS

Well-designed street medians bring multiple benefits (Credit: Dan Burden)

Medians used on urban streets provide access management by limiting left turn movements into and out of abutting development to select locations where a separate left turn lane or pocket can be provided. The reduced number of conflicts and conflict points decrease vehicle crashes, provides pedestrians with a refuge as they cross the road, and provides space for landscaping, lighting, and utilities. These medians are usually raised and curbed. Landscaped medians enhance the street or help to create a gateway entrance into a community.

Medians can be used to create tree canopies over travel lanes, contributing to a sense of enclosure. As shown in Table 3.4, medians vary in width. Recommended widths depend on available right-of-way and function. Because medians require a wider right-of-way, the designer must weigh the benefits of a median with the issues of pedestrian crossing: distance, speed, context, and available roadside width.

Table 3.4 Median Types and Widths

Median Type	Minimum Width	Recommended Width
Median for access control	4 feet	6 feet
Median for pedestrian refuge	6 feet	8 feet
Median for trees and lighting	6 feet [1]	10 feet [2]
Median for single left-turn lane	10 feet [3]	10 feet [2]
Median for single left-turn lane and pedestrian refuge	16 feet [4]	16 feet

Table Notes
[1] Six feet measured curb face to curb face is generally considered the minimum width for proper growth of small caliper trees (less than 4 inches).
[2] Wider medians provide room for larger caliper trees and more extensive landscaping.
[3] A 10-foot lane provides for a turn lane without a concrete traffic separator.
[4] Includes a 10-foot turn lane and a 6-foot pedestrian refuge.

Sample Cross Sections

The City of Norman Comprehensive Transportation Plan adopted by Council Resolution R-1314-112 on May 13, 2014, contains a number of cross-sectional options for the various roadway functional classifications. These cross sections are contained in Appendix D: Design Typical Sections.

OTHER GEOMETRIC DESIGN ELEMENTS

VERTICAL ALIGNMENT

The American Association of State Highway and Transportation Officials (AASHTO) *Geometric Design of Highways and Streets* manual (AASHTO Green Book) provides acceptable values for designing vertical curves for living streets. The values used in design of vertical curve design should be selected based on the design speed appropriate for the context of the street. Using higher values can contribute to increased vehicle speeds and may require increased modification to the natural terrain, increasing negative impacts to the natural environment.

HORIZONTAL ALIGNMENT

The AASHTO Green Book provides appropriate values for designing horizontal curves for living streets. The values used in horizontal curve design should be selected based on the design speed appropriate for the context of the street. Using higher values can contribute to increased vehicle speeds and also impacts the character of the street. Larger horizontal curves also create a more “suburban” or “rural” highway feel.

SIGHT DISTANCE

Stopping Sight Distance

The AASHTO Green Book provides appropriate values for designing stopping sight distance for living streets. Appropriate design speed selection is critical to avoid overly negative impacts such as unnecessarily limiting on-street parking and tree planting.

Intersection Sight Distance

Clear sight distance is needed at intersections and driveway connections for two reasons. The driver stopped on the cross street or driveway must have sufficient sight distance along the main street to select a gap between approaching vehicles to safely enter and depart the intersection area. The driver on the main street must have a view of the cross street from a sufficient distance to allow him to safely react when a vehicle from the cross street enters the main street. The required sight distance for intersections is based on the geometric design of the street, vehicle operating characteristics, driver behavior, and the design speed of the street. These distances are based on current American Association of State Highway and Transportation (AASHTO) criteria.

Clear-sight windows to provide drivers of vehicles on both the main street and the cross street sufficient clear view of one another must be available to afford both drivers with the opportunity to be able to safely react to a potential conflict. The spacing and size of tree trunks within the clear sight distance must be controlled. This is necessary to provide adequate clear-sight window width between trees and to limit the amount of sight blockage by the tree trunk. These controls are based on the design of the street and its design speed. Standards for tree trunk size and spacing between trees and ground cover, within the intersection sight distance, are shown in Table 3.5.

Table 3.5 Tree Spacing Table

Description	Speed (mph)											
	25		30		35		40		45		50	
Diameter	(inches)											
Within Limits of Sight Window	A	B	A	B	A	B	A	B	A	B	A	B
	(feet)											
Min. Spacing (c. to c. of Trunk)	17	74	22	91	27	108	33	126	40	146	45	165

Table Notes
[1] "A" represents a trunk diameter greater than 4 inches but not greater than 11 inches.
[2] "B" represents a trunk diameter greater than 11 inches but not greater than 18 inches.
[3] Sizes and spacing are based on the following conditions:

a. A single line of trees in the median parallel to but not necessarily collinear with the centerline.
b. Trees with diameters less than or equal to 11 inches intermixed with trees with diameters greater than 11 inches but not greater than 18 inches are to be spaced as if all trees are greater than 11 inches but not greater than 18 inches.

HORIZONTAL CLEARANCE/CLEAR ZONE

Horizontal clearance is the lateral distance from a specified point on the roadway, such as the edge of the travel lane or face of the curb, to a roadside feature or object. The clear zone is the relatively flat unobstructed area that is to be provided for safe use by errant vehicles.

In urban areas, horizontal clearance based on clear zone requirements for rural and suburban highways is not practical because urban areas are characterized by more bicyclists and pedestrians, lower speeds, more dense abutting development, closer spaced intersections and accesses to property, higher traffic volumes, and restricted right-of-way. Therefore, streets with curbs and gutters in urban areas do not have sufficiently wide roadsides to provide clear zones. Consequently, while there are specific horizontal clearance requirements for these streets, they are based on clearances for normal operation and not based on maintaining a clear roadside for errant vehicles. The minimum horizontal clearance is 1.5 feet measured from the face of the curb. This is primarily intended for sign posts and poles, so they aren't hit by large vehicles with overhangs maneuvering close to the curb.

TRAVELED WAY LIGHTING

Pedestrians are disproportionately hit when visibility is poor: at dusk, night, and dawn. Many crossings are not well lit. Providing illumination or improving existing lighting increases nighttime safety at intersections and midblock crossings, as motorists can better see pedestrians. Pedestrian scale lighting along sidewalks provides greater security, especially for people walking alone at night.

Transit stops require both kinds of lighting: strong illumination of the traveled way for safer street crossing, and pedestrian scale illumination at the stop or shelter for security.

FHWA-HRT-08-053, *Informational Report on Lighting Design for Midblock Crosswalks*, (April 2008) is a very good resource. It also contains very useful information about lighting design for pedestrians at intersections.

If bus stops are present between roadway sections, it is necessary to illuminate the roadway and the bus stop. The lighting at the bus stop is essential to provide safety for transit users. Bus stops have high pedestrian activity; therefore, it is necessary to provide adequate lighting at these facilities.

MODEL PROJECT

LA JOLLA

La Jolla Boulevard in the Bird Rock neighborhood of San Diego is an example of the conversion of a five-lane road. Due to parents' complaints that they had to drive their children across the road, a community charrette was organized in 2002. As a result, a new concept was developed that included a median, one 11-foot travel lane in each direction, park assist lanes next to the parallel parking lane on the east side, and a wider park assist lane next to the angled parking on the west side of the street. The five intersections that were controlled by two or four-way STOP control and signals were converted to single lane roundabouts.

The project was opened in stages and completed in August 2008. Although the traffic volumes have decreased because of the recession from 22,000 vehicles per day to 17,000 vehicles per day, the pedestrian and bicycle volumes have increased enormously (City of San Diego traffic counts and traffic webcam, 2010).

La Jolla Boulevard intersection before and after roundabout: San Diego, CA
(Credit: Michael Wallwork)

4. INTERSECTION DESIGN

INTRODUCTION

Lively intersection
(Credit: David Riesland)

Most conflicts between roadway users occur at intersections, where travelers cross each other's path. Good intersection design indicates to those approaching the intersection what they must do and who has to yield. Exceptions to this include places where speeds are low or where a shared space design causes users to approach intersections with caution. Conflicts for pedestrians and bicyclists, due to their greater vulnerability, lesser size, and reduced visibility to other users, are exacerbated.

This chapter describes design considerations in intersection geometry and intersection signalization, as well as roundabouts and other features to improve safety, accessibility, and mobility for all users. The benefits and constraints of each feature are examined and the appropriate use and design of each feature are described.

ESSENTIAL PRINCIPLES OF INTERSECTION DESIGN

The following principles apply to all users of intersections:

- Good intersection designs are compact.
- Unusual conflicts should be avoided.
- Simple right-angle intersections are best for all users since many intersection problems are worsened at skewed and multi-legged intersections.
- Free-flowing movements should be avoided.
- Access management practices should be used to remove additional vehicular conflict points near the intersection.
- Signal timing should consider the safety and convenience of all users and should not hinder bicycle or foot traffic with overly long waits or insufficient crossing times.

INTERSECTION GEOMETRY

Intersection geometry is a critical element of intersection design, regardless of the type of traffic control used. Geometry sets the basis for how all users traverse intersections and interact with each other. The principles of intersection geometry apply to both street intersections and freeway on- and off-ramps.

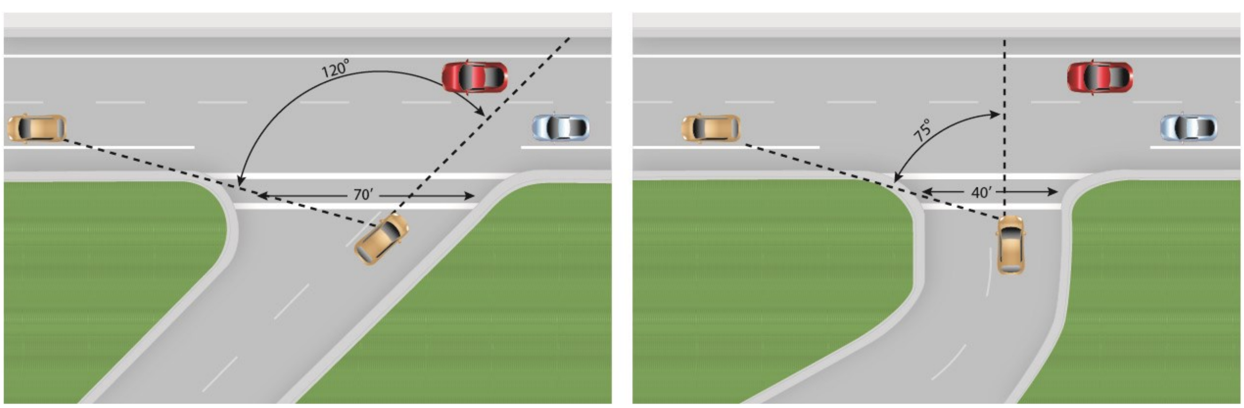
INTERSECTION SKEW

Skewed intersections are generally undesirable and introduce the following complications for all users:

- The travel distance across the intersection is greater, which increases exposure to conflicts and lengthens signal phases for pedestrians and vehicles.
- Skews require users to crane their necks to see other approaching users, making it less likely that some users will be seen.
- Obtuse angles encourage speeding.

To alleviate the problems with skewed intersections, several options are available:

- Every reasonable effort should be made to design or redesign the intersection closer to a right angle. Some right-of-way may have to be purchased, but this can be offset by the larger area no longer needed for the intersection, which can be sold back to adjoining property owners or repurposed for a pocket park, rain garden, greenery, etc.
- Pedestrian refuges should be provided for if the crossing distance exceeds approximately 40 feet.
- General use travel lanes and bike lanes may be striped with dashes to guide bicyclists and motorists through a long undefined area.



Realigning the skewed intersection in the graphic on the left to the right-angle connection in the graphic on the right results in less exposure distance and better visibility for all users.
(Credit: Michele Weisbart)

Multi-leg intersections (more than two approaching roadways) are generally undesirable and introduce the following complications for all users:

- Multiple conflict points are added as users arrive from several directions.
- Users may have difficulty assessing all approaches to identify all possible conflicts.
- At least one leg will be skewed.
- Users must cross more lanes of traffic and the total travel distance across the intersection is increased.

To alleviate the problems with multi-leg intersections, several options are available:

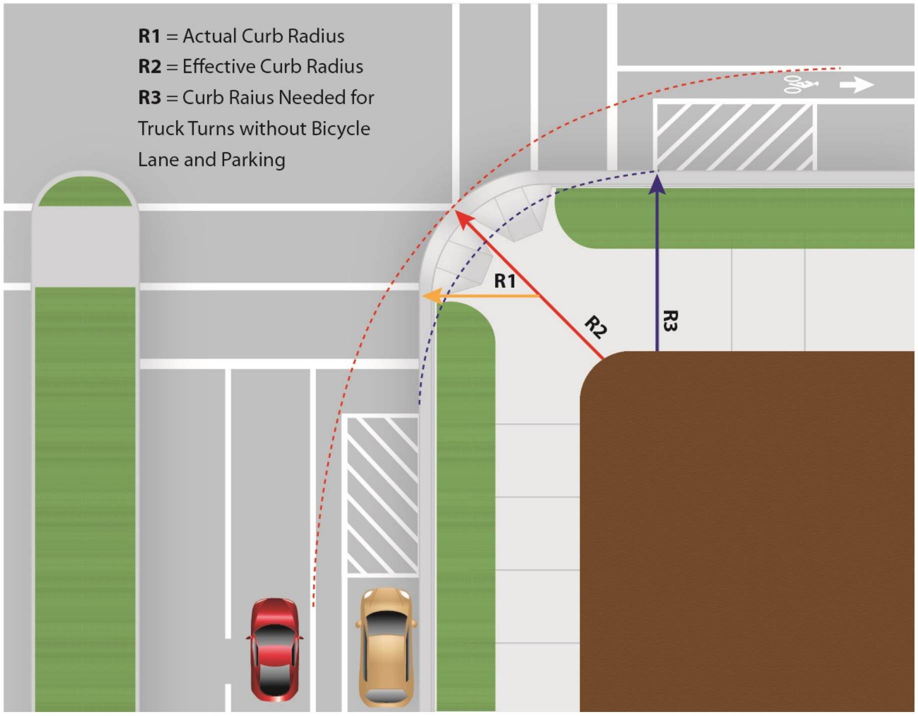
- Every reasonable effort should be made to design the intersection so there are no more than four legs. This is accomplished by removing one or more legs from the major intersection and creating a minor intersection further up or downstream.
- As an alternative, one or more of the approach roads can be closed to motor vehicle traffic, while still allowing access for pedestrians and bicyclists.
- Roundabouts should be considered.
- Pedestrian refuges should be created if the crossing distance exceeds approximately 40 feet.
- General use travel lanes and bike lanes may be striped with dashes to guide bicyclists and motorists through a long undefined area.

CORNER RADII

This intersection geometry feature has a significant impact on the comfort and safety of non-motorized users. Small corner radii provide the following benefits:

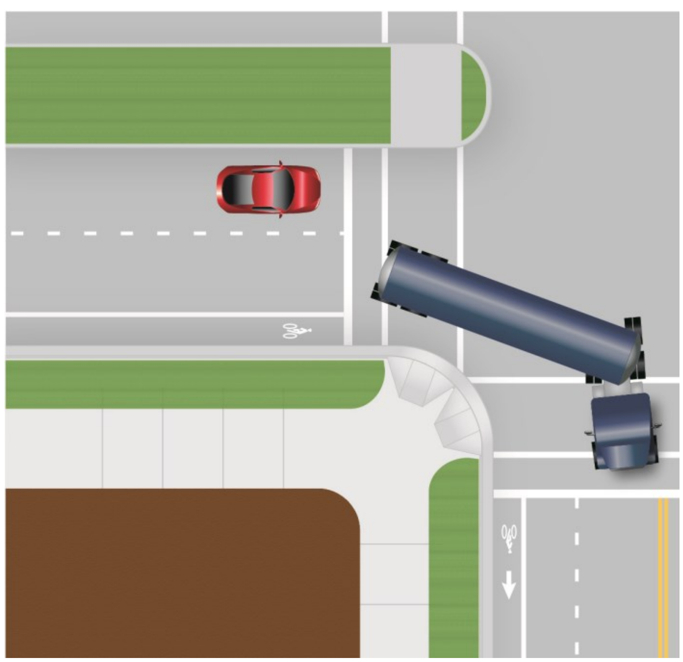
- Smaller, more pedestrian-scale intersections resulting in shorter crossing distances
- Slower vehicular turning speeds
- Reduced pedestrian crossing distance and crossing time
- Better geometry for installing perpendicular ramps for both crosswalks at each corner
- Simpler, more appropriate crosswalk placement, in line with the approaching sidewalks

When designing corner radii for complete streets, designers should make every attempt to minimize the corner radius. However, the standard corner radius is 30 feet. Larger design vehicles should be used only where they are known to regularly make turns at the intersection, and corner radii should be designed based on the larger design vehicle traveling at crawl speed. In addition, designers should consider the effect that bicycle lanes and on-street parking have on the effective radius, increasing the ease with which large vehicles can turn.



The effective corner radius controls turning speeds and the ability of large vehicles to turn. (Credit: Michele Weisbart)

In some situations encroachment by large vehicles may be acceptable onto multiple receiving lanes. As described in Chapter 3, "Traveled Way Design," larger, infrequent vehicles (the "control vehicle") can be allowed to encroach on multiple departure lanes and partway into opposing traffic lanes. In the example below, corner radii can be kept smaller by allowing trucks and buses to turn into multiple receiving lanes.

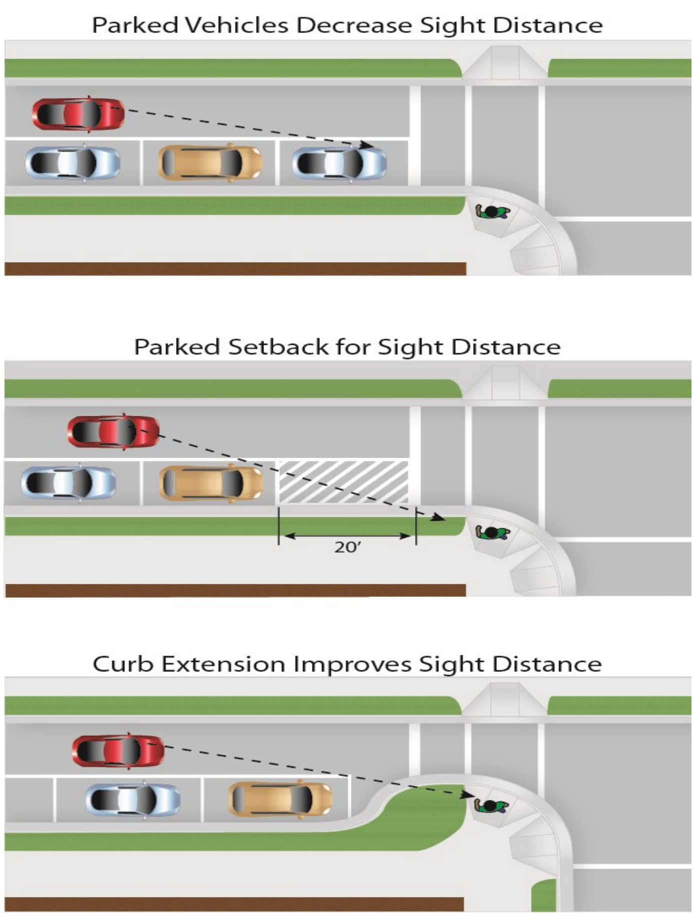


CURB EXTENSIONS

Where on-street parking is allowed, curb extensions should be considered to replace the parking lane at crosswalks. Curb extensions should be the same width as the parking lane. The appropriate corner radius should be applied based on the guidance in the section above. Due to reduced road width, the corner radius on a curb extension may need to be larger than if curb extensions were not installed.

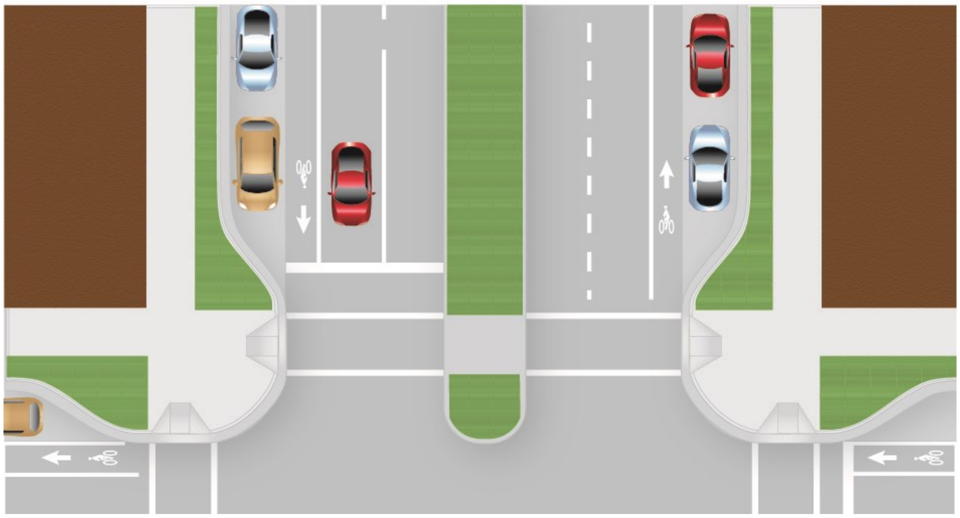
Curb extensions offer many benefits related to livability:

- Reduced pedestrian crossing distance resulting in less exposure to vehicles and shorter pedestrian clearance intervals at signals
- Improved visibility between pedestrians and motorists
- A narrowed roadway, which has a potential traffic calming effect
- Additional room for street furniture, landscaping, and curb ramps
- Slower turning vehicles
- Additional on-street parking potential due to improved sight lines at intersections. Since curb extensions allow pedestrians to walk out toward the edge of the parking lane without entering the roadway, pedestrians can better see vehicles and motorists can better see pedestrians.
- Management of storm water runoff



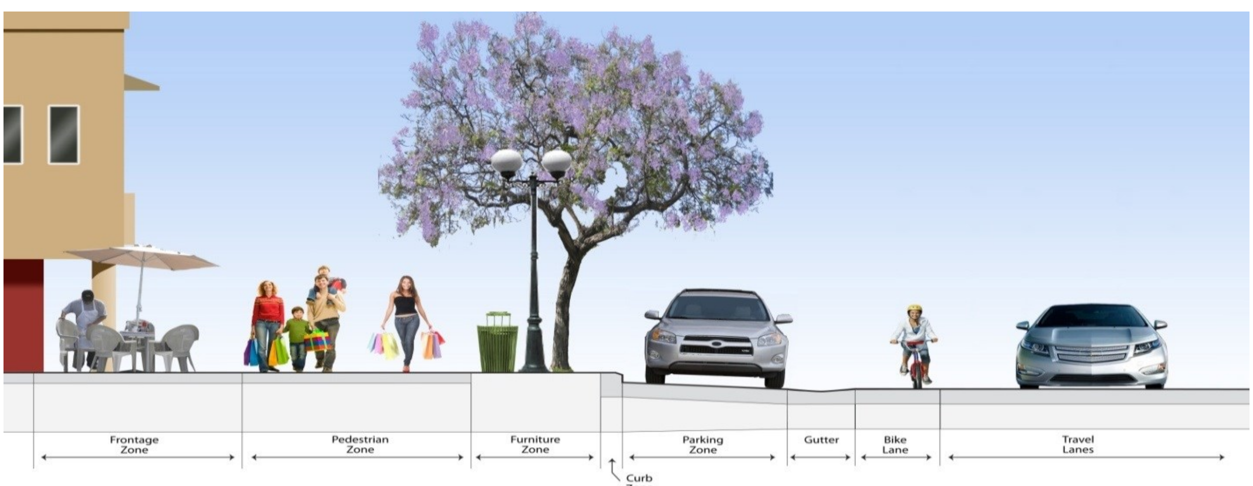
Curb extensions improve sight distance between pedestrians and motorists, possibly allowing additional on-street parking.
(Credit: Michele Weisbart)

To fully achieve livability goals, the curb extension and parking area can be integrated into the furniture zone portion of the sidewalk corridor. This technique involves using similar surface materials for the curb extension, parking area, and the sidewalk as shown in the figure below. Instead of the curb extensions appearing to jut out into the street, the parking appears as "parking pockets" in the furniture zone.



Integrating curb extensions and on-street parking into the sidewalk corridor enhances pedestrian safety and the walking experience. (Credit: Michele Weisbart)

To reinforce this design where street grades permit, the gutter line and drainage grates should be placed between the travel lane and the parking lane/curb extensions. This is called a "valley gutter" and creates a stronger visual cue separating the parking lane from the bicycle lane or travel lane. It can sometimes allow existing drainage infrastructure to be left in place.



An example of integrating curb extensions and parking into the sidewalk corridor by placing a valley gutter between the parking and the traveled way. (Credit: Michele Weisbart)

CROSSWALK AND RAMP PLACEMENT

Crosswalks and ramps at intersections should be placed so they provide convenience and safety for pedestrians. The following recommended practices will help achieve these goals:

- Allow crossings on all legs of an intersection, unless there are no pedestrian accessible destinations on one or more of the corners. Closing a crosswalk usually results in a pedestrian either walking around several legs of the intersection, exposing them to more conflicts, or crossing at the closed location, with no clear path or signal indication as to when to cross.
- Provide marked crosswalks at signalized intersections.
- Place crosswalks as close as possible to the desire line of pedestrians, which is generally in line with the approaching sidewalks.
- Provide as short as possible a crossing distance to reduce the time that pedestrians are exposed to motor vehicles; this is usually as close as possible to right angles across the roadway, except for skewed intersections.
- Ensure that there are adequate sight lines between pedestrians and motorists. This typically means that the crosswalks should not be placed too far back from the intersection.
- When a raised median is present, extend the nose of the median past the crosswalk with a cut-through for pedestrians.
- Provide one ramp per crosswalk (two per corner for standard intersections with no closed crosswalks). Ramps must be entirely contained within a crosswalk (the crosswalk can be flared to capture a ramp that cannot be easily relocated). Align the ramp run with the crosswalk when possible, as ramps that are angled away from the crosswalk may lead some users into the intersection.
- Aesthetic textured pavement materials (e.g., brick and pavers) can only be used in the frontage and furniture zones.

At intersections where roads are skewed or where larger radii are necessary for trucks, it can be difficult to determine the best location for crosswalks and sidewalk ramps. In these situations, it is important to balance the recommended practices above. Tighter curb radii make implementing these recommendations easier.

One curb ramp per crosswalk should be provided at corners. Ramps should align with sidewalks and crosswalks. (Credit: Michele Weisbart)

On-Street Parking Near Intersections

On-street parking should be positioned far enough away from intersections to allow for good visibility of pedestrians preparing to cross the street. Curb extensions allow parking to be placed closer to the intersection.

Right-Turn Channelization Islands

Right-turn lanes should generally be avoided as they increase the size of the intersection, the pedestrian crossing distance, and the likelihood of right-turns-on-red by inattentive motorists who do not notice pedestrians on their right. However, where there are heavy volumes of right turns (approximately 200 vehicles per hour or more), a right-turn lane may be the best solution to provide additional vehicle capacity without adding additional lanes elsewhere in the intersection. For turns onto roads with only one through lane and where truck turning movements are rare, providing a small corner radius at the right-turn lane often provides the best solution for pedestrians' safety and comfort.

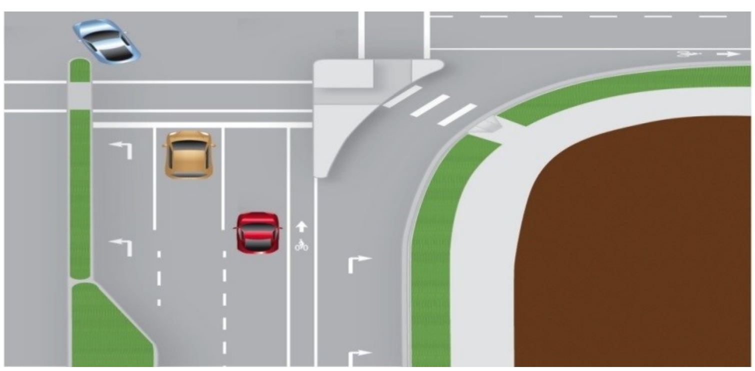
At intersections of multi-lane roadways where trucks make frequent right turns, a raised channelization island between the through lanes and the right-turn lane is a good alternative to an overly large corner radius and enhances pedestrian safety and access. If designed correctly, a raised island can achieve the following objectives:

- Allow pedestrians to cross fewer lanes at a time
- Allow motorists and pedestrians to judge the right turn/pedestrian conflict separately
- Reduce pedestrian crossing distance, which can improve signal timing for all users
- Balance vehicle capacity and truck turning needs with pedestrian safety
- Provide an opportunity for landscape and hardscape enhancement

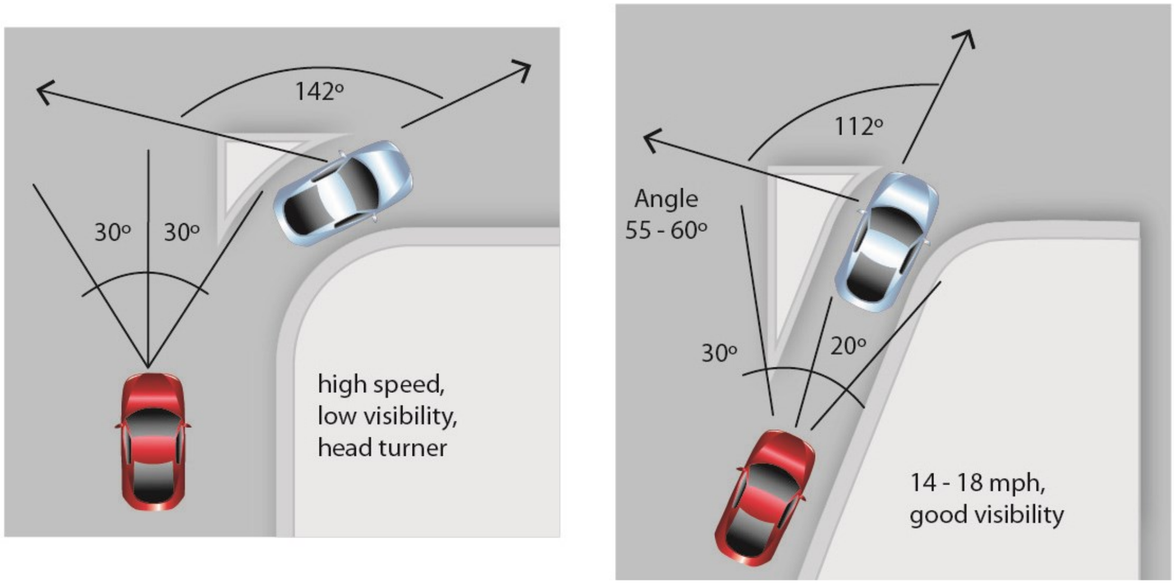
The following design practices for right-turn lane channelization islands should be used to provide safety and convenience for pedestrians, bicyclists, and motorists:

- Provide a YIELD sign for the slip lane
- Provide at least a 60-degree angle between vehicle flows, which reduces turning speeds and improves the yielding driver's visibility of pedestrians and vehicles
- Place the crosswalk across the right-turn lane about one car length back from where drivers yield to traffic on the other street, allowing the yielding driver to respond to a potential pedestrian conflict first, independently of the vehicle conflict, and then move forward, with no more pedestrian conflict

These goals are best accomplished by creating an island that is roughly twice as long as it is wide. The corner radius will typically have a long radius (150 feet to 300 feet) followed by a short radius (20 feet to 50 feet). When creating this design, it is necessary to allow large trucks to turn into multiple receiving lanes. This design is often not practical for right-turn lanes onto roads with only one through lane. This right-turn channelization design is different from designs that provide free-flow movements (through a slip lane) where right-turning motorists turn into an exclusive receiving lane at high speed. Right turns should be signal-controlled in this situation to provide for a signalized pedestrian walk phase.



Traffic channelization is an effective mitigation strategy when intersection radii reduction is not an option. (Credit: Michele Weisbart)



Sharper angles of slip lanes are important to slow cars and increase visibility
(Credit: Michele Weisbart)

YIELD AND STOP CONTROLLED INTERSECTIONS

Intersection control options include the following:

- YIELD control, which is under-utilized and should be considered to reduce unnecessary stops caused by the overuse of STOP signs.
- Uncontrolled intersections are YIELD controlled by default.
- Two-way STOP control, the most common form of intersection control. This is also an overused device. At many intersections a neighborhood traffic calming circle is a preferable and more effective option.
- All-way STOPs are often overused, incorrectly, to slow traffic. The use of all-way STOPs should be consistent with the MUTCD. At many intersections a neighborhood traffic calming circle is a preferable and a more effective option.

SIGNALIZED INTERSECTIONS

Signalized intersections provide unique challenges and opportunities for livable communities and complete streets. On one hand, signals provide control of pedestrians and motor vehicles with numerous benefits. Where signalized intersections are closely spaced, signals can be used to control vehicle speeds by providing appropriate signal progression on a corridor. Traffic signals allow pedestrians and bicyclists to cross major streets with only minimal conflict with motor vehicle traffic. On the other hand, traffic signals create challenges for non-motorized users. Signalized intersections often have significant turning volumes, which conflict with concurrent pedestrian and bicycle movements. In many cases, roundabouts can offer safer, more convenient intersection treatment than signals.

To improve livability and pedestrian safety, signalized intersections should:

- Provide signal progression at speeds that support the target speed of a corridor whenever feasible
- Provide short signal cycle lengths, which allow frequent opportunities to cross major roadways, improving the usability and livability of the surrounding area for all modes
- Ensure that signals detect bicycles
- Place pedestrian signal heads in locations where they are visible
- At locations with many crossing pedestrians, time the pedestrian phase to be on automatic recall, so pedestrians don't have to seek and push a pushbutton.
- Where few pedestrians are expected and automatic recall of walk signals is not desirable, place pedestrian pushbuttons in convenient locations, using separate pedestals if necessary. Use the recommendations regarding pushbutton placement for accessible pedestrian signals found in the Manual on Uniform Traffic Control Devices (MUTCD).
- Include pedestrian signal phasing that increases safety and convenience for pedestrians, as discussed in more detail below

Operational Design

Approximately two percent of intersections are signalized, and approximately 20 percent of all intersection crashes occur at signalized intersections. Unfortunately, in many locations signalization is the only option because of right-of-way limitations, high vehicle volumes, and the need to create gaps to provide reasonable operation for all users.

Pole-mounted signal (Credit: Ryan Snyder)

Over the years, the most common signal hardware has changed from post-mounted signals to overhead mast arms. This change has lifted drivers' eyes upward and away from pedestrians and bicyclists at street level. In urban areas the large mast arms can be intrusive. As part of the conversion to healthier streets, changing to post-mounted signals in urban areas could lower the cost of installing and maintaining signals, reduce the vision intrusion, and help lower a driver's vision back to pedestrians. The designer should implement this sort of change as part of future construction as long as all of the requirements pertaining to signal head visibility contained within the MUTCD are met. There are two advantages for pedestrians and bicyclists to pole-mounted signals:

- Drivers have to stop back from the crosswalk to see the indication so they are less likely to encroach into the crosswalk, and more likely to see pedestrians and bicyclists when turning right.
- Mast-arm signals encourage higher speeds since drivers can see several in a row. If they are green, drivers are more likely to accelerate. However, pole-mounted signals are only visible to drivers closer to the intersection, causing them to drive slower on the approach.

SIGNAL PHASING

A signal phase is defined as the cycle length allocated to a traffic movement at an intersection receiving the right-of-way, or to any combination of traffic movements receiving the right of way simultaneously. The combination of all phases is equal to one cycle length.

Basic Signal Timing

The "timing" is the time in seconds allocated to various vehicular and pedestrian movements. A traffic control signal transmits information to the users by selective illumination of different color lights at a signalized intersection. The illuminated color indicates the user should take a specific action at the signalized intersection:

- **Green time.** Green time is when motorists and bicyclists may proceed through the intersection.
- **Yellow time.** Yellow time is the cycle phase before changing to the red interval that prohibits traffic movement. It signifies to users the light is about to turn red and they should stop if they can safely do so, or continue proceeding if that is safer. A properly timed yellow time interval is important to reduce signal violations by users passing through the intersection.
- **All-red time.** All-red time is that portion of a traffic cycle time where all vehicles are prohibited from any movements at the intersection. The all-red time follows the yellow time interval and precedes the next green interval. The purpose of the all-red time is to allow vehicles that entered the intersection late during the yellow time to clear the intersection before the traffic signal displays green time for conflicting approaches.

Left-Turn Phasing

The most commonly used "left turn" phases at an intersection with a left-turn lane are:

- **Permissive.** Under permissive left turn phasing, through traffic may proceed straight through the intersection with a green ball, as side traffic is stopped (with a red ball); the left turning vehicles are permitted to make the turn when they find a safe and adequate gap from the approaching vehicles. Left-turn movements are controlled either with the green ball or a flashing yellow arrow depending on whether an exclusive left-turn lane exists. Permissive left turn phases create conflicts with pedestrians crossing the street as the timing puts the two on a collision course.
- **Protected-permissive.** Under protected-permissive left turn phasing, left turns are allowed to pass the intersection with a green arrow first during the protected phase (opposing through traffic is stopped); usually three to five vehicles are allowed in the cycle before the left turn is changed from a left arrow to a green ball, and opposing through traffic is allowed to pass through the intersection. During the permissive phase motorists may turn left while others go straight. Left-turn movements during the permissive phase are controlled either with the green ball or a flashing yellow arrow depending on whether an exclusive left-turn lane exists. Protected-permissive left turn phases create conflicts with pedestrians crossing the street as the timing puts the two on a

collision course, especially with left-turning drivers who arrived after the left-turn phase and are impatient to turn left before the signal reverts to red.

- **Protected only.** Under protected left turns, drivers can only turn left with a left-turn green arrow. The protected left turns can be either "leading" or "lagging." A leading protected left turn allows left-turns during the beginning of the cycle. A lagging protected left allows left turns at the end, after opposing through traffic has proceeded. Protected left-turn phases are preferred to both permissive phases because they eliminate the inherent conflict between left turning vehicles and pedestrians. Protected left turns, controlled by green arrows, provide the greatest safety for pedestrians. Permissive phases are typically added to protected only phasing to provide additional capacity for motorists.

Pedestrian Phasing

Basic pedestrian signal timing principles should be combined with innovative pedestrian signal timing techniques to enhance pedestrian safety and convenience.

Pedestrian signal heads provide indications exclusively intended for controlling pedestrian traffic. These signal indications consist of the illuminated symbols of a WALKING PERSON (symbolizing WALK) and an UPRAISED HAND (symbolizing DON'T WALK). Pedestrian signal head indications have the following meanings:

- A steady WALKING PERSON (WALK) signal indication means that a pedestrian facing the signal indication is permitted to start to cross the roadway in the direction of the signal indication, possibly in conflict with turning vehicles.
- A flashing UPRAISED HAND (DON'T WALK) signal indication means that a pedestrian shall not start to cross the roadway in the direction of the signal indication, but that any pedestrian who has already started to cross shall proceed to the far side of the traveled way of the street or highway, unless otherwise directed by a traffic control device to proceed only to a median or pedestrian refuge area.
- A steady UPRAISED HAND (DON'T WALK) signal indication means that a pedestrian shall not enter the roadway in the direction of the signal indication.

The text below discusses the timing of each of these indicators.

Walk Interval

The WALK interval (white walking person) must typically be a minimum of 7 seconds. However, to provide more convenience for pedestrians, and possibly more safety due to better pedestrian behavior, the WALK interval should be maximized using the following techniques:

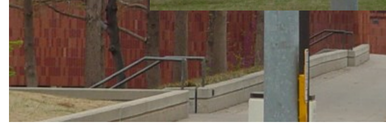
- Instead of providing the minimum WALK interval, maximize the WALK interval within the available green interval. This is accomplished by subtracting the necessary pedestrian clearance interval (discussed below) from the available green time for the concurrent vehicular movements.

- Except at intersections where pedestrians are relatively few, and anywhere that vehicle signals are set on fixed time, WALK intervals should be set on "recall" so that they are automatically provided during every signal cycle.
- Where a major street intersects a minor side street, the WALK interval for crossing the minor street can be set on recall, concurrent with the green interval for the parallel through vehicle movement, which is typically set to recall as well. This minimizes pedestrian delay along the major street with no impact to motor vehicle capacity.

Walk Signal
(Credit: David Riesland)

Pedestrian Clearance Interval

The procedures for calculating the timing of the pedestrian clearance interval (flashing orange hand) are included in the MUTCD, but have recently changed. The pedestrian clearance interval is calculated to allow a pedestrian traveling at a walking speed of 3.5 feet per second to travel the length of the crosswalk. The crosswalk length should be measured from the center of one curb ramp to the center of the opposing curb ramp. This speed allows pedestrians, especially seniors, children, and disabled people, to clear the intersection. The MUTCD includes another test that requires the total of the WALK interval plus the pedestrian clearance interval to be sufficient to allow a pedestrian traveling at a walking speed of 3 feet per second to travel the length of the crosswalk, measured from the top of one ramp to the bottom of the opposing ramp. Any additional time that is required to satisfy this second requirement should be added to the walk interval. In neighborhoods where high numbers of slow pedestrians are present, such as near senior centers, rehabilitation centers, and disabled centers, the interval should be set for even slower speeds.



Pedestrian Countdown Signal
(Credit: David Riesland)

The MUTCD also requires that countdown pedestrian signals be installed for all pedestrian signals. These signals count down the pedestrian clearance interval and provide more information to pedestrians, allowing them to more easily adjust their walking patterns to ensure they are out of the crosswalk before the end of the pedestrian clearance interval. Research on pedestrian countdown signals has determined:

- Pedestrians understand how they work.
- Fewer people start walking in the pedestrian clearance interval.
- Very few pedestrians are left in the crosswalk during the steady orange hand.
- Drivers don't accelerate to beat the light.
- Research in San Francisco shows a 25 percent reduction in all crashes.

Other Signal Design Changes for Pedestrians

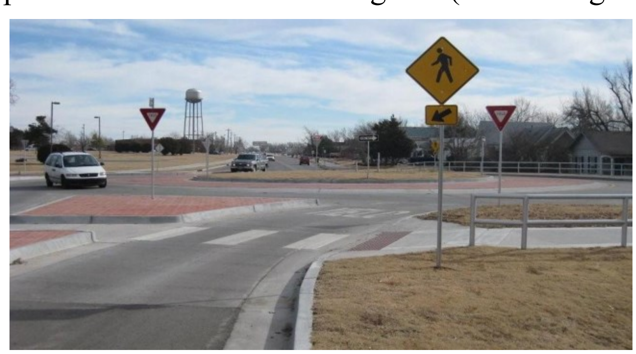
Where appropriate, use signal timing and operations techniques that minimize conflicts with pedestrians and motor vehicles, including the following:

- Protected only left-turn phases
- Leading pedestrian intervals (LPI) where the pedestrian WALK interval is displayed 2 to 5 seconds prior to the concurrent green interval. This enables pedestrians to enter the crosswalk before drivers turn, increasing their chances of being seen by drivers.
- Prohibiting right-turns-on-red where there are restricted sight lines between motorists and pedestrians, where there are an unusual number of pedestrian conflicts with turns on red compared to right-turns-on-green, or where a leading pedestrian interval is used
- Signs that remind drivers to yield to pedestrians when turning at signals
- Pedestrian-user-friendly-intelligent signals, which detect slower pedestrians in crosswalks and add clearance interval time to the pedestrian signal
- Pedestrian scrambles, which stop traffic on all legs of the intersection and allow pedestrians to cross diagonally, may be used where turning vehicles conflict with very high pedestrian volumes. Although pedestrians can cross in any direction during the pedestrian phase, pedestrians typically have to wait for both vehicle phases before they get the walk signal again. Scramble intersections can incorporate a walk phase concurrent with the green phase for pedestrians continuing along a straight path to eliminate this delay.

ROUNDABOUTS

Modern roundabouts are potentially the cheapest, safest, and most aesthetic form of traffic control for many intersections. A roundabout is an intersection design with the following characteristics and features.
Users approach the intersection, slow down, stop and/or yield to pedestrians in a crosswalk, and then enter a circulating roadway, yielding to drivers already in the roundabout. The circulating roadway encircles a central island around which vehicles travel counterclockwise. Splitter islands force drivers to turn right, and provide a refuge for pedestrians. Deflection encourages slow traffic speeds, but allows movement by trucks. A landscaped visual obstruction in the central island obscures the driver's view of the road ahead, to discourage users from entering the roundabout at high speeds. Pedestrians are not allowed to access the central island, which should not contain attractions. The central island can vary in shape from a circle to a “square-a-bout” in historic areas, ellipses at odd shaped intersections, dumbbell, or even peanut shapes.

Each leg of a roundabout has a triangular splitter island that provides a refuge for pedestrians, prevents drivers from turning left (the “wrong-way”), guides drivers through the roundabout by directing them to the edge of the central island, and helps to slow drivers. Roundabouts can range from quite small to quite large, from a central island diameter of about 12 feet for a traffic calming device at a neighborhood intersection to 294 feet to the back of sidewalk on a large multi-lane roundabout.



Roundabout: Norman, OK (Credit: David Riesland)

This section of the chapter briefly describes roundabout application and design information. For more detailed information, refer to NCHRP Report 672, *Roundabouts: An Informational Guide*, Second Edition, 2010.

ADVANTAGES AND DISADVANTAGES

Roundabouts reduce vehicle-to-vehicle and vehicle-to-pedestrian conflicts and, thanks to a substantial reduction in vehicle speeds, reduce all forms of crashes and crash severity. In particular, roundabouts eliminate the most dangerous and common crashes at signalized intersections: left-turn and right-angle crashes.

Other benefits of roundabouts include the following:

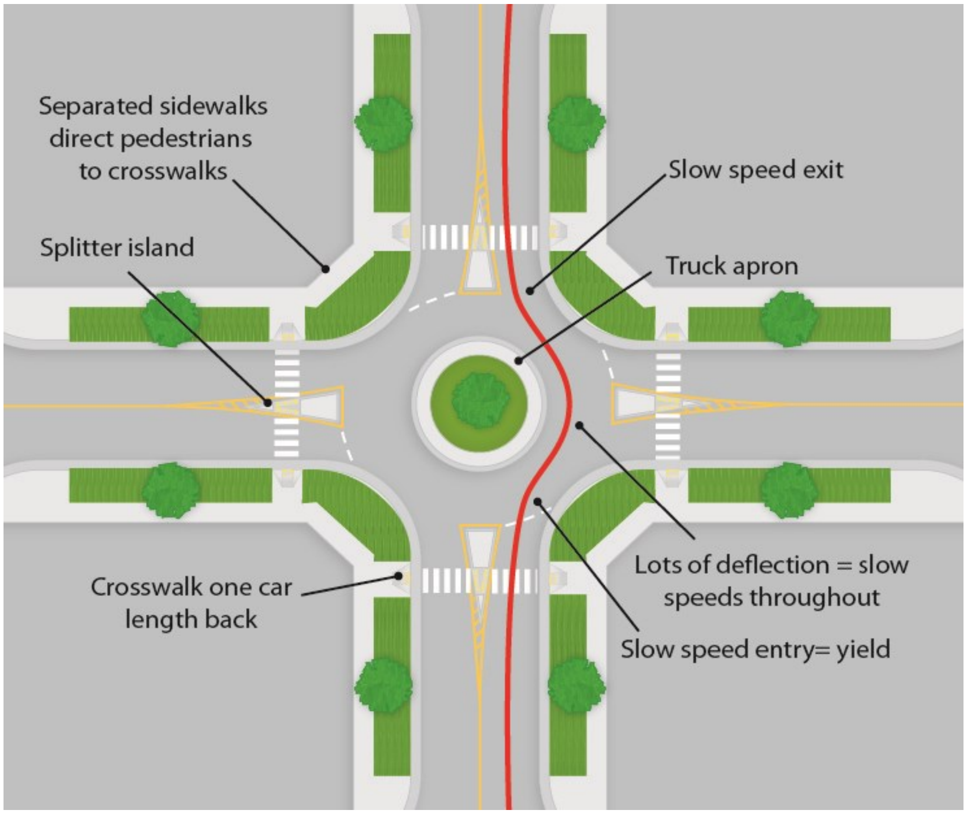
- Little to no delay for pedestrians, who have to cross only one direction of traffic at a time
- Improved accessibility to intersections for bicyclists through reduced conflicts and vehicle speeds
- A smaller carbon footprint (no electricity is required for operation and fuel consumption is reduced as motor vehicles spend less time idling and don't have to accelerate as often from a complete stop)
- The opportunity to reduce the number of vehicle lanes between intersections (e.g., to reduce a five-lane road to a two-lane road, due to increased vehicle capacity at intersections)
- Little to no stopping during periods of low flow
- Significantly reduced maintenance and operational costs because the only costs are related to the landscape and litter control
- Reduced delay, travel time, and vehicle queue lengths
- Lowered noise levels
- Less fuel consumption and air pollution
- Simplified intersections
- Facilitated U-turns
- The ability to create a gateway and/or a transition between distinct areas through landscaping
- When constructed as a part of a new road or the reconstruction of an existing road, the cost of a roundabout is minimal and can be cheaper than the construction of an intersection and the associated installation of traffic signals and additional turn lanes
- Light rail can pass through the center of a roundabout without delay because rail has the right of way

The primary disadvantage is that sight-impaired people can have difficulty navigating around large roundabouts. However, this can be mitigated with ground level wayfinding devices.

GENERAL DESIGN ELEMENTS OF ROUNDABOUTS

Central Island

The design of the central island is an important element of a roundabout. In conjunction with well-designed approach and departure lanes, the central island controls vehicle speeds through deflection and controls the size of vehicles that can pass through and turn at a roundabout. It provides space for landscaping to beautify an intersection or create a focal point or community enhancement, but it also provides space for the inclusion of a vertical element such as a tree, which is important in providing long range conspicuity of a roundabout.



Single-lane roundabout
(Credit: Michele Weisbart)

Splitter Islands

Splitter islands and/or medians on each approach serve several functions. Most importantly, they provide a refuge for pedestrians crossing at the roundabout, breaking the crossing into two smaller crossings. This allows pedestrians to select smaller gaps and cross more quickly. Splitter islands and medians direct vehicles toward the edge of the central island and limit the ability of drivers to make left turns the wrong way into the circulating roadway. Splitter islands should have a minimum width of 6 feet, and preferably 8 feet, from the face-of-curb to the opposite face-of-curb.

Truck Apron

Because central islands must be made large enough to deflect and hence control the speed of passenger vehicles, they can limit the ability of trucks to pass through or turn at a roundabout. To accommodate large vehicles, a truck apron (a paved, load-bearing area) is included around the edge of the central island. The truck apron is often paved with a fairly rough texture, and raised enough to discourage encroachment by smaller high-speed passenger cars. The truck apron should be 3 inches high.

Pedestrian Crossings

Pedestrian crossings are located one car length away from the circulating roadway to shorten the crossing distance, separate vehicle-to-pedestrian conflicts from vehicle-to-vehicle conflicts, and allow pedestrians to cross between waiting vehicles.

Signing and Marking

Signing and marking should be in compliance with the current version of the MUTCD. For detailed design guidance on roundabouts, refer to the NCHRP Report 672*, Roundabouts: An Informational Guide,* Second Edition, 2010. However, care must be taken to not over-sign roundabouts by including every sign allowed at roundabouts, except for needed directional signs; most roundabouts are designed so their function and use are self-explanatory.

ROUNDABOUT DESIGN CRITERIA

Before starting the design of a roundabout it is very important to determine the following:

- The number and type of lane(s) on each approach and departure as determined by a capacity analysis
- The design vehicle for each movement
- The presence of on-street bike lanes
- The goal/reason for the roundabout, such as crash reduction, capacity improvement, speed control, or creation of a gateway or a focal point
- Right-of-way and its availability for acquisition if needed
- The existence or lack of sidewalks
- The approach grade of each approach
- Transit, existing or proposed

Operations and Analysis

Roundabouts operate on the principle that drivers approach a roundabout and look left for any approaching vehicles that could conflict with their travel path. If there is no possible conflict, the approaching driver can enter the roundabout without delay. If there is a vehicle, or many conflicting vehicles, the approaching drivers stop and yield to the conflicting vehicle(s) on their left and wait for a safe gap to enter the roundabout.

In simple terms, a roundabout capacity analysis determines the number of vehicles seeking to enter a roundabout from each approach and the availability of gaps. Based on this gap acceptance analysis, the number and type of approach and departure lanes can be determined to provide the desired level of operation. Since roundabouts keep traffic moving they have potentially greater capacity than both signalized and STOP-controlled intersections.

Single-Lane Roundabouts

Single-lane roundabouts can vary in size with central island diameters from 12 to 90 feet to fit a wide range of intersections and accommodate through movements and different turn movements by various design vehicles. As such, they can be used at a large number of intersections to achieve various objectives.

In some cases, roundabouts are constructed to accommodate through movements by large articulated trucks but do not permit them to make turn movements. However, they do accommodate turn movements by single unit trucks such as ladder trucks and garbage trucks. In some cases, restricting or not accommodating turn movements by articulated trucks enables the construction of a smaller roundabout without acquisition of right-of-way and with all the benefits of roundabouts at the cost of forcing the occasional large truck to take an alternate route.

Design

Following a careful assessment of the need to accommodate some or all design vehicle movements and the impact of that accommodation, the size of the roundabout is selected and a concept plan is prepared. The concept plan is then refined with the simultaneous application of design vehicle templates and design speed checks until a suitable design is prepared that meets design requirements. Pedestrian and bike facilities are as applicable and the overall design is refined with the signing and marking, along with construction details. In some cases, right turn lanes can be added to accommodate specific high right turn volumes.

MULTI-LANE ROUNDABOUTS

When single-lane roundabouts prove to be inadequate for the traffic volume, consideration should be given to using roundabouts that have two through lanes on the major street and a single lane on the minor street with or without additional turn lanes before automatically designing a full multilane roundabout. Because these roundabouts are larger than single-lane roundabouts, they often accommodate all turn movements by most large vehicles. However, it is still necessary to confirm the size and movements by the design vehicle(s) because these roundabouts often have to accommodate larger trucks or special vehicles.

With many old style freeway interchanges failing, often because of a lack of storage for turning vehicles, retrofitting a roundabout on both sides of the freeway can reduce congestion and improve pedestrian mobility without widening the freeway bridge. Sometimes, the retrofit of a standard interchange with roundabouts can reduce the space allocated to the interchange, freeing the land for other community uses.

Multi-lane roundabout
(Credit: Michele Weisbart)

Accessibility

Multi-lane roundabouts are more complex for pedestrians and bicyclists to use because of the additional lanes, slightly higher speeds, and longer crossing distances. Crossing by some pedestrians with disabilities is a more complex task. As a consequence, the current draft (Proposed Right-of-Way Accessibility Guidelines) PROWAG includes a requirement to install accessible pedestrian signals at all crosswalks across any roundabout approach with two or more lanes in one direction. The PROWAG requirement does not specify the type of signal except that it must be accessible, including a locator tone at the pushbutton, with audible and vibrotactile indications of the pedestrian walk interval.

Metering signals

Often a roundabout capacity is only exceeded during one peak period and often for only a short period. Rather than constructing a larger multi-lane roundabout, consideration should be given to constructing a smaller roundabout that is adequate for 23 hours a day and adding a metering signal for the short peak period when congestion can occur. A metering signal is similar to ramp metering where the approaching vehicle queue is metered and a part time signal is used to stop the conflicting vehicle flow to allow the congested approach to enter the roundabout. The result is a smaller, slower roundabout that is more appropriate for all users for most of the day.

Design

Multi-lane roundabouts are more complex to design. However, the design process is the same as for single-lane roundabouts: confirm the design vehicle for each movement, prepare a concept plan, and refine it with the simultaneous use of design vehicle templates or software like AutoTURN and speed curves.

MINI-ROUNDABOUTS

Mini-roundabouts are a new form of roundabout that includes a traversable central island and traversable splitter islands to accommodate large vehicles.

Appropriate Applications

Mini-roundabouts are used in low-speed urban environments, where operating speeds are 30 mph or less, and right-of-way constraints preclude the use of a standard roundabout. The design is based on passenger vehicles passing through the roundabout without travelling over the central island, whereas large vehicles will turn over the central island and in some cases, the splitter islands.

Design

The design of mini-roundabouts is similar to other roundabouts in that the design vehicle for each movement must be determined following a capacity analysis. The design is undertaken using the same combination of design vehicle templates and speed curves.

NEIGHBORHOOD TRAFFIC CIRCLES

Neighborhood traffic circles are very small circles that are retrofitted into local street intersections to control vehicle speeds within a neighborhood. Typically, a tree and/or landscaping are located within the central island to provide increased visibility of the roundabout and enhance the intersection. Neighborhood traffic circles should generally have similar features as roundabouts, including yield-on-entry and painted or mountable splitter islands.

Neighbor
(Credit: David Riesland)

Neighborhood traffic circles should be used on low-volume, neighborhood streets. In these environments, larger vehicles can turn left in front of the central island.

Design

The design of neighborhood traffic circles is primarily confined to selecting a central island size to achieve the appropriate design speed of around 15 to 18 mph. See Chapter 9, "Traffic Calming," for more information.

5. UNIVERSAL PEDESTRIAN ACCESS

INTRODUCTION

Nowhere is the concept of universal access more important than in the design of the pedestrian environment. While perhaps not intuitively obvious at first glance, this is the realm of streets with the greatest variation in user capabilities, and thus the realm where attention to design detail is essential to effectively balance user needs. This is also the realm where signs and street furniture are located, and where transitions are made between modes (e.g., driver or passenger to pedestrian via parking, bus stop/train station, or bike rack). The pedestrian environment includes sidewalks, curb ramps, crosswalks, bus stops, signs, and street furniture.

Without design guidelines, sidewalks are often too narrow, utility poles obstruct travel, steep driveway ramps are impassable to wheelchair users, and bus stops become blocked by the disorderly placement of shelters, poles, trash receptacles, and bike racks.

Sidewalks constructed without adequate design guidelines (Credit: Chanda Singh)

With well-defined guidelines, sidewalks are built to accommodate pedestrians of all ages and physical abilities, and become inviting pedestrian environments as the adjacent picture shows.

Wheelchair users need accessible sidewalks (Credit: Dan Burden)

Designing the pedestrian realm for universal access enables persons with disabilities to live independently and lead full, enriched lives; they are able to go to work and to school, to shop, and otherwise engage in normal activities. Moreover, walking environments that accommodate people with disabilities improve walking conditions for everyone. People with strollers and rolling suitcases can make their way about with ease. Children can mature by learning to navigate through their neighborhoods with independence. Inaccessible pedestrian networks, on the other hand, can lead to people becoming housebound and socially isolated.

This chapter describes the legal framework for accessible design of streets and sidewalks, various users of streets and sidewalks and their needs, and important elements of pedestrian facility design. The chapter ends with sidewalk design guidelines for a number of street classifications.

ESSENTIAL PRINCIPLES OF UNIVERSAL PEDESTRIAN ACCESS

The following design principles inform the recommendations made in this chapter and should be incorporated into every pedestrian improvement:

- The walking environment should be safe, inviting, and accessible to people of all ages and physical abilities.
- The walking environment should be easy to use and understand.
- The walking environment should seamlessly connect people to places. It should be continuous, with complete sidewalks, well-designed curb ramps, and well-designed street crossings.

LEGAL FRAMEWORK

Under Title II of the Americans with Disabilities Act (ADA) of 1990, state and local governments and public transit authorities must ensure that all of their programs, services, and activities are accessible to and usable by individuals with disabilities. They must ensure that new construction and altered facilities are designed and constructed to be accessible to persons with disabilities. State and local governments must also keep the accessible features of facilities in operable working condition through maintenance measures including sidewalk repair, landscape trimming, work zone accessibility, and snow removal.

Obstructions can make passage difficult or impossible for wheelchair users. (Credit: Michael Ronkin)

Under the ADA, the U.S. Access Board is responsible for developing the minimum accessibility guidelines needed to measure compliance with ADA obligations when new construction and alterations projects are planned and engineered. These guidelines for public rights-of-way are found in draft form in the Public Rights-of-Way Accessibility Guidelines (PROWAG). The U.S.

Department of Transportation has recognized this document as current best practices in pedestrian design and has indicated its intent to adopt the final PROWAG.

In addition to the PROWAG guidelines, Title II of the ADA also requires states and localities to develop ADA Transition Plans that remove barriers to disabled travel. The City of Norman's Transition Plan was adopted… to ensure that existing inaccessible facilities are not neglected indefinitely. The Transition Plan includes:

- Inventory physical obstacles and their location
- Provide adequate opportunity for residents with disabilities to provide input into the Transition Plan
- Describe in detail the methods the entity will use to make the facilities accessible
- Provide a yearly schedule for making modifications
- Name an official/position responsible for implementing the Transition Plan
- Set aside a budget to implement the Transition Plan

USERS AND NEEDS

To fully accommodate everybody, designers must consider the widely varying needs and capabilities of the people in the community. People walk at different speeds. Some are able to endure long treks, while others can only go short distances. Some use wheelchairs and are particularly sensitive to uneven pavement and surface materials. Others have limited sight and rely on a cane. People's strengths, sizes, and judgmental capabilities differ significantly. The needs of one group of users may be at odds with those of another group of users. For instance, gradual ramps and smooth transitions to the street help people in wheelchairs, but present challenges for the sight-impaired when they can't easily find the end of the sidewalk and beginning of the street.

Steep cross slopes create difficulties for wheelchair users. (Credit: Michael Ronkin)

The text below identifies the unique constraints individuals with different types of disabilities and limitations face as pedestrians. Understanding their needs will help ensure more universal design of the sidewalk network.

PEOPLE WITH MOBILITY IMPAIRMENTS

People with mobility impairments range from those who use assistive devices, such as wheelchairs, crutches, canes, orthotics, and prosthetic devices, to those who use no such devices but face constraints walking long distances on non-level surfaces or on steep grades.
Wheelchair and scooter users are most affected by the following:

- Uneven surfaces that hinder movement
- Rough surfaces that make rolling difficult and can cause pain, especially for people with back injuries
- Steep uphill slopes that slow the user
- Steep downhill slopes that cause a loss of control
- Cross slopes that make the assistive device unstable
- Narrow sidewalks that impede the ability of users to turn or to cross paths with others
- Devices that are hard to reach, such as push buttons for walk signals and doors
- The lack of time to cross the street

Walking-aid users are most affected by the following:

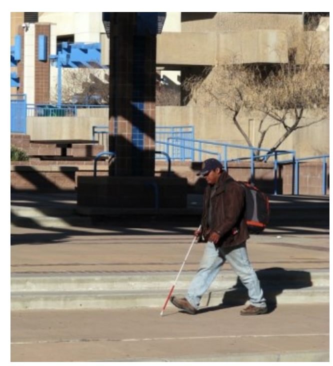
Walking-aid users need clear sidewalks. (Credit: Dan Burden)

- Steep uphill slopes that make movement slow or impossible
- Steep downhill slopes that are difficult to negotiate
- Cross slopes that cause the walker to lose stability
- Uneven surfaces that cause these users to trip or lose balance
- Long distances
- Situations that require fast reaction time
- The lack of time to cross the street

Prosthesis users often move slowly and have difficulty with steep grades or cross slopes.

PEOPLE WITH VISUAL IMPAIRMENTS

People with visual impairments include those who are partially or fully blind, as well as those who are colorblind. Visually impaired people face the following difficulties:



Sight-impaired pedestrians need additional sensory cues.

- Limited or no visual perception of the path ahead
- Limited or no visual information about their surroundings, especially in a new place
- Changing environments where they rely on memory
- Lack of non-visual information
- Inability to react quickly
- Unpredictable situations, such as complex intersections that are not at 90 degrees
- Inability to distinguish the edge of the sidewalk from the street
- Compromised ability to detect the proper time to cross a street
- Compromised ability to cross a street along the correct path
- Need for more time to cross the street

People with Cognitive Impairments

People with cognitive impairments encounter difficulties in thinking, learning, and responding, and in performing coordinated motor skills. Cognitive disabilities can cause some to become lost or have difficulty finding their way. They may also not understand standard street signs and traffic signals. Some may not be able to read and benefit from signs with symbols and colors.

Children and Older Adults

Children and many older adults don't fall under specific categories for disabilities, but must be taken into account in pedestrian planning. Children are less mentally and physically developed than adults and have the following characteristics:

- Less peripheral vision
- Limited ability to judge speed and distance
- Difficulty locating sounds
- Limited or no reading ability so don't understand text signs
- Occasional impulsive or unpredictable behavior
- Little familiarity with traffic
- Difficulty in carrying packages

Small children are also more difficult to see than adults.

The natural aging process generally results in at least some decline in sensory and physical capability. As a result, many older adults experience the following:

- Declining vision, especially at night
- Decreased ability to hear sounds and detect where they come from
- Less strength to walk up hills and less endurance overall
- Reduced balance, especially on uneven or sloped sidewalks
- Slowed reaction times to dangerous situations
- Slowed walking speed
- Increased fragility and frailty: their bodies are more likely to be seriously injured in a fall or vehicular crash and their recovery becomes longer and more tenuous. This makes older pedestrians the most vulnerable pedestrians.

PEDESTRIAN FACILITY DESIGN

To provide a seamless path of travel throughout the community that is accessible to all, designers should consider five important elements: sidewalks, curb ramps, crosswalks, signals, and bus stops.

SIDEWALKS

Sidewalks should provide a comfortable space for pedestrians between the roadway and adjacent land uses. Sidewalks along city streets are the most important component of pedestrian mobility. They provide access to destinations and critical connections between modes of travel, including automobiles, transit, and bicycles. General provisions for sidewalks include pathway width, slope, space for street furniture, utilities, trees and landscaping, and building ingress/egress.

Sidewalks include four distinct zones: the frontage zone, the pedestrian (aka walking) zone, the furniture zone, and the curb zone. The minimum widths of each of these zones vary based on street classifications as well as land uses. The Street Classifications section in this chapter describes these recommendations in more detail as applied to individual cities. The table at the end of this chapter recommends minimum widths for each zone for different street types and land uses.

Frontage Zone

The frontage zone is the portion of the sidewalk located immediately adjacent to buildings, and provides comfort distance from buildings, walls, fences, or property lines. It includes space for building-related features such as entryways and accessible ramps. It can include landscaping as well as awnings, signs, news racks, benches, and outdoor café seating (requires 2.5 foot minimum width). In single family residential neighborhoods, landscaping typically occupies the frontage zone.

Pedestrian Zone

The pedestrian zone, situated between the frontage zone and the furniture zone, is the area dedicated to walking and should be kept clear of all fixtures and obstructions. Within the pedestrian zone, the Pedestrian Access Route (PAR) is the path that provides continuous connections from the public right-of-way to building and property entry points, parking areas, and public transportation. This pathway is required to comply with ADA guidelines and is intended to be a seamless pathway for wheelchair and white cane users. As such, this route should be firm, stable, and slip-resistant, and should comply with maximum cross slope requirements (2 percent grade). The walkway grade shall not exceed the general grade of the adjacent street. Aesthetic textured pavement materials (e.g., brick and pavers) can only be used in the frontage and furniture zones. The PAR should be a minimum of 4 feet, but preferably at least 5 feet in width to provide adequate space for two pedestrians to comfortably pass or walk side by side. All transitions (e.g., from street to ramp or ramp to landing) must be flush and free of changes in level. The engineer should determine the pedestrian zone width to accommodate the projected volume of users. In no case will this zone be less than the width of the PAR.

Non-compliant driveways often present significant obstacles to wheelchair users. The cross slope on these driveways is often much steeper than the 2 percent maximum grade. Driveway aprons that extend into the pedestrian zone can render a sidewalk impassable to users of wheelchairs, walkers, and crutches. They need a flat plane on which to rest all supports. To provide a continuous PAR across driveways, aprons should be confined to the furniture and curb zones.

Furniture Zone

The furniture zone is located between the curb line and the pedestrian zone. The furniture zone should contain all fixtures, such as street trees, bus stops and shelters, parking meters, utility poles and boxes, lamp posts, signs, bike racks, news racks, benches, waste receptacles, drinking fountains, and other street furniture to keep the pedestrian zone free of obstructions. In residential neighborhoods, the furniture zone is often landscaped. Resting areas with benches and space for wheelchairs should be provided in high volume pedestrian districts and along blocks with a steep grade to provide a place to rest for older adults, wheelchair users, and others who need to catch their breath.

Curb Zone

The curb zone serves primarily to prevent water and cars from encroaching on the sidewalk. It defines where the area for pedestrians begins, and the area for cars ends. It is the area people using assistive devices must traverse to get from the street to the sidewalk, so its design is critical to accessibility.

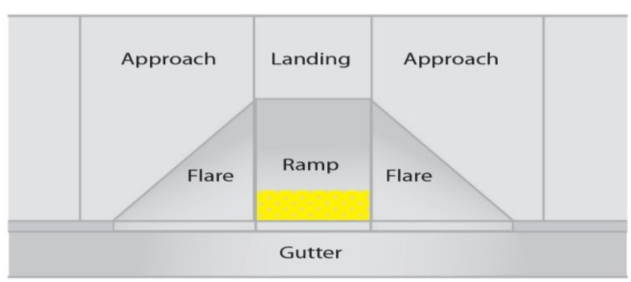
Other Sidewalk Guidelines

- Landscaped buffers or fences should separate sidewalks from off-street parking lots or off-street passenger loading areas.
- Pedestrian and driver sight distances should be maintained near driveways. Fencing and foliage near the intersection of sidewalks and driveways should ensure adequate sight distance as vehicles enter or exit.
- Where no frontage zone exists, driveway ramps usually violate cross slope requirements. In these situations, sidewalks should be built back from the curb at the driveway as shown in the adjacent photo.

Routing sidewalks around driveway ramps maintains a flush surface. (Credit: Dan Burden)

CURB RAMPS

Proper curb ramp design is essential to enable pedestrians using assistive mobility devices (e.g., scooters, walkers, and crutches) to transition between the street and the sidewalk. These design guidelines provide a basic overview of curb ramp



(Credit: Michele Weisbart)

design. The ADA requires installation of curb ramps in new sidewalks and whenever an alteration is made to an existing sidewalk or street. Roadway resurfacing is considered an alteration and triggers the requirement for curb ramp installations or retrofits to current standards. Curb ramps are typically installed at intersections, mid-block crossings (including trail connections), accessible on-street parking, and passenger loading zones and bus stops.

The following define the curb ramp components along with minimum dimensions:

- **Landing** – the level area at the top of a curb ramp facing the ramp path. Landings allow wheelchairs to enter and exit a curb ramp, as well as travel along the sidewalk without tipping or tilting. This landing must be the width of the ramp and measure at least 4 feet by 4 feet. There should also be a level (not exceeding a 2 percent grade) 4 foot by 4 foot bottom landing of clear space outside of vehicle travel lanes.
- **Approach** – the portion of the sidewalk on either side of the landing. Approaches provide space for wheelchairs to prepare to enter landings.
- **Flare** – the transition between the curb and sidewalk. Flares provide a sloped transition (10 percent maximum slope) between the sidewalk and curb ramp to help prevent pedestrians from tripping over an abrupt change in level. Flares can be replaced with curb where the furniture zone is landscaped.
- **Ramp** – the sloped transition between the sidewalk and street where the grade is constant and cross slope at a minimum. Curb ramps are the main pathway between the sidewalk and street.
- **Gutter** – the trough that runs between the curb or curb ramp and the street. The slope parallel to the curb should not exceed 2 percent at the curb ramp.
- **Detectable Warning** – surface with distinct raised areas to alert pedestrians with visual impairments of the sidewalk-to-street transition.

There are several different types of curb ramps. Selection should be based on local conditions. The most common types are diagonal, perpendicular, parallel, and blended transition. PROWAG provides additional design guidance and curb ramp examples appropriate for a variety of contextual constraints.

Diagonal Curb Ramps

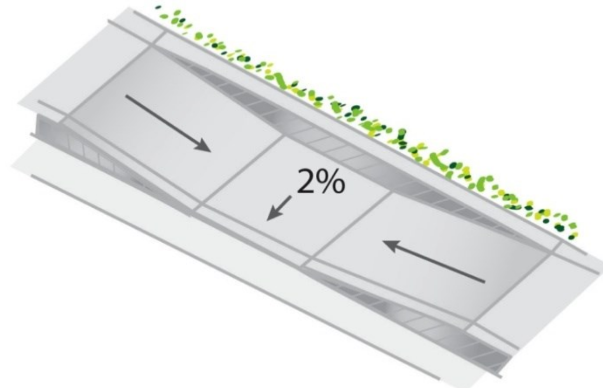
Diagonal curb ramps are single curb ramps at the apex of the corner. These have been commonly installed by many jurisdictions to address the requirements of the ADA, but have since been identified as a non-preferred design type as they introduce dangers to wheelchair users. Diagonal curb ramps send wheelchair users and people with strollers or carts toward the middle of the intersection and make the trip across longer. This design is no longer allowed in Norman.

Perpendicular Curb Ramps

Perpendicular curb ramps are placed at a 90-degree angle to the curb. They must include a level landing at the top to allow wheelchair users to turn 90 degrees to access the ramp, or to bypass the ramp if they are proceeding straight. Perpendicular ramps work best where there is a wide sidewalk, curb extension, or planter strip. Perpendicular curb ramps provide a direct, short trip across the intersection.

Parallel Curb Ramps

Parallel curb ramps are oriented parallel to the street; the sidewalk itself ramps down. They are used on narrow sidewalks where there isn't enough room to install perpendicular ramps. Parallel curb ramps require pedestrians who are continuing along the sidewalk to ramp down and up. Where space exists in a planting strip, parallel curb ramps can be designed in combination with perpendicular ramps to reduce the ramping for through pedestrians. Careful attention must be paid to the construction of the bottom landing to limit accumulation of water and/or debris.



Parallel curb ramp
(Credit: Michele Weisbart)

Curb Ramp Placement

For best practices in ramp placement, refer to Chapter 4, "Intersection Design."

One ramp must be provided for each crosswalk, which usually translates to two per corner. This maximizes access by placing ramps in line with the sidewalk and crosswalk, and by reducing the distance required to cross the street, compared with a single ramp on the apex.

Blended Transitions

Blended transitions are situations where either the entire sidewalk has been brought down to the street or crosswalk level, or the street has been brought up to the sidewalk level. They work well on large radius corners where it is difficult to line up the crosswalks with the curb ramps, but have drawbacks. Children, persons with cognitive impairments, and guide dogs may not distinguish the street edge. Turning vehicles may also encroach onto the sidewalk. For these reasons, bollards, planting boxes, or other intermittent barriers must be installed to prevent cars from traveling on the sidewalk. Detectable warnings should also be placed at the edge of the sidewalk to alert pedestrians with visual impairments of the transition to the street. Municipalities should follow the standards and guidelines for curb ramps provided in Table 5.1.

Table 5.1 Curb Ramp Design Standards and Guidelines

Curb Ramp Type	Characteristic	ADA Standards	PROWAG
Perpendicular	Maximum slope of ramps	8.33%	8.3%
	Maximum cross-slope of ramps	2%	2%
	Maximum slope of flared sides	10%	10%
	Minimum ramp width	36”	48”
	Minimum landing length	36”	48”
	Minimum landing width		48”
	Maximum gutter slope	5%	5%
	Changes in level	Flush	Flush
	Truncated domes	Full depth and width	24” min.
Parallel and combination	Maximum slope of ramps	8.33%	8.3%
	Maximum cross-slope of ramps	2%	2%
	Maximum slope of flared sides	10%	
	Minimum ramp width	36”	48”
	Minimum landing length	36”	
	Minimum landing width		48”
	Maximum landing slope		2%
	Maximum gutter slope	5%	5%
	Changes in level	Flush	Flush
	Truncated domes	Full depth and width	24”
Curb extensions and built-up	Maximum slope of ramps	8.33%	8.3%
	Maximum cross-slope of ramps	2%	2%
	Maximum slope of flared sides	10%	10%
	Minimum ramp width	36”	48”
	Minimum landing length	36”	48”
	Minimum landing width		48”
	Maximum gutter slope	5%	5%
	Changes in level	Flush	flush
	Detectable warnings	Full depth and width	24”

DETECTABLE WARNINGS

Required Truncated Domes (Credit: David Riesland)

Because a curb ramp removes the curb that visually impaired persons use to identify the location of a street, a detectable warning surface must be placed at the back of the curb. This detectable strip should be as wide as the ramp and a minimum of 24 inches deep. One corner should be located at the back of the curb and the other corner may be up to 5 feet from the back of the curb. These strips are most effective when adjacent to smooth pavement so the difference is easily detected. Color contrast is needed so partially sighted people can see them.

The ADAAG standards for detectable warnings are as follows:

- General: Detectable warnings shall consist of a surface of truncated domes and shall meet standards for size, spacing, contrast and edges
- Base diameter: 0.9 inches minimum; 1.4 inches maximum
- Top diameter: 50 percent of base diameter minimum to 65 percent maximum
- Height: 0.2 inches
- Center-to-center spacing: 1.6 inches minimum to 2.4 inches maximum
- Base-to-base spacing: 0.65 inches minimum
- Visual contrast: light on dark, or dark on light with adjacent walking surface
- Platform edges: 24 inches wide and shall extend the full public use area of the platform

PROWAG best practices include the following:

- Width: as wide as the ramp and 24 inches deep
- Location: one corner at back of the curb, the other corner up to 5 feet from back of curb
- Used at:
  - The edge of depressed corners
  - The border of raised crosswalks and intersections
  - The base of curb ramps
  - The border of medians
  - The edge of transit platforms and where railroad tracks cross the sidewalk

SIGNALS

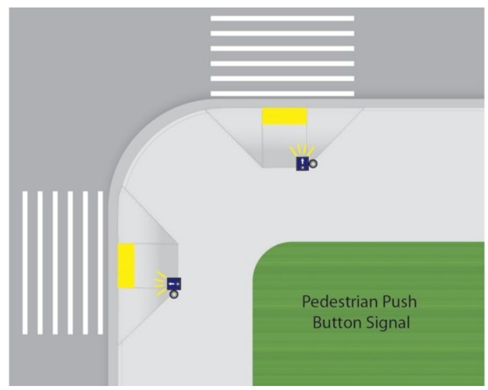
Signalized street crossings require special consideration of people with disabilities. The following text provides guidance to do that.

Crossing Times

In planning for people with disabilities, slower speeds must be considered. This is critical in setting the timing of the walk phase of signalized intersections. The Manual on Uniform Traffic Control Devices (MUCTD) requires that transportation agencies use common walking speeds for signal timing. Deviations from these common walking speeds are allowed for a variety of features specific to a certain intersection such as terrain. The use of emerging technologies is encouraged to best accommodate pedestrian movements through signalized intersections.

Pedestrian-Activated Push Buttons

Pedestrian-activated traffic controls require pedestrians to push a button to activate a walk signal. Where pedestrian-activated traffic controls exist, they should be located as close as possible to curb ramps without reducing the width of the path. The buttons should be at a level that is easily reached by people in wheelchairs near the top of the ramp. The U.S. Access Board guidelines recommend buttons raised above or flush with their housing and large enough (a minimum of 2 inches) for people with visual impairments to see them. The buttons should also be easy to push.



Pedestrian push button placement (Credit: Michele Weisbart)

Accessible Pedestrian Signals (APS)

Wayfinding for pedestrians with visual impairments is significantly improved with the use of APS at signalized intersections. In fact, APS are the most commonly requested accommodation under Section 504 of the Rehabilitation Act of 1973. APS systems communicate information about pedestrian timing in non-visual formats such as audible tones, verbal messages, and/or vibrating surfaces. Verbal messages provide the most informative guidance. These devices should be installed close to the departure location and on the side away from the center of the intersection. Since they are typically only audible 6 to 12 feet from the push button, 10 feet should separate two APS devices on a corner. If two accessible pedestrian pushbuttons are placed less than 10 feet apart or on the same pole, each accessible pedestrian pushbutton shall be provided with a pushbutton locator tone, a tactile arrow, a speech walk message for the WALKING PERSON (symbolizing WALK) indication, and a speech pushbutton information message. Volumes of the walk indication and push button locator tone shall automatically adjust in response to ambient sound.

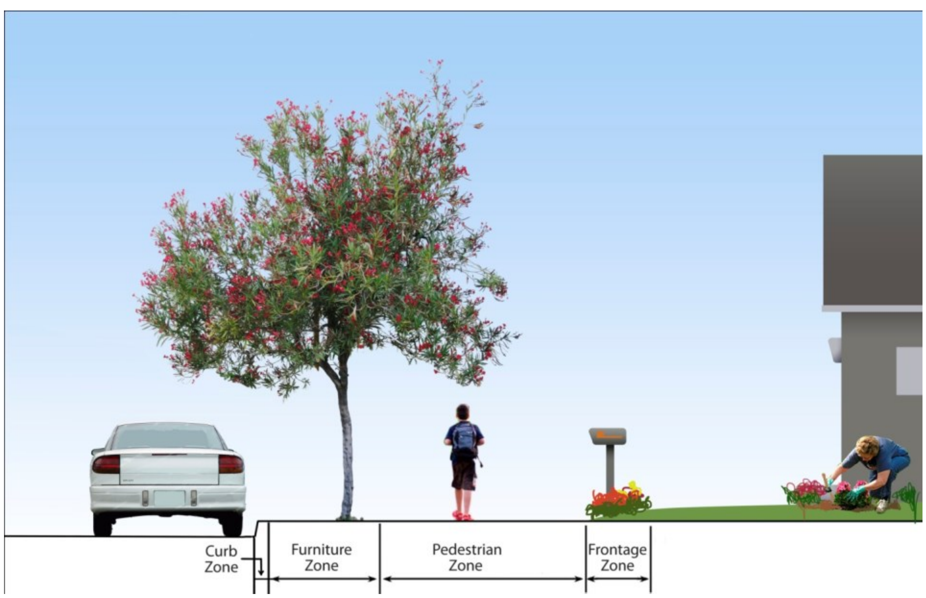
LAND USE AND SIDEWALK DESIGN GUIDELINES

The sidewalk design guidelines in this chapter integrate design and land use to provide safe and convenient passage for pedestrians. Sidewalks should have adequate walking areas and provide comfortable buffers between pedestrians and traffic. These guidelines will ensure sidewalks in all development and redevelopment provide access for people of all ages and physical abilities.

Sidewalks will vary according to the type of street. A local street with residences will require different sidewalk dimensions than an arterial with commercial establishments. The descriptions below indicate the type of pedestrian activity expected at each of the specified land uses. The graphics (credit Marty Bruinsma) illustrate the minimum widths of the sidewalk zones for each of the contexts. The matrix in the following section provides specific minimum requirements for the four sidewalk zones according to combinations of land use and street classifications.

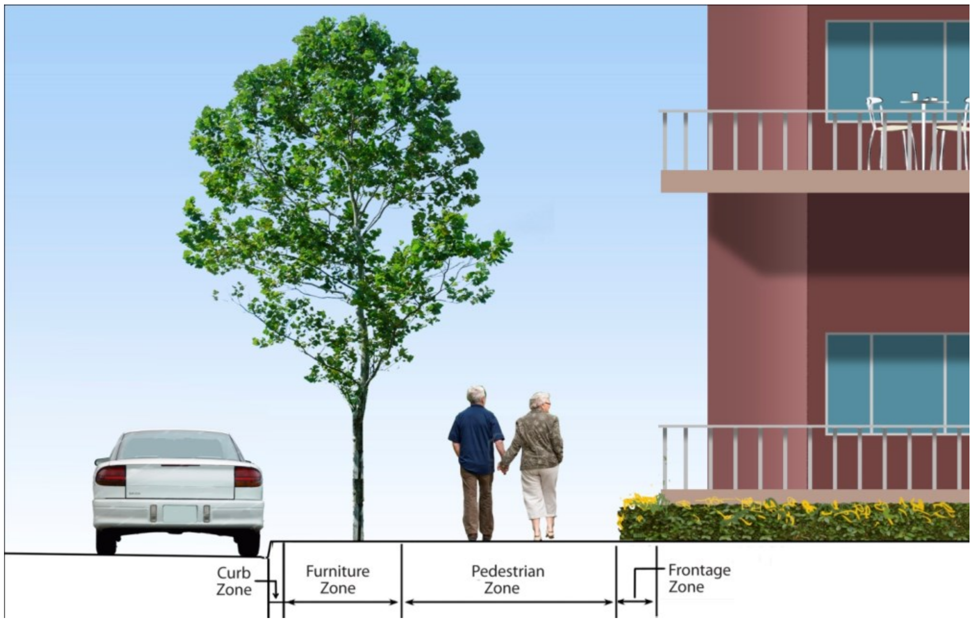
LOW / MEDIUM DENSITY RESIDENTIAL

These streets are typically quieter than others and generally do not carry transit vehicles or high volumes of traffic. Pedestrians require a pleasant walking environment within these neighborhoods, as well as to access land uses and transit on nearby streets. Of the four sidewalk zones, the furniture zone is often the widest, to provide room for street trees.



MEDIUM / HIGH DENSITY RESIDENTIAL

These streets support greater volumes of pedestrians. Streets with transit service require good pedestrian links to bus stops. The pedestrian zone should be wider than in low/medium density residential.



NEIGHBORHOOD COMMERCIAL

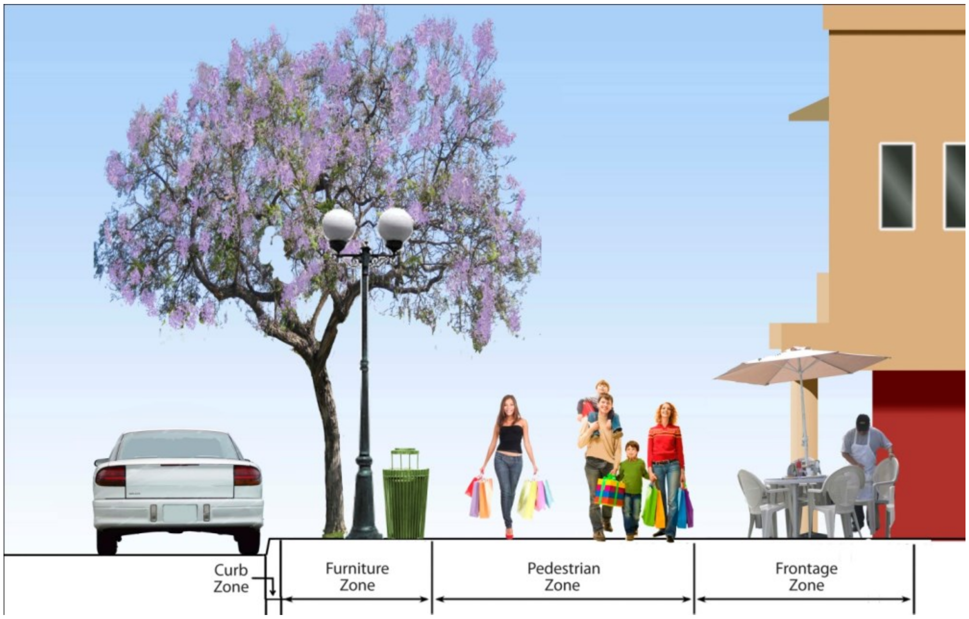
These streets often have grocers, laundromats, drug stores, and other neighborhood-serving retail establishments. Sidewalks in neighborhood commercial areas should accommodate pedestrians walking from residences to stores. Of the four sidewalk zones, the pedestrian zone should be the widest, with a generous frontage zone to provide room for features next to buildings such as newspaper boxes. These sidewalks should also be designed with the understanding that cars will cross sidewalks as they enter and exit commercial driveways.

GENERAL / REGIONAL COMMERCIAL

These streets have retail, office, civic, and recreational uses concentrated along boulevards and avenues. Transit service runs along these streets and pedestrians need buffers from traffic. Of the four sidewalk zones, the pedestrian and furniture zones are favored. These sidewalks also should be designed with the understanding that a significant number of cars will cross sidewalks as they enter and exit commercial driveways.

Mixed / Multi-Use

The sidewalks along these streets should support significant pedestrian volumes due to their integrated nature and higher densities. Of the four sidewalk zones, the pedestrian and frontage zones will be favored. Transit service runs along these streets and sidewalks will require buffers from traffic.

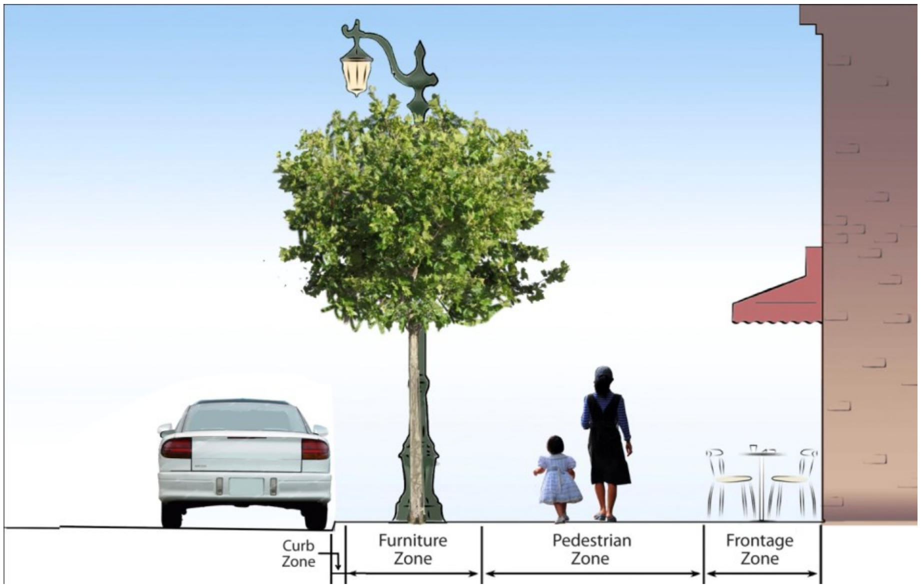


Industrial

Industrial streets are zoned for manufacturing, office warehousing, and distribution. Pedestrian volumes are likely to be lower here given that these land uses typically employ fewer people per square foot than general commercial areas. Employees will need good sidewalks to get to work.

Downtown Core/Main Street

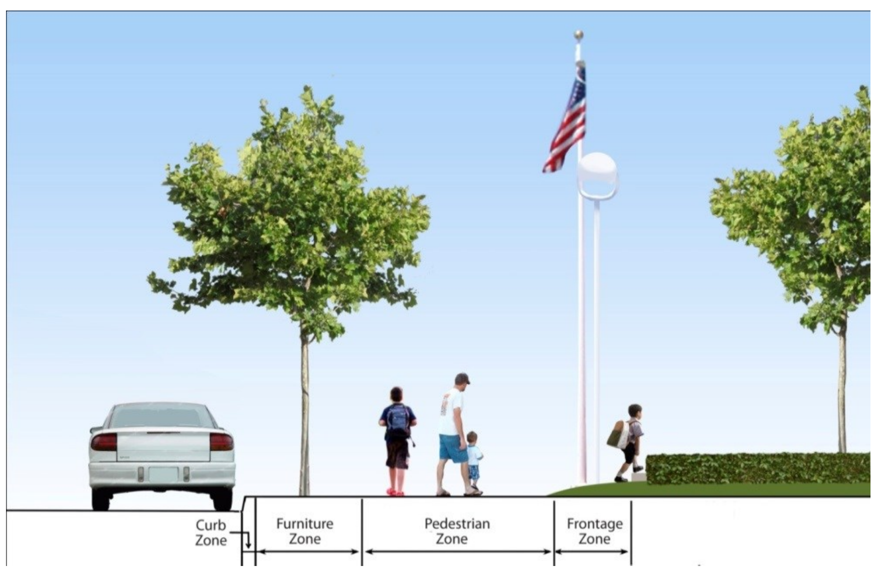
The downtown core or Main Street is a pedestrian-oriented area. This is where the greatest numbers of pedestrians are encouraged and expected. The downtown core serves as the retail, restaurant, and entertainment center of a community. This area will need the widest sidewalks, the widest crosswalks, the brightest street lighting, the most furnishings, and other features that will enhance the pedestrian environment. Of the four sidewalk zones, the pedestrian and frontage zones will be favored, with a furniture zone wide enough for street trees.



OFFICE PARK

These streets are home to national and regional offices of financial institutions, government, large companies, and other uses. Cities can expect pedestrians during the morning and evening commutes walking to and from their cars. Visitors will use the sidewalks throughout the day and employees will need them during the lunch hour. The furniture zone should provide adequate buffer from parking lots.

PUBLIC FACILITIES



Streets adjacent to public facilities, particularly streets near schools, libraries, and civic centers, require special attention and treatment. High pedestrian volumes are expected during peak times, such as school pick-up and drop-off, and during the morning and evening commute hours. Sidewalk design should accommodate these peak travel times and include adequate furniture zones to buffer pedestrians from the street. Public facilities are located in various types of streets ranging from local streets to arterials with transit service.

DESIGN SPECIFICATIONS BY ROADWAY TYPE AND LAND USE

Table 5.2 lists minimum widths for the frontage, pedestrian, furniture, and curb zones, as well as for the recommended minimum total widths. These minimums should not be considered the design width; in many cases, wider zones will be needed.

Table 5.2 Pedestrian Route Design Specifications by Roadway Type and Use

	Arterial			Minor Arterial			Collector			Local		
Use	Element	Min Width	Preferred Width	Element	Min Width	Preferred Width	Element	Min Width	Preferred Width	Element	Min Width	Preferred Width
Typical Route	Curb	8”	8”	Curb	8”	8”	Curb	8”	8”	Curb	8”	8”
	Furniture	1’	5’	Furniture	1’	7’	Furniture	1’	7’	Furniture	1’	7’
	Pedestrian	5’	5’	Pedestrian	5’	5’	Pedestrian	4’	4’	Pedestrian	4’	4’
	Frontage	1’	4’	Frontage	1’	2’	Frontage	1’	2’	Frontage	0’	1’
	Total	7’-8”	14’-8”	Total	7’-8”	14’-8”	Total	6’-8”	13’-8”	Total	5’-8”	12’-8”
Downtown/ Campus Corner	Curb	8”	8”	Curb	8”	8”	Curb	8”	8”	Curb	8”	8”
	Furniture	2’	5’	Furniture	2’	5’	Furniture	1’	5’	Furniture	1’	6’
	Pedestrian	5’	6’	Pedestrian	5’	6’	Pedestrian	4’	5’	Pedestrian	4’	5’
	Frontage	2’	8’	Frontage	2’	5’	Frontage	2’	3’	Frontage	1’	1’
	Total	9’-8”	19’-8”	Total	9’-8”	16’-8”	Total	7’-8”	13’-8”	Total	6’-8”	12’-8”
Commercial District	Curb	8”	8”	Curb	8”	8”	Curb	8”	8”	Curb	8”	8”
	Furniture	1’	5’	Furniture	1’	6’	Furniture	1’	5’	Furniture	1’	7’
	Pedestrian	5’	5’	Pedestrian	5’	5’	Pedestrian	4’	4’	Pedestrian	4’	4’
	Frontage	1’	5’	Frontage	1’	1’	Frontage	2’	4’	Frontage	0’	1’
	Total	7’-8”	15’-8”	Total	7’-8”	12’-8”	Total	7’-8”	13’-8”	Total	5’-8”	12’-8”
Trails	Curb	8”	8”	Curb	8”	8”	Curb	8”	8”	Curb	8”	8”
	Furniture	1’	7’	Furniture	1’	6’	Furniture	1’	2’	Furniture	1’	3’
	Pedestrian	10’	10’	Pedestrian	10’	10’	Pedestrian	8’	10’	Pedestrian	5’	8’
	Frontage	1’	8’	Frontage	1’	1’	Frontage	1’	2’	Frontage	1’	1’
	Total	12’-8”	25’-8”	Total	12’-8”	17’-8”	Total	10’-8”	13’-8”	Total	7’-8”	12’-8”

GENERAL GUIDELINES

The land uses included in the previous table cover those of most municipalities. For those few areas not covered, the following list provides general guidelines for sidewalks:

- The recommended minimum frontage zone width is 18 inches.
- The recommended minimum pedestrian zone width is 4 feet.
- The recommended minimum curb zone width is 6 inches or 18 inches where pedestrian or freight loading is expected and may conflict with obstacles in the furniture zone.
- The recommended minimum furniture zone width is 4 feet and 6 feet to 8 feet where bus stops exist.
- Low curbs (3 to 4 inches high) reduce the division between the traveled way and the sidewalk. They are favored in areas with significant pedestrian traffic. Low curbs also

improve the geometry and feasibility of providing two perpendicular curb ramps per corner.

Some judgment may be needed on a case-by-case basis to establish actual widths of each of the four zones.

FOR MORE INFORMATION

- ADAAG/PROWAG
- MUTCD
- AASHTO "Green Book"
- FHWA's Designing Sidewalks and Trails for Access
- NCHRP Project 20-7 (232) ADA Transition Plans: Guide to Best Management Practices
- NCHRP Project 3-62, Guidelines for Accessible Pedestrian Signals
- City of Norman Engineering Design Criteria
- City of Norman Comprehensive Transportation Plan

6. PEDESTRIAN CROSSINGS

INTRODUCTION

Walking requires two important features in the built environment: people must walk along streets and they must get across streets. Crossing a street should be easy, safe, convenient, and comfortable. While pedestrian behavior and intersection or crossing design affect the street crossing experience, motorist behavior (whether and how motorists stop for pedestrians) is the most significant factor in pedestrian safety.

Crossings are a necessary part of the pedestrian experience (Credit: David Riesland)

A number of tools exist to improve pedestrian safety and to make crossing streets easier. Effective traffic management can address concerns about traffic speed and volume. A motorist driving more slowly has more time to see, react, and stop for a pedestrian. The number of pedestrians also influences motorists; in general, motorists are more aware of pedestrians when more people walk. Most tools to address crossing challenges are engineering treatments, but tools from the enforcement, education, and planning toolboxes are also important.

Providing marked crosswalks is only one of the many possible engineering measures. When considering how to provide safer crossings for pedestrians, the question should *not* be: "Should I provide a marked crosswalk?" Instead, the question should be: "What are the most effective measures that can be used to help pedestrians safely cross the street?" Deciding whether to mark or not mark crosswalks is only one consideration in creating safe and convenient pedestrian crossings.

This chapter describes a number of measures to improve pedestrian crossings, including marked and unmarked crosswalks, raised crossing islands and medians, and lighting.

ESSENTIAL PRINCIPLES OF PEDESTRIAN CROSSINGS

The following principles should be incorporated into every pedestrian crossing improvement:

Curb extensions and median make crossing four-lane streets safer and more manageable. (Credit: Dan Burden)

- Pedestrians must be able to cross roads safely. Cities have an obligation to provide safe and convenient crossing opportunities.
- The safety of all street users, particularly more vulnerable groups, such as children, the elderly, and those with disabilities, and more vulnerable modes, such as walking and bicycling, must be considered when designing streets.
- Pedestrian crossings must meet accessibility standards and guidelines.

- Real and perceived safety must be considered when designing crosswalks—crossing must be "comfortable." A "safe" crossing that no one uses serves no purpose.
- Crossing treatments that have the highest crash reduction factors (CRFs) should be used when designing crossings.
- Safety should not be compromised to accommodate traffic flow.
- Every crossing is different and should be selected and designed to fit its unique environment.

The following issues should also be considered when planning and designing crossings:

- Ideally, uncontrolled crossing distances should be no more than 21 feet, which allows for one 11-foot lane and one 10-foot lane. Ideally, streets wider than 40 feet should be divided (effectively creating two streets) by installing a median or two crossing islands.
- The number of lanes should be limited to a maximum of three lanes per direction on all roads (plus a median or center turn lane).
- There must be a safe, convenient crossing at every transit stop.
- The use of concurrent movements (vehicular and pedestrian) should be limited to those situations where the conditions dictate such.
- People should never have to wait more than 90 seconds to cross at signalized intersections.
- Pedestrian signals should be provided at all signalized crossings where pedestrians are allowed.

PERFORMANCE MEASURES

Performance measures establish how well a crossing is performing. In all cases, baseline data should be collected to allow for before and after analysis. Performance measures for pedestrian crossings include the following:

Lively streets with many pedestrians indicate a walkable neighborhood: Hong Kong (Credit: Ryan Snyder)

- The number of pedestrians crossing at a particular crossing location goes up.
- The pedestrian crash rates go down (for an accurate determination, entire corridors should be analyzed since crashes at any one location may be infrequent).
- Pedestrian fatalities and serious injuries should decrease.
- The numbers of children, seniors, and people with disabilities crossing the street should reflect their percentage in the larger population.
- The speed of motorists either turning at an intersection or traveling at a mid-block crossing goes down.
- Motorists do not block intersections (including crosswalks).
- At uncontrolled intersections, the percentage of motorists who stop for pedestrians goes up (measure compliance with stop or yield requirement in local vehicle code).

PEDESTRIAN CROSSING TOOLBOX

Many engineering measures may be used at a pedestrian crossing, depending on site conditions and potential users. Marked crosswalks are commonly used at intersections and sometimes at mid-block locations. Marked crosswalks are often the first measure in the toolbox followed by a series of other measures that are used to enhance and improve marked crosswalks. The decision to mark a crosswalk should not be considered in isolation, but rather in conjunction with other measures to increase awareness of pedestrians. Without additional measures, marked crosswalks alone may not increase pedestrian safety, particularly on multi-lane streets.

MARKED CROSSWALKS

Crosswalks are present by law at all intersections, whether marked or unmarked, unless the pedestrian crossing is specifically prohibited. At mid-block locations, crosswalks only exist where marked. At these non-intersection locations, the crosswalk markings legally establish the crosswalk. Crosswalks should be considered at mid-block locations where there is strong evidence that pedestrians want to cross there, due to origins and destinations across from each other and an overly long walking distance to the nearest controlled crossing. Marked crosswalks alert drivers to expect crossing pedestrians and direct pedestrians to desirable crossing locations. Although many motorists are unaware of their precise legal obligations at crosswalks, the Oklahoma Vehicle Code requires drivers to yield to pedestrians in any crosswalk, whether marked or unmarked. Marking crosswalks at every intersection is not necessary or desirable.

Crosswalk Markings

According to the MUTCD, the minimum crosswalk marking shall consist of solid white lines. They shall not be less than 6 inches or greater than 24 inches in width.

Placement

The best locations to install marked crosswalks are:

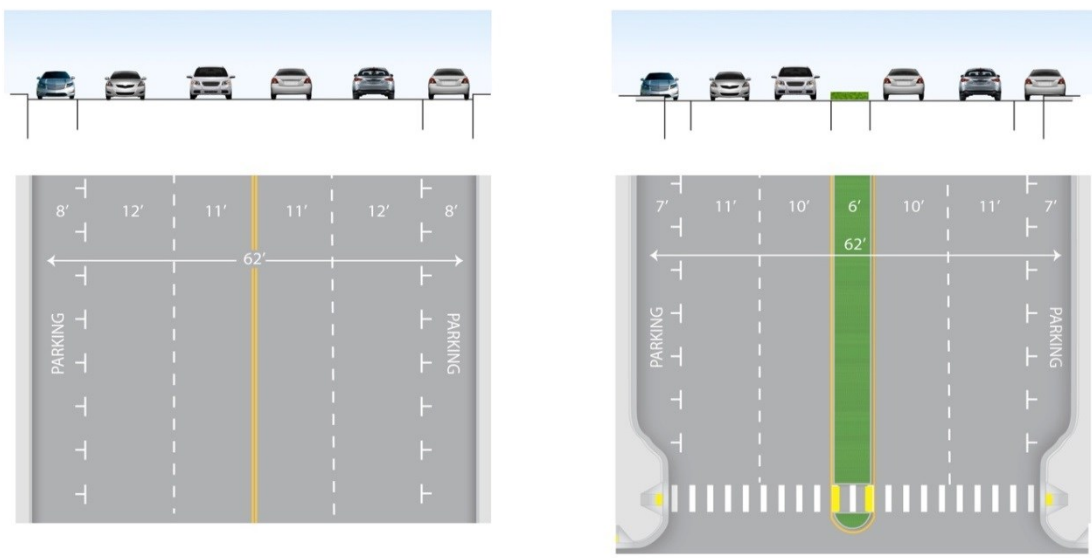
- All signalized intersections
- Crossings near transit locations
- Trail crossings
- High land use generators
- School walking routes
- When there is a preferred crossing location due to sight distance
- Where needed to enable comfortable crossings of multi-lane streets between controlled crossings spaced at convenient distances

Controlled Intersections

Intersections can be controlled by traffic signals or STOP signs. Marked crosswalks should be provided on all intersection legs controlled by traffic signals, unless the pedestrian crossing is specifically prohibited. Marked crosswalks may be considered at STOP-controlled intersections. Factors to be considered include high pedestrian volumes, high vehicle volumes, school zone location, high volume of elderly or disabled users, or other safety related criteria.

Uncontrolled Intersections and Mid-block Crosswalks

Intersections without traffic signals or STOP signs are considered uncontrolled intersections. The decision to mark a crosswalk at an uncontrolled location should be guided by an engineering study. Factors considered in the study should include, but not necessarily be limited to, vehicular volumes and speeds, stopping sight distance and triangles, distance to the next controlled crossing, night time visibility, grade, and pedestrian volumes. The engineering study should be based on the FHWA study, *Safety Effects of Marked Versus Unmarked Crosswalks at Uncontrolled Locations*. The following list provides some of the key recommendations from the study:



Uncontrolled crossings of four-lane streets can be difficult to cross without special treatments like medians and curb extensions. (Credit: Michele Weisbart)

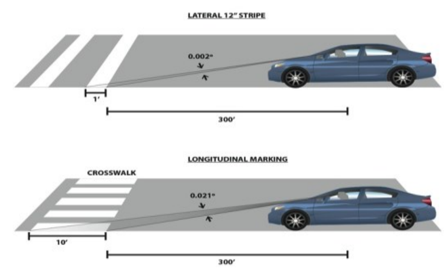
- It is permissible to mark crosswalks on two-lane roadways.
- On multi-lane roadways, marked crosswalks *alone* are not recommended under the following conditions (the other tools listed in this section can be considered to enhance the crosswalk):
    - ADT > 15,000
    - Speeds greater than 40 mph
- Raised medians can be used to reduce risk.
- Signals or other treatments should be considered where there are many young and/or elderly pedestrians.

<u>Frequency of Marked Crosswalks at Uncontrolled Locations</u>

Marked crosswalks should be spaced so people can cross at preferred locations. If people are routinely crossing streets at non-preferred locations, consideration should be given to installing a new crossing. Pedestrians need crossings with appropriate devices (islands, curb extensions, advanced yield lines, etc.) of multi-lane streets where there are strong desire lines. Along urban streets, a well-designed crossing should be provided at least every 1/8 mile.

<u>High-Visibility Crosswalks</u>

Because of the low approach angle at which pavement markings are viewed by drivers, the use of longitudinal stripes in addition to or in place of transverse markings can significantly increase the visibility of a crosswalk to oncoming traffic. While research has not shown a direct link between increased crosswalk visibility and increased pedestrian safety, high-visibility crosswalks have been shown to increase motorist yielding and channelization of pedestrians, leading the Federal Highway Administration to conclude that high-visibility pedestrian crosswalks have a positive effect on pedestrian and driver behavior.



Longitudinal crosswalk markings are more visible than lateral crosswalk markings (Credit: Michele Weisbart)

Colored and stamped crosswalks should only be used at controlled locations.

Staggered longitudinal markings reduce maintenance since they avoid vehicle wheel paths.

Typical crosswalk markings: Continental, Ladder, and Staggered Continental (Credit: Michele Weisbart)

At Left: Example of staggered continental crosswalk (Credit: Michael Ronkin)

Crosswalks and Accessibility

Decorative crosswalk treatments made of distinctive materials can become uneven over time. (Credit: Ryan Snyder)

The Pedestrian Access Route continues through the crosswalk and must conform to the surface condition, width, and slope requirements discussed in Chapter 5, "Universal Pedestrian Access."

Longitudinal crosswalk markings provide the best visibility for pedestrians with limited vision.

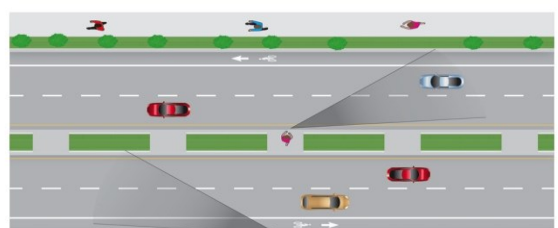
Decorative crosswalk pavement materials should be chosen with care to ensure that smooth surface conditions and high contrast with surrounding pavement are provided. Textured materials within the crosswalk are not recommended. Without reflective materials, these treatments are not visible to drivers at night. Decorative pavement materials often deteriorate over time and become a maintenance problem while creating uneven pavement. The use of color or material to delineate the crosswalks as a replacement of retro-reflective pavement marking should not be used, except in slow speed districts where intersecting streets are designed for speeds of 20 mph or less.

RAISED CROSSING ISLANDS/MEDIANS

Raised islands and medians are the most important, safest, and most adaptable engineering tool for improving street crossings. *Note on terminology: a median is a continuous raised area separating opposite flows of traffic. A crossing island is shorter and located just where a pedestrian crossing is needed.* Raised medians and crossing islands are commonly used between intersections when blocks are long (500 feet or more in downtowns) and in the following situations:

Staggered median crossing (Credit: Marcel Schmaedick)

- Speeds are higher than desired
- Streets are wide
- Traffic volumes are high
- Sight distances are poor



Medians and crossing islands allow pedestrians to complete the crossing in two stages. (Credit: Michele Weisbart)

Raised islands have nearly universal applications and should be placed where there is a need for people to cross the street. They are also used to slow traffic.

Reasons for Efficacy

Their use changes a complex task, crossing a wide street with traffic coming from two opposing directions all at once, into two simpler and smaller tasks. With their use, conflicts occur in only one direction at a time, and exposure time can be reduced from more than 20 seconds to just a few seconds.

On multi-lane streets with traffic speeds higher than 30 mph, it may be unsafe to cross without a median island. At 30 mph, motorists travel 44 feet each second, placing them 880 feet out when a pedestrian starts crossing an 80-foot wide multi-lane road. In this situation, this pedestrian may still be in the last travel lane when the car arrives there; that car was not within view at the time he or she started crossing. With an island on multi-lane roadways, people would cross two or three lanes at a time instead of four or six. Having to wait for a gap in only one direction of travel at a time significantly reduces the wait time to cross. Medians and crossing islands have been shown to reduce crashes by 40 percent (Federal Highway Administration, Designing for Pedestrian Safety course).

As a general rule, crossing islands are preferable to signal-controlled crossings due to their lower installation and maintenance cost, reduced waiting times, and their safety benefits. Crossing islands are also used with road diets, taking four-lane undivided, high-speed roads down to better performing three-lane roadways (two travel lanes and a center turn lane); portions of the center turn lane can be dedicated to crossing islands. Crossing islands can also be used with signals.

Angled pedestrian crossings through pedestrian refuges (as shown in the adjacent photo) force pedestrians to look for oncoming vehicles.

Angled median crossing
(Credit: Paul Zykofsky)

Multiple tools can be employed to improve uncontrolled crossings.
(Credit: Dan Burden)

Where to Place Crossing Islands

Crossing islands are often used for trails, high pedestrian flow zones, transit stations, schools, work centers, and shopping districts.

Design Detail

Crossing islands, like most traffic calming features, perform best with both tall trees and low ground cover. This greatly increases their visibility, reduces surprise, and lowers the need for a plethora of signs. When curves or hill crests complicate crossing locations, median islands are often extended over a crest or around a curve to where motorists have a clear (six second or longer) sight line of the downstream change in conditions. Lighting of median islands is essential. The suggested minimum width of a crossing island is 6 feet. When used on higher speed roads, and where there is space available, inserting a 45-degree bend to the right helps orient pedestrians to the risk they encounter from motorists during the second half of their crossing.

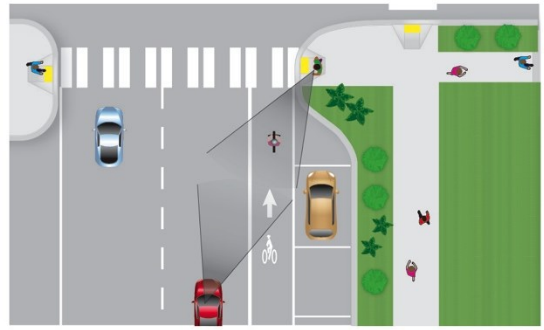
Crossing islands: Berkeley, CA
(Credit: Ryan Snyder)

RAISED CROSSWALKS

Raised crosswalk: University of North Carolina Campus, Chapel Hill, NC
(Credit: Ryan Snyder)

Raised crosswalks slow traffic and put pedestrians in a more visible position. They are trapezoidal in shape on both sides and have a flat top where the pedestrians cross. The level crosswalk area must be paved with smooth materials; any texture or special pavements used for aesthetics should be placed on the beveled slopes, where they will be seen by approaching motorists. They are most appropriate in areas with significant pedestrian traffic and where motor vehicle traffic should move slowly, such as near schools, on college campuses, in Main Street retail environments, and in other similar places. They are especially effective near elementary schools where they raise small children by a few inches and make them more visible.

CURB EXTENSIONS



Curb extensions
(Credit: Michele Weisbart)

Curb extensions extend the sidewalk or curb line out into the parking lane, which reduces the effective street width. Curb extensions significantly improve pedestrian crossings by reducing the pedestrian crossing distance, visually and physically narrowing the roadway, improving the ability of pedestrians and motorists to see each other, and reducing the time that pedestrians are in the street. Reducing street widths improves signal timing since pedestrians need less time to cross. Motorists typically travel more slowly at intersections or mid-block locations with curb extensions, as the restricted street width sends a visual cue to slow down. Turning speeds are lower at intersections with curb extensions (curb radii should be as tight as is practicable). Curb extensions also prevent motorists from parking too close to the intersection.

(Credit: David Riesland)

Curb extensions also provide additional space for two curb ramps and for level sidewalks where existing space is limited, increase the pedestrian waiting space, and provide additional space for pedestrian push button poles, street furnishings, plantings, bike parking and other amenities. A benefit for drivers is that extensions allow for better placement of signs (e.g., STOP signs and signals).

Curb extensions are generally only appropriate where there is an on-street parking lane. Where street width permits, a gently tapered curb extension can reduce crossing distance at an intersection along streets without on-street parking, without creating a hazard. Curb extensions must not extend into travel lanes or bicycle lanes.

Curb extensions can impact other aspects of roadway design and operation as follows:

- May impact street drainage and require catch basin relocation
- May impact underground utilities
- May require loss of curbside parking, though careful planning often mitigates this potential loss, for example by relocating curbside fire hydrants, where no parking is allowed, to a curb extension
- May complicate delivery access and garbage removal
- May impact snow plows and street sweepers
- May affect the turning movements of larger vehicles such as school buses and large fire trucks

PEDESTRIAN 'SCRAMBLES'

Pedestrian scramble
(Credit: Dan Burden)

Exclusive pedestrian phases (i.e. pedestrian 'scrambles') may be used where turning vehicles conflict with very high pedestrian volumes and pedestrian crossing distances are short. Although pedestrians can cross in any direction during the pedestrian phase, pedestrians typically have to wait for both vehicle phases before they get the walk signal again. This creates delay for pedestrians travelling straight, but can be mitigated by allowing pedestrians continuing along the same direction to get a WALK signal during the green signal phase and while turns are prohibited for traffic.

SIGNS

Signs can provide important information to improve road safety by letting people know what to expect, so they can react and behave appropriately. Sign use and placement should be done judiciously, as overuse breeds noncompliance and disrespect. Too many signs create visual clutter.

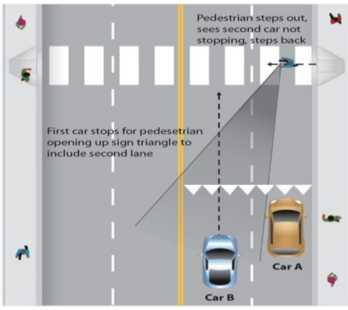
Regulatory signs, such as STOP, YIELD, or turn restrictions, require driver actions and can be enforced. Warning signs provide information, especially to motorists and pedestrians unfamiliar with an area.

Advance pedestrian warning signs should be used where pedestrian crossings may not be expected by motorists, especially if there are many motorists who are unfamiliar with the area. The fluorescent yellow/green color is designated specifically for pedestrian, bicycle, and school warning signs (MUTCD) and should be used for all new and replacement installations. This bright color attracts the attention of drivers because it is unique and the most visible color during nighttime driving conditions.

Sign R1-5 should be used in conjunction with advance yield lines, as described below. Sign R1-6 may be used on median islands, where they will be more visible to motorists than signs placed on the side of the street, especially where there is on-street parking.

All signs should be periodically checked to make sure that they are in good condition, free from graffiti, reflective at night, and continue to serve a purpose. All sign installations need to comply with the provisions of the MUTCD.

ADVANCED YIELD/STOP LINES



Advanced yield markings (Credit: Michele Weisbart)

Stop lines are solid white lines 12 to 24 inches wide, extending across all approach lanes to indicate where vehicles must stop in compliance with a STOP sign or signal. Advance stop lines reduce vehicle encroachment into the crosswalk and improve drivers' view of pedestrians.

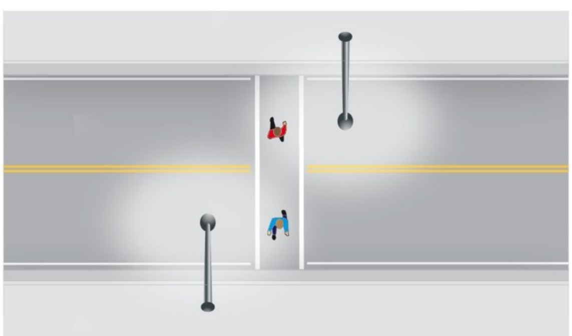

Advanced yield markings (Credit: Sky Yim)

At signalized intersections a stop line is typically set back between 4 and 6 feet.

At uncontrolled crossings of multi-lane roads, advance yield lines can be an effective tool for preventing multiple threat vehicle and pedestrian collisions. Section 3B.16 of the MUTCD specifies placing advanced yield markings 20 to 50 feet in advance of crosswalks, depending upon location-specific variables such as vehicle speeds, traffic control, street width, on-street parking, potential for visual confusion, nearby land uses with vulnerable populations, and demand for queuing space. Thirty feet is the preferred setback for effectiveness at many locations. This setback allows a pedestrian to see if a car in the second (or third) lane is stopping after a driver in the first lane has stopped.

LIGHTING

Lighting is important to include at all pedestrian crossing locations for the comfort and safety of the road users. Lighting should be present at all marked crossing locations. Lighting provides cues to drivers to expect pedestrians earlier.


Proper placement of crosswalk illumination (Credit: Michele Weisbart)

FHWA HT-08-053, *The Information Report on Lighting Design for Mid-block Crosswalks*, found that a vertical illumination of 20 lux in front of the crosswalk, measured at a height of 5 feet from the road surface, provided adequate detection distances in most circumstances. Although the research was constrained to mid-block placements of crosswalks, the report includes a brief discussion of considerations in lighting crosswalks co-located with intersections which also applies at intersections. Illumination just in front of crosswalks creates the best pedestrian visibility.

More guidance on crosswalk lighting levels comes from the Illuminating Engineering Society of North America (IESNA) intersection guidance to illuminate pedestrians in the crosswalk to vehicles (see the adjacent image). Crosswalk lighting should provide color contrast from standard roadway lighting.

Table 7.1 Recommended Illumination by Street Type

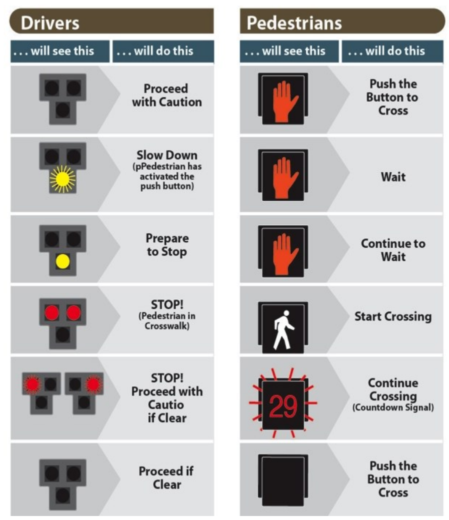
Functional Classification	Average Maintained Illumination at Pavement by Pedestrian Area Classification [FC]		
	High	**Medium**	**Low**
Major / Major (arterial/arterial)	3.4 fc	2.6 fc	1.8 fc
Major / Collector (arterial/collector)	2.9 fc	2.2 fc	1.5 fc
Major / Local (arterial/local)	2.6 fc	2.0 fc	1.3 fc
Collector / Collector (collector/collector)	2.4 fc	1.8 fc	1.2 fc
Collector / Local (collector/local)	2.1 fc	1.6 fc	1.0 fc
Local / Local (local/local)	1.8 fc	1.4 fc	0.8 fc

FC stands for "foot candle" and is defined as the amount of illuminance on a 1 square foot surface of which there is uniformly distributed flux of one lumen. ANSI-IESNA RP-8-00, "Roadway Lighting," P. 15

PEDESTRIAN HYBRID BEACON

A pedestrian hybrid beacon is used to warn and control traffic at an unsignalized location so as to help pedestrians cross a street or highway at a marked crosswalk.

A pedestrian hybrid beacon can be used at a location that does not meet traffic signal warrants or at a location that meets traffic signal warrants but a decision has been made to not install a traffic control signal. A minimum number of 20 pedestrians per hour is needed to warrant installation. This is substantially less than the 93 minimum needed for a signal installation.



Pedestrian hybrid beacon phases
(Credit: Michele Weisbart)

If beacons are used, they should be placed in conjunction with signs, crosswalks, and advanced yield lines to warn and control traffic at locations where pedestrians enter or cross a street or highway. A pedestrian hybrid beacon should only be installed at a marked crosswalk. Installations should be done in accordance with the MUTCD.

Rectangular Rapid-Flash Beacon in Norman, OK (Credit: David Riesland)

Rectangular Rapid Flash Beacon (RRFB)

The RRFB uses rectangular-shaped high-intensity LED-based indications, flashes rapidly in a wig-wag "flickering" flash pattern, and is mounted immediately between the crossing sign and the sign's supplemental arrow plaque.

FHWA Evaluation of Results

The Office of Transportation Operations has reviewed available data and considers the RRFB to be highly successful for the applications tested (uncontrolled crosswalks). The RRFB offers significant potential safety and cost benefits because it achieves very high rates of compliance at a very low cost compared to other more restrictive devices such as full mid-block signalization. The components of the RRFB are not proprietary and can be assembled by any jurisdiction with off-the-shelf hardware. The FHWA believes that the RRFB has a low risk of safety or operational concerns. However, because proliferation of RRFBs in the roadway environment to the point that they become ubiquitous could decrease their effectiveness, use of RRFBs should be limited to locations with the most critical safety concerns, such as pedestrian and school crosswalks at uncontrolled locations, as tested in the experimentation.

At a recent meeting of the National Committee on Uniform Traffic Control Devices, the Signals Technical Committee voted to endorse the future inclusion of the RRFB for uncontrolled crosswalks into the MUTCD and recommended that FHWA issue an Interim Approval for RRFB. This Interim Approval allows agencies to install this type of flashing beacon, pending official MUTCD rulemaking.

PEDESTRIAN TOOLBOX FOR RAILROAD CROSSINGS

Pedestrian crossings of railroad tracks apply a special set of tools. The following are the primary tools to apply:

- Pedestrian gates
- Channelization of pedestrians through gates and across tracks
- Warning flashers
- Signs
- Audible signals

7. BIKEWAY DESIGN

ESSENTIAL PRINCIPLES OF BIKEWAY DESIGN

The following principles inform the recommendations made in this chapter:

- Bicyclists should have safe, convenient, and comfortable access to all destinations.
- Every street is a bicycle street, regardless of bikeway designation.
- Street design should accommodate all types, levels, and ages of bicyclists.
- Bicyclists should be separated from pedestrians.
- Bikeway facilities should take into account vehicle speeds and volumes, with
  - Shared use on low volume, low-speed roads.
  - Separation on higher volume, higher-speeds roads.
- Bikeway treatments should provide clear guidance to enhance safety for all users.
- Since most bicycle trips are short, a complete network of designated bikeways has a grid of roughly ½ mile.

PLANNING FOR A RANGE OF BIKEWAY USERS

Plan bicycle facilities for various skill levels (Credit: Dan Burden)

Many early bikeway designs assumed that bicyclists resemble pedestrians in their behavior. This led to undesirable situations: bicyclists being under-served by inadequate facilities, pedestrians resenting bicyclists in their space, and motorists being confused by bicyclists entering and leaving the traffic stream in unpredictable ways. Only under special circumstances (e.g., on shared-use paths or shared-space streets) should bicyclists and pedestrians share the same space.

Bicyclists operate a vehicle and are legitimate road users, but they are slower and less visible than motor vehicles. Bicyclists are also more vulnerable in a crash than motorists. They need accommodation on busy, high-speed roads and at complex intersections. In congested urban areas, bicyclists provided with well-designed facilities can often proceed faster than motorists.

Bicyclists use their own power, must constantly maintain their balance, and don't like to interrupt their momentum. Typical bicyclist speeds range from 10 to 15 mph, enabling them to make trips of up to 5 miles in urban areas in about 25 minutes, the equivalent of a typical suburban commuter trip time. Bicyclists may wish to ride side-by-side so they can interact socially with a riding companion.

Well-designed bicycle facilities guide cyclists to ride in a manner that generally conforms to the vehicle code: in the same direction as traffic and usually in a position 3 to 4 feet from the right edge of the traveled way or parked cars to avoid debris, drainage grates, and other potential hazards. Cyclists should be able to proceed through intersections in a direct, predictable, and safe manner.

Cyclist skill level also provides a wide variety of speeds and expected behaviors. Several systems of bicyclist classification are used within the bicycle planning and engineering professions. These classifications can be helpful in understanding the characteristics and infrastructure preferences of different cyclists. However, these classifications may change in type or proportion over time as infrastructure and culture evolve. Bicycle infrastructure should use planning and designing options, from shared roadways to separate facilities, to accommodate as many user types as possible and to provide a comfortable experience for the greatest number of cyclists.

A classification system developed by the City of Norman provides the following bicycle user types:

- **Advanced Riders.** These bicyclists are on streets with high volumes of automobile traffic. These tend to be very experienced riders who are comfortable in most any traffic conditions.
- **Casual or Younger Riders.** This group prefers to bicycle on streets with low to moderate traffic volumes and lower speeds. These more casual and younger riders are less confident in traffic without special provisions for bicycles.
- **Young Riders Monitored by Parents.** This group is most comfortable riding separate from vehicular traffic. These riders are most likely to be found on bike paths that may or may not be shared with pedestrians. This type of facility can be good for all riders but is particularly good for young riders who still must be monitored in their riding.

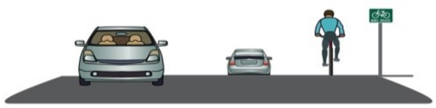
Proficient bicycle rider (Credit: Dan Burden)

Less-experienced riders prefer paths (Credit: Dan Burden)

BIKEWAY TYPES

A designated bikeway network provides a system of facilities that offers enhancement or priority to bicyclists over other roadways in the network. However, it is important to remember that all streets in a city should safely and comfortably accommodate bicyclists, regardless of whether the street is designated as a bikeway. Several general types of bikeways are listed below with no implied order of preference.

SHARED ROUTES



Bicycle Route
(Credit: Marty Bruinsma)

A shared route is a street in which bicyclists ride in the same travel lanes as other traffic. There are no specific dimensions for shared routes. On narrow travel lanes, motorists have to cross over into the adjacent travel lane to pass a cyclist.

Shared routes work well and are common on low-volume, low-speed neighborhood residential streets, rural roads, and even many low-volume highways.

BICYCLE BOULEVARDS

Bicycle boulevard: Portland, OR
(Credit: Ryan Snyder)

A bicycle boulevard is a street that has been modified to prioritize through bicycle traffic but discourage through motor vehicle traffic. Traffic calming devices control traffic speeds and discourage through trips by automobiles. Traffic controls limit conflicts between automobiles and bicyclists and give priority to through bicycle movement at intersections.

SHOULDER BIKEWAYS

This facility accommodates bicycle travel on rural highways and country roads by providing a suitable area for bicycling and reducing conflicts with faster moving motor vehicles.

BIKE LANES

Bike Lane in Norman, OK
(Credit: Angelo Lombardo)

Portions of the traveled way designated with striping, stencils, and signs for preferential use by bicyclists, bike lanes are appropriate on avenues and boulevards. They may be used on other streets where bicycle travel and demand is substantial. Where on-street parking is provided, bike lanes are striped on the left side of the parking lane.

CYCLE TRACKS

Cycle tracks are specially designed bikeways separated from the parallel motor vehicle travelway by a line of parked cars, landscaping, or a physical buffer that motor vehicles cannot cross. Cycle tracks are effective in attracting users who are concerned about conflicts with motorized traffic.

SHARED USE PATHS

Shared-use path
(Credit: Marty Bruinsma)

Shared use paths are facilities separated from motor vehicle traffic by an open space or barrier, either within the highway right-of-way or within an independent right-of-way. Bicyclists, pedestrians, joggers, and skaters often use these paths. Shared-use paths are appropriate in areas not well served by the street system, such as in long, relatively uninterrupted corridors like waterways, utility corridors, and rail lines. They are often elements of a community trail plan. Shared use paths may also be integrated into the street network with new subdivisions as described in Chapter 2, “Street Networks and Classifications.”

BIKE ROUTES

A term used for planning purposes or to designate recommended bicycle touring routes, a bike route can be any bikeway type.

INTEGRATING WITH THE STREET SYSTEM

Most bikeways are part of the street; therefore, well-connected street systems are very conducive to bicycling, especially those with a fine-meshed network of low-volume, low-speed streets suitable for shared roadways. In less well-connected street systems, where wide streets carry the bulk of traffic, bicyclists need supplementary facilities, such as short sections of paths and bridges, to connect otherwise unconnected streets.

There are no hard and fast rules for when a specific type of bikeway should be used, but some general principles guide selection. As a general rule, as traffic volumes and speeds increase, greater separation from motor vehicle traffic is desirable. For example, a bike route may be acceptable for speeds up to 30 mph and ADTs of up to 5,400. Separate bike lanes will accommodate users on streets up to 40 mph and ADTs of up to 22,000. Other factors to consider are users (more children or recreational cyclists may warrant greater separation), adjacent land uses (multiple driveways may cause conflicts with shared-use paths), available right-of-way (separated facilities require greater width), and costs.

As a general rule, designated bicycle facilities (e.g., bike lanes and cycle tracks) should be provided on all major streets (avenues and boulevards), as these roads generally offer the greatest level of directness and connectivity in the network, and are typically where destinations are located. There are occasions when it is infeasible or impractical to provide bikeways on a busy street, or the street does not serve the mobility and access needs of bicyclists. The following guidelines should be used to determine if it is more appropriate to provide facilities on a parallel local street:

- Conditions exist such that it is not economically or environmentally feasible to provide adequate bicycle facilities on the street.
- The street does not provide adequate access to destination points within reasonable walking distances, or separated bikeways on the street would not be considered safe.
- The parallel route provides continuity and convenient access to destinations served by the street.
- Costs to improve the parallel route are no greater than costs to improve the street.
- If any of these factors are met, cyclists may actually prefer the parallel local street facility in that it may offer a higher level of comfort (bicycle boulevards are based on this approach).

Off-street paths can also be used to provide transportation in corridors otherwise not served by the street system, such as along rivers and canals, through parks, along utility corridors, on abandoned railroad tracks, or along active railroad rights-of-way. While paths offer the safety and scenic advantages of separation from traffic, they must also offer frequent connections to the street system and to destinations such as residential areas, employment sites, shopping, and schools. Street crossings must be well designed with measures such as signals or median refuge islands.

DESIGN OF EACH BIKEWAY TYPE

The following sections provide design guidance for each type of bikeway.

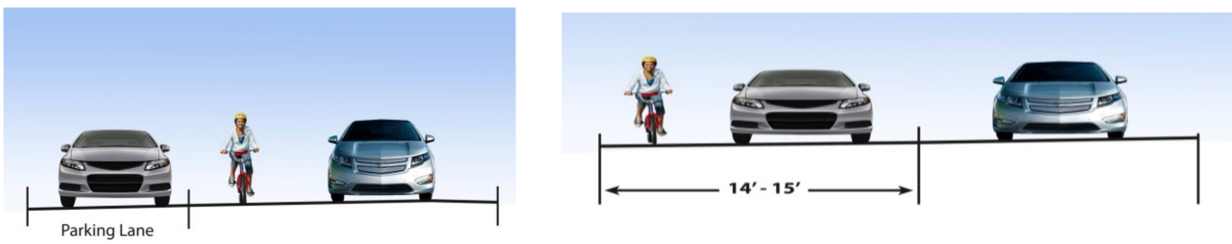
SHARED ROUTES

Shared routes are the most common bikeway type. There are no specific width standards for shared routes. Most are fairly narrow; they are simply the streets as constructed. Shared routes are suitable on streets with low motor vehicle speeds or traffic volumes, and on low-volume rural roads and highways. The suitability of a shared route decreases as motor vehicle traffic speeds and volumes increase, especially on rural roads with poor sight distance.

Many streets carry excessive traffic volumes at speeds higher than they were designed to carry. These can function better as shared routes if traffic speeds and volumes are reduced. For any street to function acceptably as a shared route, traffic volumes should not be more than 5,400 vehicles per day, and speeds should be 30 mph or less. If traffic speeds and volumes exceed those thresholds, separated facilities (e.g., bike lanes) should be considered or traffic calming should be applied to reduce the vehicle speeds/volumes. Many traffic-calming techniques can make these streets more amenable to bicycling.

Wide Curb Lanes

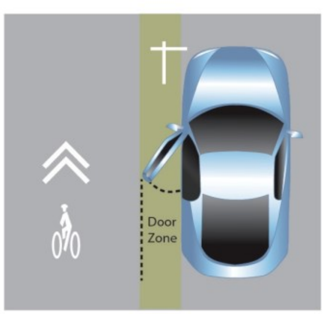
On streets where bike lanes would be more appropriate but with insufficient width for bike lanes, wide curb lanes may be provided. This may occur on retrofit projects where there are physical constraints and all other options, such as narrowing travel lanes, have been pursued. Wide curb lanes are not particularly attractive to most cyclists; they simply allow a passenger vehicle to pass cyclists within a travel lane, if cyclists are riding far enough to the right. Wide curb lanes may also encourage higher motor vehicle speeds and is contrary to the design principles of this manual; wide lanes should never be used on local residential streets. A 14 to 15-foot wide lane allows a passenger car to pass a cyclist in the same lane. Widths 16 feet or greater encourage the undesirable operation of two motor vehicles in one lane. In this situation, a bike lane should be striped.



Wide curb lane (Credit: Michele Weisbart)

Sharrows

Shared-lane marking stencils ("SLMs," also commonly called "sharrows") may be used as an additional treatment for shared roadways. The stencils can serve a number of purposes: they remind bicyclists to ride further from parked cars to prevent "dooring" collisions, they make motorists aware of bicycles potentially in the travel lane, and they show bicyclists the correct direction of travel. Sharrows installed next to parallel parking should be a minimum distance of 11 feet from the curb. Installing farther than 11 feet from the curb may be desired in areas with wider parking lanes or in situations where the sharrow is best situated in the center of the shared travel lane to promote cyclists taking the lane. Placing the sharrow between vehicle tire tracks increases the life of the markings and decreases long-term maintenance costs.

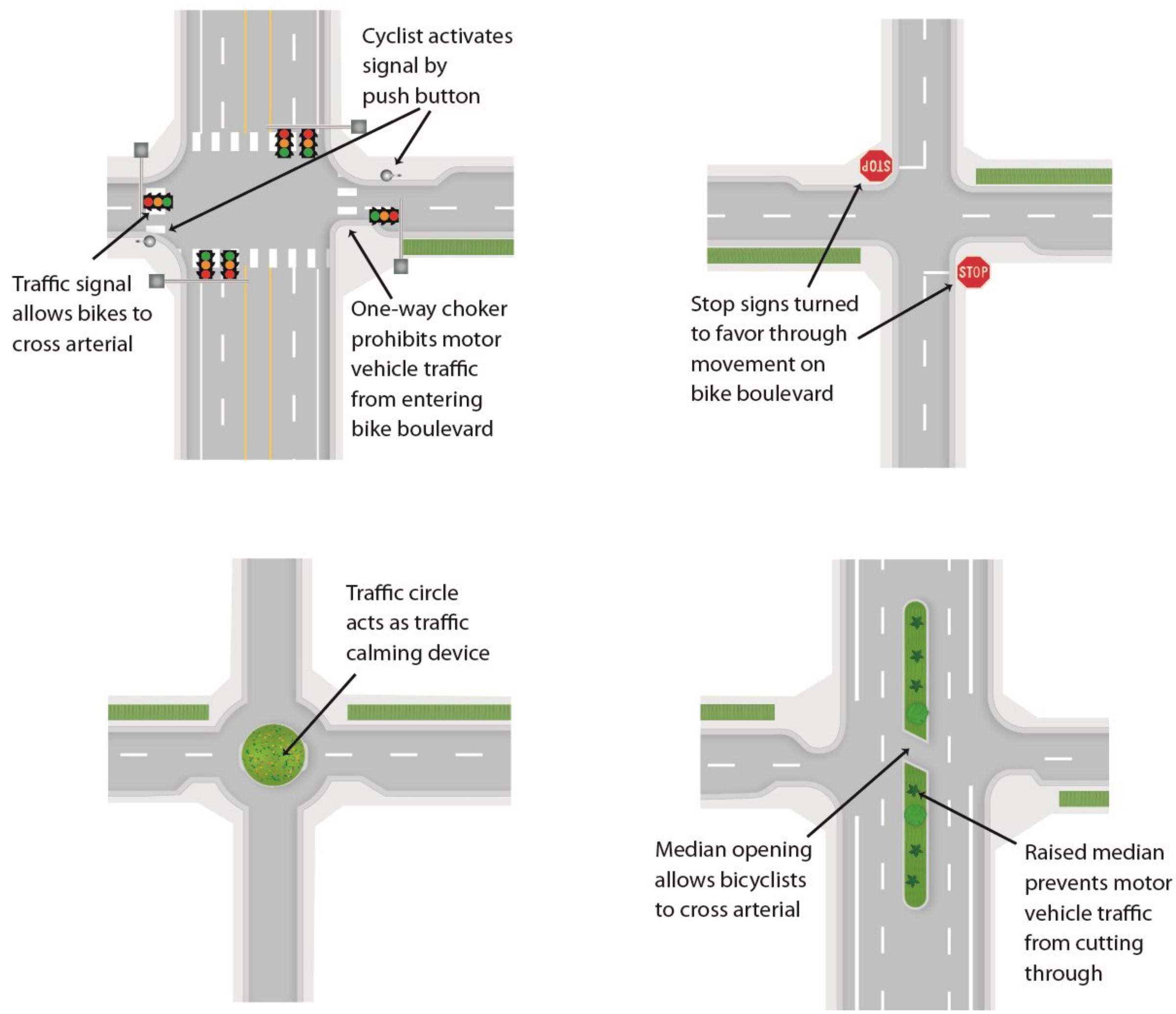


Sharrow
(Credit: Michele Weisbart)

Example of a Sharrow: Norman, OK
(Credit: CJ Whitaker)

BICYCLE BOULEVARDS

A bicycle boulevard is an enhanced shared roadway; a local street is modified to function as a prioritized through street for bicyclists while maintaining local access for automobiles. This is done by adding traffic-calming devices to reduce motor vehicle speeds and through trips, and installing traffic controls that limit conflicts between motorists and bicyclists and give priority to through bicyclist movement.



Components of bike boulevards (Credit: Michele Weisbart)

One key advantage of bicycle boulevards is that they attract cyclists who do not feel comfortable on busy streets and prefer to ride on lower traffic streets. Bicycle travel on local streets is generally compatible with local land uses (e.g., residential and some retail). Residents who want slower traffic on neighborhood streets often support measures that encourage bicycle boulevards. By reducing traffic and improving crossings, bicycle boulevards also improve conditions for pedestrians. Successful bicycle boulevard implementation requires careful planning with residents and businesses to ensure acceptance.

Traffic circles allow for landscaping opportunities (Credit: Ryan Snyder)

Elements of a Bicycle Boulevard

A successful bike boulevard includes the following design elements:

- Selecting a direct and continuous street, rather than a circuitous route that winds through neighborhoods. Bike boulevards work best on a street grid. If any traffic diversion will likely result from the bike boulevard, selecting streets that have parallel higher-level streets can prevent unpopular diversion to other residential streets.
- Placing motor vehicle traffic diverters at key intersections to reduce through motor vehicle traffic (diverters are designed to allow through bicyclist movement).
- Turning STOP signs towards intersecting streets, so bicyclists can ride with few interruptions.
- Replacing STOP-controlled intersections with mini-circles and mini-roundabouts reduces the number of stops cyclists have to make,
- Placing traffic-calming devices lowers motor vehicle traffic speeds.
- Place wayfinding and other signs or markings to route cyclists to key destinations, to guide cyclists through difficult situations, and to alert motorists of the presence of bicyclists.

- Where the bike boulevard crosses high-speed or high-volume streets, providing crossing improvements such as:
  - Signals, where a traffic study has shown that a signal will be safe and effective. To ensure that bicyclists can activate the signal, loop detection should be installed in the pavement where bicyclists ride.
  - Roundabouts where appropriate.
  - Median refuges wide enough to provide a refuge (8 feet minimum) and with an opening wide enough to allow bicyclists to pass through (6 feet). The design should allow bicyclists to see the travel lanes they must cross.

SHOULDER BIKEWAYS

Paved shoulders are provided on rural highways for a variety of safety, operational, and maintenance reasons; they also provide a place for bicyclists to ride at their own pace, out of the stream of motorized traffic.

When providing shoulders for bicycle use, a minimum width of 6 feet is recommended. This allows a cyclist to ride far enough from the edge of pavement to avoid debris and far enough from passing vehicles to avoid conflicts. On roads with prevailing speeds over 45 mph, 8 feet is preferred. If there are physical width limitations, a minimum 4-foot shoulder may be used.

BIKE LANES

Bike lanes are a portion of the traveled way designated for preferential use by bicyclists; they are most suitable on avenues and boulevards. Bike lanes may also be provided on rural roads where there is high bicycle use. Bike lanes are generally not recommended on local streets with relatively low traffic volumes and speeds, where a shared roadway is the appropriate facility. There are no hard and fast mandates for providing bike lanes, but as a general rule, most jurisdictions consider bike lanes on roads with traffic volumes in excess of 5,400 ADT or traffic speeds of 30 mph or greater.

Bike lanes have the following advantages:

- They enable cyclists to ride at a constant speed, especially when traffic in the adjacent travel lanes speeds up or slows down (stop-and-go).
- They enable bicyclists to position themselves where they will be visible to motorists.
- They encourage cyclists to ride on the traveled way rather than the sidewalk.

Bike lanes are created with a solid stripe and stencils. Motorists are prohibited from using bike lanes for driving and parking, but may use them for emergency avoidance maneuvers or breakdowns. Bike lanes are one-way facilities that carry bicycle traffic in the same direction as adjacent motor-vehicle traffic. Bike lanes should always be provided on both sides of a two-way street. One exception is on hills where topographical constraints limit the width to a bike lane on one side only; the bike lane should be provided in the uphill direction as cyclists ride slower uphill, and they can ride in a shared lane in the downhill direction.

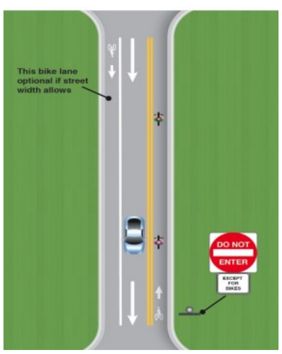
The minimum bike lane width is 5 feet from the face of a curb, or 4 feet on open shoulders. If on-street parking is permitted, the bike lane should be placed between parking and the travel lane with a preferred width of 6 feet so cyclists can ride outside the door zone. Streets with high volumes of traffic and/or higher speeds need wider bike lanes (6 feet to 8 feet) than those with less traffic or slow speeds. On curbed sections, a 4-foot (minimum 3 feet) wide smooth surface should be provided between the gutter pan and stripe. This minimum width enables cyclists to ride far enough from the curb to avoid debris and drainage grates and far enough from other vehicles to avoid conflicts. By riding away from the curb, cyclists are more visible to motorists than when hugging the curb. Where on-street parking is permitted, delineating the bike lane with two stripes, one on the street side and one on the parking side, is preferable to a single stripe.

Bike Lanes on Two-Way Streets

Basic bike lanes on two-way streets comprise the majority of bike lanes. They should follow the design guidelines for width with and without on-street parking.

Bike Lanes on One-Way Streets

Bike lanes on one-way streets should generally be on the right side of the traveled way and should always be provided on both legs of a one-way couplet. The bike lane may be placed on the left of a one-way street if it decreases the number of conflicts (e.g., those caused by heavy bus traffic or parking) and if cyclists can safely and conveniently transition in and out of the bike lane. If sufficient width exists, the bike lanes can be striped on both sides.



Contra-flow bike lane design (Credit: Michele Weisbart)

Contra-Flow Bike Lanes

Contra-flow bike lanes are provided to allow bicyclists to ride in the opposite direction of motor vehicle traffic. They convert a one-way traffic street into a two-way street: one direction for motor vehicles and bikes and the other for bikes only. Contra-flow lanes are separated with yellow center lane striping. Combining both directions of bicycle travel on one side of the street to accommodate contra-flow movement results in a two-way cycle track.

Contra-flow bike lanes are useful where they provide a substantial savings in out-of-direction travel with direct access to high-use destinations, and safety is improved because of reduced conflicts compared to the longer route. The contra-flow design introduces new design challenges and may create additional conflict points as motorists may not expect on-coming bicyclists.

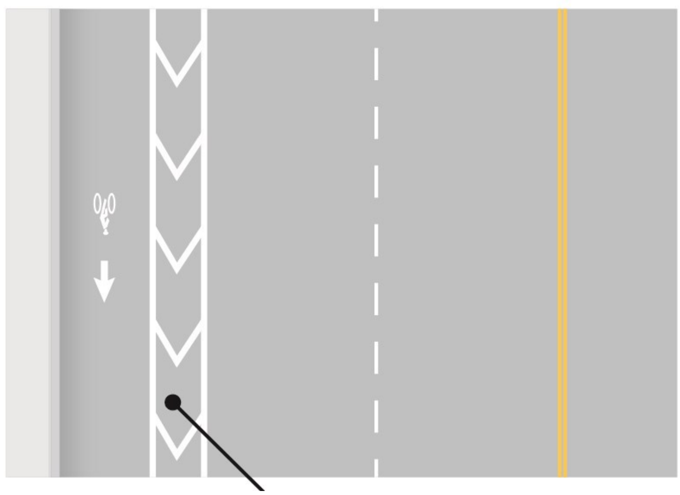
Bike Lanes and Bus Lanes

In most instances, bicycles and buses can share the available road space. On routes heavily traveled by both bicyclists and buses, separation can reduce conflicts (stopped buses hinder bicycle movement and slower moving bicycles hinder buses). Ideally, shared bicycle/bus lanes should be 13 feet to 15 feet wide to allow passing by both buses and bicyclists.

Separate bus lanes and bike lanes should be considered to reduce conflicts between passengers and bicyclists, with the bus lane at the curbside. Buses will be passing bicyclists on the right, but the fewer merging and turning movements reduce overall conflicts.

Buffered Bike Lanes

Buffered bike lanes provide a painted divider between the bike lane and the travel lanes. This additional space can improve the comfort of cyclists as they don't have to ride as close to motor vehicles. Buffered bike lanes can also be used to slow traffic as they narrow the travel lanes. An additional buffer may be used between parked cars and bike lanes to direct cyclists to ride outside of the door zone of the parked cars. Buffered bike lanes are most appropriate on wide, busy streets. They can be used on streets where physically separating the bike lanes with cycle tracks is undesirable for cost, operational, or maintenance reasons.



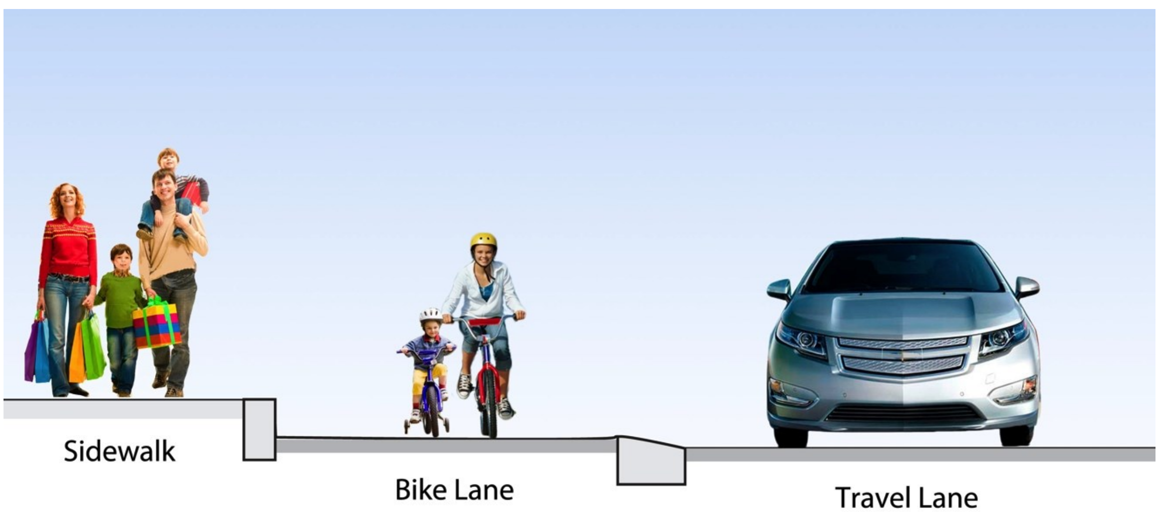
Painted-buffer bike lanes (Credit: Michele Weisbart)

Raised Bike Lanes

Bike lanes are typically an integral portion of the traveled way and are delineated from motor vehicle lanes with painted stripes. Though most bicyclists ride on these facilities comfortably, others prefer more separation. Raised bike lanes incorporate the convenience of riding on the street with some physical separation. This is done by elevating the bicycle lane surface 2 to 4 inches above street level, while providing a traversable curb to separate the bikeway from the motor vehicle travelway. This treatment offers the following advantages:

- Motorists know they are straying from the travel way when they feel the slight bump created by the curb.
- The mountable curb allows motorists to make turns into and out of driveways.
- The mountable curb allows cyclists to enter or leave the bike lane (e.g., for turning left or overtaking another cyclist).
- The raised bike lane drains towards the centerline, leaving it clear of debris and puddles.
- Novice bicyclists are more likely to ride in the bike lane, leaving the sidewalk for pedestrians.

Raised bike lanes can be constructed at little additional expense for new roads. Retrofitting streets with raised bike lanes is more costly; it is best to integrate raised bike lanes into a larger project to remodel the street due to drainage replacement. Special maintenance procedures may be needed to keep raised bike lanes swept.



Raised bike lanes (Credit: Michele Weisbart)

CYCLE TRACKS

Cycle tracks, also known as protected bike lanes, are bikeways located on or adjacent to streets where bicycle traffic is separated from motor vehicle traffic by physical barriers, such as on-street parking, posts/bollards, and landscaped islands. They can be well suited to downtown areas where they minimize traffic conflicts with pedestrians. Streets selected for cycle tracks

Cycle track (Credit: Dan Burden)

should have minimal pedestrian crossings and driveways. They should also have minimal loading/unloading activity and other street activity. The cycle tracks should be designed to minimize conflicts with these activities as well as with pedestrians and driveways.

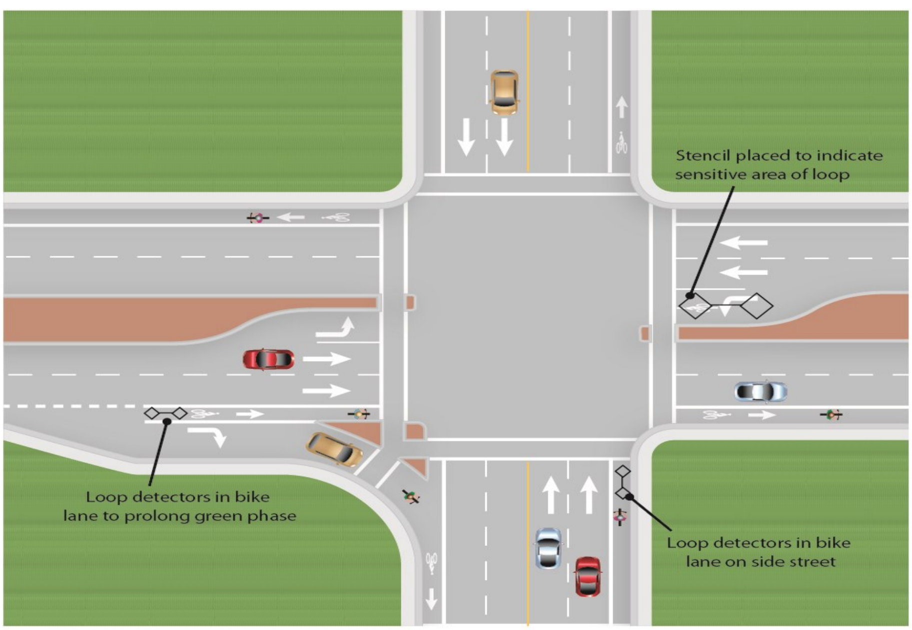
Cycle tracks can be provided on new facilities, but they require more width than other types of bikeways. They are best suited for existing streets where surplus width is available; the combined width of the cycle track and the barrier is more or less the width of a travel lane. The area to be used by bicycles should be designed with adequate width for street sweeping to ensure that debris will not accumulate. Cycle tracks tend to work most effectively where there are few uncontrolled crossing points with unexpected traffic conflicts. Cycle track concerns include treatment at intersections, uncontrolled midblock driveways and crossings, wrong-way bicycle traffic, and difficulty accessing or exiting the facility at midblock locations. There is some controversy regarding the comparative safety of cycle tracks. Recent studies have concluded that cycle tracks are as safe as other treatments when high usage is expected and when measures such as separate signal phases for right-turning motor vehicle and through cyclists, and left-turning cyclists and through motor vehicles, are deployed to regulate crossing traffic.

SHARED USE PATHS

Shared use paths should be a minimum of 8 feet wide with 2 feet of graded shoulder on each side. This width is suitable in rural or small-town settings. Generally, 12 feet of paved path is preferred. Wider pavement may be needed in high-use areas. Where significant numbers of pedestrians, bicyclists, skaters, and other users use the paths, either wider pavement or separate walkways help to eliminate conflicts. Most important in designing shared use paths is good design of intersections where they cross streets. These crossing should be treated as intersections with appropriate treatment.

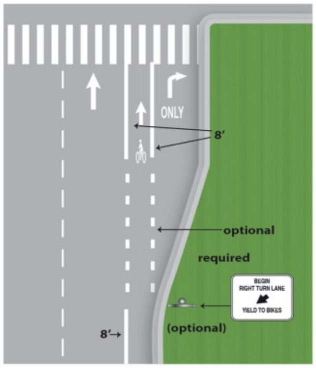
INTERSECTIONS

Intersections are junctions at which different modes of transportation meet and facilities overlap. A well-designed intersection facilitates the interchange between bicyclists, pedestrians, motorists, and transit so traffic flows in a safe and efficient manner. Designs for intersections with bicycle facilities should reduce conflicts between bicyclists (and other vulnerable road users) and vehicles by heightening visibility, denoting a clear right of way, and ensuring that the various users are aware of each other. Intersection treatments can resolve both queuing and merging maneuvers for bicyclists, and are often coordinated with timed or specialized signals.
Chapter 4, "Intersection Design," provides general principles of geometric design; all these recommendations will benefit cyclists. The configuration of a safe intersection for bicyclists may include additional elements such as color, signs, medians, signal detection, and pavement markings. Intersection design should take into consideration existing and anticipated bicyclist, pedestrian, and motorist movements. In all cases, the degree of mixing or separation between bicyclists and other modes is intended to reduce the risk of crashes and increase bicyclist comfort. The level of treatment required for bicyclists at an intersection will depend on the bicycle facility type used, whether bicycle facilities are intersecting, the adjacent street function, and the adjacent land use.



Bikeway markings at intersections (Credit: Michele Weisbart)

Bikeway Markings at Intersections



Bike lane markings at intersections with right-turn lanes (Credit: Michele Weisbart)

Continuing marked bicycle facilities at intersections (up to the crosswalk) ensures that separation, guidance on proper positioning, and awareness by motorists are maintained through these potential conflict areas. The appropriate treatment for right-turn only lanes is to place a bike lane pocket between the right-turn lane and the rightmost through lane. If a full bike lane pocket cannot be accommodated, a shared bicycle/right turn lane can be installed that places a standard-width bike lane on the left side of a dedicated right-turn lane. A dashed strip delineates the space for bicyclists and motorists within the shared lane. This treatment includes signs advising motorists and bicyclists of proper positioning within the lane. Sharrows are another option for marking a bikeway through an intersection where a bike lane pocket cannot be accommodated.

Bike Signal Heads

Bicycle signal head: Long Beach, CA (Credit: Charlie Gandy)

Bicycle signal heads may be installed at signalized intersections to improve identified safety or operational problems for bicyclists; they provide guidance for bicyclists at intersections where bicyclists may have different needs from other road users (e.g., bicycle-only movements and leading bicycle intervals) or to indicate separate bicycle signal phases and other bicycle-specific timing strategies. A bicycle signal should only be used in combination with an existing conventional or hybrid beacon. In the United States, bicycle signal heads typically use standard three-lens signal heads in green, yellow, and red with a stencil of a bicycle.

Bicycle Signal Detection

Bicycle detection is used at actuated traffic signals to alert the signal controller of bicycle crossing demand on a particular approach. Bicycle detection occurs either through the use of push buttons or by automated means (e.g., in-pavement loops, video, and microwave). Inductive loop vehicle detection at many signalized intersections is calibrated to the size or metallic mass of a vehicle, meaning that bicycles may often go undetected. The result is that bicyclists must either wait for a vehicle to arrive, dismount, and push the pedestrian button (if available), or cross illegally. Loop sensitivity can be increased to detect bicycles. Proper bicycle detection must accurately detect bicyclists (be sensitive to the mass and volume of a bicycle and its rider); and provide clear guidance to bicyclists on how to actuate detection (e.g., what button to push or where to stand).

BIKE BOXES

A bike box is a designated area at the head of a traffic lane at a signalized intersection that provides bicyclists with a safe and visible way to get ahead of queuing traffic during the red signal phase. Appropriate locations include:

- At signalized intersections with high bicycle and/or vehicular volumes, especially those with frequent bicyclist left-turns and/or motorist right-turns
- Where there may be right or left-turning conflicts between bicyclists and motorists
- Where there is a desire to better accommodate left-turning bicycle traffic
- Where a left turn is required to follow a designated bike route or boulevard or access a shared-use path, or when the bicycle lane moves to the left side of the street
- When the dominant motor vehicle traffic flows right and bicycle traffic continues through (such as at a Y intersection or access ramp)

Bicycle box: Portland, OR (Credit: Ryan Snyder)

BICYCLE COUNTDOWNS

Near-side bicycle signals may incorporate a "countdown to green" display to provide information about how long until the green bicycle indication is shown, enabling riders to push off as soon as the light turns green.

LEADING BICYCLE INTERVALS

Based on the Leading Pedestrian Interval, a Leading Bicycle Interval (LBI) can be implemented in conjunction with a bicycle signal head. Under an LBI, bicyclists are given a green signal while the vehicular traffic is held at all red for several seconds, providing a head start for bicyclists to advance through the intersection. This treatment is particularly effective in locations where bicyclists are required to make a challenging merge or lane change (e.g., to access a left turn pocket) shortly after the intersection, as the LBI would give them sufficient time to make the merge before being overtaken by vehicular traffic. This treatment can be used to enhance a bicycle box.

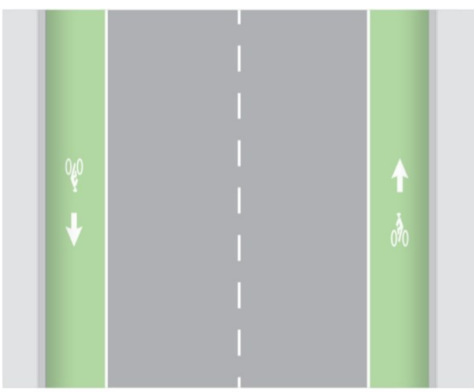
Two-Stage Turn Queue Boxes

On right side cycle tracks, bicyclists are often unable to merge into traffic to turn left due to physical separation. This makes the provision of two-stage left turns critical in ensuring these facilities are functional. The same principles for two-stage turns apply to both bike lanes and cycle tracks. While two-stage turns may increase bicyclist comfort in many locations, this configuration will typically result in higher average signal delay for bicyclists due to the need to receive two separate green signal indications (one for the through street, followed by one for the cross street) before proceeding.

Colored Pavement Treatments

Pavement coloring is useful for a variety of applications in conjunction with bicycle facilities. The primary goal of colored pavements is to differentiate specific portions of the traveled way, but colored pavements can also visibly reduce the perceived width of the street.

Colored pavements are used to highlight conflict areas between bicycle lanes and turn lanes, especially where bicycle lanes merge across motor vehicle turn lanes. Colored pavements can be used in conjunction with sharrows (shared lane markings) in heavily used commercial corridors where no other provisions for bicycle facilities are evident.



Colored bicycle lanes
(Credit: Michele Weisbart)

Installation of Green Bicycle Lanes: Norman, OK
(Credit: David Riesland)

Around the world, a variety of colored treatments for bike lanes have been used. To minimize confusion with other standard traffic control markings, the color green has been selected by the Federal Highway Administration and the MUTCD as the standard color for bicycle facilities of this type. Maintenance of color and surface condition are considerations. Traditional traffic paints and coatings can become slippery. Long life surfaces with good wet skid resistance should be considered.

WAYFINDING

Wayfinding signs: Seattle, WA
(Credit: Ryan Snyder)

The ability to navigate through a region is informed by landmarks, natural features, signs, and other visual cues. Wayfinding is a cost-effective and highly visible way to improve the bicycling environment by familiarizing users with the bicycle network, helping users identify the best routes to destinations, addressing misperceptions about time and distance, and helping overcome a barrier to entry for infrequent cyclists (e.g., "interested but concerned" cyclists).

A bikeway wayfinding system is typically composed of signs indicating direction of travel, location of destinations, and travel time/distance to those destinations; pavement markings indicating to bicyclists that they are on a designated route or bike boulevard and reminding motorists to drive courteously; and maps providing users with information regarding destinations, bicycle facilities, and route options.

<u>Legal Status</u>

A number of the designs discussed above, including cycle tracks, buffered bike lanes next to on-street parking, bike boxes, and colored treatments of travel lanes with sharrows, have not yet been fully approved by the Federal MUTCD or AASHTO and are considered experimental treatments. These devices appear to be promising improvements in bicycle access and safety as they have been widely used in Europe and experimented with in the U.S. Until fully approved, any use of these treatments should follow the appropriate experimental procedures.

BICYCLE PARKING

Secure bicycle parking at likely destinations is an integral part of a bikeway network. Bicycle thefts are common and lack of secure parking is often cited as a reason people hesitate to ride a bicycle. The same consideration should be given to bicyclists as to motorists, who expect convenient and secure parking at all destinations. Bicycle parking should be located in well-lit, secure locations close to the main entrance of a building, no further from the entrance than the closest automobile parking space. Bike parking should not interfere with pedestrian movement.

Bike racks along sidewalks should support the bicycle well, and make it easy to lock a U-shaped lock to the frame of the bike and the rack. The two samples below show an "inverted – U" rack and an art design rack: both meet these criteria. Refer to Chapter 22 of the City of Norman Zoning Ordinance for more information.

Inverted-U Bike Rack
(Credit: David Riesland)

Bicycle Racks Can Double as
Public Art: Norman, OK
(Credit: Donna Riesland)

Maintenance

Maintenance is a critical part of safe and comfortable bicycle access. Two areas that are of particular importance to bicyclists are pavement quality and drainage grates. Rough surfaces, potholes, and imperfections, such as joints, can cause a rider to lose control and fall. Care must be taken to ensure that drainage grates are bicycle-safe; otherwise a bicycle wheel may fall into the slots of the grate, causing the cyclist to fall. The grate and inlet box must be flush with the adjacent surface. Inlets should be raised after a pavement overlay to the new surface. If this is not possible or practical, the new pavement should taper into drainage inlets so the inlet edge is not abrupt.

The most effective way to avoid drainage-grate problems is to eliminate them entirely with the use of inlets in the curb face. This may require more grates to handle bypass flow, but is the most bicycle-friendly design.

IMPLEMENTATION

Implementation of a bikeway network often requires an implementation plan. The City's Comprehensive Transportation Plan provides information relative to the bicycle network and how to incorporate bicycle facilities with new and existing roadway facilities. Some bikeways, such as paths, bicycle boulevards, and other innovative techniques described in this guide, will require a capital improvement project process, including identifying funding, a public and environmental review process, and plan preparation. Other bikeway improvements often are implemented as part of planned construction, such as resurfacing, reconstruction, or utility work.

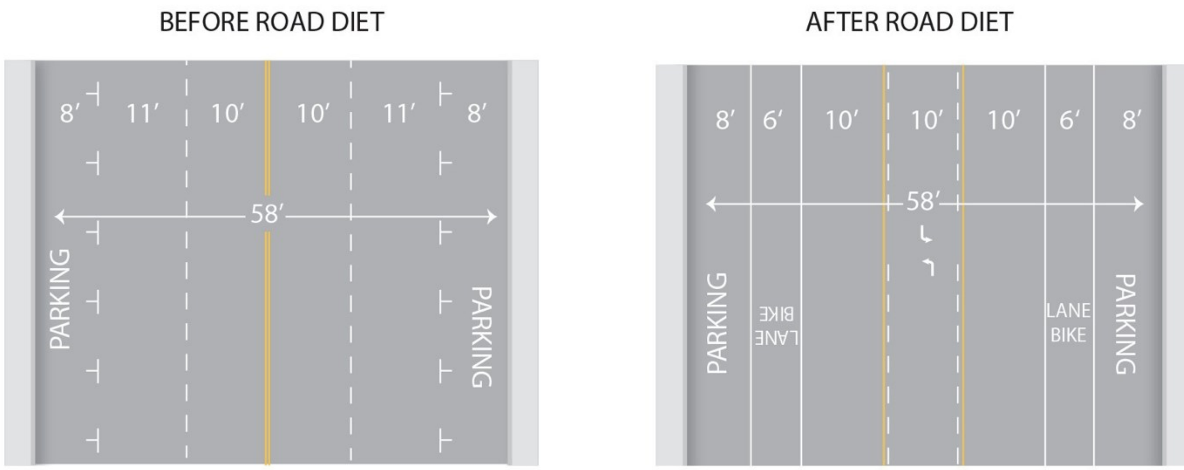
The majority of bikeway facilities are provided on streets in the form of shared roadways or bicycle lanes. Shared roadways usually require virtually no change to existing roadways, except for some directional signs, occasional markings, and minor changes in traffic control devices; removing unnecessary centerline stripes is a strategy that can be implemented after resurfacing projects. Striped bike lanes are implemented on existing roads through use of the strategies below.

RESURFACING

The cost of striping bicycle lanes is negligible when incorporated with resurfacing, as this avoids the high cost of stripe removal; the fresh pavement provides a blank slate. Jurisdictions will need to anticipate opportunities and synchronize restriping plans with repaving and reconstruction plans. If new pavement is not anticipated in the near future, grinding out the old lane lines can still provide bike lanes.

There are three basic techniques for finding room for bike lanes:

- **Lane narrowing**. Where all existing or planned travel lanes must be retained, travel lanes may be narrowed to provide space for bike lanes where applicable.
- **Road diets**. Reducing the number of travel lanes provides space for bicycle lanes. Many streets have more space for vehicular traffic than necessary. Some streets may require a traffic and/or environmental analysis to determine whether additional needs or impacts may be anticipated. The traditional road diet changes a four-lane undivided street to two travel lanes, a continuous left-turn lane (or median), and bike lanes. In other cases, a four-lane street can be reduced to a two-lane street without a center-turn lane if there are few left turns movements. One-way couplets are good lane-reduction candidates if they have more travel lanes in one direction than necessary for the traffic volumes. For example, a four-lane one-way street can be reduced to three lanes and a bike lane. Since only one bike lane is needed on a one-way street, removing a travel lane can free enough room for other features, such as on-street parking or wider sidewalks. Both legs of a couplet must be treated equally, so there is a bike lane in each direction.



Fitting in bicycle lanes with road diets (Credit: Michele Weisbart)

- **Parking Removal.** On-street parking is vital on certain streets (such as residential or traditional central business districts with little or no off-street parking), but other streets have allowable parking without a significant visible demand. In these cases, parking prohibition can be used to provide bike lanes with minimal public inconvenience.

Utility Work

Utility work often requires reconstructing the street surface to complete restoration work. This provides opportunities to implement bike lanes and more complex bikeways such as bike boulevards, cycle tracks, or paths. It is necessary to provide plans for proper implementation and design of bikeway facilities prior to the utility work. It is equally necessary to ensure that existing bikeways are replaced where they exist prior to utility construction.

Redevelopment

When streets are slated for reconstruction in conjunction with redevelopment, opportunities exist to integrate bicycle lanes or other facilities into the redevelopment plans.

Paved Shoulders

Adding paved shoulders to existing roads can be quite expensive if done as stand-alone, capital improvement projects, especially if ditch lines have to be moved, or if open drains are changed to enclosed drains. However, paved shoulders can be added at little extra cost if they are incorporated into projects that already disturb the area beyond the pavement, such as laying utility lines or drainage work.

ADDITIONAL RESOURCES

- National Association of City Transportation Officials*, Urban Bikeway Design Guide*, 2011
- Caltrans, *Complete Intersections: A Guide to Restructuring Intersections and Interchanges for Bicyclists and Pedestrians*, 2010
- AASHTO *Guide for the Development of Bicycle Facilities*

8. TRANSIT ACCOMMODATIONS

INTRODUCTION

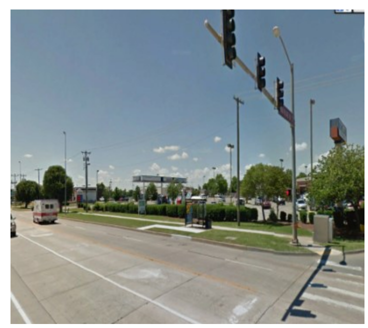
Public transit serves a vital transportation function for many people; it is their access to jobs, school, shopping, recreation, visitation, worship, and other daily functions. Except for subways and rail lines on exclusive rights-of-way, most transit uses streets. For transit to provide optimal service, streets must accommodate transit vehicles as well as access to stops. Transit connects passengers to destinations and is an integral component of shaping future growth into a more sustainable form. Transit design should also support placemaking.

Bus Stops Should be Designed for Passengers (Credit: David Riesland)

This chapter provides design guidance for both transit stops and transit operating in the streets, including bus stop layout and placement and the use of bus bulbs and transit lanes. The chapter ends with a discussion of ways to accommodate light rail, street cars, and Bus Rapid Transit (BRT).

ESSENTIAL PRINCIPLES OF DESIGNING STREETS FOR TRANSIT

Public transit should be planned and designed as part of the street system. It should interface seamlessly with other modes, recognizing that successful transit depends on customers getting to the service via walking, bicycling, car, taxi, or paratransit. Transit should be planned following these principles:



Bus Stops are Centers of Activity (Credit: David Riesland)

Bus Stop Amenities (Credit: David Riesland)

- Transit has a high priority on city streets. On some streets, transit vehicles should have higher priority than private vehicles.
- The busiest transit lines should have designated bus lanes.
- Where ridership justifies, some streets, called transit malls, may permit only buses or trains in the travelled way. These often also allow bicycles.
- Technology should be applied to increase average speeds of transit vehicles where appropriate.
- Transit stops should be easily accessible, with safe and convenient crossing opportunities.
- Transit stops should be active and attractive public spaces that attract people on a regular basis, at various times of day, and all days of the week.
- Transit stops function as community destinations. The largest stops and stations should be designed to facilitate programming for a range of community activities and events.

- Transit stops should include amenities for passengers waiting to board.
- Transit stops should provide space for a variety of amenities in commercial areas, to serve residents, shoppers, and commuters alike.
- Transit stops should be attractive and visible from a distance.
- Transit stop placement and design influences accessibility to transit and network operations, and influences travel behavior/mode choice.
- Zoning codes, local land use ordinances, and design guidelines around transit stations should encourage walking and a mix of land uses (see Chapter 12, "Designing Land Use along Living Streets").
- Streets that connect neighborhoods to transit facilities should be especially attractive, comfortable, and safe and inviting for pedestrians and bicyclists.

ACCESS TO TRANSIT

Transit depends primarily on walking to function well; most transit users walk to and from transit stops. Sidewalks on streets served by transit and on the streets that lead to transit corridors provide basic access. Bicycle-friendly streets do the same for those who access transit by bicycle.

Every transit trip also requires a safe and convenient street crossing at the transit stop; a disproportionally high number of pedestrian crossing crashes occur at transit stops. Every transit stop should be evaluated for its crossing opportunities. If the crossing is deemed unsafe, mitigation can occur in two ways: a crossing should be provided at the existing stop, or the stop can be moved to a location with a safer crossing. For street crossing measures, see Chapter 6, "Pedestrian Crossings." Simply stated, there should not be transit stops without means to safely and conveniently cross the street.

Simply moving a stop is not always a service to transit users who may have to walk further to access their stop. Convenient access by passengers must remain at the forefront of all transit stop planning: eliminating stops because they are perceived as unsafe will not be satisfactory to riders who cannot walk very far. However, eliminating or consolidating stops can be beneficial to transit operations and users by reducing the number of times a bus, streetcar, or light rail train has to stop. The trade-offs are added walking time for users but reduced transit operator delay, resulting in a shorter journey overall. For example, this might mean a two to three minute longer walk for some passengers but an eight to 10 minute shorter bus ride for all.

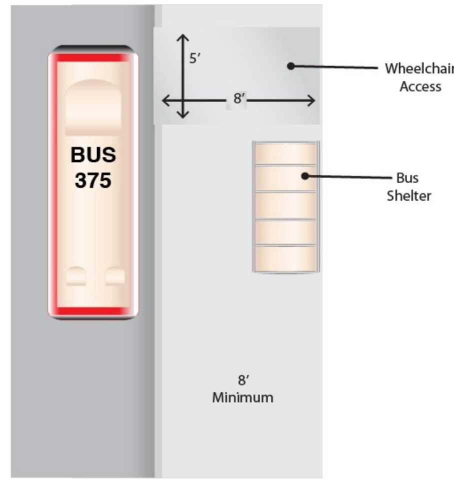
BUS STOPS

The following sections provide guidance for designing bus stops.

LAYOUT

A well placed and configured transit stop offers the following characteristics:

- Clearly defines the stop as a special place
- Provides a visual cue on where to wait for a transit vehicle
- Does not block the path of travel on the adjacent sidewalk
- Allows for ease of access between the sidewalk, the transit stop, and the transit vehicle



ADA compliant bus stop
(Credit: Michele Weisbart)

Layout guidelines include the following:

- Consolidate streetscape elements to create a clear waiting space and minimize obstructions between the sidewalk, waiting area, and boarding area
- Consider the use of special paving treatments or curb extensions (where there is on-street parking) to distinguish transit stops from the adjacent sidewalks
- Integrate transit stops with adjacent activity centers whenever possible to create active and safe places
- Avoid locating bus stops adjacent to driveways, curb cuts, and land uses that generate a large number of automobile trips (gas stations, drive-thru restaurants, etc.)

Transit stops are required by the Americans with Disabilities Act (ADA) to be accessible. Specifically, ADA requires a clear loading area (minimum 5 feet by 8 feet) perpendicular to the curb with a maximum 2 percent cross-slope to allow a transit vehicle to extend its lift to allow people with disabilities to board. The loading area should be located where the transit vehicle has its lift and be accessible directly from a transit shelter. The stop must also provide 30 by 40 inches of clear space within a shelter to accommodate wheelchairs. The greater use of low-floor transit vehicles may make this requirement moot; but it will still be necessary to provide enough room so wheelchair users can access all doors.

TRANSIT-SPECIFIC STREETSCAPE ELEMENTS

The essential streetscape elements for transit include signs, shelters, and benches.

Flag signs indicate where people are to wait and board a transit vehicle. The signs should clearly identify the transit operator, route number, and schedule. Maps showing the transit lines servicing that stop, local destinations, and additional transfer transit lines should also be provided. Flag signs should be located towards the front of the stop.

Benches should be provided at transit stops with headways longer than five minutes.

Shelters keep waiting passengers out of the rain and sun and provide increased comfort and security. Shelters vary in size and design; standard shelters are 3 to 7 feet wide and 6 to 16 feet long. They include covered seating and sign panels that can be used for transit information. Shelters should:

- Be provided at transit stops with headways longer than 10 minutes
- Have electrical connections to power lighting and/or real-time transit information, or accommodate solar power

Bus stop shelter
(Credit: David Riesland)

Be set back from the front of the bus stop to allow for the bus to merge into travel lanes when the stop is located at the far side of an intersection or at a mid-block location. This setback is not required when the stop is located at the near side of the intersection or at a bus bulb.

Shelters should be located in a sidewalk's furniture zone so they don't conflict with the pedestrian zone. Shelters may be placed in the sidewalk's frontage zone provided that they do not block building entrances or the pedestrian zone.

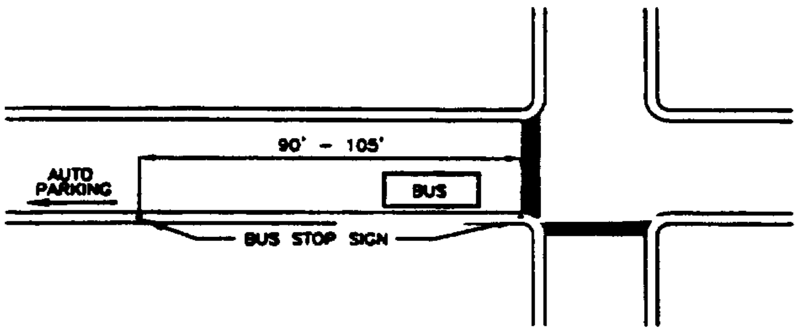
Transit stops should also provide other amenities to make waiting for the next bus comfortable:

Pre-board fare payment system: Guangzhou, China
(Credit: Ryan Snyder)

- Trash/recycling receptacles should be provided and maintained at most stops.
- Depending on headways and the number of passengers boarding and alighting, electronic "next bus" readouts can be used to inform passengers when to expect the next bus.
- Very busy bus stops and transit stations should include space for vendors to sell newspapers, magazines, flowers, and other goods to keep the stops lively.
- Rapid bus lines can include facilities that allow passengers to pay their fare before boarding the bus. Along with wide doors on buses, this allows buses to reduce their travel time by reducing dwell time at stops.

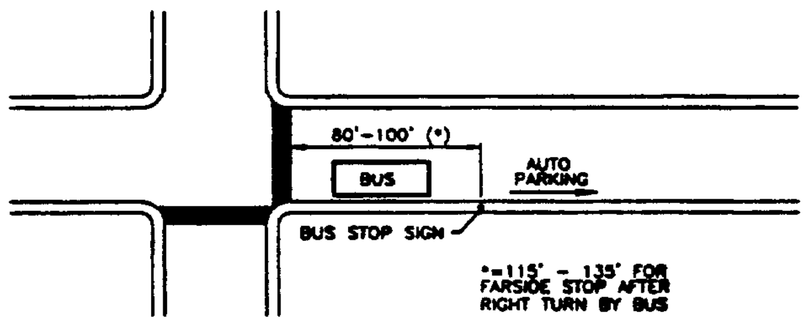
BUS STOP PLACEMENT

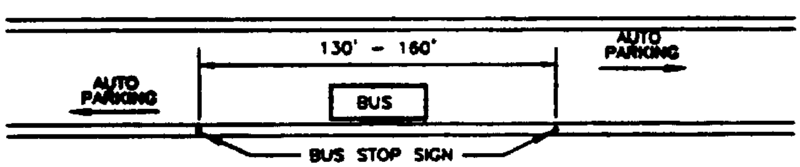
A bus stop's optimal placement depends on the operational characteristics of the roadway and transit system. The placement of bus stops at the far side of signalized intersections is generally preferred to near side or mid-block locations. The location of all bus stops should take into account the existing infrastructure such as sidewalks, marked crosswalks, street lighting, etc. The different stop location types are shown graphically below.



At left: Near Side Bus Stop

At right: Far Side Bus Stop





At left: Mid-Block Bus Stop

However, each location type has its advantages and disadvantages, as shown in Table 8.1.

Table 8.1 Bus Stop Placement Considerations

Location	Advantage	Disadvantage
Near Side	• Minimizes interference when traffic is heavy on the far side of an intersection • Provides an area for a bus to pull away from the curb and merge with traffic • Minimizes the number of stops for buses • Allows passengers to board and alight while the bus is stopped at a red light • Allows passengers to board and alight without crossing the street if their destination is on the same side of the street. This is most important where one side of the street has an important destination, such as a school, shopping center, or employment center that generates more passenger demand than the far side.	• Increases conflicts with right-turning vehicles • Stopped buses may obscure curb-side traffic control devices and crossing pedestrians • Obscures sight distances for vehicles crossing the intersection that are stopped to the right of the buses • Decreases roadway capacity during peak periods due to buses queuing in through lanes near bus stops • Decreases sight distance of on-coming traffic for pedestrians • Can delay buses that arrive during the green signal phase and finish boarding during the red phase • Less safe for passengers crossing in front of bus
Far Side	• Minimizes conflicts between right-turning vehicles and buses • Optimal location for traffic signal synchronized corridors • Provides additional right-turn capacity by allowing traffic to use the right lane • Improves sight distance for buses approaching intersections • Requires shorter bus deceleration distances • Signalized intersections create traffic gaps for buses to reenter traffic lanes • Improves pedestrian safety as passengers cross in back of the bus	• Queuing buses may block the intersection during peak periods • Sight distance may be obstructed for vehicles approaching intersections • May increase the number of rear-end accidents if drivers do not expect a bus to stop after crossing an intersection • Stopping both at a signalized intersection and a far-side stop may interfere with bus operations
Mid-Block	• Minimizes sight distance problems for pedestrians and vehicles • Boarding areas experience less congestion and conflicts with pedestrian travel paths • Can be located near a major transit midblock use generator	• Decreases on-street parking supply (unless mitigated with a curb extension) • Requires a mid-block pedestrian crossing • Increases walking distance to intersections • Stopping buses and mid-block pedestrian crossings may disrupt mid-block traffic flow

Source: Federal Transit Administration, BRT Stops, Spacing, Location, and Design, www.fta.dot.gov/research_4361.html

In general, bus stops should be located at the far side of a signalized intersection in order to enhance the effectiveness of traffic signal synchronization or bus signal priority projects. Near-side bus stops are appropriate for stop sign-controlled intersections. Regardless, in all cases priority should be given to the location that best serves the passengers.

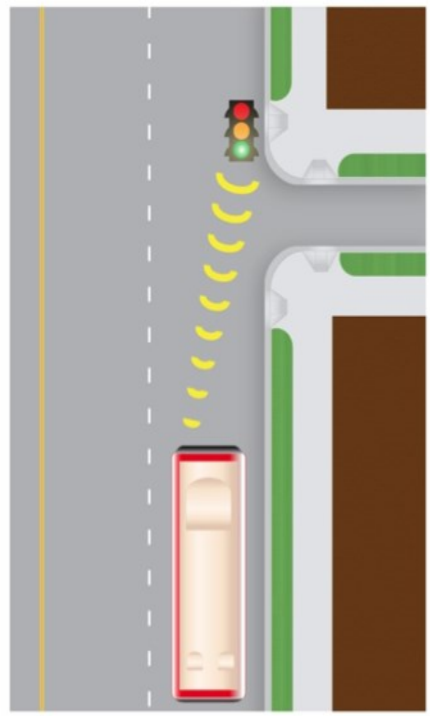
SIGNAL TREATMENT

Signal prioritization is a component of technology-based "intelligent transportation systems" (ITS). These systems are often used by road authorities in conjunction with transit agencies to help improve a roadway system's overall operations in the following ways:

- Reduce traffic signal delays for transit vehicles
- Reduce the need for transit vehicles to stop for traffic at intersections
- Help reduce transit vehicles' travel time
- Help improve transit system reliability and reduce waiting time for people at transit stops

Signal prioritization projects include signal timing or phasing projects and transit signal priority projects.

Signal timing projects optimize the traffic signals along a corridor to make better use of available green time capacity by favoring a peak directional traffic flow. These passive systems give priority to roadways with significant transit use within a district-wide traffic signal timing scheme. Transit signal prioritization can also be achieved by timing a corridor's traffic signals based on a bus's average operating speed instead of an automobile's average speed.



Signal-priority technology can help to reduce delay for buses (Credit: Michele Weisbart)

Transit signal-priority projects alter a traffic signal's phasing as a transit vehicle approaches an intersection. This active system requires the installation of specialized equipment at an intersection's traffic signal controller and on the transit vehicle. It can either give an early green signal or hold a green signal that is already being displayed in order to allow buses that are operating behind schedule to get back on schedule. Signal-priority projects also help improve a transit system's schedule adherence, operating time, and reliability.

Although they may use similar equipment, signal-priority and pre-emption are two different processes. Signal-priority modifies the normal signal operation process to better accommodate transit vehicles, while signal pre-emption interrupts the normal signal to favor transit or emergency vehicles.

The placement of a bus stop at the far side of a signalized intersection increases the effectiveness of transit signal-priority projects. Signal treatments should be used along streets with significant bus service.

BUS BAY

DESCRIPTION

Bus bays can come in several forms, depending on land use, roadway design, traffic flows, and available right-of- ways. Bus bays allow buses to pick up and drop off pas- sengers outside of the travel lane. As a result, this allows traffic to flow unobstructed while the bus is stopped. The primary types of bus bays are:

- Parallel bus bays (also referred to as bus bays, bus turn-outs, or berth)
- Saw tooth bus bays (most often used in off-street bus stopping areas)

USAGE FACTORS

Locations that should be considered for bus bays are:

- Traffic speeds exceeding 40mph
- Average peak-period dwell time exceeds 30 seconds per bus
- Buses that are expected to lay over
- Multiple buses serve the stop at the same time
- History of vehicles colliding into rear of bus

BUS BULBS

Bus bulbs are curb extensions that extend the length of the transit stop on streets with on-street parking. They improve transit performance by eliminating the need for buses to merge into mixed traffic after every stop. They also facilitate passenger boarding by allowing the bus to align directly with the curb; waiting passengers can enter the bus immediately after it has stopped. They improve pedestrian conditions by providing additional space for people to wait for transit and by allowing the placement of bus shelters where they do not conflict with a sidewalk's pedestrian zone. Bus bulbs also reduce the crossing distance of a street for pedestrians if they are located at a crossing. In most situations, buses picking up passengers at bus bulbs block the curbside travel lane; but this is mitigated by the reduced dwell time, as it takes less time for the bus driver to position the bus correctly, and less time for passengers to board.

Bus bulb: Alhambra, CA (Credit: Sky Yim)

Bus bulb: Huntington Park, CA (Credit: Sky Yim)

One major advantage of bus bulbs over pulling over to the curb is that they require less parking removal: typically two on-street parking spots for a bus bulb instead of four for pulling over.

The following conditions should be given priority for the placement of transit bus bulbs:

- Where transit performance is significantly slowed by the transit vehicle's merging into a mixed-flow travel lane
- Roadways served by express or BRT lines
- Stops that serve as major transfer points
- Areas with heavy transit and pedestrian activity and where narrow sidewalks do not allow for the placement of a bus shelter without conflicting with the pedestrian zone

Bus bulbs should not be considered for stops with any of the following:

- A queue-jumping lane provided for buses
- On-street parking prohibited during peak travel periods
- Near-side stops located at intersections with heavy right-turn movements, except along streets with a "transit-first" policy

CHARACTERISTICS

At a minimum, bus bulbs should be long enough to accommodate all doors of a transit vehicle to allow for the boarding and alighting of all passengers, or be long enough to accommodate two or more buses (with a 5-foot clearance between buses and a 10-foot clearance behind a bus) where there is frequent service such as with BRT or other express lines. Bus bulbs located on the far side of a signalized intersection should be long enough to accommodate the complete length of a bus so that the rear of the bus does not intrude into the intersection.

Table 8.2 Standard Transit Vehicle and Transit Bus Bulb Dimensions

Vehicle	Length (feet)	Number of Buses at Stop	Platform Length (feet)	
			Near Side	Far Side
Standard bus	40	1	35	45
		2	55	65
Articulated bus	60	1	80	90
		2	120	130

Federal Transit Administration, August 2004. *Characteristics of Bus Rapid Transit for Decision Making* Project NO: FTA-VA-26-7222-2004.1

URBAN DESIGN

Bus stops and amenities vary in complexity and design from standardized off-the-shelf signs and furniture to specially designed elements. The design of the bus stop elements, location of the bus stop in relation to adjacent land uses or activities, and the quality of the roadway's pedestrian environment contribute to a bus stop's placemaking. Transit operators like a branded look to their stops so they are easily identified, but often there is room for customized designs to fit in with the neighborhood, with at least some of the features and amenities.

Bus Stops Should be Integrated with Their Surroundings: Norman, OK (Credit: David Riesland)

BICYCLE CONNECTIONS

Connecting bicycle facilities to transit stations helps extend the trip length for cyclists and reduces automobile travel. Secure bicycle parking must be provided at or within close proximity to a bus stop, preferably sheltered. At a minimum, the accommodations can be bike racks or lockers. Bike stations and automated bicycle parking can be located at areas with high levels of transit and bicycle use.

Bicycle Facilities at Transit Stations Encourage Intermodal Travel: Norman, OK (Credit: David Riesland)

BUS LANES

Bus-Only Lane: Norman, OK
(Credit: David Riesland)

Bus lanes provide exclusive or semi-exclusive use for transit vehicles to improve the transit system's travel time and operating efficiency by separating transit from congested travel lanes. They can be located in an exclusive right-of-way or share a roadway right-of-way. They can be physically separated from other travel lanes or differentiated by lane markings and signs.

Bus lanes can be located within a roadway median or along a curb-side lane, and are identified by lane markings and signs. They should generally be at least 11 feet wide, but where bicycles share the lane with buses, 13 to 15 feet wide is preferred. When creating bus lanes, cities should consider the following:

- Exclusive transit use may be limited to peak travel periods or shared with high-occupancy vehicles.
- On-street parking may be allowed depending on roadway design, especially with bus lanes located in the center of the street.
- A mixed-flow lane or on-street parking may be displaced; this is preferable to adding a lane to an already wide roadway, which increases the crossing distance for pedestrians and creates other problems discussed in other chapters.
- Within a mixed-flow lane, the roadway can be delineated by striping and signs.
- High-occupancy vehicles and/or bicycles may be permitted to use bus lanes.

Pedestrian access to stations becomes an issue when bus lanes are located in roadway medians.

ACCOMMODATING LIGHT RAIL, STREET CARS, AND BRT

Light-rail in urban street: Salt Lake City
(Credit: Paul Zykofsky)

A growing number of streets have light rail lines, street cars, or BRT. These need to be carefully designed into the street.

The various options for accommodating light rail, street cars, and BRT within streets are as follows:

- Center-running
- Two-way split-side, with one direction of transit flow in each direction
- Two-way single-side, with both directions of transit flow on one side of the street right-of-way
- One-way single-side, with transit running one direction (either with or against the flow of vehicular traffic) and usually operating in a one-way couplet on parallel streets.

Bus Rapid Transit: Bogota, Colombia (Credit: Ryan Snyder)

For each configuration, transit can operate in a reserved guideway or in mixed street traffic. When installing light rail or street cars within streets, the safety of pedestrians and bicyclists needs to be fully provided for. If poorly designed, these transit lines introduce hazards and serve to divide neighborhoods where crossings are highly limited and/or difficult or inconvenient (see Chapter 6, "Pedestrian Crossings" for more guidance). In general, in areas of high pedestrian activity, the speed of the transit service should be compatible with the speed of pedestrians.

The potential for each configuration is influenced by the street type. Some transit configurations will not work effectively in combination with certain street types. The following table outlines the compatibility of each configuration with the four street types.

Table 8.3 Street Types and Transit Configurations

	Center Running		Two-Way Split Side		Two-Way Single Side		One-Way Single Side	
Street Type	Reserved Guideway	In Street	Reserved Guideway	In Street	Reserved Guideway	In Street	Reserved Guideway	In Street
Boulevard	Y	N	N	Y	Y	N	Y*	Y
Multi-way Boulevard	Y	N*	Y	Y	N	N	Y*	Y
Avenue	Y	Y	Y*	Y	Y*	N	Y	Y
Street	N	Y	Y	Y	N*	N	Y	Y

Notes
Y = Recommended street type/transit configuration combination
N = Not recommended/possible street type/transit configuration combination
*Denotes configurations that may be possible under certain circumstances, but are not usually optimal
Source: Integration of Transit into Urban Thoroughfare Design, DRAFT White Paper prepared by the Center for Transit-Oriented Development, updated: November 9, 2007.

9. TRAFFIC CALMING

DEFINITION

While the definition of traffic calming is the combination of mainly physical measures that reduce the negative effects of motor vehicle use, alter driver behavior, and improve conditions for non-motorized street users, the City of Norman experience shows that non-physical measures can also produce similar traffic calming results.

Traffic calmed street (Credit: Dan Burden)

The phrase, "the combination of mainly physical measures," means physical and non-physical measures plus a supportive policy environment such that traffic calming is permitted and encouraged. Non-physical measures promote similar behavior.

"Reduce the negative effects of motor vehicle use" means changing the role and design of streets to accommodate motorists in ways that reduce the negative social and environmental effects on individuals, neighborhoods, districts, retail areas, corridors, downtowns, and society in general (e.g., reduced speeds, reduced sense of intrusion/dominance, reduced energy consumption and pollution, reduced sprawl, and reduced automobile dependence).

"Alter driver behavior" means that the street design helps a driver to self-enforce lower speeds, resulting in less aggressive driving and increased respect for non-motorized users of the street.

"Improve conditions for non-motorized street users" means promoting walking and cycling, changing expectations of all street users to support equitable use of the street, increasing safety and comfort (i.e., the feeling of safety), improving the aesthetics of the street, and supporting the context of the street.

Therefore, the definition of traffic calming is broad enough to apply to a myriad of contexts and situations but specific enough to have independent meaning so that it is not confused with other street design elements and design approaches.

Through design, traffic calming aims to slow the speeds of motorists to the "desired speed" in a context-sensitive manner by working with the stakeholders (i.e., residents, business owners, and agencies). Traffic calming is acceptable on all street types where pedestrians are allowed.

Traffic calming typically connotes a street or group of streets that employ traffic calming measures with a "self-enforcing" quality that encourages motorists to drive at the desired speed. When a group of streets are involved, it is normally referred to as "area-wide calming."

Traffic calming measures can also be designed to treat and manage stormwater.

CATEGORIES

Cross section traffic calming measure: Santa Monica, CA (Credit: Ryan Snyder)

From a policy and design perspective, traffic calming measures fall into two broad categories: those that are appropriate for "framework" streets and those that are appropriate for both framework streets and "non-framework" streets. Framework streets are streets that (i) connect places, neighborhoods, and districts (usually most boulevards and avenues) and/or (ii) serve as emergency vehicle routes. The sorts of traffic calming measures that are appropriate on framework streets include "cross-section measures" because emergency response times are generally unaffected by cross-section changes. Non-framework streets are all the other streets in the street network. The majority of streets in cities are non-framework streets. Non-framework streets provide access to houses, businesses, offices, and parks. The sorts of traffic calming measures that are appropriate for non-framework streets include cross-section measures and "periodic measures." Periodic measures are spaced intermittently, rather than continuously. They are very popular on non-framework streets because they are inexpensive when compared to cross-section measures, which typically require construction along the entire length of the street. Examples of both types of measures and guidance for their use are shown above and below.

Periodic traffic calming measure: Raised crosswalk in Seattle, WA (Credit: Ryan Snyder)

The correct terminology for all traffic calming measures is “measures” not “devices.” “Devices” could imply a degree of portability that may not apply to all traffic calming measures. The City of Norman has historically interchanged the two terms. Regardless, adding street trees and changing the paving material to provide texture or contrast, for example, are measures to alter behavior and perceptions but they are clearly not “devices.” Traffic control “devices” are really a subset of all traffic control “measures”.

Partial closure: Riverside, CA (Credit: Ryan Snyder)

Technically, “route modification measures” are not traffic calming measures. The City of Norman recognizes that these can be useful in some circumstances to improve safety. Examples of route modifications measures include street closures, partial closures, turn prohibitions, diverters, and one-way streets. Route modifications effectively remove connectivity to parts of the network. As these measures are likely to be considered drastic to some, their implementation should be fully embraced by all stakeholders. As such, these measures are not generally applied to new streets. In general, route modification should be used sparingly.

Lastly, signs and pavement markings are often used in conjunction with traffic calming measures, but they are traffic control devices. As such, they are considered non-physical measures.

SAFETY

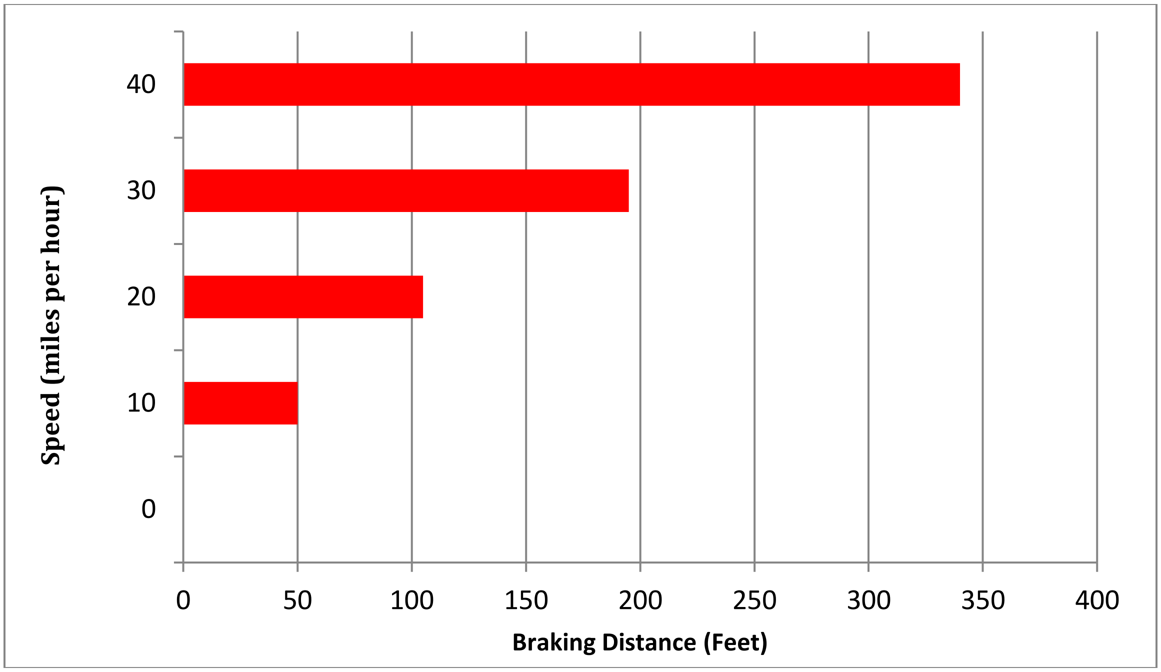
The greatest benefit of traffic calming is increased safety. Compared with conventionally designed streets, traffic calmed streets typically have fewer collisions and even higher reductions in injuries and fatalities. These dramatic safety benefits are mostly the result of slower speeds for motorists that result in greater driver awareness, wider fields of vision, shorter stopping distances, and less kinetic energy during a collision. At lower speeds, chances are higher that a motorist will not kill or severely injure a pedestrian in a collision. Other contributing factors to these improved safety results include a more legible street environment and design advantages for pedestrians and cyclists. Bulb-outs on corners of intersections, for example, allow pedestrians to see past parked cars prior to crossing the street.

Peripheral vision at 15 mph

Peripheral vision at 30 mph

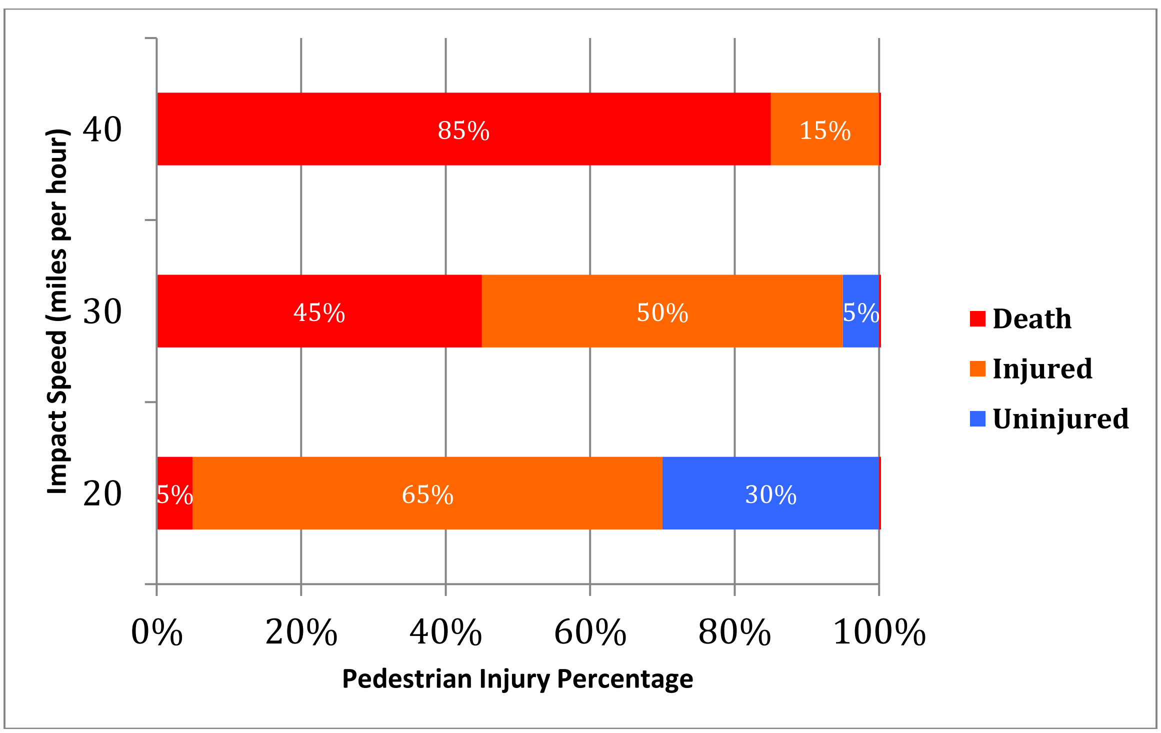
Peripheral vision decreases at higher speeds. (Credit: Michele Weisbart)

The accommodation and comfort of pedestrians increases greatly as speeds lower. For example, acceptable gaps (i.e., the space between moving vehicles) are better judged at slower speeds. Also, at 25 mph or less drivers are much more likely to yield to pedestrians and let them cross the street than at over 25 mph. The chart below shows that it takes a longer distance to brake and come to a full stop as speeds increase.



Source: (Federal Highway Administration Pedestrian Safety Design Course)

The chart below illustrates that crashes become more severe with speed.



Source: *Killing Speed and Saving Lives,* UK Department of Transportation.

EMERGENCY RESPONSE AND NUMBER OF PERIODIC MEASURES

Designing traffic calming to accommodate emergency response. (Credit: Dan Burden)

It is important to have a network of framework streets so that emergency personnel can get to, or reasonably close to, calls without encountering too many periodic measures. In this way, all or most of the length of the responders' trips are on framework streets and, if any periodic measures are encountered, then they are encountered only towards the end of the trip. From an emergency perspective and a public acceptability perspective, it is important to limit the number of periodic measures in a row on non-framework streets. The rule of thumb is, on the routes between two framework streets there should be no more than 8 to 12 periodic measures. City of Norman historical policies have been to install fewer than these numbers. If more than 8 to 12 periodic measures are used in a row, motorists who use the streets will become highly irritated with the measures and will have them removed. This rule of thumb effectively limits the length of single-street traffic calming projects. It also limits the size of the area for area-wide calming (i.e., the maximum limit is 8 to 12 multiplied by the spacing between the measures).

To achieve a desired speed of 25 mph using periodic measures, the spacing between the measures should be about 300 feet. Typically, measures are constructed at the obvious locations (i.e., pedestrian crossings, intersections, and curves) and then subsequent measures are filled in to attain the correct spacing. In this way, a slow and steady speed profile is achieved; there is little opportunity or utility for motorists to speed up between the measures.

EXCEPTIONS

There are two general exceptions to the above recommendations:

- Some local streets should be classified as framework streets due to their long lengths and inability to be effectively calmed with no more than 8 to 12 periodic measures at the correct spacing.
- Periodic measures may be appropriate on framework streets in some situations. Examples include locations with heavy pedestrian generators (e.g., at elementary schools, community centers, entertainment venues, and key intersections along a main street or in a downtown).

DESIGN VEHICLE

In general, all public streets and traffic calming measures should be designed to accommodate a WB-40 design vehicle (i.e., a tractor trailer with a 40-foot wheel base). The WB-40 design vehicle uses more space to turn than fire trucks, school buses, garbage trucks, and most service trucks. Therefore, if the WB-40 fits, all the rest fit. On streets where larger design vehicles are permitted and are expected to use the streets regularly, then the design vehicle should be changed accordingly. On high frequency bus routes where encroachment into opposing lanes would cause excessive delays to the buses, the affected radii should be altered accordingly. While all streets should be designed to accommodate WB-40 vehicles, they should not be the primary design vehicle on non-framework streets. This does not mean that every radius must be large enough to accommodate them as large trucks may use the full width of the street they are turning into. These streets are generally narrow and require slowing to turn at intersections, especially for large vehicles.

NEIGHBORHOOD TRAFFIC MANAGEMENT & CALMING PROGRAM

The City of Norman's *Neighborhood Traffic Management and Calming Program* manual (NTMCP) was developed in December, 2003 and was adopted by the Norman City Council on February 24, 2009. It came about due to the complaints of citizens who looked to the City to address their many concerns about traffic speeding through their neighborhoods thereby making their streets less safe and, consequently, less liveable. City staff researched numerous communities where traffic calming was practiced and what calming measures were utilized. From this effort, the City produced a comprehensive document that established guidelines for the City's neighborhood-driven Traffic Calming Program. The manual identifies both physical and non-physical traffic calming measures, and covers the topics of eligibility, excluded routes, prioritization, impacts, removal of calming measures, etc. Neighborhood collector streets were the targeted streets of the program because of their relatively high traffic volumes and speeds, but the qualifying criteria allows the concept of traffic calming, in one form or another, to be employed on most street classifications. This NTMCP is reproduced in the next several sections.

Introduction

One of the most persistent and emotional complaints that the City of Norman receives is speeding on residential streets. Each year, there are numerous requests received by City council members and other City administration and staff to "do something" on certain streets where residents have concerns about excessive traffic speeds and/or traffic volumes. Proper street design is essential in encouraging lower speeds, minimizing cut-through traffic, and maintaining the integrity of residential neighborhoods. Through the City platting and development process, new subdivisions are now being designed to avoid long straight stretches of streets which encourage higher speeds. It is on the long stretches of existing streets that most of the speeding complaints are being generated. This report presents a ***Neighborhood Traffic Management and Calming Program*** aimed at making existing residential streets safer and more liveable. Historically, issues of speeding and cut-through traffic could only be addressed through educational efforts, beefed-up police enforcement, and the unwarranted use of regulatory signs;

now, however, physical calming devices have been developed for use when education and enforcement endeavors have failed.

Historical Research

Traffic calming is the combination of both policies and implementation measures that help mitigate the negative impacts to residential streets and neighborhoods caused by motor vehicles. Although traffic calming techniques did not begin to be readily implemented in the United States until the 1980's, there are many examples that have existed for many years in other countries. In Europe and Australia, some of these same techniques even preceded the 1970's. Many of the successful techniques used there are into their second and third generations. Their effectiveness has been proven and many appear to be part of the original street design rather than retrofits.

Traffic calming techniques were developed to reduce speeding problems and heavy flow on residential streets. By making some residential streets more "calm," it makes the neighborhood more liveable. Although "liveable" in terms of a neighborhood does not have a precise definition, feeling safe and secure, interacting with neighbors, and experiencing a sense of home and community identification are certainly some of the characteristics. In essence, when citizens call to request a STOP sign to slow traffic on their street, they are requesting the City to make their street more liveable.

Research has shown a common theme among cities with traffic calming or management programs: there is no single measure, such as STOP signs or speed humps, for solving all traffic problems. Each location has its own unique set of problems that must be analyzed to identify solutions. For this reason, the City of Norman, like several other communities, has developed an extensive toolbox of traffic management and calming tools for customizing solutions.

Classification of Streets

City of Norman streets are classified by their function into three major categories: arterial, collector, and local. These categories are defined as follows:

Arterial: These streets provide for through traffic movement over long distances such as across the city with some access to abutting property. These streets are typically the widest and have the highest speed limits of all of the streets within the city. Within the City of Norman, most arterials have a speed limit of 40 mph or higher.

Collector: These streets provide the connection between arterials and local streets. There is often direct access to abutting properties. These streets provide for medium distance trips such as between neighborhoods. They also collect traffic from the local streets and channel it to the arterial system. Within the City of Norman, most collector streets have a speed limit of 25 mph.

Local: These streets provide for direct access to the residences and for short distance or local traffic movements. Within the City of Norman, most local streets have a speed limit of 25 mph.

Since each city street has an intended purpose related to moving traffic and serving the adjacent land use, the NTMCP must ensure that traffic management measures are compatible with those purposes. Because the installation of calming devices can result, directly or indirectly, in drivers shifting to use an adjacent street as their new route, this is appropriate only if that adjacent street is suitably classified and able to accommodate this traffic. Accordingly, while the majority of traffic management measures in the calming toolbox are appropriate for use on local streets and collectors, fewer (if any) are appropriate on arterials.

Definition of Traffic Calming

In its August 1999 report, “Traffic Calming – State of the Practice,” the subcommittee on traffic calming of the Institute of Transportation Engineers (ITE) defines traffic calming as follows:

> *Traffic calming is the combination of mainly physical measures that reduce the negative effects of motor vehicle use, alter driver behavior and improve conditions for non-motorized street users.*

In explaining its definition, the ITE subcommittee distinguishes traffic calming from route modification, traffic control devices, and streetscaping. Traffic calming measures rely on the laws of physics rather than human psychology to slow down traffic. Route modification measures, such as street closures and turn restrictions, do not change driver behavior (i.e. speed), but simply modify driver routing options. Traffic control devices, notably STOP signs and speed limit signs, are regulatory measures that require enforcement. Street trees, street lighting, striping, and other streetscape elements, while complementary to traffic calming, do not directly compel drivers to slow down. By contrast, engineered traffic calming measures are intended to be self-enforcing.

Objectives

The overall objectives for the NTMCP are:

- To implement measures, either physical or psychological, that will reduce speeding and affect driver behavior to improve the liveability and quality of life in residential neighborhoods;
- To preserve and enhance pedestrian and bicycle access to neighborhood destinations;
- To encourage citizen involvement in neighborhood calming and, in the process, provide an opportunity for neighbors to interact and create a positive community atmosphere; and
- To make fair and efficient use of City resources in prioritizing projects to balance the needs of the neighborhood with that of the entire community.

Traffic calming techniques work best when incorporated into a neighborhood traffic management program. Successful programs include good traffic data collection, a thorough planning process, community participation, and local authority support. Because residents are the main initiators of traffic calming requests, they need to be part of the process as much as possible.

Neighborhood Traffic Calming Process

Step 1 – Reporting the problem (Initial Contact)

Upon initial contact made by a resident, property owner, or homeowners association, inquiring about traffic calming in a neighborhood, City staff will mail to the requester an information packet that describes the traffic calming program, application process, and the criteria used to establish eligibility. After reading the information, if residents are still interested in the program, they must write out a formal request and return it to the City. The purpose of this written request is to initiate the NTMCP process and to formally request a traffic study be conducted to see if the neighborhood meets the NTMCP criteria; it is not a petition for traffic calming measures (that comes later in the process). The written request requires a written description of the residents' concerns and requires signatures from residents of at least four (4) different households in the impacted area that share the same traffic concerns.

Step 2 – Traffic Study

Upon receipt of a formal written request by a neighborhood, the City Traffic Control Division will schedule a traffic study in the neighborhood. Traffic studies are usually conducted during the school year unless unique circumstances, as determined by the City Traffic Engineering staff, exist. To be eligible to participate in the NTMCP, certain speed and traffic volume criteria must be met.

Step 3 – Pre-Calming Measures

If the trouble location meets the speed and volume criteria, City staff will first suggest possible solutions that do not involve the use of physical controls or impediments on the street. These include:

- Traffic Signing and Pavement Markers - Traffic Engineering staff will review all of the traffic signing and pavement markers in the area. If necessary, staff will install additional signing and striping.
- Traffic Enforcement Actions - The traffic data study will include raw counts of traffic volumes and vehicle speeds over a 72-hour period and will categorize these numbers into the time of day that they occurred. This data will be forwarded to the Norman Police Department for their increased patrol visibility and more strategic enforcement efforts.
- Radar Speed Trailer Deployment - This is a temporary device that is primarily used to educate motorists regarding the fact that they may be exceeding the posted speed limit.

Step 4 - Follow-up Data Collection

If one or more of the Pre-Calming Measures is implemented, the City Traffic Control Division will wait approximately three to six months and then collect additional speed/volume data. The new data will be analyzed to determine if the Pre-Calming Measure was successful. If the measure was successful in terms of bringing the numbers below the criteria thresholds, then the process will end at this point. If the measure was not successful, i.e. the location continues to exceed speed/volume thresholds, City staff will move on to explore the more self-enforcing types of traffic calming devices.

Step 5 - Presentation of Specific Traffic Calming Plan

If the results of the traffic studies still indicate that the neighborhood meets the NTMCP criteria, a meeting with residents in the neighborhood will be held by City staff. At this meeting, City staff will discuss the NTMCP process, give a brief summary about traffic calming devices previously tried in the City of Norman and in other communities, show the results of the traffic studies, present a Specific Traffic Calming Plan for the neighborhood, and solicit residents' input for modifications to the plan. Although residents not living directly on a potentially "calmed" street would not vote on a support petition for a traffic calming project, they may have an indirect interest and should be invited to this neighborhood meeting where the traffic calming plan is presented and discussed.

Step 6 - Petition Process

After the public meeting, and with original or modified Specific Traffic Calming Plan agreed upon, City staff will prepare a petition to be signed by residents and business owners adjacent to and surrounding the street being "calmed." A map showing the location of the traffic calming measures and the petition boundary area will also be included. This petition must document that at least 60% of all households and businesses within the petition boundary area support the Specific Traffic Calming Plan. All properties within the affected area must be accounted for (either with signature in support of plan, or without signature in opposition to plan) or by written statement by circulator why a specific property was not represented. Only one signature per household is allowed. Petitions must be completed and returned to the City within one (1) year from the date they were provided to the neighborhood coordinator or they will expire.

Petition Eligibility

Residences either fronting or otherwise directly adjacent to the street containing the calming devices will be eligible to sign the support petition for the calming project. Recognizing that every neighborhood is configured differently and that the impact of a calming project is more direct for those residents along the corridor itself, City staff will look for opportunities, such as including residents on intersecting cul-de-sacs, to expand the voting area allowed on the support petition. For a device placed in an intersection, such as a traffic circle, residences within a 300' radius of such device will also be eligible to sign. Signers can be either the property owner or his/her agent. Renters can sign, but with the understanding that the property owner could possibly reverse his/her tenant's vote. City staff will make reasonable effort to find and contact local property owners during the verification process, but will accept the renter's signature if proof of residency via utility record or other official document can be verified. The signature of any official representative of a business, church, school, homeowner's association clubhouse, etc. will be accepted for non-residential petitioners. Only valid petitioners, as described above, will be allowed to register petition support. 60% of eligible petitioners is necessary to support a calming project containing calming devices.

Step 7 - Implementation and Funding

Having verified the signatures on the petition, City staff will finalize traffic calming plans, prepare cost estimates, and enter into an agreement with a contractor to perform the work. Upon completion of work, City crews will install striping and signing. Traffic calming projects are funded primarily from public funding; however, when public funds are not available, private funding is a possibility. Any private funding must be collected on a volunteer only basis and presented to the City of Norman prior to construction.

Step 8 - Follow-up Evaluation

When construction of a traffic calming project is totally finished, the City Traffic Control Division will conduct a final traffic study to evaluate the effectiveness of the calming device(s). Additionally, City staff will send out a Feedback Survey to neighborhood residents as part of the evaluation process.

Step 9 - Landscaping

Landscaping of areas created by traffic calming, if needed, will be the responsibility of the neighborhood involved. City staff will prepare a Landscaping Agreement setting forth requirements and guidelines for the homeowners association, or other neighborhood group, accepting responsibility for the landscaping and its future maintenance. Hook-ups for utility services (e.g. water and power) may be provided in the construction phase of the project to facilitate maintenance efforts, but metering of utilities shall be initiated and paid for by the neighborhood group responsible for landscaping and its maintenance in compliance with City of Norman regulations and permits.

Qualifying Criteria

To qualify for the NTMCP, a neighborhood residential street must meet the following minimum criteria:

- 85^{th} Percentile Speed of vehicles on roadway > 8 mph over posted speed limit and
- Average Daily Traffic (ADT) > 600 vehicles/day (vpd).

If number of reported speed-related accidents in 3-year period > 5 accidents, this can be used as a substitute criterion in lieu of either the speed or volume requirement. It is important to recognize that special circumstances, including lack of sidewalks or proximity to parks or schools, in some neighborhoods may justify lower qualifying thresholds. These neighborhoods may be considered for the more permanent, self-enforcing type devices, but still must meet the following minimum criteria:

- 85^{th} Percentile Speed of vehicles on roadway > 7 mph over posted speed limit and
- Average Daily Traffic (ADT) > 500 vehicles/day (vpd).

NOTE: **85^{th} Percentile Speed** is that speed below which 85% of all traffic units travel. It is an accepted principle that the majority of drivers on a roadway select safe and proper speeds based on roadway and traffic conditions. For determining a speeding problem on a specific roadway, the 85^{th} percentile speed is often used because it is on the high end of a "normal" bell curve distribution. Typically, recorded speeds above the 85^{th} percentile occur much less frequently than the speeds below it because the highest speeds are often erroneous readings or the result of a few drivers who are either unperceptive of roadway conditions or irresponsible. The generally accepted traffic engineering practice is to set speed limits at the nearest increment to the 85^{th} percentile speed unless other considerations such as accidents and real dangers not perceivable by drivers may indicate the need for a lower speed limit. Since speed limits are generally set using the 85th percentile, it is expected that 15% of the vehicles will exceed the speed limit on a regular basis.

Excluded Routes

The use of certain traffic calming devices will be restricted on public transit routes. Devices of the speed hump genre will not be used on these routes.

On routes designated as “emergency routes” by emergency responders such as the Fire Department and ambulance services, only “drive around” type traffic calming devices, such as traffic circles and offset (divided) speed tables, will be allowed. These routes are those on which calming devices would delay emergency responders from meeting their target response times.

Prioritization of Projects

For the purpose of prioritizing projects competing for traffic calming dollars, points are assigned based on the following point system:

No. of mph that the qualifying 85th Percentile Speed is over posted speed limit:

> 8 to 10 mph = 6 points
> 10 to 12 mph = 7 points
> 12 to 14 mph = 8 points
> 14 to 15 mph = 9 points
> 15 mph = 10 points

If no. of mph that the 95th Percentile Speed is over posted speed limit:

> 15 mph = 5 points

Average Daily Traffic (ADT):

> 600 to 900 vehicles per day (vpd) = 3 points
> 900 to 1,100 vpd = 4 points
> 1,100 to 1,500 vpd = 5 points
> 1,500 vpd = 6 points

No. of reported speed-related accidents (last 3-year period):

0 – 1 = 1 point
2 – 3 = 2 points
4 – 5 = 3 points
6 – 10 = 5 points
> 10 = 7 points

Pedestrian generators (only 1 category per project):

School in petition area = 4 points
Hospital in petition area = 3 points
Park or non-home day care center on street = 2 points
Other (shopping, convenience store, church, commercial business) on street = 1 point
No sidewalks on both sides of street = 2 points (max.)

Overwhelming neighborhood petition support:

> 90 % = 1 point

Competing projects are ranked according to their sums of the above assigned points. Projects not funded may be considered for the next funding cycle, but will have to undergo the prioritization process again.

Impacts of Traffic Calming Devices

Overall Effectiveness –
The physical actions of calming devices are almost always successful (to varying degrees) in forcing traffic to behave in an intended fashion. In most cases, these devices can achieve the desired result by utilizing a one-time capital expenditure and very low ongoing maintenance costs.

Effect on Emergency Vehicles Response Times –
Creating bumps, dips, and sharp curves is precisely the objective being sought by many of the calming devices and, of course, these maneuvers can negatively impact emergency vehicles response times. It is believed, however, that these delays are minimal and, in most situations, can be tolerated. Quantitatively, research shows that both vertical and horizontal displacement devices can delay ambulances and fire trucks from 2 to 10 seconds per device. It is important in the engineering of these devices that locations and sizes of these types of devices be carefully considered to mitigate such delays. Where applicable, "test" runs of emergency vehicles will be made before installation of permanent devices.

Loss of Parking –
It is often necessary to prohibit on-street parking in the immediate vicinity of certain traffic calming devices in order to accommodate the realigned vehicle path. In these cases, the adjacent residents should be aware that a loss of on-street parking in front of their residences will occur.

Aesthetic Impacts –
While some traffic calming devices can have favorable aesthetic impacts and enhance neighborhoods when beautifully landscaped, others can be, by their nature, somewhat unsightly. Some devices (e.g. speed humps) most often pose no opportunity for the incorporation of aesthetics and could actually have negative visual impacts. In fact, virtually all traffic calming actions require signs, striping, and reflective devices which may not be construed as aesthetically pleasing to all residents. In the end; however, most residents feel that this is a minor trade-off for the calming benefits they are receiving.

Removal of Traffic Calming Devices

Devices installed for the purpose of calming traffic in residential areas may be removed or significantly modified only when all of the following criteria have been met:

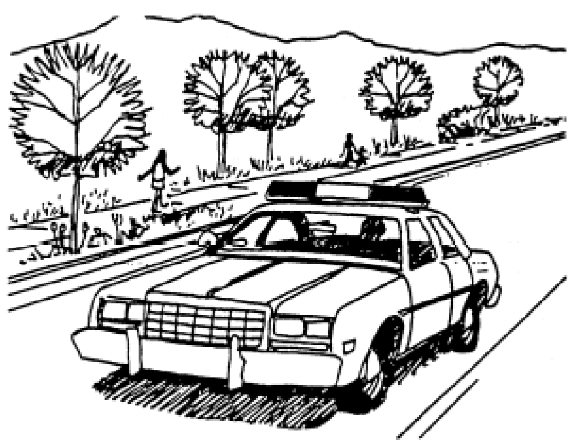
- At least 75% of the residents and/or property owners (one signature per residence) living within 600' of the device in question must agree, by petition, to remove it.
- The calming device must have been in place twelve months or longer before being considered for removal.
- The City Traffic Engineer agrees that its removal will not affect the overall effectiveness of the calming efforts in the neighborhood.
- Funding, either from City or private residential sources, must be available to restore or modify the device.

Description of Traffic Management and Calming Tools

1. ***Police Presence in Neighborhood*** (see Figure 1)
Positioning of a police vehicle on a street as a visible means of enforcement to discourage speeding.

Figure 1

Police Presence in Neighborhood	
Advantages	**Disadvantages**
Shows an enforcement presence	City resources needed to deploy units
Drivers may slow down fearing enforcement	Residents quickly realize that mere presence of police does not result in speeding citations



2. ***Police Enforcement*** (see Figure 2)
At the request of the Traffic Control Division, the Norman Police Department deploys a radar enforcement unit to issue citations in a neighborhood during certain strategic times to discourage speeding.

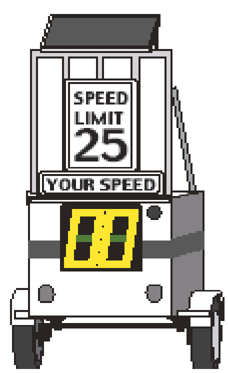
Figure 2

Police Enforcement	
Advantages	**Disadvantages**
Visible enforcement reduces speeding	Benefits are usually short term
Driver awareness about speeding is increased	
Enforcement flexible - any time of day	
Effect can be quick	

3. ***Radar Trailer*** (see Figure 3)
A non-enforcing, temporary measure to increase driver awareness about speeding in which a portable radar speed meter mounted beside a street measures vehicle speeds and displays speed on a board.

Figure 3

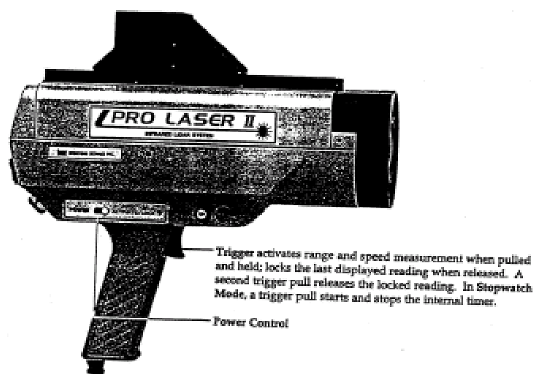
Radar Trailer	
Advantages	**Disadvantages**
An effective public relations and educational tool	Not an enforcement tool
Usually effective where radar trailer is located	Benefits are usually short term



4. ***Neighborhood Radar Monitoring*** (see Figure 4)
A hand-held radar gun is made available, with instructions provided by City staff, to certain trained residents to determine the amount of speeding and who is speeding in the neighborhood.

Figure 4

Neighborhood Radar Monitoring	
Advantages	**Disadvantages**
Effect on speeders limited to sight distance of radar gun	Not an enforcement tool
An effective public relations and educational tool	Requires training
Neighbors feel they are part of the solution	
Possibilty of long-term effects as residents interact with each other	



5. ***Automated Speed Enforcement*** (see Figure 5)
A street installation of a camera and radar determines if a car is exceeding the speed limit, takes a picture of vehicle's license plate, and a ticket is mailed to the vehicle owner.

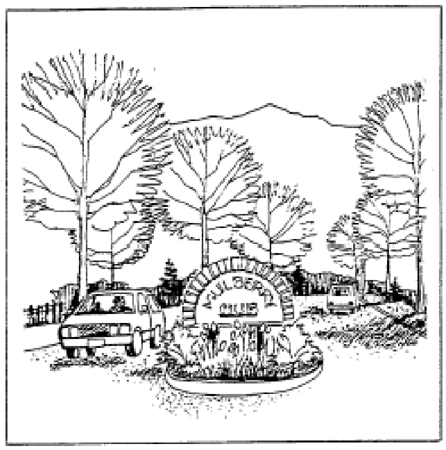
Figure 5

Automated Speed Enforcement	
Advantages	**Disadvantages**
Very effective once public is aware of the automated enforcement	Residents may not like the "Big Brother is watching you" feeling
Cost effective – private companies will install and maintain equipment	May be some legality concerns

6. ***Gateway*** (see Figure 6)
A special entrance feature to a neighborhood that narrows a street at its entrance and includes a sign and landscaping, and sometimes a median and a change of pavement texture.

Figure 6

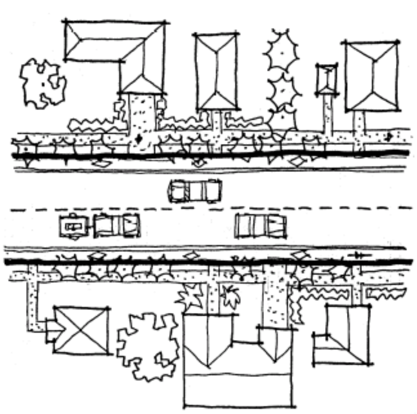
Gateway	
Advantages	**Disadvantages**
Creates an identity to a neighborhood	Increased maintenance costs
Creates added streetscape area for landscaping or monuments	Can impede legitimate truck movements
Discourages truck entry	



7. ***Striping Narrow Lanes*** (see Figure 7)
A measure by which pavement striping is used to create narrow 10 feet wide lanes to give drivers a feel of a narrower street that does not lend itself to high speeds.

Figure 7

Striping Narrow Lanes	
Advantages	**Disadvantages**
Changes can be quickly implemented	Increases regular maintenance
Striping can be easily modified	Residents don't perceive as a speed control tool
Speeds decreased and safety improved by positively guiding drivers	

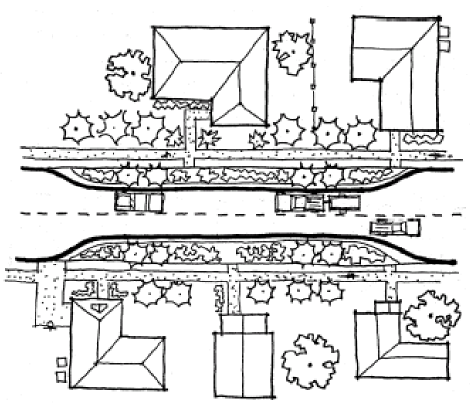


8. ***Choker / Choker Island*** (see Figure 8)

A modification of an existing curb section (or a stand alone landscape strip beside the existing curb) that "chokes" or reduces the street width at an intersection, mid-block, or other street segment to slow down traffic.

Figure 8

Choker / Choker Island	
Advantages	**Disadvantages**
Slight slowing is normal result	Potential object for motorist to run into
Shorter pedestrian crossing distances	May impede bicycle mobility and safety
Creates added streetscape area for landscaping	Can impede legitimate truck movements
Can discourage truck entry	May require drainage modifications

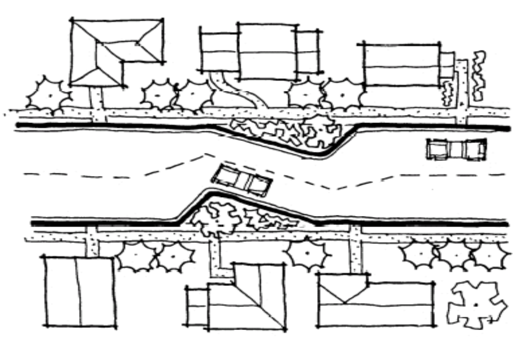


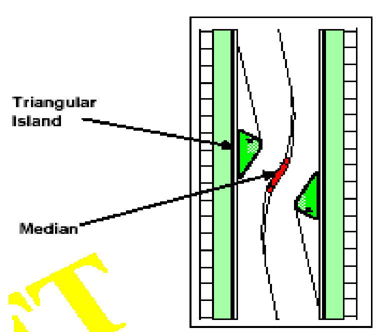
9. ***Angled Slow Points*** (see Figure 9)

A modification of an existing curb section that is used in conjuction with another one, slightly offset, on the opposite side of the street to create a narrow, angled path that makes oncoming traffic want to yield and thus slow down.

Figure 9

Angled Slow Points	
Advantages	**Disadvantages**
Reduces vehicle speeds	Loss of on-street parking
No significant impedance to emergency vehicles	Regular landscaping maintenance needed
Creates added streetscape area for landscaping	Potential for head-on collisions

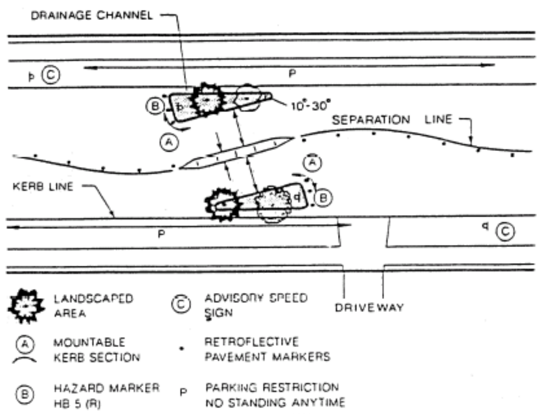




10. ***Divided Angled Slow Points*** (see Figure 10)
A modification of an existing curb section that is used in conjunction with another one, slightly offset, on the opposite side of the street, and with a center island, to create a narrow, angled path that slows down vehicles.

Figure 10

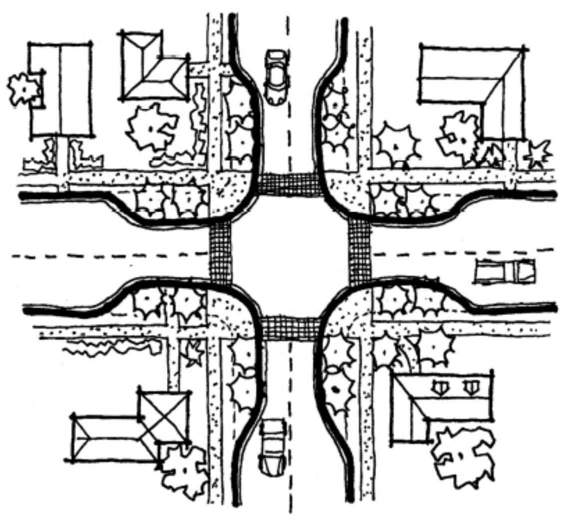
Divided Angled Slow Points	
Advantages	**Disadvantages**
Reduces vehicle speeds	Loss of on-street parking
No significant impedance to emergency vehicles	Regular landscaping maintenance needed



11. ***Neckdowns (Curb Bulb-outs)*** (see Figure 11)
A modification of existing curbs at intersections that reduces street width to slow down traffic and shortens pedestrian crossing distances.

Figure 11

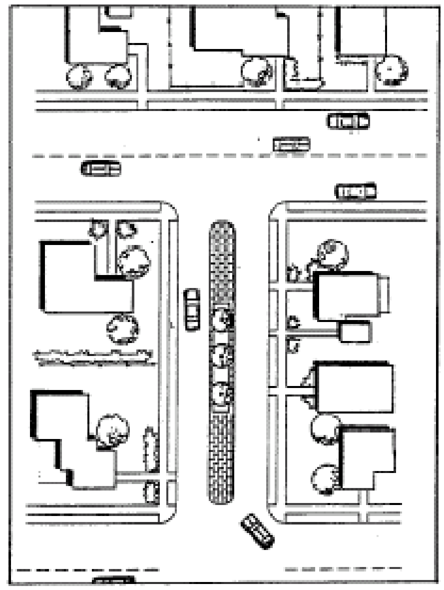
Neckdowns (Curb Bulb-outs)	
Advantages	**Disadvantages**
May be aesthetically pleasing if landscaped	Increased landscaping maintenance
Shorter pedestrian crossing distances	Landscaping could cause sight triangle problems



12. ***Center Island Median*** (see Figure 12)
A curbed stand alone strip, usually landscaped, placed in the middle of a street as an "island" that divides traffic into narrower lanes to slow down the vehicles.

Figure 12

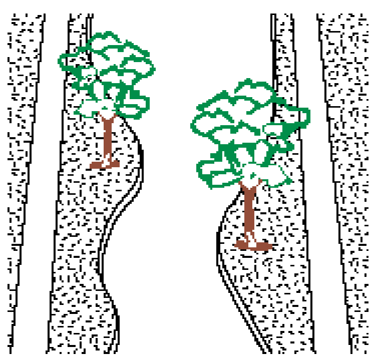
Center Island Median	
Advantages	**Disadvantages**
Reduces opportunities for head-on accidents	Loss of on-street parking
May be aesthetically pleasing if landscaped	Can restrict certain convenient turns

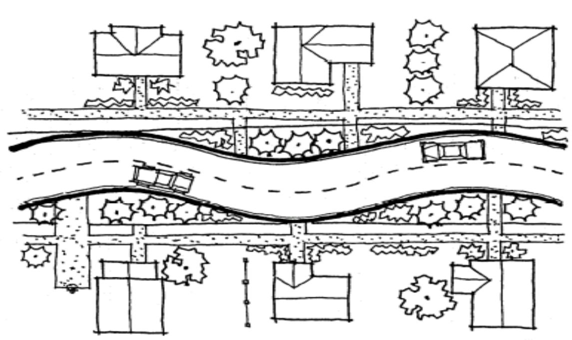


13. ***Chicane (Serpentine)*** (see Figure 13)
Long, realignment modifications of street curbs that alternate from one side of the street to the other, creating S-shaped curves that discourage speeding in order to navigate.

Figure 13

Chicane (Serpentine)	
Advantages	**Disadvantages**
Reduces vehicle speeds	Increased landscaping maintenance
May reduce through traffic volumes	Significant loss of on-street parking
	Emergency vehicles mildly effected

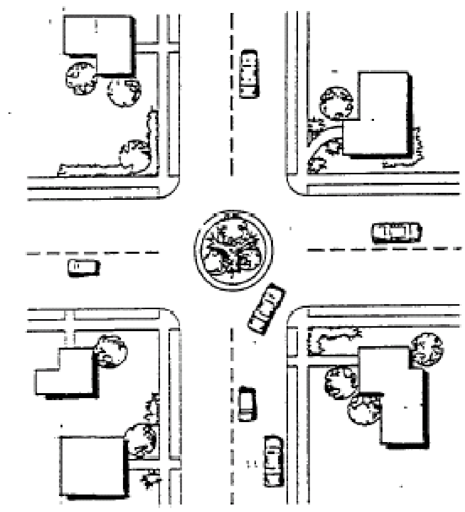


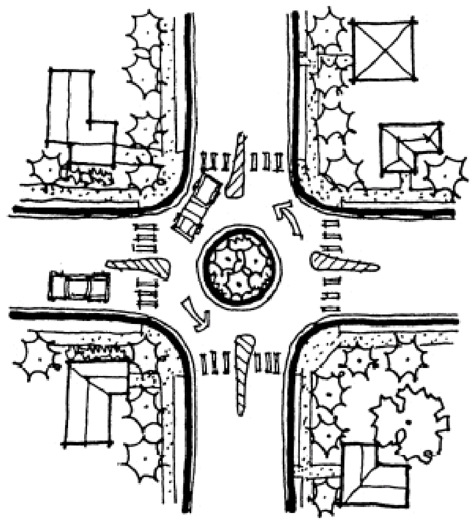


14. ***Traffic Circle*** (see Figure 14)
A circular, raised island, usually landscaped, placed in an intersection to prevent speeding through the intersection by impeding straight through movements and forcing drivers to slow down to go around it.

Figure 14

Traffic Circle	
Advantages	**Disadvantages**
Noticeable reduction of speeds	May increase accidents until drivers used to it
Aesthetically pleasing when landscaped	Pedestrians/bicyclists must adjust change of crossing patterns

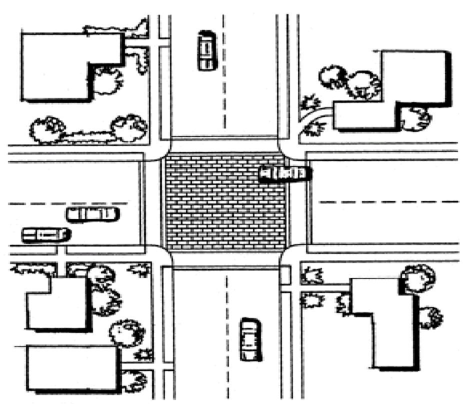




15. ***Raised Crosswalk*** (see Figure 15)
A raised plateau of roadway, usually installed at a street intersection, vertically deflects vehicles causing traffic to slow down, and enhances pedestrian safety.

Figure 15

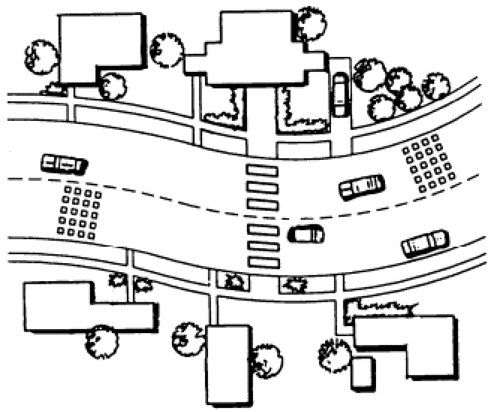
Raised Crosswalk	
Advantages	**Disadvantages**
Effective speed reduction	Affects emergency vehicle response time
Can be aesthetically pleasing	Expensive to construct and maintain
Improves pedestrian safety	Could cause drainage problems



16. ***Rumble Strips*** (see Figure 16)
"Dots" or rough strips glued to pavement causing tire "rumble" that alert drivers to heighten their awareness by slowing down.

Figure 16

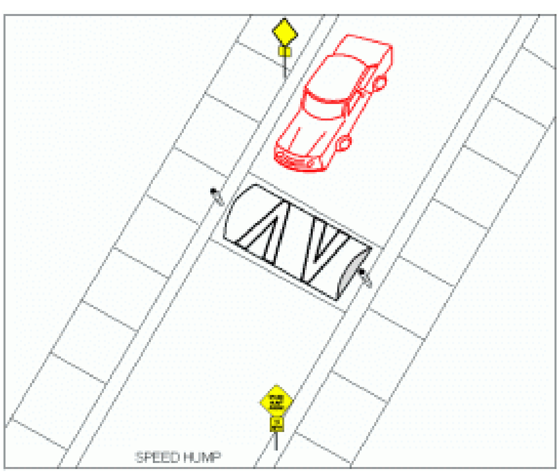
Rumble Strips	
Advantages	**Disadvantages**
Driver's attention alerted to heighten safety	High noise level for adjacent residents
Slight speed reduction	Regular maintenance needed
Low cost installation	

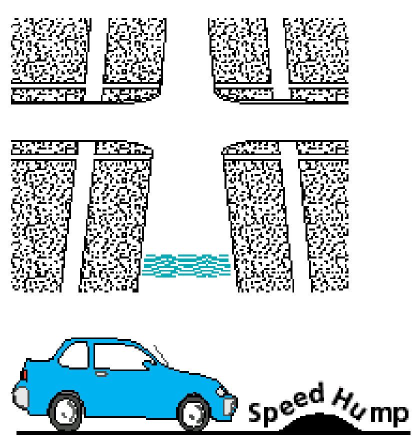


17. ***Speed Humps*** (see Figure 17)
14' long parabolic shaped mounds of paving or pre-fabricated material placed across a roadway that causes a vertical shift in a crossing vehicle resulting in its driver slowing down.

Figure 17

Speed Humps	
Advantages	**Disadvantages**
Effective speed reduction	Affects emergency vehicle response time
Can shift cut-through traffic elsewhere	Jars vehicles
	May be increased noise

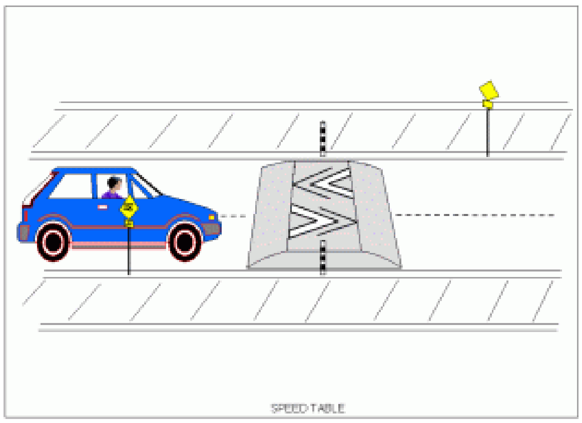


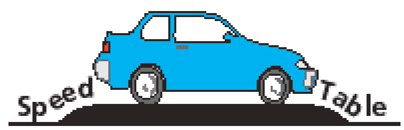


18. ***Speed Tables*** (see Figure 18)
22' long raised mounds of paving or pre-fabricated material, consisting of a flat middle section and parabolic end sections, placed across a roadway that cause a vertical shift in a crossing vehicle resulting in its driver slowing down.

Figure 18

Speed Tables	
Advantages	**Disadvantages**
Effective speed reduction	Affects emergency vehicle response time
Can shift cut-through traffic elsewhere	Jars vehicles
	May be increased noise

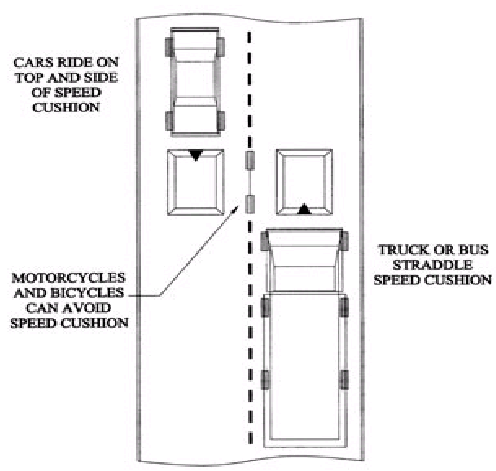




19. ***Speed Cushions*** (see Figure 19)
10' long mounded sections of pre-fabricated material placed across the roadway and spaced approximately 3' apart that cause a vertical shift in a crossing vehicle resulting in its driver slowing down.

Figure 19

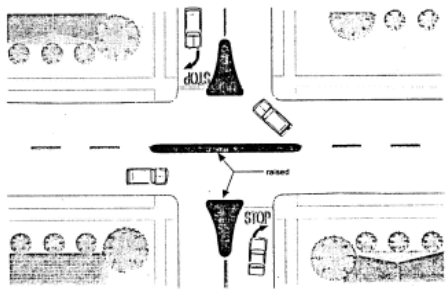
Speed Cushions	
Advantages	**Disadvantages**
Effective speed reduction	Jars vehicles
Can shift cut-through traffic elsewhere	May be increased noise
	Not too aesthetic



20. ***Turn Restriction Barrier*** (see Figure 20)
A physical barrier constructed in the form of a concrete median barrier, closely-spaced row of flexible delineator posts, or, simply delineators glued to the pavement surface that is installed to prevent vehicles from making certain movements in and out of residential streets.

Figure 20

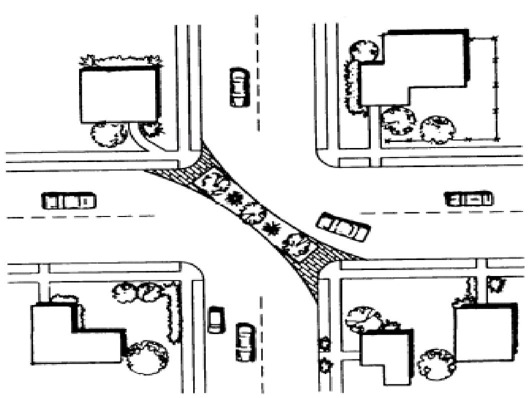
Turn Restriction Barrier	
Advantages	**Disadvantages**
Intersections safer by reducing number of conflicting movements	Little speed reduction
Can reduce traffic volumes and accidents	Gives residents fewer turning options



21. ***Diagonal Diverter*** (see Figure 21)
A physical barrier between diagonally opposite corners of a four-legged intersection, thus creating two unconnected L-shaped intersections for the purpose of reducing speeds and diverting traffic elsewhere.

Figure 21

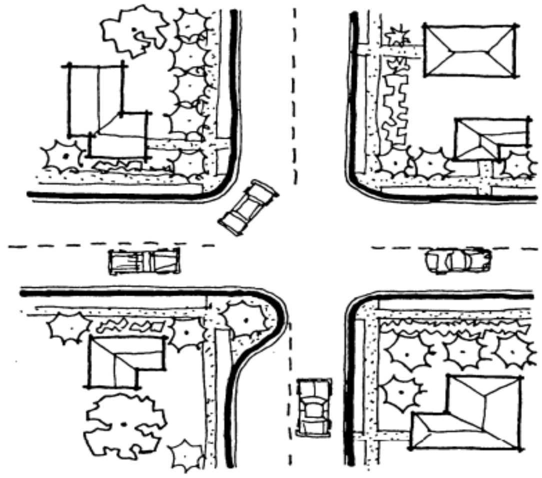
Diagonal Diverter	
Advantages	**Disadvantages**
Reduces speeds and volumes	Can shift volume problems elsewhere
Reduces accidents by reducing number of conflicting movements	Gives residents fewer path options
Has lesser impact on traffic circulation than complete street closure	



22. ***Half Closure (Semi-Diverter)*** (see Figure 22)
A partial street closing effectuated by a significant curb extension or bulb-out at an intersection that physically prevents a straight through movement of traffic across the intersecting street.

Figure 22

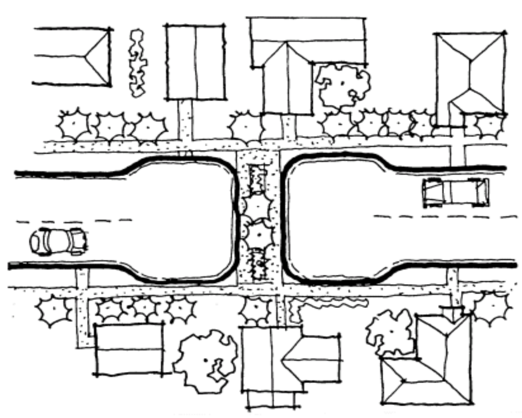
Half Closure (Semi-Diverter)	
Advantages	**Disadvantages**
Reduces cut-through traffic	Increased landscaping maintenance
May reduce traffic speeds	Easy to go around, especially at night



23. ***Mid-Block Road Closure*** (see Figure 23)
Back-to-back cul-de-sacs created by closing a street mid-block using a landscaped area for the purpose of reducing speeds and eliminating through traffic.

Figure 23

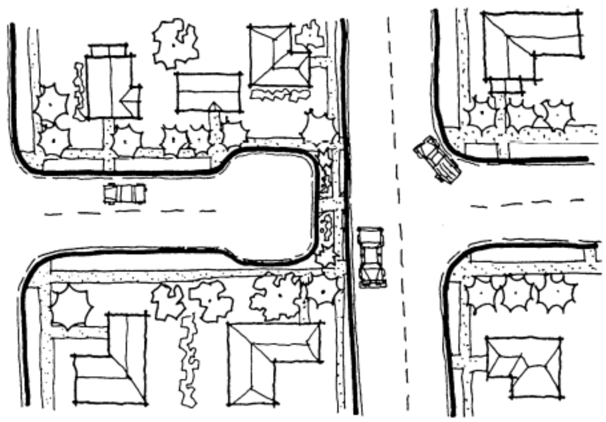
Mid-Block Road Closure	
Advantages	**Disadvantages**
Eliminates cut-through traffic	Can shift volume problems elsewhere
Reduces speeds in vicinity of closure	Increased landscaping maintenance
	Impedes emergency access
	Loss of on-street parking



24. ***Complete Road Closure*** (see Figure 24)
A street closure created by a landscaped area at the end of a block, formed as a cul-de-sac for turn-around purposes, to prevent cut through traffic and to virtually eliminate speeding on closed street.

Figure 24

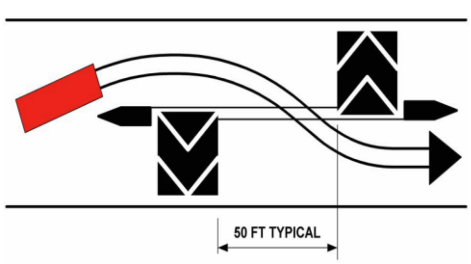
Complete Road Closure	
Advantages	**Disadvantages**
Eliminates speeding traffic	Impedes emergency access
Effective volume reduction	Gives residents fewer path options
Can be aesthetically pleasing when landscaped	Can shift volume problems elsewhere
Safer for children	



25. ***Offset (Divided) Speed Table*** (see Figure 25)
A pair of 22' long raised mounds of paving, separated so that emergency vehicles can go around them, each consisting of a flat middle section with parabolic end sections and placed in opposite direction lanes so as to cause a vertical shift in a crossing vehicle resulting in its driver slowing down.

Figure 25

Offset (Divided) Speed Table	
Advantages	**Disadvantages**
Effective speed reduction	Jars vehicles
Can shift cut-through traffic elsewhere	May be increased noise
Minimal delay for emergency vehicles	
Emergency vehicles can go around tables	



GENERAL POLICY GUIDANCE

TORT LIABILITY

The low speed environment of a traffic calmed street is a difficult place for someone to be "victimized" by a fault in the road design. Consequently, there are fewer tort actions associated with traffic calming. Furthermore, there are generally fewer collisions and injuries and deaths on traffic calmed streets than streets with higher speeds.

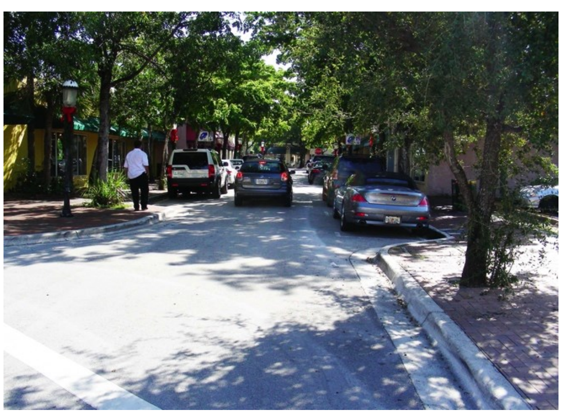
TRAFFIC CALMING CONTEXTS

Early traffic calming efforts in North America started as "programs" and often used a variety of warrants and petitions. However, traffic calming has evolved and there are many reasons to calm traffic; a city doesn't need special permission or warrants to increase the safety and comfort of its streets. In many ways, traffic calming is synonymous with other terms that are used to encourage better street designs. Depending on the term, the emphasis differs, but in all cases traffic calming measures play a role. This is especially the case with new construction.

Context-Sensitive Design (CSD)

CSD implies that the context (i.e., the social, historical, physical, fiscal, political, environmental, and policy contexts) drive the design as opposed to the conventional street hierarchy. Typically, conventional practices use general design guidelines that are indifferent to the context. Frequently, contexts along conventional streets in cities suffer from some combination of negative effects of motor vehicle use, poor driver behavior, and poor conditions for non-motorized street users. Consequently, CSD often employs traffic calming measures to respect the context of the street and neighborhood.

Complete Streets



Complete street (Credit: Ryan Snyder)

The term "complete streets" describes streets that comfortably accommodate all users of the street, with emphasis on pedestrians, cyclists, and transit users, as well as people of all ages and physical abilities. These users are more exposed and affected by the street environments than motor vehicle users. Furthermore, their comfort has been routinely ignored by conventional and automobile-oriented design. Often, traffic calming measures are used to provide comfortable accommodation as opposed to technical accommodation.

By adopting a complete streets policy in Norman, this requires that:

- When major reconstruction occurs, conventional streets be altered into complete streets as the standard operating procedure
- New streets be built as complete streets

Traffic calming measures help to implement these policies.

Smart Transportation

This term describes the transportation aspects of smart growth. The idea is to consider "transportation planning and design" as integral with "land use planning and design," as opposed to separate ideas. Too often, the two are done by separate specialists and for independent reasons. Traffic calming measures play an important role in the design of all scales of streets in cities when integration with the adjacent land use is desired.

Safe Routes to School

Safe Routes to School includes a series of operational and physical changes that help students walk and cycle to and from schools. Traffic calming measures are routinely employed with other strategies and changes to create safer walking and bicycling routes to school by slowing traffic.

Neighborhood Traffic Management

This term describes the combination of:

- Route modifications (e.g., turn prohibitions, closures, partial closures, diverters, and one-way streets) to remove parts of the street network, sever linkages, create mazes, or reduce connectivity
- Unwarranted traffic control devices (e.g., STOP signs and traffic signals) to annoy or delay motorists who cut through neighborhoods
- Traffic calming to reduce poor driver behavior (e.g., speeding and aggressive driving)

Please note that in most situations, diminishing the street network is not considered good practice. Bicycle boulevards are a primary exception to this rule; traffic control devices are desirable on bicycle boulevards to discourage through motor vehicle traffic. Route modification may also be used to reduce cut-through traffic where the traffic will be diverted to a boulevard.

Road Diet

This term describes the narrowing and/or removal of motor vehicle lanes from the cross-section. Both of these changes are traffic calming measures. Typically, the reclaimed space is used for other purposes such as wider sidewalks, landscaped spaces, bicycle lanes, linear parks, and/or on-street parking. Often, road diet projects employ other traffic calming measures as well. Roundabouts often enable implementation of road diets, especially on busier boulevards since they have greater capacity to handle traffic at intersections with fewer lanes than other controls.

Competent Street Design

Curb extensions enhance retail districts: Asheville, North Carolina (Credit: Ryan Snyder)

Competent street design combines all of the above. There is little excuse any more to ignore the context or to build incomplete, dangerous, or poorly integrated streets. The issue for traffic calming is not justification but prioritization. If there are problems with a conventionally designed street, then traffic calming is warranted. This is precisely why the City of Norman's historic traffic calming program is neighborhood driven. The questions are how to calm, when to calm, and how the project compares to other priorities in the city.

Obviously, an early priority for any city is to incorporate traffic calming measures into normal street design practices and procedures to help any new/future streets avoid the deficiencies of conventionally designed streets. The City of Norman's CTP contains a variety of cross-sections applicable to most road types. The harder part is prioritizing the rebuilding or retrofitting of the myriad of already built conventionally design streets. Rebuilding or retrofitting these streets should be prioritized based on the context, in the broadest sense.

Traffic Calming and Stormwater Management

Traffic calming measures, such as bulb-outs, roundabouts, traffic circles, chicanes, lane narrowing, and others, can be used as stormwater management tools. Some of these can create space for bioretention, detention, and pervious pavement.

PLANNING AND DESIGN PROCESSES

Traffic calming should be a normal part of any city's planning and design processes. The processes will vary dramatically depending on the context. For example, implementing a road diet in conjunction with a transit facility along a five-mile arterial would require a different process than reverting one-way streets back to two-way operation in a downtown. Similarly, a neighborhood traffic calming plan would require a different process than designing a people-friendly Main Street. Also, identifying arterial streets that are barriers in a city during comprehensive planning would require a different process than altering streets on a college campus or hospital campus.

The common threads that link all of the processes include the following:

- Gaining a good understanding of the context
- Involving the stakeholders in the definition of the problems to be solved and aspirations to be fulfilled
- Educating the stakeholders such that they can have meaningful involvement
- Aligning the project with a broader vision for the area
- Achieving an informed consent regarding the plan

Traffic calming is best done in conjunction with a development, revitalization, utility, or maintenance project; a downtown, corridor, or transit plan; a new street design; or other project. Then the traffic calming layer is simply incorporated into the larger project's processes.

Table 9.1 illustrates acceptable traffic calming measures on various types of streets.

Table 9.1: Representative Examples of Traffic Calming Measures and their Appropriateness on Various Street Categories

Traffic Calming Classificaton			Framework Street			Framework Street or Non-Framework Street	Non-Framework Street
Posted/Design/Target/Operating Speed (mph)			**35 mph +**	**25 to 30 mph**	**25 mph**	**25 to 30 mph**	**25 mph or below**
Transition Zone from / to higher speed environment							
Entrance Features (architecture / landscaping / monument)							
Cross-Section Measures	Reduction in number of lanes						
	Reduction in width of lanes						
	Long Median / Continuous Median						
	Short Median / Refuge						
	Short Medians on Curves						
	Bulb-outs						
	Curb and Gutter						
	Curbless / Flush Streets						
	Flush Medians						
	Pedestrian Scale Lighting						
	Street Trees						
	Building up the right-of-way						
	Lateral Shifts						
	Bike Lanes / Protected Bike Lanes / Cycle Tracks						
	Textured and/or Colored Paving Materials (parking, lanes, bike lanes, crossings, intersections, general purpose lanes, turn lanes, medians)						
	On Street Parking	Parallel					
		Back-in-angled					
		Front-in-angled					
		Right-angle					
		Valley gutters used in conjunction with parking					
Periodic Measures	Horizontal Measures	Roundabouts					
		Mini-Roundabouts					
		Mini Traffic Circles					
		Impellers (T-intersections)					
		Two-lane chicanes					
		One-lane chicanes (yield condition)					
		Short Medians					
		Medians on curves					
	Narrowings	Yield Streets					
		Pinch Points					
		Bulb-outs					
	Vertical Measures	Raised intersections					
		Raised crosswalks					
		Flat-top Speed Humps (speed tables)					
		Speed Cushions					
		Speed Humps					
Not Traffic Calming Measures	Vertical Changes	Rumble Strips (for warning purposes)	Rural Only				
		Speed Bumps					

Note: Many of these measures can be combined in a variety of ways that are too numerous to list in this chart.

Legend:

Legend:	**Appropriate**
	Appropriate in Specific Circumstances
	Not Appropriate

10. STREETSCAPE ECOSYSTEM

INTRODUCTION

The street is a system: a transportation system, an ecosystem, and a system of social and economic interactions. The idea of a streetscape ecosystem is to mimic nature, building reciprocal relationships within an interconnected system to sustainably enhance the local environment, its resources, the community, and the local economy. To do this, the tools addressed in this chapter should be integrated with the other chapters in this manual.

This chapter is organized based on natural hierarchy. The first section focuses on stormwater management since water is the fundamental ingredient for other components of a streetscape ecosystem. The stormwater management section provides guidance for working with and maximizing beneficial aspects of rain and other sources of water. The second section covers landscaping providing guidance for street designs that include site-appropriate vegetation to maximize environmental and social benefits. Canopy trees provide shade to cool the streets and hardscapes from which the stormwater is harvested. These sheltered micro-climates create ideal locations for people to gather, walk, and bike.

To help cities achieve street designs that create great places fostering community, the end of this chapter address street furnishings, utilities, and lighting. These elements (e.g., sheltered benches, bike racks, and bus shelters) should be placed where people can utilize them. These sections provide guidance as to the placement of utilities and how this coordinates with other streetscape components. The elements described can help attract pedestrians to a street and thereby make the street safer, more dynamic, and more vibrant economically.

PRINCIPLES OF STREETSCAPE ECOSYSTEM DESIGN

Each section in this chapter includes design principles followed by tools to achieve these principles. These streetscape element-specific principles collectively support both the overarching principles of this chapter and the broader goals of this manual. The collective use of the tools in this chapter can provide numerous aesthetic and functional elements in the public rights-of-way, including the entire space between buildings, traveled way, and sidewalks. The following overarching principles should be applied:

- **Coordinate all streetscape elements with traveled way design to maximize ecological, economic, and social benefits.** Individual street projects should not be pursued in a vacuum, but planned as part of a comprehensive strategy. Use street medians, roundabouts, chicanes, curb extensions, and other road configurations as space for people and nature. They provide opportunities for vegetation, stormwater management tools, and other streetscape elements like benches and bike racks.
- **Create a contextualized sense of place.** Using the menu provided in this chapter, select streetscape elements reflecting the context and character of the location as well as support connections to adjacent land uses. The street will function as a shared living room for the community and a welcoming front door for the buildings on the street. Native plantings are used to root the context in surrounding natural landscape while acknowledging local ecosystems and climate.

STORMWATER MANAGEMENT

The street is a constructed waterway, often differing from the natural path of water and disconnected from the hydrologic cycle. Traditional design has focused on speedy removal of water from the street and disposal of it as waste in storm drains and sewers. This section provides tools to reclaim stormwater as a resource and allow it to nourish trees and soils on its path to ground or surface waters. These tools help cities design streets to sustainably work with both dry and wet weather sources of water. During the wet season, rain and its byproduct, stormwater, are the primary sources of stormwater. During the dry season, man-made sources of water include urban runoff from irrigation, car washing, and other residential, commercial, and industrial activities.

Both dry and wet weather stormwater can contain bacteria and other pollutants, and are thereby regulated at the state and local level. Many of the sources of pollutants to waterways come from streets, which contain oils, rubber, metals, and galvanized materials from automobiles.

Above, Parkway incorporating stormwater tools: Bicknell Avenue, Santa Monica, CA (Credit: Neil Shapiro)

While conventional stormwater controls aim to move water off-site and into storm drains as quickly as possible, stormwater management seeks to use and store water on-site for absorption and infiltration in order to clean it naturally and use it as a resource. Therefore, the storm drain system becomes an overflow support system rather than a primary conveyance system. Stormwater management deals with water as an amenity rather than a liability.

Many of the stormwater management options discussed in this section can and should integrate easily with traffic calming measures installed along streets, such as boulevard islands, rotary islands, traffic circles, street ends, chicanes, and curb extensions. These elements can easily incorporate stormwater treatment into the landscape and stormwater tools can be made more cost-effective if integrated early in the design process.

Stormwater management also provides opportunities to leverage other streetscape elements and components of living streets. A strategic plan linking streetscape elements and street design can maximize benefits.

GOALS AND BENEFITS OF STORMWATER MANAGEMENT

The primary goals of stormwater management are as follows:

- Reduce—limit the amount of impervious surfaces that generate additional runoff
- Slow—friction slows flow
- Spread—allow water to be slowed enough to infiltrate
- Sink—keep water on site
- Store—contain water for direct non-potable/potable indoor/outdoor purposes
- Use—to irrigate and replace imported potable water

These goals can be expressed succinctly: slow it, spread it, store it, and sink it, but use it.

The tools provided in this section enable cities to attain regulatory compliance and provide the following ecological, economic, and aesthetic benefits:

- Reduced use of potable water for irrigation
- Reduced surface water pollution
- Support for the urban ecosystem and wildlife habitat
- Enhanced flood control
- Biological filtration and bioremediation
- Groundwater recharge
- Reduced heat island effect
- Education through best management practices (BMP) visibility
- Aeration of root zone
- Potential reductions in stormwater infrastructure and treatment cost
- Improved aesthetics and public space within neighborhoods

LOW IMPACT DEVELOPMENT PRINCIPLES OF STORMWATER MANAGEMENT

- **Use the conventional storm drain system as the overflow approach, not the primary system to manage stormwater**. Wherever possible, natural drainages should be the primary overflow.
- **Harvest, use, and/or store stormwater as close to its source as possible.** Wet weather rainfall and its byproduct, stormwater, can offset or eliminate imported potable irrigation water needs when harvested and used on-site. Harvesting and storing stormwater transforms a flooding liability into an on-site irrigation resource. This ensures natural waterways and their plant communities have local sources of water, thereby reducing the need for imported water. Harvesting and storing rainwater also reduces the need for costly drainage conveyance infrastructure for stormwater management.
- **Use on-site non-potable water sources for irrigation before any imported water source.** In dry weather, irrigation overspray can be reduced by enforcing existing laws/ordinances banning these practices. This leads to more efficient water use, reducing costly imported potable water consumption.
- **Select tools that mimic natural processes.** Minimize the cost of the installation and maintenance by using gravity flow rather than pumped flow, living filtration over synthetic/mechanical filtration, and living surface infiltration instead of piped drainage. Priority should also be given to pervious versus impervious surfaces. The primary purpose is to harvest and utilize rain as part of a healthy vegetated watershed. For example, vegetation can reduce runoff water volume and pollutant load, provide summer shade and cooling, and enhance wildlife habitat and sense of place with native vegetation rooted to the local ecosystem.
- **Maximize stormwater management by integrating it into the myriad design elements in the public right-of-way.** The water system is part of a larger, interconnected system. Maximize the benefits of stormwater strategies. For example, traffic calming and road diets can double as stormwater harvesting strategies. In addition, use vegetation to make streets better places and use stormwater management as an integral element of the urban forest.
- **Show the water flow.** The benefits of stormwater management are ecological, economic, and social. Make the functions described in this section visible for street users to see, understand, appreciate, and replicate. Public right-of-way stormwater installations can inspire private property installations and serve as model installations for neighborhoods. Visible water flow systems are also easier to maintain. Blockages are easier to notice and easier to access for regular maintenance.

DEFINITIONS

The terms below describe the elements and techniques of sustainable stormwater management.

Best Management Practice (BMP)—Operating methods and/or structural devices used to reduce stormwater volume, peak flows, and/or pollutant concentrations of stormwater runoff through one or more of the following processes: evapotranspiration, infiltration, detention, filtration, and biological and chemical treatment.

Bioretention—A soil and plant-based retention practice that captures and biologically degrades pollutants as water infiltrates through sub-surface layers containing microbes that treat pollutants. Treated runoff is then slowly infiltrated and recharges the groundwater. These biological processes operate in all infiltration-based strategies, including various retention systems.

Conveyance—This is the process of water moving from one place to another.

Daylight—This involves bringing stormwater or stormwater flow to the surface, exposed to open air and visible to the public.

Design Storm—Storms, whose magnitude, rate, and intensity do not exceed the design load for a storm drainage system or flood protection project, are considered design storms.

Detention—This is the process of collecting stormwater runoff at one rate and then releasing it at a controlled rate. The difference is held in temporary storage.

Dry weather runoff—Human activity-related sources of water, such as irrigation overspray, car wash runoff, leaking plumbing, fire hydrant and well flushing, and runoff from mechanical processes such as air conditioning are examples.

Filtration—A treatment process that allows for removal of solid (particulate) matter from water by means of porous media such as sand, soil, vegetation, or a man-made filter. Filtration is used to remove contaminants.

Hardscape—These are impermeable surfaces, such as concrete or stone, used in the landscape environment along sidewalks or in other areas used as public space.

Infiltration—This is the process by which water penetrates into soil from the ground surface.

Permeability/Impermeability—This is the quality of a soil or material that enables water or air to move through it, and thereby determines its suitability for infiltration-based stormwater strategies.

Retention—This is the reduction in total runoff that results when stormwater is diverted and allowed to infiltrate into the ground through existing or engineered soil systems.

Runnel—This narrow, shallow drainage channel is designed to carry small amounts of runoff.

Runoff—This is water from rainfall that flows over the land surface that is not absorbed into the ground.

Sedimentation—This is the deposition and/or settling of particles suspended in water as a result of the slowing of the water.

Softscape—These are the natural, permeable, landscape surfaces such as vegetation, mulch, and loose rock.

Stormwater—This is rainwater that flows and collects in the street

TOOLS FOR STORMWATER MANAGEMENT

There are many tools and best management practices (BMPs) for managing stormwater sustainably. Most popular are devices and practices that encourage water percolation on-site to the maximum degree practicable (given soil conditions, pollutant levels, etc.). The most important devices and practices are bioretention BMPs consisting of swales, planters, and vegetated buffer strips, as well as detention BMPs consisting of rain gardens, infiltration trenches, and dry wells. While permeable paving also slows and retains stormwater, it is listed separately because its primary function is to serve as a surfacing material that reduces runoff. Additional tools include delivery and conveyance tools and inlet protections.

The City of Norman has adopted the City of Wichita/Sedgwick County Stormwater Manual. This manual must be utilized as a guide in the selection and design of low impact development stormwater best management practices. The selection of these best management practices must be discussed with the City of Norman Department of Public Works. Considerations of the costs for installation, operation and maintenance must be made in the selection.

In addition, the stormwater management tools mentioned in this manual are highly customizable and can be integrated into a variety of different types of spaces in any of the street types. They can be implemented alone or in concert with one another to achieve cumulative benefits. Opportunity sites include medians, corner and midblock curb extensions, roadway and park edges, front building edges, and surrounding street trees. Selecting the appropriate BMP is very dependent on street type and site conditions. High traffic commercial streets have different parameters than smaller residential streets.
The following sections describe techniques to site and construct systems to integrate stormwater management tools into both new and existing streets. Table 10.1 below describes typical applicability of specific stormwater tools to individual street types.

Table 11.1 Best Fit for Streetwater Tools by Street Context

		BIORETENTION			DETENTION		PAVING	DELIVERY/ CONVEYANCE	INLET PROTECTIONS		
	STREET CONTEXT	**Swales**	**Planters**	**Vegetated Buffer Strips**	**Rain Gardens**	**Infiltration Trenches and Dry Wells**	**Permeable Paving**	**Channels and Runnels**	**Screens**	**Inlet Inserts**	**Pipe Filters**
Commercial	Downtown		o			o	o	o	o	o	o
	Throughway		o	o		o	o	o	o	o	o
	Neighborhood		o	o	o	o	o	o	o	o	o
Residential	Downtown	o	o		o	o	o	o	o	o	o
	Throughway	o	o		o	o	o	o	o	o	o
	Neighborhood	o	o		o	o	o	o	o	o	o
Industrial And Mixed-Use	Industrial	o	o		o	o	o	o	o	o	o
	Mixed-Use		o	o		o	o	o	o	o	o
Special	Sidewalk Furniture Zone	o	o		o	o	o	o	o	o	o
	Park Edge	o	o		o	o	o	o	o	o	o
	Boulevard	o	o		o	o	o	o	o	o	o
	Ceremonial (Civic)						o	o	o	o	o
Small	Alley		o			o	o	o	o	o	o
	Shared Public Way		o			o	o	o	o	o	o
	Walk Street		o	o		o	o	o	o	o	o

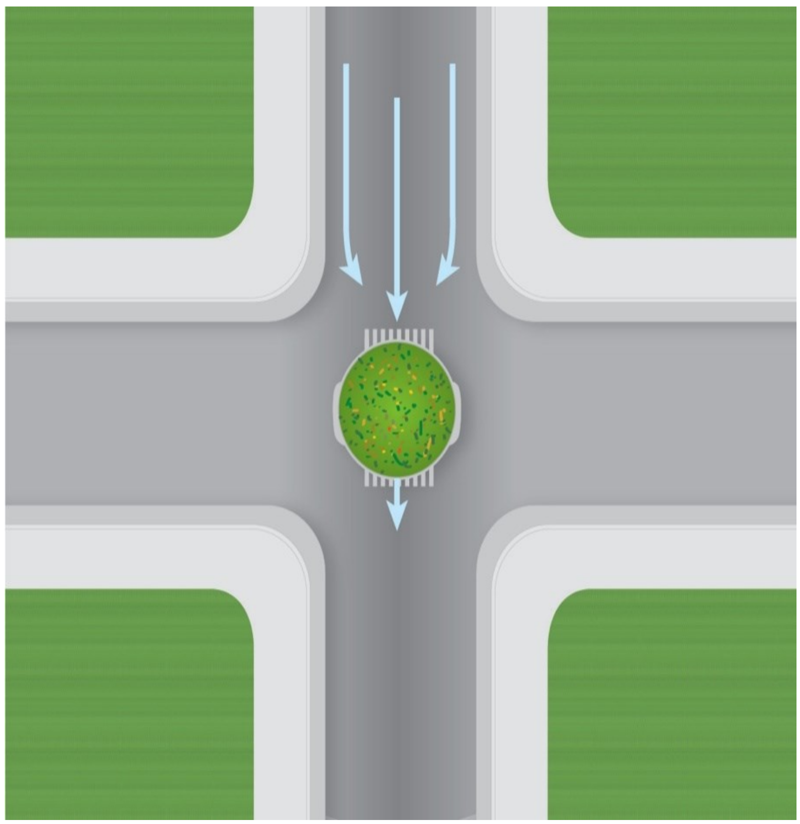
General Guidelines

Site Considerations

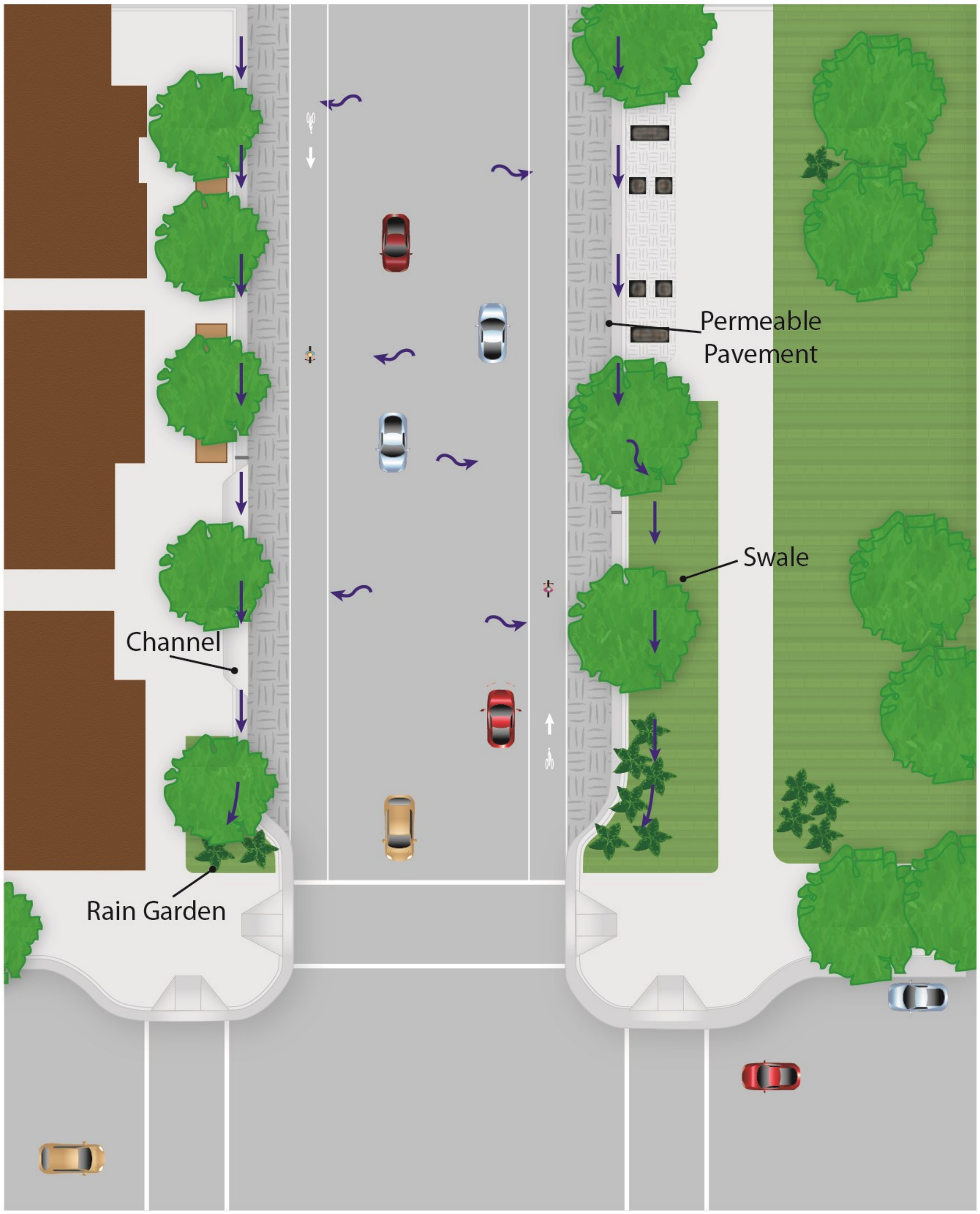
Streetscape geometry, topography, and climate determine the types of controls that can be implemented. The initial step in selecting a stormwater tool is determining the available open space and constraints. Although the maximum size of a selected stormwater facility may be determined by available area, the standard design storm should be used to determine the appropriate size, slope, and materials of each facility.

After identifying the appropriate stormwater facilities for a site, an integrated approach using several tools is encouraged. To increase water quality and functional hydrologic benefits, several stormwater management tools can be used in succession. This is called a treatment train approach. The control measures should be designed using available topography to take advantage of gravity for conveyance to and through each facility.

Traffic calming measures, such as medians, circles, chicanes, and curb extensions, should integrate stormwater management options discussed in this section. The first image at right illustrates a center-draining street utilizing a rain garden integrated into a circle. These areas offer ideal opportunities for treating runoff as they typically intercept the flow path of water along a street and provide additional surface and subsurface space for treating and infiltrating stormwater. By integrating stormwater management tools at an early design stage, new facilities can be added with only marginal cost when paired with other streetscape construction projects. The second image below illustrates a possible treatment on a traditional crowned street with traffic calming measures.



Rain garden in rotary island
(Credit: Michele Weisbart)



Crowned complete street
(Credit: Michele Weisbart)

Infiltration Considerations

Appropriate soils, infiltration media, and infiltration rates should be used for infiltration BMPs. Ideally, a complete geotechnical or soils report should be undertaken to determine infiltration rates, soil toxicity and stability, and other factors that will affect the ability and the desirability of infiltration. At a minimum, the infiltration capacity of the underlying soils should be deemed suitable for infiltration and appropriate media should be used in the BMP itself.

Using certain techniques, stormwater tools can still be incorporated into areas of low permeability or where infiltration of stormwater is not desirable. Underdrains should be used in areas of low soil permeability. The location of the underdrain is an important consideration: if placed higher in a facility, the stored water below the perforated pipe will be infiltrated. If placed at the bottom of a sealed system, the perforated pipe will release the stored water slowly over time. These infiltration BMPs may overflow to appropriate locations such as catch basins and outfalls.

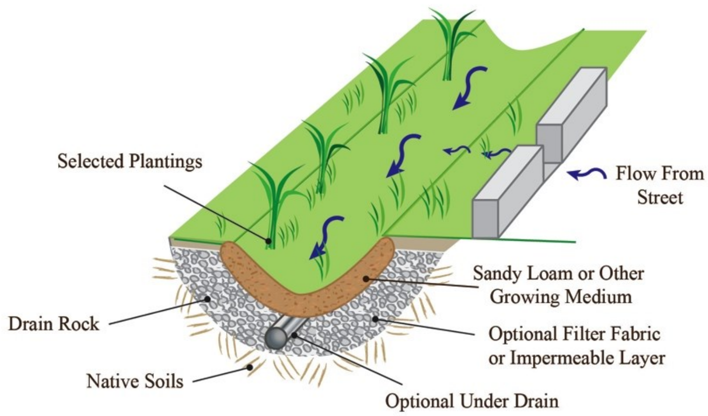
Details are important to the ultimate success or failure of an infiltration system. Poor soil conditions may cause stormwater to infiltrate either too fast or too slow. Over-compaction of subsurface soil during construction can lead to reduced infiltration capacity, flooding, and ponding. The bottom surface of infiltration areas should be level to allow even distribution. Soils and gravels in an infiltration installation should be meticulously specified and verified in the field during construction. Proper maintenance is crucial to the success of an infiltration BMP. To ensure proper caretaking, a maintenance plan or contract with a local agency is necessary.

<u>Bioretention</u>

Swale: Long Beach, CA
(Credit: Patricia Smith)

Bioretention is a stormwater management process that cleans stormwater by mimicking natural soil filtration processes as water flows through a bioretention BMP. It incorporates mulch, soil pores, microbes, and vegetation to reduce and remove sediment and pollutants from stormwater. Bioretention is designed to slow, spread, and, to some extent, infiltrate water. Each component of the bioretention BMP is designed to assist in retaining water, evapotranspiration, and adsorption of pollutants into the soil matrix. As runoff passes through the vegetation and soil, the combined effects of filtration, absorption, adsorption, and biological uptake of plants remove pollutants.

For areas with low permeability or other soil constraints, bioretention can be designed as a flow-through system with a barrier protecting stormwater from native soils. Bioretention areas can be designed with an underdrain system that directs the treated runoff to infiltration areas, cisterns, or the storm drain system, or may treat the water exclusively through surface flow.



Established swale in the landscape
(Credit: Julia Campbell and Michele Weisbart)

Included in this section are discussions of swales, planters, and vegetated buffer strips.

Location and Placement
Bioretention facilities can be included in the design of all street components: adjacent to the traveled way and in the frontage or furniture sidewalk zones. They can be designed into curb extensions, medians, traffic circles, roundabouts, and any other landscaped area. Depending on the feature, maintenance and access should always be considered in locating the device. Bioretention systems are also appropriate in constrained locations where other stormwater facilities requiring more extensive subsurface materials are not feasible.

If bioretention devices are designed for infiltration, native soil should have a minimum permeability rate of 0.5 inches per hour and at least 10 feet to the ground water table. Sites with more than a 5 percent slope may require other stormwater management approaches or special engineering.

Guidelines
A sponge-like surface application of organic mulch can quicken the rate of absorption into the soil, slow soil moisture loss to evaporation, and reduce the solid waste stream if the mulch is generated from local organic matter. This strategy can also intercept and reduce sediment and nutrient concentrations in runoff via bioremediation.

Plants should be microclimate-appropriate and must be able to tolerate occasional saturation as well as dry periods (see the Urban Forestry section of this chapter for planting recommendations).
The use of multiple small devices is often more feasible in tight urban environments than the use of one large device. Small systems can be linked together to achieve the desired cumulative capacity.

Swales

Swales are linear, vegetated depressions that capture rainfall and runoff from adjacent surfaces. The swale bottom should have a gradual slope to convey water along its length. Swales can reduce off-site stormwater discharge and remove pollutants along the way. In a swale, water is slowed by traveling through vegetation on a relatively flat grade. This gives particulates time to settle out of the water while contaminants are removed by the vegetation. Because the vegetation receives much of its needed moisture through stormwater, the need for irrigation is greatly reduced.

Sidewalk-adjacent swale during storm event
(Credit: Edward Belden, Los Angeles and San Gabriel Rivers Watershed Council)

Location and placement—Swales can easily be located adjacent to roadways, sidewalks, or parking areas. Roadway runoff can be directed into swales via flush curbs or small evenly-spaced curb cuts into a raised curb. Swale systems can be integrated into traffic calming devices such as chicanes and curb extensions.

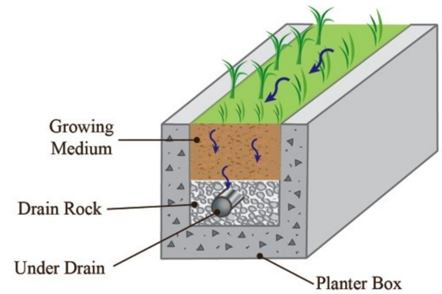
Swales can be placed in medians where the street drains to the median. Placed alongside streets and pathways, vegetated swales can be landscaped with native plants which filter sediment and pollutants and provide habitat for wildlife. Swales should be designed to work in conjunction with the street slope to maximize filtration and slowing of stormwater.

Guidelines—Soils that promote absorption and support vegetation, such as sandy loams, should be specified on a case-by-case basis. Base layers of rock and stabilizing filter fabric may also be specified. Swale length, width, depth, and slope should be determined by capacity needed for treatment of the design storm**.**

Swales are designed to allow water to slowly flow through. Depending on the landscape and design storm, an overflow or bypass for larger storm events may be needed. Curb openings should be designed to direct flow into the swale. Following the inlet, a sump may be built to capture sediment and debris. Mulch can be used in systems where it will not escape the swale system, such as in flatter, deeper swales. Check dams should be used to slow the velocity of water and catch sediment when the slope along the length of the swale exceeds 4 percent.

Swales should be landscaped with deep-rooted grasses and vegetation that tolerate short periods of inundation, deposits of sediment, and periods of drought. Vegetation will filter sediment and slow erosion, protecting the swale from failure. The sides of swales should be minimally sloped to protect the swale from erosion and slope failure.

Swale with curb cut opening and decorative grate outlet (Credit: AHBE Landscape Architects)



Planter detail (Credit Julia Campbell and Michele Weisbart)

Planters
Planters are typically above-grade or at-grade with solid walls and a flow-through bottom. They are contained within an impermeable liner and use an underdrain to direct treated runoff back to the collection system. Where space permits, buildings can direct roof drains first to building-adjacent planters. Both underdrains and surface overflow drains are typically installed with building-adjacent planters.

At-grade street-adjacent planter boxes are systems designed to take street runoff and/or runoff from sidewalks and incorporate bioretention processes to treat stormwater. These systems may or may not include underdrains.

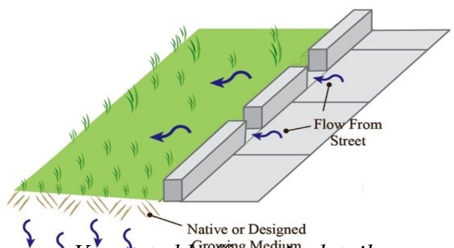
Location and placement—Above-grade planters should be structurally separate from adjacent sidewalks to allow for future maintenance and structural stability per local department of public works' standards. At-grade planter systems can be installed adjacent to curbs within the frontage and/or furniture zones.

Guidelines—All planters should be designed to pond water for less than 48 hours after each storm. Flow-through planters designed to detain roof runoff can be integrated into a building's foundation walls, and may be either raised or at grade.

For at-grade planters, small localized depressions may be included in the curb opening to encourage flow into the planter. Following the inlet, a sump (depression) to capture sediment and debris may be integrated into the design to reduce sediment loadings.

Planters along a downtown street
(Credit: David Riesland)

Vegetated Buffer Strips



Vegetated buffer strip detail
(Credit: Julia Campbell and Michele Weisbart)

Vegetated buffer strips are sloping planted areas designed to treat and absorb sheet flow from adjacent impervious surfaces. These strips are not intended to detain or retain water, only to treat it as a flow-through feature. They should not receive concentrated flow from swales or other surface features, or concentrated flow from pipes.

Location and placement—Vegetated buffer strips are well-suited to treating runoff from roads and highways, small parking lots, and pervious surfaces. They may be commonly used on multi-way boulevards, park edge streets, or sidewalk furniture zones with sufficient space. Vegetated buffers can be situated so they serve as pre-treatment for another stormwater management feature, such as an infiltration BMP.

Guidelines—Buffer strips cannot treat large amounts of runoff; therefore, the maximum drainage width (with the direction of flow being towards the buffer) of the contributing drainage area should be 60 feet. In general, a buffer strip should be at least 15 feet wide in the direction of flow to provide the highest water quality treatment.
The top of the strip should be set 2 to 5 inches below the adjacent pavement or contributing drainage area, so that vegetation and sediment accumulation at the edge of the strip does not prevent runoff from entering.

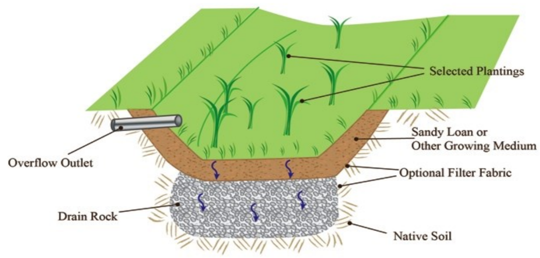
Buffer strips should be sited on gentle slopes. Steep slopes in excess of 15 percent may trigger erosion during heavy rain events, thus eliminating water quality benefits.

Detention

Detention devices differ from retention in that they are designed and sized to hold a specific volume of water and then slowly release it over time. On the other hand, the bioretention

BMPs described in the previous section are designed and sized based on flow—the rate of water passing through them. The objective of bioretention is to improve the quality of stormwater by promoting filtration and adsorption as water flows through vegetation and soil. Detention devices do not function as flow-through features, but rather the objective is to collect and contain water until it is removed by controlled release or infiltrated into the soil. Overflow outlets may be included to manage large storm events. Pollutants may be removed by vegetation and the topsoil layer as in bioretention BMPs so that stormwater is treated before it is infiltrated. Detention devices can greatly reduce the volume of runoff from streetscapes and for small storm events may completely eliminate runoff.

Rain Gardens



Rain garden detail
(Credit: Julia Campbell and Michele Weisbart)

Rain gardens are vegetated depressions in the landscape. They have flat bottoms and gently sloping sides. Rain gardens can be similar in appearance to swales, but their footprints may be any shape. Rain gardens hold water on the surface, like a pond, and have overflow outlets. The detained water is infiltrated through the topsoil and subsurface drain rock unless the volume of water is so large that some must overflow. Rain gardens can reduce or eliminate off-site stormwater discharge while increasing on-site recharge.

Rain garden in an urban landscape
(Credit: Kevin Robert Perry)

Location and placement—Rain gardens may be placed where there is sufficient area in the landscape and where soils are suitable for infiltration. Rain gardens can be integrated with traffic calming measures installed along streets, such as medians, islands, circles, street ends, chicanes, and curb extensions. Rain gardens are often used at the terminus of swales in the landscape.

Rain garden: Portland, OR
(Credit: Brad Lancaster, www.HarvestingRainwater.com)

Guidelines—Native soils should have a minimum permeability rate of 0.5 inches per hour and at least 10 feet to the ground water table. Sites with more than a 5 percent slope may require other stormwater management approaches or special engineering considerations. The topsoil layer should be designed on a case-by-case basis and may often be a type of sandy loam. Subsurface drain rock will promote infiltration and should also be designed for each installation. Local public works departments may have additional guidelines for rain garden design.

The size and shape of rain gardens will vary in each case and the available area in the landscape may determine the maximum footprint. Because rain gardens are volume-based BMPs, their surface area and depth will be designed to achieve the desired detention volume. Overflow outlets should be below the lip of the rain garden and at a height consistent with the desired detention volume. Sides should be gently sloping to prevent erosion.

Rain gardens should be landscaped with deep-rooted grasses and other vegetation that can tolerate short periods of inundation, deposits of sediment, and periods of drought.

Infiltration Trenches and Dry Wells
Infiltration trenches are linear, rock-filled features that promote infiltration by providing a high ratio of sub-surface void space in permeable soils. They provide on-site stormwater retention and may contribute to groundwater recharge. Infiltration trenches may accept stormwater from sheet flow, concentrated flow from a swale or other surface feature, or

piped flow from a catch basin. Because they are not flow-through BMPs, infiltration trenches do not have outlets but may have overflow outlets for large storm events.

Dry wells are typically distinguished from infiltration trenches by being deeper than they are wide. They are usually circular, resembling a well, and are backfilled with the same materials as infiltration trenches. Dry wells typically accept concentrated flow from surface features or from pipes and do not have outlets.

Infiltration trenches and dry wells are typically designed to infiltrate all flow they receive. In large storm events, partial infiltration of runoff can be achieved by providing an overflow outlet. In these systems, significant or even complete volume reduction is possible in smaller storm events. During large storm events, these systems may function as detention facilities and provide a limited amount of retention and infiltration.

Location and placement guidelines—Infiltration trenches and dry wells typically have small surface footprints so they are potentially some of the most flexible elements of landscape design. However, because they involve sub-surface excavation, these features may interfere with surrounding structures. Care needs to be taken to ensure that surrounding building foundations, pavement bases, and utilities are not damaged by infiltration features. Once structural soundness is ensured, infiltration features may be located under sidewalks and in sidewalk planting strips, curb extensions, roundabouts, and medians. When located in medians, they are most effective when the street is graded to drain to the median. Dry wells require less surface area than trenches and may be more feasible in densely developed areas.

Infiltration features should be sited on uncompacted soils with acceptable infiltration capacity. They are best used where soil and topography allow for moderate to good infiltration rates (0.5 inches per hour) and the depth to groundwater is at least 10 feet. Prior to design of any retention or infiltration system, proper soil investigation and percolation testing should be conducted to determine appropriate infiltration design rates. Any site with potential for previous underground contamination should be investigated. Infiltration trenches and dry wells can be designed as stand-alone systems when water quality is not a concern or may be combined in series with other stormwater tools.

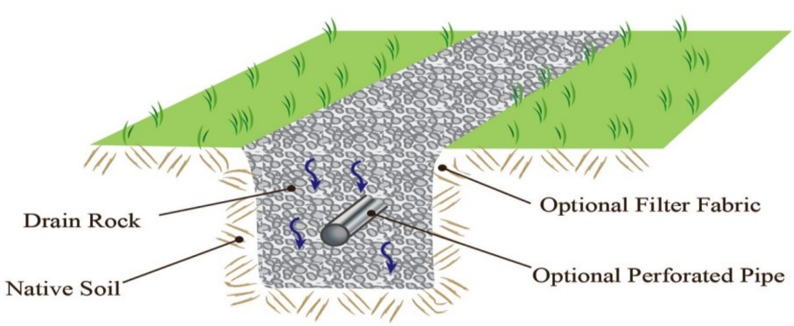
Pre-treatment, design, and installation guidelines—Infiltration features do not treat stormwater and may become damaged by stormwater carrying high levels of sediment. In general, infiltration features should be designed in series with bioretention tools unless the infiltration features receive water from well-vegetated areas where sediment is not expected. Pre-treatment features should be designed to treat street runoff prior to discharging to infiltration features. Bioretention devices, sumps, and sedimentation basins are several pre-treatment tools effective at removing sediment.

Trenches and dry wells are typically backfilled with coarse drain rock (coarse gravel) and may or may not be lined with filter fabric. Additional void space can be achieved by including materials such as perforated pipes, half pipes, or open blocks within the drain rock. The trench surface can be planted, covered with grating, covered with boardwalks, or simply remain as exposed drain rock. Local public works departments should be contacted for any local guidance on infiltration feature design.

The slope of the infiltration trench bottom should be designed to be level or with a maximum slope of 1 percent. Infiltration BMPs should be installed parallel to contours with maximum ground slopes of 20 percent and be located no closer than 5 feet to any building structure. Sub-soils should not be compacted. Drain rock and, if needed, filter fabric with an overflow drain should be designed for each installation.

Perforated pipes and piped inlets and outlets may be included in the design of infiltration trenches. Cleanouts should be installed at both ends of any piping, and at regular intervals in long sections of piping, to allow access to the system. Monitoring wells are recommended for both trenches and wells and can be combined with clean-outs. If included, the overflow inlet from the infiltration trench should be properly designed for anticipated flows.

Infiltration trench with perforated pipe during installation
(Credit: Neil Shapiro)



Infiltration trench
(Credit: Julia Campbell and Michele Weisbart)

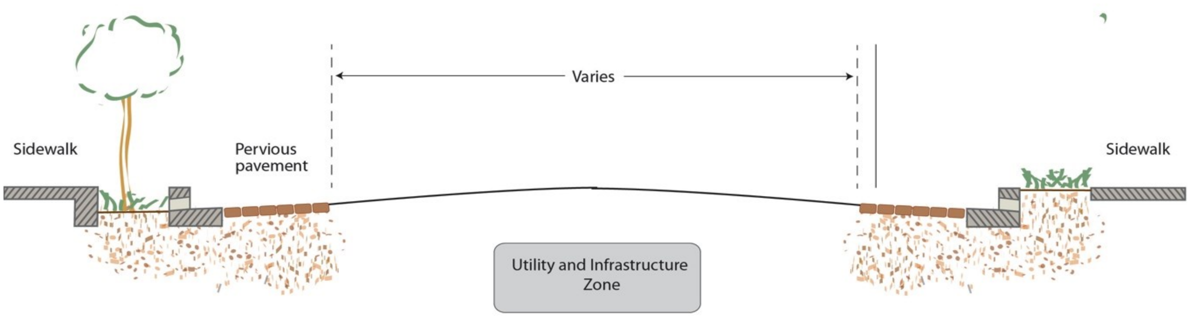
Paving

Permeable Paving
Permeable paving is a system with the primary purpose of slowing or eliminating direct runoff by absorbing rainfall and allowing it to infiltrate into the soil. This BMP is impaired by sediment-laden run-on which diminishes its porosity. Care should be taken to avoid flows from landscaped areas reaching permeable paving. In those cases, bioretention is a better choice for BMPs. Permeable paving is, in certain situations, an alternative to standard paving. Conventional paving is designed to move stormwater off-site quickly. Permeable paving, alternatively, accepts the water where it falls, minimizing the need for management facilities downstream.

Permeable paving:

- Filters and cleans pollutants such as petroleum deposits on streets
- Reduces water volumes for existing overtaxed pipe systems
- Decreases the cost of offsite or onsite downstream infrastructure

Permeable concrete after a rain event
(Credit: Neil Shapiro)



Street section elevation illustrating placement of pervious pavement
(Credit: Marty Bruinsma)

Location and placement guidelines—Conditions where permeable paving should be encouraged include:

- Sites where there is limited space in the right-of-way for other BMPs
- Parking or emergency access lanes
- Furniture zones of sidewalks especially adjacent to tree wells

Conditions where permeable paving should be avoided include:

- Where runoff is already being harvested from an impervious surface for direct use, such as irrigation of bioretention landscape areas
- Steep streets
- Large traffic volume or heavy load lanes
- Gas stations, car washes, auto repair, and other sites/sources of possible chemical contamination
- Areas with shallow groundwater
- Within 20 feet of sub-sidewalk basements
- Within 50 feet of domestic water wells

Material guidelines—When used as a road paving, pervious pavement that carries light traffic loads typically has a thick drain rock base material. Pavers should be concrete as opposed to brick or other light-duty materials. Other possible permeable paving materials include porous concrete and porous asphalt. These surfaces also have specific base materials that detain infiltrated water and provide structure for the road surface. Base material depths should be specified based on design load and the soils report.

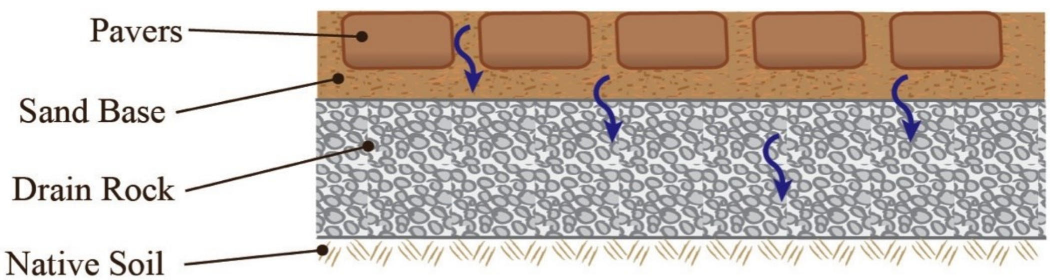
Plazas, emergency roads, and other areas of limited vehicular access can also be paved with permeable pavement. Paving materials for these areas may include open cell paver blocks filled with stones or grass and plastic cell systems. Base material specifications may vary depending on the product used, design load, and underlying soils.

When used for pedestrian paths, sidewalks, and shared-use paths, appropriate materials include those listed above as well as rubber pavers and decomposed granite or something similar (washed or pore-clogging fine material). Pedestrian paths may also use broken concrete pavers as long as ADA requirements are met. Paths should drain into adjoining landscapes and should be higher than adjoining landscapes to prevent run-on. Soil paths are not successful on slopes in excess of 4 percent. Any pervious materials used for sidewalks or paths should be very smooth for wheelchairs and bicyclists.

Permeable paving and a trench drain in a parking area
(Credit: Stephanie Landregan)

Design guidelines—Design considerations for permeable paving include:

- The location, the slope and load-bearing capacity of the street, and the infiltration rate of the soil
- The amount of storage capacity of the base course
- The traffic volume and load from heavy vehicles
- The design storm volume calculations and the quality of water
- Drain rock, filter fabrics, and other subsurface materials
- Installation procedures including excavation



Pervious pavement detail
(Credit: Julia Campbell and Michele Weisbart)

A soil or geotechnical report should be conducted to provide information about the permeability and load-bearing capacity of the soil. Infiltration rate and load capacity are key factors in the functionality of this BMP. Permeable paving generally does not have the same load-bearing capacity as conventional paving, so this BMP may have limited applications depending on the underlying soil strength and paving use. Permeable paving should not be used in general traffic lanes due to the possible variety of vehicles weights and heavy volumes of traffic.

The soil report should also provide the depth of the water table to determine if permeable pavers are an appropriate application for the site. Pervious pavement typically requires a 4-foot or more separation from the water table or bedrock to properly infiltrate stormwater. Pervious pavement is not recommended over new or compacted fill.

Because permeable pavement is damaged by sediment deposits, it should be carefully placed in the landscape so as to avoid run-on, especially from sediment-laden sources such as landscaped areas.

Pavement used for sidewalks and pedestrian paths should be ADA compliant, especially smooth, and not exceed a 2 percent slope or have gaps wider than 0.25 inches. In general, tripping hazards should be avoided.

Maintenance and installation guidelines—Proper construction and installation of permeable pavement is vital to its success. To ensure that the paving system functions properly, sub-base preparation and stormwater pollution prevention measures should be performed appropriately during installation.

Construction considerations include:

- Scarifying soils so that they remain porous
- Avoiding compaction of soils
- Preventing run-on and sedimentation during construction

Maintenance of permeable pavement systems is essential to their continued functionality. Regular vacuuming and street sweeping should be performed to remove sediment from the pavement surface. The bedding and base material should be tested to ensure sufficient infiltration rates on a regular basis. Additionally, base material may need to be removed and replaced every several years based upon the material manufacturer's specifications.

Delivery and Conveyance

Water conveyance measures in the hardscape may support the treatment BMPs outlined above. By daylighting streetwater flow, these measures draw attention to water movement and can in turn highlight bioretention and detention BMPs. Delivery and conveyance measures do not treat streetwater for quality and do not reduce water volume. They are therefore only recommended as supporting infrastructure, a preferable alternative to traditional piped flow.

Channels, Runnels, Trench Drains, and Constructed Swales

Channels, runnels, trench drains, and constructed swales are conventional methods of conveying moderate amounts of stormwater from buildings and impervious surfaces to other drainage collection systems, streets, or planters. They are hardscape features constructed from impermeable materials.

Typically, these structures work well where there is a need for water redirection and space is limited. These hardscape methods may serve to move stormwater from the street to landscaped areas. Channels and constructed swales are not used for stormwater treatment but serve as daylighted, visible conveyance features in lieu of closed pipe systems. They provide opportunities to acknowledge natural drainage processes with artistic design features along the drainage path.

A variety of materials can be used for channels, runnels, and constructed swales: stone, brick, pebbles, pavers, and concrete. Rock swales can be created by arranging stones loosely and mortaring them in place. When a closed top is required, grates can be constructed; proprietary products in standard sizes are readily available. Decorative grates are aesthetic and help illustrate water flow processes.

Because these structures are gravity fed, they require slopes to function properly. On slopes greater than 6 percent, check dams or other velocity reduction devices should be provided.

These conveyance features may direct sheet flow to bioretention or infiltration features or simply serve as an alternative to piped flow in conventional drainage systems. Dimensions should be determined based on the design storm.

Channels have vertical sides and provide a drainage path to a downstream stormwater management feature. Channels vary in depth depending on the amount of flow they are designed to carry, have a sloped bottom, and can be covered or open. In some cases, channels can be constructed with pervious bottoms. Channels can be placed in plazas, driveways, and other hardscapes where conveyance is needed. Channels may be used in some situations where swales or pipes would be too costly or impossible due to site constraints. In broad landscape contexts, channels can be large and constructed to carry large volumes of water.

Runnels are shallower than channels, typically only a couple of inches deep, and are designed to carry small flows of stormwater. Runnels may have an open top but must be covered if they cross pedestrian walkways. Most often runnels are used to convey runoff from hardscapes to adjacent stormwater treatment landscapes. Runnels may be very useful in pedestrian hardscape areas where artistic construction is highly visible. The location and design of runnels should be carefully selected so that they do not pose tripping hazards.

Decorative runnel and fountain
(Credit: Stephanie Landregan)

Trench drains are a type of conveyance system similar to runnels. Trench drains differ from runnels in that they are usually smaller and have a grated top. They also have solid sides and bottoms. Trench drains are available in standard sizes and dimensions from a variety of manufacturers.

Trench drain in hardscape
(Credit: Stephanie Landregan)

Constructed swales are similar to the swales discussed earlier but are constructed from impervious materials. They typically are long narrow depressions used to convey water. The size of a swale should be determined by the design storm and landscape features.

Constructed swale with drain
(Credit: Stephanie Landregan)

Access, design, and maintenance guidelines—All conveyance structures, both open and covered, need to meet accessibility guidelines when in the path of travel. Boardwalks can cover large swales, or decorative grates can be used over smaller widths.

Channels, runnels, and constructed swales should be designed to meet the local agency design storm requirements. Overflow features may be required in some areas and should drain to the nearest gutter or other drainage feature, always draining away from adjacent properties. These features should be designed to allow debris to move through them and account for stoppages that could limit the drainage capacity.

Maintaining a clear conduit is essential for the proper functioning of conveyance structures. These features should be cleaned before the rainy season and checked before and after storm events. Trash, cigarette butts, soil sediment, and leaf litter all can contribute to failure and decrease the function of these features.

Storm Drain Inlet Protections: Retrofitting Existing Storm Drains

Existing storm drain systems may be retrofitted to improve stormwater quality without costly capital improvements. The BMPs described below can be used with existing conventional piped storm drain systems to address water quality but not water volume concerns. The measures described below are designed to prevent particulates, debris, metals, and petroleum-based materials conveyed by stormwater from entering the storm drain system. All storm drain protection units should have an overflow system that allows the storm drain to remain functional if the filtration system becomes clogged during rainstorms.
Typical maintenance of catch basins includes scheduled trash removal if a screen or other debris capturing device is used. Street sweeping should be performed by vacuum sweepers

with occasional weed and large debris removal. Maintenance should include keeping a log of the amount of sediment collected and the data of removal. Some cities have incorporated the use of GIS systems to track sediment collection and to optimize future catch basin cleaning efforts. Bulb-outs should be designed with two return curves with a radius of over 10 feet to allow street sweepers to clean the corners.

All inlet tools located in the pedestrian access route should conform to ADA requirements.

Curb inlet grate catching debris
(Credit: David Riesland)

Storm Drain Inlet Screens: Placement and Guidelines
Inlet screens are designed to prevent large litter and trash from entering the storm drain system while allowing smaller particles to pass through. The screens function as the first preventive measure in removing pollutants from the storm water system. Storm drain inlet screens can be designed and fabricated on an as-needed basis; proprietary screens are readily available for standard size inlets.

Inlet screens are external units mounted on existing curb side storm drain catch basins. The unit captures bigger particles and allows the storm water and small particles to pass through. The screen can be mounted on hinges to create a bypass if the screen is clogged during a storm.

A wide range of storm drain inlet screens is available. The Engineering Division of the city's Department of Public Works should be consulted to ensure compliance with local specifications and to schedule regular maintenance. Annual inspection of the screen is recommended to ensure functionality.

Storm Drain Inlet Protection: Placement and Guidelines
The inlet protection should be designed to protect curbside catch basins or inlets within the traveled way. Inlet inserts contain filter cartridges that can be easily replaced.

The inlet protection can be installed on the existing wall of the catch basin. It can be placed on the curb side wall of catch basins so that during storm events water can overflow around the unit.

Inlet inserts should be sized to capture all debris and should therefore be selected to match the specific size and shape of each catch basin and inlet. Maintenance should be taken into account—systems with lower maintenance requirements are preferred.

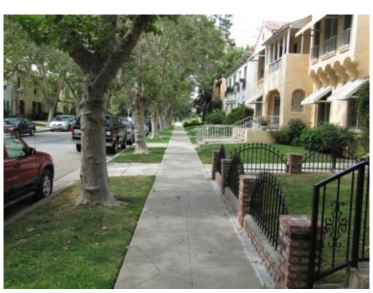
Storm Drain Pipe Filter: Placement and Guidelines
The storm drain outlet pipe protection or filter is designed to be installed on an existing outlet pipe or at the bottom of an existing catch basin with an overflow. This filter removes debris, particulates, and other pollutants from stormwater as it leaves the storm drain system. This BMP is less desirable than a protection system that prevents debris from entering the storm drain system because the system may become clogged with debris.

Outlet pipe filters can be placed on existing curbside catch basins and flush grate openings. Regular maintenance is required and inspection should be performed rigorously. Because this filter is located at the outlet of a storm drain system, clogging with debris is not as apparent as with filters at street level. This BMP may be used as a supplemental filter with an inlet screen or inlet insert unit.

URBAN FORESTRY

The urban forest includes all trees, shrubs, and other understory plantings on both public and private lands. Street trees and landscaping are essential parts of the urban forest, as they contribute positively to the urban environment—to climate control, stormwater collection, and the comfort and safety of people who live or travel along the street. A street lined with trees and other plantings looks and feels narrower and more enclosed, which encourages drivers to slow down and to pay more attention to their surroundings. Trees provide a physical and a psychological barrier between pedestrians and motorized traffic, increasing safety as well as making walking more enjoyable.

A healthy urban forest is also a powerful stormwater management tool. Leaves and branches catch and slow rain as it falls, helping it to soak into the ground. The plants themselves take up and store large quantities of water that would otherwise contribute to surface runoff. Part of this moisture is then returned to the air through evaporation to further cool the city.



As an important element along sidewalks, street trees must be provided with conditions that allow them to thrive, including adequate uncompacted soil, water, and air. This section provides guidance for appropriate conditions and selecting, planting, and caring for street trees, as well as for other landscaping along streets.

Appropriate local street trees
(Credit: Dan Burden)

STREET TREES

Goals and Benefits of Street Trees

The goal of adding street trees is to increase the canopy cover of the street, the percentage of its surface either covered by or shaded by vegetation, not simply to increase the overall number of trees. The selection, placement, and management of all elements in the street should enhance the longevity of a city's street trees and healthy, mature plantings should be retained and protected whenever possible.

A large tree will yield $48 to $62 in average annual net benefits over 40 years with costs factored in (McPherson, G. et al*,* "Tree Guidelines for San Joaquin Valley Communities," Western Center for Urban Forest Research and Education, USDA Forest Service, 1999). Adding street trees:

- Creates shade to lower temperatures in a city, reduces energy use, and makes the street a more pleasant place in which to walk and spend time
- Slows and captures rainwater, helping it soak into the ground to restore local hydrologic functions and aquifers
- Improves air quality by cooling air, producing oxygen, and absorbing and storing carbon in woody plant tissues
- Increases property values and sales revenues for existing businesses
- Enhances local neighborhood and cultural identity through specific plant forms and materials, the act of planting and sharing food crops, or by creating sheltering spaces for social interaction
- Enhances safety and personal security on a street by calming traffic and by fostering a denser and more consistent human presence, also referred to as eyes on the street
- Provides cover, food, and nesting sites for indigenous wildlife as well as facilitates habitat connectivity

Principles for Street Trees

The following principles influence the selection of street trees and landscaping design:

- **Seek out and reclaim space for trees—**Streets have a surprising number of residual or left-over spaces between areas required for travel lanes and parking, once they are examined from this perspective. Traffic circles, medians, channelization islands, and curb extensions can provide space for trees and landscaping.
- **Create optimum conditions for growth—**Space for roots and above ground growth is the main constraint to the urban forest achieving its highest potential. Typically a 6 to 8-foot wide, continuous sidewalk furniture zone must be provided, with uncompacted soil to a minimum of a 3-foot depth. If space for trees is constrained, provisions should be made to connect these smaller areas below the surface to form larger effective areas for the movement of air, root systems, and water through the soil.
- **Select the right tree for the space—**In choosing a street tree, consider what canopy, form, and height will maximize benefits over the course of its life. Provide necessary clearances below overhead high-intensity electrical transmission lines and prevent limbs from overhanging potentially sensitive structures such as flat roofs. In commercial areas where the visibility of façade-mounted signs is a concern, choose species whose mature canopy allows for visibility, with the lowest branches at a height of 12 to 14 feet or more above the ground. Select trees with non-aggressive root systems to avoid damaging paving and sidewalks.
- **Start with good nursery stock and train it well—**When installing plant material, choose plants that have complete single leaders and are in good "form," and check that boxed trees are not root bound. Proper watering and pruning every three to four years will allow trees to mature and thrive for many years of service.
- **Do not subject plants to concentrated levels of pollutants—**Trees and other plants should be integrated within streetwater management practices whenever possible, but filtering of pollutants from “first flush” rain falls and street runoff will extend the life of trees and prevent toxic buildup of street pollutants in tree wells.

Guidelines

Climate and Soil

Selecting trees that are adapted to a site's climate and local rain cycles can create a more sustainable urban forest. The urban environment is harsh for many plants. Often plants native to an area are best adapted to that area’s climate. Select plants that can tolerate the environmental elements, such as radiant heat from the sidewalk or street surface or 50 to 60 mph winds from passing traffic.

Urban soils have become highly compacted through construction activities and the passage of vehicle and even foot traffic. Compaction reduces the soil's capacity to hold and absorb water. Plants need healthy soil, air, and water to thrive.

Using planters in the urban forest can increase the biomass and canopy cover, but these plants and trees are still compromised and confined. At its bottom and sides a barrier will exist as the prepared area meets the surrounding compacted soils. Covering the soil surface with some form of mulch can help as the shade, cooling, and retained moisture that mulch provides help support the biological activities close to the soil's surface. These activities open the pore structure of the soil over time, help keep it open, and cushion the impact of foot traffic. This process works better if the mulch material is organic, as opposed to stones. If planters have limited resources for soil preparation they should have an extensive covering of mulch.

The generalized soil types map for a city can be used as a starting point when planning projects, but then the basic soil classifications should be identified on-site, especially when confronted by planting sites at the extreme ends of the spectrum: very fast-draining, nutrient-poor sands and dense, often nutrient-rich but oxygen-starved poorly drained clays.

Street trees (Credit: David Riesland)

Planting Sites

Traditionally, trees have been squeezed into whatever limited space is easily found, but this does not work well for either the tree or the street. The following guidelines provide recommended planting areas:

- Establish and maintain 6 to 8-foot wide sidewalk furniture zones where possible. Many large trees need up to 12 feet in width, and are not suitable for placement in narrower furniture zones. In residential areas, sidewalk furniture zones within the root zone should be unpaved and planted/surfaced with low groundcover, mulch, or stabilized decomposed granite where these can be maintained. Where maintenance of such extensive sidewalk furniture zones is not feasible, provide 12-foot long tree wells with true permeable pavers (standard interlocking pavers are not permeable).
- If the above conditions are not feasible, provide for the tree's root system an adequate volume of uncompacted soil or structural or gap-graded soil (angular rock with soil-filled gaps) to a depth of 3 feet under the entire sidewalk (in the furniture, frontage, and pedestrian sidewalk zones).
- Spacing between trees will vary with species and site conditions. The spacing should be 10 percent less than the mature canopy spread. Closer spacing of large canopy trees is encouraged to create a lacing of canopy, as trees in groups or groves can create a more favorable microclimate for tree growth than is experienced by isolated trees exposed to heat and desiccation from all sides. On residential streets where lots are 40 or 50 feet wide, plant one tree minimum per lot between driveways. Where constraints prevent an even spacing of trees, it is preferable to place a tree slightly off the desired rhythm than to leave a gap in the pattern.
- Planting sites should be graded, but not overly compact, so that the soil surface slopes downward toward the center, forming a shallow swale to collect water. The crown of the tree should remain 2 inches above finished grade and not be in the center of a swale, but off to the side. The finished soil elevation after planting is held below that of the surrounding paving so 2 to 3 inches of mulch can be added. The mulch layer must be replenished as needed to maintain a nearly continuous level surface adjacent to paving.
- Generally tree grates and guards are best used along streets with heavy pedestrian traffic. Along streets without heavy foot traffic and in less urban environments, use mulch in lieu of tree grates.

Species Selection

- Select trees with non-aggressive root systems to avoid damaging paving and sidewalks.
- In general, street trees should be species that will achieve a height and spread of 50 feet on residential streets and 40 feet on commercial streets within 10 years of planting to provide reasonable benefits. Typically, trees on commercial streets will not achieve the same scale as they will on residential streets where greater effective root zone volumes may be achieved. On commercial streets with existing multi-story buildings and narrow sidewalks, select trees with a narrower canopy than can be accommodated on the limited sidewalk width.

- Cities should establish a list of recommended tree species for use in the public street rights-of-way. A city's list of recommended tree species should specify minimum planting site widths for each and which trees may be planted below utility lines. Where overhead power lines are less than 50 feet above grade, braided insulated electrical wire should be used so that trees do not have to be pruned to avoid the electrical lines. If braided insulated electrical wire cannot be provided, appropriate trees that will not grow tall enough to reach the power lines should be specified and planted.
- Trees that are part of stormwater management practices must be species that respond well to the extremes of periodic inundation and dry conditions found in water catchment areas. Design of all planting areas should include provisions for improved stormwater detention and infiltration.
- Consistent use of a single species helps reinforce the character of a street or district, but a diversity of species may help the urban canopy resist disease or insect infestations. New plantings added to streets with existing trees should be selected with the aim of meeting the same watering requirements and creating visual harmony with existing trees and plantings. Native species should be considered for inclusion whenever possible, but consideration should be first given to a species' adaptability to urban conditions.
- Consider evergreen species where it is desirable to maintain foliage through the winter months, such as to slow stormwater through the rainy season.
- Consider deciduous species where their ability to allow sunlight to penetrate into otherwise shaded areas (such as south facing windows of adjoining buildings) during the winter months will be a plus.

Tree Spacing and Other Considerations

- See Chapter 3, "Traveled Way Design," for an understanding of how to take intersection sight distance into account when designing intersections. Many jurisdictions have tree spacing requirements at intersections, which typically vary from 30 to 45 feet, to provide visibility at corners. However, as discussed in Chapter 3, this distance can often be reduced with no compromise in safety in slow speed environments.
- Most jurisdictions have spacing requirements between trees and street lights (typically about 30 feet high), which typically vary from 10 to 20 feet. The smaller setback provides greater flexibility in tree spacing and allows for a more complete tree canopy.
- Pedestrian lights, which are about 12 feet tall, generally do not conflict with the tree canopy, so spacing is less rigid. Some jurisdictions still require wide clearance for their convenience in maintaining the lights, but this wide spacing greatly reduces tree canopy and is therefore discouraged. Spacing of 10 feet away from trees is generally adequate.
- An 8-foot minimum clearance must be maintained between accessible parking spaces and trees.
- Trees may be planted as close as 6 feet from bus shelters, where they provide welcoming shade at transit stops.

- Adequate clear space should be provided between trees and awnings, canopies, balconies, and signs so they will not come into conflict through normal growth or require excessive pruning to remediate such conflicts.
- Trees may be planted in medians that are 4 feet or wider, but must have an adequate clear height between the surface of the median and the lowest branches so that pedestrians can be seen. Where trees hang over the street, the clear height should be 14 feet.

UNDERSTORY LANDSCAPING

Understory landscaping refers to landscape elements beneath the tree canopy in areas within the public right-of-way not required for vehicular or pedestrian movement, including:

- Medians
- Curb extensions
- Furniture and frontage zones

Benefits of Understory Landscaping

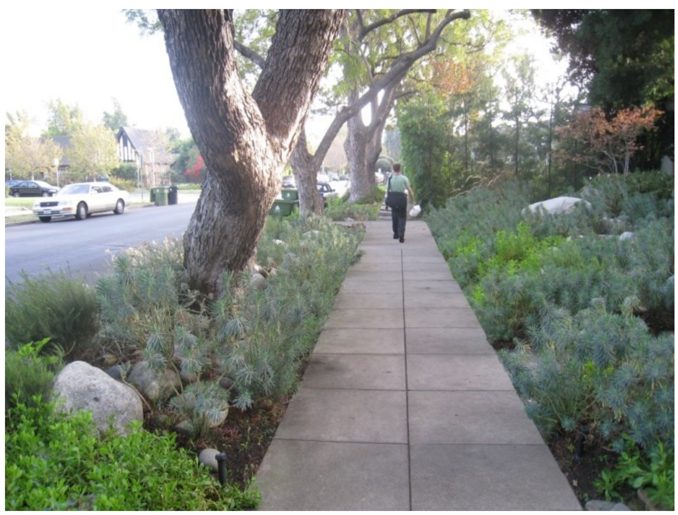
- Complements and supports street trees, in particular by providing uncompacted, permeable areas that accommodate roots and provide air, water, and nutrients
- Reduces impervious area and surface runoff
- Treats stormwater, improving water quality
- Provides infiltration and groundwater recharge
- Provides habitat
- Reduces the perceived width of the street by breaking up wide expanses of paving, particularly when the understory is in medians and sidewalk furniture zones
- Contributes to traffic calming
- Provides a buffer between the walkway zone and the street, contributing to pedestrian comfort
- Improves the curb appeal of properties along the street, potentially increasing their value
- Enhances the visual quality of the community

Principles

- Trees take precedence: the understory landscape should support them. It should not compete with them.
- Only pave where necessary: keep as much of the right-of-way unpaved and planted as possible to maximize benefits
- Design understory areas to infiltrate water
- The entire understory area does not have to be covered with plants—composted mulch is a good groundcover (top of mulch should be below adjoining hardscape so that runoff will flow into planning areas).
- Make the understory sustainable: use drought-tolerant plants

- Replenish the soil with compost
- Design the understory to contribute to the sense of place

Traditional landscaping, requiring irrigation, along a residential parkway in Southern California (Credit: Patricia Smith)



More sustainable landscaping in Southern California (Credit: Patricia Smith)

Guidelines

Soil

Provide good quality, uncompacted, permeable soil. Soil analyses should address the concentration of elements that may affect plant growth, such as pH, salinity, infiltration rate, etc. Remove and replace or amend soil as needed. Good preparation saves money in the long run because it reduces the need to replace plants, lowers water consumption, and reduces fertilizer applications.

Landscaped parkway along a commercial street
(Credit: David Riesland)

Design

Generally, understory landscaped areas should be as wide as possible where there are trees: when feasible, at least 6 to 9 feet wide for parkways and 8 to 12 feet wide for medians. However, many existing parkways and medians are less wide. Narrower parkways can support understory plants and some tree species. A path or multiple paths should be added as needed across a parkway as a means of access from the curb to the sidewalk. For example, where there are striped curbside parking spaces, a path across the parkway should be provided at every one or two parking spaces.

Walking path across the parkway provides access from parked cars to sidewalk
(Credit: Patricia Smith)

Plant with species that:

- Do not require mowing more frequently than once every few months
- Are drought tolerant and can survive with minimal irrigation upon establishment
- Do not exceed a height of 2 feet within 5 feet of a driveway/curb cut and within 20 feet of a crosswalk, and, excluding trees, 3 feet elsewhere
- Do not have thorns or sharp edges adjacent to any walkway or curb
- Are located at least 4 feet from any tree trunk

STREET FURNITURE

Street furnishings in the street environment add vitality to the pedestrian experience and recognize the importance of the pedestrian to the fabric of a vibrant urban environment. Street furnishings encourage use of the street by pedestrians and provide a more comfortable environment for non-motorized travel. They provide a functional service to the user and provide uniformity to the urban design. Street furnishings include benches and seating, bollards, flower stands, kiosks, news racks, public art, sidewalk restrooms, signs, refuse receptacles, parking meters, and other elements.

Street furnishings achieve improved vitality in many ways:

- They make walking, bicycling, and public transit more inviting.
- They improve the street economy and common city prosperity.
- They enhance public space and create a place for social interaction.

Placement of street furnishings should be provided:

- At concentrations of pedestrian activity (nodes, gathering areas)
- On streets with pedestrian-oriented destinations. Pedestrians may gather or linger and enjoy the public space.
- Site furnishing placement should follow these criteria:
    - Street furnishings are secondary to the layout of street trees and light standards as street trees and light standards develop a street rhythm and pattern. Site furnishing should be placed in relation to these elements sensitive to the vehicular flow and pedestrian use of these elements. Careful consideration to the placement provides ease of recognition and use.
    - In addition to the guidelines provided for each element, placement should adhere to the minimum spacing. Site furnishing installed within the appropriate zone will be spaced not less than as shown in Table 10.2.

Table 10.2 Site Furnishing Minimum Setbacks

Location	Setback
Face of Curb	18”
Driveway	2’
Wheelchair Ramp	2’
Ramp Landing	4’
Fire Hydrant	5’
Stand Pipe	2’
Transit Shelter	4’

- All site furnishing must be accessible per Public Rights-of-Way Accessibility Guidelines (PROWAG) and other city regulations.
- Cities should strive to include sustainable materials for street furnishings.

BENCHES AND SEATING

Public seating provides a comfortable, utilitarian, and active environment where people can rest, socialize, or read in a public space. The proper placement of a bench is a simple gesture creating a sense of place for the immediate area.

Street bench
(Credit: David Riesland)

Location

Seating arrangements should be located and configured according to the following guidelines:

- Seating should be located in a shaded area under trees.
- Seating should be oriented toward points of interest; this can be the adjacent building, an open space, or the street itself if it's lively. Where sidewalk width permits, seating can also be oriented perpendicular to the curb.
- Informal seating opportunities, incorporated into the adjacent building architecture, may be used as an alternative to free-standing benches. Low planter walls can be used as informal seating areas.

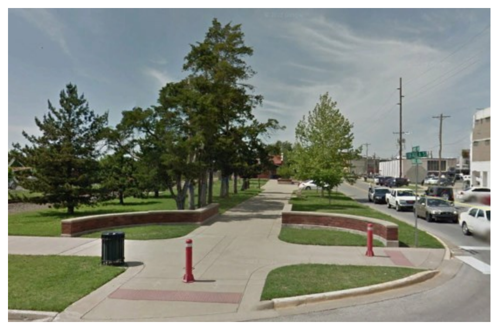
Design

Benches and seating should be made of durable high-quality materials. The seating design should complement and visually reinforce the design of the streetscape**.**

Seating opportunities should be integrated with other streetscape elements.

BOLLARDS

Bollards are primarily safety elements to separate pedestrians or other non-motorized traffic from vehicles. Thoughtful design and/or location of bollards can add interest, visually strengthen street character, and define pedestrian spaces.



Bollards
(Credit: David Riesland)

Location

Bollards are used to prevent vehicle access on sidewalks, or on other areas closed to motor vehicles. Removable bollards should be placed at entrances to permanent or temporary street closures.

Design

Bollards range in size from 4 to 10 inches in diameter. Bollards should have articulated sides and tops to provide distinct design details. The details should be coordinated with other street elements of similar architectural character.

Removable bollards should be designed with a sturdy pipe projecting from the bottom of the exposed bollard. Removable bollards should appear permanent. Electrically controlled mechanisms retract the bollard into a void below the surrounding finish surface. This allows emergency vehicle access to closed streets.

STREET VENDOR STANDS

Street vendor stands, such as flower, magazine, and food vendor stands, rely on regular pedestrian traffic to sustain their business. To maximize efficiency, the stands operate during daytime work hours and cater to those commuting to/from employment areas. In areas with a vibrant evening environment, stands may have evening hours to benefit from the extended period of exposure to pedestrian traffic.

Street vendor stand
(Credit: Sky Yim)

Location

Generally, street vendor stands should either be located outside the street right-of-way or in the sidewalk, furniture, or frontage zones.

Design

The design of the street vendor stands should have details and features coordinated with other street elements. These details should be of a similar architectural character. The stands should allow a minimum of 6 feet of clear pedestrian passage between the edge of the display area and other elements.

INFORMATIONAL KIOSKS

Kiosks in public areas provide valuable information, such as maps, bulletin boards, and community announcements. Kiosks can often be combined with gateway signs and are an attractive and useful street feature.

Location

Kiosks may be located in any of the following areas:

- The sidewalk, furniture, or frontage zones
- Curb extensions
- Where parking is not allowed
- Close to, but not within transit stops

Kiosks should not block scenic views.

Informational kiosk
(Credit: Paul Zykofsky)

<u>Design</u>

Kiosks should be designed to the following guidelines:

- Kiosks should include bulletin boards or an enclosed case for display of information.
- As a gateway element, the kiosk should include the neighborhood, commercial district, street, or park name; a map; or other information.
- Kiosks should have details and features coordinated with other street elements and should have a similar architectural character.

NEWS RACKS

<u>Location</u>

News rack placement is subject to municipal guidelines. In addition, the following guidelines should be considered:

News rack
(Credit: Ryan Snyder)

- News racks located within the furniture or frontage zones should not reduce the minimum width of the sidewalk pedestrian zone with news rack doors open.
- News racks should be placed no closer than 2 feet from adjacent street signs and 4 feet from bike racks.

Design

News racks should visually blend with their surroundings and complement the architectural character. Multiple news racks should be consolidated into a standard decorative stand.

PARKING METERS

Parking meters can be either traditional single-space meters or consolidated multi-space meters (parking stations).

Location

Parking meters should be placed in the sidewalk furniture zone. Single-space meters should be placed at the front end of the individual stalls.

Multi-space meters should be placed every 8 to 10 parking spaces and spaced approximately 150 to 200 feet apart. Signs should clearly direct patrons to the meter. The signs should be spaced at approximately 100 feet on-center.

Design

The conversion of single-space meters to multi-space units can reduce visual clutter from the urban landscape. The multi-space units should be selected to minimize their impact on the pedestrian zone.

Street signs (Credit: Sky Yim)

SIGNS

Streetscape signs provide information specific to direction, destination, or location. The sign plans should be developed individually for each neighborhood or district. Streetscape signs are most appropriate for downtown, commercial, or tourist-oriented locations or around large institutions. Streetscape signs include parking, directional, and wayfinding signs.

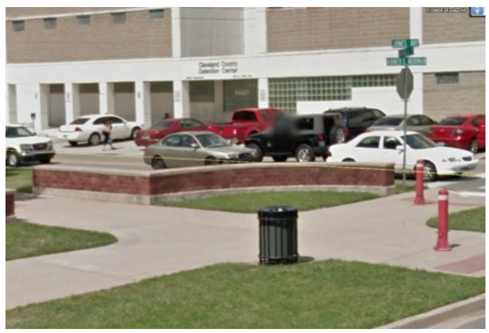
Location

Streetscape signs should be placed strategically. They should align with the existing street furnishings and be placed in the sidewalk furniture zone.

The sign design should be attractively clean and simple and complement the architectural character of other street furnishings.

REFUSE RECEPTACLES

Refuse receptacles should accept both trash and recyclables. Where there is a demand, different receptacles should be provided for different recyclable materials.



Refuse receptacle
(Credit: David Riesland)

Location

Refuse receptacles should be located:

- Near high activity generators such as major civic and commercial destinations
- At transit stops
- Near street corners but outside of the sidewalk pedestrian zone

There should be a maximum of one refuse receptacle every 200 feet along commercial streets and a maximum of four refuse receptacles at an intersection (one per corner).

PUBLIC ART

On a large scale, public art can unify a district with a theme or identify a neighborhood gateway. At a pedestrian scale, public art adds visual interest to the street experience.

Public art
(Credit: David Riesland)

Location

Public art can be situated in a variety of areas and locations, including streets, public spaces with concentrations of pedestrians, or areas of little pedestrian traffic, to create a unique space for discovery.

Design

Public art should be considered during the planning and design phase of development to more closely integrate art with other streetscape elements, taking into account the following:

- Public art is a pedestrian amenity and should be presented in an area suited for pedestrian viewing. The piece should be placed as a focal element in a park or plaza, or situated along a pedestrian path and discovered by the traveler.
- Public art can be incorporated into standard street elements (light standards, benches, trash receptacles, utility boxes).
- Public art can provide information (maps, signs) or educational information (history, culture). All installations do not need to have an educational mission; art can be playful.
- Public art should be accessible to persons with disabilities and placement must not compromise the sidewalk pedestrian zone.

SIDEWALK DINING

Outdoor café and restaurant seating adjacent to the sidewalk activates the street environment and encourages economic development.

Outdoor café seating: Utrecht, Holland
(Credit: Ryan Snyder)

Location

Tables and chairs are to be placed on the sidewalk directly at the front of the restaurant and allowed in the frontage zone or furniture zone of the sidewalk where sufficient width is available.

Design

Placement of tables and chairs may, if possible, include diverters (barriers) at the end of the dining area to guide pedestrians away from the accepted area of sidewalk. If diverters cannot be accommodated, a through pedestrian zone of a minimum five foot width, without obstructions or physical barriers, must be provided. If alcohol is served, the Alcoholic Beverage Laws Enforcement requires that the restaurant have a positive barrier to separate the dining area from the through pedestrian zone.

OTHER STREETSCAPE FEATURES

Other features that enhance the pedestrian experience include clocks, towers, and fountains, which strengthen the sense of place and invite pedestrians to come enjoy.

Other example streetscape fixtures (Credit: Ryan Snyder)

UTILITIES

The location of underground and aboveground utilities must be considered when planning new landscaped areas in the right-of-way. Each jurisdiction should establish guidelines to organize and standardize utility location and to minimize conflicts between landscaping and utilities based on input from all affected departments and agencies.

The majority of underground utilities, including sanitary sewers and storm drains, and water, gas, and electrical mains, are typically located under the roadway. Sanitary sewers are often in the center of the street directly under the potential location of a landscaped median. They are usually relatively deep. In general, if they have at least 4 or 5 feet of cover, they should not be affected by the introduction of a landscaped median. The other utilities within the roadway are typically located closer to the curbs.

Telecommunications, street lighting conduit, traffic signal conduit, and fiber optic conduit are often located under the sidewalk. Lateral lines extend from the utility mains in the public rights-of-way to serve adjacent properties.

Benefits of well-organized utility design/placement include:

- Reduced clutter in the streetscape
- Increased opportunity for planting areas and for soil volume to support tree growth and stormwater infiltration
- Reduced maintenance conflicts
- Improved pedestrian safety and visual quality

GUIDELINES

Location

- Utilities should be placed to minimize disruption to pedestrian travel and to avoid ideal locations for directing stormwater, planting trees and other vegetation, and siting street furniture, while maintaining necessary access to the utilities for maintenance and emergencies.
- Utilities within 10 feet of where a landscaped median may be located should have at least 5 feet of cover.
- Utility main lines that run laterally under the sidewalk should be located in a predetermined zone to minimize conflicts with tree roots and planting areas. The ideal location to minimize conflicts with trees would be under the pedestrian or frontage zones, although the more practical location is often under the furniture zone. Stacking dry utilities (telephone, CATV, electric, etc.) in the pedestrian or frontage zones will further reduce conflicts with the landscaped area.

Roadway/Parking Lane

- Large utility vaults and conduits running the length of a city block may be located in the roadway or parking lane where access requirements allow. Vaults in the parking lane may be located in short-term parking zones or in front of driveways to facilitate access. E ach jurisdiction typically has specific design standards for vaults and utilities based on expected use and vehicle type. They can also be placed in midblock curb extensions.

Furniture Zone

- Small utility vaults, such as residential water vaults, residential water meters, gas valves, gas vaults, or street lighting access, should be located in the sidewalk furniture zone at the back of the curb wherever possible to minimize conflicts with existing or potential tree locations and landscaped areas. Vaults should be aligned or clustered wherever possible.
- Generally, utility boxes are sited in the direction of the pipe. Utility boxes that are parallel with the curb should be located in the sidewalk furniture zone when possible. Vaults perpendicular to the curb should be located between existing or potential street trees or sidewalk landscape locations (for example, in walkways through the sidewalk furniture zone to parked cars).
- Utility laterals should not run directly under landscaped areas in the furniture zone, but instead under driveways and walkways wherever possible.

Sidewalk Pedestrian Zone

- Flush utility vaults and conduits running the length of the city block may be located in the pedestrian zone. Vaults in the pedestrian zone should have slip-resistant covers.
- Large flush utility vaults should be placed at least 3 feet from the building and 4 feet from the curb where sidewalk widths allow.
- Surface-mounted utilities should not be located in the pedestrian zone.

Sidewalk Frontage Zone

- Utility vaults and valves may be placed in the frontage zone. Placement of utility structures in this zone is preferred only when incorporating utility vaults into the furniture zone is not feasible.
- Utility vaults in the frontage zone should not be located directly in front of building entrances.

Curb Extensions

- Utility vaults and valves should be minimized in curb extensions where plantings or street furnishings are planned.
- Surface-mounted utilities may be located in curb extensions outside of crossings and curb ramp areas to create greater pedestrian through width.
- Utility mains located in the parking lane and laterals accessing properties may pass under curb extensions. With curb extensions or sidewalk widenings, utilities such as water mains, meters, and sewer vents may remain in place as they can be cost prohibitive to move.

Driveways

- Utility boxes may be located in driveways if the sponsor provides a vehicle-rated box; however, this is not a preferred solution due to access difficulties.

Pedestrian Crossings and Curb Ramps

- New utility structures should not be placed within street crossing and curb ramp areas.
- Existing vaults located in the center accessible portion of a ramp should be moved or modified to meet accessibility requirements, as feasible, as part of utility upgrades.
- Catch basins and surface flow lines associated with storm drainage systems should be located away from the crosswalk or between curb ramps. Catch basins should be located upstream of curb ramps to prevent ponding at the bottom of the ramp.

Consolidation

Utilities should be consolidated for efficiencies and to minimize disruption to the streetscape:

- Dry utility lines and conduits (telephone, CATV, electric, gas, etc.) should be initially aligned, rearranged, or vertically stacked to minimize utility zones.
- Wherever possible, utility conduits, valves, and vaults (e.g., electrical, street lighting, and traffic signals) should be consolidated if multiple lines exist within a single street or sidewalk section.
- Dry utilities (gas, telephone, CATV, primary and secondary electric, streetlights) may use shared vaults wherever possible.
- Street lighting, traffic signal, and light rail or streetcar catenary poles should share poles wherever possible. When retrofitting existing streets or creating new streets, pursue opportunities to combine these poles.

Artfully painted utility box (Credit: Sky Yim)

Other Design Guidelines

- Street design and new development should consider the overall pattern of plantings, lighting, and furnishings when placing new utilities in the street, and locate utility lines so as to minimize disruption to the prevailing streetscape rhythms.
- Utilities should be located underground wherever possible, as opposed to overhead or surface-mounted. Overhead utilities should be located in alleys where possible.
- New utilities should use durable pipe materials that are resistant to damage by tree roots and have minimal joints.
- Trenchless technologies, such as moling and tunneling, should be used wherever possible to avoid excavation and disruption of streetscape elements.
- New infrastructure projects should use resource-efficient utility materials. Re-used or recyclable materials should be incorporated wherever possible.
- Utility boxes may be painted as part of a public art program.
- Tree removal should be avoided and minimized during the routing of large-scale utility undergrounding projects.
- Any utility-related roadway or sidewalk work should replace paving material in kind (e.g., brick for brick) where removed during maintenance, or replace with new upgraded paving materials.

New Development and Major Redevelopment

- Alleys for vehicle, utility, and service access should be incorporated to enable a more consistent streetscape and minimize above-ground utilities.
- New utilities should be located to minimize disruption to streetscape elements per guidelines in this section.

Abandonment

- Currently abandoned dry conduits should be reused or consolidated if duplicate lines are discovered during street improvement projects. Utilities should be contacted for rerouting or consolidation. Where it is not possible to reuse abandoned mains, conduits, manholes, laterals, valves, etc., they should be removed per agency recommendations when possible to minimize future conflicts.
- Abandoned water and sewer lines may be retrofitted as dry utility conduits where available or if possible to minimize the need for future conduit installations.

Process

- Utility installation and repair should be coordinated with planned street reconstruction or major streetscape improvements.
- New development should submit utility plans with initial development proposals so that utilities may be sited to minimize interference with potential locations for streetscape elements.
- Utility work also offers opportunities to make other changes to the street after the work is completed and should be coordinated with planned improvements to avoid duplication of efforts or making new cuts in new pavement. Examples of improvements to streets done at low cost after utility work include restriping for bike lanes if utility work requires total street repaving, as well as building sidewalks in conjunction with utility work occurring outside the traveled way.

Lighting

Lighting provides essential nighttime illumination to support pedestrian activity and safety as well as vehicle safety. Well-designed street lighting enhances the public realm while providing safety and security on roadways, bike paths, and bike lanes as well as pedestrian paths including sidewalks, paths, alleys, and stairways.

Historically significant street light poles and fixtures should be maintained and upgraded where appropriate.

Pedestrian lighting should be coordinated with building and property owners to provide lighting attached to buildings for sidewalks, alleys, pedestrian paths, and stairways where separate lighting poles are not feasible or appropriate.

Street lamps (Credit: David Riesland)

Guidelines

Location and Spacing

1. Street and pedestrian lighting should be installed in the sidewalk furniture zone;
2. Light fixtures should not be located next to tree canopies that may block the light; and
3. Where pedestrian lighting is not provided on the street light pole, special pedestrian lamps should be located between street light poles.

Light Color

All light sources should provide a warm white (yellow, not blue) color light.

Light Poles and Fixtures

Design should relate and be coordinated with the design of other streetscape elements and recognize the history and distinction of the neighborhoods where the light poles are located.

Lighting to Minimize Light Pollution

As appropriate, full cut-off lighting fixtures should be selected to minimize light pollution cast into the sky while maximizing light cast onto the ground.

LED Light Fixtures at Night: Norman,OK
(Credit: Michelle Rudder)

Energy Efficiency

New and more efficient lighting technologies should be utilized where possible, including LED, for new installations or for retrofit projects.

Pedestrian Lighting
Retrofits of existing street lights and new installations should provide lighting on pedestrian paths. Pedestrian lighting should be added to existing street light poles where feasible unless spacing between street light poles does not support adequate pedestrian lighting, in which case pedestrian lighting may need to be provided between existing street light poles.

Light Levels and Uniformity
All optic systems should be cut off with no light trespass into the windows of residential units. The City of Norman has adopted the Roadway Lighting Design Guide published by the American Association of State Highway and Transportation Officials in order to achieve adequate lighting levels for all users.

ADDITIONAL SELECT RESOURCES

Lancaster, B. Rainwater Harvesting for Drylands and Beyond, http://www.harvestingrainwater.com/.

Landscape Architecture Foundation's Landscape Performance Series, www.lafoundation.org/lps.

11. RE-PLACING STREETS: PUTTING THE PLACE BACK IN STREETS

INTRODUCTION

Most American cities have come to view streets primarily as conduits for moving vehicles from one place to another (from A to B is the common expression). While moving vehicles is one of their purposes, streets are spaces, even destinations in and of themselves. Conceiving of a street as a public space and establishing design guidelines that serve multiple social functions involves several fundamental steps. Behind them all is a redefinition of whom streets ought to serve. By approaching streets as public spaces, cities redirect their attention from creating traffic conduits to designing a place for the people who use the street. People put the place back in streets.

Pavement to Parks program: San Francisco, CA (Credit: Sky Yim)

This chapter describes the need for cities to "re-place" their streets—make streets places and refocus their purpose on the people who use them—and how cities can do so. The chapter outlines the key features and functions of re-placed streets and the design elements used to achieve re-placed streets. The chapter concludes by describing the process cities can follow to ensure streets come to reflect a community's strengths, needs, and aspirations.

PUBLIC SPACE AND THE NEED TO RE-PLACE STREETS

Public spaces are the stages for our public lives. They are the places shared by all members of a community, of any size. Quality public spaces are places where things happen and where people want to be, vital places that highlight local assets, spur rejuvenation, and serve common needs.

Active public space: London, England (Credit: Ryan Snyder)

Streets comprise a large portion of publicly owned land in cities and towns. Streets are a huge part of any community's public space network, and historically served as meeting places, playgrounds for children, marketplaces, and more. As populations spread out from city centers, streets lost many of these functions and were instead designed and planned for one use: mobility. At best, streets conceived as complete streets address the mobility needs of all street users (pedestrians, cyclists, drivers, and transit riders). During the last century, however, automobiles have been prioritized over people as users of our streets.

As part of the public realm, successful streets have a variety of functions beyond allowing automobiles to travel rapidly. For this reason, placemaking, the process of creating high-quality destinations, must be at the core of the planning and design of our streets to meet the following challenges:

- **Population growth and urbanization**. People moving back into cities will need to be accommodated in limited space, putting greater demands on existing streets. If streets continue to largely function to move people traveling in motor vehicles, they will not be able to accommodate this growth. Streets will need to enable people to do more while traveling less and to travel more efficiently.
- **The need to maximize social and economic exchange.** Streets will need to serve the highest and best use for the land they are on, and mobility is only one among many possible uses. Streets need to be designed to maximize social value, which also spurs healthy economic exchange. In this way, streets become arteries distributing prosperity. Streets that invite social interaction are more likely to ensure healthy growth.
- **The need to reduce energy consumption and induce sustainable growth.** Streets that are places promote locality by enabling people to travel comfortably using non-motorized modes. This in turn shortens travel distance demand. With growing concerns regarding fuel resources and climate change, this shift will be critical. Because re-placed streets spur locality-serving commerce and social venues, they also set the stage for and enable healthy and environmentally sustainable practices/behaviors in the surrounding built environment.
- **A desire to create public space.** Beyond being the frames for other development, streets can be public spaces themselves. Access to public space is critical to safe, healthy, and successful communities. When streets are designed as great spaces for people, they reinforce a sense of belonging and build on the strengths of the communities they host.

PLACEMAKING FOR STREETS

In order to be places, streets must:

- Augment and complement surrounding destinations, including other public spaces such as parks and plazas
- Reflect a community's identity
- Invite physical activity through allowing and encouraging active transportation and recreation
- Support social connectivity
- Promote social and economic equity
- Be as pleasant and accessible for staying as for going
- Prioritize the slowest users over the fastest
- Balance mobility and public space functions

Public plaza: Barcelona, Spain
(Credit: Ryan Snyder)

So that people can:

- Walk and stroll in comfort
- Sit down in nice, comfortable places, sheltered from the elements
- Meet and talk—by chance and by design
- Look at attractive things along the way
- See places that are interesting
- Feel safe in a public environment
- Enjoy other people around them
- And get where they need to go!

(Credit: David Kiesland)

Good public space invites social interaction
(Credit: Dan Burden)

Re-placed streets must be slow streets that are inviting and filled with human activity. This is the most important distinction between streets designed for maximal car throughput and re-placed streets; it requires the necessary adjustment from car to people-focused street planning. Streets designed for fast and far movement favor people moving by motor vehicles, not people moving under their own power. Human energy limits people to slow and local movement.

Because people, not motors, are essential to long-term growth in places of all kinds, human-scaled streets are an inducement to healthy lifestyles and economic resilience.

DESIGN TECHNIQUES AND GOALS FOR REPLACED STREETS

A re-placed street balances the moving and staying needs of its users and has multiple, people-serving purposes. The design techniques and goals detailed below describe how to create re-placed streets.

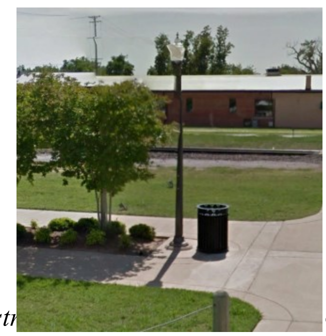
Support and Encourage Activities and Destinations

- Widen sidewalks to accommodate multiple activities
- Open streets to multiple activities
- Encourage/provide active ground floor uses in adjacent buildings
- Cluster activities and amenities
- Allow street vendors and performers

Street performer (Credit: Ryan Snyder)

Design Street Elements and Adjacent Buildings for the Human Scale

- Use amenities that are pedestrian-scaled including:
  - Signs
  - Lighting
  - Seating
- Encourage building design (e.g., through zoning regulations and design guidelines) that is scaled to the human body, such as:
  - Frequent building entrances
  - Building transparency at street level
  - Interesting facades



Pedestr OK (Credit: David Riesland)

Walk streets used as play space: Manhattan Beach, CA (Credit: Dan Burden)

Transparent storefronts blur the distinction between indoor and outdoor space, and public and private space: Avalon, CA (Credit: Ryan Snyder)

Provide a Feeling of Safety and Security on Streets

Good sidewalk buffer: Norman, OK (Credit: David Riesland)

- Keep streets well-maintained and both the street and surrounding buildings well-lit
- Select streets adjacent to round-the-clock-active buildings and public spaces
- Invite diverse people and uses throughout the day
- Slow traffic to a comfortable speed to mix with other travel modes through:
    - Low speed design elements
    - Traffic calming techniques
    - Shared space
- Maintain a buffer between pedestrians and vehicles when there is fast moving traffic using:
    - Planters
    - Bollards
    - Parked cars
    - Kiosks, newsstands, public toilets, lampposts

Shared space: Zurich, Switzerland (Credit: Ryan Snyder)

Connect Both Sides of the Street

- Shorten crossing distance through:
    - Narrow travel lanes
    - Curb extensions and pedestrian islands
    - Building activities connected to the street
- Invite people to cross in more places by:
    - Slowing vehicular traffic
    - Establishing mid-block crossings
    - Making shared streets

Farmer's market (Credit: Dan Burden)

Show a Sense of Ownership

- Provide for maintenance and cleanliness
- Engage community/local residents in maintenance
- Accommodate diverse programming appropriate for the season and time-of-day, such as:
    - Greenmarkets/farmers' markets
    - Fairs and festivals
    - Ciclovía-style events
    - Volunteer events

CicLAvia: Los Angeles, CA (Credit: Ryan Snyder)

Reflect Community Identity

Unique community identity draws from the natural setting and local history, as well as the cultural backgrounds of community residents and their architectural tastes.

- Showcase local assets including:
  - Monuments and building architecture
  - Views
  - Trees and other plants
  - Other natural features (water, topography)
  - Parks and plazas
  - History
  - People
  - Intersections transformed into meeting places
- Invite a diversity of users
- Reference or preserve continuity of local aesthetics

Statue: Santa Fe, NM (Credit: Ryan Snyder)

Move Community towards Local Sustainability

- Utilize on-site and local resources where possible
- Use surface area for energy capture
- Use effective stormwater management techniques including bioswales and raingardens
- Use open space for growing food (community gardens)

STRATEGIES TO RE-PLACE STREETS

Re-placing streets requires building streets around a community's vision that the street can support. Re-placing a street is an opportunity to open a process wherein communities remind themselves of their strengths and establish a shared and sustainable vision for their future. Before a city can proceed with street redesigns that create a sense of place, it must address the following issues.

THE STREET'S PLACE IN THE COMMUNITY

Streets, the built environments they connect, and the people who use them compose a community. Thus, it is important to situate the street in its spatial context and identify the places it connects. It is equally important to identify whose needs the street should serve. This may include tenants and property owners, students, employees, local civic associations, and religious institutions.

PLACEMAKING PARTICIPANTS

At the heart of placemaking is the idea that each community has the means and the potential to create its own public spaces. Before proceeding with street redesigns that attend to the multiple functions of public space through placemaking, it is important to identify who needs to be involved to frame the meaning of place and the vision and to provide the needed information, resources, and expertise to realize that vision.

The Community

Since place is an outgrowth of community character, re-placing should invite the collective influence of a community's diverse residents and users. In re-placing a street, it is important to establish who has a stake in the neighborhood, and give all of these groups and individuals the opportunity to come to the table and contribute. As noted above, the groups may include tenants and property owners, students, employees, and community-based groups like civic associations and religious institutions. The appropriate public space functions of streets should be defined by these multiple users, often referred to as "stakeholders."

Multiple Agencies

Within a city, multiple agencies should be included and engaged in re-placing a street. A department of transportation alone cannot create a street that is a place. Any agency with responsibility for the regulation, construction, operations, or maintenance on or adjacent to the street should be included in the project early in the process. In addition to the department of transportation, this might include public works, the parks department, utilities, and the planning or zoning department. All agencies must bring their needs and constraints to the table, but more importantly they must understand the community's vision and goals for making the street a place. They can then begin considering what they need to do to carry out the will of their community.

A Multi-Disciplinary Team

A successful street is a complex place, and the information, insight, and skills required to make it a successful place are many and diverse. It is beyond the experience of any one profession to deal with any of these issues. The role of professionals is as a resource for the community and to implement the community's vision.

THE PLACEMAKING PROCESS

The placemaking process should be fun, engaging, and empowering for a community; build on existing human resources; and result in increased community social capital. Chapter 14, "Community Engagement," provides the details of the type of public process that should be used to ensure community involvement and place-based planning. Below are processes especially important to placemaking.

Establish a Community Vision of What the Street Is and Should Be

Infrastructure forecasts what later springs from the built environment: a street's public space functions can influence a community's growth aspirations and not just accommodate existing behavior. Determining the optimal uses and design for a given community's streets involves identifying the strengths and needs of its users. Because it involves an adjustment in scale, this is the most important distinction between a street designed to be a place, with many functions, and a street designed for the single function of maximizing car throughput. A process that allows the community of street users to define these strengths and needs and establish a vision for the street is critical.

Involve the Public in Assessing the Strength, Needs and Opportunities on the Street

The project must start by going directly to the residents and neighborhoods to evaluate and establish a vision for the street. A critical part of this will be an assessment of whether places on the street are performing well or need improvement. The assessment should include a grassroots identification of needs for enhancement of underperforming places and opportunities for the creation of new places so that the street can achieve the critical mass of places needed to function as a destination itself. In addition to places on the street, the community should be engaged in an on-site diagnosis of the street itself to determine how it is performing. A variety of tools and audits exist for such assessments, but the community should be engaged in assessing the characteristics, described in the previous section, that make a street a place.

Establish a Community Vision Based on This Assessment

The community process should result in a community-generated vision for what the street can and should be, including the things people should be able to do on the street and the way that people feel doing them. The vision should be generated by people who use the street. Such a vision is generally quite realistic and practical yet contains innovative ideas because the vision is grounded in reality but isn't generated by just one individual or group.

The vision should contain:

- A mission statement of goals
- A definition of how the street will be used and by whom
- A statement of the desired character of the street
- Suggestions and a conceptual idea of how the street could be designed
- Models or examples of places that community members would like the street to be like or elements they would like to use

Develop a Plan Based on This Vision

There will need to be a plan for realizing the vision. It might not include every step to realize the vision, but it should begin to lay out next steps and identify things that all partners, including the agencies, the professionals, and the community, can do to move re-placing the street forward.

Prioritize Interventions Based on This Vision

The vision will contain many ideas. However, some will be more important or more critical than others. Additionally, some will be easier to implement than others. The community will need to prioritize individual ideas and strategies in order to begin to take action in re-placing the street.

Select and Implement Short-Term/Temporary/Pilot Projects

Examples of low-cost, short-term devices that transform streets: San Francisco, CA (Credit: Sky Yim)

First on the action plan should be short-term or pilot projects. Such projects can be a way of testing ideas for long term change at a lower cost while providing flexibility for adaptation and change. Such projects also give people confidence that change is occurring and that the ideas they have contributed matter. This is important because re-placing streets takes time, and smaller, simpler changes can provide small steps that keep people engaged in the process of placemaking. Short-term and pilot projects allow people to see how the street is working with changes introduced gradually over time, enabling people's perceptions of how the street functions and what it should be to change and reducing resistance to change.

New York, San Francisco, Portland, and other cities have quickly transformed streets into vibrant public space with such techniques as:

- Establishing non-vehicular space with planter boxes, temporary curbs, and wooden platforms
- Painting the pavement under the newly repurposed space
- Bringing in portable tables, chairs, and awnings
- Incorporating decorative street painting projects

Examples of low-cost, short-term devices that transform streets:
Broadway, New York, New York (Credit: Paul Zykofsky)

Establish a Maintenance and Management Plan

Maintenance and management is critical because streets are not static—they change daily, weekly, and seasonally—and streets must adapt and be flexible to this change. Thus, public space management may be required. Management becomes especially critical where events, such as farmers' markets, fairs, festivals, and ciclovías, are programmed. Great streets are also well loved and well used. To sustain a quality street environment, the community must commit to long-term investment in the re-placed street.

12. DESIGNING LAND USE ALONG LIVING STREETS

INTRODUCTION

Streets provide access to buildings and land uses of every kind. As discussed in Chapter 11, "Re-Placing Streets," placemaking is the practice of first designing streets and other public spaces as an interconnected network of human-scale "public living rooms" in which the safety and comfort of pedestrians and bicyclists is not subordinated to the requirements of access by automobile, and then coordinating the character and design of the adjoining properties to create a specific type of living environment, or place.

Complementary land-use and street design (Credit: Dan Burden)

All successful and sustainable communities include a range of distinct and different types of places, or environments, from quiet, shady residential streets to busy neighborhood centers, from noisier mixed-use "bright lights" downtowns to larger, single-purpose industrial and employment centers. While the type of land use is one important characteristic of private property design in these places, site and building design are critically important in ensuring that coherent, safe, functional, and valuable places result.

This chapter provides a discussion of the ways in which the planning and design of properties contribute to coherent placemaking. The discussion includes placemaking principles that are applicable to places of all types and to distinct types of places, design techniques for applying the basic placemaking principles, and implementation strategies for embedding these principles and techniques in local policies and regulations.

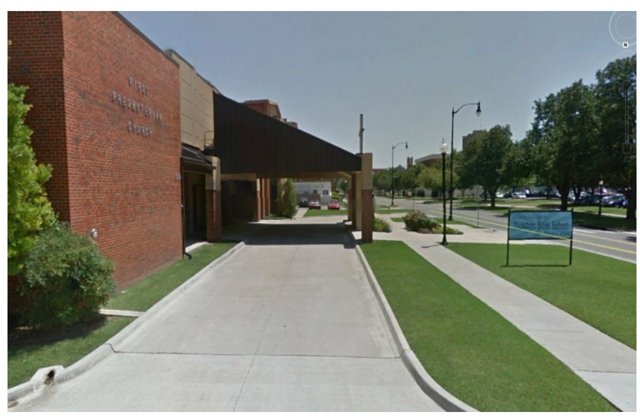
ESSENTIAL PRINCIPLES FOR BALANCED STREET ENVIRONMENTS

The following design principles inform the recommendations made in this chapter and should be incorporated into all street environment design:

- Urban patterns in livable, sustainable places of enduring value are generally based on compactness, connectivity, completeness, and continuity. This describes the opposite of sprawling, disconnected, or single-use development.
- Streets are the outdoor rooms of their neighborhoods, and should be designed

Neighborhood public square integration: Buenos Aires, Argentina (Credit: Ryan Snyder) for and scaled for people. They are also the structural framework that organizes those places, making them legible and navigable.

- The purpose of streets is to let people move about, and every street should provide safety, convenience, and comfort for pedestrians and bicyclists.
- Streets, parks, plazas, squares, and other public places make up the public space network in which all members of the community may encounter one another in the course of their daily lives, regardless of their age, income, or other individual status.
- Street networks designed with pedestrians in mind, as described in Chapter 2, "Street Networks and Classifications," naturally form small to medium-sized blocks that allow pedestrians to comfortably walk to a range of amenities as a pleasant and practical alternative to driving. In existing environments where such a network exists it should be preserved, and in areas where large parcels are being redeveloped, such a network should be inserted.
- The distribution of land uses should be designed to allow everyday destinations (e.g., schools, parks, and retail shops) to be located within a comfortable walking distance of most residences.
- All buildings should contribute to the character of the streetscape, face the street with attractive entrances that welcome pedestrians, and have windows that overlook the street to create a sense of security.
- On-street parking reinforces a pattern in which visitors enter buildings from the street, and can provide an important buffer between pedestrians and moving traffic.
- The setback between buildings and the sidewalk should be designed to enhance the pedestrian experience, whether setbacks are attractive landscaped yards that provide privacy for building occupants or shopfronts at the sidewalk that display merchandise to passing pedestrians. In no cases should cars, parked or moving, be placed between the sidewalk and the buildings.



Good building setback (Credit: David Riesland)

- Off-street parking and service access and their driveways should be designed to disrupt the pedestrian experience as little as possible. Whenever possible, access should be from an alley or shared driveway off a side street and parking and garages should be located behind or beside buildings, not between the sidewalk and the building. When a driveway to the front of the lot cannot be avoided, it should be as narrow as possible.
- Off-street parking, especially surface parking, is a non-productive use, and the amount required should be reduced to the extent possible by utilizing on-street parking and by sharing off-street parking among adjacent uses. Off-street parking requires about twice the surface area per parked car of on-street parking, due to the driveways required to access the lot and aisles needed for maneuvering within the lot. This non-productive space creates dead zones and increases the distances between destinations, further reducing the attractiveness of walking.

- The mix and intensity of land uses should be designed to support and be supported by efficient transit systems whenever possible.

STREETSCAPE ENVIRONMENT TYPES

Every city, town, neighborhood and district is unique. This uniqueness creates a sense of place. However, there are a few general types of places that repeat from community to community, within which the idealized relationship of street to adjacent land uses follows certain general guidelines. The following descriptions of archetypical environments detail concepts and strategies, not finite design solutions. Designs should be based on the best of the local and regional architectural and landscape heritage.

NEIGHBORHOODS

Neighborhoods are the main component of all cities, the places where almost everyone lives. Many of the concepts below are part of the best loved and most valuable neighborhoods, and some of the best new neighborhoods now being built are based on these simple concepts:

- Residences of various types are the predominant land use of neighborhoods, with other uses such as neighborhood-serving retail, small businesses, elementary schools, parks, and playgrounds within a pleasant walk.
- Neighborhoods can be composed primarily or even exclusively of single family homes, or can include a range of multifamily housing types that are designed and scaled for their compatibility with houses. The basic design principles listed here are the same for both.
- Neighborhood streets are the living rooms and play rooms of the neighborhood, and should be designed mainly for the safety and enjoyment of pedestrians, particularly children and the elderly, the most vulnerable pedestrians among us.

Streets and buildings working together create attractive neighborhoods (Credit: Ryan Snyder)

- The streetscape environment of neighborhoods is the most heavily landscaped type, with sidewalks flanked by street trees and landscaped parkway strips on the public side and landscaped front yards on the private. This creates a distinctive streetscape character different from that in neighborhood centers and other mixed-use environments.
- On-street parking serves visitors and residents, and provides a valuable buffer between pedestrians, children at play, and passing traffic.

- Buildings should front the street with gracious front doors and overlook the street with windows to provide eyes on the street and a sense of security for the street.
- Front yard design should create spaces through which residents and visitors come and go in their daily routines, in which neighbors interact and children play, and where food can be grown.
- The front door of houses and active uses within them should be closer to the street than the garage to emphasize the home over car storage and to bring eyes closer to the street.
- Automobiles should disrupt the pedestrian environment (primarily sidewalks) as little as possible. This can be accomplished by providing access to parking and garages via alleys and driveways from side streets, or when necessary via driveways from the fronts of lots (as few and as narrow as possible) to access garages located behind or beside, not in front of, the residences.

NEIGHBORHOOD CENTERS

Neighborhood centers take many forms and occur at all scales, from a country store at a key intersection in a rural neighborhood to a busy little "Main Street" environment in a larger town or city to a high intensity, transit-oriented center at a neighborhood edge along a major urban corridor. Regardless of the scale and character of the neighborhood center, the following set of basic design concepts can define centers that are convenient to pedestrians from adjoining neighborhoods:

Neighborhood center: Glendale, CA
(Credit: Ryan Snyder)

- Neighborhood centers, the name notwithstanding, are generally at the edges or corners of neighborhoods, facing a major street or streets that carry traffic volumes capable of supporting the businesses. An ideal arrangement is a "Main Street" that is located at the conjunction of two or more neighborhoods, making the edges of the neighborhoods into the center of the larger community, and providing a range of amenities and resources within easy walking and biking distance of the residents.
- Neighborhood centers are ideally mixed-use, providing an array of goods, services, employment, and residential options that can function both as an extension of the adjoining neighborhoods and as a convenient destination for people passing through.
- The buildings of these centers should face the primary street, creating a busy pedestrian environment that causes drivers to slow down and see what the center has to offer.
- The ground floor uses in neighborhood centers are generally commercial, providing convenient goods and services to customers; the upper floors can be residential, office, or a mix of both.

- The streetscape in neighborhood centers is usually quite formal: street trees are normally located in small planters within the sidewalk, surrounded by tree grates or very small landscaped areas, providing space for pedestrians to comfortably stroll, and for people to get in and out of cars parked curbside.
- There are many options for the design of setback areas in neighborhood centers, including forecourts with sidewalk dining, narrow landscape zones that soften the streetscape while allowing views of the shops, and simple shopfronts built right to the sidewalk.
- Neighborhood centers can also include purely residential buildings, as long as the design of the ground floor street interface provides a degree of privacy for the residents, either by setting the building back behind a landscaped yard or raising the ground floor above the sidewalk level, or both.
- Except for the smallest centers, which might just be one corner store, neighborhood centers generally require off-street parking, which should be located behind or alongside the buildings whenever possible, not between the sidewalk and the buildings.
- In larger neighborhood centers that require large off-street parking lots, the size of the lots can be reduced if they are shared by uses whose peak parking demand is in the daytime (offices) and uses whose peak use is at night (e.g., dinner restaurants and residences). Reducing parking saves cost, improves environmental performance, and improves the urban environment for people.
- Plazas can create vibrant urban centers. Their design should focus on proper size and scale, active uses, doors and windows fronting the plaza, trees, landscaping, public art, fountains, etc. Stages, bandstands, play fountains, and other features "liven" plazas.

CORRIDORS

This section focuses on major street corridors that connect across an urban area. Corridors can have many different characters and occur at all scales, from a rural main street stop along a highway to a main avenue within a town or a high intensity urban corridor in a large city. Many planning and design concepts are common to corridors at all these scales.

Mixed-use building: Los Angeles, CA
(Credit: Ryan Snyder)

Many major street corridors began as rural roads, evolved into automobile thoroughfares lined with a range of commercial uses, and have lately been losing much of their commercial value, as retail and office uses have migrated to larger-format retail centers and business parks. Many such corridors now present a significant opportunity for communities to provide infill housing mixed with modest amounts of commercial uses within walking distance of adjoining neighborhoods.

The repositioning of these often blighted "commercial strips" as more valuable mixed-use places requires a coordinated redesign of the streets and careful planning of the infill development along the corridor.

The street design principles and practices described in this manual will help create streets that do more than move cars. Using these principles and practices, undifferentiated miles of corridors can be restructured to provide the types of neighborhood centers described above, interspersed with residential or office uses along the street. The core placemaking strategies found in this manual (slowing cars, planning for people, landscaping streets, providing on-street parking, and designing property setbacks to modulate privacy for residences and visibility for businesses) can transform miles of sameness into a sequence of useful places.

Below are of some core design concepts and principles that can help to integrate land uses with such streets to make coherent, human-scale places:

- The entire length of a corridor should be lined with active uses. These can include the neighborhood centers described above at appropriate nodes, multifamily housing of various types, and even single-family housing if appropriately buffered with landscaped setbacks or a multi-way boulevard. Sound walls, berms, and other forms of "pure buffer" are an admission of urban design failure, disconnecting the city rather than connecting it, and should be employed as a last resort.

Blank walls and inactive uses on the ground floor make for poor pedestrian environments (Credit: Ryan Snyder)

- Through a community visioning process integrated with transit planning processes and retail capacity studies, the location and size of neighborhood centers (active, mixed-use, and often transit-oriented nodes) should be determined.
- Long corridors should be analyzed to define the existing or emerging character by segment, then potential nodes, centers or destinations with more focused pedestrian activity can be identified.
- A mix of land uses can be provided to encourage people to make trips by means other than cars in those locations, and a network of streets to assure connections between uses should be available.
- Design standards or guidelines for development within the segments that will remain auto-oriented should be created so these segments can be made as pedestrian and bicycle-friendly as possible (e.g., minimizing the number of curb cut locations and widths that interrupt the sidewalk, buffering street-frontage parking so the sidewalk environment is not compromised, providing setbacks for landscaping and transit amenities wherever possible to encourage transit use).

- In close consultation with the residents of adjoining neighborhoods, the vision and standards for the design and massing of buildings in each segment of the corridor should be developed.

URBAN CENTERS

Urban centers are typically the economic and social hearts of cities or towns. They can be village-scale centers in small towns, low to mid-rise downtowns in most cities, or high intensity urban centers with high-rise buildings in larger cities, where unique regional destinations are often located. Ideally, the urban center environment is a very compact mix of a wide range of land uses, creating high land values as well as a high potential for transportation congestion. Accordingly, it is vitally important that in addition to a balanced street network for pedestrians, bikes, and cars, such places be provided with high levels of transit service. Important design concepts for urban centers include the following:

Urban center: Vancouver, BC (Credit: Dan Burden)

- Urban centers are usually organized around an established network of major boulevards and urban streets that support the businesses and major public institutions. Because networks that are scaled and designed for pedestrians are finite in their traffic carrying capacity, it is critical that transit plays a major role in moving people.
- Urban centers are mixed in use, providing an array of goods, services, employment, and residential options along with important public and cultural institutions.
- Buildings in urban centers should face the primary street (which can often be more than one side of a block), and support an active pedestrian environment.
- Buildings in large urban centers should form a consistent street wall (following a consistent pattern of setback and height); the street wall is typically at the back of a wide sidewalk and appropriate to the character of the street it fronts.
- Along streets with purely residential buildings, the design of the ground floor-street interface should provide a degree of privacy for the residents, with residences normally set back from and raised above the sidewalk.
- Commercial uses generally front the sidewalk with large, transparent shopfronts, but some institutional and office uses commonly connect to the sidewalk environment with lobbies and foyers instead. In such cases, it is important that windows from the offices and other interior spaces overlook the street to support an environment that feels safe.

- For hotels and office buildings that require porte-cochere or drop-off areas for residents or guests, these should ideally be designed to occur at the street edge along the curb zone, and should not impose large curb cuts and circular driveways that interrupt the sidewalk. When such off-street vehicular access must be provided, it should be integrated into a forecourt or entry plaza that is designed first as a public space for people, and incidentally allows vehicular access that does not disrupt the pedestrian environment. The width of the pedestrian zone should be maintained throughout; the furniture and/or frontage zones can be reduced.
- Parking in urban centers should include:
  - On-street parking to buffer pedestrians from faster moving traffic
  - Shared, aggregated parking that is located underground wherever possible
- Above-grade structured parking should be lined with ground floor active uses that front the streets, not exposed or hidden with blank walls. This also applies to upper floors, where stacking exposed parking levels above the street-level commercial uses should be avoided.

Well screened surface parking: Santa Barbara, CA
(Credit: Paul Zykofsky)

Where surface parking lots are unavoidable, they should be behind a building that fronts the sidewalk and public street, or at a minimum screened with attractive landscape or public art to provide a comfortable street edge for passing pedestrians. Vendor kiosks or "slim stores" can also be used for this purpose.

- The key to district parking strategies is creating a supply of available parking that is shared by many uses, whose peak parking demands will be at different times of the day and the week. This, together with a strong transit component and an attractive walking and biking environment, will reduce the required amounts of parking, which in turn will save cost, increase real estate utilization, improve environmental performance, and improve the urban environment for people.

SPECIAL USE DISTRICTS

Special use districts are areas dominated by a single type of land use. One example of this is industrial districts, where manufacturing, production, and distribution of goods are the primary activities. Other examples are employment centers that primarily provide high concentrations of commercial offices, medical centers, and large education campuses. Such districts benefit from a location that provides easy access to regional roads and highways, and the sizes of their buildings, the volumes of truck traffic, and the hours of operation make them generally unsuitable for residential uses.

It is important to note that even within special use districts, there are many opportunities to mix in useful amenities and strong reasons to ensure that all the streets are walkable, bikeable, and served by transit. In industrial, office-dominated, educational, or medical campus districts, this enables restaurants, copy centers, and other support businesses to do well while reducing workers' need to drive out of the district for basic services. These local-serving commercial uses can thrive if the environment supports their patronage, and housing can be integrated as well. Some key principles for the design of such districts include the following:

Outdoor seating livens the street: Culver City, CA (Credit: Sky Yim)

- Districts can foster a critical mass of related businesses that function well in close proximity to each other (like industrial suppliers and manufacturers, or medical offices and a hospital).

- It is important that special use districts be organized around a balanced street network, with development standards to ensure that the urban design does not exclude pedestrians and bicyclists. Many employees and visitors arrive to their jobs by transit or bicycle, so accommodating pedestrians should be as important as moving goods and vehicles between businesses. Many employees who drive or take transit to work walk or bike to local destinations during their lunch breaks.

University of Oklahoma Campus (Credit: David Riesland)

- Where other uses (e.g., restaurants, cafes, and small convenience stores) are interspersed within the dominant land use, they should provide a pedestrian-friendly street frontage to encourage employees or visitors to arrive from nearby businesses on foot.
- Major corridors entering special use districts typically carry heavier traffic and trucks, but also need to safely accommodate bicycles and pedestrians.
- The street network should assure that truck freight traffic has clear paths of travel that do not encroach on sidewalks.
- Buildings in special use districts should provide a good public face along the streets, with noxious or unattractive uses behind buildings or attractive fences and landscaping.
- For special use districts like medical centers, the building frontage and entrances onto the campus and its individual buildings from the sidewalk should be pedestrian friendly and accommodate the mobility impaired. Services open to the public, such as cafés and gift shops, should face the street.
- Campuses, which are generally composed of larger areas without public streets, should have a clear network of pedestrian paths and streets that encourage walking and biking, not driving, and allow neighboring pedestrians and bicyclists to cut through the campus.
- Setbacks in special use districts will vary based on the street and sidewalk character the buildings front; landscaping should be provided along public sidewalks and shade trees should be provided to reduce the effects of urban heat islands, which are common in highly paved industrial districts.
- Parking in special use districts could include on-street parking to buffer pedestrians from faster moving traffic, and where provided onsite should be connected to clear, safe pedestrian pathways.
- Loading docks and service functions should be designed to not conflict with pedestrian entrances from sidewalks into the facility.

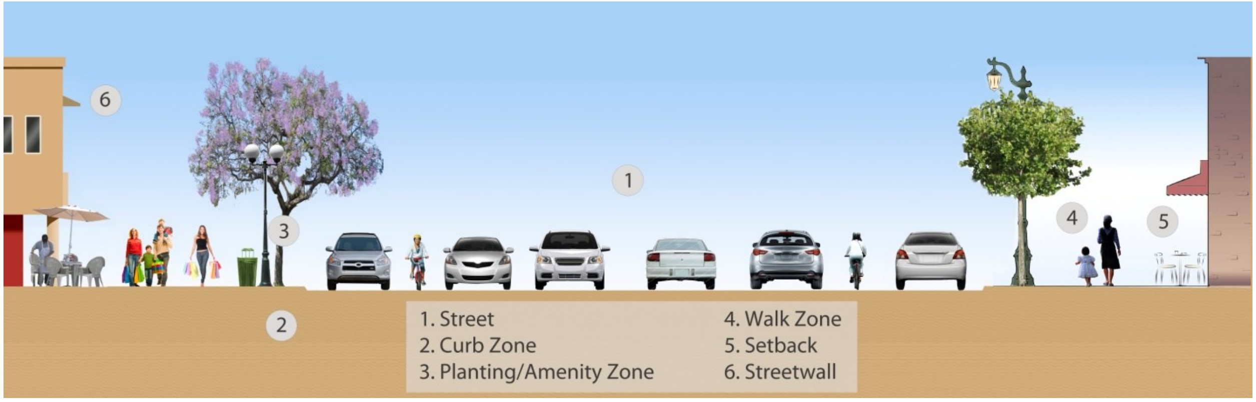
URBAN DESIGN

Urban design is the design of urban environments, whether in small villages, neighborhoods, town centers, or major urban districts. While sometimes used to describe just the selection of sidewalk patterns, benches, and streetlights, the term "urban design" is used here in its broadest and simplest sense: the design of environments in which people live, work, shop, and play.

Urban design considers the relationship of site and building to the street, creates spaces for people, and can define the overall streetscape character: West Hollywood, CA (Credit: Lisa Padilla)

"Land use" is commonly used as a rough synonym for urban design, and often as a substitute for words such as "building," "business," "parking lot," or anything else that is located on a parcel of private property. In this manual, the term is used to refer to the "use" of the "land" in question. Urban design encompasses site design and street design along with the allowed uses within a certain block or district of a city, and defines the nature of people's experience of that place. The design and use of private development—collectively the "private realm" of the city—work in tandem with and shape the public realm of the city, defining the overall character of the place. When the design of the private and public realm work well together, the places they make are often experienced as "great streets" or "great places," and desirable destinations.

Once the desired character of the urban environment and the range of allowed land uses is determined, zoning regulations and development standards are prepared to support the desired type of place and street, so that the buildings that are developed (or are redeveloped) on each parcel play the appropriate supporting role in "completing the street."



The "public room of the street" is an important public space primarily shaped by the land uses and buildings that enclose it. (Credit: Cityworks Design and Michele Weisbart)

Creating great streets with good private realm design starts at the initial phase of laying out a project on a site, including the location and design of the building(s) and the design of the access, parking, and landscape. The following principles are general and are written based on practices that support livable and healthy communities through (i) thoughtful site design, (ii) appropriate building forms, and (iii) good relationships between the building and the sidewalk and street that it fronts.

THOUGHTFUL SITE DESIGN

The orientation of every building affects that building's relationship to people on the street. Each component of building demands careful site design. The following provide site design guidance:

- New projects or buildings developed on large parcels should form new blocks and streets that create a comfortable and walkable block size to help complete the network of streets (see Chapter 2, "Street Networks and Classifications").
- Buildings should be sited to support good connectivity to the center or neighborhood destinations that are nearby.
- Buildings should be oriented to the street to promote sidewalk activity and provide eyes on the street for the safety and comfort of pedestrians.
- The design of the site should minimize disruptions of pedestrian ways, whether sidewalks or mid-block passageways (typically by limiting the number and width of driveways).
- All buildings should be sited with their primary entries and fronts along the sidewalk, to encourage access from the sidewalk and on-street parking on foot.
- The number of driveways should be limited and consolidated. They should be no wider than necessary and designed to allow motorists to see pedestrians on the sidewalk.
- Parking lots and service entrances should be located toward the rear of the lot, accommodating automobiles but making it comfortable for people to access the buildings on foot.

- Wherever buildings are not built immediately adjacent to the public sidewalk, a coherent network of pedestrian routes should extend into the property so that pedestrians approaching from the street can access each building without walking through vehicular drives and parking lots.
- In all cases, the building pattern within a block should be designed to form comfortable, habitable outdoor spaces that promote a "sense of place" and a unique local character. Each building belongs to an individual or a business—the "community" is what happens between the buildings.
- The impacts of building form and site design on the larger neighborhood or district environment should be taken into consideration. For example, storm water can be managed on private property to reduce demands on the street infrastructure (collection and percolation), poorly functioning irrigation systems can be corrected (to minimize water waste and unnecessary run-off to the street), and building forms can be designed to provide access to fresh air and sunlight to their occupants and passersby on the sidewalk.

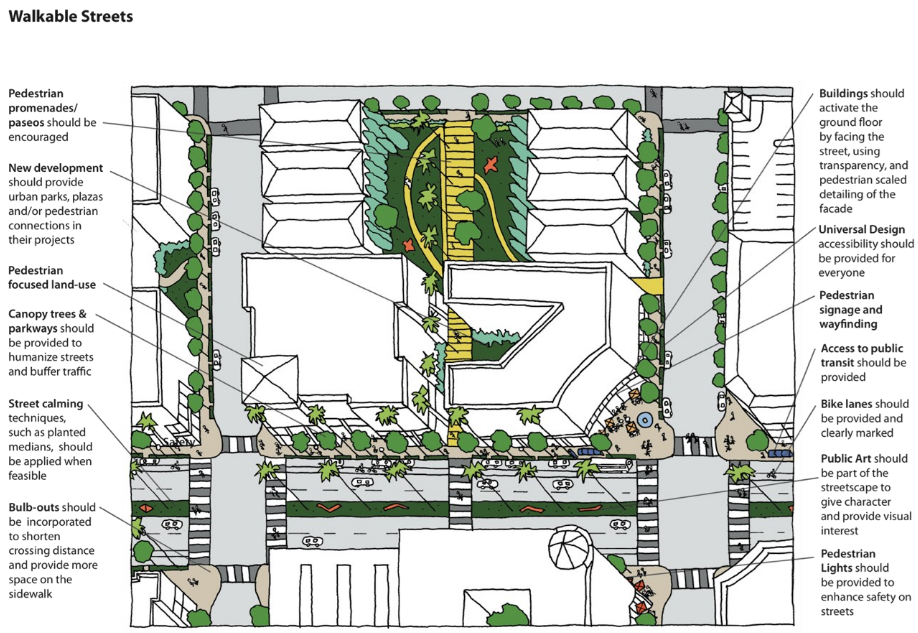
BUILDINGS' RELATIONSHIP TO SIDEWALK

Each building directly interacts with the adjacent sidewalk on a micro level. The following provide guidance for designing buildings with sidewalks in mind:

- Buildings contribute to the overall character of the street by providing well-designed frontages and clear entry points from the sidewalk.
- For active mixed-use and commercial streets, building frontages should be mostly transparent with "active storefronts" that allow pedestrians to see into shops, restaurants, and public spaces.
- Along residential streets, building frontages should include windows overlooking the street with a layering of landscape, porch, patio, or semi-public space that buffers appropriately (setbacks will vary based on street typology and scale of the buildings).
- The primary building face should be located on the most active street frontage with an attractive and welcoming facade that includes entry doors, windows, signs, and other character-defining elements.
- The secondary building face that exists along a mid-block passage or side street should also include openings overlooking the public space.
- The tertiary (back) side of the building is located along a back alley or service drive where pedestrian movement is secondary to service, with loading docks, service entries, trash storage, and other unattractive functions accommodated here.
- Blank walls should be limited to the rear, and very limited along the secondary face.
- Lighting should be integrated into the building design to indirectly illuminate the sidewalk at night by (i) light filtering through storefront windows, and (ii) architectural lighting that features the building itself and enriches the street environment at night.

APPROPRIATE BUILDING FORMS

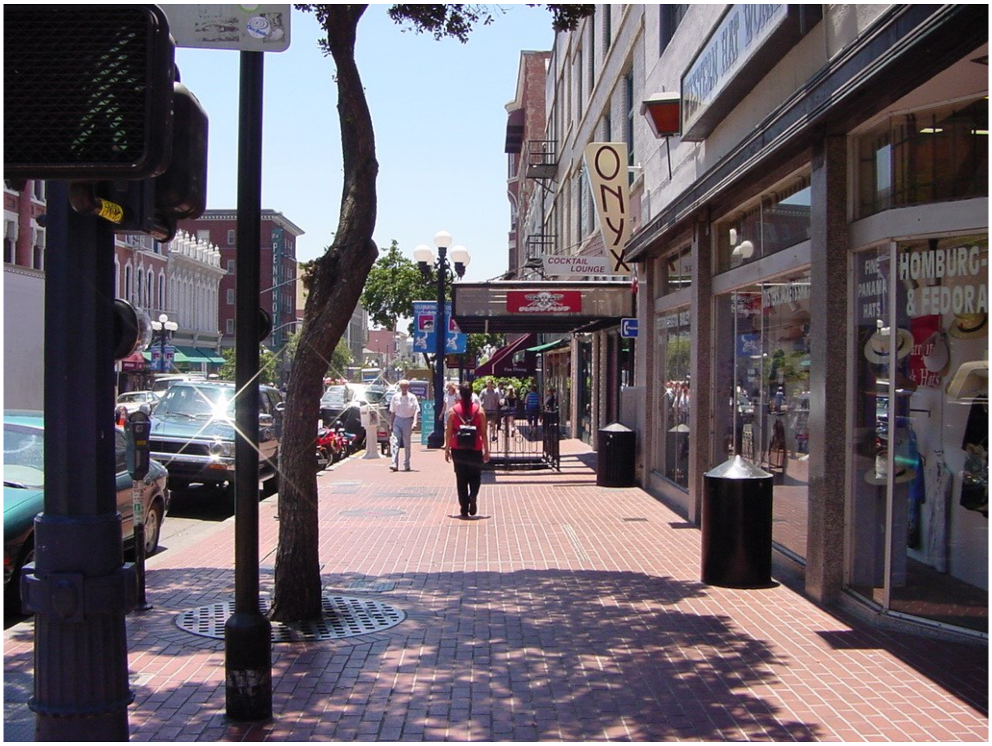
Every building interacts with the street, so the details of key aspects of its form need careful consideration. The following provide building form design guidance:



Everything from the block size to the design of buildings and open spaces contributes to making walkable streets. (Credit: Cityworks Design)

- Building height, density, and setbacks are planned and designed to create a specific type of place that has a certain scale and character closely coordinated with the street typology.
- Building design standards should be developed to support a healthy street environment for pedestrians: for example, designing buildings to take into account how they interact with strong winds to create wind tunnels or unnecessarily restrict flows of natural light and air.
- On active mixed-use and commercial streets the design of the lower 3 to 4 floors should have an appropriate level of transparency and detail to support a great sidewalk environment for pedestrians.
- Buildings of 1 to 3 stories should be designed entirely at a pedestrian-oriented neighborhood scale, with features that can be appreciated by people walking or bicycling.

- Mid-height buildings of 4 to 6 stories should be designed at a pedestrian-oriented scale at the lower 2 to 3 floors and integrate windows, balconies, and other features that provide opportunities for occupants to overlook the street from upper floors.
- Taller buildings (over 6 stories) should generally have a base of lower floors designed similarly to those of mid-height buildings, and may benefit by stepping back from the frontage above this level to provide a street character that is not overwhelming to the pedestrian.
- In most mixed-use districts and neighborhood centers, it is more important to provide a relatively steady "street wall" to define a simple "street as an outdoor room" than to provide varied setback and stepbacks to "break up the mass" (see preceding section on streetscape environment types). In suburban environments where buildings stand free in the landscape, the desire to articulate the building form is understandable. However, in urban districts and centers the primary placemaking role of buildings is to calmly define the space of the place rather than to "express themselves" as unique objects.
- Towers in very dense districts (like an urban center) should be slender and mostly transparent, with a low to mid-rise base that provides pedestrian-oriented features. Towers should be designed to appear attractive and approachable from the street and sidewalk, not just to be an icon in the skyline.
- Parking should be integrated into the site and building design; ideally parking would be (i) underground, or (ii) tucked behind the building fronting the sidewalk and accessible from an alley or side street, or (iii) sited internally to the project or block so buildings "wrap it" to the greatest degree possible.
- Buildings should be designed applying universal access principles (like locating stairs in prominent locations to encourage people to use them) making naturally legible paths through good design and an integrated site and building design approach.



Active ground floor uses (Credit: Ryan Snyder)

POTENTIAL IMPLEMENTATION STRATEGIES

Tools available to help implement good urban and architectural design that support the creation of good streets and great places include the following:

- Community-based vision plans, which are critical agreements or road maps that articulate how communities see their streets, neighborhoods, districts, and future growth
- Zoning standards that allow, encourage, and require a diverse mix of land uses that support the creation of sustainable, valuable places
- Standards and guidelines associated with this type of zoning that shape and coordinate development with street design to ultimately deliver residents and stakeholders a fully realized vision that is authentic and unique to their community, and that supports a healthy, pedestrian-centered lifestyle

HEALTH AND LAND USE

Good land use planning and urban design can help create healthy neighborhoods with great streets and innovative and sustainable buildings. Some planning principles that should be considered include the following:

- Create a variety of places where people choose to walk and feel safe doing so—walking is an important form of daily exercise than can easily be integrated into the design of communities
- Provide opportunities and incentives to create social environments in which all generations mix. These could include public or private facilities that accommodate both youth and senior activities, or planning development where adjacent uses allow different generations of the community to interact on a regular basis. By contrast, environments in which one must drive from one daily activity to the next systematically exclude the very young and the very old, who cannot drive and become "involuntary pedestrians" in environments designed for cars.

Outdoor sidewalk social environment with activities for all ages: Venice, CA (Credit: Dan Burden)

- Assure access to healthy foods and grocery stores; limit fast food establishments and allow drive-through service only in places where it is in the community's best interests to have passersby shopping without turning off their engines
- Capture opportunities for farmers' markets – ideally on streets or within public spaces that are central and part of the local neighborhood street network
- Look for underutilized public space to provide community gardens within neighborhoods, which will encourage gardening and social interaction and provide access to fresh produce
- Integrate exercise routes and equipment into the network of streets, or even within underutilized roadway space (for instance, expanding neighborhood parkways where parking can be sacrificed, or a striped section of roadway that isn't being used by cars but could be adopted for use by people)

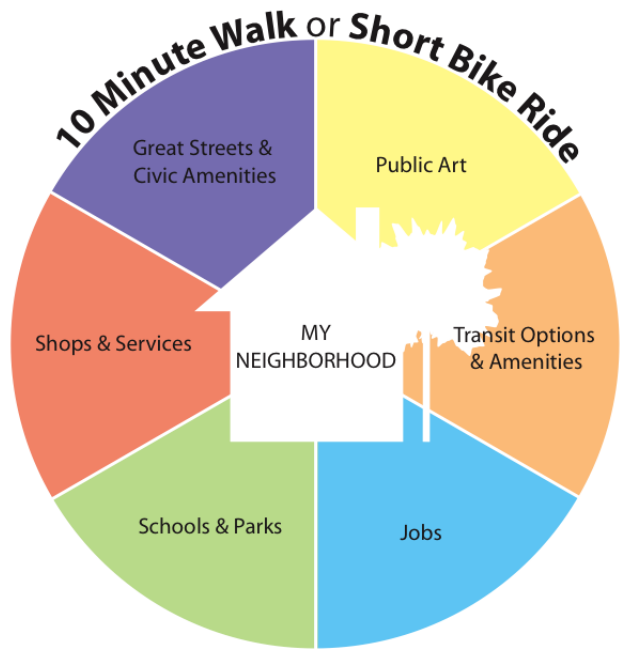
- Promote sustainable planning practices and building design that help to preserve the environment through energy efficient design. Allowing residents and visitors to access the buildings without driving is the foundation of energy efficient design.
- Ensure complete bicycle networks and provide amenities within new projects to promote bicycling as appropriate to the scale of the project (bike racks, bike lockers, showers, or even a bicycle station)

New development should be planned to promote sustainable design and integrate gardens and open spaces that can be enjoyed by residents, or by pedestrians walking by.
(Credit: Bridge Housing, David Baker Architects)

BENCHMARKS

Good land use planning and urban and architectural design are best measured by how they complete the community's vision for the specific place, and how they enhance the daily lives of their residents and users. Other qualitative and quantitative metrics that could be used to evaluate their effectiveness include the following:

- Jobs within a 15-minute commute by public transportation, bicycle, or walking
- Convenience shopping within comfortable walking or biking distance
- A school or park that a child can walk to/from home
- Useful transit within a 10-minute walk from home and/or work
- Clear zoning standards or design guidelines that help assure planning and design will be implemented as envisioned by the community
- Increased land values coming from the effective melding of transit, land use, and design
- The creation of great streets or places that people want to spend time in or live near



Proximity of amenities in walkable neighborhood
(Credit: Cityworks Design)

13. RETROFITTING SUBURBIA

INTRODUCTION

Suburban development (Credit: Ryan Snyder)

Much of suburbia will have to change in order to thrive and meet the health, environmental, and economic challenges of the coming decades. Because of their form, widely separated land uses, and disconnected street networks, most suburban areas lack walkability and require that people travel by car for most of their needs. This has serious environmental consequences (poor air quality, climate change, and high energy consumption) as well as health consequences as suburbanites live in environments that discourage active transportation and favor driving. Residents in these neighborhoods tend to become isolated due to the lack of walkable streets and walkable destinations. Increasing fuel costs pinch both family budgets and local economies as people have less discretionary income.

Suburban street (Credit: Ryan Snyder)

Changing demographics also present challenges. Suburban homes have been built to accommodate young families with children, but fewer households now fit that profile. More and more households are comprised of empty nesters, young singles, divorced adults, and other non-nuclear families, and this trend is expected to grow in the future.

As fuel prices rise and as residents age, suburbs will need to serve more of their residents' needs closer to home, and serve those needs in places that can be reached other than by driving. Suburban areas will need to be retrofitted to accommodate a new reality that rewards places that are close to more people and reachable in many ways.

This chapter describes how streets can support retrofitting suburbia, provides strategies for retrofitting streets, and recommends priorities and phasing. All of the changes recommended in this chapter will improve safety. The first priority for a city beginning to retrofit itself for the future should be to find and fix the places that are unsafe.

TRANSFORMING SUBURBAN STREETS TO LIVING STREETS

Streets play an enormous role in determining a place's quality of life. Everywhere in the country, people prefer a certain kind of street ("Redefining Charlotte's Streets," Urban Street Design Guidelines, Charlotte, North Carolina, 10/22/2007). People's favorite streets include those with:

- An abundant tree canopy and other streetscape features
- Sidewalks and buffering from traffic
- Moderate traffic speeds
- All kinds of uses (walking, cycling, driving, and enjoying the lawns or sidewalks and patios on either side)

People need not know the term "living street" to recognize and enjoy one.

The least favorite streets are those where driveways, parking lots, and utility poles are more abundant than trees and people. They often consist of wide expanses of pavement for moving traffic, and make little or no provision for any other users. In particular, there is little opportunity to cross the street.

The challenge for cities with too many least favorite streets is to transform them into most favorite, living streets.

CHANGING STREETS WITHOUT CHANGING THE RIGHT-OF-WAY

By definition, a retrofit occurs on an existing street. This manual gives design guidance for all streets, existing and new. The following section recommends how to accommodate those design recommendations on *existing* streets. Many aspects of living streets actually take *less* space than typical suburban design.

To create a living street in the right-of-way of an existing street, cities should do the following (LaPlante, J., "Retrofitting Urban Arterials Into Complete Streets," 3rd Urban Street Symposium, June 24-27, 2007, Seattle, WA):

- Consider opportunities to narrow travel lanes.
- Seek opportunities to put streets on a road diet; this involves eliminating superfluous travel lanes. Common scenarios include:
    - Consider conversion of candidate four-lane undivided roads to a center turn lane, two travel lanes, and two bike lanes. If the traffic volumes allow this sort of change, the result can be improved safety and access to adjacent destinations; the center

Curb extensions with outdoor seating (Credit: David Riesland)

turn lane can be replaced with short sections of medians and pedestrian crossing islands in selected locations. On-street parking can be substituted for bike lanes where the context and conditions warrant it.
    - Consider reduction of seven-lane roads to five lanes if conditions suggest such a change is appropriate
    - Remove a travel lane from three- and four-lane one-way streets
- Make sure that corner curb radii are designed for the appropriate design vehicle. Occasional encroachment by larger vehicles into other travel lanes is acceptable; intersections should not be designed for the largest occasional vehicle.
- Eliminate unnecessary turn lanes at intersections, such as right-turn lanes with very few right turning vehicles. Free-flow right-turn lanes**,** including freeway entry and exit ramp connections to surface streets, should be replaced with YIELD control.
- Replace painted channelization islands at intersections with raised islands, to give pedestrians a true refuge, and to break up a long crossing of many lanes into smaller discrete steps.

All of these changes can free up space, which can be used for additional elements. To improve street quality, cities can:

- Paint bike lanes
- Add sidewalks
- Add raised medians, which visually narrow the roadway and provide a median refuge for midblock crossings
- Provide median and parkway landscaping, which further visually narrows the roadway and provides a calming effect
- Add or retain curb parking, which improves community access, calms traffic, and buffers pedestrians
- Add bulb-outs, which shorten pedestrian crossing distances and improve sight lines

Non-Physical Changes

In addition to physical retrofits, cities can and should adapt existing street management and operations to:

- Adjust signal timing for slower speeds and to ensure comfortable crossing times for appropriate populations. In areas with aging populations, for example, crossing times may need to be lengthened.
- Work with transit agencies to improve bus operations
- Work with schools to develop a Safe Routes to School Program
- Reexamine the parking code (for example, off-street parking requirements may be reduced, especially in coordination with additional on-street parking)

Street Crossings

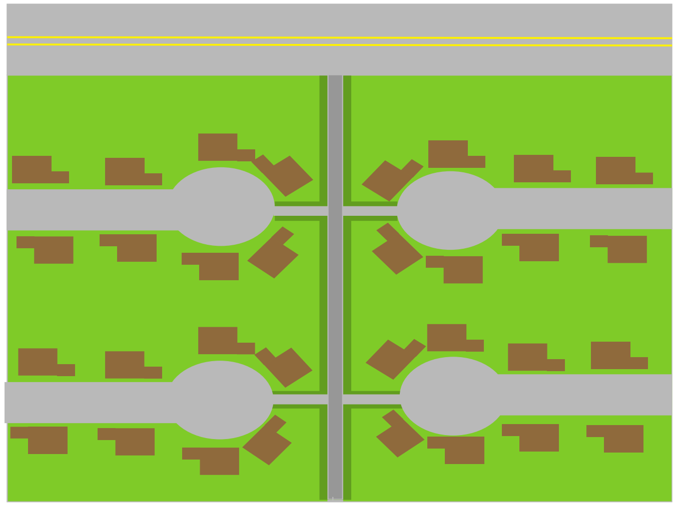
Midblock crosswalk (Credit: David Riesland)

A connected sidewalk network includes street crossings. See Chapter 4, "Intersection Design," and Chapter 6, "Pedestrian Crossings," for design details. To improve street crossings, jurisdictions can consider the following:

- Make pedestrian crossing locations safe, comfortable, and more frequent (LaPlante, J., "Retrofitting Urban Arterials Into Complete Streets," 3rd Urban Street Symposium, June 24-27, 2007 Seattle, Washington.)
- Allow crossing at every corner of all intersections
- On streets with a bus route, make provisions for pedestrians to cross the street at all bus stops. Bus riders need to cross the street either coming or going. Provide midblock crossings. Pedestrians should not be expected to travel to the closest intersection to cross the street. Signalized intersections in suburban areas are often spaced ¼ mile, ½ mile, or even further apart; it is unreasonable to expect people to walk that far to cross the street. Nor do signalized intersections offer safety benefits to pedestrians, due to the many added turning conflicts at large suburban intersections.

Many of these changes can be made through spot improvement programs. Many are relatively inexpensive; it is not necessary to wait for a reconstruction to create a living street. More substantial retrofits may require reconstruction (see the Model Project section at the end of this chapter). A planned surface repaving project is an excellent time to retrofit the corridor to add comfort, convenience, safety, aesthetics, and economic value.

RE-ESTABLISHING STREET NETWORKS



Connecting cul-de-sacs (Credit: Marty Bruinsma)

Chapter 2, "Street Networks and Classifications," details the need for interconnected street networks with short blocks. Much of today's suburban landscape was built in isolated pods: residential subdivisions, business parks, shopping centers, and schools that are poorly connected to neighboring properties. These pods create barriers to getting around other than in a car, because they create long distances between destinations and because the pods are often surrounded by sound walls, fences or berms, literally blocking potential bicycle and walking routes. These pods don't *work* well for auto traffic either, since they force all traffic onto busy streets rather than allowing connection and local circulation through local streets.

To create a vibrant suburb that will thrive in new conditions, direct connections must be created or re-created to enable efficient, direct travel by everyone. That means establishing or re-establishing street and sidewalk networks.

Re/establishing a street network can be more challenging, particularly when right-of-way has not been preserved. Some cities have purchased homes at the end of cul-de-sacs, put the connectors in, and then sold the homes. In cases where a city is still developing suburbs, it should make connectivity a fundamental priority by following the principles in Chapter 2, "Street Networks and Classifications."

Cul-de-sacs break up connections.
(Credit: PB Americas, EWA Connection Study, May 2009)

Pedestrian networks can be re-established by opening noise walls and connecting new sidewalks. (Credit: PB Americas, EWA Connection Study, May 2009)

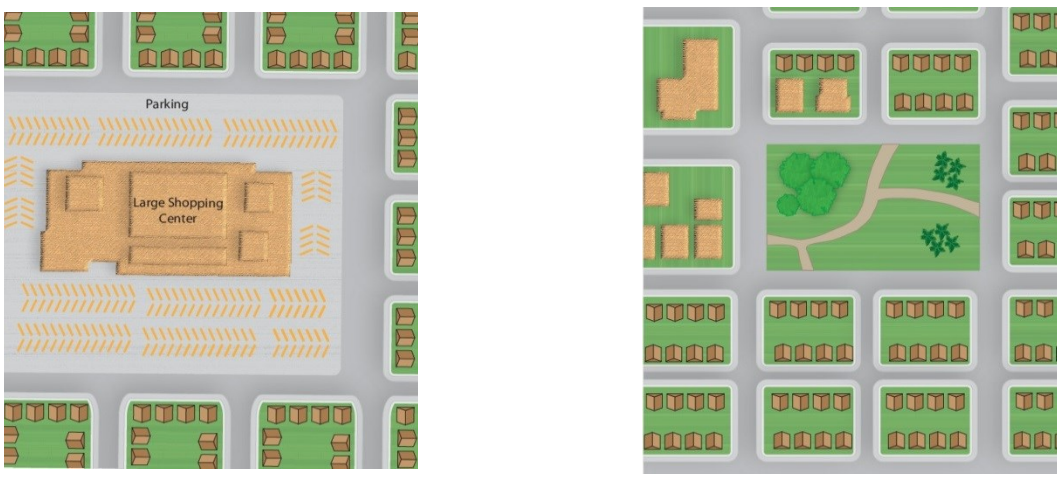
SECOND-GENERATION LAND USE ALONG TRANSFORMED STREETS

Not only streets will need to change in suburbia; many land uses are obsolete and/or no longer economically viable. However, street improvements generally come before land use change in suburban retrofitting. This is because *high-quality land uses come to high-quality streets.* Very rarely will high-quality land uses come to low-quality streets.

The street and the land use work together and determine whether a place is attractive and draws people and investment. To that end, communities retrofitting older suburban areas would do well to use the following three principles:

1. Focus new investment in nodes on streets.

   In most of suburbia, there will not be enough investment all at once to transform whole corridors. Identify and focus investment at individual nodes.



Conversion of shopping center to a neighborhood
(Credit: Michele Weisbart)

2. Focus revitalization efforts on creating genuine places in those nodes: compact, mixed-use, and at least internally walkable.

   Plan for and enable neighborhood-serving commercial districts. Where necessary, rezone from automobile-oriented commercial sites (gas stations, convenience stores, and fast food outlets). These car plazas are designed for, and dependent on, vehicular access and offer no relationships with the nearby residential areas. They absorb retail potential and will tend to discourage development of neighborhood-serving commercial districts.

3. Carefully detail the desired outcomes.

   Retrofit efforts should pay attention to the details described in the various chapters of this manual. Adopting well-intentioned policy goals is not enough. Follow through is needed by incorporating the vision's details in design and construction of the project.

Infill development between nodes that follows the principles of this manual will help to connect the nodes into livable neighborhoods.

SETTING PRIORITIES AND PHASING

The primary challenge in retrofitting suburbia is less about fixing the infrastructure and more about creating economically sustainable places—with the emphasis on place.

As suggested above, the priority should be to begin by creating vibrant nodes. Cities should not allow themselves to be daunted by the scale of the retrofit challenge. As with street retrofits, creating places can be done incrementally. The images on the next page show such an incremental process.

Example of a transformed suburban street (Credit: Urban Advantage, Inc.)

MODEL PROJECT: BRIDGEPORT WAY

Before, Bridgeport Way in University Place, Washington, was a classic auto-oriented suburban arterial street. The existing street had a high accident rate, and did not support economic growth; it attracted neither people nor investment.

Bridgeport Way before transformation: University Place, WA (Credit: Dan Burden)

After reconstruction, the corridor served more people, was far safer, and drew economic development.

Bridgeport Way after transformation: University Place, WA
(Credit: Michael Wallwork)

Safety improved significantly:

- 7% speed reduction (35.3 -> 33.4 mph)
- 60% crash reduction (19 -> 8 in five blocks)

Bridgeport Way illustrates the principle described above of leading with a street retrofit, then following with bringing higher-quality land uses to the now high-quality street.

The City of University Place identified empty, redevelopable space along the corridor and at intersections. The photo below shows ample space that has been used for parking, building setbacks, and other uses.

Bridgeport Way transformation opportunities: University Place, WA
(Credit: Michael Wallwork)

The City planned for new development that would create a new *place,* as shown in the rendering below.

Bridgeport Way plan: University Place, WA (Credit: City of University Place)

ADDITIONAL RESOURCES

ICF International with Nelson\Nygaard Consulting Associates and Reid Ewing. *Transportation Study of the U.S. Route 1 College Park Corridor*, July 14, 2008.

PB Americas, EWA Connectivity Study, May 2009.

Dunham-Jones, E. and Williamson, J., *Retrofitting Suburbia: Urban Design Solutions for Redesigning Suburbs*, John Wiley & Sons, 2009. This book focuses more on retrofitting parcels of land, rather than on the streets between them. Nonetheless, it is an excellent resource.

14. COMMUNITY ENGAGEMENT FOR STREET DESIGN

INTRODUCTION

Effective community engagement is critical when developing policies and projects that make a community's built form more livable and more supportive of active transportation. There are many benefits of effective community engagement in projects influencing the built environment, be they urban, suburban, or redevelopment projects.

Public workshops should involve people in the planning process. (Credit: Dan Burden)

Effective community engagement improves the success rates of policies and projects affecting the built environment because it helps the agencies and organizations leading a project understand and respond to local conditions. Agencies that create true community engagement are more successful at adapting to socio-economic changes that may influence the effort than those that do not conduct effective outreach (Cogan, E. and Faust, S., *Innovative Civic Engagement Tools and Practices in Land Use Decision-Making*, April 2010). When people affected by a project are involved from the beginning of the planning process, the likelihood of unexpected or significant opposition when it comes time to implement the project is reduced. Community members also have unique knowledge of local contexts, including political, cultural, and geographic settings. By interacting with the public and gaining local insight, project leaders can shape and direct the project in keeping with the community's vision and needs.

Effective community engagement also has the power to build social capital—the "social networks and interactions that inspire trust and reciprocity among citizens" (Leyden, K., "Social Capital and the Built Environment: The Importance of Walkable Neighborhoods," *American Journal of Public Health,* 2003, 93[9]:1546–1551). A community with a high level of social capital is characterized by a culture of neighbors knowing each other, interest and participation in local politics, high rates of volunteerism, and diversity in social connections. These characteristics foster a sense of community, engender trust, enhance innovative problem solving, and increase the likelihood that stakeholders will support financial investments in community projects.

Research has demonstrated that a population can achieve long-term health improvements when people become involved in their community and work together to effect change (Hanson, P., "Citizen Involvement in Community Health Promotion: a Role Application of CDC's PATCH Model," *International Quarterly of Community Health Education,* 1988-89; 9[3]:177-186). Thus, even before projects are fully developed, creating a strong community engagement process sets the community on a path toward improved health. Effective community outreach also helps address unequal access to health, including issues such as active living. Health equity, or the fair distribution of health determinates, outcomes, and resources regardless of social standing, is affected by factors such as poverty, housing, language, quality of education, and quality of healthcare. Through successful community outreach, people of all backgrounds and social standing are able to contribute to projects that support health and well-being. They also can help project leaders better understand how social, cultural, and economic barriers that impact historically disadvantaged communities are relevant to improving community health and well-being.

This chapter reviews principles and strategies to engage communities, including developing a plan for reaching out to communities, broadening the list of community stakeholders, fostering cultural competence, and achieving informed consent.

ESSENTIAL PRINCIPLES OF COMMUNITY ENGAGEMENT

Given the many benefits offered by true community engagement, it is clear that project leaders, policy-making bodies, government agencies, health agencies, and community organizations have a special obligation to develop an inclusive approach to outreach. To engage communities, leaders must move from the conventional model to one that focuses on outreach, capacity-building, inclusiveness, and collaboration. Employing the following principles and strategies will help.

DEVELOP A PLAN

Project leaders shouldn't begin a public process without first developing a thoughtful and thorough community outreach plan that describes the desired outcomes of the project, and details the public process, including who the stakeholders and audiences are, how they should be reached, the messages to garner interest and tools that will be most effective in reaching them, and how the success of the effort will be measured. The plan should describe how outreach efforts will help build capacity, promote a shared language, illustrate project benefits, and inspire participation.

In general, community engagement activities need to address issues that the public perceives as important. Thus, while developing the community outreach plan, project developers should seek ways to explain to the public why the project matters. Additionally, efforts should be made to conduct workshops, events, or meetings in places that are comfortable and familiar to the audiences, and to use language that is clear. Each communication or event should contribute to the public's understanding of the project and its purpose.

This chapter does not provide a template for a community outreach plan; it provides general guidance to help project leaders understand important principles and methods of achieving community engagement. With this guidance, a community outreach plan can be developed that utilizes best practices to accommodate local contexts and support community needs in working toward the goal of the project.

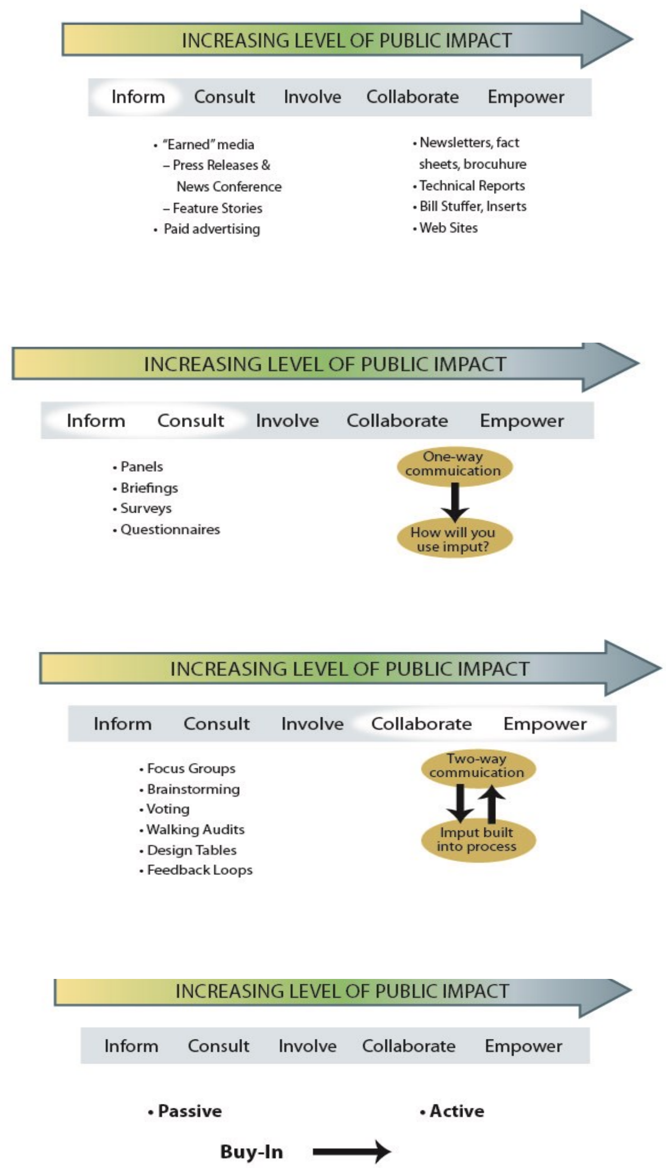
A community outreach plan should at the very least describe the project, the goals of the outreach effort (definition of success), identified issues, target audiences, messages that are meaningful and relevant to the audiences, distribution channels, key messengers or speakers, resources available, tools, timelines, desired outcomes, and methods of evaluation and adjustment.

Specific outreach tools may include educational workshops, media outreach, paid advertising, surveys, print materials (such as flyers and brochures), PSAs, educational videos, slide presentations, charrettes, newsletters, websites and other online communications, social media, direct mail, letters to the editor or guest commentaries, councils, speakers' bureaus, partnerships, coffeehouse chats, meetings, interviews, demonstrations, bulletin boards, and more.

Accept Responsibility for Success

Project leaders must take responsibility for developing effective and successful outreach programs that achieve identified goals. A meaningful outreach message would be that community members' input is needed to shape the community's future; the announcement would speak of streets, sidewalks, trees, and parks, would explain that transportation systems are integral to community-building, and would request residents' help to determine what their community should become.

If truly effective community outreach was conducted and the public showed little interest in the process, then the value of the project to the public must be revisited. If, on the other hand, project leaders understand the project truly is important and the public simply hasn't engaged, then the effectiveness of the outreach effort must be revisited. Were the messages meaningful to the identified stakeholders? Were events held at convenient and comfortable times and places? Did people perceive the process as interesting, simple, important, or relevant to their lives? Did the messages even reach the target audiences?



Credit: Michele Weisbart, adapted from the International Association for Public Participation)

Appropriately defining success and failure of a public process is an important part of developing a community outreach plan.

When defining success and failure, consider whether the community engagement effort should be designed to:

- Inform: community members are informed about the project but aren't actively involved in the process.
- Consult: the public is asked to provide feedback on analyses, alternatives, and decisions.
- Involve: feedback loops allow community members to influence multiple stages or drafts of the project.
- Collaborate: the public is a partner in each phase of the decision-making process and provides direct advice on solutions.
- Empower: the final decision is in the hands of community members and the project leaders will implement what the community chooses. Care is taken to ensure that the community is educated about approaches that work for all people, that key participants will help spread the word throughout the community, and that community members will play an active role when issues come before policy or decision-making groups such as councils and commissions.

Outreach programs that most actively engage and empower the public also lead to the highest levels of buy-in and build the greatest support, which help alleviate some of the pressure on staff and elected leaders.

Start with a Base of Shared Values and Build Understanding

Start the public process with visioning sessions or educational workshops that identify or clarify shared values. In some communities, a vision plan already exists and in those cases, the vision plan should help guide the project development. In other communities, a simple values-clarification exercise during an initial public workshop can go a long way toward helping stakeholders see that they generally want the same things for their streets—safety and security, economic development, attractive sidewalks, landscaping, and so on—and that their goal should be to collaborate on ways to achieve those ideals through the project being developed. Values clarification also can provide useful guidance to policy makers when trade-offs are concerned, for example, when the potential long-term effects of a decision are measured against short-term gains or losses. Starting with a base of shared values helps ensure outcomes aren't predetermined, but that the local vision is driving the process.

From this base of shared values, strive to build understanding and knowledge. Think like an educator, use language that is familiar and clear to the audience, and encourage reciprocal learning (learning from each other) and experiential learning (learning by doing or experiencing). Frame issues neutrally to maintain credibility and to ensure participants can make informed decisions. Facilitate well-informed and well-rounded discussions that ensure all voices are heard.

Toolbox: Active Workshops and Design Charrettes

Two tools being used by more and more communities throughout the country are active workshops and design charrettes.

Active, or experiential, workshops get participants out into the community to explore firsthand what shortcomings exist and how to improve upon those conditions. Active workshops include educational presentations, but focus on active learning and firsthand experience. Active workshops don't have to be long events. A successful one can be as short as three hours, if planned well.

Design charrette engaging stakeholders
(Credit: Dan Burden)

Charrettes are collaborative sessions to solve design problems. Charrettes usually involve a group of designers working directly with participants to identify issues and create solutions. A charrette can be one day, several days, or weeks. A charrette conducted as part of a public process for a street should include educational activities (such as short presentations and walking audits, sharing of expectations and desired outcomes, priority setting, mapping exercises during which participants break out into small groups and mark-up maps with potential challenges and opportunities) and building consensus or informed consent for a proposed solution or set of solutions. Charrettes create a collaborative planning process that harnesses the talent of residents, town-makers, community leaders, and public health officials alike. At the end of the charrette, project leaders present the outcomes and findings to stakeholder groups and to the public.

Getting all the right people together for a design charrette is essential to make sure that the outcome reflects the values and goals of the community. People from all sectors of society with diverse backgrounds are needed at a charrette, including local government officials, planners and designers, landscape architects, transportation engineers, nonprofit managers, public health officials, and of course, residents.

Even with engaged and motivated participants from all relevant backgrounds, the charrette still may be missing a group that can provide valuable insight about how to design a healthier and happier community: children. Children's charrettes can bring valuable stakeholders in that might not otherwise be able to participate. They also provide the benefit of a unique perspective. The chief objectives in a children's charrette are for it to be fun and engaging. Work with schools, parks and recreation departments, and parent/teacher associations to identify the best venue for engaging children and to conduct the needed outreach to ensure children attend. Also, make sure children's charrettes are age appropriate.

Effective active workshops and design charrettes help build social capital in the community. When people are taken outside of a classroom or presentation structure and are put in an environment, such as designing around tables or walking along streets to evaluate the built environment, where they can converse freely and naturally with others, many shared interests and connections emerge. This can foster partnerships that cross real or perceived boundaries, such as differences in generation, culture, socio-economic status, or geography. Effective workshops and charrettes often dedicate time toward the beginning of the events to help participants get to know each other through ice-breaking exercises that ideally will lead to long-lasting relationships.

Planning and conducting successful active workshops and design charrettes requires attention to the following details:

South Gate Bicycle Plan Workshop Flier (Credit: City of South Gate)

- **Engage key partners early.** Identify community-based organizations, government agencies, healthcare providers, employers, school boards, the media, and other organizations whose members or stakeholders may have an interest in the topic. Engage transportation, planning, emergency services, public health, and public works entities early in the planning process, and then enlist their help to conduct outreach and to issue invitations.
- **Choose the right audit site**. Work with the key partners to identify an audit site that captures the essence of changes needed throughout the community, or one that will have the greatest impact or has the potential to become a model project and serve as a catalyst for other projects.
- **Consider comfort and abilities**. Give careful consideration to participants' comfort and abilities. Everyone who wishes to take part should be able to do so, and any special needs should be accommodated. Also, if the event is held during hot or cold months, conduct outdoor portions during the most comfortable time of day. Accommodate the needs of participants: for example, providing food allows working people to attend a 7 p.m. workshop; parents may need an organized play room for children too young to participate in the workshops.
- **Encourage relationship-building and provide a next step**. Effective workshops and charrettes will motivate and inspire those who take part, and many will be eager to contribute their energies toward enacting change. They will need to draw upon each other's strengths, stay in contact, offer each other support, and share information to undertake the important work to be done. Encourage them throughout the event to network with each other and exchange contact information. If possible, form a "working group" and decide upon a first meeting date; invite people to opt in.

In particularly successful workshops and charrettes, project leaders can stand back and observe while residents pore over maps, draw meaningful new lines, find ways to improve access to healthy eating and active living, and generally work together toward a shared vision. Project leaders will need to provide technical guidance, but the community can and should make choices about the future together.

BROADEN THE LIST OF STAKEHOLDERS

Involve all types of stakeholders (Credit: Dan Burden)

To build effective community engagement, project leaders should broaden the list of stakeholders and partners whose involvement is sought. The overarching goal should be to achieve diversity by involving a demographically and geographically balanced group of people representing various interests and backgrounds.

Stakeholders and partners commonly include city and county staff, advocacy groups, residents, business operators, property owners, elected officials, community leaders, neighborhood safety groups, emergency responders, school representatives, health agencies, "Main Street" or downtown groups, charitable non-profit organizations, and regional employers. To be more effective, project leaders also should seek the early involvement of faith-based organizations, news outlets, potential opposition groups, and seasonal residents.

In every community, there are people and groups that serve unique roles or have connections built on local context or events. Project leaders should determine who they are and invite them into the process early.

Faith-Based Organizations

Across the country, churches, "build and sustain more social capital—and social capital of more varied forms—that any other type of institution" (*Better Together, The Report of the Saguaro Seminar: Civic Engagement in America*, Harvard University's Kennedy School of Government, 2011). In small towns or areas of sprawl, churches, temples, and mosques often serve a major role in building community and capacity for change. Thus, project leaders should seek innovative ways to work with church leaders to engage their membership in public projects.

Potential Opposition Groups

Special efforts should be made to identify and reach out to people and organizations that may be expected to oppose the project, to build their trust and involvement. Try to identify and address their concerns both as part of the public process and during special stakeholder interviews or meetings. This may include internal groups or professionals who initially may be inclined to provide technical brush-offs. For example, they may at the outset be worried that sanitation trucks won't be able to maneuver on narrow roads, that trees may disrupt drainage, or that a crosswalk isn't needed where people don't already try to cross the road.

Whether internal or external, these concerns should be addressed early in the public process to give the potential opposition time to understand the project, become comfortable with proposed solutions, ask many questions, and decide whether to support the effort. Support is much more likely when these individuals and groups have been invited into the process early and have been included as key stakeholders. If participants feel as though the outcome is their plan, they are less likely to oppose it. By working side-by-side with other stakeholders, they learn to appreciate and accommodate others' points of view.

Moreover, opposing groups often bring legitimate concerns to the design process. Through their involvement they can improve projects.

Children

Children at workshop
(Credit: Dan Burden)

Children have much to offer in the community planning and design process, yet they remain mostly untapped throughout community transformation processes. A child's imagination is a powerful tool; children can dream the perfect community in which to live, play, and go to school. Beyond the power of their imaginations, they can also bring very practical solutions to the table. For example, children are often aware of shortcuts that could be formalized into trails and added to the community's pedestrian network map. Their values and honesty helps raise the discussion to the level of guiding principles; the involvement of children in public processes can change the whole tenor of the event. Engage children through children's charrettes, art or urban design contests, school field trips, and special activities at community charrettes or workshops. Invite them on walking audits near their schools. At the very least, provide schools with flyers announcing the project or public process that can be sent home with children in their bags.

Toolbox: Media Outreach

Conducting effective outreach to news outlets is important to the success of any community engagement effort. The news media are more than simply a means to get the word out about the project. Rather, project leaders should try to build capacity among news organizations, just as the outreach effort seeks to build capacity among community members; building relationships with reporters helps ensure the general public is receiving accurate, timely, and meaningful information about the project.

The lead agency's communications department should be consulted to provide guidance, expertise, and tools, but project leaders should remain very engaged in the media outreach effort.

Project leaders should be committed to working within the agency's communications protocols, such as complying with a gatekeeper policy if one exists. If a communications department isn't available, the following paragraphs provide general guidance.

Call Key Outlets Early
As soon as the project kickoff is confirmed or possibly even earlier, call—don't email, fax, or send a letter—key reporters to share the purpose of the project and to ask them how best to provide more information when it is available. Keep a list of the contacts made and how they would like to receive additional information; then, be sure to follow up in that manner.

Depending on the news organization and its depth and structure, special effort should be made to reach transportation, public safety, and health and business reporters. Contact the primary news sources in local and regional markets, but don't overlook non-traditional news sources, such as blogs that cater to cyclists or that address transportation, public safety, community health, retirement, and business issues. Any key reporters—regardless of their medium—should be contacted as soon as possible by phone.

Also, offer to submit a guest commentary in advance of the project kick-off or to secure a prominent guest for an upcoming talk show. If the project may be especially controversial, try to schedule an editorial board meeting with the local or regional paper.

Issue Meaningful Press Releases
Develop a press release that is engaging and written in the form of a news story. Be sure to include the five W's—who, what, why, when, and where. Describe the goal of the project, how people can become involved, and any other information that will help make the story meaningful and relevant to the local and regional audience. Include keywords to ensure the press release and its contents can be easily found online. Distribute the press release initially to the key media outlets already contacted, and be sure to provide it in the manner they requested (check the list made during the initial conversations). Then, distribute the press release to all other media outlets in the region. Also, consider including non-traditional news sources in the media outreach strategy.

Finally, distribute the press release to local partners and other local contacts, asking them to share it with their media contacts. The value of the relationships the local partners already have with media contacts shouldn't be overlooked; tap into that value by supporting the local partners in their efforts to conduct media outreach for the benefit of the workshop and related efforts

Be Responsive and Keep in Touch
As project leaders build relationships with news sources, they should expect to receive more and more inquiries. Understand that reporters often are working on very tight deadlines; sometimes they receive story assignments mid-day with evening deadlines. Be responsive and provide timely information to help ensure accurate details are relayed to news audiences and to further support the relationship with the reporter. Additionally, be proactive in sharing news about project developments or milestones being met; doing so will further build capacity amongst the news sources, help keep them engaged in the project, and support the dissemination of timely and accurate information.

Media as Stakeholders
Conventional community outreach plans have treated the media as a means of simply disseminating information. A more effective approach is to engage members of traditional and non-traditional news outlets alike (newspapers, television, radio, online news services, bloggers, etc.) as stakeholders and seek their involvement early in the process. Just as project leaders should build capacity amongst residents and within the community, so too should they seek to build capacity with journalists and news outlets. The media can also help projects move forward with positive editorials and favorable reporting.

Foster Cultural Competence

Ensuring that programs and messages are designed to be relevant, appropriate, and effective in different cultures and different languages is vital to conducting successful community outreach. In fact, cultural competence has emerged as a key strategy to improving health and the quality of healthcare and social services for everyone in the U.S. regardless of race, ethnicity, cultural background, or language proficiency.

Stakeholders share the planning responsibility
(Credit: Ryan Snyder)

Translating important messages requires strong cultural knowledge, because "simply replacing one word with another won't do" (Zarcadoolas, C. and Blanco, M., "Lost in Translation: Each Word Accurate, Yet…,"*Managed Care Magazine.* August 2000). However, reaching people of all backgrounds often requires more than simply translating messages. Even in urban communities, but especially in rural areas or small towns, messages perceived to have been created by "outsiders" can actually do more harm than good by creating discomfort or mistrust.

To increase their effectiveness, many organizations working with multi-cultural populations are developing "ambassador" programs that recruit people who live in and work in a community to be community educators and liaisons between the project or program and the community. Other communities are working to culturally adapt messages, instead of simply translating them, to focus on types of behavior changes that would be relevant and appropriate in the cultural context of the different audiences.

When culturally adapting messages, consider the following:

- Language doesn't equal culture. Although a shared language is important to culture, people who speak the same language often are from different cultures. Be sensitive to the differences and develop appropriate messages.
- Start with strong cultural knowledge. Tap the knowledge of in-house staff or consultants who live, work, or grew up in the culture.
- Get feedback. Work directly with members of the audience to determine appropriate approaches. Use focus groups to screen messages before they are distributed.

Expect Emotional Connections—and Reactions—to the Built Environment

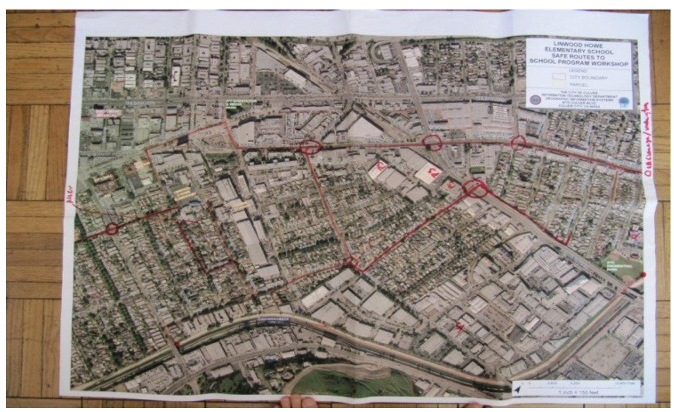
People have strong emotional connections to their built environments, and those feelings influence involvement in community-building efforts. The structures and infrastructure around people create strong frames of reference for daily living and help build comfort, a sense of security, and a sense of belonging.

Place attachment is a notable part of daily life. Project leaders should anticipate that responses to projects may be emotional, but those responses shouldn't be dismissed as invalid; they should be addressed as valuable input.

Approach Engagement as a Two-Way Conversation

Effective public engagement involves more than telling people about a project; effective engagement facilitates a dialogue that leads to reciprocal learning, collaboration, and ideally, consensus.

Community members have unique knowledge of local contexts that will affect the outcome of a project development process. By engaging in reciprocal learning, project leaders will gain insight and perspective that can help them ensure the project is tailored to meet the community's needs. Community members also will learn from each other.



Product of design charrette (Credit: Ryan Snyder)

An effective public process results in people feeling that they are well-informed and that they've had opportunities to contribute throughout the stages of decision-making.

"In fact, what appears to be most important from a citizen's perspective and from the standpoint of attaining ongoing engagement is not the strategy employed, but how government responds when citizens voice their preferences. For citizens, there are two questions that are paramount: Did the government listen and take action based on what they heard from us? Was it worth my time and effort?" (*Connected Communities: Local Government as a Partner in Citizen Engagement and Community Building*, Alliance for Innovation, Oct. 2010).

In addition to workshops, project leaders can seek community input through interactive online tools such as websites, digital storytelling, and community mapping. In communities with many seasonal residents, these tools can be especially useful in collecting input from stakeholders who aren't able to attend events in person.

Digital storytelling allows the public to use photos and presentation tools to illustrate concerns about the built environment. Many communities are starting to use this "photo voice" approach to encourage community members to present their points of view using photographs and descriptions or narration. The package can be submitted electronically to project leaders or presented as part of a public workshop or event.

Achieving Informed Consent

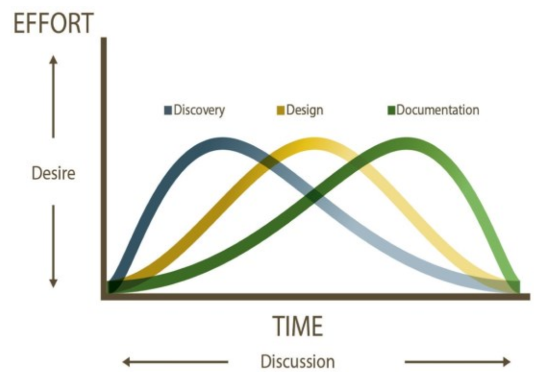
The goal of informed consent is not compromise, where everyone must give up something. Informed consent is based on the assumption that most people will give their consent to a change, even when it is not in their personal best interest, after they have been engaged, become informed, and see the value to their community. Working cooperatively, all people achieve more, and so enlightened self-interest wins, once people understand why an idea is good for their neighborhood.

Stakeholders designing their streets
(Credit: Dan Burden)

The steps of the informed consent process are as follows:

- **Desire.** The public process comes about as a result of a community coalescing around a desire for a change in its built form. Though desire comes in different forms, it is the necessary energy and often passion used to steer the project towards a sustainable and community-oriented outcome.
- **Discovery.** Discovery is the process of developing a complete and common understanding of the situation, context, and the built vision by the design team and the stakeholders. Context is a short form for the physical, social, historical, fiscal, environmental, political, and climatic contexts. Good discovery is done by:

  - Listening, looking, and involving people
  - Visiting, reading, and probing
  - Educating and exploring physically and intellectually
- **Design.** Design is the employment of people, their related skills, and what they discovered to produce products that articulate, memorialize, and motivate people towards the consensus outcomes and the vision. It tends to be the most exciting part of the process. This is when collaborators can raise the bar in terms of creativity and sustainability.
- **Discussion.** Discussion happens throughout and requires the right people/stakeholders with the capabilities present at the right times in order to maximize short feedback loops. It is the discussion phase that builds and overcomes uninformed decision making. If grassroots planning is to work, people must become informed on what helps build a community. With the combination of a strong desire and community leadership the sense of frustration will be overcome, but this must come with an informed neighborhood. Discussion involves:
  - A series of presentations to raise stakeholders' knowledge
  - Testing/viewing the design and parts of the design from a variety of perspectives
  - Circling back to alter parts that need altering
  - The project manager must prepare the community to "sell" its vision to others. True ownership of a vision comes from within.
- **Documentation.** Documentation starts at the beginning of the project but the effort is highest towards the end when the products are finalized. Example products include documents, posters, codes, speeches, agreements, construction drawings, and advice. This documentation works best when designers anticipate pushback. Messages must be clear, concise, comprehensive, and attractive to draw people into the process.



Steps of the informed consent process (Credit: Michele Weisbart, adapted from Ian Lockwood)

CARRY THE MOMENTUM FORWARD

Successful community engagement often leads people to become motivated and ready to mobilize to enact positive change. Project leaders should capitalize on this energy and help form long-lasting coalitions by organizing a working group or advisory council that will help carry the momentum forward. The members of the group should represent diverse interests and backgrounds and should be committed to continuing to communicate with each other and meeting regularly to address the issues identified through the project development process. The group can be established to provide guidance and continuing community feedback to project leaders as implementation begins.

Community celebrates and supports their achievements (Credit: Michael Ronkin)

Celebrating early successes helps ensure long-term project success. When project implementation begins, identify an early achievement and widely publicize the success; this can even be the project's public process itself. Consider holding a special event that will publicize the new community asset, bring recognition to the people involved, reaffirm that the process has worked, and build more support for work to be done. For example, the completion of a trail or trail segment could be celebrated with a special family fun run/walk held in conjunction with a ribbon-cutting ceremony and press conference. Widely celebrating projects like these helps people in nearby communities envision how they can improve their neighborhoods as well.

<u>Toolbox: Strategies for Implementation</u>

The following strategies can be helpful in implementing projects:

- **Secure and leverage the support of key partners early.** They may be members of the chamber of commerce, influential elected leaders, chief planners of agencies, or community advocates. Leverage their support by ensuring other key partners are aware of their buy-in.
- **Use data appropriately.** Too many towns don't implement projects because they lack data, or conversely, they rely on it too heavily. Presented with too much, people may argue over its meaning, leading to projects not being built and community members losing trust in project leaders. Some data is needed to ensure the context is properly understood. Thus, conducting research to collect basic data is necessary, but street design projects also should be driven by commonly held values in the community.
- **Build model projects**. Model projects can be examples of how streets can work better, especially when building something that is new for the community, such as a non-conventional crossing, a road diet, reverse-in angled parking, mini-circles, or roundabouts. Build model projects first in areas with strong backers and the greatest chances for success. If the vision is to have modern roundabouts in a dozen locations, start with the location with the most enthusiasm and support. Enlist local leaders to attend meetings, submit letters to the editor, and conduct other outreach that explains why the neighborhood wants the new feature.
- **Evaluate built projects.** Don't just build a project: evaluate it. For example, a 30 percent increase in people walking, 20 percent more bicyclists, a reduction in vehicle speeds of 7 mph, 120 column inches of positive newspaper coverage, and other metrics can validate the project and build support for similar projects. Use other performance-based measures to evaluate success not only of the project, but also of the public process that led to it. Evaluations can assess the assumptions and the planning processes that lead

to changes. Assessment of the planning process includes evaluations of how well the project performed. Evaluation can include the following:

- Did the project meet the commonly-held community vision?
- Important projects that benefit all members of the community are the first to be built. Did those built reflect the community's priorities?
- Did the project provide long-term benefits to all people?
- Did the process allow for adequate time to respond to plans?
- Were there any legal actions or complaints about the public process that could have been reduced or eliminated?
- How can the public process improve?

CONCLUSION

Creating successful community engagement through effective outreach is a significant investment of resources, but many of those resources already exist in-house and simply need to be committed to the effort. For policy-making bodies, government agencies, health agencies, and community organizations that understand the value, benefits, and processes of creating successful community engagement, the effort provides a clear return on investment.

ADDITIONAL RESOURCES

Betancourt, J., Green, A., Carrillo, J.E. and Park, E.R. 'Cultural Competence and Health Care Disparities: Key Perspectives and Trends." *Health Affairs*, 2005, 24(2):499-505.

Ikemoto, L. "Racial Disparities in Health Care and Cultural Competence." HeinOnline 48 St. Louis U. L.J. 75 (2003-2004).

Tri-County (Colorado) Health Department and Communities Putting Prevention to Work. *Built Environment and Health Handbook*. January 2011.

Manzo, L. and Perkins, D. "Finding Common Ground: The Importance of Place Attachment to Community Participation and Planning." *Journal of Planning Literature*. May 2006, 20(4):335-350.

Federal Highway Administration, Public Involvement in Transportation Decision Making. http://www.fhwa.dot.gov/reports/pittd/charrett.htm.

APPENDIX:
VISIONS OF TRANSFORMING STREETS

The photosimulations on these pages present images of how streets can be changed to make better places and neighborhoods. The simulations show the application of principles and concepts described throughout this manual.

Credit: Todd Clements


Metro
574
BUS STOP

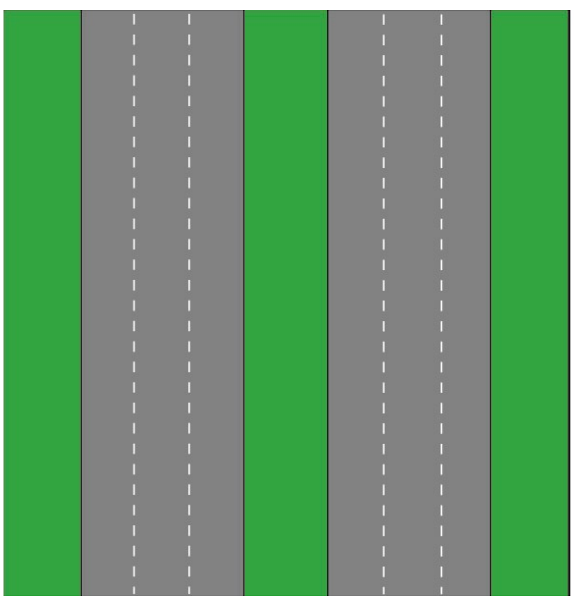

Metro
574
BUS STOP

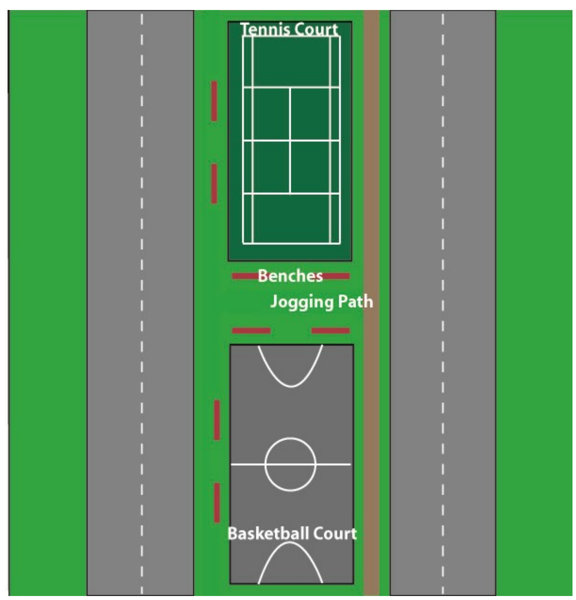
Credit: Todd Clements

Credit: Dan Burden

Credit: Alexis Lantz

Credit: Marty Bruinsma





Existing San Vicente Blvd. Concept for San Vicente Blvd.

(Credit: Marty Bruinsma)

(Credit: Marty Bruinsma)

Traffic Calming Classificaton			Framework Street			Framework Street or Non-Framework Street	Non-Framework Street
Posted/Design/Target/Operating Speed (mph)			**35 mph +**	**25 to 30 mph**	**25 mph**	**25 to 30 mph**	**25 mph or below**
Transition Zone from / to higher speed environment			Yellow	Green	Green	Red	Red
Entrance Features (architecture / landscaping / monument)			Green	Green	Green	Green	Green
Cross-Section Measures	Reduction in number of lanes		Green	Green	Green	Green	Green
	Reduction in width of lanes		Green	Green	Green	Green	Green
	Long Median / Continuous Median		Green	Green	Green	Green	Green
	Short Median / Refuge		Green	Green	Green	Green	Green
	Short Medians on Curves		Green	Green	Green	Green	Green
	Bulb-outs		Green	Green	Green	Green	Green
	Curb and Gutter		Green	Green	Green	Green	Green
	Curbless / Flush Streets		Red	Green	Green	Green	Green
	Flush Medians		Green	Green	Green	Green	Green
	Pedestrian Scale Lighting		Green	Green	Green	Green	Green
	Street Trees		Green	Green	Green	Green	Green
	Building up the right-of-way		Green	Green	Green	Green	Green
	Lateral Shifts		Red	Green	Green	Green	Green
	Bike Lanes / Protected Bike Lanes / Cycle Tracks		Green	Green	Green	Yellow	Yellow
	Textured and/or Colored Paving Materials (parking, lanes, bike lanes, crossings, intersections, general purpose lanes, turn lanes, medians)		Green	Green	Green	Green	Green
	On Street Parking	Parallel	Yellow	Green	Green	Green	Green
		Back-in-angled	Yellow	Green	Green	Green	Green
		Front-in-angled	Red	Red	Red	Red	Green
		Right-angle	Red	Red	Red	Red	Green
		Valley gutters used in conjunction with parking	Green	Green	Green	Green	Green
Periodic Measures	Horizontal Measures	Roundabouts	Green	Green	Green	Green	Green
		Mini-Roundabouts	Red	Green	Green	Green	Red
		Mini Traffic Circles	Red	Red	Red	Green	Green
		Impellers (T-intersections)	Red	Red	Red	Green	Green
		Two-lane chicanes	Red	Red	Red	Green	Green
		One-lane chicanes (yield condition)	Red	Red	Red	Green	Green
		Short Medians	Red	Red	Red	Green	Green
		Medians on curves	Red	Red	Red	Green	Green
	Narrowings	Yield Streets	Red	Red	Red	Green	Green
		Pinch Points	Red	Red	Red	Green	Green
		Bulb-outs	Green	Green	Green	Green	Green
	Vertical Measures	Raised intersections	Yellow	Yellow	Yellow	Green	Green
		Raised crosswalks	Yellow	Yellow	Yellow	Green	Green
		Flat-top Speed Humps (speed tables)	Red	Red	Red	Green	Green
		Speed Cushions	Red	Red	Red	Green	Green
		Speed Humps	Red	Red	Red	Green	Green
Not Traffic Calming Measures	Vertical Changes	Rumble Strips (for warning purposes)	Rural Only	Red	Red	Red	Red
		Speed Bumps	Red	Red	Red	Red	Red

Legend:
- Green: **Appropriate**
- Yellow: **Appropriate in Specific Circumstances**
- Red: **Not Appropriate**

APPENDIX C

Water Quality Protection Zone (WQPZ) Ordinance

AN ORDINANCE OF THE COUNCIL OF THE CITY OF NORMAN, OKLAHOMA AMENDING CHAPTER 19 OF THE CODE OF THE CITY OF NORMAN TO PROVIDE FOR STANDARDS AND REQUIREMENTS FOR A DESIGNATED WATER QUALITY PROTECTION ZONE INCLUSIVE OF THE LAKE THUNDERBIRD WATERSHED; AND PROVIDING FOR THE SEVERABILITY THEREOF.

NOW, THEREFORE, BE IT ORDAINED BY THE COUNCIL OF THE CITY OF NORMAN, OKLAHOMA:

§ 1. That Section 19-210 of Chapter 19 of the Code of the City of Norman shall be amended to read as follows:

Sec. 19-210. Definitions.

The following words and phrases when used in this chapter, shall for the purposes of this chapter, have the meanings respectively ascribed to them in this article, except where the context otherwise requires:

A. *Alley:* A minor right-of-way dedicated to public use, which gives a secondary means of vehicular access to the back or side of properties otherwise abutting a street, and which may be used for public utility purposes.

B. *Best Management Practices (BMP):* An effective integration of storm water management systems, with appropriate combinations of non-structural controls and structural controls which provide an optimum way to convey, store and release runoff, so as to reduce peak discharge, reduce pollutants, enhance water quality, assist in stream and/or stream bank stabilization, prevent property damage due to flooding, and assist in sediment reduction. BMP's include, but are not limited to, the following:

1. Structural controls such as:
    a. Sediment forebay;
    b. Grassed swale;
    c. Enhanced bio-swale;
    d. Voluntary urban nutrient management;
    e. Statutory urban nutrient management;
    f. Wetlands;
    g. Extended detention-enhanced;
    h. Retention basins;

   i. Bioretention, surface sand, organic, and similar filters;
   j. Soaking trench;
   k. Infiltration trench;
   l. Storm water pond;
   m. Dry extended detention pond; and
   n. In-channel detention.

2. Non-structural controls such as:
   a. Landscape conservation;
   b. Reduction in impervious cover;
   c. Schedule of maintenance activities;
   d. Prohibition of practices;
   e. Maintenance procedures.
   f. Street sweeping;
   g. Fertilizer restrictions.

C. *Bicycle lane:* That portion of a roadway set aside and appropriately designated for the use of bicycles.

D. *Bicycle path:* A paved facility physically separating the bicycle from motor vehicle traffic.

E. *Block:* A parcel of land, intended to be used for urban purposes, which is entirely surrounded by public streets, highways, railroad rights-of-way, public walks, parks or greenstrips, rural land or drainage channels or a combination thereof.

F. *Buffer:* A vegetated area, including trees, shrubs, and herbaceous vegetation that exists or is established to protect a stream system, lake or reservoir, reduce pollutants, enhance water quality, assist in stream and/or stream bank stabilization, and assist in sediment reduction.

G. *Building line:* A line parallel to the lot or property line beyond which a structure or building cannot extend, except as specifically provided under the zoning ordinance. It is equivalent to the setback or yard line.

H. *Cluster development:* cluster development is a method of subdividing land which allows the maximum density available within the zoning district while allowing smaller lots than those specified, provided that the land saved is reserved for permanent agricultural use or open space, ideally in common ownership for community use.

I. *Combustible structure:* That which is built or constructed, an edifice or building of any kind, or any piece of work artificially built up or composed of parts joined together in some definite manner and consisting of any material that, in the form in which it is used and under the conditions anticipated, will ignite and burn or will add appreciable heat to an ambient fire.

J. *Degradation:* any condition caused by the activities of humans which result in the prolonged impairment of any constituent of the aquatic environment.

K. *Development:* The erection, construction, or change of use of buildings; or the erection or construction of any additions to existing buildings where outer walls are added or altered as to location, but not including alterations or remodeling of buildings where said outer walls are not added or altered as to location. As it relates to water quality protection, any man-made change to improved or unimproved real estate, including, but not limited to, buildings or other structures, mining, dredging, filling, grading, paving, excavation, drilling, or storage of equipment or materials.

L. *Development committee:* The City of Norman Development Committee shall be comprised of the following staff members: The Director of Public Works (who shall be the chairman), the Director of Planning and Community Development, the Director of Utilities, the City Engineer, the Development Coordinator, and the Manager of Current Planning, or their designees.

M. *Director of Public Works:* The Director of Public Works of the City of Norman, including his or her designee.

N. *Easement:* A grant by the property owner to the public, a corporation, or persons, of the use of an area of land for specific purposes.

O. *Impervious Cover:* Roads, parking areas, buildings, pools, patios, sheds, driveways, private sidewalks, and other impermeable construction covering the natural land surface. This shall include, but not be limited to, all streets and pavement within a subdivision. Vegetated water quality basins, vegetated swales, other vegetated conveyances for overland drainage, areas with gravel placed over pervious surfaces that are used only for landscaping or by pedestrians, and public sidewalks shall not be calculated as impervious cover.

P. *Lot:* A subdivision of a block or other parcel intended as a unit for the transfer of ownership or for development.

Q. *Lot, corner:* A lot which abuts two (2) intersecting streets. The front of a lot is defined by the filed plat of the subdivision, and is addressed accordingly. Although the front door of the house should face the front yard, a house may be oriented towards the side street if the plat was designed to provide two (2) front and rear yards or if there is sufficient room to provide both a new front and rear setback.

R. *Lot, depth:* The average distance from the front property line of the lot adjacent to the street to its rear property line, measured in the general direction of side lines of the lot.

S. *Lot, double frontage:* A lot which runs through a block from street to street and which has frontage on two (2) or more streets, but not including a corner lot.

T. *Lot, reverse frontage:* A corner lot of such size and shape that a building erected on it might logically be designed to face on either adjoining street, thus causing the building to rear on the side line of any abutting lot.

U. *Lot, townhouse:* A lot shown on a townhouse plat and intended as the site of a single attached dwelling unit.

V. *Lot line adjustment:* A relocation of the lot lines of two (2) or more lots included in a plat which is filed of record, for the purpose of making necessary adjustments to building sites.

W. *Low Impact Development (LID):* a comprehensive land planning and engineering design approach to development that can be used to replicate or restore natural watershed functions and/or address targeted watershed goals and objectives.

X. *Non-degradation*: The proper use of BMP's and pollution prevention criteria in activity so as to prevent property damage due to flooding and degradation as defined herein.

Y. *Non-structural controls*: Pollution prevention measures that focus on the management of pollutants by practices and procedures which minimize exposure to runoff, as well as preserve open space and natural systems. Non-structural controls may include riparian buffers, modified development practices, and regulations on pesticide, herbicide, and fertilizer use.

Z. *Norman 2025 Plan:* The comprehensive development plan for the City of Norman which has been officially adopted to provide long-range development policies for the City in the foreseeable future and which includes, among other things, the plan for land use, land subdivision, traffic circulation and community facilities, utilities, and drainage facilities.

AA. *Person:* Any natural person, corporation, partnership, joint venture, association (including homeowners or neighborhood associations), trust, or any other entity recognized by law.

BB. *Planning Commission:* The City Planning Commission of the City of Norman.

CC. *Plat, final:* A map of a land subdivision giving, in form suitable for filing in the office of the County Clerk, necessary affidavits, dedications, and acceptances, and delineating the layout of such subdivision as required herein.

DD. *Plat, preliminary:* A map of a proposed subdivision showing the character and proposed layout of the tract in sufficient detail to indicate the relationship of the proposed development to topography, existing streets, drainage facilities and utilities, existing easements of record, the Norman 2025 Plan, existing urban development and zoning, and to indicate the nature of the land planning design.

EE. *Pollution:* the contamination or other alteration of the physical, chemical or biological properties of any stream or other water source, or such discharge of any liquid, gaseous or solid substance into any stream or other water source as will or is likely to create a nuisance or render such waters harmful or detrimental or injurious to public health, safety or welfare, or to domestic, commercial, industrial, agricultural, recreational, or other legitimate beneficial uses, or to livestock, wild animals, birds, fish or other aquatic life.

FF. *Public improvements:* Any utility, structure, or modification of topography which is, or will be, located within, under, or over a right-of-way or easement of record and which is, or will be, owned and/or maintained by other than the individual owner(s) of developed real estate.

GG. *Raised mound septic system:* a soil absorption system that is elevated above the natural soil surface in a suitable fill material. It is a variation of the raised bed utilizing sandy fill material but not requiring a stabilization period prior to the construction of the absorption area.

HH. *Raised septic system:* a wastewater absorption trench system which has been constructed in soil fill material which has been placed on top of the natural soil on a building lot.

II. *Reserve strip:* A strip of land located adjacent to a public easement or right-of-way which has the effect of denying access to adjacent property owners to said public easement or right-of-way.

JJ. *Right-of-way:* Any street, avenue, parkway, highway, boulevard, road, alley, bicycle path or pedestrian walkway reserved and/or dedicated for public or private use chiefly by vehicular or pedestrian traffic. Its width shall be established as the shortest horizontal distance measured between lines delineating the right-of-way.

KK. *Rural and suburban area:* All that part of the incorporated area of the City of Norman which is not classified on the Norman 2025 Plan for urbanization.

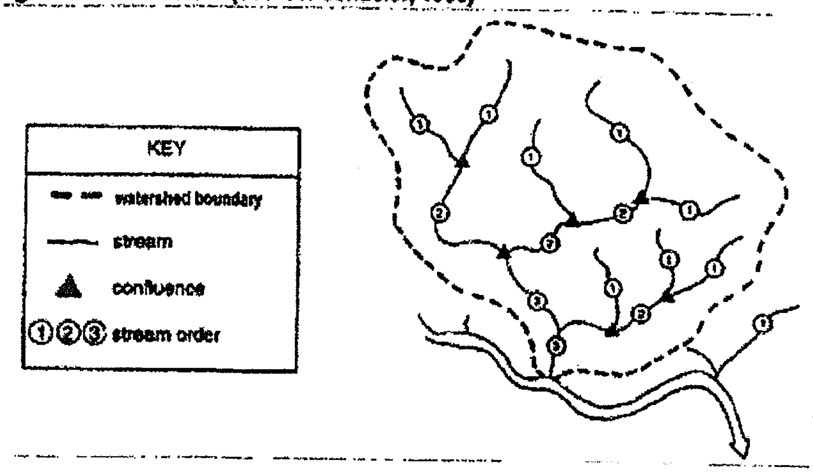
LL. *Setback line:* See building line or yard line.

MM. *Site development plan:* A plan drawn at a scale of not less than fifty (50) feet equal one (1) inch which shows the topographic characteristics of the site not more than a one (1) foot contour interval in the urban areas and not more than two (2) feet contour intervals in the rural areas; the location and dimensions of buildings, yards, courts, landscape, pedestrian and vehicular circulation and parking, fences and screening; service areas and service courts, and other features; the use of each building and area; the height of buildings; adjacent street, alleys, utility, drainage and other easements; and the relationship of the development to adjacent areas which it may affect.

NN. *Streams:* Watercourses that are either identified through site inspection and/or notification by the United States Army Corp of Engineers or by the United States Geological Survey (USGS) 7.5 minute series (topographic) maps drawn at a scale of 1:24,000 or 1 inch = 2000 feet. Perennial streams are those which are depicted on a USGS map with a solid blue line. Intermittent streams are those which are depicted on a USGS map with a dotted blue line.

OO. *Stream Order:* A method of numbering streams as part of a drainage basin network. Tributaries which have no branches are designated as of the first order, streams which receive two first-order tributaries are of the second order, larger branches which receive two second-order tributaries are designated third order, and so on, the main stream being always of the highest order. Designation of stream order shall be determined utilizing a USGS 7.5 minute series (topographic) map drawn at a scale of 1:24,000 or 1 inch = 2000 feet. See Figure 1 below.

Figure 1: Stream Order (Source: Schueler, 1995)



PP. *Stream Planning Corridor (SPC):* the areas of land designated as an SPC in Exhibit 4-4 to the PBS&J Storm Water Master Plan dated October 2009 along both sides of a stream or natural drainage corridor that encompasses the area projected to be inundated by the one-percent (1%) chance flood event (i.e. the 100-year floodplain) in any given year assuming full build-out watershed conditions (based upon the Norman 2025 Plan and subsequent updates) in those areas with 40 or more acres of drainage area in the Lake Thunderbird watershed.

QQ. *Street:* Any public or private right-of-way which affords the primary means of access to abutting property.

RR. *Street, collector.* A minor street collecting traffic from other minor streets and serving as the most direct route to a major street or community facility.

SS. *Street, cul-de-sac:* A local street having one (1) closed end terminated by a turn-around.

TT. *Street, estate type:* A local street in a Residential Estate (R-E) or Agricultural (A-1, A-2) zone or district.

UU. *Street, frontage or service:* A minor street located adjacent and parallel to a major street for land service to abutting properties and access to adjacent areas and for allowing control of access to the major street.

VV. *Street, local:* A minor street which collects and distributes traffic between parcels of land and collector or arterial streets, with the principal purpose to provide access to abutting property.

WW. *Street, major:* A freeway, principal arterial, or minor arterial designated on the adopted Transportation Plan of the City of Norman.

XX. *Street, minor:* Any street other than one (1) designated as a freeway, principal arterial, or minor arterial on the adopted Transportation Plan of the City of Norman, but not including alleys.

YY. *Street, public:* Any pre-existing county road heretofore annexed by the City of Norman and which forms a part of said City by reason of such annexation, or any street or road granted or dedicated to and accepted by the City of Norman.

ZZ. *Structural controls:* engineered solutions designed to reduce pollution in surface water runoff primarily through five basic mechanisms: infiltration, amelioration, treatment, filtration and detention. In effect, these systems attempt to counteract the opposite tendencies of decreased infiltration, filtration and detention which urbanization imposes upon the land.

AAA. *Subdivider (developer):* Any person, firm, partnership, corporation, or other entity acting as a unit, subdividing or proposing to subdivide or develop land as herein defined.

BBB. *Subdivision:* The division, re-division, or delineation of land by lots, tracts, sites or parcels for the purpose of transfer of ownership, or for urban development, or for the dedication or vacation of a public or private right-of-way or easement.

CCC. *Swale:* A natural depression or wide shallow ditch used to temporarily store, route, or filter runoff and encourage infiltration.

DDD. *Top of bank:* The point along a stream bank where abrupt change in slope is evident, and where the stream is generally able to overflow the banks and enter the adjacent floodplain. The top of bank may be identified from topography maps but must be verified through field inspection. Where no top of bank is discernable by the City Storm Water Engineer or his designee, measurements should be taken from the center line of the stream.

EEE. *Transportation Plan:* The arrangement, character, extent, and width of major streets within the City of Norman as designated on the most currently adopted Land Use and Transportation Plan document.

FFF. *Townhouse:* One (1) of a series of two (2) or more attached dwelling units, separated from one (1) another by continuous, vertical party walls without openings from basement floor to the roof deck and tight against same or through the roof and which are intended to have ownership transferred in conjunction with a platted lot.

GGG. *Urban area:* All that part of the incorporated area of the City of Norman which is designated on the Norman 2025 Plan for urbanization.

HHH. *Water Quality Protection Zone (WQPZ):* A vegetated strip of land that lies along a Stream or Lake Thunderbird and its adjacent wetlands, floodplains or slopes that is comprised of the stream bed and areas adjacent to the stream bed and the distance of which is determined by Section 19-411(B), (C) and (D) herein.

III. *Way:* Any street, avenue, parkway, highway, boulevard, road, alley, bicycle path or pedestrian walkway reserved and/or dedicated for public or private use chiefly be vehicular or pedestrian traffic. Its width shall be established as the shortest horizontal distance measured between lines delineating the right-of-way.

JJJ. *Wetland:* the term, as used herein, shall have the same meaning as set forth in 40 C.F.R. §230.3.

KKK. *Yard line:* An open space at grade between a building and the adjoining lot lines, unoccupied and unobstructed by any portion of a structure from the ground upward except as specifically provided in Chapters 18 or 22. In measuring a yard for the purpose of determining the width of the side yard, the depth of a front yard, or the depth of a rear yard, the least horizontal distance between the lot line and the main building shall be used.

LLL. *Yard line, front.* A yard extending the full width of a lot between the side property lines and being the minimum horizontal distance between the street side property line and the main building or any projection thereof.

MMM. *Yard line, rear:* A yard extending across the rear of a lot measured between side yard lines and being the minimum horizontal distance between the rear lot line and the rear of the main building or any projections other than steps, unenclosed balconies or unenclosed porches. On corner lots the rear yard shall be considered as parallel to the street upon which the lot has its least dimension. On both corner lots and interior lots the rear yard shall in all cases be at the opposite end of the lot from the front yard.

NNN. *Yard line, side:* A yard between the building and the side line of the lot and extending from the front yard line to the rear lot line and being the minimum horizontal distance between a side lot line and the side of the main building or any projections other than steps.

§ 2. That Section 19-303 of Chapter 19 of the Code of the City of Norman shall be amended to read as follows:

Sec. 19-303. Preliminary Plat: Contents.

The preliminary plat shall be drawn at a scale of not more than one hundred (100) feet to the inch, except where impractical and shall show:

A. The scale, north arrow, date and legend;

B. The proposed name of the subdivision;

C. The name and address of the owner of record, the subdivider, the owner's engineer, and the registered land surveyor preparing the plat;

D. Legal description of the proposed subdivision, including the acreage and the number of lots proposed in the subdivision, by type;

E. A key map showing the location of the proposed subdivision referenced to existing or proposed arterial streets or highways and to government section lines, and including the boundaries and number of acres of the drainage area of which the proposed subdivision is a part;

F. The names, with locations of intersecting boundary lines, of adjoining subdivisions, and the location of the Norman City limits if falling within or immediately adjoining the tract;

G. The land contours with vertical intervals of one foot in the urban areas and two (2) feet in the rural areas referenced to a United States Geological Survey datum (1988) or Coast and Geodetic Survey bench mark or monument;

H. The location of dedicated streets at the point where they adjoin and/or are immediately adjacent; but actual measured distances shall not be required;

I. Important features such as existing permanent buildings; large trees (a minimum eight (8) inch caliber); streams; railway lines; oil and gas line or wells as shown on the records of the Oklahoma Corporation Commission (including abandoned gas or oil wells and dry holes which remain unplugged);

J. The location of all existing easements of record, sanitary and storm sewers, water mains, streets, culverts, power lines, and other surface or subsurface structures within the tract or immediately adjacent thereto, and the proposed location, layout, type, and size of the following structures and utilities:

   1. Water mains;

   2. Sanitary sewer mains, sub-mains and laterals;

   3. Storm sewers; and,

   4. Street improvements.

K. The location of all drainage channels and subsurface drainage structures, and the proposed method of disposing of all run-off from the proposed subdivision, and the location and size of all drainage easements relating thereto, whether they be located within or outside of the proposed plat;

L. The length of the boundaries of the tract, measured to the nearest foot, and the proposed location and width of streets, alleys, easements, and setback lines, and the approximate lot dimensions;

M. The existing zoning and proposed changes of zoning in the tract and of the property immediately adjacent thereto;

N. One hundred (100) year flood boundaries;

O. Water Quality Protection Zone boundaries;

P. Preliminary drawings showing compliance with the applicable requirements of this Chapter for structural controls on development;

Q. A topographic map, drawn to a scale of one hundred (100) feet to one inch, or in an appropriate scale. The map should display, according the best information available, topographic information and features (including, but not limited to, faults and fractures along waterways, wetlands, and sinkholes), and the WQPZ. Current limits of the FEMA floodplain and the SPC shall be displayed;

R. Location of all temporary and permanent runoff detention basins, constructed and altered waterways and other physical facilities to be installed to comply with the terms of this ordinance;

S. Location of all existing monitoring stations, sample points or other significant devices used in measuring or assuring water quality;

T. Any technical surveys or studies necessary to support a request for modification of WQPZ boundaries affecting the subject parcel;

U. In the instance where there is one (1) or more active oil and/or gas well(s), lease road(s), tank batteries, flow lines, gas sales lines, dead man anchors or any other related equipment, located within a proposed preliminary plat, any and all such items shall be shown on the submitted preliminary plat. Both existing conditions and any proposed changes to the existing conditions must be indicated on the preliminary plat. The information shall include, but not be limited to well access, size of the well location, including appurtenant equipment, any change in lay out or operations of the well site such as relocation of the lease road or moving of the tank batteries and flow lines, fencing, easements for flow lines, gas sales line, communication cables, and electric power lines. The information must also stipulate the parties responsible for constructing any lease road and approach and fencing. Easements necessary to provide for flow lines, gas sales lines, power supply lines and communication cables must be designated in writing. All information required must be shown on a site plan that has been reviewed and approved for compliance with oil and gas ordinances. A copy of the site plan shall be provided to the oil and gas inspector to become part of the well records until such time of the plugging and restoration of well location(s) has been completed. Oil well operators shall be notified by the oil and gas inspector of any predevelopment informational meeting(s) as an interested part where a preliminary plat contains a well(s), lease road, tank battery, flow line, gas sales line, dead man anchors, or any other related equipment that they operate. Notice shall be given in the same format as property owners within the required notice area.

§ 3. That Section 19-308(E) of Chapter 19 of the Code of the City of Norman shall be amended to read as follows:

E. In the case of a plat proposing the reserving or dedicating of land or amenities to be used in common by owners of lots in a single-family residential subdivision, or in the case of a plat or Norman Rural Certificate of Survey that contains any portion of the WQPZ, the applicant shall submit evidence acceptable to the City Attorney that all necessary steps have been taken for:

1. The establishment of a mandatory Property Owner's Association ("POA") or establishment of another acceptable arrangement for adequate maintenance of the common elements and any designated non-structural controls for storm water management. All mandatory POAs shall submit a Declaration of Covenants, Conditions and Restrictions (the "Declaration") which establishes a minimum framework that provides for the fair and effective administration of the POA and thereby assures the greater likelihood that the interests of the City and its citizens are secure and which include the following provisions:
    a. A list of all common property in the plat, by legal description. A specific description of all of the common elements within the subdivision including any abutting arterial roadways, the uses allowed for each common element and a description of the person responsible for initially constructing or installing each common element and the responsibility for maintaining the common element after initial installation;
    b. In those plats containing any portion of the WQPZ, a list of any non-structural controls located on the property.

*　　　*　　　*　　　*　　　*

§ 4. That Section 19-411 of Chapter 19 of the Code of the City of Norman shall be added to read as follows:

Sec. 19-411. Water Quality Protection Zone Design Standards.

A. The Water Quality Protection Zone (WQPZ) for a stream system shall consist of a vegetated strip of land, preferably undisturbed and natural, extending along both sides of a stream and its adjacent wetlands, floodplains, or slopes. The width shall be adjusted to include contiguous sensitive areas, such as steep slopes, where development or disturbance may adversely affect water quality, streams, wetlands, or other water bodies.

B. The required base width for all WQPZ's shall be equal to:

1. The greater of the following:

    a. 100 feet in width, measured from the top of the bank, on either side of the stream; OR

    b. The designated Stream Planning Corridor as delineated on Exhibit 4-4 to the Storm Water Master Plan, dated October 2009 and accepted by City Council on November 10, 2009 and as available on the appropriate scale through the Public Works Department, or as indicated by the Applicant's independent engineering analysis ; OR

    c. The FEMA Floodplain; OR

2. An alternative width equal to 25 feet in width, measured from the top of the bank, on either side of the stream when a reduction in nitrogen of at least 75% and a reduction in phosphorus of at least 58% is achieved through the use of an engineered process that is certified by a licensed Professional Engineer. A development plan using an alternative width less than the SPC shall also document protection against flooding and bank erosion that would be anticipated during the 1% chance flood event in an given year assuming full build-out watershed conditions in those areas with 40 or more acres of drainage area in the Lake Thunderbird watershed. For the purpose of determining the applicable reduction in the base width of the buffer, the table below may be utilized to determine pollutant removal for a particular structural control, as long as such control is constructed in accordance with the specifications for said control contained in Wichita/Sedgwick County Stormwater Manual.

Table of Design Pollutant Removal Efficiencies for Storm Water Controls (%)				
Structural Control	Total Suspended Solids	Total Phosphorus	Total Nitrogen	Metals
Storm Water Pond	80	55	30	50
Dry Extended Detention Pond	60	35	25	25
Enhanced Dry Swales	90	50	50	40
Grass Channel	50	25	20	30
Infiltration Trench	90	60	60	90
Soaking Trench	90	60	60	90
Vegetative Filter Strips	50	20	20	40
Surface Sand Filters	80	50	30	50

C. For each portion of any 25 foot segment of the buffer, as set forth in Section 19-411(B), that has a slope over 20%, 25 feet shall be added to the width of the WQPZ. To determine the extent of steep slopes, a cross section of the topography every 100 feet shall be prepared and utilized by the Applicant.

D. In second-order streams with continuous water or in higher order streams, 25 feet shall be added to the base width outlined in Section 19-411 (B) above.

E. Drainage easements, of sufficient size to carry the runoff of a 1% chance flood event from all drainage areas on the Plat greater than forty (40) acres within the WQPZ must be shown on dotted lines on the Preliminary and Final Plats, along with a written legal description of any such easement, all certified by a licensed Professional Engineer. Such easement shall be granted to the City of Norman for the purpose of access for inspecting, repairing, and maintaining drainage channels.

F. For all developments, particularly those containing some portion of the WQPZ, utilization of low impact development strategies are encouraged. For plats or Norman Rural Certificates of Survey that include portions of the WQPZ, the current Engineering Design Criteria may be modified when Low Impact Development strategies are utilized in accordance with City of Wichita/Sedgwick County Stormwater Manual.

G. Water Pollution Hazards. The following land uses and/or activities are designated as potential water pollution hazards and must be set back from the top of the bank of any stream or waterbody by the distance indicated below:

1. Storage of hazardous substances—(300 feet)

2. Aboveground or underground petroleum storage facilities—(300 feet)

3. Drainfields from onsite sewage disposal and treatment systems (i.e., septic systems)—(200 feet)

4. Raised septic systems and raised mound septic systems—(500 feet)

5. Solid waste landfills or junkyards—(600 feet)

6. Subsurface discharges from a wastewater treatment plant—(200 feet)

7. Land application of biosolids—(200 feet)

H. WQPZ Design Restrictions. Except as required for initial construction, there shall be no clearing, grading, construction that disturbs vegetation on any portion of the WQPZ, the width of which is determined by Section 19-411(B), (C) and (D) herein. Any development containing a WQPZ shall not be designed to contain within that zone any permanent structures or portions of septic systems, except for structural controls or other enhancing design features that will further the objectives of this ordinance.

I. All applications for preliminary plats and Norman Rural Certificates of Survey that contain any portion of property within the WQPZ shall also submit a report outlining the Best Management Practices to be employed.

§ 5. That Section 19-514 of Chapter 19 of the Code of the City of Norman shall be added to read as follows:

Sec. 19-514. Water Quality Protection Zone Management and Maintenance.

A. All preliminary plats, final plats, and Norman Rural Certificates of Survey shall clearly:

1. Show the extent of any WQPZ on the subject property.

2. Label the WQPZ.

3. Provide a note to reference any WQPZ stating: "There shall be no clearing, grading, construction or disturbance of vegetation

except as permitted by the Director of Public Works unless such disturbance is done in accordance with 19-514(E) of the Norman City Code.

4. Provide a note to reference any protective covenants governing all WQPZ areas stating: "Any WQPZ shown hereon is subject to protective covenants that may be found in the land records and that restrict disturbance and use of these areas."

5. All subdivisions containing a WQPZ area shall ensure maintenance of the non-structural controls/aspects in the WQPZ area by its Property Owners' Association through the filing of a protective covenant, which is required to be submitted to the City Attorney's office for approval. The covenant shall be recorded in the land records and shall run with the land and continue in perpetuity. Any changes to the covenants and restrictions shall be consistent with the provisions herein.

B. An offer of dedication of a WQPZ to the City of Norman does not convey to the general public the right of access to this area unless such a right is explicitly set forth in said dedication. Further, an offer of dedication of a WQPZ is not a mandate for a public trail system or any portion thereof.

C. The Public Works Department shall inspect the buffer annually and following severe storms for evidence of sediment deposition, erosion, or concentrated flow channels and corrective actions taken to ensure the integrity and functions of the WQPZ.

D. Any portion of the WQPZ that is within thirty (30) feet of a combustible structure shall be maintained (regardless of the underlying zoning designation) as provided in Section 10-209.

E. Portions of the WQPZ that are not within thirty (30) feet of a combustible structure may be left undisturbed and natural, and in no event, shall grassy vegetation in this area be mowed or otherwise cut down to less than six (6) inches tall.

§ 6. That Section 19-601 of Chapter 19 of the Code of the City of Norman shall be amended to read as follows:

Sec. 19-601. Variations.

A. Occasionally the tract to be subdivided is of such unusual size or shape or is surrounded by such development or unusual conditions that the strict application of the requirements contained in this chapter would result in substantial hardship or inequity. The City Council may vary or modify, except as otherwise indicated, such requirements of design, but not of procedure or public improvements, so that the subdivider may develop the subject property in a reasonable manner. At the same time, the public welfare and interests of the City must be protected and the general intent and spirit of this chapter are preserved by granting such variance. Such modification may be granted upon written request of the subdivider or the subdivider's engineer, stating the reason for each modification, and may be approved by vote of the regular membership of the City Council, with the recommendation of the Planning Commission, subject to the acceptance of the plat and the dedications thereon by the City Council; provided, however, that a variation based on unique condition(s) shall not be granted when the unique condition(s) was created or contributed to by the subdivider.

B. WQPZ Averaging. The width of the WQPZ may be reduced in some circumstances to accommodate unusual or historical development patterns, shallow lots, stream crossings, or storm water ponds. Any averaging of the WQPZ must be done in accordance with the following:

   1. An overall average WQPZ width of at least the base width as determined in 19-411(B) must be achieved within the boundaries of the property to be developed. The WQPZ on adjoining properties cannot be included with buffer averaging on a separate property, even if owned by the same property owner.

   2. The average width must be calculated based upon the entire length of stream bank that is located within the boundaries of the property to be developed. When calculating the WQPZ length, the natural stream channel should be followed.

   3. WQPZ averaging shall be applied to each side of a stream independently. If the property being developed encompasses both sides of a stream, WQPZ averaging can be applied to both sides of the stream, but must be applied to both sides of the stream independently, unless the natural topography of the stream makes one side of the stream not conducive to the establishment of a WQPZ and in that event, averaging using both sides may be utilized.

4. WQPZ averaging is prohibited in developments that have, or will have after development areas that have slopes greater than 15% that are located within fifty feet of the stream to be buffered.

5. Appeal from Decision of Public Works Director. If the applicant desires to appeal from the decision of the Public Works Director or his or her designee made in accordance with this subsection, the applicant may file such request, and any documentation supporting said appeal, with the City Clerk. The City Clerk will place the appeal on the agenda of the next available regular City Council meeting. The decision of the Public Works Director, or his or her designee, may be upheld or overturned by vote of the regular membership of the City Council.

C. Whenever infrastructure has been installed that will benefit the full build-out of a Preliminary Plat which was approved within five (5) years prior to the effective date of this ordinance, the Preliminary Plat shall not be deemed expired, for purposes only of the application of this ordinance, even after the passage of three (3) years from the date of approval of the Preliminary Plat, or five (5) years from the date of approval of the Preliminary Plat if a Final Plat has been filed on part of the land embraced in the Preliminary Plat.

§ 7. That Section 19-606 of Chapter 19 of the Code of the City of Norman shall be amended to read as follows:

Sec. 19-606 Exception to allow Norman Rural Certificates of Survey as plats in A-1 and A-2 Zoning Districts.

A. It is the purpose of this exception to allow lots of ten (10) acres or more to be developed and sold adjacent to public or private roadways in the A-1 and A-2 Agricultural Districts; however, private roadways should be constructed and maintained in such a manner that said roadways may be traversed and used by police, fire and other official vehicles of all municipal, county, state and federal agencies. Lots created under this process shall be designated as "Norman Rural Certificate of Survey Subdivisions" and may be permitted under the following procedures (Ord. No. O-0203-34):

*   *   *   *   *

2. An accurate survey of the lot, prepared by a land surveyor registered in the State of Oklahoma, and the proposed subdivision thereof shall be submitted to the Public Works Department and shall show the same information required for a preliminary plat as referenced in Section 19-303 of this Code, except the ground

contours may be drawn at five-foot intervals in such cases where the average ground slope is three (3) percent or greater.

* * * * *

§ 8. If the provisions of any existing section of Chapter 19 conflicts with any section of this Water Quality Protection Zone ordinance, then the provisions of this ordinance O-1011-52 will control and prevail.

§ 9. <u>Severability.</u> If any section, subsection, sentence, clause, phrase, or portion of this ordinance is, for any reason, held invalid or unconstitutional by any court of competent jurisdiction, such portion shall be deemed a separate, distinct, and independent provision, and such holding shall not affect the validity of the remaining portions of this ordinance, except that the effective date provision shall not be severable from the operative provisions of the ordinance.

ADOPTED this 28th day

of June, 2011.

Cindy Rosenthal

Cindy Rosenthal, Mayor

NOT ADOPTED this _______ day

of ____________________, 2011.

____

Cindy Rosenthal, Mayor

ATTEST:

Brenda Hall

Brenda Hall, City Clerk

CITY OF NORMAN CORPORATE SEAL OKLAHOMA

APPENDIX D
Fee Schedule