City of Orem

STORM WATER SYSTEM DESIGN AND MANAGEMENT MANUAL

Updated 10/13/2022

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SECTION 1 PURPOSE

This manual was prepared as a collaborative effort between the City of Orem and Bowen Collins and Associates (BC&A). The City of Orem plans to continue to make revisions to this manual on an as needed basis.

This manual has been prepared to document the approval process, design standards, regulations, and hydrologic and hydraulic computation methods for evaluating and designing storm drain and flood control facilities in the City of Orem's jurisdiction. This manual will provide the standards and requirements that shall be used when planning and designing storm drain facilities. Following these standards and requirements shall ensure that storm drain improvements are designed and constructed in a manner that is consistent throughout the City. The developer and/or storm drain engineer shall be responsible to ensure that construction projects conform to the requirements of the City's Storm Water Master Plan. All storm drain construction projects shall conform to requirements in this Storm Drainage System Design and Management Manual, the City's Storm Water Master Plan, and shall be approved by the City Engineer or designee.

This manual is organized into the following sections:

Section 1 – Purpose

Section 1 describes the purpose of this manual.

Section 2 – Design Submittal Requirements

Section 2 describes the design approval process and procedures for new storm drain facilities in the City of Orem. The process requires that a developer or land owner prepare and submit calculations, reports and drawings for review and approval. The specific requirements for various types of development are provided in this section.

Section 3 – Design Criteria for Storm Drain Facilities

Section 3 outlines the general guidelines that should be followed with respect to grading and drainage when a property is developed. It also contains detailed and specific criteria that shall be followed when designing typical storm drain facilities, including: pipes, inlets (catch basins), streets, manholes, outlet structures, open channels, detention and retention facilities, and culverts. Development in and near floodplains is also discussed.

Section 4 – Hydrologic Analysis

Section 4 describes the hydrologic methods and parameters that shall be used when performing runoff calculations, including: design storm, drainage basin characterization, runoff computational methods and model calibration.

SECTION 2
DRAINAGE SUBMITTAL REQUIREMENTS

2.1 INTRODUCTION

Site grading and drainage plans for parcels of any size must be reviewed in conjunction with the City's development review process. Every property owner or developer that wishes to obtain building permit approval from the City shall submit data as required in this Section. A checklist has been developed by City personnel which must be completed and approved by the City Engineer or designee prior to construction. The checklist can be found on the City's website or at the link provided https://orem.org/planning/.

2.2 STORM WATER POLLUTION PREVENTION PLAN

For all projects that involve a land disturbance of more than 500 square feet or are part of a common plan of development which is larger than 500 square feet, a Storm Water Pollution Prevention Plan (SWPPP) shall be submitted to the City Development Services Department, unless this requirement is waived by the City Engineer or designee. For development impacting less than an acre, a land disturbance permit will be required. Additionally, a Utah Pollutant Discharge Elimination System (UPDES) General Construction Permit shall be obtained by the land owner or developer for all projects as required by The Utah Division of Water Quality (https://secure.utah.gov/stormwater/faq.html#faq04). See the City's Storm Water Management Plan for approved construction Best Management Practices (BMPs) and additional information regarding the SWPPP. These BMPs shall be implemented during the construction period in order to minimize the discharge of pollutants and help protect the water quality of downstream sources.

2.3 LONG-TERM STORM WATER RUNOFF CONTROL

In order to protect downstream water bodies from unnecessary contamination from the storm water system, the use of long-term BMPs is required. The City's Storm Water Management Plan identifies typical pollutants of concern and a list of recommended long-term BMPs. Prior to site plan or final plat approval, a plan must be provided to the City's development review personnel or the Long-term Storm Water Program Manager which includes the following information.

1.) A list of potential contaminants specific for the project site.
2.) A site plan identifying the location and type of all long-term BMPs which address the potential contaminants for the project site.
3.) A maintenance plan for maintaining selected BMPs.
4.) A long-term storm water inspection and maintenance agreement between the property owner and the City.

2.4 FLOODPLAIN PERMIT

A Floodplain Development Permit must be obtained from the City's Development Services Department for all developments that are located in a floodplain as defined on a current FEMA Flood Insurance Rate Map. The permit application must address activities that may include, but are not limited to: modifying the existing ground in or near the floodplain (i.e. cutting or filling), adding a culvert or bridge in the floodplain, or constructing a structure or fence in the floodplain.

SECTION 3 DESIGN CRITERIA FOR STORM DRAIN FACILITIES

Correct design of storm drain facilities is critical to the performance of the facilities during runoff events. The purpose of this section is to provide approved design criteria for projects within the City of Orem to ensure that drainage master planning and facility design efforts for developments within the City are consistent. Design engineers shall follow the criteria within this section unless specific waivers are given by the City Engineer or designee.

3.1 GENERAL GRADING AND DRAINAGE

Proper management of storm water runoff is essential to fulfill grading and drainage objectives, which are:

1. Reduce flood damage, including life and property, from storm water runoff events.
2. Minimize any increase in storm water runoff from new developments or reduce storm water runoff from redevelopment.
3. Reduce soil erosion and sedimentation from development and construction projects.
4. Assure the adequacy of existing and proposed storm drainage facilities.
5. Minimize pollutants in storm water runoff.
6. Direct storm water runoff to vegetated areas (roof drains, dumpster areas, etc).

3.2 CONDUITS

Design Flow – Storm drain pipelines shall be designed to convey the computed design storm runoff (see Section 4.1 for design storm parameters) under full pipe capacity, but with no surcharging. Backwater from receiving streams and full detention/retention basins shall be accounted for in the design.

Minimum Pipe Size – The minimum allowable pipe diameter is 15 inches for mainline storm drain pipes and 12 inches for laterals to inlets. If double inlets are proposed the developer will be required to provide calculations showing the necessary size.

Pipe Material – Refer to the City's Constructions Specifications, Standards, and Drawings manual found at https://orem.org/engineering/. Pipe material larger than 12 inches on city-owned infrastructure shall be reinforced concrete pipe unless otherwise approved by the City Engineer or designee.

Minimum Cover – Refer to APWA's design specifications for minimum pipe cover.

Minimum Slope / Velocity – The minimum slope of the pipe should be determined by the desired velocity of storm water discharge. The pipeline minimum slope shall be designed such that the velocity of the design discharge is greater than 2 feet per second unless approved by the City Engineer or designee. In the case of discharge to an open channel, refer to section 3.6 and 3.7.

Location – Public storm drain pipelines shall be located within the public right-of-way or dedicated open space. All storm drain facilities not located in the street right-of-way shall have a 20 foot wide drainage easement. The minimum width of the easement shall be calculated using the equations below. The easement shall be centered on the drain line, unless otherwise approved by the City Engineer or designee. Drainage easements shall extend ten feet beyond dead end structures.
Easements shall be shown on the development plat and on the City's Standard Easement forms, which grants easements to the City. Easements must be executed and returned to the City Office prior to final approval.

1. Single pipe in the Easement

   $W_{easement} = B_c + 2H + 3$

   Where:

   $W_{easement}$ = Easement Width (in feet)
   B_c = Diameter of the outside wall of the pipe (in feet)
   H = Depth from top of pipe to final grade

   $W_{easement}$ shall be rounded up to the next highest five-foot increment and a **minimum width of 20 feet.**

2. Multiple pipes in the easement, shall be calculated as a special case as approved by the City Engineer or designee.

3. Open Channel/Swale

Q100 < 20 cfs	$W_{easement}$ = 15 feet
Q100 < 100 cfs	$W_{easement}$ = 25 feet
Q100 > 100 cfs	Easement to be determined with maintenance requirements from coordination with City Engineer or designee.

Exceptions to this section may be waived by the City Engineer or designee.

3.3 MANHOLES

Location – A manhole or cleanout structure shall be located at the upstream end of a storm drain conduit and at all changes in pipe size, horizontal alignment, slope, and material of the storm drain conduit. Manholes shall be located in paved roads unless approved by the City Engineer or designee. Concrete collars are preferred as outlined in the City's Constructions Specifications, Standards, and Drawings manual.

Spacing – Unless otherwise approved by the City Engineer or designee, the maximum horizontal distance between manholes is 400 feet.

Size – The minimum manhole size is 48-inches in diameter and shall be sized to meet manufacturer's recommendations based on pipe penetration size and configuration. Refer to the City's Constructions Specifications, Standards, and Drawings manual found at https://orem.org/engineering/ for specifications regarding cover size.

Configuration – Either cast-in-place or precast concrete manhole structures or cleanouts can be used as junction structures. These structures shall have concrete troughs to reduce hydraulic losses and improve inspection access. For main line pipes that are 48-inches in diameter or larger, a precast tee manhole may be used as a cleanout structure if approved by the City Engineer or designee.

3.4 INLETS

Location – Storm drain catch basins or inlets shall generally be located on both sides of the street and in road sag locations. Cleanout boxes shall be located at every change in alignment or slope and at junctions with other lines, as approved by the City Engineer or designee.

Configuration – All inlets shall have a curb-back opening and bicycle-safe grate with a 12-inch minimum sump depth as shown in standard Detail SD-4. This detail and other Orem City standard construction details can be found at https://orem.org/engineering/.

Road Sags – At a minimum, double inlets spaced four feet apart shall be installed in road sag locations. See Section 3.5 for 100-year flow conveyance requirements.

Spacing – Inlet spacing and configuration shall be designed to meet the design spread requirements from the FHWA Urban Drainage Manual. Table 3-1 below lists the allowable gutter spread in conjunction with street design frequency and classification. As a general rule, inlets shall be installed at intervals not to exceed 400 feet. Inlet spacing shall be addressed and documented during the design phase.

Table 3-1
Allowable Gutter Spread for Design of Streets

Street Classification	Design Frequency	Design Gutter Spread
High Volume		
< 45 MPH	25-Year	Shoulder plus 3 feet
> 45 MPH	25-Year	Shoulder
Sag Point	50-Year	Shoulder plus 3 feet
Collector		
< 45 MPH	25-Year	½ Driving Lane
> 45 MPH	25-Year	Shoulder
Sag Point	25-Year	½ Driving Lane
Local Streets	25-Year	½ Driving Lane

3.5 HYDRAULIC CAPACITY OF STREETS

Design Spread – Storm drain facilities in streets shall be designed to meet the design gutter spread indicated in section 3.4.

100-Year Flow Conveyance – Streets shall be designed to safely convey runoff from a 100-year design storm (see Section 4.1 for design storm parameters) to adequate downstream conveyance facilities. The 100-year design storm runoff in streets shall be contained within the street right-of way. Provisions shall be made, such as storm water easements, to allow runoff within the street to enter downstream detention basins, to allow runoff to be conveyed out of road sags or other similar situations.

Cul-De-Sacs and Dead-End Streets – Downhill-sloping cul-de-sacs and dead ends will not be allowed unless specifically approved by the City Engineer or designee. If they are allowed, means to safely convey runoff from a 100 year design storm event across the site to appropriate drainage facilities must be provided with appropriate drainage easements and building restrictions.

Tee Intersections – Special consideration, such as higher curbs, additional inlets or flood easements, shall be given to downhill tee intersections to ensure that flooding will not occur outside of the right-of-way during a 100 year design storm event. Also, an evaluation shall be provided to address where flood water will go if the storm drain facilities plug or become overwhelmed. The City may consider obtaining a storm water easement on the adjacent properties to allow for drainage.

3.6 OUTLET STRUCTURES FROM CLOSED CONDUIT TO OPEN SYSTEM

Location – An outlet structure shall be installed on the downstream end of all closed conduits at the point where the storm water will be discharged into an open channel. The structure shall be designed to minimize erosion within the receiving drainage.

Grating – The outlet structure shall have vertical bars only with an opening spacing of 4 inches and shall be hinged at the top.

Rip Rap Design – Rip rap shall be designed for outlet structures based on discharge velocity and receiving drainage. The D_{50} is the nominal rock diameter in inches, of which 50 percent of the rocks are smaller. The minimum allowable rock size is a D_{50} of 6 inches. Riprap design calculations shall be submitted to the City Engineer or designee for review.

The minimum thickness of rip rap shall be 1.5 X D_{50}. For example if a D_{50} of 24 inches was calculated, the riprap would need to be stacked such that the interlocking riprap is not less than 36 inches ($1.5*D_{50}$) thick perpendicular from the stream slope.

Stream Alteration and Corps of Engineers Permits – A State of Utah Stream Alteration permit may be required if the project is to alter the bed or banks of a natural stream. Contact the Division of Water Right (DWR) office (phone 801-538-7240) to find out if your proposed project will require a stream alteration permit. Be aware that there is a fee and review period associated with the application. A joint or separate US Army Corps of Engineers (ACOE) permit may also be required. Contact the local ACOE office at 801-270-8380 to find out if your proposed project will require an ACOE permit.

3.7 OPEN CHANNELS

The use of open channels to convey storm water runoff must be approved by the City Engineer or designee. If the use of an open channel is approved, the open channel shall be designed to meet the following criteria:

Velocity – Open channel design shall be dictated by the maximum permissible velocity of the channel material/lining. Table 3-2 shows the maximum permissible velocity for the most common channel material/lining. Provisions shall be made to irrigate naturally lined channels until vegetation is established.

Table 3-2
Maximum Permissible Mean Channel Velocities
(From the Clark County Hydrologic Criteria and Drainage Design Manual)

Material/Lining	Maximum Permissible Mean Channel Velocity (feet per second)
Natural and Improved Unlined Channels	
Fine Sand, Colloidal	1.5
Fine Gravel	2.5
Coarse Gravel, Noncolloidal	4.0
Cobbles	5.0
Fully Lined Channels	
Unreinforced Vegetation	5.0
Loose Riprap	10.0
Grouted Riprap	15.0

Longitudinal Channel Slope – Channel slope is dictated by maximum permissible velocity requirements. Where the natural topography is steeper than desirable, drop structures shall be utilized to limit design velocities. Channels shall maintain sufficient slope to be self-draining. Adverse slopes are not acceptable without approval from the City Engineer or designee.

Soils – Soil testing shall be required to determine if imported fill is required and whether existing soils will support adequate plant growth.

Easements – Easements shall be finalized and recorded prior to approval.

Channel Cross Section – Channels shall be constructed with a trapezoidal shape. Unless otherwise approved, channel side slopes shall not be designed steeper than 3 horizontal to 1 vertical. Channels with 2 horizontal to 1 vertical side slopes may be allowed by the City Engineer, provided the lining materials and velocities are reasonable. Other cross section types shall be reviewed and approved on an individual basis by the City Engineer or designee.

Maintenance – Channels shall be designed to be low maintenance and to minimize erosion potential. All open channels shall be accessible by City vehicles for maintenance.

Freeboard – The open channel shall have a minimum of 1 foot of freeboard above the 100-year design flow water surface elevations.

Depth – Unless otherwise approved by the City Engineer, the maximum allowable design depth of flow is 4 feet.

Bottom Width – Unless otherwise approved by the City Engineer, the minimum bottom width shall be 4 feet.

Low Flow Channel – All low flow channels shall be grass-lined, rock mulch, or vegetated. Exceptions must be approved by the City Engineer or designee.

Levees – Levees or berms along the channel will only be allowed to meet freeboard requirements. Levees or berms shall not be designed to impound storm water.

Channel Transitions and Bends – All channel transitions and horizontal bends in the alignment shall be designed to be gradual enough so as to not induce erosion or have adequate bank stabilization measures installed.

Non-FEMA Floodplains – In general, all building floor levels shall be constructed two feet above the 100-year flood level. Encroachments into the 100-year floodplain for natural water courses will not be allowed unless otherwise permitted by the City. All natural drainages, washes, and waterways that convey a developed 100-year flow of greater than 150 cfs will be left open unless otherwise approved. Developments located adjacent to or in floodplains shall be required to stabilize the continual degradation and erosion of the channel by installing grade control structures and/or by other effective means as outlined in Chapters 10 and 17 of City code. Any alteration of the floodplain is not permitted unless the proposed use can be shown to have no significant negative influence on the flood conveyance, the floodplain, or the alteration itself.

In the layout and design of new developments, adequate access to floodplains and erosion protection shall be provided. It is preferred that streets be positioned between floodplains and structures. Where not possible or feasible, additional structural setbacks will be required.

Hydrologic, hydraulic, erosion, and geomorphologic studies will be required of developments adjacent to floodplains.

3.8 RETENTION BASINS

It is required that a Low Impact Development (LID) approach be taken for each project. The City's Storm Water Management Plan identifies long-term Best Management Practices (BMPs) which include several LID approaches. If an LID approach is not technically feasible, documentation must be provided which identifies the issues and provides an alternative which uses infiltration and evapotranspiration to the maximum extent possible. Recommended BMPs can be found in *A Guide to Low Impact Development within Utah*. Additional resources regarding the implementation of LID have been outlined in Appendix A.

In order to mimic historic runoff, the City of Orem requires that all sites retain the first 0.5 inches of precipitation. The State Division of Water Quality requires that storm water be managed on site for all developments larger than an acre or part of a common plan of development larger than one acre. All events less than or equal to the 80th percentile storm event are required to be managed on site (retained and infiltrated). The 80th percentile storm has been calculated to be the first 0.50 inches of precipitation as outlined in Appendix B. If this is not technically feasible, a rationale must be presented to the City Engineer for review. Documentation must show that infiltration, evapotranspiration and rainwater harvesting have been used to the maximum extent technically feasible. At the discretion of the City Engineer, alternative design criteria may be established for projects where this is infeasible.

With the exception of retaining the first 0.5 inches or the 80th percentile storm, the use of retention basins will only be allowed under the following conditions as approved by the City Engineer or designee.

Volume – Retention basins shall be sized to retain runoff from a 25-year design storm event (see Section 4.1 for design storm parameters).The volume requirements shall not be reduced based on evaporation or infiltration due to percolation, unless approved by the City Engineer or designee.

Freeboard – A minimum of 1 foot of freeboard shall be provided.

Emergency Outlet – An emergency outlet shall be designed to safely discharge the peak runoff from the maximum storm event into an appropriate existing drainage facility.

Retention Time – The retention basin shall be designed to drain completely within 72 hours at the end of the storm event. Retention time must be addressed during the design process and retention parameters must be approved by the City Engineer or designee.

Water Depth – The maximum water depth shall not exceed 3 feet for a retention basin in a landscaped area unless otherwise approved by the City Engineer or designee.

Side Slope – Retention basin side slope shall be 4H:1V or flatter unless otherwise approved by the City Engineer or designee.

Location – Retention basins should be located as to minimize their impact on the site and to ensure public safety. Retention basins shall be located at least 40 feet from any structure with a foundation and 10 feet from property lines. If it is desired to be closer than 40 feet to a structure, a site specific geotechnical report outlining potential risks for damaging or flooding adjacent structures is required. All retention basins shall have vehicular access for maintenance. All public retention basins shall be accessible from a public right-of-way or a dedicated easement.

Ownership and Maintenance – The property owner or home-owners association shall own and maintain the retention facility including landscaping. No alterations to the pond shall be permitted without the approval of the City Engineer or designee. Means of vehicular access to the facility shall be provided.

Landscape – All facilities shall be landscaped in accordance with the City’s Code.

3.9 DETENTION BASINS

All detention basins serving a development shall be designed according to the criteria listed below and the criteria from the City, whichever is more conservative. Design criteria for regional detention basins, or detention facilities that receive storm water runoff from multiple developments, shall be defined by the City Engineer or designee on a case by case basis.

Release Rate – In order to minimize long reaches of large diameter storm drain pipes, the City will require all development and redevelopment to detain runoff in excess of the 80^{th} percentile storm. The post-construction release rate shall be equal to or less than the historical pre-development discharge for the 100-year event. Under no circumstances shall the post development discharge be greater than 60 gpm per acre.

Volume – Detention facilities shall be designed to prevent local increases in the 25-year design storm, for the 3 hour and 24 hour durations, whichever case requires the largest volume (see Section 4.1 for design storm parameters). The volume requirements shall not be reduced based on evaporation or infiltration due to percolation unless the basin has been designed and will be maintained specifically for infiltration. In this case, a maintenance agreement acceptable to the City Engineer or designee must be in place prior to construction of the basin.

Freeboard – A minimum of 1 foot of freeboard above the maximum water surface elevation.

Emergency Outlet – An outlet shall be designed to safely discharge runoff from the maximum storm event.

Detention Time – The detention time shall be as short as possible; typically limited to a maximum of 18 hours.

Water Depth – The maximum water depth shall not exceed 3 feet for a detention basin in a landscaped area and 6 inches in a parking lot unless otherwise approved by the City Engineer or designee.

Side Slope – Detention basin side slopes shall be 4H:1V or flatter unless otherwise approved by the City Engineer or designee.

Bottom Slope – Detention basins shall have a minimum floor slope of 2% unless approved by the City Engineer or designee.

Inlet Design – A concrete apron must be installed at entrance and exit structures to minimize erosion and accommodate maintenance.

Outlet Design – All detention basins shall have an outlet to the City's storm drain system. A trash rack shall be installed at the outlet(s) to prevent debris from entering the storm drain system. The orifice restriction shall be designed to minimize clogging from debris.

Dewatering – All low flow channels shall be grass-lined, rock mulch, or vegetated. Exceptions must be approved by the City Engineer or designee.

Location – Detention basins shall be located in a manner to minimize their impact on the site and to ensure public safety. Detention basins shall be located at least 40 feet from any structure with a foundation and 10 feet from property lines. If it is desired to be closer than 40 feet from a foundation, a site specific geotechnical report outlining potential risks for damaging or flooding adjacent structures is required. All detention basins shall have vehicular access for maintenance. All public detention basins shall be accessible from a public right-of-way or a dedicated easement.

Ownership and Maintenance – The property owner or home-owners association shall own and maintain the detention facility including landscaping as prescribed in their SWMP. No alterations to the pond shall be permitted without the approval of the City Engineer or designee.

Landscape – All facilities shall be landscaped in accordance with the City Code.

3.10 CULVERTS/BRIDGES

Culverts are conduits that convey runoff in an open channel under or across a road or parcel. A culvert is a type of bridge, but bridges do not have to be a conduit, they may simply be an opening underneath the structure that allows the channel to convey flows.

Location – Culverts/bridges shall be sized to convey the computed design storm runoff (see Section 4.1 for design storm parameters) without runoff overtopping the road or leaving the channel. The minimum allowable culvert diameter is 24 inches and should be RCP unless otherwise approved by the City Engineer or designee.

Design Load – The existing and future street design shall be used to develop the design load and minimum cover. HS-20 loading shall be used if no other loading information is available.

Headwall – Improvements shall be installed at entrance and exit structures to minimize erosion and accommodate maintenance. Typically, culverts shall have a headwall with wing walls.

Debris – A culvert/bridge blockage factor of 50 percent shall be used for culverts/bridges placed in drainages with upstream debris producing potential as determined by the City.

Backwater – Backwater surface computations upstream of culverts shall be performed and shown to be non-damaging to upstream properties.

Freeboard – A minimum of 2 feet of freeboard above the maximum water surface elevation is required unless otherwise approved by the City Engineer or designee.

Configuration – Where possible, culverts shall be designed to have a single opening. Multiple side-by-side culverts are susceptible to clogging and are not allowed unless approved by the City Engineer or designee.

Ownership and Maintenance – The property owner or home-owners association shall own and maintain culverts and bridges including necessary maintenance. No alterations to the culvert or bridge shall be permitted without the approval of the City Engineer or designee.

3.11 SENSITIVE LANDS

Sensitive Lands include steep sloped (greater than 30% slope) areas, wetlands, watercourse, drainage channels, one hundred year floodplains, potential landslide areas, fault lines, sensitive soils, and rock fall areas.

Proposed construction on sensitive lands will comply with City Code, Chapters 10, 17 and 22. Additional requirements are highlighted below.

Hillside Development Standards – Land having a slope greater than 10% is defined as “steep slope”. A geologic study report shall be submitted for development on lands steeper than 10%. No development will be permitted on land where the slope is steeper than 30%. All development shall comply with Chapter 17 of City Code.

Floodplain Development Standards – Development located in or near floodplains shall meet the requirements of the National Flood Insurance Program and conform to the City’s Code. For all developments that cover over 5 acres or have 50 or more lots, a developer shall perform a study to estimate the 100-year flood elevations if those elevations are not defined on the FEMA Flood Insurance Rate Map. Construction of habitable structures will not be allowed in the 100-year special flood hazard area.

SECTION 4
HYDROLOGIC ANALYSIS

4.1 DESIGN STORM

Rainfall Depth and Intensity – Rainfall depth and intensity shall be obtained from the National Weather Service's Precipitation Frequency Data Server (https://hdsc.nws.noaa.gov/hdsc/pfds/) using the annual maximum time series option. The NOAA site contains depth-duration-frequency and intensity-duration-frequency tables for a location within the City of Orem. The storm water engineer shall refer to the website to determine site specific data for their area of development.

Distribution and Duration – Cloudburst rainfall events along the Wasatch Front in Utah typically have durations ranging from a few minutes to three hours. Storms producing general rainfall over longer periods of time are rare, and are typically associated with slow-moving tropical storm remnants. The following design storms and duration shall be used for sizing drainage and storm water facilities.

- 10-year, 3-hour Farmer Fletcher synthetic storm duration shall be used to evaluate and design storm drain pipeline facilities.
- 100-year, 6,12, and 24-hour NOAA Atlas 14 storm duration shall be used to evaluate and design major conveyance facilities such as bridges, culverts, channels, and facilities where public health and safety are a concern. The worst case shall be chosen for all facilities unless otherwise approved by the City Engineer or designee.
- 25-year, 3-Hour Farmer Fletcher and 24-hour NOAA Atlas 14 storm durations shall be used for all detention facilities' volume design. The maximum peak volume from these two storm durations shall be used to evaluate the design of the storage facilities

Frequency - Storm drain facilities shall be designed to include major and minor conveyance facilities. Minor system facilities generally include storm drain pipes and detention/retention basins. Minor system facilities shall be designed to collect and convey storm water runoff from a storm with a return frequency of 10 years for storm drain pipes and a return frequency of 25 years for detention/retention facilities.

Major system facilities generally include streets, bridges, culverts, and streams. Major system facilities shall be designed to collect and convey storm water runoff from a 100 year design storm. Streets shall be designed to convey the 100-year discharge from upstream to downstream (i.e. avoid local street sags or low points).

4.2 DRAINAGE BASIN CHARACTERIZATION

Soil Classification – Soil classification shall be estimated from site specific analysis or from a soil survey, such as the NRCS soil survey data. The NRCS soil survey data and reports are available at http://websoilsurvey.nrcs.usda.gov and http://datagateway.nrcs.usda.gov/ .

Land Use – Existing land use shall be obtained from site survey or analysis of current aerial photography. Future land use shall be estimated based on proposed development or from the City's General Plan if future development plans are unknown.

Physical Parameters – Physical parameters such as drainage basin area, length and slope shall be obtained using a current topographic map and existing storm drain facilities.

4.3 RUNOFF COMPUTATIONAL METHODS

Acceptable Methods – The most commonly used method for estimating the peak runoff is the Rational Method. Two other methods may be used that are acceptable to the City, but are less commonly used. The two alternative methods are described below including the standard Rational Method. TR-55 and HEC-HMS can also be used to estimate runoff volume for storage facility sizing. See Section 3 for design criteria.

The TR-55 method worksheets can be found online through reference #7 found at the end of this document. In addition, the USDA also has a workable computer model system to assist in using this method.

Other methods for estimating peak runoff and runoff volume must first be approved by the City Engineer or designee. Table 4-1 indicates the applicable total drainage area for each modeling approach.

Table 4-1 Drainage Models and Applicable Total Drainage Area

Drainage Model	Maximum Drainage Area
Rational Method	< 50 Acres
TR-55	< 2000 Acres for Urban Areas
HEC-HMS	Any

Rational Method

i. **Runoff Equation** – Q = CiA where,
Q – Instantaneous Peak Runoff **C** –
Runoff Coefficient (see Table 4.2) **i** –
Intensity (inches/hour)
A – Area (acres)

ii. **Time of Concentration** – Time of concentration shall be calculated using the method found in SCS Technical Release 55 (SCS, 1986). The minimum allowable time of concentration to be used in runoff calculations shall be 10 minutes.

iii. **Rainfall Intensity** – The rainfall intensity shall be selected from the intensity-duration frequency curve in Appendix B. The duration is assumed to equal the time of concentration. The design storm frequency can be obtained from Section 4.1.

iv. **Runoff Coefficient** – Table 4-2 shall be used to estimate the runoff coefficient.

Table 4-2 Rational Method Runoff Coefficients[1]

Type of Drainage Area	Runoff Coefficient, C*
Business:	
Downtown areas	0.95
Neighborhood areas	0.70
Residential:	
Single-family areas	0.50
Multi-units, detached	0.60
Multi-units, attached	0.75
Suburban	0.40
Apartment dwelling areas	0.70
Industrial:	
Light areas	0.80
Heavy areas	0.90
Parks, cemeteries	0.25
Playgrounds	0.35

Type of Drainage Area	Runoff Coefficient, C*
Railroad yard areas	0.35
Unimproved areas	0.30
Lawns, sandy soil:	
Flat, 2%	0.10
Average, 2 – 7%	0.15
Steep, 7%	0.20
Lawns, heavy soil:	
Flat, 2%	0.17
Average, 2 – 7%	0.22
Steep, 7%	0.35
Pavement:	
Asphaltic and Concrete	0.95
Brick	0.85
Roofs	0.95

*Upon submission of a site specific engineering report, a lower runoff coefficient may be approved by the City Engineer or designee.

v. **Runoff Computations.** Runoff computations for directly connected impervious areas shall be performed separately from areas that have pervious surfaces.

SCS TR-55

- The NOAA Atlas 14 storm distribution shall be used if the TR-55 method is used.

- The storm depths shall be selected from the depth-duration-frequency curve found on the NOAA site.

- Table 2-2a-d in TR-55 shall be used to estimate the runoff Curve Number (CN). See below for note regarding modeling impervious area.

Note: A composite SCS curve number may be used to estimate runoff from areas with pervious surfaces. These composite curve numbers represent all of the different soil groups and land use combinations (such as lawn and xeriscaping) within the subbasin for the PERVIOUS areas only. When modelling a developed subbasin to estimate storm water runoff, the pervious and impervious areas must be modelled using separate subbasins. Some methods, including TR-55, suggest that a composite can be selected that will account for impervious area. However, those methods tend to underestimate the runoff potential for the impervious areas and should not be used.

TR-55 Worksheet 3: Time of Concentration, and TR-55 Worksheet 4: Graphical Peak Discharge Method will be most helpful.

HEC-HMS

There are four main input categories in HEC-HMS which are: design storm, loss method, transform method and routing method. The design storms shall be obtained using the procedure described below. For the loss, transform and routing methods, there are multiple options within HEC-HMS that can be used. Below is a description of the preferred method. Other methods may be allowed, but must first be approved by the City Engineer, or designee.

i. **Design Storm -**The design storm shall be developed in accordance with Section 4.1.

ii. **Loss Method –** The SCS Curve Number loss method shall be used. The primary input parameter for this method is the Curve Number. As described below, for developed areas, the percent impervious is also entered. The initial abstraction is typically left blank. The program will calculate the initial abstraction based on the Curve Number using the equation documented in TR-55.

a. **Curve Number –** Table2-2a-d in TR-55 shall be used to estimate the pervious runoff Curve Number (CN).

b. **Soil Classification** – In order to estimate the CN, the hydrologic soil group classification for the drainage basin must be determined. The hydrologic soil groups shall be obtained as defined in Section 4.2.

c. **Modeling Impervious Areas –** The directly connected impervious area (DCIA) should be used when modelling developed areas. The DCIA should be measured from aerials for existing developments, or should be obtained from the design plans for a proposed development.

iii. Transform Method – The SCS Unit Hydrograph transform method shall be used. This method requires the input of a single variable: lag time.

a. **Lag Time for Natural Watersheds -** The Corps of Engineers version of Snyder's equation shall be used to calculate the lag time for natural watersheds (USBR, 1989) as shown below:

$$\text{Lag Time} = C_t \left(\frac{L L_{ca}}{S^{0.5}} \right)^{0.33}$$

Where:

C_t = Constant between 1.3 and 2.2. 1.6 is typical for the Orem Area. L = Length, in miles, of the longest watercourse
L_{ca} = Length, in miles, along L to the centroid of the drainage basin S = Overall drainage basin slope, in feet/mile.

b. **Lag Time of Urban Areas -** The lag time for small urban areas is assumed to be equal the time of concentration. Worksheet 3 from TR-55 can be used to calculate the time of concentration.

iv. Routing Method - The Muskingum-Cunge method shall be used for routing runoff hydrographs. This method uses "reaches" to connect subbasins. Examples of reaches in the real world include open channels and pipes. The method requires that the follow parameters be input:

Length – Total length of the reach element.

Slope – Average slope for the entire reach.

Invert – Optional. Typically not used.

Cross Section Shape – Multiple cross sections are available to select from. Depending on the cross section chosen, additional information is required (i.e. diameter, side slope).

Manning's "n" – Average value for the entire reach. Typical values for Manning's "n" used for storm drain conveyance facilities area shown in Table 4-3.

Table 4-3
Values of Manning's Coefficient (n) for Channels and Pipes

Conduit Material	Manning's n*
Plastic pipe	0.009
Steel/cast iron pipe	0.014
Concrete pipe	0.013
Corrugated metal pipe	0.026
Concrete-lined channel	0.02
Excavated or Dredge Channels	
Earth channel – straight and uniform	0.025
Earth channel – winding, fairly uniform	0.04
Rock	0.045
Unmaintained	0.14
Natural Channel	
Fairly regular section	0.07
Irregular section with pools	0.10

Other Models

Other computer programs can be used to model the rainfall-runoff process that use similar hydrologic modeling methods, but care should be taken to make sure modeling methods are used correctly. Examples of similar programs include StormCAD, SWMM-5 and StormNET. The City Engineer, or designee, must approve the use of all computer programs and methods that are not described above.

4.4 MODEL CALIBRATION

Peak runoff records are typically not available for local drainage studies. Research should be conducted to ensure that rainfall runoff analysis results for local drainage studies are consistent and compatible with the City's Storm Water Master Plan and other pertinent local drainage studies.

It should be noted that the term "calibration" in this context refers to the process of adjusting parameters to achieve results consistent with available reference information, rather than adjusting for actual stream flow observations from the study area. Multiple hydrologic methods should be evaluated and compared to identify reasonable runoff computation results. These methods may include the Rational Formula, the SCS Curve Number Method, the SCS Pervious CN Method, and the Constant and Initial Loss Method. Regional regression equations may also be used to evaluate results depending on the basin size.

Calibration for Natural Watersheds

Results from hydrologic models should be compared to:

- Actual flow records for modeled drainage channels
- Stream flow records from hydrologically similar drainages in the vicinity of the study
- Regional stream flow data (in the event that stream flow records for the local area are not available).

Calibration for Urban Areas

For small urban (developed) areas, the USGS published regression equations than can be used to “calibrate” hydrologic models (see Peak-flow Characteristics of Small Urban Drainages Along the Wasatch Front, Utah). The range of basin characteristics used to develop the regression equations are shown in Table 4-4.

Table 4-4
Range of Basin Characteristics Used
To Develop Regression Equations for Small Urban Drainages

Basin Characteristic	Unit	Range in Values
Drainage Area (DA)	mi^2	0.085 – 0.87
Basin Slope (BS)	Percent	0.3 – 15
Effective Impervious Area (EIA)	Percent	22 – 57

The equations shown in Table 4-5 are only applicable to drainage basins that meet the range of values shown above.

Table 4-5
Regression Equations for Peak Flows
For Small Urban Drainages

Design Storm Recurrence Interval (Years)	Equations	Average Standard Error of Estimate (Percent)
10	$Q_{10} = 0.575\ DA^{0.285}\ BS^{0.410}\ EIA^{1.29}$	32
25	$Q_{25} = 66.1\ DA^{0.093}\ BS^{0.243}$	33
100	$Q_{100} = 120\ DA^{0.158}\ BS^{0.194}$	29

The unit peak runoff varies depending on slope and the drainage basin percent impervious. In general, the 10-year event for small urban drainages should be between 0.25 cfs/acre and 1.0 cfs/acre. Modification to input parameters should be considered if simulated runoff results are not within this range.

REFERENCES

1. American Society of Civil Engineers, New York, p. 332, 1969, Design and Construction of Sanitary and Storm Sewers.

2. Farmer, E.E., and J.E. Fletcher, February 1972,Rainfall Intensity-Duration-Frequency Relations for the Wasatch Mountains of Northern Utah, Water Resources Research, Vol.8, No. 1.

3. Federal Highway Administration, August 2001, Urban Drainage Design Manual, Hydraulic Engineering Circular No. 22, Second Edition.

4. National Oceanic and Atmospheric Administration, 2006, NOAA Atlas 14, PrecipitationFrequency Atlas of the United States, Volume I, Version 4, Semiarid Southwest.

5. Thomas, B.E., H.W. Hjalmarson and S.D. Waltemeyer, 1994, Methods for Estimating the Magnitude and Frequency of Floods in the Southwestern United States, U.S. Geological Survey, Open File Report 93-419.

6. U.S. Army Corps of Engineers, December 1979, Project Cloudburst, Salt Lake County, Utah, Internal File Report.

7. U.S. Department of Agriculture, Soil Conservation Service, June 1986, Urban Hydrology for Small Watersheds, Technical Release 55.

8. U.S. Department of the Interior, Bureau of Reclamation, 1989, Flood Hydrology Manual.

9. U.S. Department of the Interior, Geological Survey, March 1982. Interagency Advisory Committee on Water Data, Office of Water Data Coordination, Hydrology Subcommittee, Bulletin No. 17B.

10. WRC Engineering, Inc., October 1990. Hydrologic Criteria and Drainage Design Manual, Clark County Regional Flood Control District, Las Vegas, Nevada.

APPENDIX A

LOW IMPACT DEVELOPMENT

LOW IMPACT DEVELOPMENT

The MS4 permit for the City of Orem requires the following: "For new development or redevelopment projects that disturb greater than or equal to one acre, the program shall include a process which requires the evaluation of a Low Impact Development (LID) approach which encourages the implementation of BMPs that infiltrate, evapotranspire or harvest and use storm water from the site to protect water quality" (Small MS4 General Permit No. UTR090000). As the City continues to develop and redevelop, LID practices have been implemented to comply with State and Federal regulations.

WHAT IS LID?

LID is a comprehensive approach to micromanaging storm water where it is generated. The goal of LID is to develop a storm water management strategy where post-development hydrologic conditions mimic pre-development conditions through utilizing storm water features that infiltrate and evapotranspirate in a cost-effective, flexible manner. It also involves protecting water quality by treating and filtering storm water near the source, before it infiltrates into the ground.

LID practices focus on minimizing flooding, erosion, and pollution by utilizing natural processes to filter, treat, and allow storm water to infiltrate into the ground. It typically preserves, restores, and creates green infrastructure using soils and vegetation. By implementing LID principles and practices, water can be managed in a way that reduces negative environmental impacts often associated with developed areas and promotes the natural movement of water within the area.

LID strategies include several techniques to generate less runoff from developed land. LID practices are flexible, offering a wide variety of techniques to reduce runoff timing and volume. LID practices control storm water runoff at the lot level, using a series of integrated strategies that rely on natural processes. LID principles:

- preserve and recreate natural landscape features
- minimize directly-connected impervious area
- comprehensive, landscape-based approaches to sustainable development
- utilize natural hydrologic functions and processes
- focus on prevention, rather than mitigation
- emphasize simple, low-tech, low cost methods
- manage storm water runoff as close to the source as possible
- minimize disturbance
- increase drainage flow paths
- utilize onsite filtering and treatment methods

POTENTIAL LID FEATURES AND PRACTICES

There are many practices that can be utilized when implementing LID principles. Some are listed below.

Xeriscape Swale/Grassy Swale – A swale landscaped with xeriscape plants or grass can be used to infiltrate storm water in place. Curb cuts along roads can be used to discharge storm water runoff generated in paved streets and parking lots into the swale.

Underground Storage Tanks – Underground storage can include R-tanks, StormTech systems, or other underground storage facilities that are designed to detain or retain storm water runoff and allow it to infiltrate into the ground. Underground storage facilities should have an overflow to a centralized storm drain system. Treatment should be included in any underground storage facility.

Rain Barrels – Some runoff can be captured in rain barrels and utilized for non-potable purposes. It is important to keep in mind that in Utah, only 2,500 gallons per parcel of rain water runoff is allowed to be collected and stored onsite.

Roof Drains – Roof drains shall be directly routed to vegetated areas. Roof drains may be connected to underground facilities, such as infiltration trenches or dry wells after passing through appropriate vegetated landscaping. Infiltration trenches or dry wells consist of perforated manholes and pipes surrounded by gravel and a geotextile fabric. The purpose of the infiltration trench or dry well is to store water and allow it to percolate into the ground. It is important that the roof runoff be treated prior to infiltrating into the ground.

Grass Filter Strips – Grass Filter Strips are low-angled vegetated slopes that drain away from the parking lot or roadway.

Bioretention – Bioretention includes the use of vegetation and soils to clean storm water runoff in an earthen basin lined with plants and mulch.

Soil Amendments – In areas where native soils have low infiltration rates, the native soils can be amended by mixing in organics or other materials to increase infiltration capacity. Soil amendments can also improve water quality, depending on the materials added. It is important that the soil is not compacted during construction.

Preserve Vegetation – The natural vegetation of an area to be developed should be preserved by reducing the total impervious area for a site by clustering buildings close together, reducing building footprints, reducing road widths, and other methods to preserve as much of the native vegetation as is feasible for a given site.

Storm Water Planters – Storm water planters are boxes with drought resistant vegetation that are used to capture storm water runoff from roofs and other impervious surfaces. They function like bioretention on a small scale.

The concepts listed above do not represent all the approaches for implementing LID. Ultimately, the developer and their engineer are responsible for researching the most effective methods for implementing LID practices on a development site. Additional resources to research, plan and design LID are listed below:

MacAdams, James. Green Infrastructure for Southwestern Neighborhoods. (Oct 2012) Watershed Management Group. EPA Website.
https://www.epa.gov/green-infrastructure/green-infrastructure-design-and-implementation

Dorman, T., M. Frey, J. Wright, B. Wardynski, J. Smith, B. Tucker, J. Riverson, A. Teague, and K. Bishop. 2013. San Antonio River Basin Low Impact Development Technical Design Guidance Manual, v1. San Antonio River Authority. San Antonio, TX. https://www.epa.gov/green-infrastructure/green-infrastructure-design-and-implementation

Environmental Protection Agency. (April 2009) Managing Stormwater with Low Impact Development Practices: Addressing Barriers to LID. EPA 901-F-09-003. https://www3.epa.gov/region1/npdes/stormwater/assets/pdfs/AddressingBarrier2LID.pdf

Environmental Protection Agency. (1995, November). Pollution Control Programs for Roads, Highways and Bridges. (EPA 841 F 95 008c). Office of Water. Washington, DC: Environmental Protection Agency. http://www.epa.gov/owow/nps/education/control.html

Environmental Protection Agency. (2008, March 7). NPS Categories | Roads, Highways and Bridges | Polluted Runoff (Nonpoint Source Pollution) | US EPA. http://www.epa.gov/owow/nps/roadshwys.html

Spanish Fork City. Low Impact Development. (Dec 2013). Project Engineering Consultants. http://www.spanishfork.org/dept/pubworks/utilities/storm/pdf/Low_Impact_Development_Report.pdf

National Cooperative Highway Research Program. Evaluation of Best Management Practices for Highway Runoff Control. Low Impact Development Design Manual for Highway Runoff Control. (2006) http://www.coralreef.gov/transportation/evalbmp.pdf

Michael Baker International & Environmental Planning Group, LLC. A Guide to Low Impact Development within Utah. (2020). https://documents.deq.utah.gov/water-quality/stormwater/updes/DWQ-2019-000161.pdf

IMPLEMENTING LID PRACTICES

All development and redevelopment in the City is required to consider an LID approach for managing storm water. The planning and design processes are critical for the successful implementation of LID. Below are the criteria to consider during the planning and design process.

PLANNING

As part of the Drainage Plan Report, the following criteria will need to be addressed.

LID Feasibly - All plans for LID facilities will need to be approved by the City prior to design. During the planning process, groundwater levels, and drinking water source protection zones, and other concerns with subsurface conditions need to be considered. Site conditions such as collapsible soils, low percolation rates, wetlands, and high groundwater levels will limit the types of LID facilities that can be used. We encourage the developer and the engineer to be creative in developing innovative means to implement LID. If the developer believes that LID facilities cannot be utilized on their particular site, documentation will need to be submitted and approved by the City Engineer or designee, explaining the reasons why

LID cannot be utilized. The documentation must illustrate that infiltration, evapotranspiration and rainwater harvesting has been used to the maximum extent technically feasible and that full employment of LID facilities are not feasible due to site constraints.

Geo-technical Analysis - Prior to proceeding with design, soils testing and an associated soils report need to be completed and submitted to the City to document subsurface conditions at each individual site. The geo-technical report must include (at a minimum) percolation rates, groundwater levels, and soil type (including whether the soils are collapsible). The geo-technical report is usually added to the Drainage Report as an appendix.

Drinking Water Source Protection Zones - Some LID practices may not be appropriate in the City's Drinking Water Source Protection Zones as presented in Figure 5-1 of the Storm Water Master Plan, because they require infiltration. LID facilities in the Drinking Water Source Protection Zones may require additional treatment at the discretion of the City.

Hydrologic Calculations - During the planning process, hydrologic calculations of pre-development conditions, that includes the peak storm water runoff rate and volume needs to be completed. Post-development hydrologic calculations also need to be completed. The peak runoff rate and volume from pre-development and post-development calculations need to be similar, as one of the goals of LID is for post-development hydrologic conditions to closely mimic pre-development conditions. See Section 5 for acceptable criteria for hydrologic evaluations.

DESIGN

Design of LID facilities should include the following:

- **Design Storm** – LID facilities in the City should be designed to accommodate, at a minimum, the peak runoff rate and volume generated from a 25-year storm. Calculations will need to be completed and submitted to the City documenting the design parameters of the LID facilities.
- **Retention** – Onsite retention of the first 0.5 inches of stormwater is required.
- **Overflow** - LID facilities need to have an overflow that connects to a centralized storm drain system for larger storm events.
- **Treatment** – Underground storage and infiltration facilities need to include treatment as outlined in the City's code.
- **Inventory** – All LID facilities should be marked clearly on the design plans and as built plans given to the City post construction. Electronic as-built plans are required, georeferenced CAD drawings and GIS files are encouraged.

Generally, above-ground LID facilities will be owned and maintained by the property owner, unless the City agrees otherwise.

APPENDIX B

80^{TH} PERCENTILE STORM CALCULATION

80th Percentile Storm Calculation

In order to calculate the 80th percentile storm the following steps were taken:

1.) Download data from Utah Climate Center Website (https://climate.usu.edu/index.php)

  a.) Data must consist of a minimum of 30-years of data. The gage selected for this report was the Orem Treatment Plant.

2.) Delete time steps having less than 0.1 inches of precipitation.

3.) Delete time steps where precipitation came in the form of snowfall.

4.) Calculate the rank of each precipitation event.

5.) Calculate the exceedance probability percentile using the following equation: Exceedance Probability = Rank/(Total # of Values +1)

6.) Calculate the depth of the 80th percentile storm.

Following these steps, the 80th percentile storm for the City of Orem has been calculated to be 0.5 inches.

Refer to the online NOAA Atlas 14 tables at

https://hdsc.nws.noaa.gov/hdsc/pfds/pfds_map_cont.html