Missoula City Public Works
Standards and Specifications Manual

CHAPTER 6 – STORM WATER SYSTEM

November 18, 2020

CHAPTER 6 – STORM WATER SYSTEM

Table of Contents

This page intentionally left blank

CHAPTER 6 – STORM WATER SYSTEM

6.1 Introduction

6.1.1 References

A. *Montana Public Works Standard Specifications* (MPWSS), 6th Edition, 2010 – by purchase only
B. US DOT FHA Hydraulic Engineering Circular-14– Hydraulic Design of Energy Dissipators for Culverts and Channels
C. US DOT FHA Hydraulic Engineering Circular-15 – Design of Roadside Channels with Flexible Linings
D. US DOT FHA Hydraulic Engineering Circular-22 – Urban Drainage Design Manual
E. US DOT FHA Hydraulic Design Series-5, Hydraulic Design of Highway Culverts
F. Montana Department of Environmental Quality Circular-8: Montana Standards for Subdivision Storm Water Drainage (DEQ-8)
G. General Permit for Storm Water Discharges Associated with Small Municipal Separate Storm Sewer Systems (MS4s)
H. *AASHTO Drainage Manual* Chapter 7 with MDT Changes, Hydrology
I. *AASHTO Drainage Manual* Chapter 9 with MDT Changes, Culverts
J. *AASHTO Drainage Manual* Chapter 10 with MDT Changes, Bridges
K. *AASHTO Drainage Manual* Chapter 13 with MDT Changes, Storm Drainage Systems
L. *Montana Post-Construction Storm Water BMP Design Guidance Manual*
M. Montana Department of Transportation's *Erosion and Sediment Control Best Management Practices Manual*
N. Montana Department of Transportation's *Hydraulics Manual*
O. Minnesota Pollution Control Agency' *Minnesota's Stormwater Manual*

6.1.2 Appendices

A. Appendix 6-A – Storm Water Management Site Plan Review Checklist
B. Appendix 6-B – Storm Water Site Evaluation Form
C. Appendix 6-C – Storm Water Drainage Report Content
D. Appendix 6-D – Private Storm Water Facility Maintenance Covenant and Access Easement
E. Appendix 6-E – Operation and Maintenance Requirements
F. Appendix 6-F – Test Pit Infiltration Test Method

6.1.3 Standard Modifications to MPWSS

A. Specifications not specifically contained herein related to storm water improvements shall be in conformance with the *Montana Public Works Standard Specifications* (MPWSS), 6th Edition, 2010 and the following City of Missoula Modifications to the MPWSS, which are located in Appendix 2-A:

1. SECTION 01400 Contractor Quality Control and Owner Quality Assurance
2. SECTION 02221 Trench Excavation and Backfill for Pipelines and Appurtenant Structures
3. SECTION 02724 Insulation
4. SECTION 02720 Storm Drain Systems

5. SECTION 02740 Pipe Casings

6.1.4 Standard Drawings

A. Standard drawings related to storm water system improvements shall be in conformance with the *Montana Public Works Standard Specifications* (MPWSS), 6th Edition, 2010 Standard Drawings and the 600-series of the City of Missoula Standard Drawings contained in Appendix 2-B.

6.1.5 Design Criteria

A. The storm water design criteria presented in this Chapter are based on standard engineering practice for storm water management, modified to suit the needs of the City of Missoula. The design of storm water facilities may need to exceed minimum standards presented here in order to provide adequate protection from flooding. The City will conduct review of drainage plans and reports for compliance with requirements set forth in this Chapter. The City's review is not an endorsement of the plan or approval or verification of the engineering data and plans. The Applicant is exclusively responsible for ensuring that the design, construction drawings, constructions, and record drawings comply with acceptable engineering practices and this Manual.

6.1.6 Deviations from these standards

A. Any requests for deviations for the standards outline in this chapter shall follow requirements in Section 3.6.1 of this Manual.

6.2 General Requirements

6.2.1 Design Requirements

A. Minimum storm water controls are required for developments with land disturbance ≥ 2500 square feet.

B. Using the Storm Water Site Evaluation Form found in Appendix 6-B, projects are classified as low, medium, and high priority and must meet minimum standards set for each priority level. Medium and high priority developments must provide a Storm Water Management Site Plan and report for permanent water quality treatment facilities to manage runoff from the post-developed site conditions.

C. A Storm Water Management Site Plan Review Checklist is provided in Appendix 6-A.

D. The minimum design standards stated in this chapter apply to the management of storm water in a post-construction environment.

E. Requirements for storm water erosion and sediment control during construction is covered in Chapter 8 - Erosion Control.

F. Low Impact Development (LID)/Green Infrastructure

1. LID/Green Infrastructure is highly prioritized by the City of Missoula. While it is currently not required, in the future credits or incentives may be implemented.
2. LID practices are intended to manage storm water as close to its source as practicable by preserving and recreating natural landscape features; minimizing effective imperviousness; creating functional and aesthetically appealing site drainage; and treating

storm water as a resource rather than a waste product.

3. Examples include bioretention facilities, green roofs, vegetative biofilters, and permeable pavements.
4. LID/green infrastructure practices aim to preserve, restore, and create green space using soils, vegetation, and rainwater harvest techniques.
5. Additional information is found in the *Montana Post-Construction Storm Water BMP Design Guidance Manual* and in *Minnesota's Stormwater Manual* from the Minnesota Pollution Control Agency.
6. Successful implementation of LID/green infrastructure is accomplished using strategies and standards that meet two or more of the major objectives below.
    a. Flood and peak discharge control.
    b. Water quality control.
    c. Multi-parameter controls, including aquifer recharge and channel protection.
    d. Habitat protection and ecological sustainability.

G. Low Priority Sites. The requirements in this section apply to those projects classified as low priority using the Storm Water Evaluation Form.

1. Improvement plans shall include a grading and drainage plan sheet addressing requirements listed in Section 6.2.2 of this chapter.
2. Projects that disturb 1-acre or greater during construction shall adhere to water quality treatment requirements in Section 6.2.6 of this chapter.
3. The following minimum requirements apply to this classification:
    a. Site grading shall follow specific requirements established in/on the plat, subdivision conditions of acceptance or any covenants that apply.
    b. The finished grade of the ground shall slope away from the house.
    c. Roof drainage facilities shall be installed to divert storm water away from the foundation of the structure.
    d. Roof drainage facilities directed toward unfinished landscaping shall be equipped with sediment bags and/or energy dissipaters until landscaping is established.
    e. Storm water shall not be concentrated onto an adjacent property. Storm water from impervious surfaces shall be routed over a minimum length of 15 feet of pervious surfaces before flowing off site or must follow mitigation techniques approved by Missoula Storm Water Utility Division. These techniques may include the use of swales, dry wells, or piped connections to dry wells or French drains. The slope of the pervious surfaces shall be no greater than 8% for lawns and 2% for other surfaces.
    f. The finished grade shall be contoured to move storm water away from both on- and off-site structures. This includes consideration of:
        1. Storm water from impermeable surfaces such as roofs, driveways, and sidewalks on the subject property; and
        2. Storm water coming onto the site from adjacent properties.

g. Storm water shall not affect structures on adjacent parcels and shall be configured to direct storm water to vegetated areas.
h. Storm water to or from the site shall be not be impeded or accelerated.
i. Irrigation shall be installed and used in a manner that does not affect adjacent properties.
j. Developers are encouraged to utilize LID and green infrastructure methods for managing storm water.

4. The elevation of residential dwellings and other lot features shall be established to ensure storm water runoff from the 100-year storm does not inundate buildings.
5. Erosion and sediment controls shall be installed per requirements in Chapter 8.
6. Finished grade slopes may not exceed 50%.
7. Use of LID/green infrastructure techniques is encouraged.

H. Medium and High Priority Sites. The requirements in this section apply to those projects classified as medium and high priority using Storm Water Site Evaluation Form (Appendix 6-B). The storm water management systems for these projects shall be designed, signed, and sealed by a registered professional engineer in the State of Montana. These projects shall adhere to the minimum requirements listed for low priority projects as well as the following:

1. Post-Development Runoff Control Requirements
   a. Post-development storm water from the project shall be completely retained and infiltrated on site for the 100-year storm event; or
   b. Post-development storm water from the project shall be released from the site at pre-developed peak flow rates for the 100-year storm event; or
   c. Post-development storm water shall be routed through an adequate storm water conveyance to a regional storm water facility for which it was designed. This requires prior approval by City Engineering.
2. Projects shall meet post-construction water quality control requirements in Section 6.2.6.
3. The Storm Water Management Site Plan shall meet the requirements in Section 6.2.2 and a design report shall be provided in accordance with Section 6.2.3.
4. Projects shall include a Private Storm Water Facilities Maintenance Covenant and Access Easement (Appendix 6-D) filed with the Missoula County Clerk and Recorder, along with an Operations and Maintenance (O&M) Manual (Appendix 6-E). The O&M Manual, recorded covenant for maintenance and easements, and accurate record drawings shall be included in the final project closeout, prior to City approval of the facilities.
   a. Projects that propose to infiltrate, evapotranspire, and/or capture for reuse all post-development storm water on-site—without the use of piped conveyance—shall be exempt from the requirements of a Private Storm Water Facilities Maintenance Covenant and Access Easement and O&M Manual. The owner will still be responsible for all maintenance required to ensure facilities are operating as designed.
5. Natural drainage patterns shall remain unaltered where applicable.
6. Use of LID/green infrastructure techniques is encouraged.

6.2.2 Plan Requirements

A. Storm Water Management Site Plan. Storm water system improvement plans shall comply with the general requirements in Section 3.2 of this Manual and shall at a minimum include:

1. The area of each lot;
2. Locations of existing and proposed driveways, buildings, wells and drainfields; Locations, sizes, and design details of existing and proposed storm water facilities;
3. Locations of natural and constructed drainage way and streams;
4. Floodplains as delineated by FEMA or local floodplain authorities;
5. Existing and proposed contours at 1-foot intervals;
6. Direction of drainage flow adjacent and across the site, along each street, and at each intersection;
7. Drainage basin and sub-basin limits with analysis points used for design
8. Existing storm water management facilities including irrigation ditches, roadside swales, open channels, storm sewers, culverts, detention ponds, etc.
9. Location and design details of any proposed detention facilities, retention facilities, infiltration facilities, and erosion control measures;
    a. Where dry wells are proposed they shall be labeled with the total drainage area and total impervious area draining to the structure
10. Profile sheets of proposed conveyance structures and storm drain systems shall be required;
11. Drainage easements, both on and off site, proposed and existing;
12. Details for outfalls, BMPs, other drainage structures and access streets;
13. Spot elevations and grades of features - back of curb, sidewalk, driveway (at garage door), finished floor at threshold of structure, street intersection monuments, bench marks, temporary bench marks, location of existing and proposed storm water structures;
14. Cross-hatching indicating spill curb/gutter differentiating it from catch curb/gutter;
15. Curb/gutter alignment;
16. Flow grades on asphalt (street) surface and curb/gutter sections;
17. Directional flow arrows and % grade.

6.2.3 Design Report

A. Storm Water Drainage Report. Shall follow the report format in Appendix 6-C and include the following:

1. Peak flow attenuation requirements and a description of how they are met;
2. Water quality treatment description;
3. Description of existing drainage facilities function (natural or constructed);
4. Acceptable Methods for calculating runoff.
5. Pre-development basin conditions exhibit, including flow patterns, off-site runoff contributions, land cover assumptions, curve numbers and/or runoff coefficients, soil types, time of concentration paths, and analysis points;

6. Post-development basin conditions exhibit, including proposed development, drainage infrastructure locations, flow patterns, off-site runoff contributions, land cover assumptions, curve numbers and/or runoff coefficients, soil types, time of concentration paths, and analysis points;
7. Identification of potential existing wetlands, nearby waterbodies, and depth to groundwater (if applicable);
8. Soil information including soils maps, soil descriptions, and hydrologic soil group;
9. Infiltration facilities. Soil profiles and infiltration testing data per Section 6.2.4;
10. Supporting Information & Calculations. Includes site photos, design graphs, charts, Nomograph, maps, figures, time of concentration calculations, software input/output, hydraulic grade line calculations for storm drain systems, inlet spread width and bypass flow calculations, and all related hydrologic and hydraulic calculations;
11. Down Gradient Impact Analysis. Analysis and discussion of any existing downstream drainage issues and potential impacts to adjoining parcels and/or existing storm water infrastructure. Analysis shall adhere to Section 6.2.7.
12. Inlet capacity and spread-width calculations
13. The report shall be based on the outline in Appendix 6-B

B. Geotechnical Report.

1. A geotechnical report shall be provided for projects meeting the requirements in Section 6.2.4.
2. A minimum of one test pit (or boring) and one infiltration test shall be provided for every USDA soil classification type that will be used for infiltration.
3. A minimum of one soil test pit (or boring) and one infiltration test shall be provided within 300 LF of each infiltration facility.
4. Soil profiles showing thickness of soil layers and designation of USDA soil classifications must be provided for each pit/boring.
5. Soil infiltration tests shall be performed per the technique in Appendix 6-F, DEQ-8, Appendix C or the *Montana Post-Construction Storm Water BMP Design Guidance Manual*, Appendix C. In some areas, the City has unusually high soil infiltration rates relative to other locations around the State, therefore test procedures may need to be adapted. Methods other than those listed may be acceptable if approved by the City Engineer.
6. If dry wells are proposed for storm water management, field testing the infiltration rate of a nearby existing dry well may be used in place of test pits (or borings) and infiltration tests. The tested dry well must be within 300 LF of the proposed dry well. Dry wells shall be tested at their expected operational water level. Dry wells shall be pre-soaked for an appropriate amount of time before infiltration testing. Pre-soaking shall achieve a constant infiltration rate if possible. Two methods are acceptable for performing the dry well infiltration test after the pre-soak period:
    a. Falling Head Test. The dry well shall be presoaked by filling the dry well with a minimum one-foot depth of water and continuously kept at that level for a

minimum of two hours or until infiltration rates stabilize to within 10% over a 30-minute interval. The dry well shall then be filled to the top of the slotted barrel or a minimum of 2 feet. The water level shall be allowed to drop a minimum of 2 feet and the time recorded. This procedure shall be repeated until four consecutive readings do not vary more than 10%. An average of the four readings will be used as the infiltration rate.

b. Average Constant Rate. The dry well shall be filled to the expected operational water level and continuously kept within ± 2 feet of that level for 2 hours or until infiltration rates stabilize to within 10% over a 30-minute interval, while water levels are recorded. After water levels have stabilized, measurements shall be taken at intervals no greater than 10 minutes for a minimum of 1 hour. The average of the measurements taken over this 1 hour period shall be the infiltration rate.

7. Regardless of the method used to determine infiltration rates, a safety factor shall be applied in order to account for long-term degradation of infiltration rates as the dry wells accumulate sediment. The safety factors below are a minimum. The engineer performing the site analysis and infiltration tests may recommend a safety factor greater than those shown based on-site specific conditions.

a. Where pre-treatment is provided before the infiltration facility the minimum factor of safety shall be 2.0. Pretreatment shall be a catch basin piped to a solid-lid dry well, a vegetated swale with a minimum of 8-feet of travel distance along the swale before discharge into a dry well, or other methods approved by the Utility Engineer.

b. Where no pre-treatment is provided before the infiltration facility the minimum factor of safety shall be 3.0.

8. Where storm water infiltration is proposed in areas where it is suspected by the Public Works Department that the infiltrated storm water will have an impact on groundwater elevation which may affect facilities or structures a groundwater assessment shall be included in the report. This shall include an assessment of the potential storm water impact to on- or off-site facilities or structures. The assessment will also demonstrate that impacts to groundwater elevation or flow, resulting from the proposed infiltration system will be confined to the property.

9. Groundwater monitoring may be required based on the surrounding hydrological and hydrogeological data and/or if there is evidence of groundwater in test pits. Sufficient perforated pipes shall be installed to adequately define the groundwater conditions in the proposed infiltration area(s). The perforated pipes shall be installed at a depth at least five-feet below the proposed bottom of infiltration facility. For a dry well this is the bottom of the sump rock. These test wells shall be monitored at a frequency which will establish the peak seasonal groundwater depth. Results may not be accepted when precipitation or snow pack water equivalent is more than 20% below historical average.

6.2.4 Storm Water Infiltration

A. If infiltration facilities (including dry wells) are proposed for storm water management, there are two acceptable methods for selecting the design infiltration rate for soils:

1. **Reference Infiltration Rate** – For infiltration facilities that have less than 8,000 sf of total contributing drainage area, a design infiltration rate may be selected from a standard reference table source, such as Table 2 in Appendix C of DEQ Circular 8, or Table 2.1-1 in DEQ Circular 4.
2. **On-site Soil Investigation** – For infiltration facilities with greater than 8,000 sf of drainage area, non-standard drainage systems, or projects located within or draining to a drainage problem or study area as recognized by the City of Missoula, a signed and sealed geotechnical report must be provided by a registered professional engineer with relevant experience in infiltration and soils testing and licensed in the State of Montana. The report shall meet the requirements in Section 6.2.3.B.
    a. In areas where there has been a long-standing record of satisfactory performance of dry wells and no drainage problems are known to exist, the minimum requirements outlined in this section may be reduced or waived after a formal written request from the project engineer has been reviewed and accepted by City Engineering.

6.2.5 Regional Storm Water Facilities

A. Some areas within the City are served by existing regional storm water facilities that help provide conveyance, peak flow attenuation, and/or water quality treatment. Developments that propose to use existing regional facilities must be treated on a case-by-case basis in consultation with the City Engineer. In general, to utilize regional facilities, the capacity of the facility and the capacity of the conveyance to the facility must be examined. Depending on the capacity and function of the regional facility, projects may be responsible for providing supplementary conveyance, capacity, and/or water quality treatment meeting requirements in Section 6.2.6.

6.2.6 Storm Water Quality Control

A. Using the Storm Water Site Evaluation Form, all medium and high priority developments must provide plans for permanent water quality treatment facilities to manage runoff from the post-developed site conditions.

B. Storm water management controls shall be designed to infiltrate, evapotranspire, and/or capture for reuse the post-construction runoff volume generated from the first 0.5 inch of rainfall from a 24- hour storm preceded by 48 hours of no measurable precipitation. Design guidance is provided in the Montana Post-Construction Storm Water BMP Design Guidance Manual (MTDEQ, 2017). If dry wells are used to meet this requirement, each dry well contributes a volume of 160 ft^3 of storage to the Runoff Reduction Volume. If the volume of the sump is not adequate to contain the Runoff Reduction Volume (RRV), then the Runoff Treatment Flow Rate (RTF) can be calculated using the formula in the Montana Post-Construction Storm Water BMP Design Guidance Manual. The bottom area of the dry well, 61.23 ft^2 (based on a dry well installed per City standards with a diameter of 8.83 ft) shall be used in the calculation. The dry well shall be considered adequate if the infiltration rate is larger than the RRF.

C. Developments that cannot meet 100% of this runoff reduction requirement must

1. Treat onsite using controls expected to remove 80% TSS; or
2. Manage off site within the same sub-watershed with controls designed to infiltrate, evapotranspire, and/or capture for reuse; or
3. Treat off site within the same sub-watershed using controls expected to remove 80% TSS.

D. All new storm water outfalls to a named waterbody shall be approved by the City Utility Engineer. Any new storm water outfall to a named waterbody will be required to implement BMPs to the maximum extent practicable to reduce pollutant discharges as approved by the City Utility Engineer.

E. Compliance with storm water requirements does not necessarily result in compliance with the Missoula Valley Water Quality Ordinance 13.26.092 which prohibits activities that may allow pollutants to contaminate our local water resources.

6.2.7 Hydrology

A. Drainage System. The City storm water system is composed of two elements: The Minor Drainage System and the Major Drainage System. The Minor Drainage System consists of the components that have been historically considered as part of the storm water system such as pipes, inlets, dry wells, etc. The Major Drainage System provides overland relief for storm water flows exceeding the capacity of the Minor Drainage System, to minimize health and life hazards, damage to structures, and interruption to traffic and services.

1. Minor Drainage System. The Minor Drainage System consists of curbs, gutters, ditches, culverts, storm drains (and other conduits), open channels, pumps, detention/retention basins, infiltration facilities, and outfalls. The Minor Drainage System shall be designed to carry runoff from the peak flow rate from the 10-year storm event.
2. Major Drainage System. The Major Drainage System consists of pathways that are provided for runoff to safely flow to natural or engineered channels. The Major Drainage System shall be designed to safely carry runoff from the 100-year storm, without inundating structures and drain fields, overtopping roadways, or interrupting traffic and emergency services. Flows from the 100-year storm event can be carried in the urban street system (within acceptable depth criteria), open channels, storm pipes, and other conveyance facilities.

B. Design Storm Depth. The design storm depths in Table 6-1 are based on the 24-hour storm duration at the Missoula International Airport as published in MDT Hydraulics Manual Chapter 7, Appendix B (MDT, 2017).

Table 6-1 – Design Storm Depths

	2-yr, 24-hr storm (in)	10-yr, 24-hr storm (in)	100-yr, 24-hr storm (in)
Missoula Airport	1.17	1.66	2.28

C. Design Storm Intensity. Design storm intensities shall be based on the time of concentration used for the drainage basin. Design storm intensities shall be referenced from the Missoula International Airport as published by the MDT Hydraulics Manual Chapter 7, Appendix B.

D. Hydrologic Methods. Acceptable hydrologic methods for calculating runoff rates and storage requirements are below. Procedures for use of these methods can be found in HEC-22, Chapter 3.

1. Rational Method. May be used to determine runoff peak flow for the design of conveyance systems for contributing areas less than 5 acres. Rational Method may not be used for volume-based calculations or routing.
2. SCS Curve Number Method. May be used to determine runoff volume and peak flow for the design of conveyance systems, storage facilities, and routing effects for contributing areas less than 1,920 acres. The SCS Type II rainfall distribution shall be used for the analysis.
3. EPA SWMM. Consult the City Utility Engineer for approval for use of this method.

E. Time of Concentration. Time of concentration shall be calculated using the TR-55 Method to determine the time is takes for storm water to travel from the most distant point of a drainage basin to a specific point of interest.

1. The minimum time of concentration shall be 5 minutes.
2. Sheet flow length shall be limited to a maximum of 300 feet in undeveloped areas and 150 feet in developed areas.
3. For multiple drainage areas, the longest time of concentration must be selected.

F. Drainage Basin Delineation. The total area, including off-site or up-gradient areas that contribute to the storm water on a site, must be included in the analysis. Large drainage basins shall be divided into sub-basins and evaluated separately based on contributions to individual facilities. Include all elements of off-site drainage basins, such as undeveloped sites, developed sites, and off-site drainage facilities. A final analysis shall always be conducted at the point where runoff finally discharges from a site.

G. Pre- and Post-Development Conditions. Pre-development runoff shall be calculated based on conditions prior to any development. Post-development runoff shall be calculated based on proposed developed conditions. When the extent of impervious areas is unknown (such as on individual residential lots), an assumed estimate must be provided.

H. Allowable Off-Site Release Rates. A project shall not release runoff off site at a rate more than the peak pre-development runoff rate, unless the site is contained within a comprehensive drainage plan designed to allow off-site discharge to a regional collection facility. Runoff from a developed site shall leave the site in the same manner and location as in the pre-development condition. Flow may not be concentrated onto down-gradient properties where sheet flow previously existed.

I. Up-Gradient Analysis. Design of conveyance structures for a project must account for any up-gradient flows passing through the site.

J. Down-Gradient Analysis. A down-gradient analysis shall be conducted to identify and evaluate potential adverse impacts to downstream properties due to increased runoff from the proposed development. Adverse impacts may include receiving more runoff than pre-developed conditions, increased erosion, increased flooding, or change in historical runoff patterns such that pre-development runoff conditions concentrated at a single discharge location may cause increased erosion. This analysis shall continue through down-gradient areas to the point where the adverse impacts are deemed negligible, or to a point where the contributing drainage area is 1% (or less) of the total drainage area. The analysis shall include at a minimum:

1. Visual inspection of the site and down-gradient areas.
2. A site map that clearly identifies the project boundaries, study area boundaries, down-gradient flow path, and any existing or potential areas identified as problematic.

3. Pre- and post-development hydraulic capacities (flow rate and volume) for the 10-year and 100-year storm events.
4. Existing or potential off-site drainage problems that may be aggravated by the project.
5. The condition and capacity of the conveyance route, including existing and proposed elements, potential backwater conditions on open channels, constrictions or low capacity zones, surcharging of enclosed systems, and localized flooding.
6. The presence of existing natural or constructed land features dependent upon pre-developed surface or subsurface drainage patterns.
7. Existing or potential erosive conditions such as scour or unstable slopes onsite or downgradient of the project.
8. Flood areas identified on FEMA maps.
9. If there are existing or potential off-site drainage problems down gradient of the project, the project must demonstrate that the proposed storm water system has been designed to meet the following conditions:
    a. The storm water runoff (volume and flow rate) leaves the site in the same manner as that of the pre-developed condition.
    b. The proposed design does not influence existing drainage problems or create a new drainage problem.
10. If down-gradient release of runoff is at a rate or volume greater than the pre-developed condition, then potential adverse impacts on down-gradient property and drainage infrastructure (due to an increase in storm water rate, volume, velocity, and flow duration) shall be addressed and mitigated.

6.2.8 Private Connections

A. Private storm water system connections to the public storm water system may be approved by the City.

B. Connections shall be entirely owned and maintained by the owner of the development in which the connection was installed. A Private Storm Water Facility Maintenance Covenant and Access Easement shall accompany the Storm Water Management Site Plan.

C. Connection must include backflow prevention or other accommodations on site to prevent storm water from the City storm water system from surcharging onto private property and causing damage and/or flooding.

D. The maximum pipe diameter allowed will depend on an evaluation of the capacity of the City storm water system and approval from the City Utility Engineer.

E. Pumped connections to the City storm water system are not allowed.

F. Lateral connections within the right-of-way and public easements shall be made at right angles.

G. Core-drill or appropriate fitting directly on the main line. Connection to adjacent catch-basins/manhole shall only be made with approval from the City Utility Engineer.

6.3 Design Standards

A. Storm water facilities shall be designed to control the conveyance, storage, and flow rate of storm water runoff. Facilities include conveyance systems such as channels, pipes, gutters, and culverts that are designed to deliver storm water from a receiving point to a discharge location without surcharging or causing surface flooding for a specified design storm.

B. Conveyance systems shall generally be designed to convey the expected post-development peak flow without overtopping curbs during a 10-year storm event and without inundating buildings, or inundating drainfields during a 100-year event.

C. The use of green infrastructure/LID is highly encouraged as discussed in Section 6.2.1 and the *Montana Post-Construction Storm Water BMP Design Guidance Manual* (MDEQ, 2017).

6.3.1 Streets

A. Design standards for streets are contained in Section 7.3.1. Specific storm water design standards for streets are contained in Table 6-2 and Table 6-3.

Table 6-2 – Maximum Street Spread Width for 10-year Storm Event

Street Classification	Design Standard
Local	No curb overtopping. Flow may spread to crown of street.
Collectors	No curb overtopping. Flow spread must leave at least one, 11 foot lane free of water, 5 feet either side of the street crown.
Arterials	No curb overtopping. Flow spread must leave at least two, 11 foot lanes free of water, 10 feet each side of the street crown or median.

Table 6-3 – Maximum Depth for 100-year Storm Event

Street Classification	Design Standard
Local and Collectors	The depth of water at the gutter flow line shall not exceed 18 inches. Residential dwellings and public, commercial, and industrial buildings shall not be inundated at the ground line unless flood-proofed.
Arterials	To allow for emergency vehicles, the depth of flow at the street crown shall be no more than six inches. Residential dwellings and public, commercial, and industrial buildings shall not be inundated at the ground line unless flood-proofed.

B. Where no curbing exists, storm water encroachment shall not extend beyond the right of way during the 100-year storm event, unless accommodated by a drainage easement.

6.3.2 Gutters

A. Design standards for streets are contained in Section 7.3.8.

B. Standard gutter designs are published in City of Missoula Standard Drawings 740-745.

C. Runoff shall not overtop the curb during the 10-year rainfall event.

D. Minimum gutter running slope is 0.4%.

E. Gutter flow calculations shall be performed using methods in the HEC-22 Manual.

6.3.3 Inlets

A. Standard inlet design is published in City of Missoula Standard Drawing 600 and 601. Other inlet types may be approved by the City Utility Engineer if additional inlet interception capacity is necessary.

B. Inlets shall be located at grade low points, prior to pedestrian crossings, and/or at street intersections. Additional inlet spacing is based on interception capacity of the inlets, gutter geometry, flow bypass, and allowable spread.

C. Where installed in roadways, inlet grates shall be sloped to match the running slope and cross slope. Where curbing exists inlets shall be installed in the curb and shall be City of Missoula Standard combination curb inlet frame and grate.

D. Curb cuts may be used to convey storm water into boulevards and swales. Curb cuts shall be sized to intercept the design flow.

E. Maximum inlet spacing shall be 400 feet. Additional inlets shall be included to meet flow depth and spread width requirements for the 10-year storm.

F. Bypass flow at inlets shall be less than 0.1 cfs at intersections and at project boundaries.

G. Inlets placed in sag locations shall use a 50% clogging factor for sizing and placement.

H. The interception capacity, spread widths, and required spacing shall be determined in accordance with the procedures described in Section 4.3 and 4.4 of the HEC-22 Manual.

I. Design deviations from standards shall be evaluated using Section 4.4.6.2 of the HEC-22 Manual.

6.3.4 Storm Drains

A. Storm drainage infrastructure shall comply with the City's best practices for wet utility construction, as listed in Chapter 4 of this Manual.

B. Manhole lids and rings shall comply with City of Missoula Standard Drawings 604A, 604B, and 605. Manholes shall comply with City of Missoula Standard Drawing 612-1, 612-2, or 612-3.

C. Trench, bedding, and backfill shall be in conformance with City of Missoula Modification to MPWSS Section 02221 and City of Missoula Modification to MPWSS Section 01400.

D. Storm drains shall operate in a non-pressurized flow conditions during the 10-year storm event. Storm drains may be designed to surcharge during the 100-year storm event as long as the requirements of Section 6.3.1 regarding street flow depths are not violated.

E. Slopes must maintain a flow velocity of at least 2.5 ft/sec but not more than 12 ft/sec during the 10-year storm event. A minimum slope of 1% is preferred unless the minimum flow velocity can be achieved.

F. Minimum diameter of pipes shall be 12 inches for public main lines and laterals, and 6 inches for private connections. Pipe sizes shall only increase in the downstream direction.

G. Materials for storm drains shall comply with City of Missoula Modification to MPWSS 02720.

H. Design deviations from standards shall be evaluated using Chapter 6 and 7 of the HEC-22 Manual.

I. The minimum clearance distances from other utilities listed in Table 5-1 shall be maintained.

J. Manholes are required where two or more storm drains converge, pipe sizes change, changes in alignment, or changes in grade and shall be sized according to with City of Missoula Standard Drawing 612-1, 612-2, or 612-3. Maximum manhole spacing along storm drains is 400 feet for storm drain diameters up to 36 inches and 500 feet for storm drain diameters up to 60 inches.

K. 30-inch diameter catch basins are allowed if depths do not exceed 6 feet.

L. Maximum manhole depth shall be 20 feet without special safety provisions such as intermediate platforms and minimum diameter rises of 48 inches.

M. Water main crossings shall be designed to prevent freezing due to minimal clearance from storm drains and insulation installed per City of Missoula Modification to MPWSS Section 02724.

N. Avoid crossing other utilities at highly acute angles. The angle measure between utilities shall be between 45° and 90°.

O. Energy dissipation or erosion protection measures shall be required when outfall velocities exceed the permissible velocity of the soil or channel lining during the 2-year storm event. Design energy dissipation measures in accordance with FHWA HEC-14, Hydraulic Design of Energy Dissipaters for Culverts and Channels. See Section 6.3.7 for outfall requirements.

P. Where required by City Utility Engineering or the jurisdictional authority (i.e. railroad, Interstate (MDT), etc.), storm drains shall be installed through a casing. Casing requirements shall conform with City of Missoula Modification to MPWSS Section 02740, or jurisdictional standards.

6.3.5 Open Channels

A. Procedures for designing open channel conveyance systems including Manning's roughness factors (n), are contained in Chapter 5 of the HEC- 22 Manual.

B. Channels shall be located no closer than 10 feet from any structural foundation measured from the edge of the channel at the top of the freeboard elevation.

C. Shear stresses on channel side slopes shall be evaluated during the 2-year storm event to ensure adequate erosion protection and slope stability. This analysis shall include the bare soil condition immediately after construction as well as the final vegetation or lining of the channel. Temporary lining may be required until final vegetated conditions are achieved.

D. Channels must be designed with a full-flow capacity to safely convey the 100-year storm event with a minimum of 0.5 feet of freeboard.

E. Design of a low-flow channel shall be required to account for sustained low flows.

F. Side slopes shall be no steeper than 4H:1V for grass-lined channels requiring maintenance by mowing, 3H:1V for unmaintained native grass-lined channels and 2H:1V for all other stabilized channels.

G. Vegetated channels shall be maintained to ensure that vegetation does not limit the conveyance capacity of the facility.

6.3.6 Drainage Culverts

A. Culverts shall be designed using the procedures contained in HDS-5, Hydraulic Design of Highway Culverts.

B. Culverts shall be designed with capacity to allow the safe passage of peak flows without overtopping

roadways during the Minor Storm event or inundating buildings and drainfields during the Major Storm event. The roadway flow depth restrictions in Section 6.3.1 apply during roadway overtopping conditions.

C. Sizing must account for all upstream flow contributions.

D. The minimum culvert diameter is 12 inches.

E. A minimum velocity of 2.5 feet per second and a minimum slope of 0.5% during the Minor Storm event is required to prevent sediment accumulation through the culvert.

F. Minimum and maximum cover shall be in accordance with the pipe manufacturer recommendations.

G. Energy dissipation or erosion protection measures shall be required when outfall velocities exceed the permissible velocity of the soil or channel lining during the 2-year storm event. Design energy dissipation measures in accordance with FHWA HEC-14, Hydraulic Design of Energy Dissipaters for Culverts and Channels. See Section 6.3.7 for outfall requirements.

H. Flared end treatments for culverts and inlets shall be required inside the right-of-way for the purpose of enhancing crash safety.

I. A safety grate or trash rack with maximum clear spacing of 4 inches for child safety is required for all culverts over 30 inches in diameter.

6.3.7 Outfalls

A. Use the methods of Chapter 7.1.5 of the HEC-22 Manual as well as HEC-14 to address storm water discharge and erosion protection at outlet points. Design considerations include backflow, erosion protection, and energy dissipation methods.

B. The adequacy of the receiving channel must be analyzed for capacity and stability against erosion during the 10-year storm event.

6.3.8 Bridges

Hydraulic sizing for bridges across major drainages shall conform to the requirements of the AASHTO Drainage Manual Chapter 10 with MDT Changes, Bridges.

6.3.9 Detention Facilities

A. Detention facilities shall discharge a peak flow rate equal to or less than the pre-development peak flow rate for the 2-year, 10-year, and 100-year 24-hour storm events. Outlet facilities must safely accommodate the peak flow from the 100-year storm event with a minimum of 1 foot of freeboard and without damage to the facility from erosion.

B. Storm water shall not be held in a storage facility for more than 72 hours, unless designed for the purposeful creation of wetland and wildlife habitat.

C. Outlet structures must take into account exit velocities and erosion control requirements contained in Section 6.3.7 of this chapter and Chapter 8 of the HEC-22 Manual. Minimum orifice diameter without screening in 6 inches. The minimum diameter for outlet conduits shall be 12 inches. The HEC-22 Manual shall be used for additional design requirements such as, anti-seep collars placed on outlet conduits through embankments.

D. All detention facilities with constructed berms two feet or greater in height shall include a provision

for non-erosive control of emergency overflows. This overflow spillway shall be designed to have the capacity to pass the 100-year post-developed peak flow with a freeboard of 1.0 foot minimum and shall be designed per Section 6.3.7. Overflows shall be directed to a safe discharge path to protect adjacent and downstream properties from damage.

1. The full width of the spillway shall be armored with riprap and extended downstream to where emergency overflows enter the conveyance system. The armoring may have four inches of topsoil and grass cover.
2. Designers may choose to design the outflow structure with an emergency bypass that can route the 100-year post-developed peak flow through the structure and out to the conveyance system in which case an emergency spillway is not required.

E. If storage facilities are used in conjunction with water quality facilities, designs must follow recommendations in the *Montana Post-Construction Storm Water BMP Design Guidance Manual*.

F. Storage facilities shall be at least 3 feet above the seasonally high groundwater table.

G. Embankments more than four feet in height shall be constructed as recommended by a geotechnical engineer. Depending upon the site, geotechnical recommendations may be necessary for lesser embankment heights. The height of an embankment is measured from the top of the berm to the catch point of the native soil at the lowest upstream or downstream elevation.

H. Maximum water depth shall not exceed 6 feet during the 100-year event.

I. Designers are encouraged to design detention facilities with irregular and curved shape to look natural. Avoid straight lines and regular shapes where possible.

J. Side slopes shall be no steeper than 4H:1V, preferably flatter, for vegetated basins requiring maintenance by mowing, and 3H:1V, preferably flatter, for unmaintained native grass-lined basins. Safety benches should be installed for large facilities to provide a method for people and animals that inadvertently enter, to exit the basin.

K. Bottom slopes shall be no less than 1% to promote drainage across vegetated surfaces and shall include the design of a low-flow channel where runoff enters in a concentrated manner.

L. The maximum water surface elevation during the 100-year storm event shall be at least 1-foot below adjacent ground, finished floors, top of foundation or any other entry point vulnerable to flooding.

M. Detention facilities shall be located such that adequate access, maintenance, and operation needs are met. Maintenance access easements shall be provided where appropriate for full access.

N. Fencing is generally required on drainage facilities with the first overflow at two or more feet above the pond bottom, drainage facilities with retaining walls 2.5 feet high or taller, or drainage facilities located adjacent to schools, daycares, or similar facilities. Fencing shall be a minimum of four feet tall and provide visual access to the facility.

O. Detention facilities shall be landscaped to provide for slope stability, erosion control and low maintenance. Landscape materials shall be compatible with storm water quality treatment and the function of the drainage facility. Utilized plant species native to the Missoula area to the maximum extent possible. Vegetation on embankments shall be limited to shallow rooted varieties. Points of inflow to the facility shall be armored to prevent erosion.

P. Maintenance shall be performed by the HOA or commercial site owner, unless this responsibility is

accepted by the City. Maintenance will be required to remove invasive plants and debris.

Q. Storage facilities may be designed with multi-purpose use, such as athletic fields, parks, play areas, and picnic areas with written approval of the Parks and Trails Design/Development Manager from Missoula Parks and Recreation. Measures must be taken to ensure amenities are anchored and maintained and access to the site must comply with Americans with Disabilities Act (ADA) requirements. Runoff from the 2-year event shall be stored away from multiple use areas.

R. Setback and clearance requirements to surrounding existing conditions contained in Table 6-4 shall be maintained.

Table 6-4 – Minimum Clearance Requirements for Placement of Detention Facilities

Element	Minimum Distance Required
Floodplains	Outside 10-year High Water Level (HWL) Work inside floodplain may require floodplain development permit
Buildings	50 feet horizontal up-gradient, 10 feet from outfalls
Top of 15% Slopes	50 feet horizontal
Septic Tanks/Drain Fields	30 feet horizontal up-gradient, 10 feet down-gradient
Shallow Water Wells	100 feet horizontal
Easements, Property Lines	20 feet horizontal
Schools, Nursing Home, Day Care	200 feet horizontal

6.3.10 Infiltration Facilities

A. Infiltration facilities include any features that use soil infiltration as the primary storm water management method, such as dry wells, French drains, boulder pits, retention basins, bioretention/bioinfiltration basins (without underdrains), and infiltration trenches.

B. If storage facilities are used in conjunction with water quality facilities, designs must follow recommendations in the *Montana Post-Construction Storm Water BMP Design Guidance Manual*.

C. These facilities are not appropriate for use with tight clays or other soils with low infiltration rates or in areas with a shallow water table.

D. There shall be a minimum 4-foot separation between the bottom of the infiltration facility or dry well and the seasonally high groundwater table. See Section 6.2.3.B for requirements.

E. Storm water shall not be held in an infiltration facility for more than 72 hours, unless pre-approved by the City Utility Engineer.

F. Infiltration facilities shall be designed according to the expected infiltration rate of the surrounding soils. Soil profiles and infiltration testing shall be performed per Section 6.2.4.

G. Dry Wells

1. Dry wells shall be designed using a minimum 8-foot depth as shown on City of Missoula Standard Drawings 616.
2. Dry well storage capacity shall be based on the structure size and the void space of the specified fill material surrounding the structure.

3. Dry wells shall be designed, at a minimum, to infiltrate the anticipated peak flow and volume from the 10-year storm event and drain within 72 hours.
4. The bottom of the sump rock of a dry well shall be installed at the depth that infiltration rate was tested. This depth is generally 10 feet and shall always be in a highly infiltrative gravel layer. Deeper dry wells can be utilized with prior permission from the Utility Engineer.
5. Dry wells are classified as Class V underground injection wells. An inventory form for each well must be submitted to the EPA. This form must be included with the design report.
6. A dry well approval is required under a City of Missoula excavation permit.

H. Setback and clearance requirements to surrounding existing conditions contained in Table 6-5 shall be maintained.

Table 6-5 – Minimum Clearance Requirements for Placement of Infiltration Facilities

Element	Minimum Distance Required
Floodplains	Outside 10-year High Water Level (HWL) Work inside floodplain may require floodplain development permit
Seasonal High Water Table	4 feet vertical
First Limiting Layer (bedrock, clay lens)	5 feet vertical
Buildings	50 feet up-gradient, 20 feet down-gradient
Top of 15% Slopes	50 feet horizontal
Springs	200 feet horizontal
Septic Tanks/Drain Fields	100 feet horizontal
Domestic Wells	100 feet horizontal
Easements, property lines	20 feet horizontal