PUBLIC DRAFT

CITY OF BEND
STORMWATER MASTER PLAN

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ABBREVIATIONS

BMPs	Best Management Practices
BPRD	Bend Parks and Recreation District
BNSF	Burlington Northern Santa Fe
CIP	Capital Improvement Project
CN	Curve Number
COID	Central Oregon Irrigation District
COSM	Central Oregon Stormwater Manual
CWA	Clean Water Act
DMA	Designated Management Agency
DEHP	Di(2-ethylhexyl)phthalate, also known as Bis(2-ethylhexyl)phthalate
DEM	Digital Elevation Model
DWPA	Drinking Water Protection Area
EPA	U.S. Environmental Protection Agency
ERU	Equivalent Residential Unit
°F	degrees Fahrenheit
FP	Flood Plain
GIS	Geographic Information Systems
ISWMP	Integrated Stormwater Management Plan
LID	Low Impact Development
MB	Major Basin
MADL	Maximum Allowable Discharge Limit
Mag	Magnesium Chloride
MCL	Maximum Contaminant Level
MEP	Maximum Extent Practicable
MS4	Municipal Separate Storm Sewer System
ND	Non-Detect
NFA	No Further Action
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resources Conservation Service (Previously Soil Conservation Service)
OAR	Oregon Administrative Rules
ODEQ	Oregon Department of Environmental Quality
ODOT	Oregon Department of Transportation
OHA	Oregon Health Authority
PCP	Pentachlorophenol
SBUH	Santa Barbara Unit Hydrograph
SDWA	Safe Drinking Water Act
SPA	Shaun Piggott & Associates
SMP	Stormwater Master Plan
SWMP	Stormwater Management Plan
T_c	Time of Concentration
TMDL	Total Maximum Daily Loads
UIC	Underground Injection Control
UDWC	Upper Deschutes Watershed Council

UGB	Urban Growth Boundary
USGS	United States Geological Survey
WOZ	Waterway Overlay Zone
WPCF	Water Pollution Control Facility
WRF	Water Reclamation Facility

DEFINITIONS

Bioswale – A drainage ditch with shallow grade designed to reduce velocities of stormwater to allow for settling of sediment and removal of other pollutants through biological interactions. Pollutants adhering to sediments are also removed. Swales can be vegetated or rock-filled.

Catch Basin – A catch basin is a box-shaped receptacle fitted with a grate and a pipe outlet drain to collect rain water and floating debris from the roadway surface and to retain solid material for periodic removal. Catch basins may be installed horizontally in the roadway surface or be imbedded in the curb (curb inlet).

Detention Pond – A detention pond is a facility that is designed to temporarily hold stormwater runoff while slowly draining to an outlet. Detention ponds are a means to reduce downstream flooding by slowing the movement of stormwater to downstream pipes, creeks, and rivers. They have a negligible effect on water quality (compared to dry ponds) because sediments and pollutants do not remain in the ponds long enough to settle out of the stormwater. These facilities are normally dry when it is not raining.

Drill Hole – A drill hole is a borehole that is drilled or blasted through impermeable geologic layers. Drill holes are used for disposal of stormwater in areas where dry wells do not function. Many of the city's drill holes were installed in the earlier days of the city's development before dry wells became common practice. Drill holes are typically 6 to 8 inches in diameter and extend deep into the ground. Because drill holes pose a greater threat to groundwater, the Oregon Department of Environmental Quality (ODEQ) does not allow them to exceed 100 feet in depth unless they are covered under a UIC WPCF Permit.

Dry Pond – Dry ponds (also known as dry extended detention basins) are basins whose outlets are designed to detain the stormwater runoff from a rain event for a minimum duration (e.g., 24 hours) to allow sediment particles and pollutants associated with them to settle out. Water flows more slowly through dry ponds than through detention ponds. Dry ponds do not have a permanent pool of water and are normally dry between storm events.

Dry Well – A dry well is a vertical drainage facility (a well) with perforations along its walls that drain stormwater into the surrounding soil. A dry well is surrounded by washed drainage rock (2” to 3” drain field rock) to enhance infiltration capabilities and provide additional void space for storage. They are intended to dry up between storms.

Low Impact Development (LID) – LID is a stormwater management strategy that emphasizes conservation and use of existing natural site features integrated with distributed, small-scale stormwater controls to more closely mimic natural hydrologic patterns and prevent, reduce and treat runoff and pollutant loadings as close to the source as possible in residential, commercial, and industrial settings.

Retention Pond – See Wet Pond.

Swale – Vegetated swales (also known as grassed channels or biofilters) are constructed facilities that are open-channel drainageways used to convey and treat stormwater runoff. Vegetated swales are often used either instead of traditional storm sewer pipes or to provide treatment for discharges from stormwater pipes. Swales encourage infiltration, and water does not pond in them for very long. Vegetated swales generally have a relatively flat slope to provide sufficient time for treatment of pollutants, including sediment.

Sonde – A sonde is a submersible multi-parameter continuous recording device for monitoring physical and chemical water quality parameters.

Tc – The time in minutes that it takes a drop of water to travel from the farthest point in a drainage area to the point of discharge.

Total Maximum Daily Load – The Total Maximum Daily Load process determines how much of a pollutant a water body can receive without violating water quality standards.

Two-Year Time of Travel – In reference to drinking water protection areas, the horizontal distance a particle of water is expected to travel in an aquifer before entering a water well.

Underground Injection Control – Underground injection control (UIC) facilities are drainage systems that allow stormwater to infiltrate into the ground and are deeper than they are wide. Dry wells and drill holes are the most common UICs in Bend. The federal Safe Drinking Water Act and state regulations regulate UICs to protect groundwater quality for current or potential beneficial uses such as drinking water.

Urban Growth Boundary – A regional boundary set in an attempt to control urban sprawl by allowing the area inside the boundary to be used for higher-density urban development and the area outside for lower-density development. An urban growth boundary circumscribes an entire urbanized area and is used by local governments as a guide to zoning and land use decisions.

Water Quality Design Storm – The water quality design storm is defined as the storm that produces the runoff that requires water quality treatment prior to discharge. For the City of Bend, the water quality storm is the 6-month NRCS Type I storm or other type of storm as designated in the Central Oregon Stormwater Manual, latest edition. Treatment of the design storm runoff is intended to treat 80 to 90% of the first-flush pollutant-generating impervious surface runoff.

Wet Pond – Wet ponds (also known as stormwater ponds, retention ponds, and wet extended detention ponds) are facilities designed to contain a permanent pool of water throughout the year, particularly in the wet season. Ponds provide treatment of incoming stormwater runoff by capturing and holding the water for a long time, allowing solids and associated pollutants to settle. Nutrient removal also occurs as a result of plant activity and activity of aquatic organisms.

EXECUTIVE SUMMARY

INTRODUCTION AND BACKGROUND INFORMATION

This Stormwater Master Plan (SMP) developed for the City of Bend is an initial attempt to inventory and assess the stormwater facilities located within the City. It includes a discussion of the stormwater issues the City must address to meet regulatory requirements. Recommendations include a strategy for addressing stormwater for specific regions throughout the City and an approach for addressing stormwater issues and implementing stormwater infrastructure improvement projects over a 20-year period. Initially written in 2008, this SMP was revised in 2014. Some of the initial recommendations of the SMP have been completed and are noted herein.

The stormwater challenges the City faces over the next several years are categorized as follows:

1. Complying with water quality requirements mandated by state and federal laws.

2. Improving the collection and conveyance of stormwater so that the regulatory requirements can be met.

3. Reducing flooding to protect property and public safety.

4. Determining the vulnerability and susceptibility of groundwater to contamination from injected stormwater. A Risk Evaluation was conducted by GSI Water Solutions and presented in a Technical Memorandum dated September 21, 2011.

5. Determining if and how stormwater discharged to the Deschutes River may be interfering with the river's beneficial uses and affecting compliance with receiving water quality standards.

6. Ensuring that limited stormwater funds are spent on projects that are most likely to provide demonstrable benefits.

Stormwater regulatory requirements are explicit and compliance with these requirements is expensive. There are currently no significant ongoing state or federal funding sources for these types of projects. How the City deals with items 3 through 5 will depend largely on the wishes and priorities of the City's residents, elected officials and City management.

Although not required, by implementing items 4 and 5, the City has and may limit the impact of implementing the first two items. For example, the City has demonstrated that stormwater runoff is not negatively impacting water quality of groundwater by conducting a Risk Evaluation of stormwater discharged to groundwater (GSI, 2011b). This information has helped inform the regulatory discussion resulting in significantly reduced requirements of facilities that drain to groundwater than were anticipated in 2008. Similarly, studies on the impact of runoff to the Deschutes River may inform regulatory requirements for the piped system to the river.

Before 2007, hydrologic, hydraulic, and geologic data for the City had not been comprehensively analyzed within the context of stormwater management. Reported drainage and flooding problems have been increasing in recent years with the increasing amount of impervious surface area. The City started documenting these problems in 2007. The purpose of this plan is to evaluate the City's stormwater drainage needs within the 2007 urban growth boundary (UGB), and to meet increasingly stringent regulations governing stormwater.

Bend's topography ranges from relatively flat to hilly. There are two distinctive buttes in Bend: Awbrey and Pilot. Regional geologic features are largely the result of volcanic activity and subsequent weathering along the Cascade Range. These processes have resulted in the relatively recent deposition of a thick sequence of volcanic and volcanically derived sedimentary rocks. The volcanic geology has created a complex landscape with many ridges, drops, sinks, and hills.

Drainage patterns and directions vary greatly throughout the City, although both surface and subsurface flows are generally northward. Several large irrigation canals run through the City, conveying water from the Deschutes River to serve agricultural areas as far away as Madras, some 50 miles to the north. These canals and laterals have a strong influence on drainage patterns within the City. The Deschutes River divides the City into eastern and western halves.

Some areas of the City are underlain by consolidated basalt or "pink tuff", which is highly impermeable and does not provide acceptable geotechnical conditions for the use of infiltration, dry wells or drill holes that are not deep enough to penetrate through it.

A large part of Bend's drinking water comes from a deep, very high-quality and abundant aquifer beneath the City that is fed by snow melt high in the Cascade Mountains. The City and its residents are committed to protecting this valuable resource along with protecting surface water quality.

EXISTING DRAINAGE SYSTEM

For many years, the City of Bend's drainage system has depended primarily on underground injection (dry wells and drill holes) to discharge stormwater into the fractured volcanic rock that underlies much of the City. Bend does not have a city-wide piped storm drain system. The lack of defined drainage ways, the expense of digging in rock, and the difficult topography have limited the installation of piping. The existing piped system to the Deschutes River is limited to about 14 miles of pipe and 28 river outfalls. There are approximately 4,600 dry wells and 1,000 drill holes on public property in the City and an unknown number on private property. Including interconnections between inlets and UICs, there are 47 miles of pipe total throughout the City.

HYDROLOGIC AND HYDRAULIC ANALYSIS

A hydrologic and hydraulic analysis of the City of Bend was undertaken to define drainage basins in order to develop alternatives and recommendations for stormwater management and construction of stormwater facilities.

The drainage basins were defined using ArcGIS (Hydrology Modeling, ESRI) to identify low-lying areas and the direction of flow based on topography. Flow patterns were established to identify subbasins and major basins. Equations in the Central Oregon Stormwater Manual and the Santa Barbara Urban Hydrograph method were used to calculate peak runoff flows and total volumes for three storm events: the 6-month water quality storm (1.0 inch in 24 hours), along with the 25-year (2.5 inches in 24 hours) and 100-year (3.1 inches in 24 hours) storms.

WATER QUALITY

Bend relies heavily on groundwater to provide potable water for the City. Within its UGB, the City owns 21 municipal drinking water wells, and there are about 400 private water wells. Although the City obtains about half of its drinking water from the Bridge Creek surface water supply, the other water franchises in Bend obtain theirs solely from water from wells. Whereas drinking water levels of groundwater may be relatively deep, in some cases over 700 feet below the ground surface, there are also perched layers of water underneath the City. Protection of all groundwater including perched water and seasonal high groundwater is required by the State of Oregon.

Underground Injection Control (UIC) regulations are in the process of being rewritten and the City received its first Water Pollution Control Facility (WPCF) – UIC permit in May 2013. A general permit for other private and institutional UICs is under development by ODEQ as of this writing, and several non-City owned UICs are covered by rule authorization. Prior interpretation of UIC regulations did not allow stormwater injection within 500 feet of any drinking water well, or within the 2-year time-of-travel zone delineated by the Oregon Health Division as Drinking Water Protection Areas, without a UIC WPCF permit. These restricted areas covered a large part of the City and it would have been potentially very costly if UICs located within them must be decommissioned or equipped with pretreatment that treats the stormwater to drinking water standards prior to being discharged underground. The City of Bend therefore needed to obtain clarity on the UIC regulations and water quality implications of stormwater UICs prior to finalizing the Master Plan. The results of the UIC Risk Evaluation (September, 2011) and other scientific data are helping to inform UIC policy direction. Requirements of the WPCF permit have and will impact strategies implemented by the City in their efforts to maximize benefits and minimize costs.

Stormwater discharge sampling completed to date provides only preliminary information on the quality of stormwater in Bend. Water quality pollutants in Bend include typical urban stormwater pollutants such as sediment, nitrates, chlorides and oil and grease and heavy metals. However, a statewide review of stormwater data, including data from Bend, indicated that only 10 of 45 analytes sampled exceeded one or more of the three screening levels of interest by the ODEQ UIC program (i.e., the Oregon Administrative Rules (OAR) Numerical Groundwater Reference Level, U.S. Environmental Protection Agency (EPA) Maximum Contaminant Levels (MCLs), and ODEQ Drywell Compliance Maximum Allowable Discharge Limit (MADL)). Only lead, Pentachlorophenol (PCP), and Bis(2-ethylhexyl)phthalate (DEHP) exceeded one or more of the screening levels in greater than 1% of samples analyzed. The data also showed a statistically significant relationship between stormwater pollutant levels and streets with greater than 1,000 average trips per day. A later study specific to Central Oregon municipalities including Bend (April 2011) found that only 4 of 38 analytes sampled had an exceedance of the regulatory screening levels (cadmium, chromium, lead, and nitrate-nitrogen). Lead exceeded in 7.7% of samples and the remainder exceeded around 1% of the samples.

The City also completed an ambient water quality study in conjunction with the Upper Deschutes Watershed Council in June 2010 that will serve as a baseline as the City continues to collect ambient water quality data.

Water quality recommendations include:

- Promote the use of low-impact development (LID) principles in all City projects; and require private projects to consider LID principles.
- Consider the performance, reliability, maintenance requirements and life-time costs in selecting pretreatment devices.
- Continue to develop a better understanding of water quality in stormwater runoff by the continuation of monitoring water quality in UICs and the Deschutes River.
- Install efficient spill/sediment traps in the storm drain system ahead of discharges to either surface waters or groundwater. Sediment from unpaved roads, poorly installed landscaping, poor sediment and erosion control at construction sites and traction materials used on City streets during the winter months contribute the majority of the sediment that is discharged through stormwater runoff. The City has already implemented some measures to reduce the negative effects of traction materials.

STORMWATER GOALS, POLICIES, ORDINANCES, AND STANDARDS

Stormwater policies, ordinances, and standards were reviewed along with City goals to identify improvements and updates to support implementation of a comprehensive stormwater management program.

City goals for general stormwater management, stormwater drainage and stormwater quality are described below:

General Stormwater Management Goals:

- Ensure that public and private stormwater systems and facilities provide adequate levels of service to the public at reasonable cost.

- Ensure that development, including development involving the installation of drinking or irrigation water wells, pays its fair share of the cost of installing and upgrading stormwater facilities that are needed to support the development and meet City, state and federal stormwater quantity and quality standards.

- Ensure that before new areas are annexed, they are either brought up to City stormwater quantity and quality standards or pay their fair share of the cost of upgrading stormwater facilities that are needed to support the areas to meet City stormwater drainage quantity and quality standards. Stormwater requirements will be established as part of the annexation agreement.

- Eliminate drainage nuisance problems.

- Meet all federal and state regulatory requirements, including but not limited to the federal Clean Water Act, federal Safe Drinking Water Act, and Oregon Groundwater Protection and Oregon Drainage Law requirements.

- Work with stakeholders in the watershed to realize efficiencies in protecting stormwater quality and providing stormwater drainage.

- Provide education to help citizens protect themselves from flood hazards and understand how to prevent stormwater pollution.

Stormwater Drainage (Quantity) Goals:

- Reduce and manage runoff from developed lands.

  1.A. Require stormwater to be managed on the site of origin except when formal offsite arrangements that address both stormwater runoff quantity and quality have been negotiated and recorded.

1.B. Ensure that systems are sized and maintained correctly to ensure that stormwater is safely and adequately maintained on site and to allow safe passage for the 100-year storm.

1.C. Ensure that stormwater facilities are suited to the specific geologic conditions of the site.

- Preserve and maintain natural drainage systems.

- Preserve floodplains and drainage low spots for stormwater drainage.

Stormwater Quality Goals:

1. Protect the health, safety, and general welfare of the public and the environment with respect to stormwater quality.

   1A. Protect underground aquifers from urban runoff pollutants.

   1B. Protect surface waters from urban runoff pollutants.

2. Manage stormwater pollutants at the source to the degree possible using Low Impact Development (LID) and other development techniques.

3. Engage in a watershed approach to ensure surface drainage (river/creek) and groundwater health.

Recommended policies to address the City's goals include:

- No new development or significant redevelopment shall be allowed to occur without requirements in place for maximizing appropriate LID and providing onsite storm drainage that will meet water quality requirements and provide safe passage of runoff to the final disposal point.

- Upgrading of streets and storm drainage systems to meet City standards shall be a minimum requirement before new areas are accepted for annexation into the City. The City shall require that areas outside the City limits have a stormwater utility plan that shows the stormwater facilities for the development prior to annexation.

- New developments and neighborhoods can hasten the process of constructing new stormwater facilities by paying for the construction of regional facilities, defined as any system that serves more than one tax lot. Written agreements shall be required for all participants of stormwater districts to ensure the equitable funding of storm drainage improvements and the ongoing maintenance of these improvements.

- System Development Charges for funding storm drainage facilities can be used following development of detailed subbasin plans

- Sensitive areas, such as DWPAs, areas adjacent to clean-up sites, areas near private well-heads, and industrial sites or other areas where the potential for a hazardous material spill is great or the impact of such a spill would be large may need greater protection, including more stringent location requirements, treatment, or spill control standards.

- Strategic regional drainage areas may be reserved for stormwater treatment and storage.

These goals and policies are incorporated into the drainage analysis and recommendations for implementation of a comprehensive stormwater drainage system identified in this master plan.

STORMWATER UTILITY FUNDING

Funding for construction, maintenance and operation of stormwater infrastructure and stormwater management programs to address water quality issues requires a consistent and dedicated source of revenue. The City convened a citizen’s task force in 2007 to discuss the issues, evaluate options, and develop recommendations.

The Task Force made the following recommendations to the City Council:

- The primary funding approach should be a stormwater utility service charge.
- A separate utility is the preferred structure for the funding program. The utility would be dedicated to stormwater management. The rate can be related to a customer’s estimated use or contribution of runoff to the stormwater system.

- The appropriate basis of the service charge should be the measured impervious surface area because it is most closely related to runoff factors.

- Based on an estimate of the City's total impervious area, the initial rate per month per Equivalent Residential Unit, or ERU, would be $4.00 to meet the annual rate revenue requirement.

- A credit procedure should be available to non-residential stormwater customers. The credit should be structured to reflect the degree to which constructed facilities or best management practices exceed current standards, and therefore provide a benefit to the utility.

- Stormwater system development charges (SDCs) should be considered after the City Council approves the Stormwater Master Plan.

The stormwater utility recommended by the Task Force was formed in April, 2007 and the stormwater service charge of $4/month/ERU was approved by the City Council on June 20, 2007. The service charge was enacted beginning on July 1, 2007. Appeals and credit programs were adopted in 2007.

STORMWATER INFRASTRUCTURE IMPROVEMENT OPTIONS

A number of options were evaluated for addressing stormwater issues in the City of Bend. Funds are limited and it is important to maximize benefits of capital improvement projects while addressing stormwater flooding, water quality regulations, and public concerns.

Possible solutions to the stormwater drainage and water quality problems that were evaluated are listed below. Some of these options may not be applicable in some parts of the City.

- Continue using dry wells where geotechnical conditions are appropriate, including appropriate pretreatment, where necessary.

- Pipe with pretreatment as necessary to the Deschutes River or to a regional detention facility (i.e., serving more than one lot).

- Construct piped systems with regional detention and treatment in strategic locations.

- Implement Low Impact Development (LID) techniques on City property and require their use for all new development and redevelopment.

- Construct piped gravity system to discharge at the Water Reclamation Facility.

- Design and construct a combination of systems described above.

Each of the potential solutions listed above, with the exception of the option to pipe all stormwater to the WRF, can be used in combination to address stormwater. For example, LID can be used to the degree that there is space and infiltration capacity, in all areas of the City. Dry wells can be used in combination with other LID, or also with regional detention. Using infiltration where appropriate can reduce the amount of storage required for detention or retention, potentially resulting in reduced costs for land acquisition and rock removal.

Additional factors for the City to consider in addressing stormwater management include:

- Combine construction of stormwater infrastructure with construction of other utilities, such as roads, sanitary sewers, and water lines. Infrastructure improvements would be coordinated with other utility infrastructure improvements. This saves construction costs and minimizes community disruptions. The City should formalize its internal procedures to facilitate seeking opportunities for joint projects.

- Coordinate with regional and local agencies. Work with ODOT and Bend Parks and Recreation District (BPRD) to develop dual-purpose facilities that serve transportation or recreation purposes as well as stormwater management purposes.

  Although this Master Plan project is being managed by the Public Works Department and Engineering Infrastructure Planning Departments, those Departments have and will continue to coordinate with and seek input from other City Departments and divisions such as Community Development, Administration, Transportation, Private, Engineering, Water, and Water Reclamation.

- Develop plans and facilities to prevent or respond to spills from railroads and streets that may threaten surface or groundwater.
- Complete and maintain an accurate stormwater drainage system asset management in GIS.
- Develop a hydrology model using GIS data for further analysis in order to refine recommended drainage systems.

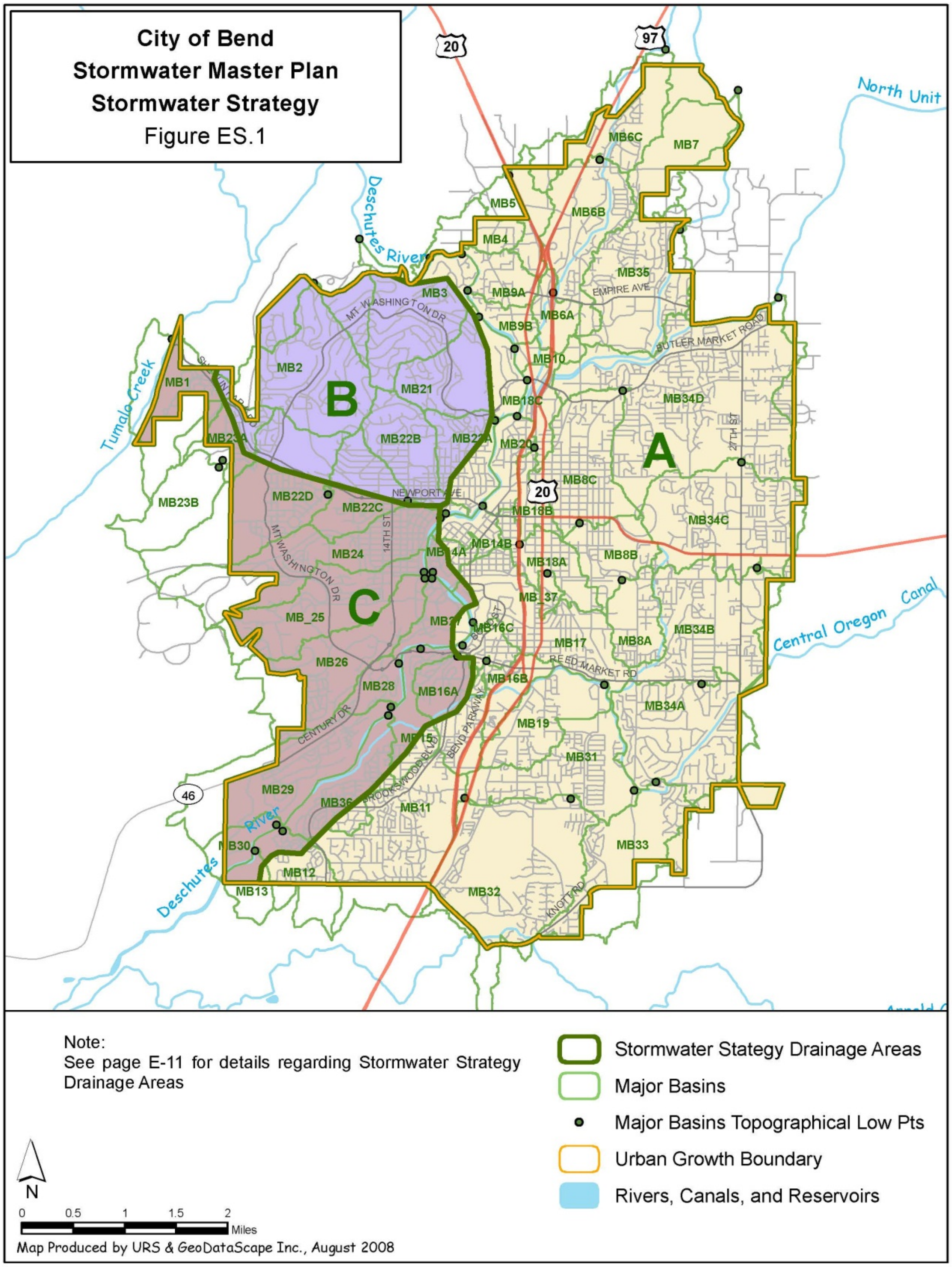
Soils in the City are a potentially limiting factor for implementation of infiltration and/or injection in all areas. Bend has four major geological conditions. Generally, the eastern part of the City and the northwest provide good to moderate geotechnical conditions for infiltration and UICs. The southwestern part of the City includes soils that drain very poorly. Although these are general conditions, individual sites may vary; there may be well draining pockets in areas in the southwest part of Bend generally underlain with pink tuff. Infiltration testing must occur to verify the infiltration capacity of any specific site. This information was used to generate 3 drainages areas within the City to create recommended stormwater management strategies on an area- and site-specific basis.

These drainage areas are shown in Figure ES.1 and are as follows:

- Drainage Area A: Areas of the City that have well-draining soils
- Drainage Area B: Areas of the City that are steep with soils that are not well-draining
- Drainage Area C: Areas of the City that have generally poorly-draining soils

RECOMMENDED STORMWATER MANAGEMENT STRATEGY

At the start of the SMP process drainage solutions focused on elimination of UICs and development of alternatives that included regional storage/treatment and a piped collection system. This was largely due to the cost implications associated with required treatment of UICs at the time, which has since been significantly reduced. Cost estimates were developed for that approach and are provided in Appendix E.



City of Bend
Stormwater Master Plan
Stormwater Strategy
Figure ES.1
A
B
C
MB1
MB2
MB3
MB4
MB5
MB6A
MB6B
MB6C
MB7
MB8A
MB8B
MB8C
MB9A
MB9B
MB10
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MB29
MB30
MB31
MB32
MB33
MB34A
MB34B
MB34C
MB34D
MB35
MB36
MB_37
20
97
46
Deschutes River
North Unit
Tumalo Creek
Central Oregon Canal
MT WASHINGTON DR
EMPIRE AVE
BUTLER MARKET ROAD
NEWPORT AVE
14TH ST
27TH ST
REED MARKET RD
CENTURY DR
BEND PARKWAY
KNOTT RD
Note:
See page E-11 for details regarding Stormwater Strategy Drainage Areas
Stormwater Stategy Drainage Areas
Major Basins
Major Basins Topographical Low Pts
Urban Growth Boundary
Rivers, Canals, and Reservoirs
N
0 0.5 1 1.5 2
Miles
Map Produced by URS & GeoDataScape Inc., August 2008

In addition to the stormwater management approaches that were evaluated, this SMP when first drafted made additional recommendations for the City to better understand its stormwater system and refine its management strategy. Several of these recommendations have since been completed, and the City will continue to conduct studies recommended in this SMP but not yet completed. This has helped the City to gain a better understanding of its system and use the results of those to refine the strategy on an area specific and site specific basis. Table ES.1 below lists the recommendations originally made to the City of Bend, and their status of completion.

Table ES.1: Stormwater Management Recommendations

Recommendation	Status
Promote the use of low-impact development (LID) principles in all City projects; and require private projects to consider LID principles.	Underway via Bend Code Title 16 and Bend Standards and Specifications
Develop standards for LID facilities such as bioretention systems and planters, to promote and facilitate their use	Adopted standards in COSM
Consider the performance, reliability, maintenance requirements and life-time costs in selecting pretreatment devices.	In process
Continue to develop a better understanding of water quality in stormwater runoff by the continuation of monitoring water quality in UICs, and the Deschutes River.	Continuing
Install efficient spill/sediment traps in the storm drain system ahead of discharges to either surface waters or groundwater. The City has already implemented some measures to reduce the negative effects of traction materials.	In process
Conduct a demonstration project(s) using permeable pavement.	Underway
Perform a UIC infiltration study	Done

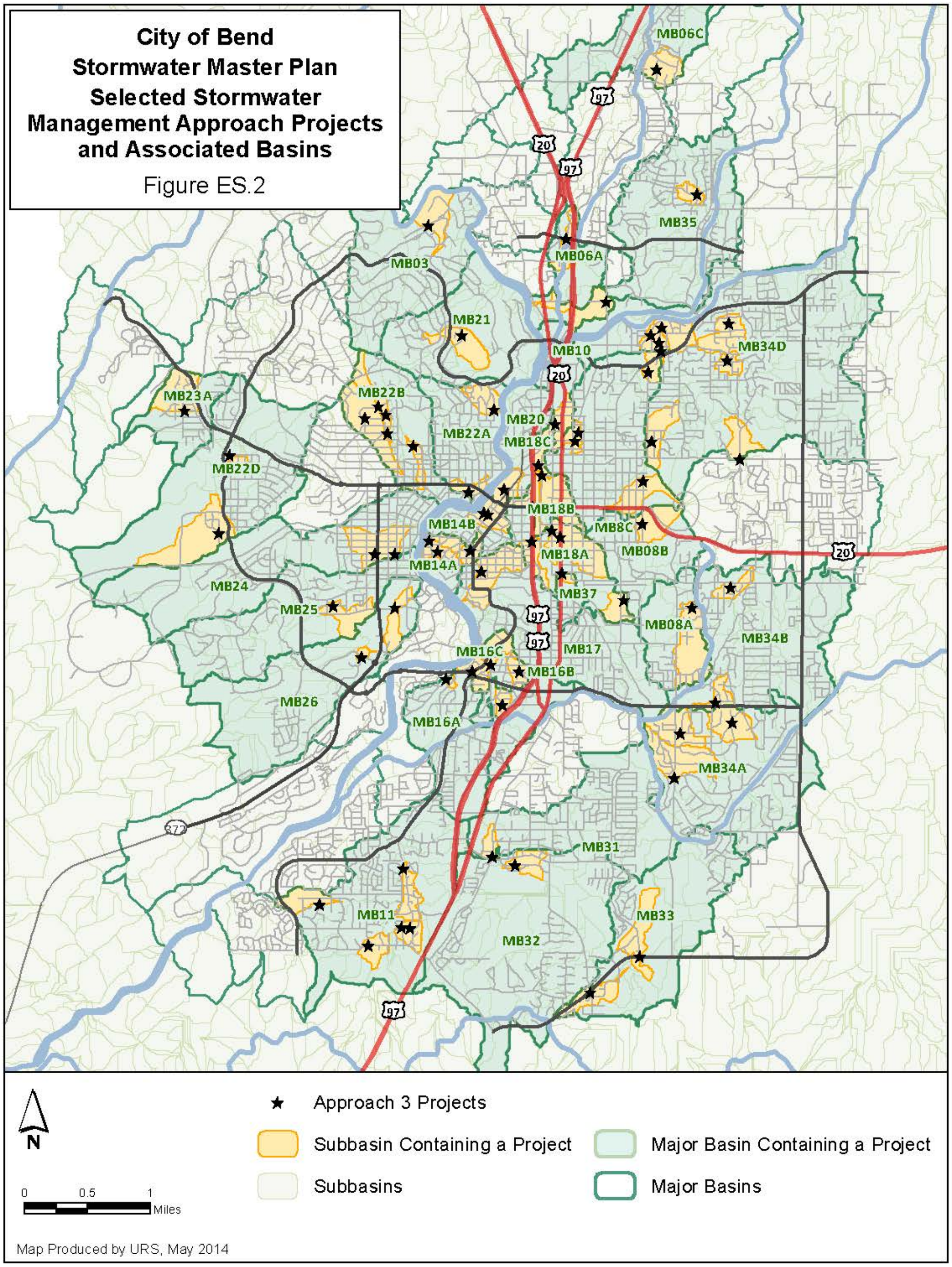
Perform a Groundwater Risk Analysis	Done
Update Drinking Water Protection Areas	Done
Evaluate long range funding needs	Done
Implement a pipe system rehabilitation program	Proposed

STORMWATER MANAGEMENT APPROACH

The City of Bend opted to pursue the combined systems option to address stormwater management within the City over the next 20 years. This option provides the City with the most flexibility, since it can be implemented piecemeal over time as resources are available. The City considered three different approaches for implementing the combined systems option with each approach including a different level of new projects and required funding. All three approaches include an increase to the stormwater utility charge. The first approach would primarily address maintenance and regulatory needs. The second approach would include a consistent improvement approach, with a target of approximately one infrastructure improvement project per year on average and would have the second highest associated cost of the three approaches. The third approach would correct all the known (as of April 2011) problem areas within the 20 year planning period.

The City presented all three approaches along with the associated potential stormwater utility rate increases to the public with two public open houses on April 9 and 10, 2014. Input was also obtained from the Stormwater Quality Public Advisory Group and the IAC. The City Council decided to move forward with Approach 3 at the City Council work session on May 7, 2014, using input gathered from the public and the IAC recommendation. Approach 3 includes 58 new projects (in addition to the pipe repair and spill risk abatement programs) and a total estimated cost of $25.2 M over 20 years. The projects included in Approach 3 address stormwater issues throughout the City and include several different methods for managing stormwater as appropriate based on area and site conditions. Projects include drainage improvement plans, pump station improvements, LID, drywell pre-treatment, piping, and other stormwater project types.

Figure ES.2 shows the locations of the projects and also indicates which subbasin and major basin each project is located in. This provides information on where drainage improvements would be recognized at a basin level.


City of Bend
Stormwater Master Plan
Selected Stormwater
Management Approach Projects
and Associated Basins
Figure ES.2
MB06C
MB35
MB06A
MB03
MB21
MB10
MB34D
MB23A
MB22B
MB20
MB22A
MB18C
MB22D
MB18B
MB14B
MB8C
MB18A
MB08B
MB14A
MB24
MB37
MB25
MB08A
MB34B
MB16C
MB17
MB16B
MB26
MB16A
MB34A
MB31
MB11
MB33
MB32
N
Approach 3 Projects
Subbasin Containing a Project
Major Basin Containing a Project
Subbasins
Major Basins
0
0.5
1
Miles
Map Produced by URS, May 2014

1.0 INTRODUCTION, AUTHORITY, AND SCOPE

1.1 INTRODUCTION

The City of Bend has grown rapidly creating increasing amounts of impervious area and subsequent stormwater runoff. Until recently the management of stormwater runoff has not caused much concern due to the semi-arid climate and well draining but generally shallow soils in the City. In the earlier history of the City when most development was close to the Deschutes River, piped systems were constructed to convey stormwater to the river. As growth expanded, drill holes became the main stormwater disposal method followed by dry wells. Dry wells and, to a lesser extent, drill holes have been predominately used for many years to dispose of stormwater in the City. Because they worked reasonably well and are relatively inexpensive to install, their use has continued throughout the City even in areas with natural impermeable layers and near drinking water wells.

Dry wells and drill holes require regular maintenance. Road cinders (used to improve traction for the motoring public during icy weather), eroded soils, and debris accumulate in downstream drainage systems, reducing the effectiveness of dry wells if not properly maintained. Failed or failing drill holes and dry wells, dry wells installed in inappropriate places, and the increase in the impervious surface area all contribute to the frequent and widespread flooding that now takes place in Bend.

In recent years, flooding has more frequently rendered underpasses on three of the City's busiest streets impassable for up to several hours at a time. Detours over crowded streets are both an annoyance to the public and a safety hazard. Population growth and the resulting increase in development density have exacerbated drainage problems by increasing flooding frequency, duration, and impacts. Flooding has become a public safety problem and a threat to homes and businesses.

Stormwater quality is also a serious issue. The federal Safe Drinking Water Act (SDWA) and the State of Oregon's Underground Injection Control (UIC) and Drinking Water Protection rules regulate the City's dry wells and drill holes. The federal and state National Pollutant Discharge Elimination System (NPDES) Municipal Separate Storm Sewer (MS4) Phase II rules regulate the City's discharges to the Deschutes River. Both of these regulatory programs require the City to obtain and comply with a permit and to use Best Management Practices (BMPs) to reduce the amount of pollutants discharged.

Outdated, weak, or poorly enforced development standards can allow continued construction of inadequate drainage systems as evidenced by photographs of flooding and the growing list of documented drainage complaints. Recognizing the need to construct systems that prevent flooding and adequately protect water quality, the importance of the Deschutes River as a Bend icon, and the protection of groundwater as a high priority drinking water resource, the City has embarked on a program to address its stormwater problems responsibly. Consequently, it issued a Request for Proposals to implement a stormwater utility funded through user service charges; develop a Stormwater Master Plan for meeting existing and future infrastructure needs; provide conceptual solutions for several of the highest priority flooding problems; and develop recommendations for meeting regulatory requirements.

This is the first formal Stormwater Master Plan (SMP) developed for the City of Bend. Before 2007, there was little documentation of drainage or flooding problems, or characterization of hydrologic, hydraulic, and geologic data. Now, flooding problems are increasing, and the regulations governing stormwater quality have become more stringent. The City of Bend is now faced with the need to define the issues surrounding stormwater, including the magnitude of the water quantity and water quality problems, consider the benefits of addressing policies and programs, and develop the best approach to fund stormwater services.

This SMP developed for the City of Bend is an initial attempt to inventory and assess the stormwater facilities located within the City. It includes a discussion of the stormwater issues the City must address to meet regulatory requirements. Due to the uncertainty of a number of issues such as the outcome of regulations impacting stormwater, this SMP is developed at a highly strategic level and is meant to act as a starting point for the development of more detailed plans to address the specific stormwater issues identified herein. Recommendations include a strategy for addressing stormwater for specific regions throughout the City, and potential solutions for five locations of chronic flooding along with prioritized listing of capital improvement projects to be addressed over the 20-year planning horizon. These projects are preliminary in evaluation and analysis and require further study prior to implementation.

Initially written in 2008, this SMP was put on hold awaiting clarity with regards to regulatory requirements for UICs, and updated in 2012. Some of the initial recommendations of the SMP have been completed and are noted herein.

1.2 AUTHORITY

URS Corporation signed a contract with the City of Bend in November 2006 to prepare a comprehensive SMP for areas within the City's Urban Growth Boundary (UGB), a regional boundary that was set in an attempt to control urban sprawl by encouraging higher density urban development inside the boundary. Because the City relies heavily on dry wells and drill holes for storm drainage, URS teamed with GeoEngineers, Inc. to prepare a geologic study and produce a report on the subsoil conditions and infiltration capabilities in Bend. Using existing reports and studies, GeoEngineers prepared a report describing the relative infiltration rates that are likely in various parts of the City.

Shaun Pigott and Associates, the third member of the URS team, prepared the financial analysis and recommendations for funding stormwater management activities in Bend. They led a community Task Force in a process of evaluating options and studying issues for development of a stormwater utility and appropriate service charges.

1.3 OUTLINE OF THE MASTER PLAN

This SMP was developed to address existing problems and identify future needs for public drainage and water quality infrastructure in the UGB for the City of Bend. The scope of work did not include private facility stormwater management. The project was divided into two phases with the following specific tasks:

Phase 1 – Stormwater Utility Formation

- Identification of high-priority problem areas and development of a prioritization process to determine the top five flooding problems (Section 4.2 and Appendix A)
- Preparation of conceptual solutions and fact sheets, including cost estimates, for the five highest-priority flooding areas (Appendix B)
- Preparation of a geologic study of the soils to identify opportunities and appropriate applications for infiltration of stormwater (Section 2.9)
- Development of a financial analysis to evaluate options for funding the stormwater program (Chapter 8 and Appendix D)
- Implementation of a stormwater utility (Chapter 8)

Phase 2 – Hydrology/Hydraulic Analysis and Recommended Improvements

- Delineation of drainage basins for the City of Bend (Chapter 5)
- Preparation of a hydrologic and hydraulic analysis of peak runoff flows and runoff volumes from drainage basins in the City (Chapter 5 and Appendix C)
- Evaluation of existing data to identify water quality and stormwater quantity strategies to meet regulations and public concerns (Chapter 6)
- Identification of strategies that address water quality and quantity for existing conditions and future buildout development expected to occur over 20 years, or FY 2032/33 (Chapter 9, 10, and Appendix E)

This SMP was prepared to provide the City with options to alleviate flooding and address water quality concerns for the NPDES Phase II and the UIC regulations and permits. Due to the complexities and challenges of managing stormwater in Bend, this SMP provides a recommended general strategy for implementing stormwater drainage, rather than specific capital improvement projects, recommendations for further studies and a hierarchy for implementing stormwater facilities.

The organization of the remaining chapters of the City of Bend's SMP is described below.

- Chapter 2 provides information about the City of Bend.
- Chapter 3 reviews environmental regulations and discusses a geologic analysis performed for this project.
- Chapter 4 describes existing drainage conditions, evaluates existing problems, and suggests solutions for the highest-priority areas.
- Chapter 5 describes the hydrologic and hydraulic analysis completed and presents the results.
- Chapter 6 discusses the water quality concerns, issues, and existing conditions.
- Chapter 7, written by City of Bend staff, provides a review, analysis and recommendations regarding the City's stormwater ordinances, policies, standards,

specifications and codes. It also outlines the general goals for stormwater and drainage and water quality.

- Chapter 8 describes the financial analysis and process used in forming the stormwater utility and determining the service charges.
- Chapter 9 describes and evaluates stormwater drainage improvement alternatives.
- Chapter 10 presents the SMP recommendations.

1.4 STORMWATER GOALS

Stormwater goals established by the City are incorporated into the analysis and recommendations provided in this master plan. The City has identified general goals for stormwater management as well as goals for drainage and water quality. Additional detail is located in Chapter 7.

General stormwater utility goals include:

- Ensure that public and private stormwater systems and facilities provide adequate levels of service to the public at reasonable cost.
- Ensure that development, including development involving the installation of drinking or irrigation water wells, pays its fair share of the cost of installing and upgrading stormwater facilities.
- Ensure that before new areas are annexed that stormwater facilities meet City water quantity and water quality standards.
- Eliminate drainage nuisance problems.
- Meet all federal and state regulatory requirements.
- Work with stakeholders in the watershed to realize efficiencies in protecting stormwater quality and providing stormwater drainage.
- Provide education to help citizens protect themselves from flood hazards and understand how to prevent stormwater pollution.

Stormwater Drainage (Quantity) Goals:

- Reduce and manage runoff from developed lands.
- Preserve and maintain natural drainage systems.
- Preserve floodplains and drainage low spots for stormwater drainage.

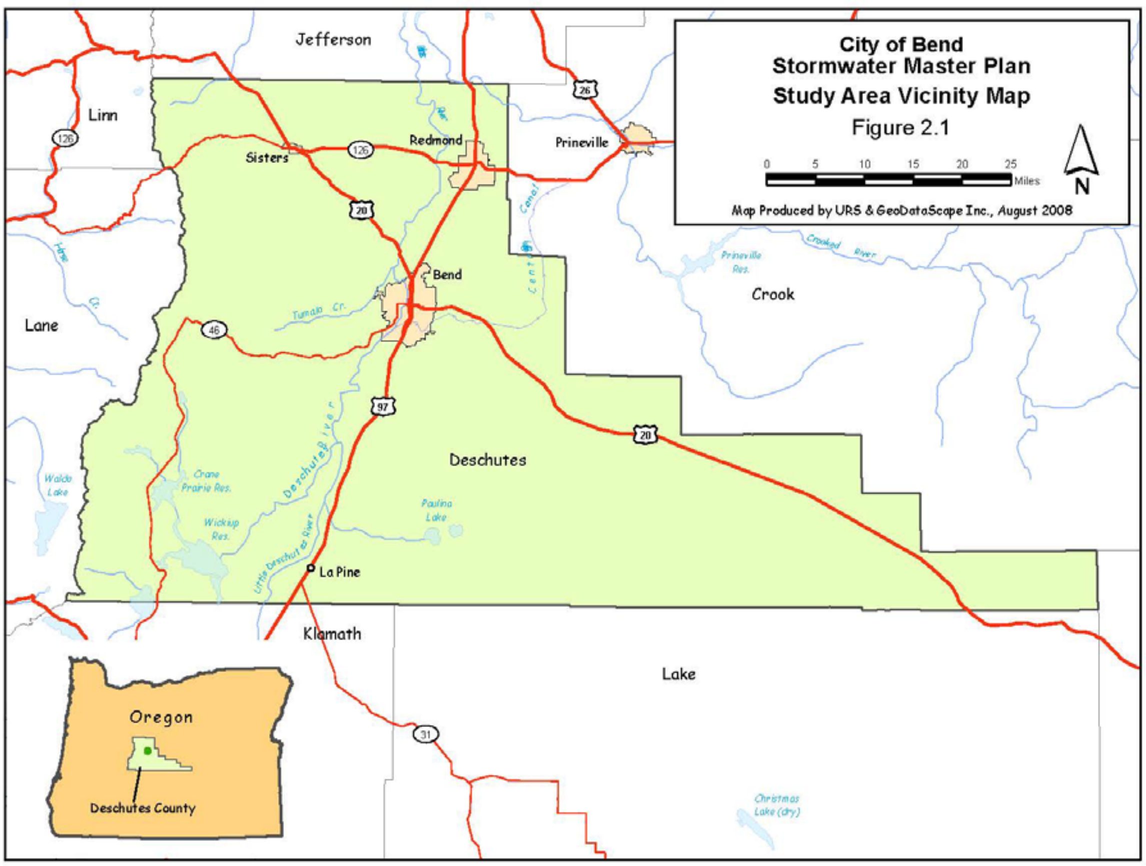
Stormwater Quality Goals:

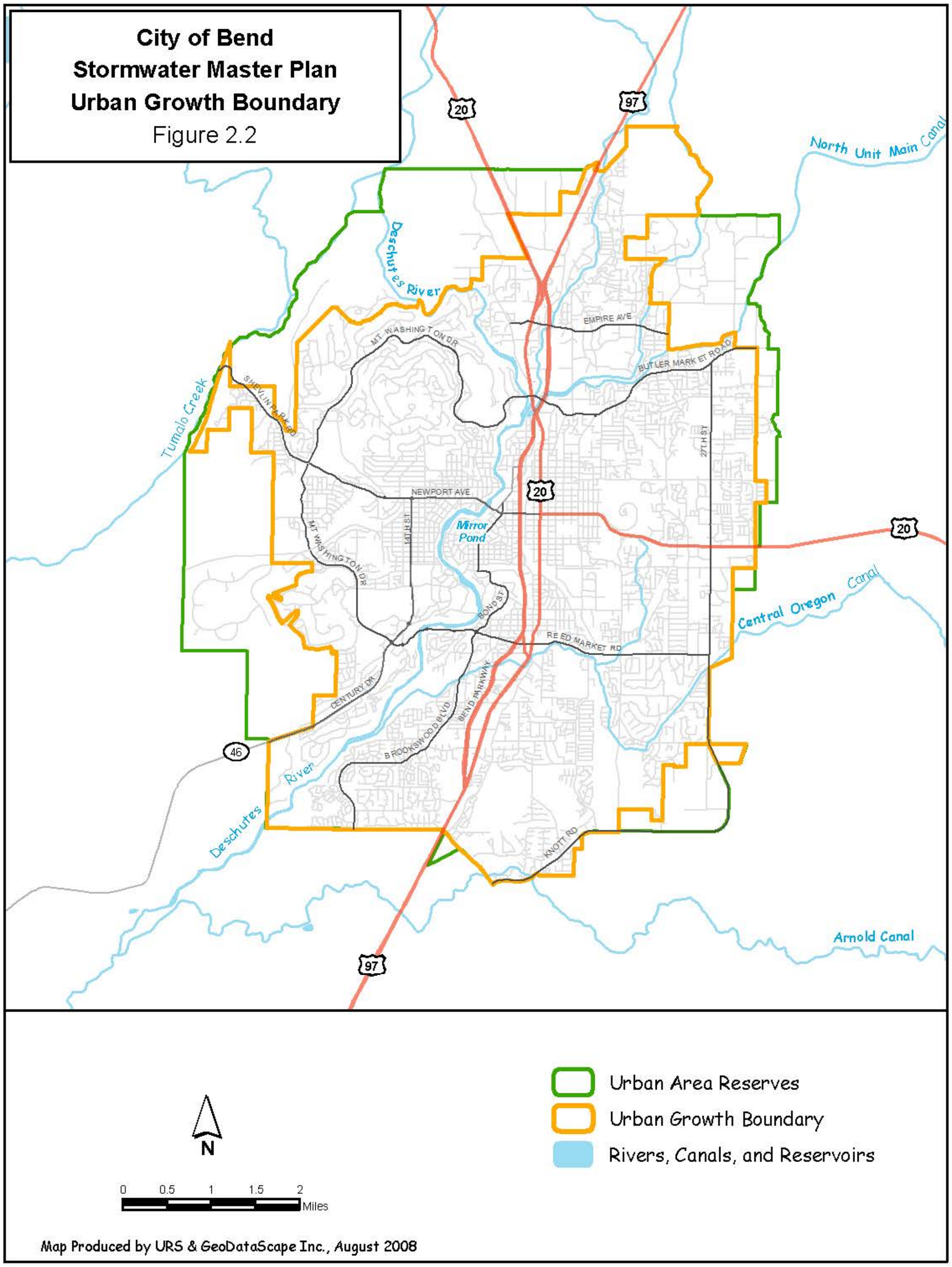
- Protect the health, safety, and general welfare of the public and the environment with respect to stormwater quality.
- Manage stormwater pollutants at the source to the degree possible using low-impact development (LID) and other development techniques.
- Engage in a watershed approach to ensure surface drainage (river/creek) and groundwater health.

2.0 STUDY AREA CHARACTERISTICS

2.1 LOCATION

The City of Bend is the county seat of Deschutes County in Central Oregon. On a high plateau in the foothills east of the Cascade Range, the City is about 16 miles south of Redmond and 30 miles north of LaPine (Figure 2.1). Its clear view of Mt. Bachelor and the Three Sisters, along with a recreational bounty of year-round outdoor activities, makes Bend a very desirable place to live. Bend covers an area of 32 square miles within the State-approved UGB (Figure 2.2), which coincides with the city limits. The City Council has adopted a new UGB since the initial development of the SMP, but the new boundaries have not been approved by the State as of May, 2014. Highways 97, 97 Business, and 20 run through the City.



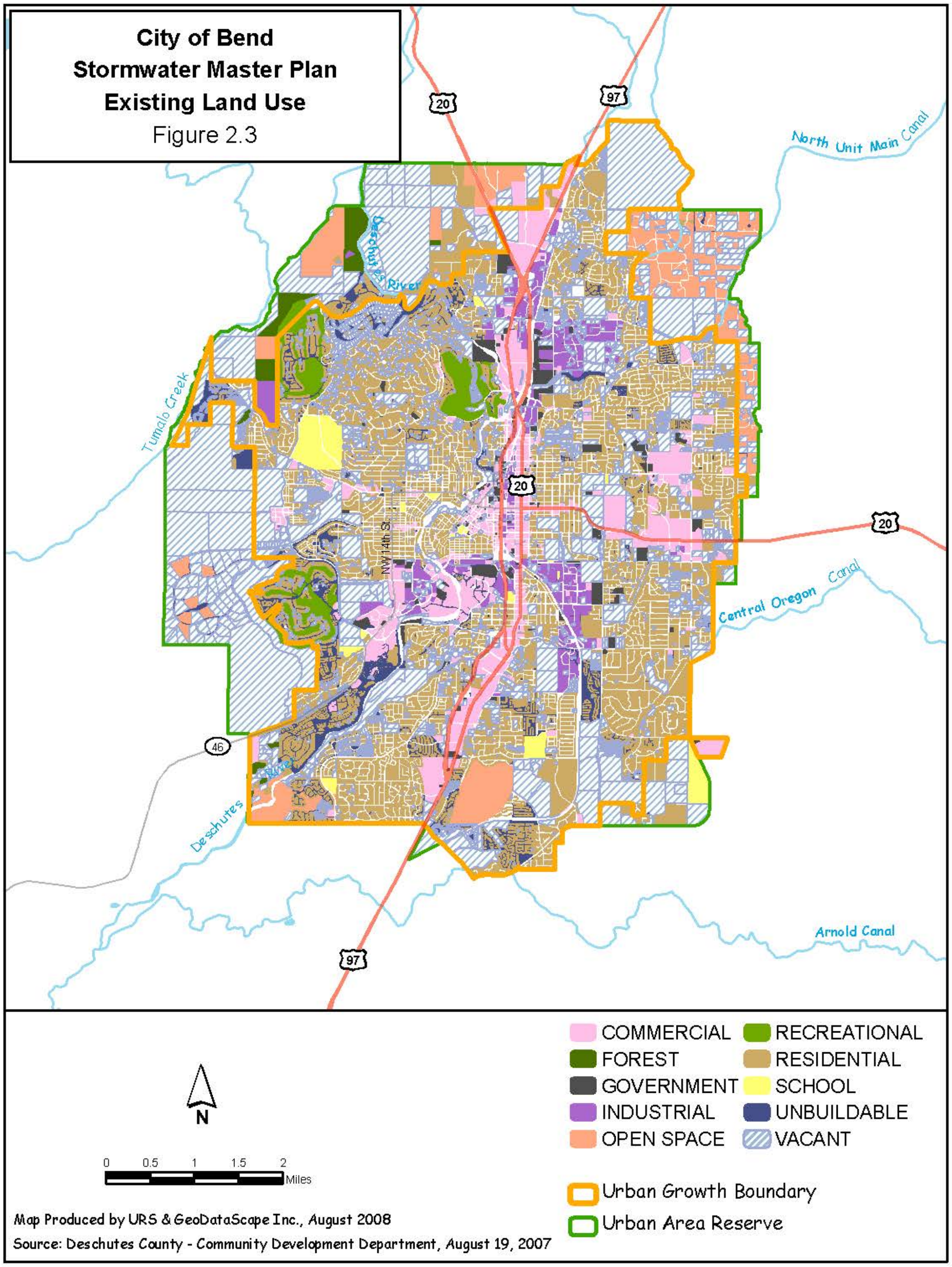

City of Bend
Stormwater Master Plan
Urban Growth Boundary
Figure 2.2
North Unit Main Canal
Deschutes River
Tumalo Creek
EMPIRE AVE
BUTLER MARKET ROAD
MT. WASHINGTON DR
SHEVLIN PARK RD
27TH ST
NEWPORT AVE
Mirror Pond
14TH ST
MT WASHINGTON DR
BOND ST
REED MARKET RD
Central Oregon Canal
CENTURY DR
BROOKSWOOD BLVD
BEND PARKWAY
KNOTT RD
Deschutes River
Arnold Canal
20
97
46
Urban Area Reserves
Urban Growth Boundary
Rivers, Canals, and Reservoirs
N
0 0.5 1 1.5 2
Miles
Map Produced by URS & GeoDataScape Inc., August 2008

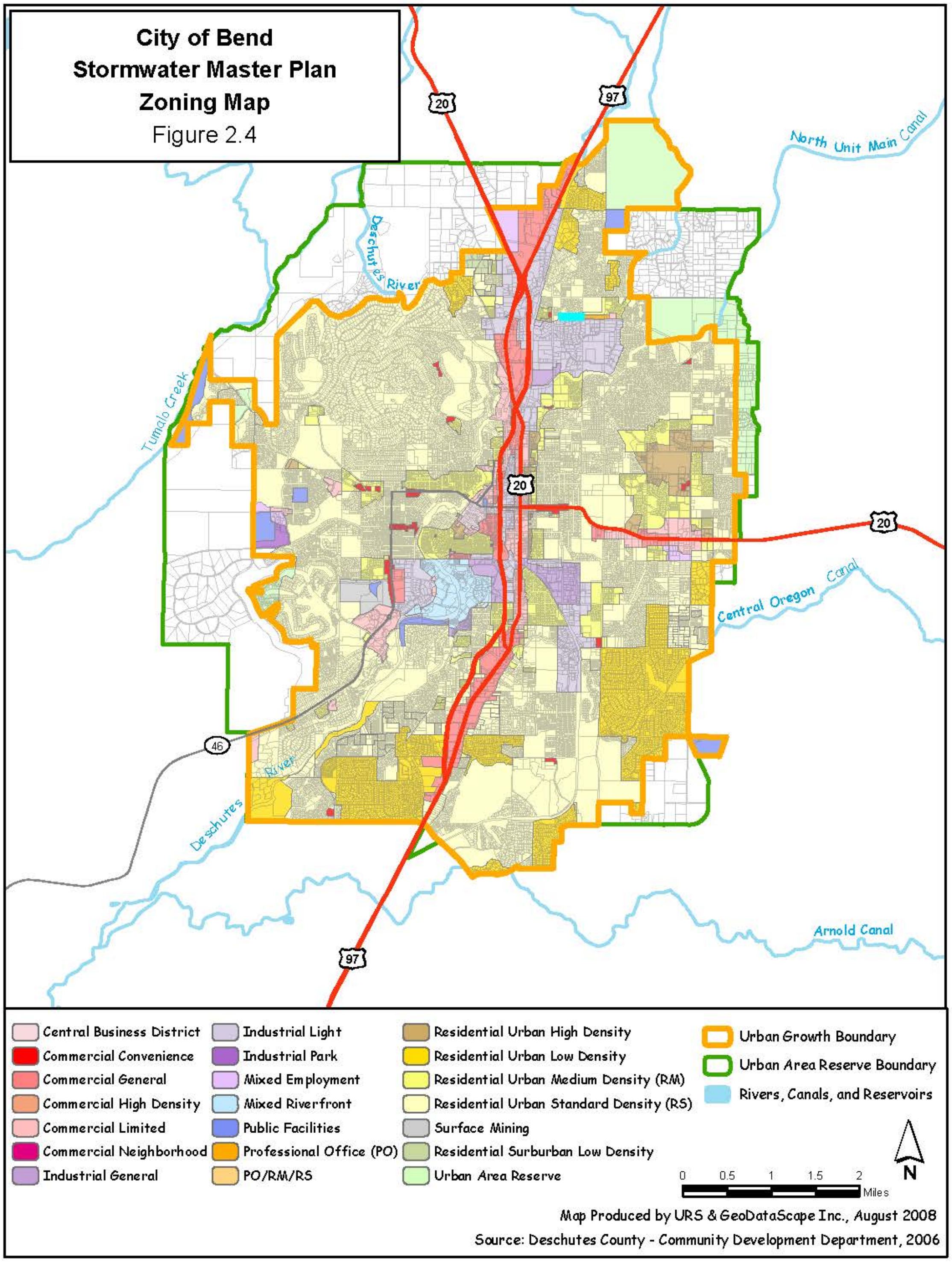
2.2 POPULATION

Incorporated in 1905, Bend has grown from a small logging town of 300 residents to a City with an estimated population of 77,780 in 2007 (Portland State Population Research Center, 2008). By 1990, the City had a population of approximately 20,000. The population increased from 29,425 to 77,780 between 1995 and 2007. The average annual growth rate varied from 5 percent in the late 1990s to 15 percent in recent years (Portland State University Center for Population Research and the U.S. Census Bureau, 2008), and at times its growth rate was the fastest in the country. Economic stresses in recent years have reduced the population to 76,639 (Portland State Population Research Center, 2010). Bend's abundant high-quality drinking water, dry climate, and year-round recreational opportunities have attracted many residents in the past, and as the economy recovers, Bend is forecasted to continue its high growth rate. City planning division staff is relying on growth projections that estimate the City population to exceed 100,000 by the year 2025.

2.3 LAND USE

Land use in Bend currently consists of a mix of residential, commercial, and industrial properties within the City. The downtown district is in the center of town near the Deschutes River. Figures 2.3 and 2.4 depict current land use and zoning for future growth within the current UGB, respectively.


City of Bend
Stormwater Master Plan
Existing Land Use
Figure 2.3
20
97
North Unit Main Canal
Deschutes River
Tumalo Creek
20
20
NW 14th St.
Central Oregon Canal
46
Deschutes
Arnold Canal
97
N
0 0.5 1 1.5 2
Miles
COMMERCIAL
RECREATIONAL
FOREST
RESIDENTIAL
GOVERNMENT
SCHOOL
INDUSTRIAL
UNBUILDABLE
OPEN SPACE
VACANT
Urban Growth Boundary
Urban Area Reserve
Map Produced by URS & GeoDataScape Inc., August 2008
Source: Deschutes County - Community Development Department, August 19, 2007



City of Bend
Stormwater Master Plan
Zoning Map
Figure 2.4

Statewide Land Use Planning Goal 11 requires planning for water and sewer services within the City and for areas within an established UGB. For the City of Bend, the city limits are basically the same as the UGB. This plan covers the City and UGB and does not call for piped facilities outside of the UGB. All evaluations and alternatives in this plan involve serving only areas within the UGB and this plan is consistent with Goal 11.

About 37 public parks throughout the City are operated and managed by the Bend Parks and Recreation District (Figure 2.5), and additional facilities are being planned. Drake Park along Mirror Pond and Juniper Park in the eastern part of the City are two of the largest parks in Bend. Pilot Butte, a popular hiking trail and scenic overlook, also in the eastern part of the City, is managed by the Oregon State Parks Department.

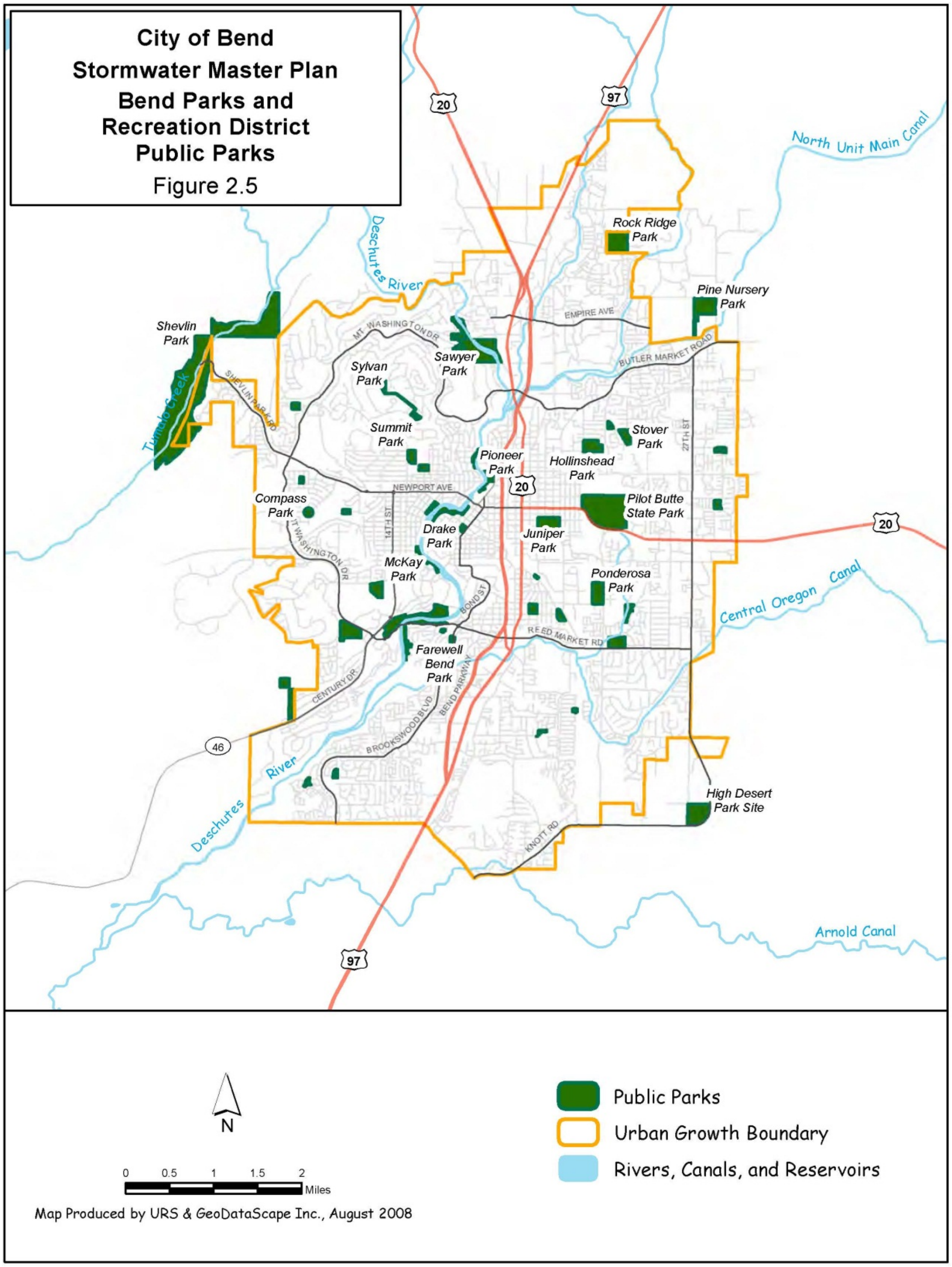
2.4 INDUSTRY

Central Oregon is home to a diverse group of industries. Top employers include government, retail industries, and leisure and hospitality (Economic Development for Central Oregon, 2008). Manufacturing, natural resources, mining, and construction follow closely behind the three major employment sectors. Recreation and tourism are large industries for the City. During Bend's rapid growth, industries continued to diversify and provide more jobs. Most of Central Oregon's residents shop in Bend, and stores and shopping centers in the City were increasing in number and size prior to the recent economic downturn. Growth of industry may return as the economy recovers.

2.5 CLIMATE

Bend has a mild climate, classified as semiarid or High Desert. With average annual precipitation of only 11.7 inches, the City experiences an average of 300 days of sunshine per year. Most of the 34 inches of average annual snowfall occurs between October and May. Bend is to the east of the Cascade Mountains and in their rain shadow, and receives a fraction of the precipitation experienced west of the mountains as storms from the Pacific Ocean bring warm moist air inland. Although there is relatively little annual rainfall, it often comes in short, intense bursts, particularly in the spring and fall, causing considerable localized flooding throughout the City. During the winter months, when drainage systems are blocked by snow and ice, rapid snowmelt and rain-on-snow events exacerbate flooding.

Average monthly low temperatures of 23 to 35 degrees Fahrenheit (°F) occur in winter months, while average high winter temperatures vary from 41 to 65°F. Average monthly


City of Bend
Stormwater Master Plan
Bend Parks and
Recreation District
Public Parks
Figure 2.5
Rock Ridge Park
Pine Nursery Park
Shevlin Park
Sylvan Park
Sawyer Park
Summit Park
Pioneer Park
Hollinshead Park
Stover Park
Compass Park
Pilot Butte State Park
Drake Park
Juniper Park
McKay Park
Ponderosa Park
Farewell Bend Park
High Desert Park Site
Deschutes River
North Unit Main Canal
Central Oregon Canal
Arnold Canal
Tumalo Creek
EMPIRE AVE
BUTLER MARKET ROAD
MT. WASHINGTON DR
SHEVLIN PARK RD
NEWPORT AVE
14TH ST
27TH ST
BOND ST
REED MARKET RD
CENTURY DR
BROOKSWOOD BLVD
BEND PARKWAY
KNOTT RD
20
97
46
N
0 0.5 1 1.5 2
Miles
Map Produced by URS & GeoDataScape Inc., August 2008
Public Parks
Urban Growth Boundary
Rivers, Canals, and Reservoirs

summer temperatures vary from lows of 38 to 46°F to highs of 73 to 82°F (Oregon Climate Service, 2008).

2.6 VEGETATION

Except where it is irrigated, vegetation is limited to drought-tolerant species in the arid, high desert climate of Bend. A number of deciduous and evergreen trees and shrubs are drought tolerant; these include plants native to Central Oregon (Native Plants of Oregon, 2008), and others such as juniper (*Juniperus occidentalis*) and ponderosa pine (*Pinus ponderosa*). Deciduous trees growing in Bend include alder (*Alnus* sp.), ash (*Fraxinus latifolia*), aspen (*Populus tremuloides*), larch (*Larix occidentalis*), and maple (*Acer macrophyllum*). Chokecherry (*Prunus virginiana*), elderberry (*Sambucus racemosa* or *Sambucus nigra* ssp. *cerulea*), rabbitbrush (*Chrysothamnus* sp.), and snowberry (*Symphoricarpos albus*) are a few of the local shrubs. Sagebrush and bunch grasses thrive in the area. Xeriscaping™, landscaping with vegetation that requires minimal amounts of water, is widely practiced.

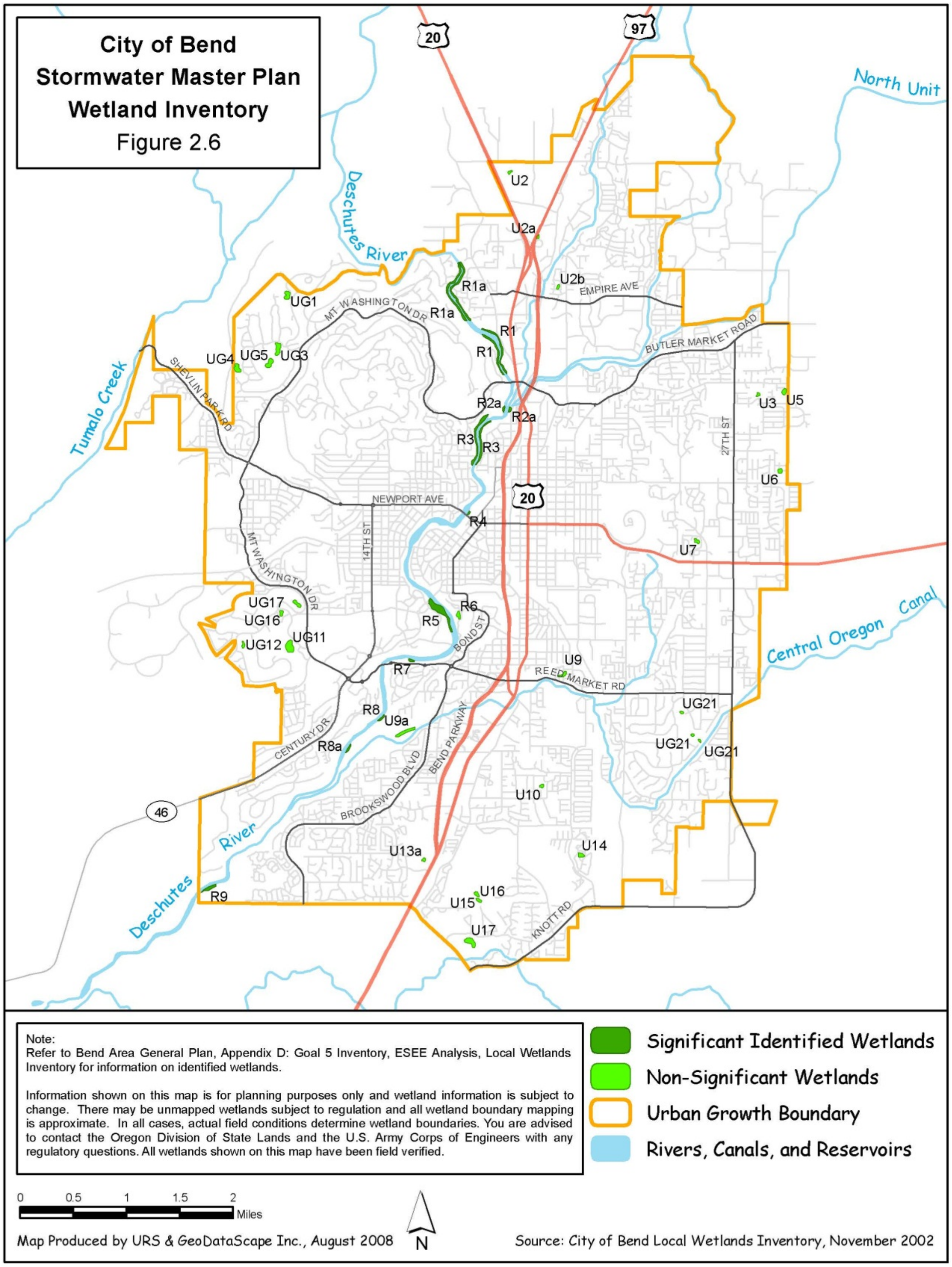
Invasive species create problems for wildlife by removing habitat, increasing soil erosion, and outcompeting native vegetation. Concern over the spread of invasive weeds is being addressed through a public information program, including the creation and distribution of pamphlets describing how to identify and eradicate problem vegetation. Some of the major invasive weeds of concern are Canadian thistle, Scotch thistle, poison hemlock, whitetop, perennial pepperweed, spotted knapweed, diffused knapweed, Dalmatian toadflax, and purple loosestrife.

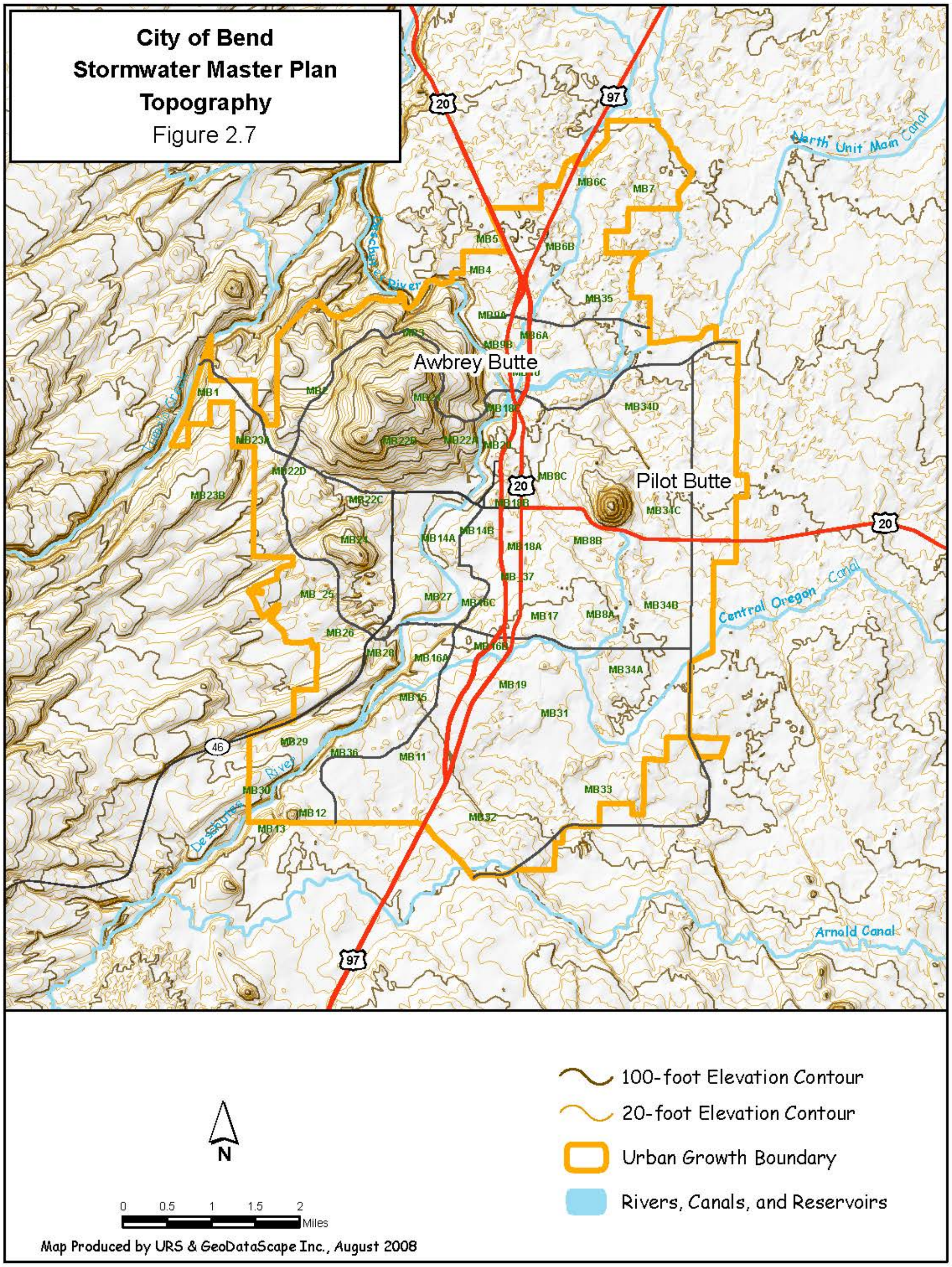
2.7 WETLANDS

A local wetlands inventory map prepared by the City is shown on Figure 2.6. Significant wetlands have been identified along the length of the Deschutes River in the City. These wetlands may not yet have been field verified and need to be evaluated by a wetlands scientist to verify their protection status before any activity that could affect them can be undertaken.

2.8 TOPOGRAPHY

Central Oregon’s topography ranges from relatively flat to hilly, with two distinctive buttes in the vicinity of Bend. Awbrey Butte is the highest point in the City, at an elevation of 4,214 feet and Pilot Butte is nearly as high at 4,138 feet (Figure 2.7). The


City of Bend
Stormwater Master Plan
Wetland Inventory
Figure 2.6
20
97
North Unit
Deschutes River
Tumalo Creek
U2
U2a
U2b
EMPIRE AVE
R1a
R1a
MT WASHINGTON DR
UG1
UG4
UG5
UG3
SHEVLIN PARK RD
R1
R1
BUTLER MARKET ROAD
R2a
R2a
R3
R3
U3
U5
27TH ST
U6
20
NEWPORT AVE
R4
14TH ST
U7
MT WASHINGTON DR
UG17
UG16
UG12
UG11
R6
R5
BOND ST
Central Oregon Canal
U9
R7
REED MARKET RD
UG21
R8
U9a
UG21
UG21
CENTURY DR
R8a
BROOKSWOOD BLVD
BEND PARKWAY
46
U10
Deschutes River
U13a
U14
R9
U16
U15
U17
KNOTT RD
Note:
Refer to Bend Area General Plan, Appendix D: Goal 5 Inventory, ESEE Analysis, Local Wetlands Inventory for information on identified wetlands.
Information shown on this map is for planning purposes only and wetland information is subject to change. There may be unmapped wetlands subject to regulation and all wetland boundary mapping is approximate. In all cases, actual field conditions determine wetland boundaries. You are advised to contact the Oregon Division of State Lands and the U.S. Army Corps of Engineers with any regulatory questions. All wetlands shown on this map have been field verified.
Significant Identified Wetlands
Non-Significant Wetlands
Urban Growth Boundary
Rivers, Canals, and Reservoirs
0
0.5
1
1.5
2
Miles
N
Map Produced by URS & GeoDataScape Inc., August 2008
Source: City of Bend Local Wetlands Inventory, November 2002


City of Bend
Stormwater Master Plan
Topography
Figure 2.7
Awbrey Butte
Pilot Butte
North Unit Main Canal
Central Oregon Canal
Arnold Canal
Deschutes River
20
97
46
100-foot Elevation Contour
20-foot Elevation Contour
Urban Growth Boundary
Rivers, Canals, and Reservoirs
N
0 0.5 1 1.5 2 Miles
Map Produced by URS & GeoDataScape Inc., August 2008

URS

volcanic geology has created a tortured landscape with many ridges, drops, sinks, and hills. Drainage patterns and directions vary greatly throughout the City, although both surface and subsurface flows are generally northward. The Deschutes River parts the City into eastern and western halves. Tumalo Creek influences the drainage patterns in the northwestern area of the City. There are no other creeks or significant drainage ways in the City. East of the river the ground slopes in a northeasterly direction, directing stormwater away from the river.

Mirror Pond, an icon in the heart of the City, was created in the first decade of the 1900's by a hydroelectric dam now owned by Pacific Power and Light. The pond is in an approximately one-mile-long stretch of the Deschutes River, bordered roughly by the Galveston Bridge to the south and Newport Bridge to the north. The dam is a few hundred feet downstream from the Newport Bridge.

Several large irrigation canals run through the City, conveying water from the Deschutes River to serve agricultural areas as far away as Madras, some 50 miles to the north. These canals and laterals still have a large influence on drainage patterns within the City.

For several reasons, irrigation districts are unwilling to risk contaminating irrigation water with potential stormwater pollutants and may also be concerned that accepting stormwater may require them to obtain NPDES discharge permits.

2.9 GEOLOGIC AND HYDROGEOLOGIC CONDITIONS

The following summary of geologic and hydrogeologic conditions within the City of Bend and surrounding area is based on the more technical and comprehensive text provided in GeoEngineers' 2007 report entitled *Stormwater Infiltration Evaluation, City of Bend, Oregon*. This report is a geologic and geotechnical study based on existing documentation, and provides general guidance on the effectiveness of dry wells and drill holes in various areas of Bend.

Regional geologic features are largely the result of volcanic activity and subsequent weathering along the Cascade Range. These processes have resulted in the relatively recent deposition of a thick sequence of volcanic and volcanically derived sedimentary rocks (GeoEngineers, 2007). For example, Awbrey Butte, in the northwestern part of town, is a volcanic vent composed of basalt. Volcanic rock is at or near the surface throughout the City, and its permeability and topography vary, creating many areas where stormwater infiltration is very slow with a high risk of localized flooding.

As the volcanic and sedimentary rocks weather, they create a thin soil layer that ranges in depth from 0 to 60 inches or more. In some areas, the soil layer is too thin to allow for deeply rooted vegetation. Soil within the City tends to drain well, with some exceptions, such as Tumalo and Plainview sandy loams. Soil close to or within the Deschutes River channel is primarily river deposits composed of gravels, sand, and silt. The soil layers adjacent to the river have variable permeability (GeoEngineers, 2007).

Portions of the City are underlain by basalt that is relatively fractured with a sufficiently high permeability to allow for infiltration of stormwater at relatively high rates, particularly given the relatively low annual rainfall experienced in Central Oregon. Before the City was developed, the permeability of this basalt was generally high enough to allow infiltration of large quantities of stormwater runoff, even for large storm events. Dry wells for disposal of stormwater runoff performed reasonably well when Bend was a smaller town with a smaller impervious area. However, when stormwater runoff is concentrated to a higher volume and increased rate of runoff because of the increase in impervious area, the permeability of the basalt does not always allow the increased stormwater runoff to infiltrate quickly enough, and flooding occurs.

Some areas of the City are underlain by consolidated basalt or pink tuff, which is highly impermeable and does not provide acceptable geotechnical conditions for the use of dry wells or drill holes that are not deep enough to penetrate through it. Many of these areas can be identified by the presence of drill holes, installed to allow stormwater to be disposed of below near-surface low-permeability layers. Drill holes are generally about 6 inches in diameter with casing in the top several feet.

With Bend's rapid growth in the past 20 years, the number of UIC systems in the public right-of-way has increased to over 5,000. Many private properties also have UICs which are required to be registered through ODEQ and are not part of the City's system. Construction of piped drainage is expensive in Bend due to the rocky geology and has been avoided in most areas of the City. The City has not had the time or resources to develop an adequate drainage infrastructure to keep up with the growth in population and the resulting increase in impervious areas. Many of the existing UICs no longer handle the design volume and rate of stormwater runoff for reasons such as improper installation, inappropriate geotechnical conditions, plugging by road traction cinders, soil erosion from construction sites, and having been constructed according to standards and specifications that are now outdated.

In their 2007 report, GeoEngineers identified four major geologic areas (shown on Figure 2.8).

Geologic Area 1 is composed of fractured basalt and generally provides the best geotechnical conditions for the use of dry wells, drill holes and infiltration. The older basalt rock of Geologic Areas 2 and 3 provides moderately good geotechnical conditions for dry wells, drill holes and infiltration. Geologic Area 4 has an impermeable layer of volcanic rock locally known as pink tuff and is generally not suitable for dry wells or infiltration that cannot penetrate the layer.

The infiltration capabilities of underlying soil and rock are only one consideration in the siting and operation of infiltration facilities. State and federal regulations, drinking water wells located throughout the City, percent slope, protection of drinking water sources, and maintenance of these facilities are additional issues to evaluate when considering whether to construct infiltration facilities. These issues are explored further in Chapter 3, Regulations, Chapter 4, Existing Drainage System, and Chapter 6, Water Quality.

2.10 WATER QUALITY

A large part of Bend's drinking water comes from a deep, very high-quality and abundant aquifer beneath the City that is fed by snow melt high in the Cascade Mountains. The City has won several awards for the quality of its drinking water, and the City and its residents are committed to protecting this valuable resource. Chapter 6 discusses water quality in more detail.

REFERENCES

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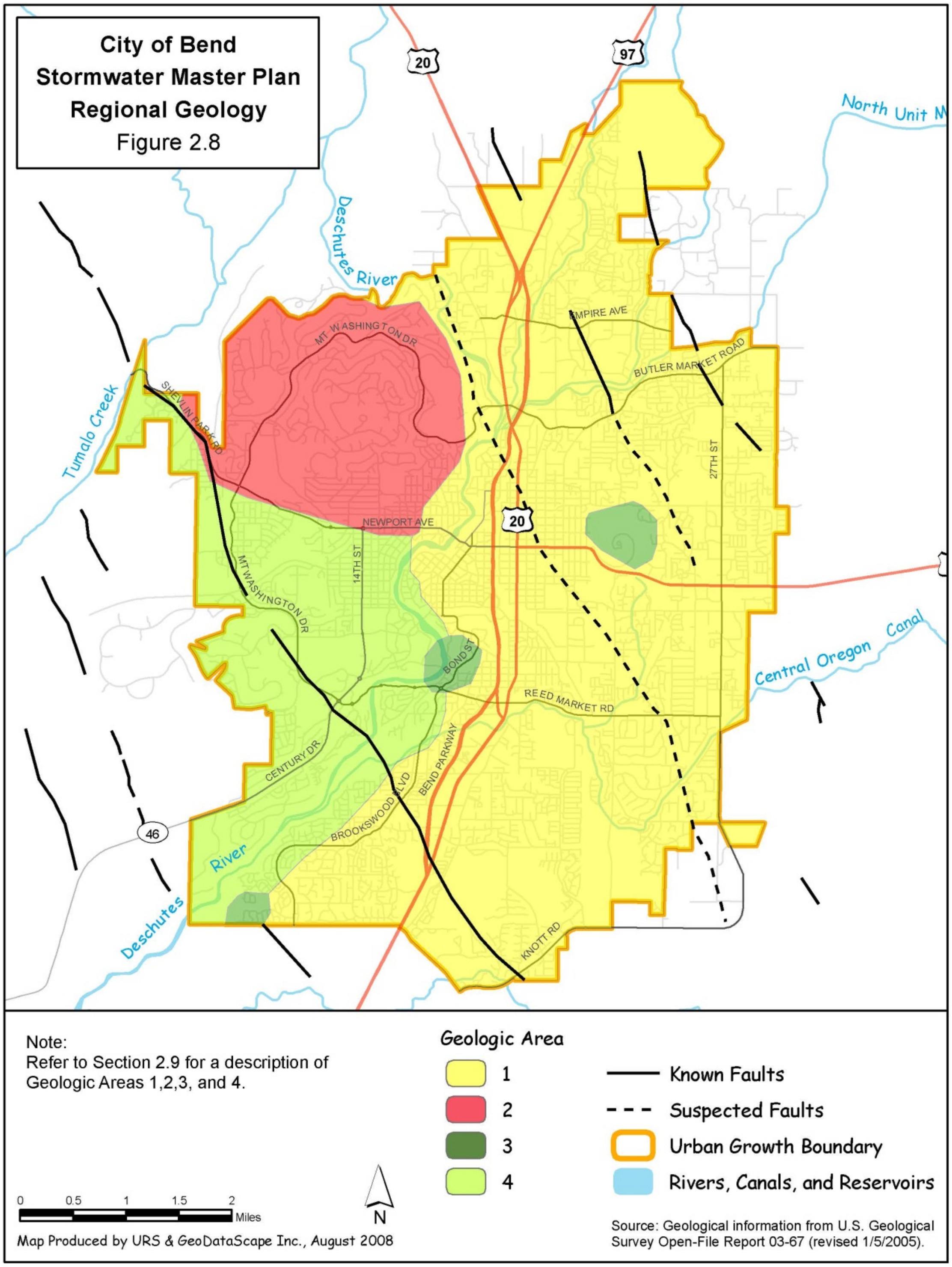

City of Bend
Stormwater Master Plan
Regional Geology
Figure 2.8
Deschutes River
North Unit
Tumalo Creek
Central Oregon Canal
MT WASHINGTON DR
SHEVLIN PARK RD
NEWPORT AVE
14TH ST
EMPIRE AVE
BUTLER MARKET ROAD
27TH ST
BOND ST
REED MARKET RD
CENTURY DR
BROOKSWOOD BLVD
BEND PARKWAY
KNOTT RD
20
97
46
Note:
Refer to Section 2.9 for a description of Geologic Areas 1,2,3, and 4.
Geologic Area
1
2
3
4
Known Faults
Suspected Faults
Urban Growth Boundary
Rivers, Canals, and Reservoirs
0 0.5 1 1.5 2 Miles
N
Map Produced by URS & GeoDataScape Inc., August 2008
Source: Geological information from U.S. Geological Survey Open-File Report 03-67 (revised 1/5/2005).

3.0 REGULATIONS

Federal regulations address the quality of stormwater that is discharged to surface waters and groundwater. Discharges to surface water are regulated by the federal Clean Water Act (CWA) and Oregon Administrative Rules (OARs) through National Pollutant Discharge Elimination System (NPDES) Municipal Separate Storm Sewer System (MS4) permits. Certain construction sites are required to obtain NPDES 1200C permits to ensure that erosion control procedures are in place. Discharges to groundwater are regulated by the federal Safe Drinking Water Act (SDWA) and state regulations.

To comply with the regulations for both stormwater and groundwater, the City prepared an Integrated Stormwater Management Plan (ISWMP). The ISWMP is a living document that is updated as necessary to meet requirements of the permits and the needs of the City.

3.1 DISCHARGES TO SURFACE WATER

In compliance with CWA requirements, the City of Bend applied for and obtained a Phase II NPDES permit, for cities with populations greater than 50,000 and less than 100,000. The Phase II NPDES permit requires the City to reduce the amount of pollutants it discharges to the Deschutes River "to the maximum extent practicable" (MEP) using best management practices (BMPs). The permit application was originally submitted to the ODEQ on March 10, 2003. One year later, the City submitted to the ODEQ an *Integrated Stormwater Management Plan* (ISWMP) defining, among other things, activities the City would undertake to address pollution associated with stormwater discharged to the Deschutes River. The Phase II permit was delayed by legal issues and resource limitations, and the City was obliged to update the ISWMP in 2006. The permit was issued in February 2007 and the ISWMP was made part of the permit by reference. (The ISWMP is discussed further in Chapter 7.) NPDES permits are issued for five years; the Phase II permit expired in January, 2012 and has been administratively extended by ODEQ to provide the City with permit coverage until the permit renewal process is completed. In preparation for a new permit, the City developed a draft revision to their ISWMP in July 2011 to cover the new planning period. Public comments have been received on this draft revision and the City submitted a revision in December 2012 to address public comments and UIC requirements. The City prepares an annual report, submitted to ODEQ by November 1 of each year, outlining the City's progress in implementing the ISWMP.

The City will need a Phase I NPDES permit when its population exceeds 100,000. Although the population has declined in recent years, as the economy recovers, Bend may return to a high rate of growth. When the City qualifies for a Phase I permit they will require more staff and funds than the current Phase II permit to meet additional requirements including expensive monitoring and inspecting public and private water quality treatment facilities.

3.1.1 Clean Water Act 303(d) List of Impaired Waters

CWA regulations require pollutants of concern for water bodies to be identified on a 303(d) list. ODEQ and others collect water quality sampling data for streams and rivers throughout the state. If the sample data indicate that water quality standards are not being met, the water body is considered impaired and is placed on the 303(d) list. ODEQ sets water quality standards for Oregon, develops the 303(d) list and updates the list every two years.

Pollutants of concern in the Deschutes River include chlorophyll-a, dissolved oxygen, pH, temperature, turbidity, and sedimentation. Stormwater is one of the sources of turbidity and sedimentation. Excess chlorophyll-a typically indicates that an excessive amount of algae has grown in a waterway as a result of excess nutrients; this can result in algae-filled channels, odors from decomposing algae, and reduced dissolved oxygen and pH levels. Oxygen is taken up in the decomposition process, reducing its availability for fish, insects, and other aquatic life. A reduction in pH creates greater acidity in the water, which is harmful to aquatic organisms. The current TMDL is being developed for temperature, dissolved oxygen, pH and sediment/turbidity, and chlorophyll a.

3.1.2 Development of Total Maximum Daily Loads

Total Maximum Daily Loads (TMDLs) are developed for each of the pollutants for which a water body is 303(d) listed, if its water quality does not improve. TMDLs quantify the maximum amount of a pollutant that a water quality impaired stream or river can accept and still meet water quality standards. If the water quality does not improve, ODEQ creates TMDLs for the pollutants of concern within a defined segment of the creek or river.

To develop TMDLs, ODEQ uses a complex technical analysis to identify the quantity of a pollutant that a stream segment can absorb without violating water quality standards.

This analysis is performed for each pollutant of concern and for each segment that does not meet water quality standards. ODEQ will only develop TMDLs for parameters for which it has sufficient information to verify ongoing violations of the water quality standard. Parameters for which there is insufficient or only preliminary data will remain on the 303(d) list while additional data are collected.

The Deschutes River has been on the 303(d) list for a number of years. ODEQ has been working on the Upper and Little Deschutes River TMDL since 2007 and is currently completing modeling efforts and writing the TMDL. A public hearing will be held prior to finalizing the TMDL and submitting the document to U.S. Environmental Protection Agency (EPA) for approval. Since there are areas within the City that drain to the Deschutes River, the ODEQ has identified the City of Bend as a likely Designated Management Agency (DMA). If designated as a DMA, the City would need to develop and comply with waste load allocations (WLA) for the pollutants of concern. WLAs describe the amount of a pollutant each DMA can discharge and still meet the TMDL.

A DMA has one year, following completion of the TMDLs, to develop an Implementation Plan or benchmarks to submit to ODEQ. Stormwater discharges are generally infrequent and of short duration so it can be difficult to determine their impact on receiving water quality. One of the readily visible effects of stormwater is the sediment and trash that accumulate near outfalls. Since 2003, the City and the Upper Deschutes Watershed Council (UDWC) have jointly monitored the river to try to determine the impact of stormwater discharges, among other things. To develop effective TMDLs, it is necessary to know how a given reduction in the discharge of a pollutant of concern will affect the concentration of that pollutant in the river. This information will be provided through the use of existing data and computers that model the fate and transport of pollutants within the river.

Temperature is an issue for nearly every water body in the state. Elevated water temperatures are harmful to aquatic life in general, and particularly for salmon and efforts to restore healthy populations in Oregon. While temperature is a parameter of concern in the river, the relative significance of the City's stormwater discharges on river temperature is considered to be minor because of the highly transient nature of stormwater discharges.

Communities with Phase II NPDES permits are not required to address the 303(d) list until the ODEQ develops a TMDL and the associated WLA. After ODEQ completes the TMDLs, the permit renewal may require the City to provide an analysis of how it will manage its stormwater discharges to meet the TMDL WLAs, and to develop benchmarks to meet those allocations. NPDES permits are valid for five years, but are often administratively extended rather than renewed due to limited ODEQ resources.

3.1.3 Surface Water Quality Monitoring

Communities like Bend with Phase II NPDES permits are not required to perform surface water quality monitoring. When the City's population exceeds 100,000, it will need a Phase I permit which will require monitoring.

A multi-year monitoring project starting in 2005 and completed in 2010 provides the City with baseline data on ambient water quality in the Deschutes River and Tumalo Creek. The City plans to continue annual river monitoring. The City's UIC monitoring will help inform this analysis as well.

3.1.4 Sensitive Species

The Oregon spotted frog has been proposed for listing as a threatened species under the federal Endangered Species Act by the US Fish and Wildlife Service and has populations in Bend, including within stormwater management ponds.

3.2 EROSION CONTROL FOR CONSTRUCTION PROJECTS

NPDES also regulates certain construction site erosion control by means of the 1200-C NPDES permit. Construction sites that disturb an area of one acre or more are required to obtain a 1200-C NPDES permit from ODEQ if there is a potential for runoff to enter the Deschutes River or Tumalo Creek directly or via a conveyance system. Construction plans must be submitted to ODEQ along with the permit application that provides details on how erosion will be minimized and soil maintained on the construction site. Plans for construction sites, including certain sites smaller than one acre, are reviewed by the City.

3.3 UNDERGROUND DISCHARGES

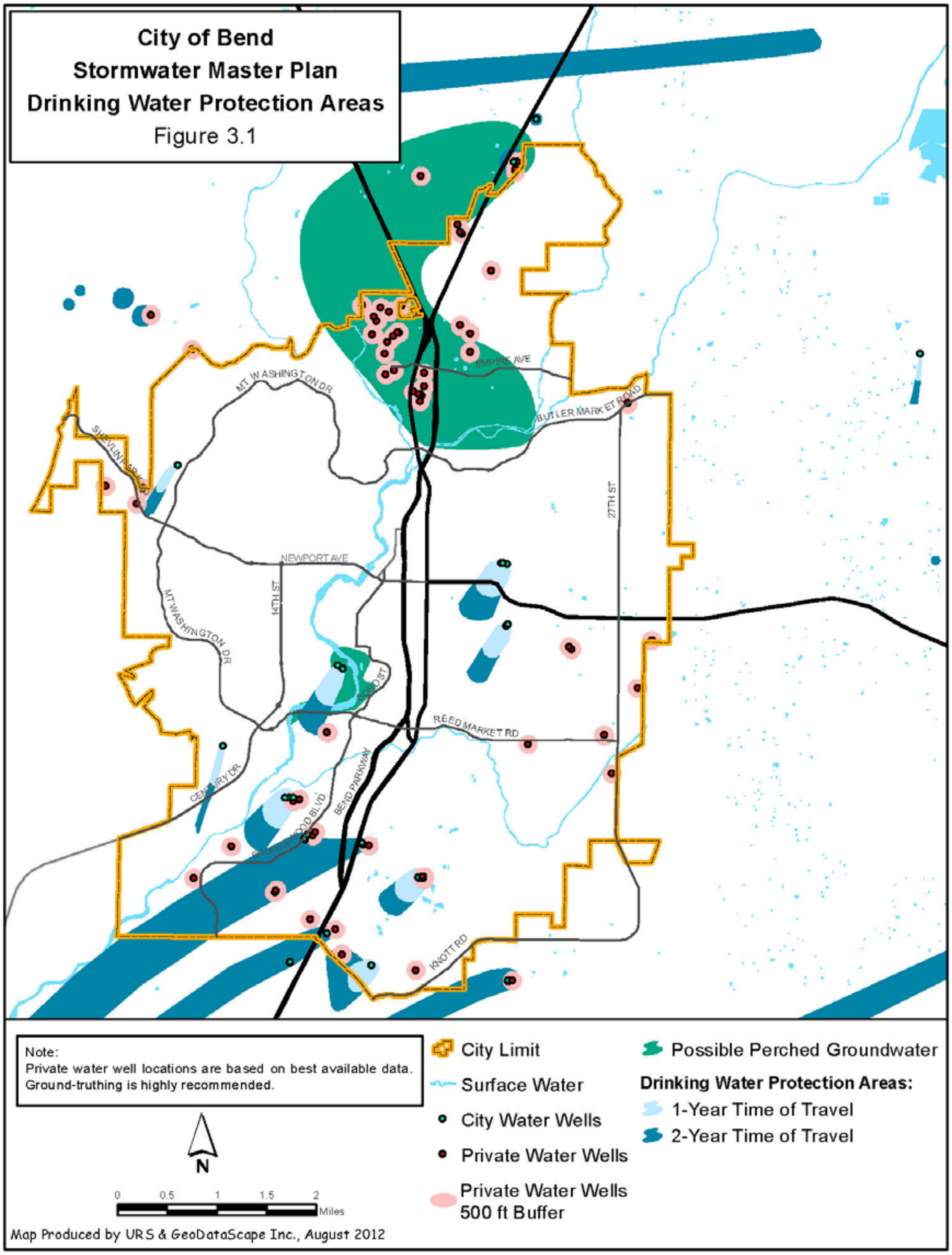
Dry wells, drill holes, and some other types of infiltration systems are considered underground injection controls (UICs). Groundwater quality is particularly important in Bend because much of the City's drinking water comes from the City's 21 municipal wells. In addition, three private water purveyors have several wells, and several hundred individual families have residential water wells.

All UICs must be registered with the ODEQ. In addition, each UIC must either meet the rule-authorization requirements or be covered under a UIC WPCF permit. Many of Bend's UICs do not meet rule authorization requirements so the City applied for a UIC WPCF permit. The City received its first WPCF – UIC permit in May 2013. A general permit for other private and institutional UICs is under development by ODEQ as of this writing, and several non-City owned UICs are covered by rule authorization.

Under the state's UIC program rules, Bend is required to conduct a representative monitoring program to determine the concentrations of certain pollutants it discharges underground. The City's monitoring plan has been accepted by the DEQ for purposes of the City's WPCF-UIC Permit. Because some UICs are in the same areas served by the City's piped system, monitoring in those areas provides important information about underground discharges as well as river discharges. See Chapter 6 for more information about monitoring.

3.3.1 Drinking Water Protection Areas

Drinking water safety and quality are regulated through the SDWA. The SDWA and Oregon's equivalent rules establish protection areas and strictly regulate UICs that have the potential to contaminate or contribute to the contamination of sources of drinking water. As can be seen in Figure 3.1, there are areas of the City located within several of these protection areas.


City of Bend
Stormwater Master Plan
Drinking Water Protection Areas
Figure 3.1
Note:
Private water well locations are based on best available data. Ground-truthing is highly recommended.
N
0 0.5 1 1.5 2 Miles
Map Produced by URS & GeoDataScape Inc., August 2012
City Limit
Surface Water
City Water Wells
Private Water Wells
Private Water Wells 500 ft Buffer
Possible Perched Groundwater
Drinking Water Protection Areas:
1-Year Time of Travel
2-Year Time of Travel

Drinking Water Protection Areas (DWPAs) (also known as Wellhead Protection Areas (WHPAs)) are delineated for the municipal wells the known wells owned by the private purveyors. A permit is required for any UICs located in a DWPA or within 500 feet of a water well. DWPAs are delineated by the Oregon Health Authority (OHA) using computer models. The City's DWPAs shown in Figure 3.1 were re-delineated in 2011. The DWPAs in Figure 3.1 show that groundwater flows from the southwest toward the northeast. The state UIC program is concerned about the use of UICs within the 2-year time-of-travel DWPA. The DWPA identifies the areas where groundwater, if contaminated, would convey the contamination to the water well within a certain time frame (e.g., in two years or less for the two-year time of travel zone; ten years or less for the ten year time of travel zone). A DWPA is an elevated risk area within which a community should develop protection strategies for the groundwater. It is also the outer zone of the area within which microbial sources could affect the drinking water. The City has demonstrated that day-to-day stormwater runoff is not negatively impacting water quality of groundwater by conducting a Risk Evaluation of stormwater discharged to groundwater (GSI, 2011b). This information has helped inform the regulatory discussion regarding requirements of facilities that drain to groundwater. For cases of spills, ODEQ has a separate clean up program and regulations.

The City must develop a plan to provide protection for the groundwater underlying its approximately 4,600 publicly owned dry wells and 1,000 drill holes. Each UIC must be registered, per ODEQ's UIC regulations. For those UICs that do not meet ODEQ's UIC regulations for compliance with protecting groundwater, each UIC must either be decommissioned and replaced with an alternative drainage system, or retrofitted to treat stormwater unless it can be demonstrated that these dry wells do not negatively impact groundwater. No new UICs (private or public) should be constructed in the DWPAs without stormwater pretreatment. Adequate separation distance as defined in the WPCF permit issued to the City between the bottom of the UIC and high seasonal groundwater or perched water is encouraged for all UICs.

A recently completed Water System Master Plan Update (Optimatics, 2011) identified six new wells to be constructed to assist the City meet the demands for potable water. The recommended new wells are located throughout the City with the following general locations: Awbrey Butte, two located in southern part of City, two located east of Pilot Butte and one north of Pilot Butte. Five of the six recommended new wells are proposed to be located east of the Deschutes River. Prior to UIC construction, particularly east of the Deschutes River, the City should be contacted to identify the exact location of proposed wells and determine what additional requirements are needed to protect groundwater quality.

3.3.2 Cleanup Sites

Figure 3.2 shows ODEQ cleanup sites within the City.

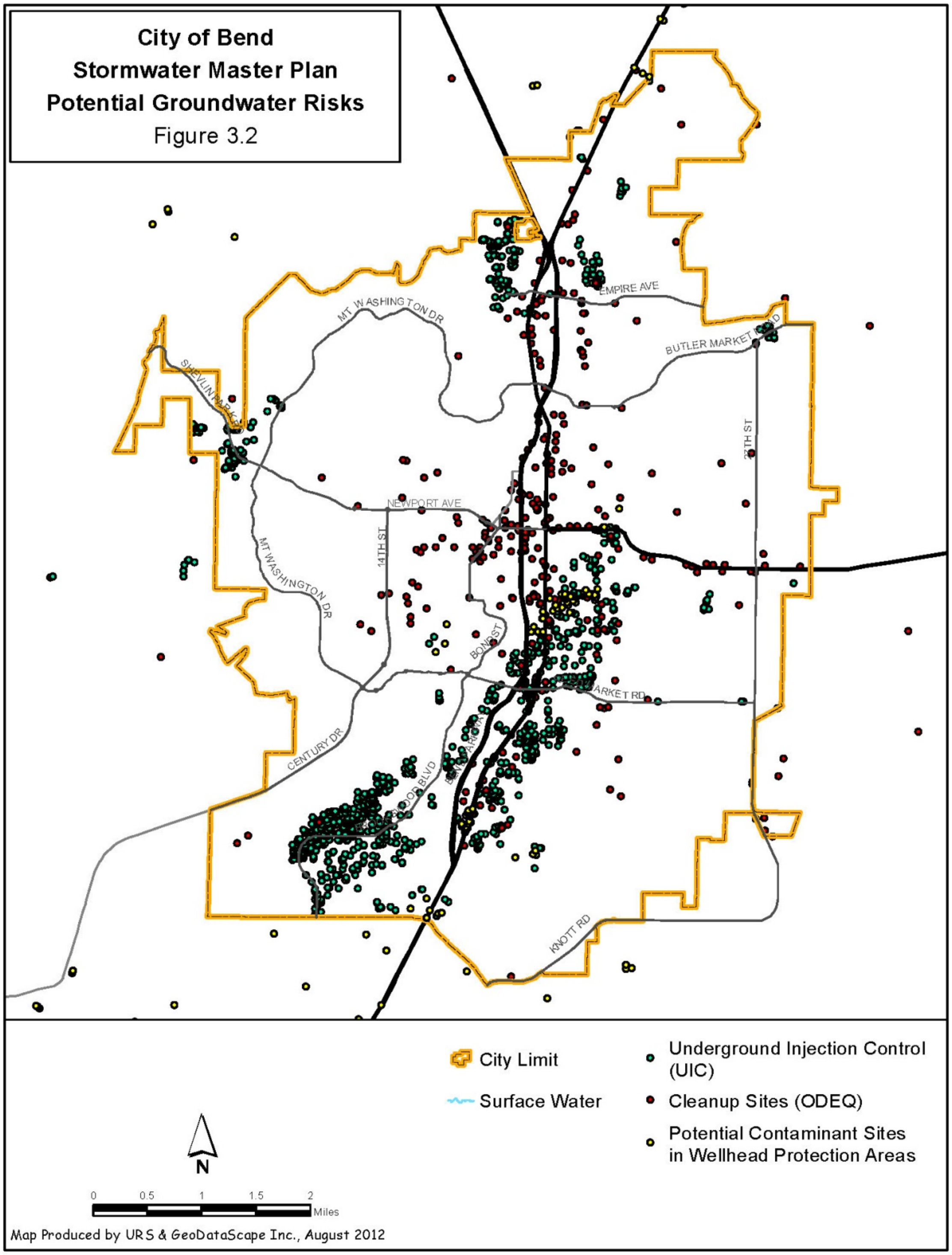
To protect human health and the environment, ODEQ investigates sites that are contaminated with hazardous materials. ODEQ assists and enforces the prompt cleanup of sites, while trying to control expenses. ODEQ's goal is to issue No-Further-Action (NFA) designations swiftly and cost effectively. Dry wells need careful review prior to being installed close to areas designated by the ODEQ as cleanup sites to avoid risks of expanding the contaminated area or interfering with cleanup of the sites. The buffer zones around the cleanup sites are shown with a half-mile radius. The ODEQ may approve a smaller radius on a case-by-case basis. The City performed a Source Water Assessment in October 2013 which identified potential contamination sources associated with land use and assessed their threat to the City's drinking water wells (GSI, 2013)

3.3.3 Discharge Monitoring

Under the state's UIC program rules, Bend is required to conduct a representative monitoring program to determine the concentrations of certain pollutants it discharges underground. The City began monitoring some of its stormwater discharges as early as 2004. See Chapter 6 for more information about monitoring.

3.4 CENTRAL OREGON STORMWATER MANUAL

Recognizing that unique stormwater issues affect Central Oregon, the communities of Bend, Madras, Redmond, Prineville, Sisters, and Crook and Deschutes County, joined forces with the Central Oregon Intergovernmental Council to develop the Central Oregon Stormwater Manual (Otak, 2007, 2010). This manual was published in 2007 and updated in 2010, following completion of the hydrologic and hydraulic analysis for this master plan. The stormwater drainage manual provides guidance on good engineering practices for conditions specific to Central Oregon. The Association of Clean Water Agencies and the Central Oregon Investment Board assisted with the development of this award-winning guidance document.


City of Bend
Stormwater Master Plan
Potential Groundwater Risks
Figure 3.2
EMPIRE AVE
MT WASHINGTON DR
BUTLER MARKET ROAD
SHEVLIN PARK RD
27TH ST
NEWPORT AVE
14TH ST
MT WASHINGTON DR
BOND ST
MARKET RD
CENTURY DR
KNOTT RD
City Limit
Surface Water
Underground Injection Control (UIC)
Cleanup Sites (ODEQ)
Potential Contaminant Sites in Wellhead Protection Areas
N
0 0.5 1 1.5 2 Miles
Map Produced by URS & GeoDataScape Inc., August 2012

The COSM is designed to standardize stormwater design processes appropriate for Central Oregon, and addresses stormwater runoff quality and quantity to protect surface and groundwater resources. Guidance and design criteria for stormwater conveyance and water quality treatment specific to the climate and geology of Central Oregon are provided. Conditions characteristic of Central Oregon include volcanic rock, reliance on groundwater for drinking water, relatively dry climate, potential for short intense storms, snow and ice in winter months, and rapid population growth. Minimum criteria are provided for stormwater drainage design for new development, re-development, and roadway projects. The City has recently reviewed its development standards to determine how best to incorporate the COSM into Bend codes and policies for design and construction of stormwater infrastructure. Recently adopted Bend Code Title 16 (January 2012) and City standards and specifications (July 2011) incorporate COSM (2010) standards and requirements for stormwater policies and design. COSM (2007) criteria were used in the hydrologic and hydraulic calculations, and water quality recommendations for this SMP.

3.5 INTEGRATED STORMWATER MANAGEMENT PLAN

The ISWMP outlines a comprehensive program to protect the quality of the Deschutes River and the City's groundwater. The ISWMP identifies a number of BMPs for preventing pollutants from entering stormwater or removing them before the water is discharged to the river or underground.

The following BMPs are required elements of the Phase II (surface water) program:

- Public Education and Outreach
- Public Involvement and Participation
- Illicit Discharge Detection and Elimination
- Construction Site Stormwater Management Activities
- Post-Construction Stormwater Management in New Development and Redeveloped Areas
- Pollution Prevention/Good Housekeeping for Municipal Operations

Bend's ISWMP also addresses monitoring and protecting drinking water sources provisions to meet UIC requirements.

REFERENCES

City of Bend, 2004. Integrated Stormwater Management Plan for the City of Bend, Oregon, 2004. March 10, 2004; revised November 2006

City of Bend. 2011. City of Bend website Stormwater Annual Report page. http://www.ci.bend.or.usdepts/public works/stormwater/docs/City of Bend WQ 6 30 FINAL.pdf

City of Bend, 2012. Integrated Stormwater Management Plan 2012 revised draft December 2012.

City of Bend. 2012. Bend Code Title 16, Grading, Excavation, and Stormwater Management. Adopted January 4, 2012.

GSI Water Solutions, 2013. *City of Bend Groundwater Production Wells Source Water Assessment Update*, October 2013.

Optimatics, 2011. *Water System Master Plan Update Optimization Study*, February, 2011.

Otak, 2010. COSM (Central Oregon Stormwater Manual), 2007. May 2007. Updated August 2010.

Portland State University, Population Research Center, 2008. http://www.edcoinfo.com/COFacts/population/ Accessed July 20, 2008, and May 15, 2012.

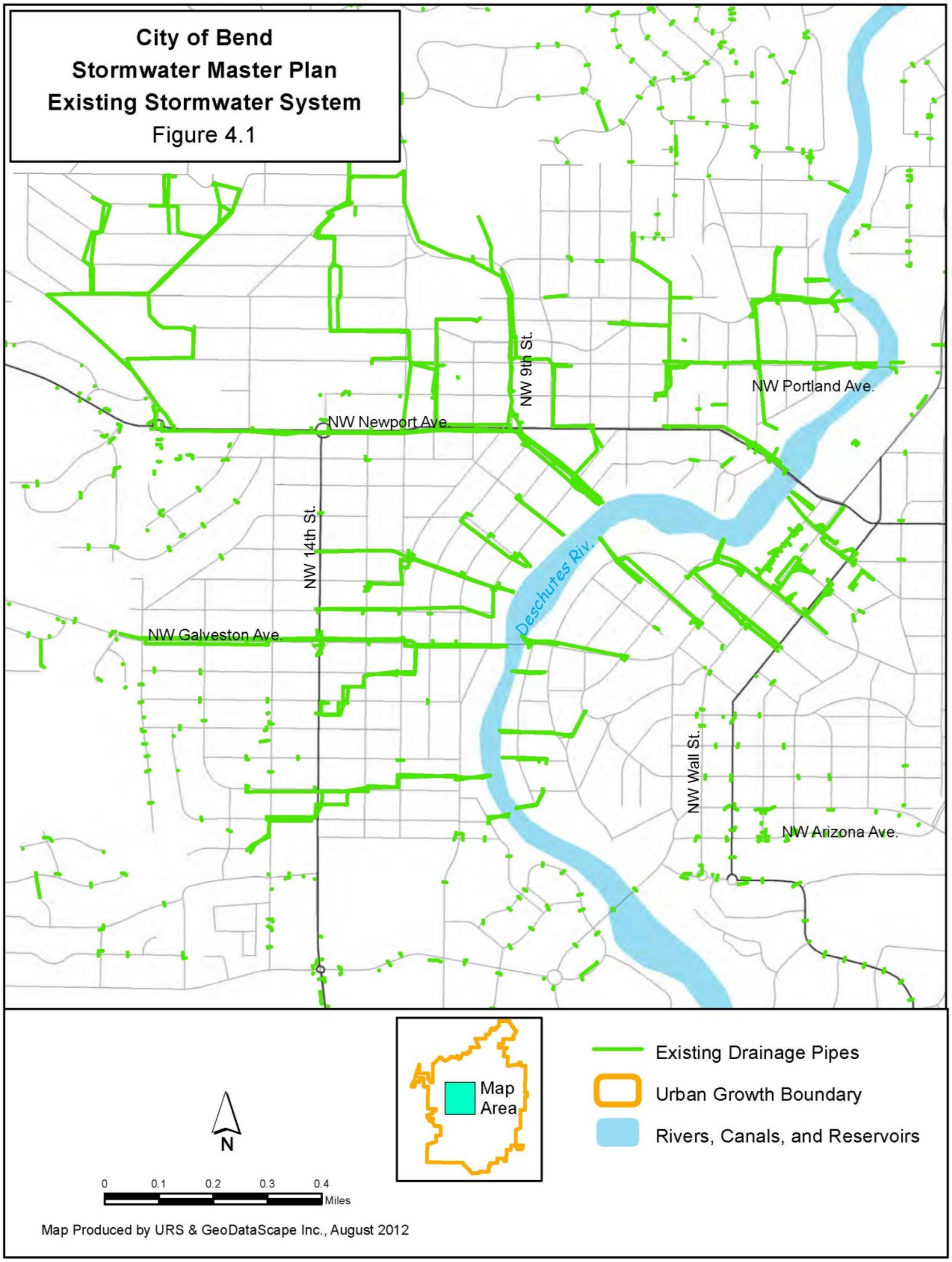
4.0 EXISTING DRAINAGE SYSTEM

For many years, the City of Bend's drainage system has depended primarily on underground injection (dry wells) to discharge stormwater into the fractured volcanic rock that underlies much of the City. One big advantage of dry wells and other types of dispersed infiltration is that they help maintain groundwater recharge patterns. Another advantage is that disposing of stormwater at many dispersed locations avoids the problems associated with managing high-volume discharges such as those from piped systems that serve large areas. When the City was not as densely developed, the percentage of impervious area was much lower and dry wells and drill holes worked reasonably well.

Bend does not have a city-wide piped storm drain system; the lack of defined drainage ways, the expense of digging in rock, and the difficult topography have limited the installation of piping. Areas nearest the river drain through about 14 miles of pipe to one of 28 outfalls to the Deschutes River (Figure 4.1). The existing piped system should be studied to determine if it is undersized hydraulically and much of it is near end-of-life or has exceeded its life expectancy.

Undisturbed soils in Bend are able to absorb large amounts of rainfall with little or no runoff even during intense storm events. For this reason, current standards for new development require all storm drainage to remain on site, and require catch basins and dry wells to be installed below grade to dispose of stormwater. (City of Bend General Plan-Public Facilities and Services Policy No. 12, Stormwater and City Development Code 10-10). This code requirement has resulted in the installation of dry wells throughout the City.

Dry wells do not work well in areas underlain by layers of impermeable material unless those layers are penetrated. Drill holes are an alternative to dry wells, intended to penetrate impermeable layers to reach more permeable material beneath them. The City has historically installed drill holes in areas where dry wells are not appropriate. The City is responsible for about 4,600 dry wells and 1,000 drill holes in public rights-of-way and on public property. Public UICs are reviewed by the City of Bend; however, they are also required to meet federal and state regulations. A large but unknown number of dry wells and drill holes are owned privately. Private UICs are installed to meet City drainage requirements. The City requires privately-owned UICs to meet its installation and drainage requirements, but their water quality is regulated by the ODEQ. Bend requires new UICs to be registered with ODEQ. The City's recently adopted


City of Bend
Stormwater Master Plan
Existing Stormwater System
Figure 4.1
NW 9th St.
NW Portland Ave.
NW Newport Ave.
NW 14th St.
Deschutes Riv.
NW Galveston Ave.
NW Wall St.
NW Arizona Ave.
Map
Area
Existing Drainage Pipes
Urban Growth Boundary
Rivers, Canals, and Reservoirs
N
0
0.1
0.2
0.3
0.4
Miles
Map Produced by URS & GeoDataScape Inc., August 2012

stormwater ordinance (Bend Code Title 16) states that water quality treatment of private stormwater prior to discharge to UICs or downstream pipe may be required.

Bend experiences a variety of weather conditions that can cause drainage problems, including short and intense storms, long periods of subfreezing temperatures, heavy snows, snow with freezing temperatures followed by rain, and rain on snow. Non-piped drainage systems are particularly vulnerable to failure during these kinds of weather conditions, and these failures occur when the need for adequate drainage is greatest.

The use of cinders on roads in winter causes a major maintenance problem for the City's stormwater division, as the cinders fill and reduce the performance and life expectancy of dry wells, drill holes, pretreatment filters, and infiltration ponds. With the fees generated by the new stormwater service charge that went into effect on July 1, 2007, the City has stepped up its maintenance efforts, and has worked to refine its design standards to help overcome the problems associated with cinders.

Maintenance of the City-owned or operated storm drainage facilities is the responsibility of the Public Works Department Stormwater Division. Drainage and maintenance for the three highways that run through the City—97 Parkway, 97 Business from the north to Highway 20, and Highway 20 east—are the responsibility of the Oregon Department of Transportation (ODOT).

4.1 CANALS

Effective coordination with the irrigation districts will be important for efficiently addressing stormwater drainage in areas near canals. As mentioned in Chapter 2, several irrigation canals and laterals running through the City affect the City's drainage patterns. Concerned about the potential for contaminating the irrigation water with possible pollutants in the stormwater, and the possibility that if they accept stormwater they may be required to apply for NPDES permits, the irrigation districts have not allowed the canals to accept stormwater runoff. In part because of these concerns and concerns about cost and liability associated with obtaining and operating under an NPDES permit, some of the irrigation districts have built berms along portions of their canals to prevent natural stormwater drainage from entering the canals. In several areas, open canals have been replaced with low-pressure pipe placed near the top of the previously used trench and some canals have been lined with concrete. Berms are still present to keep storm drainage out of the canals and from crossing the canal rights-of-way.

The disturbance of natural drainage patterns caused by the canals and laterals presents some major stormwater management challenges. For example, in one section of the Central Oregon Canal that flows north past Pilot Butte, the canal has been piped and backfilled. The backfilling of the canal has removed a barrier to stormwater runoff from Pilot Butte, and subdivisions downgradient from the canal then experienced new stormwater runoff and associated flooding. Coordination with irrigation districts is recommended to minimize unintended consequences.

4.2 DRAINAGE PROBLEMS

Bend's drainage problems are increasing due to its rapid growth, lack of funding for construction and maintenance of infrastructure and challenging landscape. The City established a database to track complaints about drainage, and as of April 2011, there were 121 documented complaints (CH2M Hill, 2011).

Rainfall often comes in short, intense bursts, causing considerable localized flooding throughout town. Many catch basins and dry wells do not have sufficient capacity to handle runoff from these storm events, and flooding can thus be expected to occur every year or two.

Drainage problems can adversely affect real estate transactions. With Oregon's Real Estate Disclosure requirements and the common practice of banks and buyers requiring Environmental Site Assessments as routine elements of commercial real estate transactions, the City's Stormwater Division is receiving an increasing number of telephone inquiries regarding stormwater drainage and flooding.

4.2.1 Primary Issues

The conditions that contribute to drainage problems include:

- Under-design of infiltration systems and installation of infiltration systems in areas not suitable for infiltration. (See Chapter 2 for a discussion of soils.)
- Historical lack of sufficient criteria for new development and redevelopment for design and testing to ensure adequate drainage and disposal.

- Lack of other drainage alternatives when infiltration is not feasible.
- Construction in areas of high groundwater causing flooded crawl spaces and basements.
- Uneven terrain creating ridges and valleys that are barriers to flow.
- Inadequate maintenance resources reducing the effectiveness of dry wells and drill holes.
- Plugging of infiltration facilities with road traction cinders.
- Incorrect construction resulting in drainage bypassing catch basins with inlets that are too high.
- Intense rainfall, snow melt and rain-on-snow events that generate large rates and volumes of water that exceed the capacity of catch basins, dry wells and pipes.
- Drain inlets plugged with ice and plowed snow.
- Areas added to the City that had no drainage facilities when they were annexed.
- Canals, laterals and canal piping that modify drainage patterns.
- Stormwater facilities that do not meet state and federal water quality requirements.

4.2.2 Identification of Sites with High-Priority Drainage Problems

Recognizing that stormwater flooding problems and water quality concerns were increasing in significance and needed to be addressed, the City embarked on the development of a Stormwater Master Plan and the creation of a stormwater utility dedicated to capital improvement projects and maintenance activities for the stormwater system and funded by a stormwater service charge. The utility will also cover monitoring and implementation of BMPs needed for water quality and to comply with the permits.

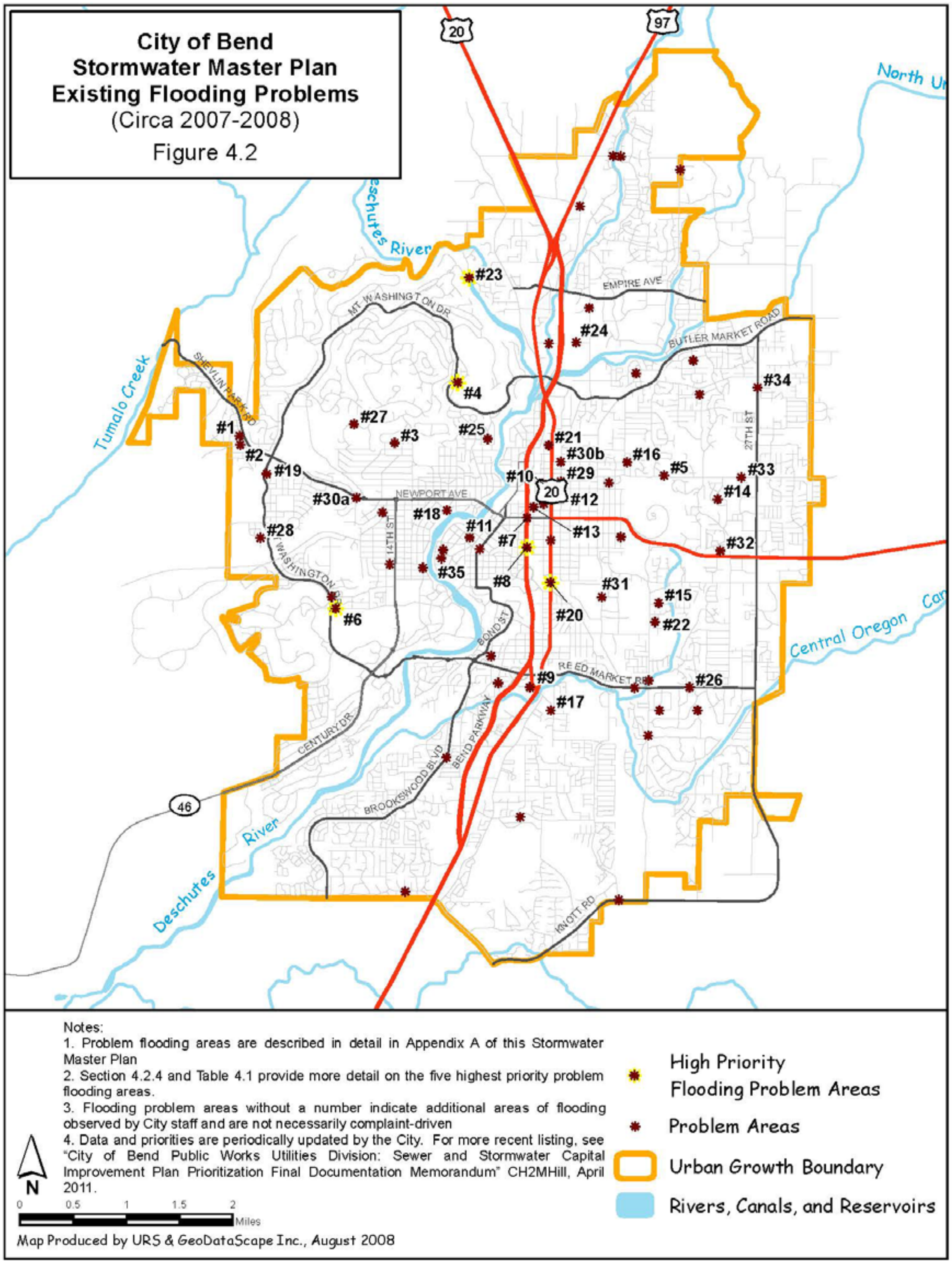
As part of the preparation of this Stormwater Master Plan, before establishment of the database mentioned in the introduction to section 4.2 above, a list was made of 35 areas experiencing chronic drainage problems. These areas are identified in Figure 4.2 and listed in Appendix A. The flooding problems are fairly evenly distributed around the City and are based on complaints.

City staff and the URS team met in a workshop setting to identify and discuss the problem flooding areas and to prioritize the list to determine the five highest-priority problem flooding areas to be further analyzed. Some problems were removed from further discussion because they were already being addressed by the City.

4.2.3 Criteria for Selecting Highest-Priority Problem Flooding Areas for Further Analysis

Criteria for prioritization of the highest priority problem flooding areas experiencing chronic flooding, included consideration of the following:

- Concerns about safety, health, and fire
- Regulatory compliance
- Magnitude of impact
- Costs for repair
- History of flooding – length of problem
- Whether a solution is apparent
- Property damage (actual and perceived)
- Access
- Effects on water quality
- Number of complaints
- Severity of flooding
- Whether flooding is private or public
- Equity – conceptual solutions need to be established for areas around the City, not focused in one area


City of Bend
Stormwater Master Plan
Existing Flooding Problems
(Circa 2007-2008)
Figure 4.2
Deschutes River
Tumalo Creek
North Unit
Central Oregon Canal
EMPIRE AVE
BUTLER MARKET ROAD
MT WASHINGTON DR
SHEVLIN PARK RD
NEWPORT AVE
27TH ST
14TH ST
BOND ST
REED MARKET RD
CENTURY DR
BROOKSWOOD BLVD
BEND PARKWAY
KNOTT RD
20
97
46
#1
#2
#3
#4
#5
#6
#7
#8
#9
#10
#11
#12
#13
#14
#15
#16
#17
#18
#19
#20
#21
#22
#23
#24
#25
#26
#27
#28
#29
#30a
#30b
#31
#32
#33
#34
#35
Notes:
1. Problem flooding areas are described in detail in Appendix A of this Stormwater Master Plan
2. Section 4.2.4 and Table 4.1 provide more detail on the five highest priority problem flooding areas.
3. Flooding problem areas without a number indicate additional areas of flooding observed by City staff and are not necessarily complaint-driven
4. Data and priorities are periodically updated by the City. For more recent listing, see "City of Bend Public Works Utilities Division: Sewer and Stormwater Capital Improvement Plan Prioritization Final Documentation Memorandum" CH2MHill, April 2011.
High Priority Flooding Problem Areas
Problem Areas
Urban Growth Boundary
Rivers, Canals, and Reservoirs
N
0 0.5 1 1.5 2 Miles
Map Produced by URS & GeoDataScape Inc., August 2008

The City chose three of the criteria from the above list to establish priorities: Safety/ health/fire, Property damage, and Magnitude of impact.

The Fire and Life criteria have to do with ensuring that the standards for protecting the public are met, including not only access for emergency vehicles, but also timely response of emergency vehicles. Safety involves the protection of drinking water, and includes decommissioning or treating dry wells in DWPAs.

Property damage includes damage by flooding structures and can also include heavy erosion of yards and landscaping.

Magnitude of impact considers the number of people affected by the problem and the amount of public benefit gained by the solution.

4.2.4 Refining the List of Highest-Priority Problem Flooding Areas

Ten sites were selected for field survey. These sites are listed in Appendix A. To further refine the list to the five highest-priority sites, a URS engineer and a hydrogeologist from GeoEngineers visited the sites to determine drainage areas, identify flows generated for a 2-year and 25-year storm event, identify potential solutions, and determine whether infiltration is a workable solution based on the underlying soils. The five sites listed below, not necessarily in order of priority, were identified as the areas most urgently needing resolution. Table 4.1 summarizes the priority of these sites according to the selection criteria. The sites were rated as high, medium or low for each criterion.

Table 4.1
Summary of Prioritization for Five Highest Priority Problem Flooding Areas

Criteria	**Problem Flooding Area**[1]				
	#6	**#20**	**#8**	**#3**	**#4**
Fire/life/safety	H	H	H	H	L
Property damage	H	L	L	M	H
Magnitude of impact	H	H	H	M	H

H = High Priority
M = Medium Priority
L = Low Priority
NOTE:
[1]Numbers coincide with numbering of existing flooding problem areas identified in Appendix A and shown in Figure 4.2

#6 Bend Westside Fire Station – Simpson and Century

Developments both north and south of Simpson and east of Century include large impervious surfaces in this commercial area. The area sits over shallow pink tuff where infiltration capacity is very low. Flooding is common in the area. The location of the catch basins away from the curb allows water to bypass the basins and their associated dry wells. A cascading effect occurs as runoff from Safeway crosses Simpson Avenue, combines with runoff from Ray's Foods and the shopping center, and inundates the fire station with 12 to 18 inches of water. The runoff continues past a storage facility and then discharges down an embankment, flooding Nosler's manufacturing plant.

#20 Franklin Avenue Underpass

An excavated low area exists where Franklin Avenue passes under the Bend Parkway (Highway 97) and the Burlington Northern Santa Fe (BNSF) railroad tracks. This underpass is closed to traffic due to flooding twice a year on average. It receives drainage from a large area that is almost entirely impervious. Dry wells and drill holes are unable to keep up with the rate and volume of stormwater runoff even during small storm events. Flooding of this underpass creates a barrier and safety hazard for vehicles traveling east and west on this busy street. This is a serious concern, because emergency vehicles need to be rerouted.

#8 Third Street Underpass

Similar to the Franklin Avenue underpass, the Third Street underpass is in an excavated low area where the roadway was constructed under the at-grade railroad, and drains about 55 acres. The underpass floods to the point of blocking traffic an average of two or three times a year. This is one of the busiest streets for motorists moving north and south through the City. Detours over crowded streets are time consuming and pose a safety hazard to residents who live along the detour routes. Public safety is also an issue, because drivers sometimes attempt to drive through the flooded area and become stranded, and emergency vehicles are sometimes rerouted and delayed. Several of the dry wells and drill holes at this underpass are in one or more of the City's DWPAs. As is the case with the other underpasses, this one is vulnerable to spills from the railroad, as well as from trucks and other vehicles especially with the lane changes and the deep drill holes. The drainage solution to this problem may be combined with solutions to similar flooding problems at the Franklin Avenue and Greenwood Avenue underpasses.

A project to address this priority problem flooding area is currently undergoing final construction with the majority of work completed in 2013. The project includes pumping the runoff to infiltration ponds at the Colorado Avenue/Bend Parkway cloverleaf, owned by ODOT. Greenwood Underpass, another problem area, was not analyzed as part of this project, but its stormwater may be incorporated into the solution for the Third Street underpass and the stormwater pumped to the same Colorado Avenue/Bend Parkway cloverleaf.

#42 Archie Briggs Road, West of the Deschutes River

Archie Briggs Road includes a steep section of roadway that collects runoff from a large area and lacks adequate drainage structures. During heavy rains, stormwater blocks one of the lanes of traffic, leaves the uncurbed roadway, and discharges onto residential property and then into the Deschutes River. Some improvements were made as part of a sewer pump station upgrade completed, and some maintenance work has provided temporary help.

#4 Fairview Heights on Awbrey Butte

Stormwater from both public and private areas combines to create this problem. A large part of Awbrey Butte drains to too few or poorly constructed dry wells and through undersized ditches and culverts. At its lower end, the drainage flows through a residential area, flooding garages, driveways, and sometimes homes before it discharges to the golf course below. Easements throughout the drainage way do not all line up, so water short-circuits some of the structures, causing much of the damage. It is noted that high liability is associated with this drainage problem.

These five sites were analyzed and evaluated to develop alternatives and conceptual solutions. Fact sheets were developed for each alternative (see Appendix B). Alternatives include piping, pumping, onsite storage, offsite storage, and increased sizing or rearrangement of existing facilities. Each solution includes a water quality component. These last two described sites should be considered closed as part of the proposed butte/hillside specific plan proposed.

Priorities may change over time for several reasons including regulatory mandates, funding availability, opportunities to coordinate with other utility projects and development patterns. The City built on the results of the flooding problem area analysis described above and additional projects identified on the City's complaint database. These projects were prioritized using a city utility standard Multi-attribute Utility Prioritization Analysis and Capital Model (CH2M Hill, 2011).

REFERENCES

CH2M Hill, 2011. "City of Bend Public Works Utility Division: Sewer and Stormwater Capitol Improvement Plan Prioritization Final Documentation Memorandum", April, 2011.

City of Bend, 1998. City of Bend General Plan. Public Facilities and Services Policies, Stormwater-Number 12.

City of Bend, 2006. City Development Code 10-10, Section 2.1.300 Subsection F.8 and Section 2.3.600 Subsection 7.

City of Bend, 2012. Code Title 16, Grading, Excavation, and Stormwater Management, adopted January 4, 2012

5.0 HYDROLOGIC AND HYDRAULIC ANALYSIS

A hydrologic and hydraulic analysis of the City of Bend was undertaken to define drainage basins in order to develop recommendations for addressing stormwater drainage options. This chapter describes the analyses performed to define the drainage basins and to determine stormwater peak runoff flows and volumes. Peak flows and volumes can be used to determine the size of storm drainage and treatment facilities, such as pipeline diameters and the capacity needed for regional detention and infiltration facilities. Results of this analysis are described in Appendix E.

While the City does not currently require it, detention can reduce peak flows downstream and thereby save costs by allowing the use of smaller pipes, pumps and treatment devices, and also by reducing maintenance. Some detention designs also allow stormwater to infiltrate, which helps maintain aquifer recharge and reduce the volume of stormwater for disposal. Smaller pipe sizes are less expensive, easier to maintain, require smaller machinery for installation, and can be installed on steeper slopes. A single large regional detention facility is much easier to maintain than many smaller detention systems.

The drainage basin analysis involved establishing major basins (MB) by grouping subbasins based on direction of flow and topography. The direction of flow and locations of discharge points were used to initially identify major basins. After these major basins were mapped, the low point of each major basin was identified. The discharge flow rate and volume for each of the major basins are shown in Tables C.1 and C.2 of Appendix C for existing and future land uses. See Appendix E for further information.

5.1 DRAINAGE BASINS

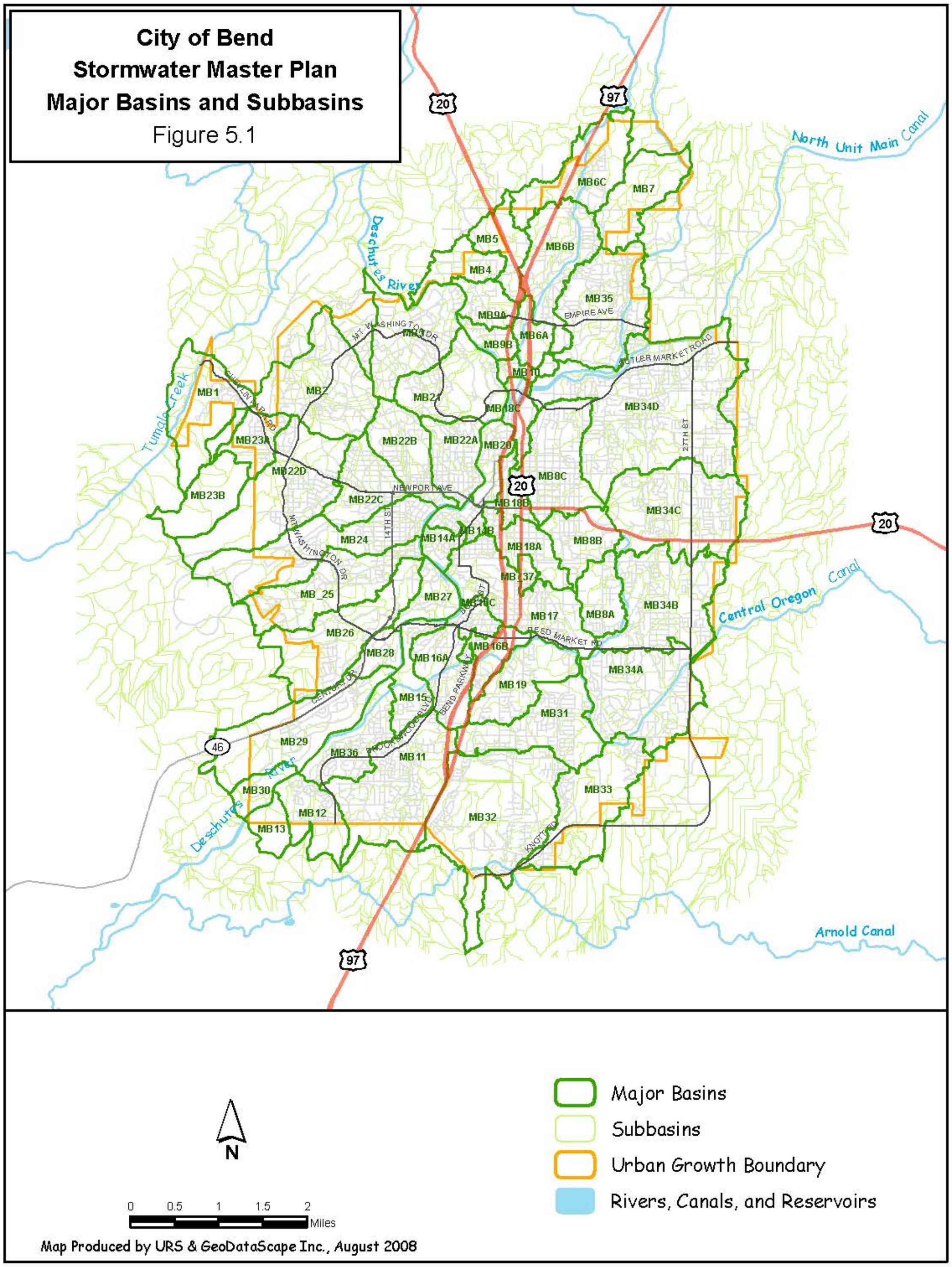
The drainage basins were defined for the first time as part of the work performed for this SMP. This task was difficult because of the complicated and variable topography and geology; the disruption of natural drainage due to the canals and their laterals; the lack of a city-wide piped drainage infrastructure; and the use of underground injection. Numerous canals and laterals convey water from the Deschutes River through open and piped systems within the City and to agricultural areas throughout Central Oregon.

From the 10-foot contours on U.S. Geological Survey (USGS) maps it was determined that the topographic features generally run in a northward and easterly direction. Initial basins identified using USGS maps with 10-foot contours resulted in basins of several hundred acres in size. Because the City wanted to find localized solutions to its drainage problems, it needed to define smaller basins that would indicate how local areas drain.

ArcGIS (Hydrology Modeling, ESRI) was used to identify low-lying areas and the direction of flow based on topography. This Geographic Information System (GIS) model allows the development of flow lines and provides information on flow direction. The City's 2-foot contour GIS was used to refine the analysis of the drainage basins. A Digital Elevation Model (DEM) derived from 2-foot contours divided the ground surface into cells (units of approximately 40 acres in area). The difference in elevation between adjacent cells was used to determine slope direction and the direction of surface water flow. GIS was used to compute how many cells contribute flow to a given cell until a specified threshold number of cells was reached. Cells contribute flow until a subbasin fills to the specified threshold, then water flows into the next downstream group of cells to define the next subbasin. This continues until a river or creek is reached, or the cells are outside of the City's boundary. Infiltration, or the use of dry wells, was not included in this part of the analysis. The use of UICs is discussed in Chapters 3 and 9.

The first iteration of this model was performed using a threshold of 50,000 cells to define a subbasin. This threshold resulted in basins of several hundred acres, similar to the USGS analysis, and larger than desired for this project. Because of the complex landscape, the difficulty in determining drainage patterns, and the strong interest in using LID techniques to address water quality concerns locally, it was necessary to identify subbasins on a smaller scale. A second iteration using a threshold of 25,000 cells to define a subbasin resulted in subbasin sizes that range from a fraction of an acre up to 170 acres. About 80 percent of the subbasins were smaller than 40 acres, a suitable size both for identifying local solutions and for groundtruthing model results.

To accurately develop overland flow directions, one of the first steps in the modeling process was to fill all sinks to eliminate trapped flow. The model's primary disadvantage is its inability to define a "sink," or a low area that has no natural outlet. For example, Shevlin Ridge and Westside Meadows Developments (MB 23A and 23B, Figure 5.1) are in a bowl with no natural outlet. The model shows this area draining out and illustrates why groundtruthing is necessary. These developments are examples of areas in Bend that do not drain anywhere.


City of Bend
Stormwater Master Plan
Major Basins and Subbasins
Figure 5.1
North Unit Main Canal
Deschutes River
Tumalo Creek
Central Oregon Canal
Arnold Canal
20
97
46
MB1
MB2
MB4
MB5
MB6A
MB6B
MB6C
MB7
MB8A
MB8B
MB8C
MB9A
MB9B
MB10
MB11
MB12
MB13
MB14A
MB15
MB16A
MB16B
MB17
MB18A
MB18B
MB18C
MB19
MB20
MB21
MB22A
MB22B
MB22C
MB22D
MB23A
MB23B
MB24
MB_25
MB26
MB27
MB28
MB29
MB30
MB31
MB32
MB33
MB34A
MB34B
MB34C
MB34D
MB35
MB36
NEWPORT AVE
EMPIRE AVE
BUTLER MARKET ROAD
27TH ST
14TH ST
REED MARKET RD
BEND PARKWAY
KNOTT RD
N
0 0.5 1 1.5 2 Miles
Major Basins
Subbasins
Urban Growth Boundary
Rivers, Canals, and Reservoirs
Map Produced by URS & GeoDataScape Inc., August 2008

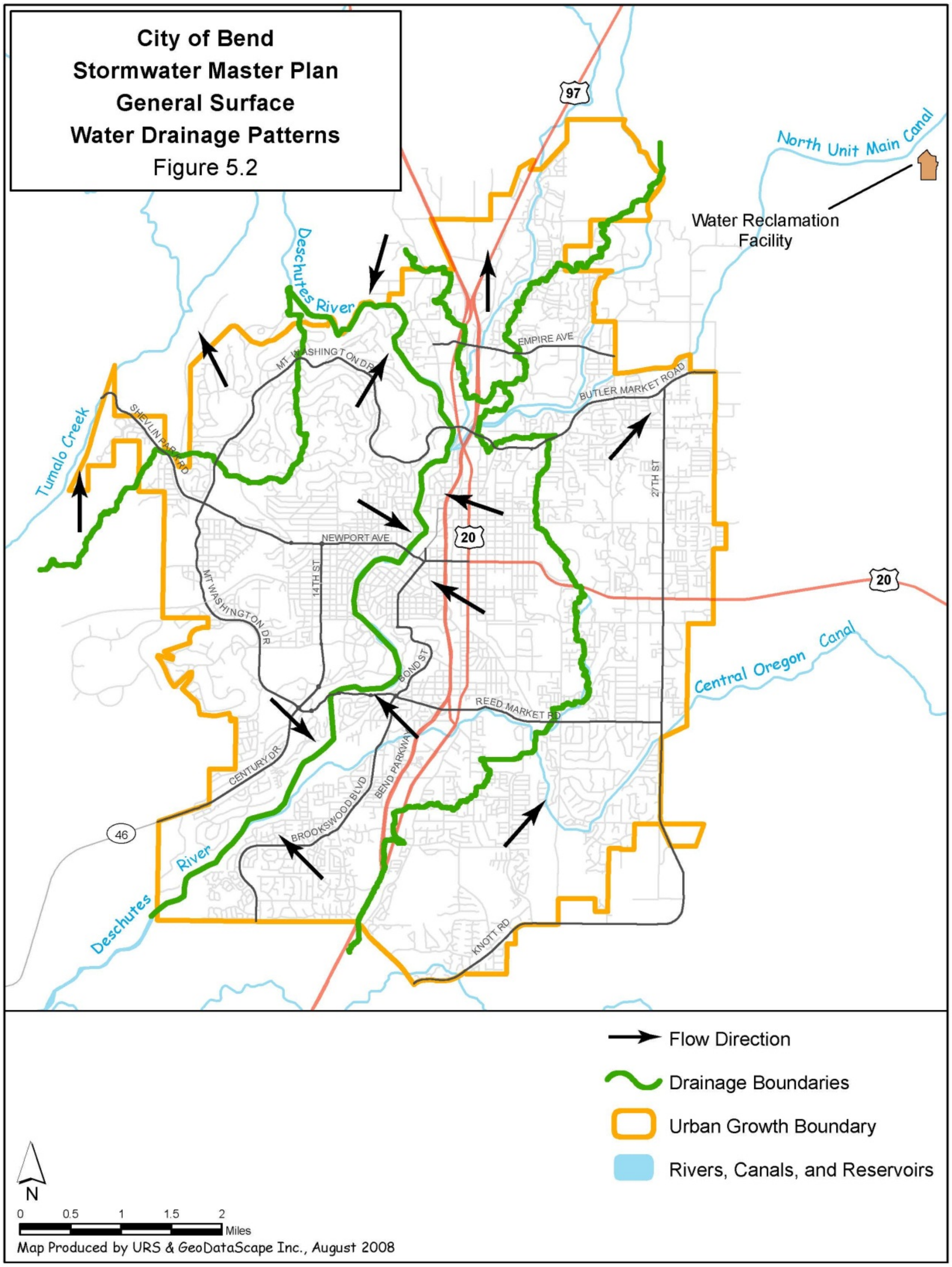
Roadways, railroads, and the irrigation canals all are barriers that mislead the model. Groundtruthing was required to adjust some of the watershed boundaries to reflect existing topographic conditions. Resulting major basins and subbasins are shown in Figure 5.1.

Major basins were created by following the flow lines of the smaller drainage basins. Figure 5.2 provides a graphical view of general drainage patterns. In general, basins adjacent to and on both sides of the Deschutes River flow naturally to the river. Areas farther east of the river but west of Pilot Butte tend to flow northward while areas east of Pilot Butte tend to flow north and east. The areas west of the river that do not flow toward the river tend to flow in a northwesterly direction toward Tumalo Creek. At an elevation of 4,214 feet (UTM NAD 27) Awbrey Butte is the highest point in the City and is a prominent topographical feature in Bend. Except for the southern and southeastern sides of the butte, which drain toward the river, drainage flows down the butte and joins the general drainage flowing north and east. Pilot Butte, a state park east of the Deschutes River, is at 4,138 feet almost as high as Awbrey Butte, but is smaller in circumference. Storm drainage runoff from Pilot Butte flows down the steep hillside and then follows the surrounding drainage flowing in a northeasterly direction.

More than 2,500 subbasins were identified for Bend and the surrounding areas to allow analysis of the drainage patterns. Nine hundred and fifty four of these subbasins are located within the current UGB. To assist in evaluating infrastructure alternatives and recommendations, including a City-wide piped system, the subbasins were grouped into 36 major basins, as shown in Figure 5.1. In general, each of the major basin numbers MB1 through MB36 are comprised of subbasins that flow in the same direction and either naturally flow to the Deschutes River or to points outside the UGB. Major basins that became very large were subdivided and designated by adding letters to the major basin designation, such as drainage basin MB34A through MB34D.

5.2 ANALYTICAL CRITERIA

When the preliminary engineering was done for the five highest-priority flooding problem areas, the COSM was still in draft form and the criteria for a design rainfall distribution required the use of an NRCS Type II storm for conveyance system design. A Type II storm is a high-intensity storm that produces a higher peak runoff rate than produced by a Type I storm. The design storm was changed to Type I when the COSM was finalized. The high priority flooding problem area evaluations and solutions are based on the previously required Type II storm and the Master Plan basin analysis is based on


City of Bend
Stormwater Master Plan
General Surface
Water Drainage Patterns
Figure 5.2
97
North Unit Main Canal
Water Reclamation Facility
Deschutes River
EMPIRE AVE
MT. WASHINGTON DR
BUTLER MARKET ROAD
Tumalo Creek
SHEVLIN PARK RD
27TH ST
NEWPORT AVE
20
14TH ST
MT WASHINGTON DR
BOND ST
Central Oregon Canal
REED MARKET RD
CENTURY DR
BROOKSWOOD BLVD
BEND PARKWAY
46
River
Deschutes
KNOTT RD
Flow Direction
Drainage Boundaries
Urban Growth Boundary
Rivers, Canals, and Reservoirs
N
0 0.5 1 1.5 2
Miles
Map Produced by URS & GeoDataScape Inc., August 2008

the Type I storm. The Master Plan major basins, subbasins, and watersheds cover all areas within the City, including the problem flooding areas discussed in Chapter 4.

Equations in the COSM were used to calculate the parameters used for the hydrologic calculations, as discussed in Section 5.3. The SBUH method was then used to calculate peak runoff flow rates and total volumes for four storm events: the 6-month water quality storm along with the 25- and 100-year storms. These storms were used to evaluate each of the subbasins as well as the major basins. The 10-year storm event was added for analysis of the major basins. These storm events are defined by the May 2007 version of the COSM and the City of Bend as follows:

water quality storm:	1.0 inch/24 hours
10-year storm:	2.1 inches/24 hours
25-year storm:	2.5 inches/24 hours
100-year storm:	3.1 inches/24 hours

The storms selected for evaluation address the major criteria and elements of storm drainage planning and design, including water quality, conveyance, detention, disposal, and life safety and property damage.

Water Quality: Per the COSM and the ODEQ water quality regulations for UICs, the stormwater from a water quality storm is required to be treated prior to being discharged underground.

Conveyance and Detention: Chapter 8 of the COSM requires the storm drainage system capacity to be designed for at least a 25-year storm, including pipe systems and regional detention.

Life Safety and Property Damage: The COSM requires providing safe passage for the 100-year storm event to protect the public from infrequent yet potentially dangerous flooding. The rate and volume of water resulting from this storm need not be included in the design of conveyance systems but must be provided safe passage to the point of discharge.

5.3 ANALYSIS OF PEAK RUNOFF FLOW RATES AND VOLUMES

Due to the City's inadequate storm drainage infrastructure, minimal available information on existing systems, and challenging topography and geotechnical conditions, a decision was made to perform hydrologic calculations using the SBUH to identify water quantity projects identified in Appendix E. As stated in the COSM, the SBUH is an approved method for identifying peak flow rates and volumes.

The SBUH method develops peak runoff flow rates and volumes for a specified storm defined by the depth, intensity, and duration of rainfall using the following information:

- Pervious and impervious areas
- Curve number (CN) based on the infiltration capacity of the soil
- Time of concentration (T_c), a measure of how rapidly the basin responds to storms to produce runoff

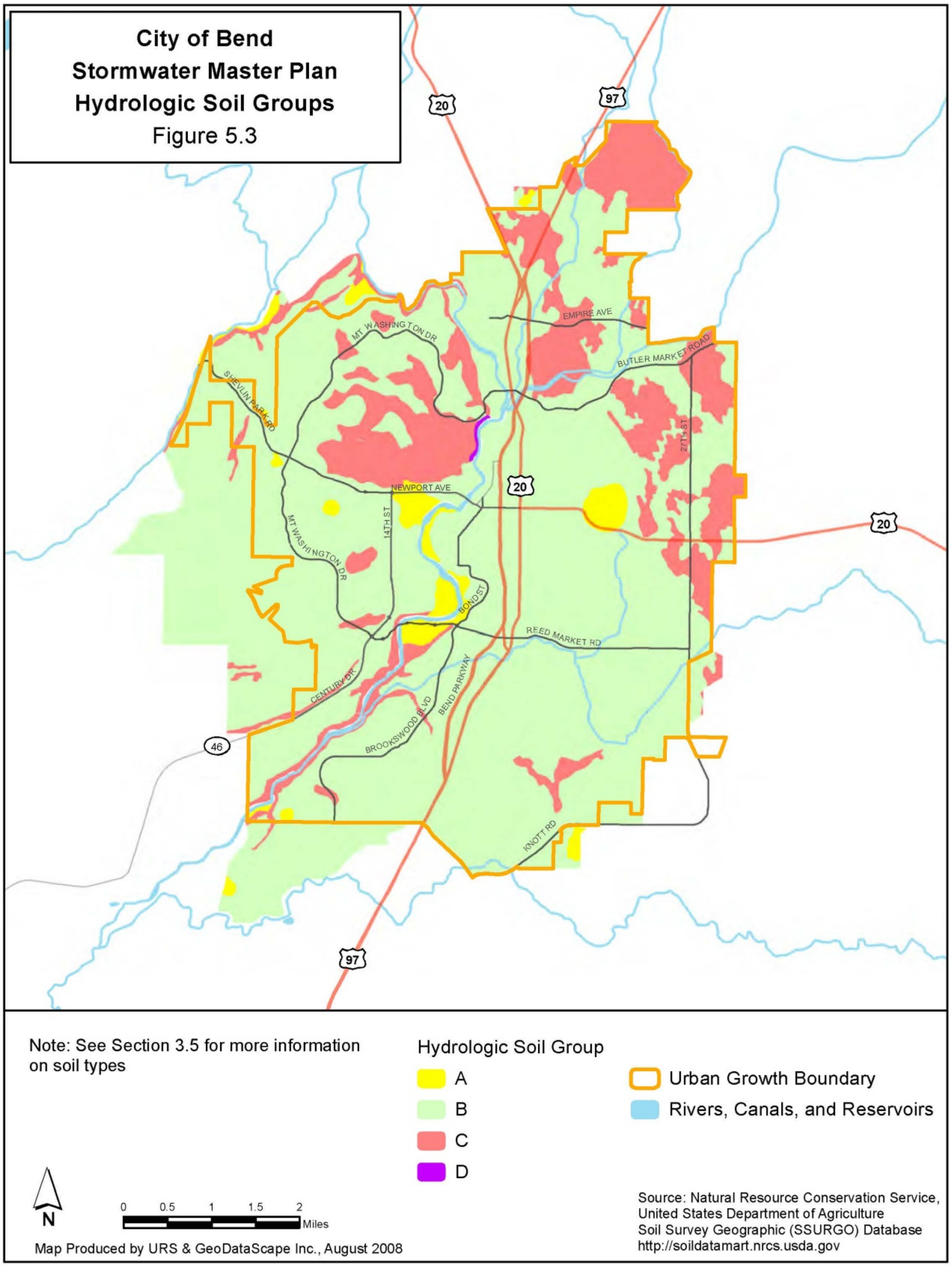
The CN is a runoff coefficient that is based on the infiltration rates of the various surfaces in the basin. Higher CN values indicate less infiltration and higher rates and volumes of runoff. Soils are categorized into four different hydrologic soil groups based on their drainage, from Type A which drains well to Type D which drains poorly. Hydrologic soil groups for the City of Bend are identified on Figure 5.3.

Table 5.1 in the COSM (2007) provides CN values for various ground covers. Impervious areas of Bend, such as pavement and roofs, were given a CN value of 98. CN values for other areas depend on the ground cover and hydrologic soil group of the underlying soils. These "pervious" areas were assumed to be in the category identified as "Pasture, Grassland, or Range Continuous Forage for Grazing" per the COSM. Fair condition values were used, described as ground cover of 50 to 75 percent. The CN values used in the calculations are as follows:

Soils Runoff Coefficient CN

Soil Type	A	B	C	D
CN[1]	49	69	79	84
Approximate range of infiltration rates[2]	1.4-14 inches/hour	0.14-1.4 inches/hour	0.014-0.14 inches/hour	0.0014-0.014 inches/hour

1. Source: Otak, 2007
2. Source: USDA technical manual, Chapter3c


City of Bend
Stormwater Master Plan
Hydrologic Soil Groups
Figure 5.3
20
97
EMPIRE AVE
MT WASHINGTON DR
BUTLER MARKET ROAD
SHEVLIN PARK RD
27TH ST
NEWPORT AVE
14TH ST
MT WASHINGTON DR
BOND ST
REED MARKET RD
CENTURY DR
BEND PARKWAY
BROOKSWOOD BLVD
46
KNOTT RD
Note: See Section 3.5 for more information on soil types
Hydrologic Soil Group
A
B
C
D
Urban Growth Boundary
Rivers, Canals, and Reservoirs
N
0 0.5 1 1.5 2
Miles
Map Produced by URS & GeoDataScape Inc., August 2008
Source: Natural Resource Conservation Service, United States Department of Agriculture
Soil Survey Geographic (SSURGO) Database
http://soildatamart.nrcs.usda.gov

The time of concentration, T_c, is the amount of time it takes the first runoff from the most distant point in the basin to arrive at the discharge point. For a given area, the longer the T_c , the lower the peak runoff rate. For highly developed basins that are mostly impervious, the T_c is short, producing high peak runoff rates. Other factors affecting runoff include the medium used for transporting flows, such as surface sheet flow, channel flow, or pipe flow. The roughness of each of these components affects the T_c, as the greater the friction, the longer it takes flows to reach their destination. Slope and the amount of stormwater detention distributed throughout the basin are major factors in determining T_c.

Sheet flow is calculated using the following equation (Equation 5-5, COSM, 2007, Page 5-9): $T_c = \frac{0.42(n_s L)^{0.8}}{(P_2)^{0.5}(S_o)^{0.4}}$

where:

T_c = travel time in minutes
n_s = Manning's effective roughness coefficient for sheet flow
L = flow length in feet
P_2 = 2-year, 24 hour rainfall in inches (a value of P_2 = 1.5 inches is used for this Master Plan)
S_o = slope of the land surface in feet/foot

Shallow concentrated flow is based on the following equations (Equations 5-6, 5-7, and 5-4, COSM, 2007, Page 5-9,10):

$$T_c = \frac{L}{60V}$$

$$V = k(S_o)^{5.0}$$

$$k = \frac{1.49R^{2/3}}{n}$$

where:

V = average velocity in feet/second
k = time of concentration velocity factor in feet/second

R = hydraulic radius
n = Manning's roughness coefficient for open channel flow, in this case, the same as n_s used above

The following assumptions were made:

- The first 300 feet of flow was sheet flow, with T_c calculated from COSM Equation 5-5.
- The remaining surface flow was shallow concentrated flow based on the velocity and open channel flow equations (COSM Equations 5-6, 5-7, and 5-4).
- The pipe flow was estimated to be 3 feet/second.

T_c was developed for both subbasins and major basins. Appendix C describes simplifying assumptions used in the development of T_c for subbasins.

Future conditions were evaluated using the City's zoning map and land use designations. Where existing land use had a larger percentage of impervious surface area than future zoning, the existing percentage was used. Impervious percentages for different land uses were obtained from Table 5.1, Page 5-6 of the COSM, and are as follows:

Commercial	85%
Industrial	72%
High-density residential	65%
Medium-density residential	38%
Low-density residential	25%
Open space and parks	15%

T_c calculations were made for existing and future land use. The City Community Development Department provided existing information on land use and impervious areas. Slopes were calculated from topographical maps provided by the City, and CN values were established for each subbasin as part of the hydrologic analysis. Future zoning data provided by the City did not include parks and open spaces. Runoff from these areas was conservatively accounted for as low-density residential land use.

5.4 SUMMARY

Each subbasin and major basin was evaluated to establish runoff volumes and peak flows using a Type I storm. The subbasin evaluation was based on a number of simplifying assumptions to establish T_c. These assumptions and results for the subbasins are presented and discussed in Appendix C. Tables C.1 and C.2 of Appendix C show the discharge flow rates and volumes for each of the major basins for existing and future land uses. Subbasins were evaluated to provide information for onsite facilities such as LID or shallow infiltration units. Major basins were analyzed to develop a City-wide piped storm drainage system. Appendix E provides details of a piped system, an approach currently abandoned due to the expense of constructing pipe in rocky terrain, together with the implications of recent UIC-related regulatory updates. Major basins were used to estimate pipe sizes and to evaluate regional detention/retention and treatment systems.

REFERENCES

Hydrology Modeling, ESRI, 2007. ArcHydro v1.2.

Otak, 2010. COSM (Central Oregon Stormwater Manual). May 2007. Updated August 2010.

6.0 WATER QUALITY

6.1 BACKGROUND AND REGULATIONS

Bend relies on groundwater for a significant portion of its drinking water. Water quality regulations affecting the City include the CWA and the SDWA. UICs, including dry wells and drill holes, are governed by SDWA rules. The City received a UIC Water Pollution Control Facility (WPCF) permit from the ODEQ for its estimated 4,600 dry wells and 1,000 drill holes in May 2013.

The City is required to monitor UICs to demonstrate that its stormwater does not contain significant quantities of pollutants of concern and has conducted studies to show that its groundwater is not susceptible to contamination. A monitoring plan has been developed and accepted by ODEQ as a requirement of the City's WPCF permit. In areas where pretreatment is required for UICs (i.e., new and replacement UICs), the City should consider the use of bioswales, phytofiltration (vegetative filter buffers), and constructed wetlands for stormwater treatment. The City is requiring all development projects—public or private—to consider non-UIC stormwater disposal such as engineered infiltration ponds and swales and other LID techniques.

6.2 EXISTING WATER QUALITY CONDITIONS

The City has done a limited amount of stormwater runoff monitoring mainly to develop a baseline of existing conditions and to gain knowledge that will help it design an appropriate UIC and river discharge monitoring program. Data from such a program will help the City identify the main pollutants of concern, provide information to help select and design BMPs to remove the pollutants of concern, and determine compliance with regulatory requirements.

6.2.1 Stormwater Runoff Monitoring

Runoff monitoring has been conducted at Pageant Park where stormwater pipes discharge to Mirror Pond, on Newport Avenue at the inlet to a stormwater treatment vault that was installed as part of the Veteran's Memorial Bridge project, and at the inlet and outlet of a treatment device located in Neff Avenue at Pilot Butte Middle School along with 5 to 10 UIC sites. All of these monitoring locations are located where high pollutant concentrations would be expected because of land use and traffic count. The

Neff Road treatment device is a proprietary device that was under evaluation by the City.

The City has also installed two tipping bucket rain gauges, one on Awbrey Butte at the water facility and one on the roof of the Public Works building on 15th Street. Data from these gauges, along with the AgriMet Gauge near the Old Mill District, are used to correlate sampling times with runoff curves, determine storm sizes and improve the spatial accuracy of rainfall data.

Water quality pollutants in Bend include typical urban stormwater pollutants such as sediment, nitrates, chlorides and oil and grease and heavy metals from motor vehicles. However, a statewide review of stormwater data, including data from Bend, indicated that only 10 of 45 analytes sampled exceeded one or more of the three screening levels of interest by the ODEQ UIC program (i.e. the Oregon Administrative Rules (OAR) Numerical Groundwater Reference Level, EPA Maximum Contaminant Levels (MCLs), and ODEQ Drywell Compliance Maximum Allowable Discharge Limit (MADL)) (Kennedy/Jenks, 2009). Only lead, Pentachlorophenol (PCP), and Bis(2-ethylhexyl)phthalate (DEHP) exceeded one or more of the screening levels in greater than 1% of samples analyzed. The data also showed a statistically significant relationship between stormwater pollutant levels and streets with greater than 1,000 average trips per day.

Bend stormwater monitoring conducted to date is not conclusive. Preliminary data suggested that particulate matter and three stormwater contaminants may be present at levels of concern (MaxDepth Aquatics, 2005). These are Barium and Nitrates among the inorganics and Bis(2-ethylhexyl)phthalate (DEHP) among the organics on the ODEQ's list of 19 inorganic and 27 organic potential stormwater contaminants. A later study specific to Central Oregon municipalities including Bend and Redmond (April 2011) found that only 4 of 38 analytes sampled had an exceedance of the regulatory screening levels for UICs (cadmium, chromium, lead, and nitrate-nitrogen). Lead exceeded in 7.7% of samples and the remainder exceeded around 1% of the samples (Kennedy/Jenks Consultants, 2011).

Particulate matter (sediment) is the primary stormwater pollutant of concern both for underground and river discharges. Particulate matter plugs underground injection systems and infiltration ponds, creating unsightly sediment deposits around the river outfalls. Some other contaminants attach themselves to particulate matter so particulate matter removal also removes some of these contaminants.

6.2.2 Phase II Permit Sampling

Although monitoring is not required by the Phase II NPDES program or permit, the City has worked cooperatively with the UDWC and ODEQ to monitor the Deschutes River and stormwater discharges to try and determine whether and how those discharges may affect the quality of the river and its beneficial uses. This information is helping the City target its stormwater quality management funds and efforts to obtain maximum benefits.

To gain an understanding of impacts of the City's stormwater discharges on river water quality, from 2004 to 2010 sampling was performed both upstream and downstream of the City's UGB along the Deschutes River and at its confluence with Tumalo Creek. In conjunction with the Upper Deschutes Watershed Council (UDWC), grab samples were taken at 16 locations along with continuous temperature monitoring, and 3 locations had continuous monitoring of several parameters using submersible sondes. The sondes record continuous measurements of basic parameters including pH, temperature, specific conductivity, turbidity, and dissolved oxygen. One sonde is upstream of all City stormwater outfalls and one is downstream of all City outfalls. A third, roving sonde is currently at the Drake Park Footbridge. Known as the City of Bend Ambient Water Quality Monitoring project, this study produced a report (City of Bend, 2010b) that provides baseline conditions for water quality in the Deschutes River and Tumalo Creek. This information will be useful to the City as they continue to monitor and conduct evaluations of the effectiveness of their stormwater program. The report resulted in agreement with ODEQ on some of the parameters on the 303d list and conflicting information on others.

Ongoing monitoring by the City includes collection and analysis of river and stormwater samples over an 8 month period of the year. The samples are collected and analyzed by the City of Bend Laboratory for temperature, pH, dissolved oxygen, conductivity, turbidity, total dissolved solids, total nitrogen, total phosphorus, nutrients, *escherichia coliform* and total coliforms (City of Bend, 2011):

River water quality is significantly affected by a hydroelectric impoundment, irrigation impoundments and withdrawals on the river. Large quantities of sediments are transported into Mirror Pond from upstream bank erosion.

6.2.3 Groundwater Quality Monitoring

The three major water purveyors providing drinking water to Bend residents are Avion Water District, Roats Water District, and the City of Bend. The City owns 23 municipal drinking water wells, and there are about 400 private water wells. The City currently relies mainly on surface water for its drinking water except during the irrigation season, but Avion and Roats rely solely on groundwater year round. The City currently monitors stormwater discharges and conducts City drinking water aquifer testing for drinking water quality per requirements of the SDWA.

A Groundwater Protectiveness Demonstration project has been conducted by the City and has determined stormwater discharges to UICs have not negatively impacted water quality of groundwater (GSI, 2011). The City is currently implementing a UIC monitoring plan accepted by ODEQ as part of its WPCF – UIC Permit.

DWPAs that are based on a two-year time of travel have been delineated for the City's water wells with assumptions for flow of groundwater through the aquifer beneath the City. A survey conducted in 2011 provided improved accuracy for DWPAs, see Figure 3.1.

6.3 WATER QUALITY ISSUES

Potential water quality pollutants in Bend include typical urban stormwater pollutants such as sediment, excess nutrients such as phosphorus and nitrogen, and oil and grease and heavy metals from motor vehicles. In addition, as discussed in Chapter 3, the City must consider the pollutants-of-concern on the Deschutes River 303(d) list.

6.3.1 Water Quality Limited Streams

As discussed in Chapter 2, the ODEQ has determined that the water quality of the Deschutes River is impaired by several pollutants. When ODEQ completes TMDLs for the Upper and Lower Deschutes River, the City will be required to develop and implement a program to reduce the pollutants that are addressed by the TMDLs.

6.3.2 Materials Used for Winter Road Safety

The City uses cinders, crushed basalt, and magnesium chloride on its streets during the winter. The water quality issues associated with these materials are described below.

Cinders. For many years, the City used cinders for traction on its streets during the winter. The cinders are pulverized as vehicles drive over them. The fine material is washed into dry wells, drill holes, pretreatment filters, and infiltration ponds, severely reducing the capacity, life expectancy, and performance of these devices. Material that cannot be swept up is washed into the Deschutes River, creating visible and objectionable islands of sediment and debris, or gets washed into UICs reducing their effectiveness. The extensive use of cinders for traction is not compatible with the City's use of underground injection, pretreatment devices, or infiltration ponds but is necessary for public safety.

Although used judiciously, cinders were often applied to roads in large quantities all across the City. Cinders are relatively inexpensive and are less prone to damage vehicles than sand or gravel.

Crushed Basalt. During the winter of 2007-2008, the City began experimenting with crushed and screened basalt in place of cinders. The basalt is denser than cinders and less likely to be pulverized. This is desirable from a stormwater system maintenance and air quality perspective. The City now uses crushed basalt exclusively, and recycles it for reuse. The City does its best to sweep up this material as soon possible after it is applied but weather conditions often delay sweeping.

Magnesium Chloride. Since 1998, the City uses the ice-preventing agent magnesium chloride (Mag). To maximize its effectiveness and to minimize the amount used, Mag must be applied before icing occurs. It is mixed with an organic carrier such as corn syrup and applied as a liquid. In Bend, Mag is often used along with crushed basalt. Although it is more expensive than salt (sodium chloride), the City has chosen to use Mag because it is relatively less toxic and does not attract wildlife as salt does. The main environmental concern associated with Mag is its chloride content. Chloride is highly mobile in soil and can contaminate groundwater and surface water.

6.3.3 Dry Wells and Drill Holes

As Bend has grown, so has the amount of impervious surface area. Storm drainage practices that were acceptable in the past are no longer acceptable. Although dry wells are effective where geotechnical conditions are appropriate, geotechnical conditions vary greatly throughout the City. Dry wells and other types of dispersed infiltration help maintain groundwater recharge patterns and avoid the problems associated with managing high-volume discharges. However, a drainage system based primarily on underground injection has potential disadvantages. The advantages and disadvantages of dry wells are discussed in previous sections.

Due to groundwater quality, ability-to-properly-size, and clogging concerns the City has sought to use other solutions besides drill holes. In some areas, such as the areas of pink tuff on the west side of Bend (see Chapter 2), even drill holes are not always effective. New drill holes are not allowed per City standards. The City owns nearly 1,000 drill holes.

The City has prepared a UIC systemwide assessment as part of its WPCF – UIC permit to examine potential threats to groundwater by UICs. A recent Groundwater Protectiveness Demonstration project (GSI Water Solutions, 2011) conducted by the City has indicated that day-by-day use of UICs are not negatively impacting groundwater. Nevertheless, the City may wish to decommission UICs for other reasons, such as minimizing the risk of a spill or reducing maintenance costs. When UICs are decommissioned, alternative means of disposal must be developed. Alternative facilities for stormwater disposal can include LID techniques, regional detention/retention and piped systems. The City's standards and specifications and Bend Code Title 16 require pretreatment prior to disposal for new and redevelopment in the right of way and for private development, respectively. ODEQ-registered cleanup sites should also be considered when locating UICs.

6.3.4 Spill Protection

Bend developed a spill prevention and response plan in 2010. As a general plan to address City operations, these Best Management Practices do not discuss spill protection plans for its City-wide stormwater system. The stormwater and street division trucks carry select sizes of pipe and public works has a spill response trailer available to help block storm facilities and contain spills when needed. Spills on the railroad or any of the City's streets would quickly flow to the nearest drywell or drill hole or to the river before the spill could be contained and recovered. Stormwater management that includes retention or detention or sedimentation manholes and sumped catch basins can help protect groundwater and surface water from spills. The greatest risk is from hydrocarbon spills. Systems and devices are available for retrofitting catch basins with automatic valves that can prevent hydrocarbons from being released from the catch basins. URS recommends that the City periodically review and update their stormwater spill prevention and response plan and enhance the plan to address potential spills that might impact stormwater facilities throughout the City. The City has started a program to add plug values to its drill holes for psill impact minimization and public safety.

6.3.5 Sources of Contamination

Sources of pollutants associated with stormwater runoff in urban areas may include the following:

- illegal dumping of trash and debris
- spills
- construction site and landscape runoff
- runoff from industrial or commercial sites
- motor vehicle leaks, brake wear and wheel weights
- roadway traction materials
- ice prevention chemicals
- landscape fertilizers and pesticides
- air pollutant deposition
- runoff from residential sites.

These are examples of typical potential sources of contamination. Further information can be found in the ISWMP.

6.3.6 Mirror Pond

Mirror Pond, in the Deschutes River in downtown Bend, is the location of many of the City's piped stormwater outfalls. It is unknown how much of the sediment that accumulates in Mirror Pond is contributed by these outfalls. The majority of the sediment in Mirror Pond is transported from upstream and adversely affects the recreational, water quality, and aesthetic values of the pond. Sediment and debris that accumulate near each of the outfalls, while small in quantity relative to sediment coming from upstream, is unsightly and causes sedimentation problems in the pond.

Mirror Pond is created by a roughly century old Pacific Power and Light hydroelectric dam. Whether or not the pond remains, Phase II NPDES rules require the City to reduce the amount of pollutants it discharges to the pond and the river “to the maximum extent practicable” (MEP) using BMPs. Currently, there are sedimentation manholes in place at Pageant Park, an infiltration basin at Drake and Dohema, two sedimentation manholes and a roadside border of permeable pavement along Drake Park, and a Stormfilter cartridge treatment unit that is in place on the west side of the Veterans Memorial Bridge at Newport Avenue. The BPRD is the major landowner along the river.

6.4 SUMMARY AND RECOMMENDATIONS

Statewide analysis of stormwater quality data over the past twenty years provides a good understanding of the pollutant types in stormwater (Kennedy/Jenks Consultants, 2011). Per recommendation in the 2008 draft SMP, the City has completed a Groundwater Protectiveness Demonstration project (GSI Water Solutions, 2011) for the potential impact of UICs to the water quality of groundwater, updated it’s DWPAs, and continues to conduct studies and evaluations of existing conditions to verify water quality concerns and maximize limited resources.

This plan recommends the following additional actions be taken by the City to address water quality:

- With the increasing costs of water quality treatment and maintenance, the City should select appropriate systems to protect water resources and to provide sufficient treatment for parameters of concern.

- The City should implement its monitoring plan to assess the impact of its stormwater discharges on UICs and use that information to inform Deschutes River water quality as well.

- The City promotes the use of LID principles in all City projects and requires private projects to consider LID principles (City Code Title 16). In addition, the City should consider:

    - Conducting a demonstration project(s) using permeable pavement and other LID measures. Based on the results of the demonstration project(s), consider further promoting permeable pavement (asphalt, concrete and/or pavers) in new and re-development projects including low-use residential streets, driveways and parking lots.

  - Further develop and refine City-specific standards for LID facilities such as bioretention systems and planters overtime, to promote and facilitate their use.

- Consider the performance, reliability, maintenance requirements and life-time costs in selecting pretreatment devices.

- Continue to develop a better understanding of water quality in stormwater runoff and program effectiveness by the continuation of monitoring water quality in UICs, and the Deschutes River.

- Install efficient sediment/spill traps in the storm drain system ahead of discharges to either surface waters or groundwater. Sediment from unpaved roads, poorly installed landscaping, poor sediment and erosion control at construction sites and traction materials used on City streets during the winter months contribute the majority of the sediment that is discharged through stormwater runoff. The City has already implemented some measures to reduce the negative effects of traction materials.

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7.0 STORMWATER GOALS, POLICIES, ORDINANCES, AND STANDARDS

The stormwater program, policies, ordinances, and standards were reviewed along with City goals to identify improvements and updates to support implementation of a comprehensive stormwater management program. Recommendations are provided to address water quality and water quantity issues for new development and redevelopment, to meet federal and state regulations, and to protect Bend's water resources.

7.1 STORMWATER UTILITY GOALS

The City's stormwater utility was formed by the passage of City Council Resolution No. 2623 in April 2007. The Council set up the stormwater utility to have regulatory and enforcement authority and responsibility for planning, design, construction, maintenance, administration, and operation of all City-owned stormwater conveyances and facilities. In passing the resolution, the City Council determined:

- That the City's physical growth and urban development has and will continue to increase the volume of stormwater runoff collected in and routed through the City's manmade and natural stormwater facilities and system ("stormwater system");
- That stormwater runoff, when not properly managed and treated, can cause property damage and erosion; carry concentrations of nutrients, heavy metals, oil and toxic materials into receiving waters and ground water; degrade the integrity of City streets and the transportation system; and reduce citizen access to emergency services and pose hazards to both lives and property;
- That stormwater runoff must be managed in a manner that protects the public health, safety and welfare, and the environment;
- That the City must meet regulatory requirements related to water quality;
- That stormwater quality and quantity problems cannot be allowed to escalate as a result of inadequate design criteria, regulation, maintenance, improvement, public awareness or code enforcement;

- That the City's stormwater system must be funded in a manner that enables regulatory compliance, ongoing maintenance, operation, regulation and system improvements;

- That absent effective maintenance, operation, regulation, enforcement, and control, existing stormwater systems in all areas of the City constitute or will constitute a potential hazard to the environment, health, safety and general welfare of the City; and

- That natural and manmade stormwater facilities and conveyances, including those owned by the City, constitute a stormwater system.

Based on the above Council findings, the following goals have been developed to address general, stormwater drainage and stormwater quality components of the City's stormwater utility.

7.1.1 General Stormwater Utility Goals

- Ensure that public and private stormwater systems and facilities provide adequate levels of service to the public at reasonable cost.

- Ensure that development, including development involving the installation of drinking or irrigation water wells, pays its fair share of the cost of installing and upgrading stormwater facilities that are needed to support the development and meet City, state and federal stormwater quantity and quality standards.

- Ensure that before new areas are annexed, they are either brought up to City stormwater quantity and quality standards or pay their fair share of the cost of upgrading stormwater facilities that are needed to support the areas to meet City stormwater drainage quantity and quality standards.

- Eliminate drainage nuisance problems.

- Meet all federal and state regulatory requirements, including but not limited to the federal Clean Water Act, federal Safe Drinking Water Act, and Oregon Groundwater Protection and Oregon Drainage Law requirements.

- Work with stakeholders in the watershed to realize efficiencies in protecting stormwater quality and providing stormwater drainage.

- Provide education to help citizens protect themselves from flood hazards and understand how to prevent stormwater pollution.

7.1.2 Stormwater Drainage (Quantity) Goals

- Reduce and manage runoff from developed lands.
  - Require stormwater to be managed on the site of origin except when formal offsite arrangements that address both stormwater runoff quantity and quality have been negotiated and recorded.
  - Ensure that systems are sized and maintained correctly to ensure that stormwater is safely and adequately maintained on site or in a regional control as per the bullet above and to allow safe passage for the 100-year storm.
  - Ensure that stormwater facilities are suited to the specific geologic conditions of the site.

- Preserve and maintain natural drainage systems.

- Preserve floodplains and drainage low spots for stormwater drainage.

7.1.3 Stormwater Quality Goals

- Protect the health, safety, and general welfare of the public and the environment with respect to stormwater quality.
  - Protect underground aquifers from urban runoff pollutants.
  - Protect surface waters from urban runoff pollutants.

- Manage stormwater pollutants at the source to the degree possible using low-impact development and other development techniques.

- Engage in a watershed approach to ensure surface drainage (river/creek) and groundwater health.

7.2 EXISTING CITY POLICIES

The existing City of Bend policies, codes, and ordinances related to stormwater management in 2010 are summarized below. One of the purposes of this first Stormwater Master Plan was to assess whether additional or different policies or measures should be considered to conform to the utility goals outlined in Section 7.1. The City has recently thoroughly updated its standards and specifications (July 2011) and adopted a stormwater ordinance (Bend Code Title 16) (January 2012) that addresses many of the issues listed below.

7.2.1 Critique of Stormwater Quantity Policy

The City restricts development within the 100-year floodplain, and both the General Plan and the Bend Code specify that stormwater must be kept on site, thereby promoting the limitation of runoff to pre-development levels.

Storm Sewer Policy No. 12. General Plan (1998), Public Facilities and Service Policies, Storm Sewer, Policy No. 12:

> Due to the lack of a defined drainage pattern for most of the urban area, development shall contain storm drainage on site.

Residential Districts. Chapter 2.1 of the Development Code applies only to Residential Districts. Section 300, Paragraph F.8 reads as follows:

> Onsite surface water drainage shall be retained on the lot of origin and not trespass onto the public right-of-way or private property, including roof drainage.

Mixed Use Districts. Chapter 2.3 applies only to Mixed Use Districts. Section 600, Paragraph D.7., reads as follows:

> All drainage from buildings, parking/loading areas, and other impervious surfaces shall be retained on the development site or directed to a drainage facility as part of an overall drainage Master

Plan using dry wells or other City approved methods such as landscaping, retention basin, swale, or similar bio-filtration systems that are not directly connected to a surface stream or canal.

Storm Drainage Improvements. Chapter 3.4 of the Development Code applies to Public Improvements except for Table D which applies to private streets. Section 500 applies to Storm Drainage Improvements and reads as follows:

3.4.500 Storm Drainage Improvements.

A. Storm Drainage Improvements Required. Storm drainage facilities shall be depicted on City-approved engineered construction drawings and installed to serve each new development in accordance with applicable City construction specifications as described in the City of Bend Standards and Specifications and the Grading/Clearing Ordinance NS-1879.

B. Accommodation of Upstream Drainage. Drainage facilities shall be designed and constructed to accommodate increased runoff so that discharge rates existing before the proposed development shall not be increased, and accelerated channel erosion will not occur as a result of the proposed land disturbance or development activity. Such facilities shall be subject to review and approval by the City Engineer.

C. Effect on Downstream Drainage. Where it is anticipated by the City Engineer that the additional runoff resulting from the development will overload an existing drainage facility, the City shall withhold approval of the development until provisions have been made for improvement of the potential condition or until provisions have been made for management of additional runoff caused by the development in accordance with City of Bend Standards and Specifications. Drainage shall not be directed to an existing watercourse, channel, stream, or canal. Storm drainage facilities shall comply with applicable state and federal regulatory requirements.

D. Easements for Existing Watercourses. Where an existing watercourse traverses a development, such as a natural watercourse, drainage way, channel, or stream, or any other existing drainage facility including but not limited to irrigation canals, laterals, and associated ditches, there shall be provided and recorded an easement conforming substantially with the lines of such existing watercourses and such further width as will be adequate for conveyance and maintenance, as determined by the City Engineer.

E. Easements for Developed Drainage Facilities. Where new drainage facilities are provided that include elements located outside the dedicated public right-of-way, such facilities shall be located within an area provided for in a recorded easement. The easement shall be adequate for conveyance and maintenance as determined by the City Engineer.

Footnote 1 of Table D of Section 500, which applies to private streets, reads as follows: “1. Drainage must be retained on site and not drain to public right-of-way.”

As there is no obvious reason for having different code requirements for stormwater management for residential districts, mixed use districts and public improvements, the requirements should be consolidated into their own chapter. The City should consider modifying Development Code Section 3.4.500, Storm Drainage Improvements, to allow properly treated stormwater to flow to surface water if, due to the geology or public health/safety concerns, no other options are available.

Nuisance Ordinance. Other stormwater-related requirements are incorporated into the City’s nuisance code. Specifically, the nuisance code contains sections related to stormwater drainage and illicit discharges.

With respect to drainage, the nuisance code reads:

5.365 Surface Waters, Drainage.

(1) No owner or person in charge of a building or structure shall permit rainwater, ice, or snow to fall from the building or structure onto a street or public sidewalk or to flow across the sidewalk.

(2) The owner or person in charge of property shall install and maintain, in a proper state of repair, adequate drainpipes or a drainage system so that overflow water accumulating on the

roof or about the building is not carried across or onto the sidewalk.

(3) A violation of this section is a Class B Civil Infraction.

Because this section refers only to water or ice that falls directly onto a street from a building or across a sidewalk, it can be argued that it does not cover water that flows down a driveway or across unpaved land and then onto the streets or public property. A recommended update is to rewrite the section to apply to water that gets onto the streets or public property regardless of the course it takes first, whether or not it falls directly from a building or crosses a sidewalk.

The Development Code should also be revised to clarify that water cannot be allowed to flow onto an adjacent private lot (a subservient lot), even if that lot is under common ownership, unless there is a recorded drainage easement on the subservient lot.

The nuisance code contains general language to prevent illicit discharges:

4.502 Use of Public Sewers Required.

(1) No person shall place, deposit, or permit any human or animal excrement, garbage or other objectionable waste to be deposited in any unsanitary manner on public or private property within the City of Bend, or on any City property outside the City.

(2) No person shall discharge any sewage or other polluted waters into any natural outlet within the City of Bend, or in any area under the jurisdiction of the City, except where suitable treatment has been provided in accordance with this provision.

Here, a natural outlet means any outlet into a watercourse, pond, ditch, lake, or other body of surface water or groundwater. The City may want to develop more specific language for addressing stormwater illicit discharges.

Floodplain Development. The City has a floodplain zone ordinance that was updated in September 2007 and incorporated into Development Code Section 2.7.600 Waterway Overlay Zone (WOZ). Section 640, Paragraph E reads as follows:

> No development shall occur in an FP [Flood Plain] zone unless a permit has been received for the work. Except for improvement of an existing structure which is less than substantial, as determined by the City, no permit shall be issued unless the work will be reasonably safe from flooding, otherwise complies with this ordinance, and all necessary state and federal, and local permits will be obtained as a condition of approval on any permit in an FP zone.

Section 640, Paragraph B reads as follows:

> 2. The Planning Director is hereby appointed to administer and implement the Flood Plain Combining Zone by granting or denying development permit applications in accordance with its provisions…
>
> c. Review all development permits to determine if the proposed development is located in the floodway. If located in the floodway, assure that the encroachment provisions of Section M.1 are met.

Section 640, Paragraph M reads as follows:

> 1. Prohibit encroachments, including fill, new construction, substantial improvements, and other development unless certification by a registered professional civil engineer is provided demonstrating through hydrologic and hydraulic analyses performed in accordance with standard engineering practice that encroachments shall not result in any increase in flood levels during the occurrence of the base flood discharge.

The City may consider incorporating additional language into the development rules to protect itself from liability for drainage overflows from private developments.

7.2.2 Critique of Stormwater Quality Policy

The City has performed a thorough analysis of its development policies, codes, and ordinances with respect to water quality as part of a separate study entitled "City of Bend Stormwater and Watershed-based Development Policy, Code, and Ordinance

Review" (July 2008), which is incorporated by reference. The report includes highlights and recommends improvements for consideration. The analysis found:

- Inconsistencies among the General Plan, Development Code, Standards and Specifications and implementing ordinances that should be rectified.
- Construction site erosion, sediment control, good housekeeping requirements, and education should be improved to help minimize pollutants from construction sites.
- Adoption of the design standards in the COSM would help to ensure that water quantity and quality issues are properly addressed.
- The City should examine ways to offer incentives for single-family residences and duplexes to implement stormwater BMPs.
- The City should require as-built drawings of developments to provide a better understanding of impervious surface coverage, and location and sizing of stormwater drainage and treatment facilities throughout the City.
- The City should consider including requirements or encouragement for specific types of source controls and other appropriate post-construction controls by land use.
- The City should establish policies and implementing measures to ensure that private and public stormwater controls are operated and maintained over the life of the project.
- The City should consider incorporating expanded buffers along local waterways where practicable in the built environment and especially within newly incorporated boundaries to allow for protection of riparian vegetation to help address pollutants of concern that may impair Deschutes River or Tumalo Creek water quality.
- The City has in place good policies to promote alternative transportation and limit auto use.
- The City should consider using overlay maps or specific plans for applying more stringent design standards and prioritization of water quality retrofits

for surface water drainages or UICs in drinking water protection areas and areas proximate to clean-up sites and private wells.

As an example of the inconsistencies alluded to above, some City stormwater policies are vague, some require stormwater treatment or filtration prior to disposal to surface waterways, and some do not allow any drainage to surface waterways. The City's General Plan includes a policy to "work to minimize the discharge of street run-off directly into the Deschutes River," and the City's Development Code requires applicants for developments in the Waterway Overlay Zone to "demonstrate that surface runoff from impervious areas will not flow unfiltered or untreated into the adjacent waterways." The stormwater section of the code does not allow drainage to be directed to an existing waterway:

3.4.500 Storm Drainage Improvements.

> **C. Effect on Downstream Drainage**. Where it is anticipated by the City Engineer that the additional runoff resulting from the development will overload an existing drainage facility, the City shall withhold approval of the development until provisions have been made for improvement of the potential condition or until provisions have been made for management of additional runoff caused by the development in accordance with City of Bend Standards and Specifications. Drainage shall not be directed to an existing watercourse, channel, stream or canal. Storm drainage facilities shall comply with applicable state and federal regulatory requirements.

Similar discrepancies occur with regard to UICs, erosion and sediment controls, and the definition of steep slopes.

Drinking Water Protection Area Plan. The City has completed the source water assessment for its groundwater supplies plan—delineation of the drinking water protection areas, and a source assessment of what sources pose the greatest risks to its drinking water. The City has not yet developed a formal protection plan but includes protective elements as part of its ISWMP and through the proposals in this SMP related to its pipe replacement program and UIC retrofit program.

7.3 TRENDS AND CHALLENGES IN STORMWATER MANAGEMENT

Regulatory Trends. The EPA, which nationally oversees the CWA and SDWA, promotes a watershed management approach for addressing stormwater management. This includes addressing stressors in a geographic area defined by hydrology by working with stakeholders on a watershed level to address the principle water resource goals for the watershed in a strategic, coordinated manner.

ODEQ has permit authority in the State of Oregon to provide oversight for the CWA and SDWA. In 2000, ODEQ outlined its environmental priorities:

Priority One:	Increase opportunities for Oregonians to prevent and solve environmental problems.
Priority Two:	Clean up Oregon's rivers and streams.
Priority Three:	Protect Oregonians from harmful toxics.

National Trends in Stormwater Management. Over the past twenty years, a national trend has emerged where communities are turning to better site designs, LID and "smart growth" to address both quantity and quality issues, including addressing pollutants at the source. The fundamental aspects of better site design include the following:

- Define the development envelope. At the initial conceptual stages of the project, first examine the unique hydrologic and topographic features of the site, and determine which areas should be protected and which areas are best suited for development. This can result in a site plan that reduces both environmental and construction costs.
- Minimize directly connected impervious surface coverage and maximize permeability. This will help reduce both the stormwater volume and velocity and reduce the amount of stormwater treatment that is needed.
- Plan for alternative modes of transportation to reduce automobile-related pollutants to stormwater.
- Design with drainage in mind. Using drainage as part of the design element can allow for infiltration where appropriate, suggest alignments

optimum locations for parks and play areas, and building sites that work with the natural environment.

- Incorporate source controls, such as covered loading docks and waste disposal areas that keep stormwater from coming into contact with pollutants.

LID can have both environmental and economic benefits to a development site. The COSM, a regional design manual addressing stormwater concerns, promotes better site design.

Another national trend that is emerging is the recognition that, to be effective, post-construction/permanent stormwater controls must be adequately maintained over the life of the project. Poorly maintained controls can actually contribute to the problem by causing localized flooding when blocked. Maintenance and operation verification programs, including maintenance agreements, are beginning to be implemented in communities nationwide to ensure this occurs.

Challenges. As elaborated upon in other chapters of the Master Plan, the City of Bend faces some common and some unique challenges in managing both stormwater quantity and quality that should be taken into account when developing stormwater policies, ordinances, and standards. These challenges are described below:

- **Development Rule Consistency.** Current development rules are inconsistent and therefore do not provide for adequate stormwater drainage protection and quality treatment. They allow for loopholes and result in developments being installed that do not meet the intent of the City's regulations. The City needs to ensure that it has consistent adequate legal authority throughout its development rules to provide for public safety and meet regulatory requirements for both drainage control and treatment.

  Because it is collected from diffused sources, stormwater runoff and the pollutants associated with it are difficult to control. Therefore, preventing drainage and pollutant issues is the most effective management tool for addressing stormwater. Stormwater pollution prevention and drainage volume considerations are best considered during the conceptual review stage of a development rather than added in at the end of the project.

Long-term operation and maintenance agreements for operational and treatment controls should be required and verified over the life of the project.

However, in areas that are predominantly built out, there is less opportunity to promote pollution prevention via new development standards. Redevelopment retrofits should be considered in such areas.

City divisions also need to work together to ensure that any potential conflicts that might result from proposed changes to the development rules to protect stormwater are understood and addressed to find the best overall solutions that optimize public safety across disciplines.

- **Geologic Implications.** The City currently lacks adequate geotechnical requirements for plan approval of development projects. Parts of the City infiltrate well, but other parts are underlain with pink tuff, basalt, or lava tubes. The local volcanic geology of Bend makes the proper selection, and sizing of drainage systems and their associated water quality protection facilities challenging, and, in many cases, expensive. Understanding the geology of the area is important to ensure the drainage system being installed will work effectively and protectively (e.g., meet UIC regulations).

- **Increases in Impervious Surface.** As the City becomes more urbanized, more land is compacted and covered with impervious surfaces, reducing the landscape's natural abilities to infiltrate runoff or for stormwater to evapotranspirate naturally. As a result, increased amounts of water typically run off the site than would occur if the site were in its natural, pre-developed state.

  Because impervious surfaces do not have vegetation to slow precipitation and typically are not structured to slow down the runoff, the runoff drains off impervious surfaces at a higher velocity than it would under natural conditions. Without proper mitigation, this can have erosive impacts when the water outfalls to a stream or soil-covered area.

  This problem is especially serious in areas annexed from the County where the existing roadways have few drainage structures, and instead rely on the rural character of the surrounding land for runoff disposal. When these lands are annexed into the City and become developed, the City takes on the burden of ensuring that adequate drainage is provided.

- **Limited Financial Resources.** The City has an MS4 NPDES permit and a UIC WPCF permit. Meeting the requirements of these permits is financially challenging for the City because of the necessary treatment and associated maintenance costs.

  In addition to the piped system draining to the river, the City has a dispersed system of dry wells and drill holes, UICs for which the water quality regulations had not been finalized at the time that the initial stormwater utility fund study was being done. New permit requirements for UICs were assumed to include increased monitoring requirements. Dispersed treatment sites and underground manufactured treatment can be very costly, both initially and from an ongoing operation and maintenance perspective, and can be problematic if maintenance is deferred. Moreover, the number of approved manufactured controls to treat stormwater pollutants is very limited, and these are approved only at certain velocities and only for certain pollutants. Land costs for landscape controls are high.

  Concurrently, other public systems (water, wastewater) will also need upgrading over the next twenty years to maintain adequate levels of service for Bend’s expected growth.

- **Drinking Water Protection Areas and Other Restricted Areas.** Many areas of the City are within DWPAs. These are priority areas for special considerations to ensure that groundwater quality is not impacted by stormwater runoff or spills. UICs have stronger restrictions in these areas and near private drinking water wells than in other areas. UICs are not allowed in these areas except under a UIC WPCF permit.

- **Hazardous Spill Management.** A liquid spill almost anywhere in the City would quickly flow to a nearby UIC or to the river. Detention capacities in these systems are short and provide little opportunity to retain a large spill until it can be cleaned up. Whereas the City has plugs, pigs, and a spill trailer, the nearest spill response contractor is in Prineville and by the time the contractor arrives in Bend, groundwater or the river could be seriously contaminated. The City should review and update their 2010 spill prevention and response plan (City of Bend, 2010) to address specific potential spill issues, evaluating opportunities for containment and cleanup. The proposed UIC retrofit program proposes to upgrade UICs to minimize spill impact threats.

- **Winter Driving Safety.** During the winter, the City uses traction materials and magnesium chloride for melting ice on the streets to improve winter driving safety. Traction materials need to be properly collected to avoid clogging stormwater facilities or impacting surface waters. Magnesium chloride has less impact on the environment than other types of road salts but chlorides are capable of polluting water and are difficult to remove once in water.

7.4 RECOMMENDED POLICIES

To address the City's goals, described in Section 7.1, the following recommendations are made to improve the City's development rules, building off the analysis in Section 7.2, and the trends and challenges outlined in Section 7.3.

7.4.1 General Policies

New Development and Significant Redevelopment

No new development or significant redevelopment shall be allowed to occur without requirements in place for maximizing onsite storm drainage and provisions for downstream drainage to meet current requirements. Onsite storage and treatment can include a number of LID facilities or design techniques, as described in the COSM. UICs with pretreatment can be used where allowed and appropriate. Minimum requirements for new development and redevelopment shall be clearly specified and enforced. Geologic studies shall be required to determine suitable drainage options.

Annexations to City Boundaries

Annexations of areas previously developed and maintained under Deschutes County regulations and standards occur for a variety of reasons. Owners of some properties are interested in City services for police and fire protection. Other annexations occur for access to urban utilities and the ability to develop to higher densities. As annexations occur, Bend's limited maintenance budget is stretched beyond its abilities to provide upgrades for storm drainage or streets to meet City standards in these areas. Newly annexed areas tend to have chronic drainage problems, and increase the list of flooding concerns the City needs to deal with. The ability to provide stormwater facilities for developments proposed for annexation into the City shall be a consideration for annexation approval. Upgrading of streets and storm drainage systems to meet City standards shall be a minimum requirement prior to accepting new areas into the City. The City shall require that areas outside the City limits shall have a stormwater utility plan that shows how the development would get stormwater service prior to annexation. These areas shall be required to meet current City, state, and federal stormwater quantity and quality standards prior to development approval.

Funding Options

Stormwater facilities will be expensive and will take a long time to plan, design and construct. New developments, and neighborhoods, can hasten the process by paying for the construction of regional facilities, defined as any system that serves more than one tax lot. These facilities may be of many types, such as pipe, regional treatment, pretreatment for UICs, and LIDs, to name a few.

Written agreements shall be required for all participants of stormwater districts to ensure the equitable funding of storm drainage improvements and the ongoing maintenance of these improvements.

Alternatively, or in addition to stormwater districts, the City may use the improvements identified in this Master Plan to develop System Development Charges (SDCs) to fund storm drainage facilities. SDCs are fees assessed on new developments to pay for improvements required to serve future needs of buildout conditions within the City. In part, SDCs are also new developments' contribution to the City for the ability to use an existing system that has been installed and paid for by existing development. There are strict regulations for calculating SDCs. New development can only be assessed by the difference in costs between needs for existing development and facility needs for future development. In other words, SDCs cannot be used to build infrastructure to solve existing problems.

Restricted Areas

The City shall consider more stringent location requirements, treatment, or spill control standards in restricted areas, such as DWPAs, adjacent to cleanup sites, near private well-heads, and industrial sites or other areas where the potential for a hazardous material spill is great or the impact of such a spill would be large. This could potentially be accomplished using an overlay map. The City should complete its drinking water protection program. The City should locate all of the water wells within the UGB and make this information available to the public so these wells can be protected.

Special Drainage Areas

The City shall seek to reserve strategic regional drainage areas for stormwater treatment and storage.

Winter Weather Deicing/Traction

The City shall continue studying how best to use traction materials and deicers and investigate methods of application and cleanup to provide the best balance between public safety and water quality. Another important component is the education of both staff and the public on the issues and concerns related to traction material and deicer use, particularly best management practices, water quality impacts, and the maintenance costs and facility replacement costs when systems fail.

7.4.2 General Plan Policies

The City promotes incorporating the following General Plan policies into the next update of the General Plan to assist in meeting the goals of the stormwater utility described at the beginning of this chapter. These goals include but are not limited to protecting public and environmental health and safety. Additionally, the City shall review the recommendations in the City of Bend Policy, Code, and Ordinance Review (July 2008) and make additional modifications to the General Plan, as appropriate, resulting from that effort during the comprehensive review.

Storm Drainage Facilities and Systems

1. All public and private stormwater facilities shall be designed and operated in accordance with the City's Stormwater Master Plan and shall meet appropriate drainage quantity and quality requirements, including, but not

limited to, the requirements in the City's NPDES MS4 Stormwater Permit, Integrated Stormwater Management Plan, WPCF UIC Permit and any applicable TMDL requirements. Underground injection and surface discharges to the Deschutes River or Tumalo Creek shall only be approved when other alternatives, such as retention basins or bioinfiltration swales, are not reasonably available. Low impact site designs shall be a required part of all new development and redevelopment projects.

2. Due to the lack of defined drainage patterns for most of the urban area, development shall, to the extent practicable, contain and treat storm drainage on site. In instances where containing storm drainage on site would not be safe or practicable, the developer shall enter into a formal and recorded arrangement with the City or a private party to adequately address the storm drainage off site such as a regional control.

3. The use of stormwater disposal systems shall be coordinated with the ODEQ and Water Resources Department to protect the quality of groundwater and surface water.

4. The City shall work to minimize the discharge of untreated stormwater run-off from streets into the Deschutes River and Tumalo Creek.

5. The City shall seek efficiencies and consistency by working with other municipalities and stakeholders within Central Oregon on land use issues to address flood control, watershed health, and stormwater pollution prevention.

6. The City shall require the following stormwater protection measures for all new development and redevelopment proposals during the planning, project review, and permitting processes:

    - Submit geotechnical site assessments when dry wells or other infiltration or injection systems are proposed.

    - Avoid conversion of areas particularly susceptible to erosion and sediment loss (e.g., steep slopes), or establish development guidance that identifies these areas and protects them from erosion and sediment loss.

- Retain natural drainage channels in their natural state to prevent undue erosion of banks or beds, and preserve or restore areas that provide water quality or quantity benefits and/or are necessary to maintain riparian and aquatic biota.

- Promote site development that limits impacts on, and protects the natural integrity of, topography, drainage systems, and water bodies.

- Promote integration of stormwater quality protection into construction and post-construction activities at all development and redevelopment sites.

7. The City shall review its Stormwater Master Plan and Integrated Stormwater Management Plan as needed for compliance with changes in state or federal requirements and at least every five years.

8. The City will initiate funding options (e.g., SDCs, grants, low-income loans) for stormwater capital projects in accordance with applicable laws.

9. The ability to provide stormwater facilities for developments proposed for annexation into the City shall be a consideration for annexation approval.

7.4.3 Drainage Requirements

In addition to the water quality considerations outlined in the *Stormwater and Watershed-based Development Policy, Code, and Ordinance Review,* July 2008, the City should improve Code language pertaining to drainage requirements. This recommendation has already been implemented by Bend Code Title 16. In Title 16 the City has provided the following Stormwater Drainage requirements:

> Except as provided below, impervious surface stormwater drainage shall be retained on the lot of origin and not trespass onto the public right-of-way or private property.
>
> 1. If the City Engineer or Public Works Director determines that retaining all stormwater on the site of origin would pose a threat to public safety or adjacent properties, or if the

developer chooses to direct all or part of the runoff off site and there is enough capacity in the conveyance system, the runoff or a specified portion thereof shall be directed to an off site drainage facility approved by the City Engineer or Public Works Director.

2. When runoff from non-City-owned property is directed to or allowed to flow to City-owned property, the owner(s) of the lot(s) of origin shall compensate the City for the costs it incurs for constructing, operating, and maintaining the additional stormwater drainage and treatment capacity.

3. Access to, and maintenance and operation of, all stormwater facilities on private property shall be as required by the most current version of the COSM.

Title 16 was revised to include the definition of "impervious surface" that was adopted as part of the City's stormwater service charge resolution:

> *Impervious surface:* A hard surface area that either prevents or retards the entry of water into the soil mantle. Common impervious surfaces include building roofs, walkways, patios, driveways, parking lots, concrete or asphalt paving, gravel roads, and packed earthen materials.

This definition is intended to include all surfaces that impede the natural infiltration of stormwater. These include gravel roads, compacted soils, and even permeable pavement. This definition does not include landscaped areas.

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8.0 FUNDING EVALUATION AND DEVELOPMENT OF UTILITY FEE

8.1 BACKGROUND

The purpose of this SMP is to lay groundwork for correcting and preventing stormwater drainage and water quality problems. In the early 1980s, the City made a big financial commitment to protect its groundwater by constructing a sanitary sewer system and treatment plant. Prior to this, sewage was discharged to septic systems many of which were failing lava tubes and drill holes (there are still several hundred septic systems within the UGB). The City must now address stormwater quantity and quality and the potential effects of spills to the stormwater system on the quality and safety of surface water and groundwater. This SMP is the first significant effort to estimate the costs of implementing a comprehensive stormwater program.

The highest priority is to correct the most serious existing problems and prevent new problems from being created as the City continues to grow. This must be done quickly. Funding the stormwater improvements needed for continued growth, protection of critical water resources and public amenities, and compliance with state and federal regulations will be expensive and a major commitment by the City. CWA grants and low-interest loans are not currently available for stormwater projects. Efforts are under way at various levels of government to make such funding available for stormwater projects, but it is not clear if or when this will happen.

The City decided to establish a funding source that legally can be used only for stormwater. Consequently, during Phase I of this SMP, the City Council established a Stormwater Utility and a stormwater service charge. Assisted by a financial consultant, the City prepared an evaluation of its stormwater needs and developed funding options for providing the resources necessary to implement a stormwater program. To assist with the development of the utility fee, the City convened an advisory Citizens Stormwater Utility Fee Task Force (Task Force) to discuss issues, evaluate options, and develop recommendations.

Development of the stormwater utility fee provides a funding source for immediate stormwater needs such as operations, planning, and some capital projects. However, an evaluation of long range funding needs is recommended once the City obtains its UIC WPCF permit. It is recommended that the City address long range funding needs as part of the specific planning for UIC requirement resulting from the UIC WPCF permit, or conduct a separate process for this purpose.

8.2 CITIZENS STORMWATER UTILITY FEE TASK FORCE

The Task Force was convened in February 2007, at the City Council's direction, to provide input into the design and implementation of the stormwater utility fee. A diverse group of stakeholders was recruited, including members of the business community, environmental interests, neighborhood associations, City staff, and a Bend City Council member. Task Force duties identified in the Charter (Appendix D) consisted of the following four elements:

1. Review and make recommendations concerning the elements of the stormwater program and utility.

2. Review and make suggestions with respect to the stormwater utility's goals, objectives, and levels of service.

3. Review and provide advice on the financing for the stormwater utility.

4. Assist in developing and participating in a community awareness and education program.

The Task Force met five times. Working with an aggressive agenda and under a tight schedule, the Task Force delivered its recommendations to the City Council in June 2007.

8.3 ISSUES ADDRESSED BY THE TASK FORCE

The Task Force first discussed the needs of a comprehensive stormwater program. They determined that components of a program sufficient to meet regulatory needs and citizen expectations include:

- Capital improvement projects for flood control and water quality.
- Operation and maintenance of existing facilities.
- Plan review, inspection, and enforcement for new development.
- Controls for new construction runoff to address erosion.
- Post-construction controls to address water quality.

- Illegal discharge detection and elimination for spills and cross connections.
- Public education and involvement.

Shaun Piggott and Associates, working with the City, developed issue papers both as a mechanism to provide information and to respond to questions raised by the Task Force (see Appendix D). Each issue paper provided background information and alternatives for the Task Force to consider and explore before they provided recommendations to City staff and the City Council. The issue papers addressed the following topics:

1. What is the most appropriate basis for a stormwater rate structure in Bend?
2. How should Bend's stormwater utility address the issue of service charge exemptions and credits?
3. How should Bend structure the calculation of stormwater service charge credits?
4. How should private roads within special subdivisions such as Planned Unit Developments be treated under the stormwater utility's rate structure?

The first issue paper surveyed other jurisdictions regarding how they developed their service charges and how much they charge. Because some of these utilities have been challenged in court over their procedures and charges, the results of their cases were used to help Bend ensure that its procedures and charges are legally defensible. The service charge must be related to the cost of providing the service; proportionate among customer classes; equitable; and include provisions for customers to opt out if they do not make use of or benefit from the services.

Many jurisdictions assess service charges based on impervious surface area and courts have found this to be an equitable method. Impervious surfaces shed water that otherwise would naturally filter into the ground. Generally, the service burden for the City is proportionate to the amount of impervious surface area. The Task Force agreed that impervious surface area should be used as the basis for the rate structure.

The Task Force recommended the following approach and the City agreed. Fifty single-family/duplex residential lots in the City were randomly selected. The impervious surface area for each lot was determined using high-resolution multi-spectral aerial imagery. The average area of impervious surface for these lots, 3,800 square feet, was defined as an Equivalent Residential Unit (ERU). All persons who have the right to occupy developed single family and duplex residential lots are charged monthly for one ERU; all persons or entities that have the right to occupy any other type of lot or facility pay on the basis of the number of ERUs assigned to them. The initial per-ERU charge was determined to be $4.00/month, based on the stormwater utility budget and the number of ERUs estimated to be in the City.

Issue paper 2 dealt with rate exemptions and credits. It was determined that parcels that were completely in their natural state or that had been restored to their natural state would not be charged a fee. Because City streets and some private streets are designed to collect and convey stormwater runoff, they are also exempt from the fee; however, other public properties and entities that are exempt from paying taxes would not be exempt from the stormwater service charge (this is consistent with the concept that the stormwater service charge is a fee for services rendered and not a tax, an important legal distinction). Credits would be granted for entities that provide onsite stormwater management facilities that exceed code requirements, in recognition that such facilities proportionately reduce City stormwater management costs. An appeals process was also established for customers to request corrections in their delineated impervious surface area.

Credits were further explored in issue paper 3, which discussed a possible structure for the rate credit program. A credit approach determined by the Task Force to be equitable was used to categorize types of utility costs as either fixed or variable. Fixed costs are largely unaffected by the quality or quantity of stormwater managed by the City; variable costs are roughly proportionate to quality and quantity. Only the variable portion of the utility budget could be used for determining credits, and only occupants of properties that are not residential single-family or duplex can qualify for credits. This is because all other occupants are charged the same fixed monthly rate. City staff were tasked with developing a process for the public to apply for credits. Using this issue paper and the legal requirements that apply to service charges as a foundation, the City developed a detailed credit approach that includes specific design standards as the basis for determining credit eligibility and for applying a credit calculation.

Issue paper 4 addressed the specific topic of whether to charge private roads within special subdivisions. In analyzing the issue, it was determined that some of the private streets were not designed to City standards and may add to the stormwater problem. Recommendations from the Task Force provided for exemption from the utility rate for those private streets that were designed and constructed to meet the City's street standards and function as part of the stormwater management system. Other private streets would be charged the stormwater fee.

The City Council agreed with the Task Force recommendations that the City should charge itself, just as it charges others, for any impervious surface areas that do not function as part of a stormwater management system. Task Force members recognized the effort required to review each public street to confirm whether it functions as part of the stormwater conveyance system, and recommended that this be performed after the initiation of the stormwater service charge. The Task Force recommended that, in the meantime, all City streets be presumed to be part of the stormwater conveyance system.

8.4 BUDGET ESTIMATES FOR STORMWATER PROGRAM

The Task Force discussed likely program functions and services for the initial stormwater program along with budget estimates for these program functions. Budgets were developed for Fiscal Year 2007-2008 based on City costs, and were upgraded to reflect an increased level of effort for maintenance for the stormwater system.

Maintenance: Emphasis on field maintenance operations throughout Bend will be increased. This emphasis on increased maintenance frequency and enhanced maintenance procedures that are necessary to reduce stormwater pollutant loads will require a commitment of labor and equipment resources to this program element. The relative large prominence of maintenance in this program reflects the fact that many of the initial operations will involve remedial maintenance on a stormwater system that has never been adequately maintained. Currently, maintenance of the system is sporadic and focuses on problem dry wells, drill holes, catch basins, and inlet grates. A more preventative level of stormwater maintenance service is outlined in Table 8.1.

Budget Estimate = $286,560 for FY 2007-2008

Table 8.1
City of Bend
Stormwater Maintenance Program Activity List

No	Category	Maintained	Type of Measure	Frequency (Times/Year)	Standard	Type of Measure	Crew Size	Total Days Annually	Preliminary Cost Est. Labor ($240/day)	Preliminary Cost Est. Totals	Labor Cost/Unit
1	Clean Catch Basins/Inlets	300	EA	2.0	30	EA/DA	2	40	$9,600	$9,600	$16.00
2	Detention Pond: Sediment	5	EA	3.0	2	EA/DA	3	23	$5,400	$5,400	$360.00
3	Drainage Ditch	50000	LF	0.2	400	LF/DA	3	75	$18,000	$18,000	$1.80
4	Maintenance	75	EA	1.0	2	EA/DA	2	75	$18,000	$18,000	$240.00
5	Water Quality Devices	3280	EA	0.2	2	EA/DA	2	656	$157,440	$157,440	$240.00
6	Drywells	1020	EA	0.2	4	EA/DA	2	102	$24,480	$24,480	$120.00
7	Drill Holes	20	LF	1.0	1	EA/DA	2	40	$9,600	$9,600	$460.00
8	System Repair &	1	EA	1.0	0.5	EA/DA	4	8	$1,920	$1,920	N/A
9	Construction	1	EA	3.0	1	EA/YR	6	18	$4,320	$4,320	1,440.00
10	Training/Education/Safety	1	EA	180.0	3	EA/DA	1	60	$14,400	$14,400	N/A
11	Flood Response	240	EA	1.0	4	EA/DA	1	60	$14,400	$14,400	N/A
12	Equipment Maintenance	150	EA	1.0	4	EA/DA	1	38	$9,000	$9,000	$60.00
	Work										
	Schedules/Monitoring										
	Customer										
	Complaint/Investigate										
Categories:				**Sub-Total: All Maintenance**				**1,194**	**$286,560**	**$286,560**	
							Grand Total:			**$286,560**	
Note: This table was prepared for estimation purposes only.											

Stormwater Improvement Program: The initial stormwater improvement recommendations focus on local structural improvements and neighborhood repairs/replacement of the stormwater system. Specific repairs considered were identified based on complaint logs and subsequent engineering analysis. The high-priority flooding projects listed below are included in this part of the budget. (See Chapter 4 for more information about the problem flooding areas.)

Westside Village Shopping Center & Bend Fire Station (Problem Flooding Area #6): An area with very poor infiltration, the solution for this area is to provide a regional piped collection network to convey the stormwater to a regional detention and treatment pond for ultimate disposal to the Deschutes River.

Franklin Underpass (Problem Flooding Area #20): Storm water will be collected in a sump and pumped to the Colorado-Parkway interchange for treatment and disposal by means of infiltration.

Third Street Underpass (Problem Flooding Area #8): Similar to the Franklin Avenue Underpass, storm water will be collected in a sump and pumped to the

Colorado-Parkway interchange for treatment and disposal by means of infiltration.

Archie Briggs Road (Problem Flooding Area #3): Stormwater will be conveyed by means of a new drainage pipe beneath a new sidewalk along the roadway to a treatment system and an energy dissipater prior to discharging to the Deschutes River. This will reduce chronic flooding from the steep roadway west of the river.

Fairview Heights on Awbrey Butte (Problem Flooding Area #4): Steep open channel flows will be piped, existing piped systems will be replaced with larger pipe and new manholes constructed to contain flows as the drainage changes direction and proceeds downhill.

Additional equipment will also be needed, including a Vactor truck (used for line, catch basin, and dry well cleaning) and a utility truck. SMP development expenses will be funded under this budget category.

Budget Estimate = $521,000 for FY 2007-2008

Water Quality Management: Ongoing permit compliance with the NPDES Phase II permit as defined in the City's adopted and recently revised ISWMP (see Table 8.1) will require additional expenditures for public education, detection of illicit discharges, construction site controls, and development of best management practices. Compliance monitoring will be an additional ongoing and increasing cost to the City.

It should be emphasized that activities related to implementation of the ISWMP are contained in virtually all of the budget categories, and that the budget amounts do not include the costs of water quality activities that are included in the ISWMP but were under way prior to adoption of the stormwater utility fee. Costs related to water quality are specific to a response to the regulatory permit conditions.

Budget Estimate = $324,000 for FY 2007-2008

Table 8.2 is the City of Bend Budget Forecast for implementing the SMP.

Table 8.2
Budget Forecast - Implementing the Bend Integrated Stormwater Management Plan

Program/BMP	FY '08 Labor Hours	Labor	Materials	Total Costs
	Hrs	Cost		$$
Program Administration, Finance, and Planning (Section II)				
1. Administration and Coordination	1,235	$43,917	$4,392	$4,839
2. Legal Authority	368	$11,628	$1,163	$12,791
3. Financing	1,176	$38,282	$3,828	$42,110
4. Planning	80	$2,554	$255	$2,809
5. Annual Reporting	198	$5,912	$591	$6,503
6. UIC Registration	104	$3,306	$331	$3,637
Subtotal	3,161	$105,599	$10,560	$116,159
Public Education and Outreach (Section III)				
1. Utility Bill Inserts, Brochures or Posters	204	$5,722	$5,572	$11,294
2. Stormwater Pollution Prevention Web Site	59	$1,676	$168	$1,844
3. City News Broadcast Stormwater Quality Messages	130	$4,196	$420	$4,616
4. Stormwater/Watershed Diorama	42	$1,104	$110	$1,214
5. Performance Standards	0			$0
Subtotal	435	$12,698	$6,270	$18,968
Public Involvement and Participation (Section IV)				
1. Public Advisory Committee (PAC)	72	$2,318	$232	$2,550
2. Public Meetings	118	$4,168	$417	$4,585
3. Stormwater Quality Volunteer Opportunities	26	$802	$80	$882
4. Performance Standards	0			$0
Subtotal	216	$7,288	$729	$8,017
Illicit Discharge Detection and Elimination (Section V)				
1. Public Education on Illegal Discharges & Improper Disposal	54	$1,460	$5,146	$6,606
2. Illicit Discharge Reporting Mechanism	54	$1,806	$181	$1,987
3. Post Warnings About Illicit and Illegal Discharges	17	$581	$58	$639
4. Post Illicit Discharge Prevention Information on Web Site	42	$1,362	$136	$1,498
5. Stormwater System Map	0			$0
6. Illicit Discharge Ordinance	92	$3,110	$311	$3,421
7. Program to Detect and Address Illicit Discharges	46	$1,428	$143	$1,571
8. Minimize Landscape Irrigation Runoff	30	$984	$98	$1,082
9. Promote Commute Alternatives for Municipal Employees and the Public	0			
10.Performance Standards	0			
Subtotal	335	$10,731	$6,073	$16,804
Construction Site Stormwater (Section VI)				
1. Evaluate and Update Regulatory Authority and Procedures	174	$6,158	$616	$6,774
2. Construction Site Brochures or Flyers	106	$2,912	$17,291	$20,203
3. Construction Site Inspection and Violation Hotline	0			$0

Program/BMP	**FY '08 Labor Hours**	**Labor**	**Materials**	**Total Costs**
4. Construction Site Education	212	$6,852	$3,685	$10,537
5. Regional Stormwater Control Manual	129.4	$4,097	$410	$4,507
6. Performance Standards				
Subtotal	621.4	$20,019	$22,002	$42,021
Post-construction Stormwater Management in New and Redevelopment (Section VII)				
1. Acceptable Controls	50	$1,826	$183	$2,009
2. Regional Stormwater Control Manual/Tailor to City of Bend	205.4	$6,725	$672	$7,397
3. Operation and Maintenance	124	$3,972	$397	$4,369
4. Evaluate and Update Plan Review and Inspection Programs	214	$6,734	$673	$7,407
5. Post-Construction Control Education	258	$8,960	$896	$9,856
6. Performance Standards				
Subtotal	851.4	$28,217	$2,821	$31,038
Municipal Operations and Maintenance (Section VIII)				
1. Street Sweeping	24	$764	$76	$840
2. Parking Lot Sweeping and 3. Litter Collection and Material Disposal	28	$892	$89	$981
4. Landscape Maintenance Practices	0			$0
5. Improve Catch Basin/ Storm Drain Facilities Cleaning	38	$1,190	$119	$1,309
6. Spill Prevention, Response Materials, and Training				
7. Illicit Dumping				
8. City-owned Corporation Yards, Industrial and Commercial Facilities				
9. Detect and Correct Cross-connections and Leaks				
10. Performance Standards				
Subtotal	90	$2,846	$284	$3,130
Monitoring (Section IX)				
1. Discharges to Deschutes River				
2. Enhanced Water Well Monitoring	584	$16,840	$1,684	$18,524
3. Stormwater Monitoring				
4. Performance Standards				
Subtotal	584	$16,840	$1,684	$18,524
DWPA Investigation, Re-delineation and Management (Section X)				
1. DWPA Delineation			$55,000	$55,000
2. Drinking Water Protection Plan	298	$9,396	$940	$10,336
3. Groundwater Risk Evaluation Study	104	$3,608	$361	$3,969
Subtotal	402	$13,004	$56,301	$69,305
Total	**6,696**	**$217,242**	**$106,724**	**$323,966**

*Includes consultant costs + 10% of labor assumed.
Note: Costs do not include those activities underway prior to creation of the stormwater utility.

Engineering and Project Management: This function involves implementation of neighborhood projects as they are developed. The engineering element will provide lead technical support for all stormwater program areas and be a direct service provider in the area of plan review, design, field inspection, and enforcement. Although project management will be an increasingly important function, emphasis will also be placed on both structural and non-structural program planning. Initial program priorities will include preparing consistent design criteria and standards and developing an accurate stormwater system inventory. This SMP will be managed within this program function. A complete physical feature inventory and condition assessment of the stormwater system within the service area has not been completed, but will be an important element within this program heading.

Regulatory functions of nonstructural aspects of the stormwater system include enforcement and oversight of stormwater policies within the City. It is through enforcement of the regulatory provisions that the overall Stormwater Management Program will be applied on a consistent basis and maximizes nonpoint load reductions from all areas of Bend. This mechanism also provides the means to monitor the consistent application of standards and criteria to provide a uniform level of water quality and quantity protection to Bend citizens.

Budget Estimate = $110,000 for FY 2007-2008

Public Information: The public information component includes expenditures for public awareness brochures and flyers about the stormwater program. Newsletters about onsite controls for quantity and quality will also be developed. A number of different approaches can be used to integrate the stormwater program into the community. Public education needs to emphasize what can be done through a commitment to stormwater management. Among the approaches considered by the Task Force are using the theme “We All Live Downstream” or stenciling inlet grates with the statement “Drains to the Deschutes.” Programs geared toward grade-school children that show how stormwater systems work and how pollutants get into these systems can be a very effective tool. The use of onsite water quality best management practices regarding issues such as fertilizer application and erosion control should also be part of these education programs.

Budget Estimate = $17,500 for FY 2007-2008

City Administration: Internal City Services and Administration includes the transfers to various City departments for services provided to the stormwater utility, including facility management, administrative support, financial services, and utility billing. City Administration differs from Program Administration costs listed in Table 8.2. Program Administration costs are related to program management for stormwater functions internal to the stormwater program while City Administration functions cross City departments.

The 2007-2008 estimated budget is summarized in Table 8.3.

Annual Budget Estimate = $197,000 for FY 2007-2008

Table 8.3
Total Budget Estimate for Fiscal Year 2007-2008

Stormwater Annual Program Requirements (FY 2007-2008):	
Maintenance	$286,000
Capital Improvement Program	$521,000
Water Quality Management	$324,000
Engineering and Project Management	$110,000
City Administration	$197,000
Total	**$1,438,000**

FY 2007-2008 Total Budget Estimate = $1,438,000

Based on the results of a preliminary impervious surface estimate that took into account the number of single-family residences as well as the City's zoning and commercial development statistics, and the preliminary budget estimate for the utility, a rate recommendation of $4 per ERU per month was made in order to generate the revenue necessary to support the City's estimated program costs. These estimates were developed in advance of the final measurement data prepared by the City through a separate subcontractor.

8.5 TASK FORCE REPORT TO THE BEND CITY COUNCIL

In its final report to the City Council on June 6, 2007, the Task Force noted the following issues affecting stormwater management in the City of Bend:

- The City's stormwater system is not being maintained on a routine or preventative level. This has resulted in more flooding during smaller storm events. Repairs and replacements to the system are long overdue due to lack of funds;
- Bend has not kept up with its infrastructure needs, and has put off building necessary capital facilities.
- Pollutants carried by stormwater to the Deschutes River are affecting water quality;
- The pace of new development and redevelopment is significant, and the City's ability to ensure that developers meet Bend stormwater regulations also needs to increase;
- The public needs to be an active partner in this program, and the City needs to better inform them regarding their role in stormwater quality; and
- Compliance with the NPDES regulations affecting stormwater quality and state UIC requirements affecting dry wells and drill holes are immediate needs, and a long-term expense.

In response to these issues, the Task Force made the following statements to the City Council:

- Bend has significant and largely unfunded needs in terms of stormwater quantity and quality management.
- Bend is required to comply with both federal and state NPDES Phase II and UIC regulations.
- Bend has tremendous water resources and natural systems that are vital to the City's economic and quality-of -life standards. Stormwater is a key factor affecting these systems and should be managed into the future.

- The question is not if but when Bend will begin to address these problems. The City's existing system is largely at or over its design capacity for very small storm events.

- Long-term fixes to the City stormwater system require dedicated and consistent revenues in order to plan for and carry out maintenance and capital improvements.

- The primary funding approach should be a stormwater utility service charge.

- A separate utility is the preferred structure for the funding program because by law, the revenues generated by the utility fee will be dedicated to stormwater management, and the rate can be related to a customer's estimated use or contribution of runoff to the stormwater system.

- The appropriate basis of the service charge should be measured impervious surface coverage because it is consistent and most closely related to runoff factors. It is also reasonable to apply a uniform rate of one ERU to single-family residences.

- Based on a representative sampling of homes in Bend, the average amount of impervious surface for a single-family residence is approximately 3,800 square feet.

- Based on a very preliminary estimate of total impervious coverage, the rate per month per ERU would be about $4.00 to meet the annual rate revenue requirement.

- A credit procedure should be available to non-residential stormwater customers. The credit should be structured to reflect the degree to which constructed facilities or best management practices (BMPs) exceed current standards, and therefore provide a benefit to the utility.

These recommendations were presented to the public in an Open House on May 24, 2007. Comments were provided to the City on issues and concerns. Comments and responses are provided in Appendix D. The Task Force Report was presented to the Bend City Council on June 6, 2007. Following the Task Force process, public hearings, and council briefings, the City Council adopted the recommended $4 monthly utility rate at their regularly scheduled meeting on June 20, 2007 and specified that any revenues above the budgeted amount be used for stormwater infrastructure improvements. The stormwater utility was implemented July 1, 2007. Complete meeting summaries from each Task Force meeting, Issue Papers, summary reports, and recommendations are included in Appendix D.

The stormwater projects identified in this SMP are extensive. The cost of the proposed stormwater projects will require more funds than can be raised through the stormwater utility rate. Other potential sources of funding for the stormwater projects are listed below.

The rate adopted by the Bend City Council in June 2007 primarily focused on the programmatic elements of utility operations. It was expected that as the full scope of the capital improvements were identified through this SMP, both a revised rate and a new stormwater system development charge (SDC) would be considered by the Council. It is also anticipated that some construction cost sharing can be achieved by combining efforts with other utilities, such as sanitary and water line construction. The City should also consider applying for grant funding, and taking advantage of low interest loans available for public projects through the State Revolving Loan Fund. In the event that federal money becomes available in future years, the City should apply for any appropriate funding, particularly for federally mandated work. Finally, Bend's establishment of the stormwater utility and service charge does allow the City to issue revenue bonds for stormwater capital projects. Under this bonding scenario both stormwater utility rates as well as SDC revenues can be used to pay back both the principal and interest for these bonds.

The flooding complaint list and estimated costs for construction of the highest priority problem flooding areas informed the Task Force about the magnitude of the infrastructure problem and the expense of addressing existing problem areas. Costs for constructing the five highest priority flooding problems were presented to the Task Force and were incorporated into budgets developed to determine the appropriate monthly stormwater utility fee.

8.6 STORMWATER UTILITY UPDATE

The City of Bend's Stormwater Utility formation was completed in April 2007. Based on a $4 per ERU per month, the stormwater utility provides about $2.4 million per year for stormwater management activities. Fees pay for a comprehensive stormwater program including: operation and maintenance of stormwater facilities, engineering and project management, water quality management, utility administration and public response, as well as setting aside funds for capital improvement projects. Table 8.4 provides the City's 2011-12 budget. More information is available at the City's website (http://www.bendoregon.gov/modules/showdocument.aspx?documentid=2123).

Table 8.4
Stormwater Management Budget for Fiscal Year 2011-2012

Stormwater Management Budget (Fiscal Year 2011-2012):	
Operation and Maintenance	$956,000
Engineering and Project Management	$776,000
Capital Improvement Projects	$1,514,000[1]
Water Quality Management	$430,000
Utility Administration & Public Response	$417,000
Total	**$4,093,000**
Note: [1]Current Capital Improvement Budget is $1,514,000, based on carryover from previous years and an annual budget of $300,000	

9.0 STORMWATER INFRASTRUCTURE IMPROVEMENT OPTIONS

9.1 OVERVIEW

A number of options were evaluated for addressing stormwater issues in the City of Bend. Funds are limited and it is important to maximize benefits of capital improvement projects while addressing stormwater flooding, water quality regulations, and public concerns. Rapid development and increases in impervious surface area have increased flooding within the City despite the relatively low 11.7 inches of average annual precipitation and exacerbate water quality concerns for both surface and underground stormwater discharges. In public meetings, citizens have expressed concern about proposals that would cause the City to discharge more stormwater to the Deschutes River, which could result in negative impacts from higher flows and increased pollutant discharges.

The City needs to take into account costs of construction and maintenance, protecting water quality, solving chronic and increasing flooding problems, and meeting regulatory requirements, as it implements its stormwater program. Because of the challenging topography, lack of adequate infrastructure, and the cost of building pipelines in rock, it is necessary to evaluate a number of options.

Water quality regulations may indicate the need for different levels of treatment, a potentially very expensive option. Treatment can be provided in a number of ways, including using underground filters or other mechanical devices, natural systems, or a treatment train with a combination of natural and structural systems.

Stormwater quality requirements cannot be met unless stormwater quantity (flow rate and volume) is properly managed. Runoff that bypasses collection, conveyance and treatment components because they are under designed will not be treated before it is injected underground or discharged to the river.

Possible solutions to the stormwater drainage and water quality problems evaluated and discussed herein are listed below. Some of these options may not be applicable in some parts of the City.

- Continue using dry wells where geotechnical conditions are appropriate, including appropriate pretreatment, where necessary.

- Pipe with pretreatment as necessary to the Deschutes River (not preferred), or to a regional detention facility.
- Construct piped systems with regional detention and treatment in strategic locations.
- Implement LID techniques on City property and require their use for all new development and redevelopment.
- Construct piped gravity system to discharge at the Water Reclamation Facility.
- Design and construct a combination of systems described above.

9.2 DRY WELLS AND DRILL HOLES

Dry wells and drill holes have been used for many years with success in much of the City. Until recently, infiltration through dry wells and drill holes has been the stormwater disposal method of choice by both the public and private sector. Without a piped drainage system, there is no stormwater network for connecting new development. The apparent low cost of dry wells and drill holes without flow management and pretreatment perpetuates their use even in areas with low infiltration rates. Dry wells and drill holes can become ineffective over time if adequate precautions are not taken. The City conducted a UIC Risk Analysis that indicated drywells in Bend may lose their capacity by an average of 8 gpm per year, a small decline in infiltration over time (GSI, 2011a). Trends related to capacity loss for drill holes over time were not able to be defined in a statistically-significant manner. As observed by the City, over a period of 5 years or less, road traction materials (cinders/basalt) used on roadways in the winter along with other sediments and debris often resulting from construction activities may accumulate in dry wells and drill holes in areas without appropriate erosion and sediment control protection and without appropriate inspection and maintenance schedules. In such cases, the dry wells and drill holes may lose their infiltration capacity prematurely. The best defense against dry wells and drill holes failing due to plugging is to prevent erosion and remove sediment and debris by means of sweeping and pretreatment. Catch basins and sedimentation manholes along with bioretention swales and other practices are being evaluated by the City to establish efficiency of these facilities to remove sediment from stormwater runoff. The City is currently tracking and researching operation and maintenance data to refine cleaning schedules for catch basins and sedimentation manholes, manufactured treatment systems, and other facilities. Extended detention and filters perform well for sediment removal, and hydrodynamic separators may be acceptable in some applications. Unpaved streets and roads, road traction materials, and poor erosion control during and after construction are also major contributors to early dry well and drill hole failures. Poor dry well construction practices and location of inlets also contribute to the problem. If catch basins are not properly placed, stormwater from intense storms can bypass the inlets and cause flooding due to the catch basins being too far from the curb or the pavement being lower than the catch basin inlets.

Bend's drainage systems do not include any provisions for capturing spills besides catch basins and sedimentation manholes before they enter the river or disappear underground. Spills, therefore, pose a high risk of environmental damage and expensive remediation. The risk is particularly acute at the railroad underpasses and on streets with heavy truck traffic, and within wellhead protection areas and areas that drain to the river.

As the number of UICs without adequate pretreatment and spill protection continues to increase, the risks of groundwater contamination also increase. State and federal laws and regulations require that drinking water supplies and groundwater be protected from contamination. The City is committed to protecting the groundwater its residents rely on for a significant portion of their drinking water. The State of Oregon's UIC regulations implement the SDWA. In the UIC rules and Oregon's Groundwater Protection Rules, groundwater is defined as any water found underground, including seasonal high groundwater and water that mounds around UICs as a result of runoff events. The canals in Bend create large areas of shallow groundwater that extend far beyond the canal easements. Areas with pink tuff, clay layers, and consolidated rock often contain lenses of perched groundwater. The City needed to demonstrate that discharging stormwater to UICs that discharge to groundwater, or are within 500 feet of a drinking water well, will not pose a threat to groundwater. A Groundwater Protectiveness Demonstration project which assessed stormwater discharged through UICs has been conducted by the City (GSI, 2011b). Results of this analysis indicate no negative impacts from stormwater to the water quality of groundwater. As part of the effort, the City checked UICs within 300 feet of canals and have found no standing water that would signify canal infiltration resulting in "wet feet".

The City currently is responsible for about 5,600 UICs and there are an unknown number of private UICs within the UGB. Due to sizing and clogging challenges, together with spill risks associated with their deeper depths, the City does not promote drill holes as an appropriate standard injection device. As existing drill holes come to the end of their life they should be replaced by more reliable facilities. Drywells and pretreatment devices need to be protected from the high sediment loads from unpaved streets, erosion, and road traction material by an efficient upstream sediment removal device or effective operational controls. In almost all applications, the design should include upstream detention, or LID, in order to manage flow to the stormwater system and help remove solids.

Situating detention and sediment removal as near as possible to the stormwater's point of origin is highly desirable. Detention greatly reduces peak flow rates and consequently aids in reduced flooding. Detention, with appropriate design features, also helps remove sediment, thereby protecting UICs from erosion and plugging.

9.3 PIPE AND PUMP TO A REGIONAL DETENTION FACILITY OR TO THE DESCHUTES RIVER

As discussed in Chapter 2, the natural topography, in addition to roads and canals, prevents drainage of parts of the City to the Deschutes River or Tumalo Creek. Where UICs work well, they help overcome drainage barriers to stormwater flow and help to infiltrate the stormwater closer to the source of creation as in a more natural setting. A limited pipe system can help overcome drainage barriers as well. Stormwater accumulates in natural depressions where, before development, it eventually infiltrated into the ground, or dissipated through evaporation and evapotranspiration or overflowed to the river. In soils left in their natural condition, evapotranspiration alone can dissipate approximately 43 inches annually in Bend (Agrimet, 2012). Where development covers over these natural soils, the area available for infiltration and evapotranspiration is greatly reduced and drainage to the river increases. Manmade barriers also interfere with natural drainage. When constructed disposal methods cannot infiltrate enough runoff to make up for these losses, flooding occurs. One solution is to install a piped system to collect and convey the stormwater to a regional retention/infiltration pond or surface water body. Undeveloped natural depression areas should be evaluated and acquired if they are in a suitable location for stormwater detention or disposal.

Many areas of the City naturally drain by gravity toward the Deschutes River. Piping of these areas would be recommended to be part of the overall stormwater solution only as a final resort if UICs or regional detention is not appropriate and then only if specifically treated to address those pollutants of concern in the receiving water that are stormwater-related. The City's need to better manage its stormwater quality is not solely determined by federal and state mandated regulatory requirements, but also by the City's responsibility to protect the quality of the Deschutes River and Tumalo Creek. Therefore, all drainage to these surface waters should be treated and discharged indirectly if possible to address pollutants of concern and meet water quality requirements. Only a minor amount of this drainage is currently treated.

9.4 REGIONAL DETENTION, TREATMENT, AND DISPOSAL

Another option is to use gravity flow piping and open channels to convey stormwater to natural depressions, where it can either be retained and allowed to infiltrate, or detained and pumped to another location for disposal. There are several locations throughout the City where this option may be the most desirable way to solve existing drainage problems and allow development to proceed. Regional detention and treatment systems can provide multiple benefits, including some forms of recreation and enhanced natural areas, in addition to functioning as stormwater facilities. Regional systems can also be amenities to the neighborhoods.

One option to finance regional systems is to create a special district for funding the capital improvements and the ongoing maintenance of the facility. In such a case, properties that benefit from the system would be assessed a charge to cover the construction and ongoing maintenance and operating costs.

Vacant land is still available in many areas of the City, and some of these lands are suitable for stormwater facilities, especially detention facilities. Even considering land acquisition costs, detention facilities often will be cost-effective because they greatly reduce downstream system costs.

New developments can provide land for regional detention, treatment and, possibly, disposal. Setting aside areas at the time of planning for large developments can provide a network of regional facilities for storage, treatment, and disposal of stormwater. This set-aside of land can be made a condition for development approval. Alternatively, the City can acquire land, build a regional facility, and require new developments to purchase rights to use the facility. With either approach, clearly defined roles, responsibilities, and requirements for operation, maintenance, and management of the systems must be recorded and communicated for ongoing success.

9.5 IMPLEMENT LOW IMPACT DEVELOPMENT SYSTEMS

LID techniques should be evaluated for stormwater management in all new development and redevelopment for both public and private projects in the City. The City's development code (Bend Code Title 16), the standards and specifications and the COSM (2010) encourage the use of LID where appropriate.

Implementation of LID for all new development and redevelopment, where appropriate, will minimize flow rates and volumes and reduce the amount of soil erosion within the City. Solutions such as reducing impervious surface areas through site design, installation of vegetated infiltration swales or filter strips, landscape detention, bioretention stormwater planters, extended detention dry ponds and grassy swales would be standard recommendations as appropriate. Upon development of proved demonstration projects, alternatives such as pervious pavement, and street tree applications using structural soils should also be considered to address both water quality and quantity. LID projects can be implemented as needed throughout the majority of the City. One of the advantages of LID is that it reduces stormwater pollutants, peak flows, and volumes at the points of origin. In addition, it helps maintain groundwater recharge patterns.

9.6 PIPE STORMWATER TO THE WATER RECLAMATION FACILITY

Bend's WRF, about 3 miles northeast of the City, provides treatment for the City's sanitary sewer flows. The City owns approximately one thousand acres of land at the WRF where infiltration ponds could be constructed for stormwater disposal. Large areas on the east side of the City naturally drain in the direction of the WRF. Sanitary lines already exist for most of the City, but a recently completed Wastewater Master Plan identifies a number of new interceptors planned to enhance sanitary sewer service throughout Bend, particularly for new development. Two proposed new gravity flow wastewater interceptors are expected to connect to the WRF. If gravity flow stormwater pipe were to be installed at the same time, adjacent to the new sewer pipe, the City could reduce overall construction costs and derive other benefits, such as savings on rock excavation and road repairs, and reduced inconvenience to the community.

Piping stormwater for surface detention treatment at the City's Water Reclamation Facility (WRF) was extensively studied and is currently tabled despite potential cost-savings resulting from combined project efficiencies due to the cost of implementation and the lack of funding. Additional details are provided in Appendix E.

9.7 IMPLEMENT A COMBINATION OF SYSTEMS

Each of the options listed above, with the exception of the option to pipe all stormwater to the WRF, can be used in combination to address stormwater. For example, LID can be used to the degree that there is space and infiltration capacity, in all areas of the City. Dry wells can be used in combination with LID, or also with regional detention. Using infiltration where appropriate can reduce the amount of storage required for detention or retention, potentially resulting in reduced costs for land acquisition and rock removal. As the subbasin plans are developed, as described in Appendix G, the City can implement a variety of options to address stormwater drainage and water quality.

9.8 ADDITIONAL FACTORS FOR STORMWATER MANAGEMENT

Additional factors for the City to consider in addressing stormwater management include:

- Combine construction of stormwater infrastructure with construction of other utilities, such as roads, sanitary sewers, and water lines. Infrastructure improvements would be coordinated with other utility infrastructure improvements as possible. This saves construction costs and minimizes community disruptions. The City should formalize its internal procedures to facilitate seeking opportunities for joint projects.
- Coordinate with regional and local agencies. Work with ODOT and Bend Parks and Recreation District (BPRD) to develop dual-purpose facilities that serve transportation or recreation purposes as well as stormwater management purposes.

  The City has already negotiated an Intergovernmental Agreement with ODOT. Both agencies have areas that can be used for stormwater purposes while providing improvements consistent with the agency’s objectives. Currently, the City is working with ODOT to use portions of the cloverleaf at Colorado Avenue as part of the solution to the Third Street, Franklin, and potentially Greenwood underpass flooding problems.

  Although this Master Plan project is being managed by the Engineering and Infrastructure Planning Department together with the Public Works Department, the departments have and will continue to coordinate with and seek input from other City Departments such as Community Development, Transportation, Private, Engineering, Finance, Water, Administration, and Water Reclamation.

- Develop plans and facilities to prevent or respond to spills from railroads and streets that may threaten surface or groundwater.
- Complete an accurate stormwater drainage system asset management in GIS.
- Develop a hydrology model using GIS data for further analysis in order to refine recommended drainage systems.

9.9 COMPARISON OF OPTIONS

Table 9.1 provides a comparison of the general advantages and disadvantages of options discussed in this chapter.

Table 9.1
Comparison of Options

	Low Impact Development	Regional Detention	Infiltration – Dry Wells	Piped System
Advantages	LID measures tend to reduce piping and impervious surface costs over traditional systems. Potential for early action by the City providing drainage relief; recharging of groundwater and improvements to water quality. These dispersed systems provide storage for smaller storms, allowing gradual release to downstream systems and evaporation and transpiration to take place between storms.	Suitable for new development and vacant properties. Provides relatively quick solution as it is not dependent upon upstream and downstream drainage facilities. Could reduce pipe costs.	Expedient solution and relatively inexpensive to construct.	Long-term drainage solution.
Disadvant-ages	Concern over some locally untested LID techniques such as porous pavement. Codes, standards, specifications, policies, and interpretations may need to be changed to allow. Proven demonstration projects may be needed prior to widespread acceptance. Non-traditional maintenance (vegetation management) may cause concern for public works crews.	Takes property out of development and taxable status. Requires ongoing maintenance that is not typical of public works projects, i.e., vegetation control; Property acquisition and construction of large facilities can be expensive.	Systems may clog due to use of cinders; Systems need to be replaced when no longer functioning; May need pretreatment facilities or increased maintenance for longevity and to protect groundwater; larger number of specific sites to travel to for maintenance. Potential impacts to quality of groundwater (e.g., significant spill).	Expensive solution due to topography and rocky terrain; Will take many years to construct. Full segments must be built to work appropriately; cannot be easily piecemealed.

Soils in the City are a potentially limiting factor for implementation of infiltration and/or injection in all areas. Section 2.9 provides information on geology underlying the City and describes the infiltration characteristics of four major geological conditions. Generally, the eastern part of the City and the northwest provide good to moderate geotechnical conditions for infiltration and UICs. The southwestern part of the City includes soils that drain very poorly. Although these are general conditions, individual sites may vary; there may be well draining pockets in areas in the southwest part of Bend generally underlain with pink tuff. Infiltration testing must occur to verify the infiltration capacity of any specific site. This information was used to generate 3 drainages areas within the City to compare stormwater management options.

These drainage areas are show in Figure 9.1 and are as follows:

- Drainage Area A: Areas of the City that have well-draining soils
- Drainage Area B: Areas of the City that are steep will soils that are not well-draining
- Drainage Area C: Areas of the City that have poorly-draining soils

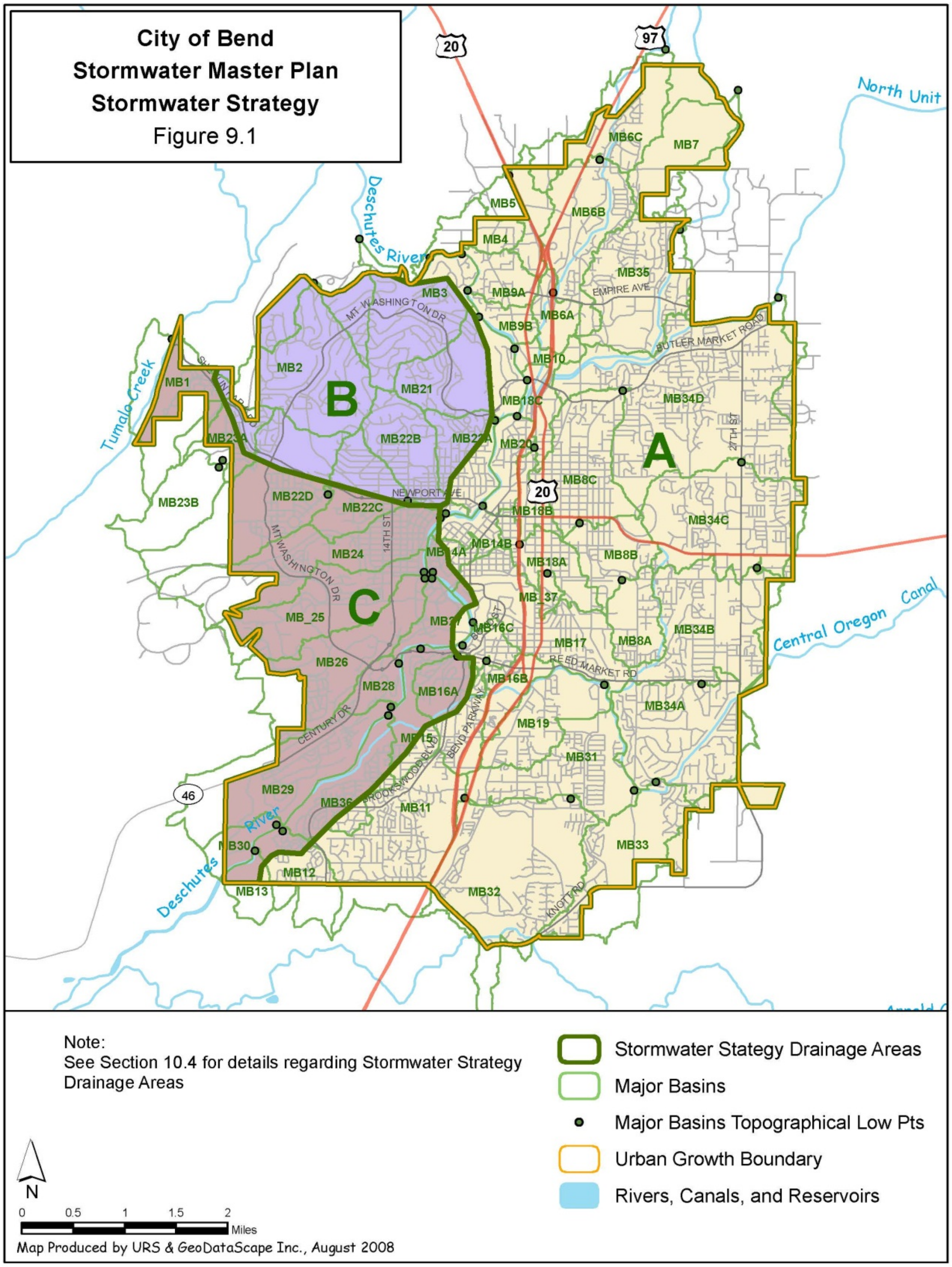
The stormwater management options were further evaluated by the three drainage areas. Table 9.2 below summarizes this evaluation.

Table 9.2
Comparison of Options by Location

Drainage Area[1], see Figure 9.1		**Low Impact Development**	**Regional Detention**	**Infiltration – Dry Wells**	**Piped System**
Area A – well draining soils	Advantage	Encouraged throughout.	Suitable for new development and vacant properties.	Generally acceptable solution where appropriate.	Piping to Deschutes River with pretreatment for drainage basins adjacent to River provides long-term solution.
	Disadvant-age	Additional maintenance needs.	Challenge to identify suitable locations for drainage and property availability.	Potential impacts to quality of groundwater (e.g., significant spill).	Very expensive, particularly as distances from the river increase, and topography requires pumping. Regulatory requirements will

Drainage Area[1], see Figure 9.1		Low Impact Development	Regional Detention	Infiltration – Dry Wells	Piped System
					become more strict over the planning period (NPDES MS4 permit reissuance, TMDL, endangered species, etc.)
Area B – steep and not well-draining soils	Advantage	Encouraged throughout with overflows and downstream drainage system	Limited suitability due to steep slopes.	Limited suitability due to steep slopes.	Pipe to regional detention; Long-term drainage solution.
	Disadvant-age	Soils do not allow infiltration in many areas. May need to consider evaporative systems.	Potentially expensive due to need for rock excavation.	Soils not suitable for infiltration. Requires additional testing to verify sufficient infiltration capacity. Potential impacts to quality of groundwater (e.g., significant spill).	Expensive solution due to topography and rocky terrain; could impact surface water quality depending on outfall location. Will take many years to construct. Not easy to piecemeal.
Area C – poorly draining soils	Advantage	Generally acceptable solution with overflows to downstream drainage.	Suitable for new development and vacant properties.	Generally acceptable solution where appropriate.	To WRF; Long-term drainage solution.
	Disadvant-age	Additional maintenance needs.	Potentially expensive due to need for rock excavation and property acquisition.	Soils not suitable for infiltration. Requires additional testing to verify sufficient infiltration capacity. Potential impacts to quality of groundwater (e.g., significant spill).	Expensive solution due to topography and rocky terrain; Will take many years to construct. Needs to be fully constructed to operate.

Notes:
1. See GeoEngineers Report, Stormwater Infiltration Evaluation, City of Bend, Oregon, October 4, 2007, for further information.


City of Bend
Stormwater Master Plan
Stormwater Strategy
Figure 9.1
A
B
C
Deschutes River
North Unit
Tumalo Creek
Central Oregon Canal
20
97
46
MT WASHINGTON DR
EMPIRE AVE
BUTLER MARKET ROAD
NEWPORT AVE
14TH ST
27TH ST
REED MARKET RD
CENTURY DR
BROOKSWOOD BLVD
BEND PARKWAY
KNOTT RD
MB1
MB2
MB3
MB4
MB5
MB6A
MB6B
MB6C
MB7
MB8A
MB8B
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MB32
MB33
MB34A
MB34B
MB34C
MB34D
MB35
MB36
MB_37
Note:
See Section 10.4 for details regarding Stormwater Strategy Drainage Areas
Stormwater Stategy Drainage Areas
Major Basins
Major Basins Topographical Low Pts
Urban Growth Boundary
Rivers, Canals, and Reservoirs
N
0 0.5 1 1.5 2
Miles
Map Produced by URS & GeoDataScape Inc., August 2008

9.10 SUMMARY

Each of the options discussed above, with the exception of Section 9.6, offers part of the solution for providing better stormwater management in the City. Site designs using LID techniques suitable to the site can see cost savings (e.g., reduced impervious surface area). The use of dispersed UIC systems with pretreatment can be very cost effective and efficient in many areas of the City, particularly east of the Deschutes River. Areas west of the Deschutes River may be served better with a piped system to a regional control facility due to the limited infiltration capacity of the soils. Avoiding new and minimizing existing outfalls to the Deschutes River is preferred. Therefore the option to use a combination of systems is considered to be the most appropriate option to address stormwater management within the City over the next 20 years. This option provides the City with the most flexibility, and allows the City to start implementing storm drainage immediately with construction of new development/redevelopment projects and as needed in the more critical areas, such as areas of frequent flooding, safety hazards, and property damage (see Section 4.2.3). Sequencing of projects with the approach identified herein has great flexibility in the ability to construct improvements as needed throughout the City. This allows the City to address negative impacts to surface waters over time and as funding allows. Hydromodification impacts would be minimized and water quality protected. Chapter 10 discusses the implementation strategy for addressing stormwater in the City of Bend.

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10.0 RECOMMENDED STORMWATER MANAGEMENT STRATEGY

10.1 BACKGROUND

At the start of the SMP process drainage solutions focused on elimination of UICs and development of alternatives that included regional storage/treatment and a piped collection system. This was largely due to the cost implications associated with required removal and treatment of UICs at the time, which has since been significantly reduced. Cost estimates were developed for that strategy involving planning for a piped system that was included in the 2008 public draft and are provided in Appendix E.

In addition to the stormwater management approaches that were evaluated, this SMP has made additional recommendations for the City to better understand its stormwater system and refine its management strategy. Several of these recommendations have already been completed, and the City will continue to conduct studies recommended in this SMP but that are not yet completed. This will help the City to continue to gain a better understanding of its system and use the results of those to refine the strategy on an area specific and site specific basis. Table 10.1 below lists the recommendations made to the City of Bend, and their status of completion.

Table 10.1: Stormwater Management Recommendations

Recommendation	Status
Promote the use of low-impact development (LID) principles in all City projects; and require private projects to consider LID principles.	Done
Develop standards for LID facilities such as bioretention systems and planters, to promote and facilitate their use	Adopted standards in COSM
Consider the performance, reliability, maintenance requirements and life-time costs in selecting pretreatment devices.	In process
Continue to develop a better understanding of water quality in stormwater runoff by the continuation of monitoring water quality in UICs, river outfalls and the Deschutes River.	Continuing

Install efficient spill/sediment traps in the storm drain system ahead of discharges to either surface waters or groundwater. The City has already implemented some measures to reduce the negative effects of traction materials.	In process
Conduct a demonstration project(s) using permeable pavement.	In process
Perform a UIC infiltration study	Done
Perform a Groundwater Risk Analysis	Done
Update Drinking Water Protection Areas	Done
Evaluate long range funding needs	Done
Implement a pipe system rehabilitation program	Proposed

10.2 STORMWATER MANAGEMENT APPROACHES CONSIDERED

The City considered three different approaches for implementing the combined systems option with each approach including a different level of effort for constructing new projects and required funding. The approaches were based on the prioritized capital improvement needs list for stormwater that was updated in April 2011. All three approaches included an ongoing pipe replacement program and spill risk abatement improvement program for underground drinking water protection. All approaches include an increase to the stormwater utility charge.

Approach 1 seeks to mimic the level of effort for capital improvement projects that City Council set in 2007, accounting for inflationary considerations. Approach 1 included six (6) new projects (in addition to the pipe replacement and spill risk abatement programs) and a total estimated cost of $11.4 M over 20 years. The six projects included the 3rd Street underpass project that is finalizing construction and this stormwater master plan. Approach 2 is a consistent approach with a target of approximately one infrastructure improvement project per year on average. Approach 2 includes 16 new projects (in addition to the pipe replacement and spill risk abatement programs) and a total estimated cost of $17.0 M over 20 years. Approach 3 sets as a goal to correct all the known (as of April 2011) problem areas within the 20 year planning period, recognizing that stormwater facilities will continue to fall into disrepair over the planning period as well. Approach 3 includes 58 new projects (in addition to the pipe replacement and spill risk abatement programs) and a total estimated cost of $25.2 M over 20 years.

The City presented all three approaches along with the associated stormwater utility rate increases to the public with two public open houses on April 9 and 10, 2014. Input was also obtained from the City's Infrastructure Advisory Committee (IAC) and the City's Stormwater Quality Public Advisory Group. The City Council decided to move forward with Approach 3 at the City Council work session on May 7, 2014, using input gathered from the public and the IAC.

10.3 SELECTED APPROACH

Approach 3 includes 58 projects to address all stormwater problem areas identified by the City in April 2011 (CH2MHill, 2011). The projects included in Approach 3 address stormwater issues throughout the City and include several different methods for managing stormwater as appropriate based on area and site conditions. Projects include drainage improvement plans, pump station improvements, LID, drywell pre-treatment, piping, and other stormwater project types. As pipes are coming to the end of their useful life and are in need of replacement, as part of the pipe replacement program options for abandoning those outfalls to the river and replacing with other options such as UIC disposal will be considered. Where there are efficiencies to do so, some projects were combined for cost-savings reasons. Approach 3 incorporates the following general strategies by drainage area as shown in Figure 9.1.

- Areas generally located east of the Deschutes River (Drainage Area A, see Figure 9.1):
    - These are generally well draining soils and surface controls and drywells with sufficient LID and pretreatment may work well and are considered a primary strategy for source control of water quality and quantity.
    - Regional detention remains a viable option in this area and should be included in the solutions established for regional stormwater planning within a major basin.

- Areas generally west of the Deschutes River (Drainage areas B and C, see Figure 9.1):
  - o Soils in the southwest part of town may not drain sufficiently to provide capacity through UICs. Additional measures to ensure adequate infiltration may be necessary if natural drainage is poor. Site specific geotechnical conditions will need to be examined carefully. Increased volume may be required for UICs to assure proper function. Appropriate LID techniques should be evaluated. In problem drainage areas, see Figure 4.2, a primary strategy for the southwest area of the City is installation of a combination of piped systems with pretreatment and retention/detention facilities where possible.
  - o Although the northwest part of the City, known as Awbrey Butte, may provide moderate infiltration, the steep slopes may cause downslope flooding or instability of soils if saturated. Appropriate LID techniques combined with piping to regional detention/retention systems are recommended for this area when necessary for safety.

The strategies outlined above do not preclude the use of regional detention in Drainage Area A or UICs in Drainage Areas B and C if it makes sense on a site-specific basis. Approach 3 follows the hierarchy of stormwater solutions outlined below, which stresses the importance of addressing water quality as well as water quantity. This set of solutions is to be implemented sequentially:

1. Reduce runoff volumes and polluted runoff through acceptable LID designs and source control measures.
2. Address stormwater drainage with surface systems, such as above ground bioretention facilities, to the degree possible through on site source controls.
   a. Minimum capacity should be provided for storage of a 25-year storm with safe passage of any overflows for a 100-year storm.
   b. In the event there are special circumstances, such as the potential for extensive flooding, safety, or other concern, design capacity should be provided for a 50-year storm with safe passage for a 100-year storm. Criteria for determination of treatment capacity will be developed by the City through the establishment of design standards.

3. If surface source controls, such as a swale or a rain garden, do not provide adequate capacity, add an overflow to a drywell or a regional above ground retention facility.
4. If surface controls are inadequate for treatment of a water quality storm, provide additional treatment controls necessary to meet water quality regulations prior to discharging stormwater to a UIC, regional facility or to, only as a last resort, a surface waterbody. Additional treatment controls to be considered include sedimentation manholes and compost filter demonstration projects and should focus on the pollutants of concern for the area the stormwater is draining. Effectiveness and lifecycle costs including long term operation and maintenance costs should be accounted for in selecting facilities.

Table 10.2 lists and provides a short description of all projects included in Approach 3. Figure 10.1 shows the locations of the projects and also indicates which subbasin and major basin each project is located in. This provides information on where drainage improvements would be recognized on a basin-level. Timing of the projects should be coordinated with infrastructure improvements for water, wastewater, and transportation to the degree practicable.

Table 10.2: Stormwater Infrastructure Improvement Projects for Selected Stormwater Approach

Project Name	Description
Stormwater Master Plan	*Note: This project is underway and moving towards finalization using stormwater utility funds*. This project provides a plan for urban drainage services by identifying stormwater issues, evaluating the needs, and identifying potential solutions in a manner that informs the City for planning and budgetary purposes.
MB37 - Drainage Improvement Project 1	*Note: With existing utility funding, the City has completed the main construction phase and is currently moving towards final completion/approval.* This project acts to protect underground drinking water quality by improving drainage infiltration in the ~55 acre basin and replacing deep drill holes in a high spill risk area with a vault, pump station and pipe to a regional retention basin at the Colorado interchange. Additional health and safety benefits are realized by minimizing the number of times the Third Street railroad undercrossing, a major north-south thoroughfare is closed due to flooding.
MB22A - Pump Station Project	*Note: The City is in the construction phase of this utility-funded project.* This is the final phase of a 13-acre sub-drainage basin improvement that included development of an infiltration swale to protect water quality of the Deschutes River as part of a flooding control drainage improvement project for an area that was experiencing structure damage. This phase involves installing a pump station in a storm drainage vault.

Table 10.2: Stormwater Infrastructure Improvement Projects for Selected Stormwater Approach

Project Name	Description
Butte Drainage Improvement Plan	This project would develop a plan to improve stormwater management by considering strategies such as Low Impact Development, regional detention, dry wells, and stormwater piping based on site specific details such as topography, geology, groundwater information, and existing stormwater facilities. Project benefits include improved drainage, reduced flooding, enhanced water quality, drinking water protection, increased efficiency with operations and maintenance, and regulatory compliance.
MB18A - Drainage Improvement Project 1	This project seeks to improve drainage in a mainly commercial 257-acre drainage basin wherein flooding problems typically present in the Franklin Street underpass. The project involves a new pump station and a solution that integrates with that for the Greenwood underpass project (MB18B #1). The project will provide health and safety, and access benefits by reducing the number of times this east-west undercrossing is closed due to flooding, providing improved access to the downtown and Third Street commercial areas along with residential access; and improve an antiquated drainage structure that poses safety problems for maintenance personnel.
MB18B - Drainage Improvement Project 1	This project seeks to improve drainage in a 133-acre drainage basin wherein flooding problems typically present in the Greenwood Avenue railroad underpass. The project will provide health and safety, and access benefits by reducing the number of times this east-west undercrossing is closed due to flooding.
UIC Facility Upgrade Program	The UIC water quality upgrade program seeks to provide enhancements to existing underground injection controls (UICs) to protect underground drinking water sources for all citizens from spill threats and stormwater pollutants. The UIC upgrade program will first focus on drill holes and then dry wells, and will focus on those located in wellhead protection areas as the highest priority.
Storm Drain Line Replacement Program	This project would upgrade existing storm drain lines throughout the City that are in various states of disrepair. Project benefits include reduced flooding and improved stormwater drainage. Initial work will focus on the piped municipal separate storm system that drains to the river.
MB23A - Drainage Improvement Project 1	This project would improve the stormwater drainage within the 208 acre drainage basin where problems present in the residential Shevlin Meadows subdivision by installing new drainage facilities in the underserved area. Project benefits include reduced flooding, and reduced property damage risk.
MB16C - Drainage Improvement Project 1	This project would design and construct two stormwater retention basins on City owned properties at SW Roosevelt Ave and SW McKinley Ave located within a 114-acre drainage basin to alleviate flooding that is exacerbated by the locate of the wall shielding the parkway that obstructs the normal north-west flow of the stormwater runoff in the residential neighborhoods.. Project benefits include reduced flooding that results in property structure damage of multiple residences, enhanced water quality, and potentially neighborhood aesthetics/ safety.
MB14B - Drainage	This project would involve a new piped system including

Table 10.2: Stormwater Infrastructure Improvement Projects for Selected Stormwater Approach

Project Name	Description
Improvement Project 1	sedimentation manholes and catch basins. The project would help address flooding problems near the downtown business district near Wall Street and Minnesota in the 120 acre drainage basin. Project benefits include reduced flooding and resulting property damage, improving access to businesses during precipitation events, and enhanced water quality protection improvements.
MB18C - Drainage Improvement Project 1	This project would include new drainage improvements to a mainly commercial/industrial basin with new drywells and with stormwater treatment along NE Thurston Ave near Second St. where problems present at a low point. The project would improve drainage in an impervious area where current drill holes do not properly function. Project benefits include reduced flooding, enhanced water quality, and drinking water protection (pre-treatment for UICs), along with operation and maintenance efficiency within the 146 acre drainage basin.
MB8C - Drainage Improvement Project 1	The project would involve regional stormwater drainage and treatment enhancements on NE Seward Ave. within a large mainly residential drainage area that is currently underserved. Project benefits include reduced flooding, reduced property damage, and increased efficiency of operations and maintenance.
MB18A - Drainage Improvement Project 2	This project, located in an industrial commercial area within a drinking water protection area would place a new culvert under SE Textron Drive to improve drainage in the 257 acre drainage basin. Project benefits include reducing flood risk in a manner that helps protect drinking water quality.
MB14B - Drainage Improvement Project 2	This source control project would install a new roof structure over existing dumpsters at a public facility on NW Brooks Ave to prevent runoff from coming into contact with pollutants in an area adjacent to the Deschutes River. Project benefits include water quality.
MB8C - Drainage Improvement Project 2	This project would install a new drywell along the 400 block of NE Revere Ave. where water currently partially blocks a busy road. Project benefits would include improved drainage and water quality, while protecting public safety.
MB22D - Drainage Improvement Project 1	This project would construct a new stormwater swale along the 500 block of NW York Drive to address problems that present at a sag in the 859 acre drainage. Project benefits would include stormwater drainage, enhanced water quality, and aesthetics (roadway landscaping).
MB18B - Drainage Improvement Project 2	This project would replace an existing drill hole in an industrial/commercial area along 1st Street and include treatment to address a problem that presents in the 1400 block of 1st St. Project benefits include stormwater drainage in the 133 acre basin, drinking water protection, and increased operation and maintenance efficiency.
MB18A - Drainage Improvement Project 3	This project, located within a commercial/ industrial area, would replace an existing drill hole along the 700 block of 2nd Street and include treatment. Project benefits include stormwater drainage, drinking water protection, regulatory compliance, and

Table 10.2: Stormwater Infrastructure Improvement Projects for Selected Stormwater Approach

Project Name	Description
	increased operation and maintenance efficiency.
MB14A - Drainage Improvement Project 1	This project would construct a new drywell with treatment along the 700 block of NW Georgia Ave. where problems present in a 106 acre drainage basin. Project benefits include enhanced water quality and regulatory compliance as well as improved drainage and reduced flooding.
Drill Hole Conversion Projects (MB18B, MB18A, MB11, MB16A, MB8B, MB8C, MB32, MB34D, MB22B, MB33)	This collection of projects would replace several drill holes that have reached end of life with more reliable drainage facilities, and provide treatment along the following streets: 1st Street, 2nd Street, SW Granite Drive, Woodriver Drive, NE 3rd Street, NE 12th Street, Parr Lane, NE Waller Drive, NW Trenton Ave, NE Lotno Drive, NE Cordata Drive, Brosterhous Road, and SW McMullin Drive. Project benefits include stormwater drainage, drinking water protection, regulatory compliance, and increased operation and maintenance efficiency.
MB33 - Drainage Improvement Project 1	This project would construct a new stormwater swale along the 60600 block of Newcastle Drive where drainage problems present. Project benefits would include stormwater drainage improvements to protect public health and safety, enhanced water quality, and aesthetics (roadway landscaping) in the 666-acre basin.
MB26 - Drainage Improvement Project 1	This project would repair existing drywells along Yates Road. Project benefits include drinking water protection and drainage improvements.
MB11 - Drainage Improvement Project 1	This project, located in an 866-acre drainage basin, would install new curbing along the 19800 block Nugget Ave. to improve conveyance and prevent public runoff-related property damage. Project benefits would include improved drainage conveyance and aesthetics (street improvements).
MB31 - Drainage Improvement Project 1	This project would construct new sedimentation manholes and new drywells along the 61100 block of Parrell Road where drainage problems present within a 574 acre drainage basin. Project benefits include reduced flooding and improved operations and maintenance efficiency.
MB34D - Drainage Improvement Project 1	This project would construct a new sedimentation manhole and new drywell at the intersection of NE Madison and NE Taylor Ct. to help address drainage issues within this 1,724-acre drainage basin. Project benefits include reduced flooding and enhanced water quality.
MB35 - Drainage Improvement Project 1	This project would construct a new drywell along Eastview Drive to help alleviate flooding issues that present in the 63200 block within the 705-acre drainage basin. Project benefits include improved drainage.
MB22B - Drainage Improvement Project 1	This project would stabilize banks at Awbrey Butte and install new catch basins in this residential area. Stabilizing banks will help prevent erosion, which has been plugging drill holes, causing flooding problems; and the catch basins will help improve conveyance and help protect against property damage. Project benefits include reducing erosion, improved drainage, and reduced flooding.
MB16C - Drainage	This project would install new curbs and grade SW Hill Street in

Table 10.2: Stormwater Infrastructure Improvement Projects for Selected Stormwater Approach

Project Name	Description
Improvement Project 2	the 900 block to improve conveyance and help prevent flooding. Project benefits include improved street drainage and conveyance within a 114-acre drainage basin.
MB34A - Drainage Improvement Project 1	This project located within a 799-acre drainage would incorporate conveyance improvements to protect against property damage and repair an existing drywell along Twin Lakes Loop where problems present in the 61500 block. Project benefits include improved drainage and enhanced water quality.
MC8C - Drainage Improvement Project 3	This project would construct a new stormwater swale along NE Jones Road where problems present in the 2600 block. Project benefits would include stormwater drainage, enhanced water quality, and improved aesthetics (roadway landscaping).
MB25 - Drainage Improvement Project 1	This project would construct a new catch basin and drainage facilities along the 1700 block of SW Forest Ridge Road where problems present in the 606 acre drainage. Project benefits include improved drainage, enhanced water quality, and regulatory compliance.
MB06A - Drainage Improvement Project 1	This project would construct a new catch basin and stormwater swale along Nels Anderson Road where problems present in the 3200 block of the 149-acre drainage basin. Project benefits include improved drainage, enhanced water quality, aesthetics (landscaping), and regulatory requirements.
MB18B - Drainage Improvement Project 3	This project would install new dry wells with appropriate pretreatment in various locations in the area north of US 20 in between US 97 and US Business 97. These projects are designed to help alleviate problem areas that present in the 61600 block of Summer Shade Drive, the alley behind the 1200 block of NE 3rd, the 1100 block of NE Paula Drive, the 1500 block of NE Revere, the 300 block of SW Maricopa Drive and the 900 block of NE 11th. Project benefits include improved stormwater drainage and water quality.
MB18B - Drainage Improvement Project 4	This project would construct a new stormwater swale along Olney Ave. Project benefits would include stormwater drainage, enhanced water quality, reduced flooding, and aesthetics (roadway landscaping).
MB22B - Drainage Improvement Project 2	This project, located within a 375-acre drainage basin, would construct a new asphalt curb, expand the existing collection system along NW Iowa Ave. and improve connections to the existing system. Benefits include improved drainage and conveyance.
MB14A - Drainage Improvement Project 2	This project located in a106 acre drainage would construct a new catch basin and facility improvements to contain drainage and minimize impacts to the river along NW Congress Street for problems that present in the 100 block. Project benefits include improved stormwater drainage and regulatory compliance.
MB34D - Drainage Improvement Project 2	Located within a 1.24-acre drainage basin approximate to Pilot Butte, this project takes measures to improve stormwater conveyance and drainage issues in the drainage area along Neff Road between Juniper Middle School and the sag east of Purcell. The project benefits include conveyance and flooding relief.

Table 10.2: Stormwater Infrastructure Improvement Projects for Selected Stormwater Approach

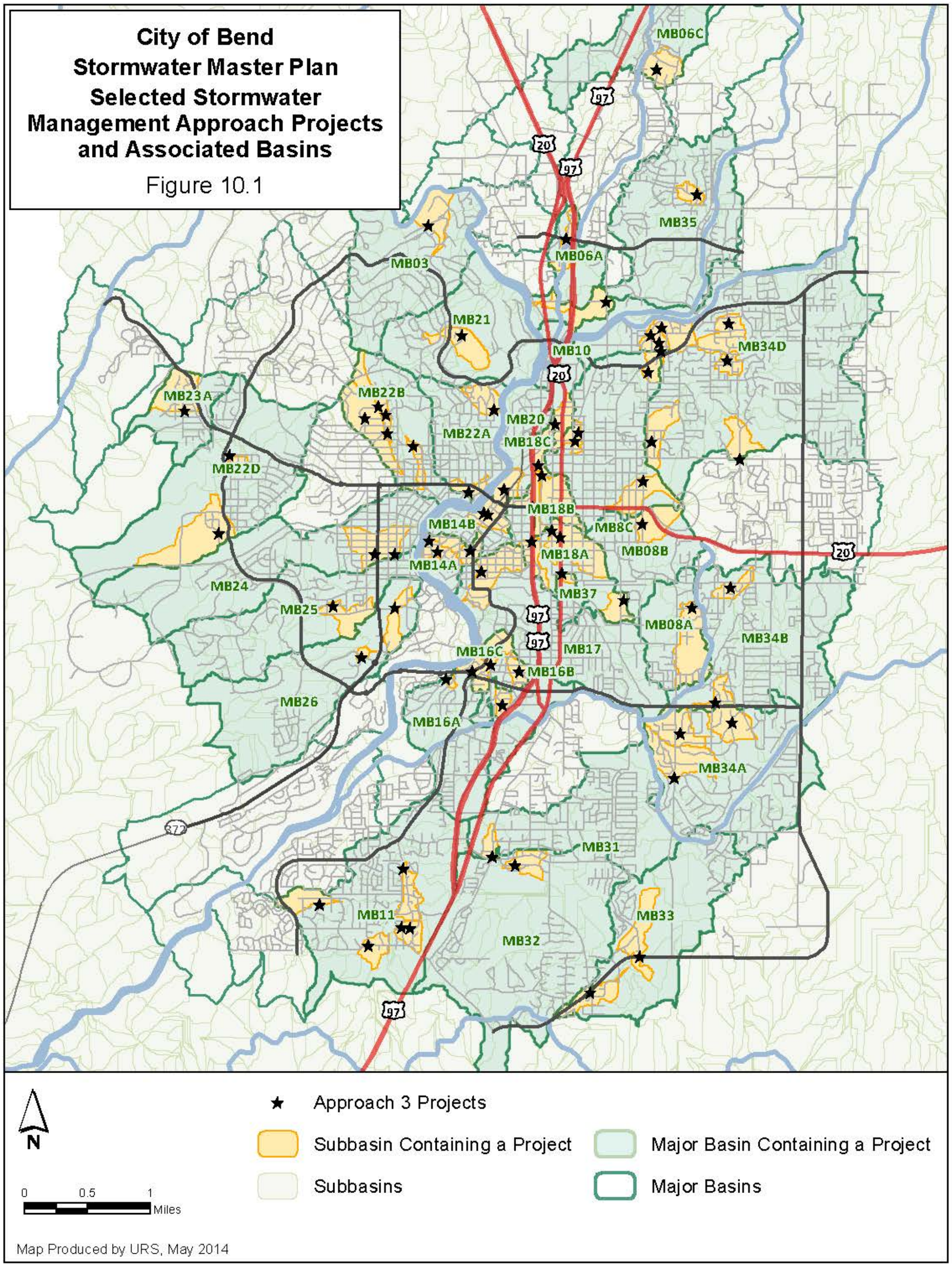
Project Name	Description
MB11 - Drainage Improvement Project 2	This project, located within a 866-acre drainage basin, would construct a new catch basin and stormwater swale along Driftwood Lane where problems present. Project benefits would include stormwater drainage, enhanced water quality, regulatory compliance, and aesthetics (roadway landscaping).
MB17 - Drainage Improvement Project 1	This project would improve stormwater drainage in the 500 block of NW Colorado Avenue in a currently underserved area within a 653-acre drainage basin where problems present at Colorado Avenue and Staats. Project benefits would include stormwater drainage and conveyance improvements.
MB34B - Drainage Improvement Project 1	This project located within a 773-acre drainage basin would construct new catch basins and new drywells or bioswales with treatment where problems present in the 1800 block of SE Arborwood, a residential area. Project benefits include reduced flooding, improved drainage, and enhanced water quality.
MB24 - Drainage Improvement Project 1	This project would connect the area around NW 14th and NW Davenport to an existing stormwater system. Project benefits include improved stormwater drainage and improved conveyance within a 773-acre drainage basin.
MB16B - Drainage Improvement Project 1	This project, located within 190-acre drainage basin, would construct new drainage controls along SW Hayes Ave. where problems present in the 0-100 block. Project benefits include improved stormwater drainage.
MB10 - Drainage Improvement Project 1	This project, located within a 910-acre drainage basin, would construct new drainage controls near the intersection of Murray Road and Boyd Acres Road where problems present in an industrial area. Project benefits include improved stormwater drainage conveyance and management, and reduced flooding.
MB11 - Drainage Improvement Project 3	This project, located within a 866-acre drainage would construct a new catch basin and an infiltration swale with treatment in the 60900 block of Platinum Drive to help ensure the prevention of drainage from the public road from causing flooding on private property. Project benefits include improved stormwater drainage, enhanced water quality, and regulatory compliance.
MB34A - Drainage Improvement Project 2	This project located within a 799-acre drainage basin, would construct a new drywell and roadside bioswales along King Hezekiah Way. Project benefits include improved stormwater drainage and conveyance.
MB22A - Drainage Improvement Project 1	This project, located within a 319-acre drainage basin, seeks to improve drainage within the 2400 block of NW 1st Street where drainage problems present in an underserved area. Project benefits include improved conveyance and flow control to prevent downhill erosion and property impacts.
MB22D - Drainage Improvement Project 2	This project, located within an 859-acre drainage basin, would construct a stormwater swale along NW Shields Drive in the 200 block where drainage problems present. Project benefits include improved drainage, reduced flooding, and enhanced water quality.
MB34D - Drainage Improvement Project 3	This project would replace an existing drill hole and provide treatment and additional drainage along NE Broken Bow Drive where problems present in the 2700 block. Project benefits

Table 10.2: Stormwater Infrastructure Improvement Projects for Selected Stormwater Approach

Project Name	Description
	include improved drainage and enhanced water quality.
MB34A - Drywell/Treatment Project 1	This project, located within a 799-acre drainage basin would construct a new driveway apron, sedimentation manhole, and drywell along West View Drive where drainage problems present in the 20900 block. Project benefits include improved stormwater drainage and enhanced drinking water quality protection.
MB06C - Drainage Improvement Project 1	This project, located within a 518-acre drainage basin, would construct new drainage improvements along Boyd Acres Road where problems present in the 63600 block. Project benefits include improved stormwater drainage and reduced flooding.
MB34D - Drainage Improvement Project 4	Within this 1,724-acre drainage basin, the project seeks to replace end-of-life facilities and improve drainage capacity where problems present in the 1200 block of NE Revere Ave. Project benefits include reduced flooding, property protection, and conveyance improvements.
MB14A - Drainage Improvement Project 3	This project, located within an 106-acre drainage basin, would improve drainage facilities through either construction of proper infiltration or drywell facilities with appropriate pretreatment or construct a new pump station with treatment vault near NW Hixon and NW Riverfront Street. Project benefits include improved stormwater drainage, enhanced water quality, and regulatory compliance.
MB16A - Drainage Improvement Project 1	This project, located within a 359-acre drainage basin, would construct new drainage controls and bank stabilization measures along SW Bond St. where problems present in the 800 block, Project benefits include improved stormwater drainage, enhanced water quality, and erosion prevention.
MB34B - Drainage Improvement Project 2	This project would construct new curbs, catch basins, and drywells with treatment along SE Waco Drive where the problem presents in the 1900 block. Project benefits include improved drainage, conveyance, and enhanced water quality.
MB24 - Drainage Improvement Project 2	This project would install new catch basins to drain the area near NW 12th and NW Davenport and drain to an existing storm drain system. Project benefits include improved stormwater drainage and regulatory compliance.
MB20 - Drainage Improvement Project 1	This project located within a 176-acre drainage basin will improve drainage issues that present in the 300 block of NW Vermont Street. The project benefits include improved conveyance and drinking water quality protection.
MB03 - Drainage Improvement Project 1	This project, located in a 602-acre residential and recreational drainage basin, would improve the drainage around Awbrey Butte by improving conveyance and pretreatment (e.g. the pipe size) in accordance with recommendations to be refined in the Hillside Drainage Plan. Project benefits include reduced flooding and improved stormwater drainage and water quality benefits.
MB26 - Drainage Improvement Project 2	Located within a 694-acre drainage basin, this project would construct a new gravity stormwater collection system with treatment along SW Century Drive where problems present in the 200 block. Project benefits include reduced flooding, improved stormwater drainage, and enhanced water quality, and

Table 10.2: Stormwater Infrastructure Improvement Projects for Selected Stormwater Approach

Project Name	Description
	regulatory compliance.
MB8A - Drainage Improvement Project 1	Located within a 253-acre drainage basin, this project will improve drainage conveyance and collection issues within the 100 block of Windance Ct. to ensure public stormwater is handled onsite within this residential area. The benefits of this project include conveyance and drainage control improvements, and property protection.


City of Bend
Stormwater Master Plan
Selected Stormwater
Management Approach Projects
and Associated Basins
Figure 10.1
MB06C
MB35
MB06A
MB03
MB21
MB10
MB34D
MB23A
MB22B
MB22A
MB20
MB18C
MB22D
MB18B
MB14B
MB8C
MB08B
MB18A
MB14A
MB24
MB37
MB25
MB08A
MB34B
MB16C
MB17
MB16B
MB26
MB16A
MB34A
MB31
MB33
MB11
MB32
Approach 3 Projects
Subbasin Containing a Project
Major Basin Containing a Project
Subbasins
Major Basins
N
0
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1
Miles
Map Produced by URS, May 2014