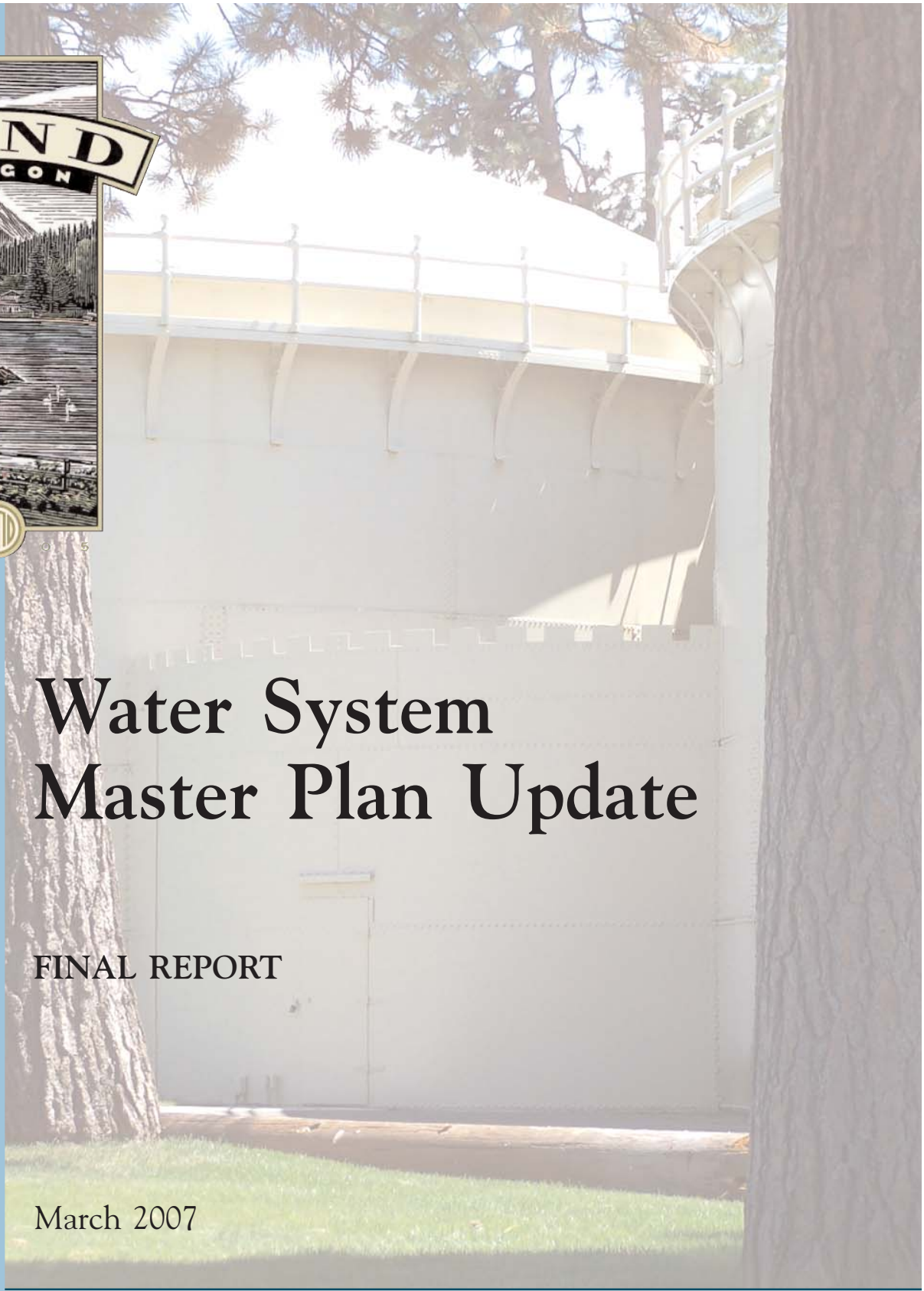

Water System Master Plan Update

FINAL REPORT

March 2007

Murray, Smith & Associates, Inc.

CITY OF BEND, OREGON

MSA
Murray, Smith & Associates, Inc.
Engineers/Planners

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05-0765.104
March 7, 2007

Mr. Michael Miller
Assistant Public Works Director
Public Works Department
575 NE 15th Street
Bend, OR 97701

Re: City of Bend Water System Master Plan Update -- Final Report

Dear Mr. Miller:

In accordance with our agreement we have completed the engineering studies required for the preparation of the Water System Master Plan Update for the City of Bend. Our Final Report of these studies is transmitted herewith.

We wish to express our appreciation for the participation and cooperation of the City of Bend staff throughout the course of this study. Thank you for the opportunity to provide this service to the City of Bend.

Sincerely,

MURRAY, SMITH & ASSOCIATES, INC.

Kyle P. McTeague, P.E.
Project Manager

Brian M. Ginter, P.E.
Project Engineer

KPM:kpm

Enclosure

WATER SYSTEM MASTER PLAN UPDATE

FOR

CITY OF BEND, OREGON

March 2007

Prepared by:

MURRAY, SMITH & ASSOCIATES, INC.
Engineers/Planners
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ACKNOWLEDGMENTS

Appreciation is expressed to all who contributed to the completion of this report.

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EXECUTIVE SUMMARY

Introduction

The purpose of this Water Master Plan (WMP) is to provide the City of Bend a comprehensive planning document that provides basic information and guidance necessary for the sound stewardship of the municipal water system within its water service boundary. This plan is important because it:

- Compiles basic information relevant to the water system.
- Describes the basic functional parameters of the system.
- Presents planning and analysis criteria for system improvements and expansions.
- Highlights known system deficiencies.
- Describes and graphically illustrates recommended improvements.
- Presents basic cost information for general budgeting and the development of an adoptable 25-year capital improvements program (CIP).
- Provides a physical tool for informing customers and other interested parties of the existing system and proposed improvements.
- Serves as an invaluable resource for gaining public support for needed improvements.
- Facilitates logical planning decisions relative to other City programs.

How This Plan Should Be Used

This Water System Master Plan Update should be used in the following manner:

- This master plan should be viewed as a dynamic working document.
- The plan should be reviewed annually for the purpose of prioritizing and budgeting for needed improvements.
- Plan mapping should be updated periodically to reflect current development and constructed system upgrades.
- The plan hydraulic model should be used to coordinate and integrate developer-constructed system improvements.
- Specific recommendations set forth in this plan should be considered as conceptual only. Additional details and potential alternatives should be investigated and analyzed in the preliminary engineering phase of final project designs.
- Cost estimates should be considered as planning level only, and should be updated and refined with preliminary engineering and final project designs.
- This plan should be used as the guiding document for future water system improvements.

Authorization

In 2005, the firm of Murray, Smith & Associates, Inc. (MSA) was authorized by the City of Bend to prepare this Water System Master Plan.

Compliance

This plan complies with water system master planning requirements established under Oregon Administrative Rules (OAR) for Public Water Systems, Chapter 333, Division 61.

Planning Period

The planning period for this water system master plan is through the year 2030. Based on anticipated development rates and probable infill densities, saturation development within the existing service area and the Tetherow and Juniper Ridge areas is anticipated to occur near the end of the planning period. Saturation development, or build-out, occurs when all existing developable land within the service area has been developed, and all planning and facility sizing recommendations are based on saturation development conditions. The improvements presented in Section 6 of this report are recommended for implementation within the planning period (through 2030).

Study Area

The City of Bend currently serves water to approximately 53,000 people within the City limits, which at this time is the same as the Urban Growth Boundary (UGB). The remaining area within the City limits/UGB is served by two separate, private water providers, the Avion Water Company and Roats Water System. It is anticipated that areas outside of the current UGB will be incorporated into the City during the planning period of this report. These areas are currently being studied by the City, as part of the City of Bend Residential Lands Study, for inclusion in future expansions of the UGB and for designation of Urban Reserve Areas (URAs). For the purpose of this report, it is anticipated that the Tetherow and Juniper Ridge areas, both areas outside of the current City limits/UGB, will develop within the planning period of this study. Thus, the planning period service area includes the current service area within the UGB and the Tetherow development area as well as the Juniper Ridge area.

Oregon's Statewide Planning Goal No. 11 establishes requirements regarding public facilities planning. To comply with Goal 11 this plan provides a distinction between the facilities that are meant to serve areas within the existing UGB and those facilities intended to serve areas outside of the existing UGB. Where facilities are intended to eventually commingle service to areas both within the existing UGB and outside the existing UGB, those facilities can not be used to serve the later until they are included within the UGB.

Existing Water System

General

The City of Bend's existing water system consists of a surface water intake facility, 23 groundwater production wells, 14 finished water storage reservoirs, 5 booster pump stations, transmission and distribution mains, and associated appurtenances such as control valves, pressure reducing valves, isolation valves, meters, and fire hydrants. The system includes eleven primary pressure zones serving water system customers ranging in elevation from approximately 3,450 feet to 4,160 feet above mean sea level (msl).

Water Rights

Currently the City holds water rights totaling 51.9 million gallons per day (mgd) (80.35 cubic feet per second (cfs)). 28.6 mgd (44.24 cfs) of these water rights are groundwater water rights and 23.3 mgd (36.11 cfs) are surface water rights. Approximately 10.0 mgd of the City's surface water rights are junior rights and are only available during the wintertime. Furthermore, the City's surface water rights are further limited to approximately 7.6 mgd during the peak season in drought years to prevent impact to more senior rights.

Supply

Surface water is collected approximately 13 miles west of the City at the Bridge Creek Intake Facility located near the confluence of Bridge Creek and Tumalo Creek. Flows in Bridge Creek are supplemented by the diversion of natural springs located in the Tumalo Creek drainage basin. Spring flows are collected in a diversion pond and transferred through two parallel transfer pipes to a canal flowing to Bridge Creek. Raw water is then routed from the Bridge Creek Intake Facility approximately 11.5 miles via two parallel steel transmission pipelines measuring 14 inches and 16 inches in diameter to the Outback Site.

In addition to the surface water source, the City currently has 9 groundwater production sites that include 23 wells located throughout the service area and at the Outback site westerly of the City. The total groundwater production capacity is approximately 31 million gallons per day (mgd).

Pressure Zones

The City of Bend's existing water distribution system includes eleven primary service areas, or pressure zones. Pressure zones are generally defined by ground topography and designated by overflow elevations of water storage facilities or discharge hydraulic grades of pressure reducing or booster pumping facilities serving the zone. The highest elevation zone includes the top of Awbrey Butte, and the lowest elevation zone extends towards the northeasterly edge of the service area boundary.

Storage

The City of Bend has a total of 15 storage reservoirs located throughout the water service area, including the 1.5 mg CT Basin at the Outback site, providing a total of approximately 30 million gallons (MG) of storage.

Pumping

The City's distribution system includes five booster pump stations designed to deliver water from one pressure zone to a higher zone. The Awbrey Pump Station pumps from Zone 5 to Zone 1, the College Pump Station pumps from Zone 3 to Zone 2, the Westwood Pump Station pumps from the Westwood reservoir (Zone 4W) to the Westwood Service Area, the Scott Street Pump Station pumps from Zone 5 to Zone 4E, and the Murphy Pump Station pumps from Zone 4E (4 East) to Zone 3SB (3 South Bend).

Water System Piping

The City of Bend's water system is composed of various pipe materials in sizes up to 36 inches in diameter. The total length of piping in the service area is approximately 290 miles. The majority of the piping in the system is ductile iron, cast iron and steel. The piping in the former Juniper Utility Company (Zones 2SB and 3SB) is primarily small diameter, 2-inches to 6-inches polyvinyl chloride (PVC) pipe.

Water Demands

Existing Water Demands

Based on the City's historical water use, the water service area's total average daily demand has ranged from approximately 8.6 mgd to approximately 11.5 mgd since the year 1998. It appears that the per capita usage of water has decreased in recent years due to ongoing water conservation efforts and to the recent implementation of service meters for all customers.

Population and Water Demand Projections

The estimate of the population for the service area at saturation, or build out, was developed by analyzing comprehensive plan zoning classifications for all developed and undeveloped residential, commercial and industrial areas within the City's service area, and through the application of occupancy assumptions. These forecasts were developed in close coordination with City staff.

For the year 2005 the total maximum day demand was approximately 26.9 mgd. The maximum day demand is the anticipated demand for the "highest-use" day of the year. Based on historical system demands from 1998 through 2005, and on population projections, the total maximum day demand is estimated to be approximately 71.5 mgd at saturation

development. Based on historical water production records the peak hour demand is estimated to be equal to 1.5 times the Maximum Day Demand (MDD) (See Table ES-1).

Table ES-1
Population Projections and Water Demand Summary

Year	Water Service Area Population	Water Demand (mgd)		
		Average Day Demand (ADD)	Maximum Day Demand (MDD)	Peak Hour Demand [5]
2005	52,941	11.3 [1]	26.9 [2]	40.4
Saturation Development[6]	103,000	30.7 [3] [6]	71.5 [4] [6]	107.3[6]

Notes: (1) Existing Average Day Demand based on 2005 water use records.
(2) Existing Maximum Day Demand based on 2005 water use records.
(3) Average Day Demand equals the Population multiplied by the estimated average daily per capita usage for the service area (250 gpcd).
(4) Maximum Day Demand equals the Population multiplied by the estimated maximum daily per capita usage for the service area (590 gpcd).
(5) Peak Hour Demand equals 1.5 times the Maximum Day Demand
(6) Includes Juniper Ridge ADD, MDD and Peak Hour Demand of 4.75, 10.67 and 16.0 mgd, respectively.

Planning and Analysis Criteria

Criteria for the analysis of the City of Bend water system are summarized as follows:

- The City's supply, treatment and transmission systems should be capable of providing estimated maximum day demands through the end of the 25-year planning period.
- Water storage capacity should provide for operational, fire, and emergency storage capabilities.
- Water storage capacity should be provided to each pressure zone where practical.
- Pressure zones should be established so that the maximum service pressures do not exceed 120 pounds per square inch (psi).
- The distribution system should be capable of delivering the maximum day demand while maintaining a minimum service pressure at the highest point in the service zone of 40 psi.
- Distribution main lines should be looped and should not be less than 8 inches in diameter unless there are no fire hydrants and/or is no potential for future extension of the main line.
- Pump stations that pump to a reservoir should be sized to supply the maximum day demand to the areas served.

- Constant pressure pumping systems should be capable of providing maximum day demands plus fire flows to the areas served.
- The distribution system should be capable of supplying adequate fire flows when the system is experiencing the maximum day demand while maintaining a minimum service pressure of 20 psi.
- Recommended minimum fire flows are 1,500 gallons per minute for residential zones, 2,500 gallons per minute for general commercial and industrial zones, and 3,500 gallons per minute for the Commercial Highway zone.

Water System Analysis

An analysis was conducted to evaluate the adequacy of the existing system, and to identify system improvements that would most efficiently serve to correct existing deficiencies and to provide for future growth. The analysis included an evaluation of pressure zone requirements and potentially beneficial adjustments, development and use of a hydraulic network computer model to evaluate the distribution system, evaluation of distribution storage and pumping requirements and how best to meet future capacity needs, and a general assessment of the condition of the existing distribution piping and pumping facilities.

The findings identified in the course of the analysis are as follows:

- The City will need to expand supply, storage and pumping capacities to satisfy growing demands through the 25-year study period.
- Available fire flow capacity is generally sufficient; however, certain system improvements should be implemented to bolster the City's ability to suppress potential fires, and to provide expanded capacity looking forward.
- Due to the existing robust aquifer beneath the City, water supply may be expanded in a geographically strategic manner to minimize the need for major transmission piping and to maximize the value of existing facilities.
- The robust nature of the aquifer allows the City significant flexibilities with respect to future service area expansions.
- The City could derive tremendous additional value from the robust aquifer by allocating a significant portion of emergency storage to this source, thereby offsetting the need to construct tank capacity for such storage.
- The City could benefit by developing a better geographic "balance" of facilities through the implementation of expanded supply and storage capacity easterly of the Deschutes River, where most of the capacity needs exist.

- Minimal pressure zone adjustments are required to satisfy service and fire demand needs looking ahead; however, it is suggested that further study be conducted to evaluate the integration of the former Juniper Utility Area in greater detail.

- The piping within the former Juniper Utility Area is generally undersized and of low quality and much of it should be programmed for replacement over the long term.

- Emergency backup power generation capabilities should be implemented at all groundwater well sites to help minimize risks relating to water supply during power failures.

Recommended Capital Improvements

This plan recommends supply and distribution system improvements to correct existing deficiencies and to provide for future service needs within the study area through the next 25 years. Two detailed system graphics were prepared that illustrate the existing distribution system and identify proposed improvements (see Figures 1 & 2 in Appendix A). In addition, a hydraulic profile graphic was developed to present a vertical representation of both existing and proposed facilities (see Figure 6-3 in Section 6). The recommendations include improvements to supply capacity, the distribution system piping, storage reservoirs, and pump station capacity.

The recommended system improvements include proposed additional storage reservoirs at Pilot Butte and Rock Bluff, as well as at the Juniper Ridge Area. In addition, pump station upgrades are proposed for the Westwood Pump Station, and a total additional supply capacity of approximately 40 million gallons per day is proposed. Planning level budget cost estimates for the recommended improvements have been developed. The plan outlines distribution system improvements through the end of the 25-year study period. A long-term financing plan is recommended to support the proposed distribution system capital improvement plan. Adequate system development fees should be established to collect needed funds from new customers for both existing facilities and for improvements that expand the capacity of the system.

Presented below in Table ES-2 is a summary of recommended water system improvements for supply and distribution system storage, pumping, and piping. Project cost estimates of recommended improvements are presented for capital improvement programming. The 25-year average annual capital requirement in 2006 dollars would be approximately $6,800,000 per year. An annual increase of roughly 3% for inflation should be applied to this estimate for future budgeting purposes.

Table ES-2
Summary of Estimated Water System Improvement Project Costs

Improvement Category	Project Costs, 2006 Dollars
Groundwater Supply Capacity Expansion	**$48,360,000**
Emergency Backup Power Generation Upgrades	**$1,300,000**
Surface Water Supply Improvements	**$50,000,000**
Storage Capacity Expansion	**$21,100,000**
Pumping Capacity Upgrades	**$2,100,000**
Transmission Piping Improvements	**$7,680,000**
Pressure Reducing Stations	**$1,080,000**
Water System Planning	**$1,000,000**
Distribution Piping Improvements	**$37,400,000**
GRAND TOTAL	**$170,020,000**
USE	**$170,000,000**

Cost Estimating Data

An estimated project cost has been developed for each improvement project recommendation presented in this study. Itemized project cost estimate summaries are presented in Appendix B. Project costs include construction costs and an allowance for administration, engineering, and contingencies.

The estimated costs included in this plan are planning level budget estimates presented in 2006 dollars. Since construction costs change periodically, an indexing method to adjust present estimates in the future is useful. The Engineering News Record (ENR) Construction Cost Index (CCI) is a commonly used index for this purpose. For purposes of future cost estimate updating, the October 2006 ENR CCI for Seattle, Washington of 8630 is referenced.

Water Management and Conservation Plan

The Oregon Administrative Rules (OAR) for Public Water Systems, Chapter 690, Division 86 requires water systems with water rights to submit a Water Management and Conservation Plan that documents current water conservation measures, provides a water curtailment plan,

evaluates long-term water supply planning and provides a water rights implementation schedule. The City recently completed a Water Management and Conservation Plan and it is understood that the City intends to update this plan approximately every five to ten years.

Financial Evaluation and Plan

A long-term financial planning evaluation and strategy is required to support the recommended capital improvement plan. The financial evaluation should include a cost-of-service analysis and income generating options that support an adequate funding source without placing an undue burden on existing customers. Adequate SDC's should be established to collect funds from new customers to pay for improvements that expand the capacity of the system. It is understood that a financial evaluation and plan is currently under way and information contained in this water system master plan update is intended to be used as needed for that plan.

Recommendations for Plan Implementation

It is recommended that the City take the following actions:

1. Formally adopt this study as the City of Bend's Water System Master Plan for the water service area.
2. Adopt the recommended system improvements described in Section 6 as part of the City's capital improvement plan (CIP) for the water service area.
3. Develop and adopt a financing plan to implement the capital improvements recommended in this study.
4. Review and update this plan within five to seven years to accommodate changed or new conditions.

Summary

Bend continues to experience steady population and water demand growth. This water system master plan evaluates the City water system's ability to adequately meet existing and future water needs. The ultimate completion of recommended improvements to the distribution and supply systems will ensure that the City has adequate supply, storage, pumping and distribution system piping capacity to meet these needs well into the future. The total estimated project costs of these improvements are approximately $170 million for the 25 year planning horizon. Approximately $6,800,000 per year should be budgeted over the next 25 years for the completion of the recommended projects. A financial planning and analysis study should be undertaken to determine the ultimate impact of the capital improvement program on City ratepayers and new development and to determine overall capital funding needs.

SECTION 1
INTRODUCTION

Authorization

In September 2005, the firm of Murray, Smith & Associates, Inc. was authorized by the City of Bend to prepare this Water System Master Plan Update.

Purpose

The purpose of this study is to perform a comprehensive analysis of the City of Bend's water supply and distribution system, to identify system deficiencies, to determine future water distribution system and supply requirements, and to recommend water system facility improvements that correct existing deficiencies and allow for future system expansion. Since the completion of the City's Utilities System Master Plan Update in 1999, the City has experienced population growth exceeding projections and has plans for expansion of the Urban Growth Boundary (UGB) to accommodate anticipated continued accelerated growth. This study will provide the City with the guidance needed for the sound stewardship of the water system over the next 25 years and beyond.

Compliance

This plan complies with water system master planning requirements established under Oregon Administrative Rules (OAR) for Public Water Systems, Chapter 333, Division 61.

Scope

The scope of work for this study includes the following work tasks:

- ***Information Compilation and Review*** – Compile and review existing information relevant to water master planning work, including previous water system master plan documents, record drawings of key facilities, reports and studies, planning data, water use data, population data, water rights documentation, information on neighboring water systems, working hydraulic computer models of City systems and interfacing adjoining systems, and other pertinent information.

- ***Model Evaluation*** – Evaluate the current City of Bend H20Net water system hydraulic model update, completed in July 2005, relative to the City's existing Utilities System Master Plan Update (completed in 1999) and current assumptions for development of supply and storage through the planning horizon.

- ***Juniper Utility System Model Integration*** – Integrate the City's existing H20Net model with H20Net model of the former Juniper Utility Company system.

- ***Hydraulic Model Start-up, Verification and Calibration*** – Investigate, verify and modify the existing hydraulic model so as to confirm that it is functioning properly and that it is appropriately reflecting existing City of Bend water system conditions as regards to the water master planning objectives. Conduct a water system operation review workshop with City staff to help establish and confirm critical operational input parameters that are important to hydraulic model verification, and performance. Complete hydraulic model calibration with City flow testing data to better match model outputs with observed and expected physical system performance.

- ***Water System Review*** – Conduct a field review of the City's major water system facilities to establish an "on the ground" understanding of existing facilities.

- ***Identification of System Deficiencies*** – Through field reviews and discussions with City engineers, operations and public works staff identify known deficiencies and/or problems within the existing water supply and distribution system. Conduct a workshop with City staff to inventory current known system deficiencies, relative to the water master planning work.

- ***Review Water Demand Forecasts*** – Review historical water consumption records and current water demand forecasts. Review and confirm short-term and long-term population estimates and water demand forecasts with City Public Works Department and Planning Department Staff.

- ***Review Future Service Area and Assess Water Demand Forecasts*** – Complete further analysis to verify the anticipated future service area and to asses water demand forecasts. Evaluate certain existing Urban Reserve Areas (URA's), as well as other areas under consideration by the City currently outside the Urban Growth Boundary (UGB), for inclusion in the future service area and analyze water demand forecasts for the future service area.

- ***Water Supply/Source Review*** – Conduct a brief review of current surface and groundwater supply sources relative to projected water demand forecasts and develop preliminary recommendations.

- ***Finished Water Storage Analysis*** – Review and evaluate requirements for finished water storage and develop recommendations for improvement. Review historical methodology for finished water storage volumes. Review and develop recommendations for overall storage requirements relative to water distribution system pressure zone and piping layouts, source development and ground topography within developable urban areas.

- ***Pressure Zone Analysis*** – Review and evaluate the existing pressure zone layout with respect to existing and planned future development in relation to topography. Confirm and/or establish acceptable elevation limits and service pressure limits for

each of the City's existing pressure zones. Illustrate proposed pressure zones on updated water master plan mapping.

- ***Water System Analysis Criteria Review*** – Review and update water system analysis criteria, including fire flows, residual pressures, and flow velocities.

- ***Water Distribution System Analysis*** – Update prior hydraulic modeling relative to updated recommendations on water supply and storage locations.
    - Analyze existing system using personal computer based MWHSoft H2ONet hydraulic analysis software to identify and confirm distribution system deficiencies. Consider both peak hour demand conditions and maximum day demand conditions combined with strategically applied fire demands.
    - Develop trial improvement alternatives to correct existing deficiencies and to provide for future system expansions to serve future development.
    - Analyze various trial alternative configurations and with City input, develop recommendations for improvements.
    - Develop an overall AutoCAD based water system map of the existing City of Bend system utilizing the mapping features of the hydraulic modeling software.
    - Develop overall AutoCAD based water system map of the proposed improved system showing improvements recommended for saturation development of the existing UGB and conceptual level improvements for proposed Urban Reserve Areas (URA's).

- ***Cost Estimates and Recommended Capital Improvements Program*** – Develop preliminary planning level cost estimates for recommended capital improvements. Work with City Staff on prioritizing capital improvements and developing a comprehensive water system improvements program.

- ***Water SDC Technical Assistance*** – Provide engineering support and technical assistance to the City and the City's financial consultant in the development of the water System Development Charge (SDC).

- ***Water System Master Plan*** – Prepare a bound Water System Master Plan document in draft and final form. Develop reporting narrative, data, tables, figures, illustrations and mapping to clearly present findings, recommendations and capital improvement program. Include an overall water system master plan update "wall-map" style figure. With City staff concurrence, submit the Water System Master Plan to the State of Oregon Department of Human Services – Drinking Water Division on the City's behalf for review and approval.

SECTION 2
EXISTING WATER SYSTEM

General

This section inventories and describes the City of Bend's existing water service area and water system facilities. Included in this section are discussions of existing surface water and groundwater supply facilities, pressure zones, storage reservoirs, pumping facilities, and distribution system piping.

Background and Study Area

The City of Bend's water supply, transmission, and distribution system currently provides potable water to approximately 53,000 people through residential, commercial, industrial and institutional services. The study area for this master plan includes the area that lies within the City of Bend's existing Urban Growth Boundary (UGB) not currently served by private water companies (Avion Water Company and Roats Water Company), as well as two areas outside of the current UGB that are anticipated to be developed during the study period (Tetherow and Juniper Ridge). While an expanded area is currently being studied by the City of Bend for proposed UGB expansion and designation as Urban Reserve Areas (URAs), Tetherow and Juniper Ridge are the only areas outside of the UGB included within the study area of this plan as they are the highest priority planning areas for the City at this time. Also, total saturation population projections completed as part of this report, that include these areas match relatively well with population projections recently prepared by other City planning interests.

The City of Bend's existing water system consists of a surface water intake facility, 23 groundwater wells, 15 finished water storage reservoirs, 5 booster pump stations, transmission and distribution mains, and associated appurtenances such as control valves, pressure reducing valves, isolation valves, meters, and fire hydrants. The system includes eleven primary pressure zones serving water system customers ranging in elevation from approximately 3,450 feet to 4,160 feet above mean sea level (msl).

Figure 1, "Existing Water System Map", in Appendix A illustrates the study area, current UGB, other nearby water systems, existing source, supply, storage and pumping facilities, transmission and distribution mains and pressure zones. Figure 1 is also a digital representation of the computerized distribution system hydraulic model used for the system analysis.

Source, Supply and Transmission System

General

The City of Bend supplies potable water to its customers from a surface water supply system that originates in the nearby Bridge Creek watershed and from 23 groundwater production

facilities located throughout the water system. A more detailed description of the City's water supply sources and water rights for these supply sources is presented below.

Water Rights

Currently the City holds water rights totaling 51.9 mgd (80.35 cfs). 28.6 mgd (44.24 cfs) of these water rights are groundwater water rights and 23.3 mgd (36.11 cfs) are surface water rights. Approximately, 10.0 mgd of the City's surface water rights are junior rights and are only available during the wintertime. Further discussion of the City's surface water supply is presented below. The City also has submitted two groundwater right applications for approximately 15.5 mgd (24 cfs) that are currently pending further action by the State of Oregon Water Resources Department and the City of Bend. A summary of the City's water rights is presented in Appendix C.

Surface Water Supply

Surface water is collected approximately 13 miles west of the City at the Bridge Creek Intake Facility located near the confluence of Bridge Creek and Tumalo Creek. Flows in Bridge Creek are supplemented by the diversion of natural springs located in the Tumalo Creek drainage basin. Spring flows are collected in a diversion pond and transferred through two parallel transfer pipes to a canal flowing to Bridge Creek. Raw water is then routed from the Bridge Creek Intake Facility approximately 11.5 miles via two parallel steel transmission pipelines measuring 14 inches and 16 inches in diameter to the Outback Site. Disinfection of the surface water supply is achieved at the Outback Site with the addition of chlorine. Raw surface water from the Bridge Creek Intake Facility is mixed with a chlorine solution and then flows through the CT Basin, a baffled reservoir designed specifically to eliminate short-circuiting and increase disinfectant contact time, and Outback Reservoir 1 before entering the distribution system. Further discussion of the storage facilities at the Outback site is presented later in this section.

The City of Bend has been granted an exemption from the Safe Drinking Water Act's Surface Water Treatment Rules by the Oregon State Health Division. This exemption is based on a review of the raw water quality in the Bridge Creek watershed and ongoing efforts by the City of Bend to protect this watershed. The exemption allows the City to forego the need for a water treatment facility for the surface water collected from the Bridge Creek watershed. The City is currently evaluating the sustainability of the exemption under the recently promulgated Long Term 2 Enhanced Surface Water Treatment Rule and investigating potential watershed and piping improvements to maintain the high level of raw water quality it currently enjoys.

The City holds water rights for 23.3 mgd of supply from the surface water source; however, the actual capacity of this source varies significantly throughout the year with seasonal stream flow fluctuations. As stipulated by the City's surface water supply rights, the available capacity of water to the City is limited by the actual stream flow so that water uses by more senior water rights are not impacted. For water system planning purposes, the capacity of individual sources available during the summer peak season, is used because

supply sources must be adequate to meet the larger demands experienced during this time of year. As documented in the City's October 2004 Water Management and Conservation Plan, it is understood that the actual reliable capacity of the City's surface water supply source during the peak season can be limited to 7.6 mgd in years where drought conditions are experienced due to minimum stream flow requirements. During the peak summer demand season, the capacity of this supply source is the limitation on the amount of supply available. This report uses this value for analysis associated with supply.

Groundwater Supply

The City currently has 9 groundwater production sites that include 23 wells located throughout the service area and at the Outback site. A table summarizing these groundwater production facilities is listed below in Table 2-1. This information was gathered from previous City efforts and discussions with City staff.

Finished Water Transmission Piping (Outback Site)

Four finished water transmission pipes transmit water from the Outback site to the City's distribution system. A 14-inch and 16-inch diameter pipeline transmit surface water from Outback Reservoir I to the Overturf Reservoir and Awbrey Reservoir, and a 16-inch and 36-inch diameter transmission main transmit groundwater from Outback Reservoir II to Pressure Zone 3. These facilities are discussed in further detail later in this Section and in Section 5.

The City is currently reconfiguring the piping at the Outback site so that the surface and groundwater supplies are blended at the Outback site and delivered to the distribution system through the four transmission mains.

Interties

The City of Bend has existing interties with two neighboring water service providers, the Roats Water System and the Avion Water Company. Bend relies on a connection with the Roats Water System to meet the demands of a small portion of the former Juniper Utility Company service area (South Bend service area). In addition, the City maintains an emergency intertie with the Avion Water Company. This intertie is meant strictly for emergency purposes, such as fire events or emergency backup. The City of Bend has an agreement with the Avion Water Company to allow for future emergency water interties if requested by either water provider.

Table 2-1
Groundwater Production Facility Summary

Groundwater Production Facility	Pump Size (hp)	Pump Type	Approx. Static Water Level (feet)	Capacity (mgd)
Awbrey Glenn (Copperstone)	250	Line Shaft Turbine	510	1.4
Bear Creek Well I	350	Line Shaft Turbine	629	1.5
Bear Creek Well II	350	Line Shaft Turbine	652	1.6
Outback I	150	Submersible	482	1.2
Outback II	150	Submersible	482	1.2
Outback III	250	Line Shaft Turbine	478	1.6
Outback IV	250	Line Shaft Turbine	482	1.6
Outback V	250	Line Shaft Turbine	486	1.8
Outback VI[1]	250	Line Shaft Turbine	480	1.8
Pilot Butte I	250	Line Shaft Turbine	743	1.2
Pilot Butte II	250	Line Shaft Turbine	734	1.1
Pilot Butte III	250	Submersible	786	1.3
River Well I	500	Line Shaft Turbine	360	2.8
River Well II	400	Line Shaft Turbine	242	2.8
Rock Bluff I	150	Line Shaft Turbine	393	1.2
Rock Bluff II	150	Submersible	395	1.1
Rock Bluff III	150	Line Shaft Turbine	395	1.2
Westwood	150	Submersible	283	1.0
Shiloh North	25	Submersible	335	0.2
Shiloh South	25	Submersible	335	0.2
Shiloh III	250	Line Shaft Turbine	355	2.2
Hole Ten North	150	Submersible	410	0.6
Hole Ten South	150	Submersible	412	0.6
Total Groundwater Supply Capacity (mgd)				**31.2**

Note: 1. Outback Well VI is currently under construction.

Pressure Zones

General

The City of Bend's existing water distribution system includes eleven primary service areas, or pressure zones. Pressure zones are generally defined by ground topography and designated by overflow elevations of water storage facilities or discharge hydraulic grades of pressure reducing or booster pumping facilities serving the zone. A summary of the City's pressure zones is presented in Table 2-2. A brief discussion of each pressure zone is presented below.

It should be noted that there are a number of small "subzones" throughout the City that are controlled by PRV connections to one of the eleven primary zones discussed below. For the purposes of analysis, these smaller "subzones" are considered a part of one of the eleven

primary zones where appropriate. A pressure zone analysis and recommendations are presented in Sections 5 and 6 of this report.

Table 2-2
Existing Pressure Zone Summary

Pressure Zone	Elevation Range Served (feet)	Primary Supply Source	Storage Reservoirs	Controlling Overflow Elevation (feet)	Approximate Pressure Range (psi)
1	3,970 – 4,160	Awbrey PS	Tower	4,244	30-120
2	3,830 – 4,010	College PS	College I and II	4,123	50-130
2SB	3,800 – 3,890	Hole 10 Wells	--	--	60-100
Westwood	3,840 – 3,940	Westwood Pump Station	Westwood Reservoir	3,872	50-100
3	3,730 – 3,860	Outback Site	CT Basin Outback I, II and III	4,011	65-120
3SB	3,730 – 3,790	Shiloh Wells/ Murphy PS	--	--	50-85
4W	3,640 – 3,750	Outback Site	Overturf I and II	3,871	50-100
4E	3,650 – 3,770	Bear Creek Wells Rock Bluff Wells	Pilot Butte II Rock Bluff I	3,879/3,880	50-100
5	3,540 – 3,680	River Wells Pilot Butte Wells	Awbrey Pilot Butte I and III	3,795	50-110
6	3,460 – 3,635	PRV	--	--	40-110
7	3,450 – 3,510	PRV	--	--	40-110

Pressure Zone 1

Pressure Zone 1 serves customers with ground elevations between roughly 3,970 and 4,160 feet. Service to customers in Pressure Zone 1 is provided by gravity from the Tower Rock Reservoir, the overflow elevation of which is 4,244 feet. Supply to this zone is provided from the Awbrey Booster Pump Station. Service pressures in Zone 1 are between approximately 30 and 120 psi. A certain number of customers in the higher elevations of Zone 1 have individual booster pump stations to increase service pressure to acceptable levels. Pressure Zone 1 currently serves a population of approximately 835.

Pressure Zone 2

Pressure Zone 2 serves customers with ground elevations between roughly 3,830 and 4,010 feet. Service to Pressure Zone 2 is provided by gravity from College Reservoirs I and II, the overflow elevations of which are 4,123 and 4,118 respectively, and from PRV connections from Pressure Zone 1. Supply to the zone is provided primarily through a pumped connection to the College Booster Pump Station in Zone 3. Pressures in Zone 2 are between approximately 50 and 130 psi. Zone 2 currently serves a population of approximately 1,000.

Pressure Zone 2SB (South Bend)

Pressure Zone 2SB represents the higher elevation areas of the former Juniper Utility Company that the City recently acquired. This zone serves customers with ground elevations between roughly 3,800 and 3,890 feet. Service to Pressure Zone 2SB is provided through a constant pressure pumped system. Supply is provided through Hole Ten Well North and South. Operating pressures in Zone 2SB generally range between approximately 60 and 100 psi. Zone 2SB currently serves a population of approximately 600.

Westwood Service Area

When the City assumed water service responsibilities for the Westwood neighborhood in the southwesterly portion of Bend it inherited an area operating with a hydraulic grade between Zone 2 and Zone 3. This pressure zone is supplied from a groundwater well, the Westwood Well, which pumps into a 0.5 million gallon (mg) ground level reservoir, the Westwood Reservoir. A continuous operation pump station, the Westwood Pump Station, provides constant pressure service to the zone from the Westwood Reservoir. The Westwood service area is also connected to Pressure Zone 3 via a 16-inch diameter main in Mt. Washington Drive. A normally closed isolation valve separates the Westwood service area from Pressure Zone 3.

Pressure Zone 3

Pressure Zone 3 serves customers with ground elevations between roughly 3,730 and 3,860 feet. Service to customers in Pressure Zone 3 is provided by gravity from Outback Reservoirs I, II and III, the overflow elevations of which are 4,011, and from PRV connections from Pressure Zone 2. Supply to the zone is provided primarily by the groundwater production wells at the Outback site. In addition, supply is provided from the Copperstone well within Zone 3. Service pressures in Zone 3 are between approximately 65 and 120 psi. Pressure Zone 3 currently serves a population of approximately 4,420.

Pressure Zone 3SB (South Bend)

Pressure Zone 3SB represents the relatively lower elevation areas of the former Juniper Utility Company that the City recently acquired. This zone serves customers with ground elevations between roughly 3,730 and 3,790 feet. Service to Pressure Zone 3SB is provided through a constant pressure pumped system. Supply is provided by Shiloh Wells "North", "South" & No. 3. Within Zone 3SB, the Murphy Pump Station can supply water from Zone 4E, and supply may be provided through a PRV connection from Zone 2SB. Operating

pressures in Zone 3SB generally range between approximately 50 and 85 psi. Zone 3SB currently serves a population of approximately 1,250.

Pressure Zone 4W (West)

Pressure Zone 4 represents two separate service areas on either side of the Deschutes River, connected by a 16-inch diameter pipeline with a normally closed valve. The area on the westerly side of the river operates at a hydraulic grade that is set by the overflow elevations of the Overturf reservoirs at 3,871 feet, and the area on the easterly side of the river operates at a hydraulic grade that is set by the overflow elevations of the Rock Bluff Reservoir at 3,879 and the Pilot Butte Reservoir II at 3,880 feet. Thus, for the purposes of this planning report these two areas are identified as Pressure Zone 4W (West) and Pressure Zone 4E (East).

Pressure Zone 4W serves customers with ground elevations between roughly 3,640 and 3,750 feet. As described above service to Pressure Zone 4W is provided by gravity from Overturf Reservoir I and Overturf Reservoir II. Supply to the zone is provided primarily from the Outback surface water and groundwater facilities, as well as through PRV connections from Zone 3. Service pressures in Zone 4W range between roughly 50 and 100 psi. Pressure Zone 4W currently serves a population of approximately 5,400.

Pressure Zone 4E (East)

Pressure Zone 4E serves customers with ground elevations between roughly 3,650 and 3,770 feet. Service to Pressure Zone 4E is provided by gravity from the Rock Bluff Reservoir and the Pilot Butte Reservoir II. Supply to the zone is provided primarily from groundwater wells at the Rock Bluff site, the Pilot Butte wells and the Bear Creek site. Supply may be pumped from Zone 5 via the Scott Street Pump Station as well as routed through PRV connections from Zone 3SB. Service pressures in Zone 4E range between roughly 50 and 100 psi. Pressure Zone 4E currently serves a population of approximately 8,750.

Pressure Zone 5

Pressure Zone 5 serves customers with ground elevations between roughly 3,540 and 3,680 feet. Service to customers in Pressure Zone 5 is primarily provided by gravity from the Awbrey Reservoir and the Pilot Butte I and III Reservoirs, the overflow elevations of which are 3,795, 3,782 and 3,782 respectively, and by PRV connections from Pressure Zone 4W and 4E. Supply to the zone is provided primarily by the City's surface water supply and groundwater production wells at the Outback site, in addition to Pilot Butte Wells 1, 2 & 3, and River Wells 1 & 2. Service pressures in Zone 5 range between approximately 50 and 110 psi. Pressure Zone 5 currently serves a population of approximately 20,890.

Pressure Zone 6

Pressure Zone 6 serves customers with ground elevations between roughly 3,460 and 3,635 feet. Service to customers in Pressure Zone 6 is provided by PRV connections from Pressure

Zone 4 and Pressure Zone 5. Currently there are no storage facilities serving Zone 6 directly by gravity. Storage for this zone is provided by reservoirs in higher elevation pressure zones. Supply to the zone is provided by the City's surface water source and various groundwater production wells located in higher elevation pressure zones. Service pressures in Zone 6 generally range between 40 and 110 psi, and this zone currently serves a population of approximately 8,320.

Pressure Zone 7

Pressure Zone 7 serves customers with ground elevations below 3,510 feet. Service to customers in Pressure Zone 7 is provided by PRV connections to Pressure Zone 6. Currently there are no storage facilities serving Zone 7 directly by gravity. Storage for this zone is provided by reservoirs in higher elevation pressure zones. Supply to the zone is provided by the City's surface water source and various groundwater production wells located in higher elevation pressure zones. Service pressures in Zone 7 generally range between 40 and 110 psi, and this zone currently serves a population of approximately 1,460.

Storage Reservoirs

The City of Bend has a total of 15 storage reservoirs located throughout the water service area providing 30.13 mg of storage throughout the distribution system, including the 1.5 mg CT Basin at the Outback site. Storage facility data was collected from previous reporting, discussions with City staff, and data provided by the City of Bend. A summary is presented in Table 2-3.

Pump Stations

The City's distribution system includes five booster pump stations designed to deliver water from one pressure zone to a higher zone. A brief summary of each pump station is presented in Table 2-4, including pump unit number and capacity, horsepower rating, and zones serviced.

Water System Piping

The City of Bend's water system is composed of various pipe materials in sizes up to 36 inches in diameter. The total length of piping in the service area is approximately 290 miles. The majority of the piping in the system is ductile iron, cast iron and steel. Table 2-5 presents a summary of pipe lengths by diameter.

The piping in the former Juniper Utility Company (Zones 2SB and 3SB) is primarily small diameter, 2-inches to 6-inches, pipe of material and workmanship that may not be suitable for the flow and pressure requirements of distribution system providing domestic and fire suppression water supply. Further analysis and recommendations for former Juniper Utility Company service area are presented in Sections 5 and 6.

Table 2-3
Storage Reservoir Summary

Reservoir Name	Reservoir Type	Capacity (mg)	Overflow Elevation (feet)	Floor Elevation (feet)	Source	Pressure Zone Served
Awbrey	Concrete	5.00	3,795	3,775	Surface Water	5
College I	Welded Steel	0.50	4,123	4,100	Surface Water	2
College II	Welded Steel	1.00	4,118	4,087	Surface Water	2
CT Basin	Bolted Steel	1.50	4,024	3,980	Surface Water	3
Outback I	Bolted Steel	2.00	4,011	3,976	Surface Water / Outback Wells	3
Outback II	Welded Steel	3.00	4,011	3,976	Outback Wells #3 - #6	3
Outback III	Welded Steel	3.63	4,011	3,982	Outback Wells #3 - #6	3
Overturf I	Riveted Steel	1.50	3,871	3,843	Outback Reservoir I	4
Overturf II	Riveted Steel	1.50	3,871	3,843	Outback Reservoir I	4
Pilot Butte I	Welded Steel	1.50	3,782	3,750	Pilot Butte Wells	5
Pilot Butte II	Welded Steel	1.00	3,880	3,840	Rock Bluff and Bear Creek	4E
Pilot Butte III	Concrete	5.00	3,782	3,758	Pilot Butte Wells	5
Rock Bluff	Welded Steel	1.50	3,879	3,841	Rock Bluff Wells	4E
Tower	Welded Steel	1.00	4,224	4,213	Surface Water	1
Westwood	Welded Steel	0.50	3,872	3,842	Westwood Well	Westwood
Total Storage Capacity		**30.13 MG**				

Table 2-4
Existing Booster Pump Station Summary

Pump Station	Unit	Capacity (gpm)	Motor Horsepower	Zones Serviced
Awbrey	1	1,200	200	Boosts water from Zone 5 to Zone 1
	2	1,200	200	
	3	1,200	200	
College	1	1,000	100	Boosts water from Zone 3 to Zone 2
	2	1,000	100	
Westwood	1	240	20	Boosts water from Westwood Reservoir to Westwood service area
	2	700	40	
	3	550	25	
	4	800	75	
Murphy	1	450	25	Boosts water from Zone 4E to Zone 3SB
	2	450	25	
	3	450	25	
	4	450	25	
	5	450	25	
Scott	1	1,250	50	Boosts water from Zone 5 to Zone 4E
	2	1,250	50	
	3	1,250	50	

Table 2-5
Water System Pipe Summary

Pipe Diameter (inches)	Pipe Length (miles)
2	1.3
4	3.0
6	53.8
8	116.1
10	25.5
12	62.3
14	0.7
16	23.5
24	1.1
30	1.1
36	2.8
Total	**291.2**

Note: Water System Pipe Summary only includes potable water piping systems.

Summary

This section presents a summary of the City of Bend's existing water system, including the supply system, storage and pumping facilities, and water system piping. Also included is a discussion of the existing water rights and pressure zones. Section 3 develops estimates of the future population and water demand requirements.

SECTION 3
SERVICE AREA, LAND USE AND WATER REQUIREMENTS

General

This section develops population projections and estimated water demand forecasts for the anticipated planning period. Population and water demand forecasts are developed from regional and City planning data, current land use designations, historical water demand records, previous City water supply planning efforts and discussions with City staff.

Service Area

The City of Bend currently serves water to approximately 53,000 people within the City limits, which at this time is the same as the Urban Growth Boundary (UGB). The remaining area within the City limits/UGB is served by two separate, private water providers, the Avion Water Company and Roats Water System. It is anticipated that areas outside of the current UGB will be incorporated into the city during the planning period of this report. These areas are currently being studied by the City, as part of the City of Bend Residential Lands Study, for inclusion in future expansions of the UGB and for designation of Urban Reserve Areas (URAs). For the purpose of this report, it is anticipated that the Tetherow and Juniper Ridge areas, both areas outside of the current City limits/UGB, will develop within the planning period of this study. Thus, the planning period service area includes the current service area within the UGB and the Tetherow development area as well as the Juniper Ridge area (see Figure 1 in Appendix A).

Oregon's Statewide Planning Goal No. 11 establishes requirements regarding public facilities planning. To comply with Goal 11 this plan provides a distinction between the facilities that are meant to serve areas within the existing UGB and those facilities intended to serve areas outside of the existing UGB. Where facilities are intended to eventually commingle service to areas both within the existing UGB and outside the existing UGB, those facilities can not be used to serve the later until they are included within the UGB.

Due to the apparently robust nature of the underground aquifer significant flexibility exists with respect to distribution system expansions. Since there does not appear to be physical limitations as to the geographic location of new groundwater production facilities system expansions have less impact on the existing system as compared to systems with limited supply sources. Thus, the total costs of the recommended capital improvement program presented herein would appear to require relatively modest adjustments to accommodate system expansions that are different than those identified for the Tetherow and Juniper Ridge areas.

Planning Period

The planning period for this water system master plan is through the year 2030. Based on anticipated development rates and probable infill densities, saturation development within the

existing service area and the Tetherow and Juniper Ridge areas is anticipated to occur near the end of the planning period. Saturation development, or build-out, occurs when all existing developable land within the service area has been developed, and all planning and facility sizing recommendations are based on saturation development conditions. The improvements presented in Section 6 of this report are recommended for implementation within the planning period (through 2030).

Land Use

Land use designations within the study area are established in the City of Bend General Plan. Existing land uses within the study area generally include residential, commercial, industrial and flood plain. Table 3-1 presents residential zoning designations, zone descriptions and maximum densities allowed by the General Plan and the City of Bend Zoning Ordinance which guide present and future land use and are the basis for the estimates of the ultimate service area population.

Table 3-1
Residential Land Use and Zoning Summary

Zone Designation	Zone Description	Maximum Density (Dwelling Units per Acre)
RH	Residential Urban High Density	43.0
RM	Residential Urban Medium Density	21.7
RS	Residential Urban Standard Density	7.3
RL	Residential Low Density	2.2

The population forecasts presented in this section include estimates of population to the year 2030. Through a review of existing land uses, development densities, population growth trends and discussions with City Planning Division staff it was determined that the existing UGB limits may approach saturation development within the planning period.

For the purposes of this plan, it is assumed that the UGB will be expanded prior to the end of the planning period to accommodate growth. As the City finalizes planning efforts currently underway, the demand distribution assumptions presented in this plan should be reviewed and updated if needed, especially as relates to the proposed URAs. It is anticipated the water distribution system improvements developed in this plan can accommodate minor adjustments in current zoning and densities without requiring significant modifications.

Population Estimates

Estimates of the existing and proposed population within the water system planning area were developed through discussions with City staff and through review of existing City of Bend planning data and population forecast data developed by Deschutes County.

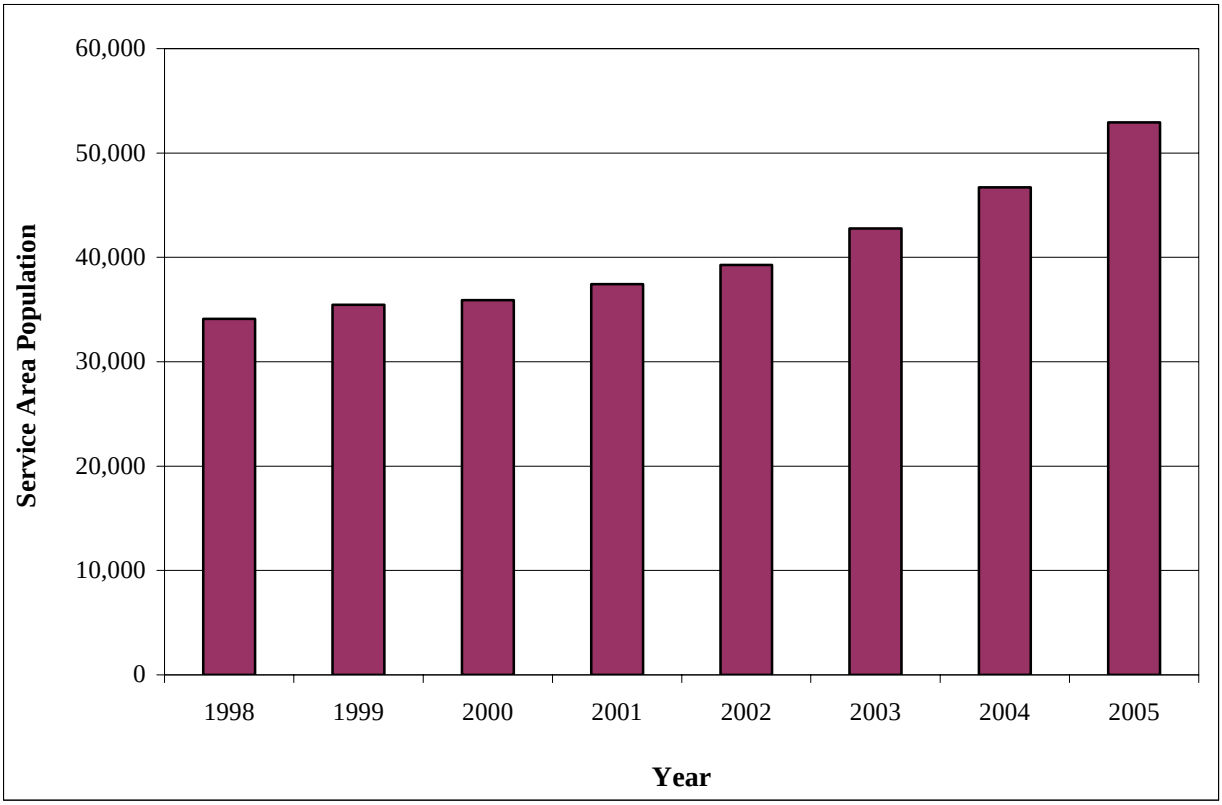
Historical Population

Historical population estimates for the City of Bend water service area were obtained from previous water system planning data and the Deschutes County Coordinated Population Forecast. The Deschutes County Coordinated Population Forecast estimates for the years 2000 through 2005 are estimates of the total population within the City. Previous water system planning studies, including the 2004 Water Management and Conservation Plan, have estimated that the percentage of the City population served by the City of Bend is approximately 68%. This percentage has been applied to the City-wide estimates to determine the historical population of Bend's water service area. The current population of the City's water service area was estimated by tabulating the number of developed dwelling units within the City's water service area. Table 3-2 and Figure 3-1 present a tabular and graphical summary of these historical population estimates.

Table 3-2
Service Area Historical and Current Population Summary

Year	Service Area Population
1998	34,090
1999	35,450
2000	35,900
2001	37,450
2002	39,270
2003	42,770
2004	46,711
2005	52,941

Figure 3-1
Service Area Population Summary



Population Forecasts

As discussed above, it is anticipated that the proposed City of Bend water service area will reach saturation development near the end of the planning period. As such, population forecasts for the ultimate, build-out condition of the water service area were developed for this study using the same methodology applied by the City of Bend Planning Department in the Residential Lands Study for the entire City. As City Planning Department staff complete the Residential Lands Study and update long-term population forecasts for the City, population forecasts may vary from those presented in this report. Since recommended improvements presented in this report are based on the ultimate needs of the service area, only the timing of improvements may need to be adjusted to meet anticipated growth patterns throughout the service area.

The ultimate population of the anticipated water service area is determined by evaluating the infill potential, or the capacity to support additional population of existing vacant land within the water service area and developed land that may be redeveloped into additional smaller lots. An analysis of each of these two infill mechanisms is presented below.

Vacant Land

As part of the Residential Lands study, City planning Department staff developed a Buildable Lands Inventory for the existing UGB. This data was used to determine the total area of vacant buildable land within the water service area. Vacant buildable land is defined as land with no existing residential dwelling units and assessed improvement value of less than $20,000 in the Deschutes County Assessor's Office records. Vacant lots with slopes of 25 percent or greater, within Water Overlay Zones or within areas identified as "Areas of Special Interest" are excluded from the vacant buildable lands.
The total area of vacant buildable land within the water service area for each type of residential zoning category is presented in Table 3-3. Table 3-3 also presents the maximum number of dwelling units that can be developed on this land in accordance with the City's Zoning Ordinance.

Table 3-3
Water Service Area Vacant Land Infill Summary

Zoning Designation (Maximum Density)	Vacant Acres	Maximum Potential Dwelling Units
RH (43 units/acre)	54	2,322
RM (21.7 units/acre)	146	3,168
RS (7.3 units/acre)	1,630	11,899
RL (2.2 units/acre)	2	4
Total	**1,832**	**17,393**

Note: Zoning designation descriptions are presented in Table 3-1.

Redevelopable Land

The City's Buildable Lands Inventory included an estimate of the area within the existing UGB that may be redeveloped. Several criteria were established to determine which lots were candidates for future redevelopment. In order to be considered as redevelopable in the inventory, a lot had to meet all three of the criteria below.

- A zoning designation of RH, RM, RS, or RL.
- An area greater than 0.5 acres in size
- An improvement value less than their land value.

The total area of redevelopable land within the water service area for each type of residential zoning category is presented in Table 3-4. Table 3-4 also presents the maximum number of dwelling units that can be developed on this land in accordance with the City's Zoning Ordinance.

Table 3-4
Water Service Area Redevelopable Land Infill Summary

Zoning Designation (Maximum Density)	Redevelopable Acres	Maximum Potential Dwelling Units
RH (43 units/acre)	0	0
RM (21.7 units/acre)	40	868
RS (7.3 units/acre)	280	2,044
RL (2.2 units/acre)	5	11
Total	***295***	***2,923***
Dwelling Units Replaced by Redevelopment		*331*
Net Additional Dwelling Units		**2,592**

Note: Zoning designation descriptions are presented in Table 3-1.

Saturation Development Forecast

Table 3-5 presents a summary of the water service area saturation development population based on the current population and the total additional population growth within the UGB that can be supported by existing vacant land and redevelopment. A population density of 2.4 people per dwelling unit was used based on 2000 U.S. Census Bureau data for the City. Table 3-5 also includes an estimate of the saturation population of the Juniper Ridge and Tetherow developments. The Juniper Ridge development is planned for primarily commercial and industrial development, although a residential component of approximately 5,000 people is anticipated for the saturation development of the service area. Given the mixed use nature of the residential component of the Juniper Ridge development and the uncertainty associated with ultimate development of this area, the population component of this development is not included in the saturation forecast presented below. Further discussion of the methodology for forecasting demands in the Juniper Ridge area is presented later in this section.

Table 3-5
Saturation Development Population Forecast Summary

Population Category	Dwelling Units	Population
Infill – Vacant Land	17,393	41,743
Infill – Redevelopable Land	2,592	6,221
Juniper Ridge	N/A	N/A
Tetherow	889	2,134
Existing Population		*52,941*
Estimated Saturation Development Population		**103,039**
USE		**103,000**

Note: Population estimate based on 2.4 people per dwelling unit.

Water Demand Estimates

General

The term "water demand" refers to all of the water requirements of the system including domestic, commercial, municipal, institutional and industrial as well as non-revenue water consumption. Water demand estimates were developed from a review of historical water consumption records provided by the City, previous water master planning efforts, and population forecasts presented earlier in this section. Demands are discussed in terms of gallons per unit of time such as gallons per day (gpd), million gallons per day (mgd) or gallons per minute (gpm). Demands are also related to per capita use as gallons per capita per day (gpcd).

Historical Water Demands

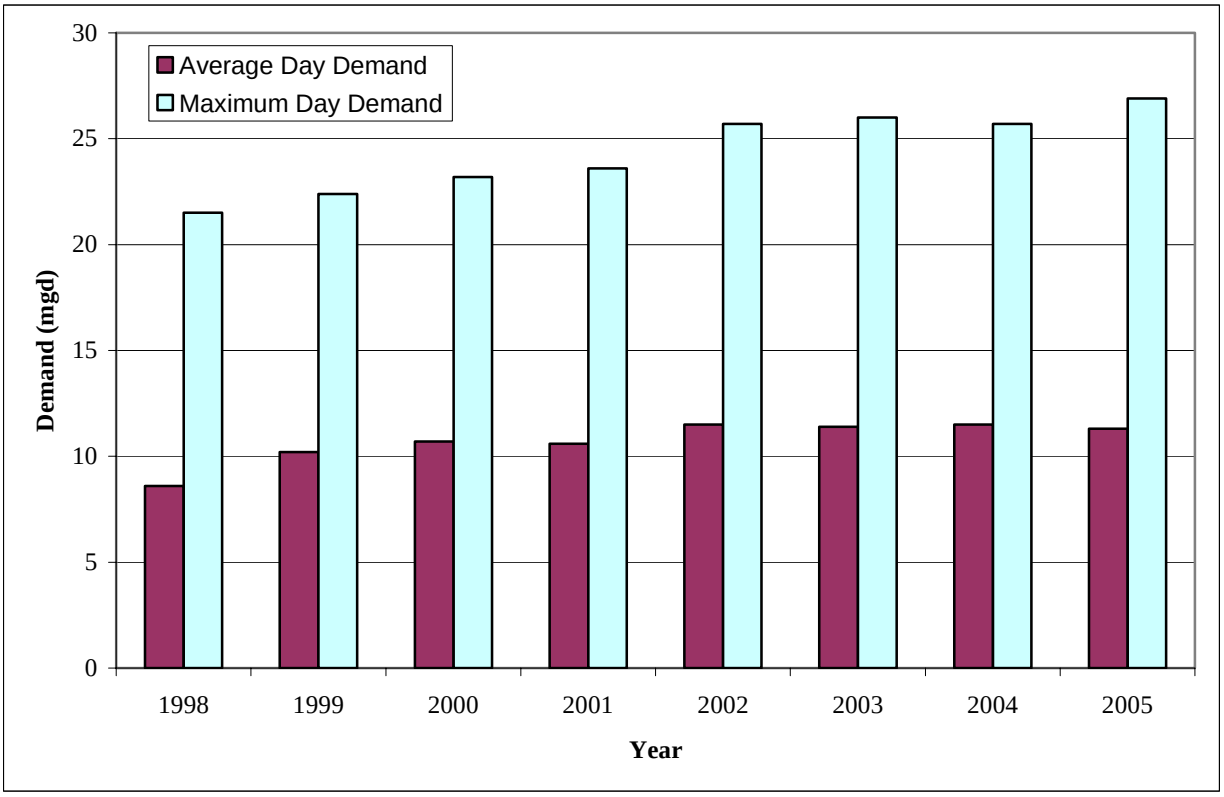
Historic water demand information was gathered from water demand data provided by the City, previous water master planning and the 2004 City of Bend Water Management and Conservation Plan. Table 3-6 and Figure 3-2 summarizes this data for the years 1998 through 2005 in tabular and graphical formats. The water use data presented in Table 3-6 is an estimate of the system-wide water usage (residential, commercial, industrial and institutional) and has been applied to the water service area population to determine a per capita water usage for the entire system. As such, the per capita water usage presented in this report does not represent actual water usage for individual water system customers and differs from the estimated residential per capita water usage of approximately 158 gpcd presented in the City's 2004 Water Management and Conservation Plan. Further discussion of the per capita water use presented in Table 3-6 is included later in this section.

Table 3-6
Historical Water Demand Summary

Year	Water Service Area Population	Historical Water Demands				
		Average Day Demand (ADD)		Maximum Day Demand (MDD)		Calculated Peaking Factor
		mgd	gpcd [(1)]	mgd	gpcd [(1)]	
1998	34,085	8.6	252	21.5	631	2.5
1999	35,451	10.2	288	22.4	632	2.2
2000	35,904	10.7	298	23.2	646	2.2
2001	37,454	10.6	283	23.6	630	2.2
2002	39,270	11.5	293	25.7	654	2.2
2003	42,772	11.4	267	26	608	2.3
2004	46,711	11.5	246	25.7	550	2.2
2005	52,941	11.3	208	26.9	508	2.4

Note: 1. Demands presented on a per capita basis represent system-wide demands and are not actual individual customer water use rates.

Figure 3-2
Water Demand Summary



Existing Water Demands

Based on historical water consumption patterns, the water service area's average daily demand (ADD) has ranged from approximately 298 gpcd to 208 gpcd. By placing emphasis on the most recent historical water usage patterns and historical populations, it is estimated that the water service area has an ADD of approximately 250 gpcd. The recent decrease in per capita water use rates would appear to be attributed both to recent water conservation efforts and to the implementation of service meters for all customers in recent years.

Recent maximum day water demand usage has ranged from 2.2 times to 2.5 times the average day demand, with an average of approximately 2.3. Placing emphasis on the most recent historical water usage patterns and historical populations, the water service area has a maximum day demand (MDD) of approximately 588 gpcd. As can be seen from Table 3-6 and Figure 3-2, the City has seen a significant reduction in MDD on a per capita basis. As with the reduction in the ADD above, this reduction is most likely attributed to the City's aggressive water conservation efforts in recent years, as well as implementation of water meters for all customers within the service area.

As discussed above, the demands presented on a per capita basis in this section are not actual individual customer water use rates but represent system-wide water use.

Water Demand Projections

Existing UGB and Tetherow

Future water demand estimates were developed by applying historical system-wide water use trends to the population forecasts previously presented. A significant increase in water demands is expected within the planning period as residential infill development and expansion of the UGB occurs.

For the purposes of this plan, estimated average daily water use is assumed to remain at approximately 250 gpcd and estimated maximum day water use is assumed to remain at approximately 590 gpcd.

Total estimated average and maximum day water demands for the City's water service area are developed by multiplying the estimated system-wide per capita usage by the anticipated population. To provide an estimate of peak hourly usage, a peak hour factor of 1.5 is applied to maximum day water demands.

Juniper Ridge

Demand forecasts for the Juniper Ridge Area were developed using previous reporting prepared by the City in conjunction with certain assumptions established with this water master plan. As per the 2004 Water Management and Conservation Plan (WMCP), the overall commercial demand for the total area inside the City's Urban Growth Boundary (UGB) for the year 2035 is estimated at approximately 8.4 mgd (Figure 5-3, page 5-7, WMCP).

It is assumed that the UGB will have reached build-out conditions by the year 2035. The reasoning for this assumption is as follows: The forecasted population for the entire City (both inside and outside the current UGB) for the year 2035 is 129,219 people (Table 5-1, page 5-2, WMCP), and the projected build out population of the area within the UGB is 95,242 people (page 3 of 4, Capacity of UGB for Housing Memorandum October 5, 2005).

The commercial demand for the entire City as per the WMCP was allocated to the area within the current UGB. This approach is conservative because the year 2035 commercial demand will likely include all of the area within the UGB plus certain areas outside of the current UGB.

The total area of land within the existing UGB zoned for commercial development is approximately 1876 acres (City of Bend General Plan). From the forecasted commercial demand of 8.4 mgd (5,830 gpm) and the total commercial acreage, an estimated commercial demand of 4,500 gpd per acre was developed (8.4 mgd/1876 acres = 4500 gpd/acre). The forecasted demand per acre was then applied to the net developable acreage in the Juniper Ridge development, assumed to be 70% of the gross acreage (1,516 acres* 0.70 *4500 gpd/acre = 4.8 mgd).

While this value is higher than typical commercial and industrial water use rates currently experienced in the City of Bend, it provides a conservative estimate that allows the City to plan for highly variable water use that can be experienced in future unanticipated commercial and industrial development in this area. Given the high degree of variability in industrial water usage, the forecasts presented herein are intended to be somewhat conservative. This approach is intended to help the City plan water system infrastructure that is capable of supporting a reasonably wide range of potential development interests. As planning for the Juniper Ridge area advances, water demand forecast for this area should be updated to confirm actual supply, storage and transmission needs.

Water Demand Projection Summary

Table 3-7 presents a summary of water demand forecasts for existing and saturation development conditions within the study area (UGB plus Tetherow and Juniper Ridge).

Table 3-8 summarizes water demand estimates for each pressure zone for the year 2005 and water demand projections for each pressure zone at saturation development of the study area.

Table 3-7
Population Projections and Water Demand Summary

Year	Water Service Area Population	Water Demand (mgd)		
		Average Day Demand (ADD)	Maximum Day Demand (MDD)	Peak Hour Demand (5)
2005	52,941	11.3 (1)	26.9 (2)	40.7
Saturation Development(6)	103,000	30.7 (3) (6)	71.5 (4) (6)	107.3(6)

Notes:
(1) Existing Average Day Demand based on 2005 water use records.
(2) Existing Maximum Day Demand based on 2005 water use records.
(3) Average Day Demand equals the Population multiplied by the estimated average daily per capita usage for the service area (250 gpcd).
(4) Maximum Day Demand equals the Population multiplied by the estimated maximum daily per capita usage for the service area (590 gpcd).
(5) Peak Hour Demand equals 1.5 times the Maximum Day Demand
(6) Includes Juniper Ridge ADD, MDD and Peak Hour Demand of 4.8, 10.7 and 16.0 mgd, respectively.

Table 3-8
Pressure Zone Water Demand Summary

Pressure Zone	Existing (mgd)			UGB Saturation Development (mgd)		
	Average Day Demand (ADD) [1]	Maximum Day Demand (MDD) [2]	Peak Hour Demand [3]	Average Day Demand (ADD) [4]	Maximum Day Demand (MDD) [5]	Peak Hour Demand [3]
1	0.18	0.42	0.64	0.3	0.8	1.2
2	0.22	0.51	0.76	0.6	1.4	2.0
2SB	0.13	0.31	0.46	0.7	1.6	2.4
Westwood	0.07	0.09	0.14	0.4	0.9	1.4
3 [6]	0.88	2.07	3.10	2.5	6.1	9.2
3SB	0.27	0.64	0.95	0.9	2.0	3.0
4W	1.17	2.74	4.11	2.6	6.1	9.1
4E	1.89	4.45	6.67	4.9	11.5	17.3
5	4.1	10.61	15.91	7.5	17.6	26.4
6	1.80	4.23	6.34	4.8	11.2	16.9
7	0.32	0.74	1.12	0.7	1.6	2.4
Juniper Ridge	--	--	--	4.8	10.7	16.0
TOTALS	**11.3**	**26.9**	**40.7**	**30.7**	**71.5**	**107.3**

Notes: (1) Average Daily Demand for existing conditions equals the population multiplied by the estimated average daily per capita usage for the service area in 2005 (216 gpcd).
(2) Maximum Day Demand for existing conditions equals the population multiplied by the estimated maximum daily per capita usage for the service area in 2005 (508 gpcd).
(3) Peak Hour Demand equals 1.5 times the Maximum Day Demand.
(4) Average Daily Demand for Saturation Development equals the Population multiplied by the estimated average daily per capita usage for the service area (250 gpcd).
(5) Maximum Day Demand for Saturation Development equals the Population multiplied by the estimated maximum daily per capita usage for the service area (590 gpcd).
(6) Pressure Zone 3 Saturation Development Demands include Tetherow.

Summary

This section presents a discussion of existing and projected land uses within the study area, estimates of the current and future water service area population and forecasts of future water demands. Section 4 outlines the planning criteria that, with the water demand estimates presented in this section, are used in the water system analysis presented in Section 5.

SECTION 4
PLANNING AND ANALYSIS CRITERIA

General

This section develops and presents the planning and analysis criteria and assumptions used for the water system analysis. Criteria and planning assumptions are presented for the City of Bend's water supply, treatment, distribution system, service pressures, and storage and pumping facilities. Recommendations for water needs for emergency fire suppression are also presented. The water demand forecasts developed in Section 3 are used in conjunction with the criteria presented in this section for the analysis of Bend's water system presented in Section 5.

Supply, Treatment and Transmission Criteria

The City's supply, treatment and transmission systems should be capable of providing estimated maximum day demands through the end of the 25-year planning period and beyond. For planning purposes the end of the 25-year planning period (year 2030) is anticipated to correspond with saturation build-out of the service area within the urban growth boundary (UGB), as well as saturation build-out of the proposed Tetherow development and proposed Juniper Ridge area (both URA's). This planning report recommends system improvements for ultimate build-out of the other remaining URA's and identifies them as "long-term" improvements (beyond 2030). Based on water demand estimates presented in Section 3, the supply system will need to be expanded to supply an average day demand of approximately 31.5 mgd and a maximum day demand of approximately 71.5 mgd in the year 2030. The current capacity of the supply system is approximately 38 mgd.

As described in Section 2 the City has both surface water and groundwater supply sources. Surface water is collected from Bridge Creek at the Bridge Creek Intake Facility from where it flows by gravity to first an overflow standpipe and then to the Contact "CT" Basin at the Outback Reservoir Site. Groundwater is withdrawn from the Deschutes Aquifer through 23 water production facilities located at 9 sites throughout the City and at the Outback Reservoir site westerly of the City. From these production facilities water is either pumped into finished water reservoirs or pumped directly into the distribution system piping. The City has been granted an exemption from the Surface Water Treatment Rules by the Oregon State Health Division. This exemption is based on a review of the water quality in the Bridge Creek watershed and the maintenance of this watershed. As such, the City currently has no need for a raw water treatment plant; however, the City currently chlorinates the surface water prior to distribution.

Distribution System Criteria

The water distribution system should be capable of operating within certain system performance limits, or guidelines, under several varying demand and operational conditions. The recommendations of this plan are based on the following performance guidelines, which

have been developed through a review of State requirements, American Water Works Association (AWWA) acceptable practice guidelines, operational practices of similar water providers, and discussions with City water system operations staff.

The recommended analysis criteria are as follows:

1. The distribution system should be capable of providing the peak hour demand while maintaining a minimum service pressure at any meter in the system of 40 pounds per square inch.

2. The distribution system should be capable of providing the recommended fire flow to a given location while, at the same time, supplying the maximum day demand and maintaining a minimum residual service pressure at any meter in the system of 20 pounds per square inch (psi). This is the minimum water system pressure required by the Oregon State Department of Human Services Drinking Water Program. Reservoirs are assumed to be approximately half-full during fire flow events.

It should be noted that the City has historically used 30 psi as the required minimum residual pressure during fire flow analyses for sizing new facilities. In addition, historically the City has assigned fire flow rates of 1,000 gpm for residential areas and 3,000 gpm for commercial/industrial areas. However, due primarily to the increase in the residential fire flow rate to 1,500 gpm and the increase in the maximum commercial fire flow rate to 3,500 gpm (Commercial Highway), the City has adjusted the required residual pressure to the State mandated 20 psi. These two modifications to analysis criteria appear to strike a good balance between satisfying life and safety interests with updated fire flow capacities, and providing sound economic solutions with a reasonable adjustment to residual pressures. The residential fire flow rate has been increased to 1,500 to match the International Building Code (IBC) for residential structures 3,000 square feet and larger, since homes of this size are allowed in residential zones throughout the City.

Recommended fire flows are identified in Table 4-2 below. The hydraulic computer analysis of the water system assumes that for fires greater than 1,500 gpm more than one hydrant will be operated. In addition, it is assumed that fire suppression through the operation of municipal fire hydrants within the Commercial Highway zone is supplemented with internal sprinkler fire suppression systems. The hydraulic analysis assumes fire flow rates of 2,500 gpm and 3,500 gpm for the various commercial and industrial zoning designations.
The above analysis criteria are established as water system performance requirements in the hydraulic computer model and proposed improvements are guided by how the system responds to such requirements. In addition, recommended water system improvements are guided by professional judgment and standards of practice.

While the computer model provides important information on system response to certain demand and proposed improvement scenarios, variables that are not included in the computer model are given a high degree of consideration as part of the distribution system analysis and for identifying recommended system improvements. Such variables include corridor/street characteristics, anticipated and ongoing developments, other City utility planning objectives,

project and overall program costs, City system planning philosophy, desired remedying of operation and maintenance issues, etc.

For the City of Bend water system looped water mains should normally be at least 8 inches in diameter except for short loops where 6-inch diameter mains are acceptable. Mains smaller than 6 inches in diameter are generally appropriate where no fire hydrant connections are required, if there are limited services on the main, or if the main is dead-ended and looping or future extension of the main is not anticipated. In addition, while not analyzed with the assistance of the hydraulic computer model the distribution system should be capable of supplying the peak hour demand while maintaining minimum service pressures of not less than approximately 70 percent of normal system pressures.

As discussed in Section 2, water distribution systems are typically separated into pressure zones or service levels to provide service pressures within an acceptable range to all customers. Bend's existing water service area is divided into eleven primary pressure zones. Pressure zones are established by ground topography and designated by overflow elevations of water storage facilities, outlet settings of pressure reducing facilities, or discharge pressures of booster pump stations serving the zone. Typically, water from reservoirs will serve customers by gravity within a specified range of ground elevations so as to maintain acceptable minimum and maximum water pressures at individual service connections. When it is not feasible or practical to have a separate reservoir serving each pressure zone, pumping facilities or pressure reducing facilities are used to serve customers in different pressure zones from a single reservoir.

Generally, 100 psi is considered the desirable upper pressure limit for any pressure zone and 40 psi the lower limit. Whenever feasible, it is desirable to achieve the 40 psi lower limit at the point of the highest fixture within a given building being served. Conformance to this pressure range may not always be possible or practical due to topographical relief, existing system configurations and economic considerations. In some areas system pressures of up to 120 psi are allowed, anticipating the need for individual pressure reducing valves (PRV's) to be installed at each service connection to help satisfy pressure requirements of the Uniform Plumbing Code. Table 4-1 summarizes the service pressure criteria used in the analysis of the water system.

Table 4-1
Recommended Service Pressure Criteria

Condition	Pressure (psi)
Minimum Service Pressure Under Fire Flow Conditions	20
Minimum Normal Service Pressure	40
Maximum Preferred Service Pressure	95
Maximum Service Pressure	120

Storage Volume

Water storage facilities should be in place to provide gravity fed supply to each pressure zone except in special cases where direct pumping can be justified. Storage facilities are provided for three purposes: operational storage (or "equalization storage"), emergency storage, and fire storage. The total storage required is the sum of these three elements. A brief discussion of each element is provided below.

Operational Storage

Operational storage is required to meet water system demands in excess of delivery capacity from the supply source to system reservoirs. Operational storage volume should be sufficient to meet normal system demands in excess of the maximum day demand and is generally considered as the difference between peak hour demand and maximum day demand (on a 24-hour duration basis). For Bend's water system, operational storage volume in the amount of 25 percent of maximum day demand is considered appropriate.

Emergency Storage

Emergency storage is intended to provide water during emergencies such as pipeline failures, equipment failures, power outages or natural disasters. While any number of emergencies may occur over time, it is prudent to plan for the anticipated emergency conditions that would have the greatest impact on water storage in the City. It is recommended that the criteria for emergency storage assume the single largest supply source, the City's surface water supply, is interrupted. This condition could potentially occur if perhaps there were a large enough fire in the Bridge Creek watershed. It should be noted that the criteria for emergency storage in portions of South Bend should assume that the single largest groundwater well site is out of service.

The amount of emergency storage for a water system can be highly variable depending upon an assessment of risk and the desired degree of system reliability. Provisions for emergency storage in other systems vary from none to a volume that would supply several day's maximum flow (maximum day demand (MDD)) or higher. Considering the region's risk of forest fires on one hand, and the City's recognized robust subsurface water source on the other hand, it would seem prudent to plan for sufficient emergency storage to accommodate two days of average day demands (ADD). It is acknowledged that this recommendation is somewhat more conservative than the single ADD recommended for emergency storage by prior reporting (see City of Bend 1999 Water Master Plan Update). However, this plan presents an efficient and "high value" program to developing storage that would support the somewhat more conservative approach as discussed below.

Because of how the City's water system is configured and how water sources are distributed, it is recommended that certain emergency storage volume requirements be provided by existing underground "storage" in the subsurface aquifer, rather than through costly constructed reservoir "tank" storage capacity. The City reports the belief that ample

quantities of groundwater are indeed broadly available and accessible throughout the City's urban planning area, as supported by prior studies. Thus, it is suggested that during the above described emergency condition, with the surface water source non-operational, the existing and proposed groundwater supply facilities could provide a significant volume of emergency storage to the City. By assuming that the subsurface aquifer could provide available emergency storage capacity, the needed additional constructed "tank storage" volume may be reduced significantly, potentially saving considerable costs for the City in the long-term. The analysis and recommendations presented in this report include this assumption and further discussion and analysis associated with this interest are presented in Section 5.

Fire Storage

While the water distribution system provides water for domestic uses, it is also expected to provide water for fire suppression. The amount of water recommended for fire suppression purposes is based on the size and duration of the anticipated fire which is typically associated with the local building type or land use of a specific location. Standard engineering practice is to assume that the largest fire for a given area may occur during maximum day demand conditions. This Master Plan Update presents a recommended capital improvements program that meets these requirements.

Table 4-2 presents assumptions for fire flows for distribution piping analysis. However, for fire storage analysis, fire flow assumptions have been increased assuming there is the potential for more than one fire occurring at a time. This approach assumes that two simultaneous fires may rely on the storage capacity of a single pressure zone, but are less likely to impact the same distribution system pipeline capacities. Thus, the storage analysis assumes fire flow rates of 3,000 gpm and 5,000 gpm, in lieu of 2,500 gpm and 3,500 gpm for the respective zoning designations presented in Table 4-2. The resultant fire storage for residential areas is 180,000 gallons, for commercial/industrial areas it is 540,000, and for the commercial highway zone it is 1,500,000 gallons.

Fire Flow Recommendations

A summary of fire flow recommendations by land use designation is presented in Table 4-2. The fire storage volume is determined by multiplying the recommended fire flow rate by the expected duration of that flow. The recommended fire flows were developed through a review of fire flow criteria adopted by the City, fire flow guidelines as developed by the AWWA, the Insurance Services Office (ISO) and recommended by the International Fire Code. It should be noted that for the recommended 3,000 gpm and 5,000 gpm fire flow rates presented in Table 4-2, the distribution system analysis assumed 2,500 gpm and 3,500 gpm respectively. The higher fire flow rates shown in Table 4-2 are used for storage capacity analysis only as a measure to help offset the potential risks for multiple simultaneous fires, heightened by the semi-arid environment in and around the City of Bend.

Table 4-2
Summary of Recommended Fire Flows and Fire Storage Volume

Zone	Zoning Description	Recommended Fire Flow Rate (gpm)	Duration (hours)	Recommended Fire Storage Volume (MG)
RS	Residential Urban Standard	1,500	2	0.18
RM	Residential Urban Medium	1,500	2	0.18
RH	Residential Urban High	1,500	2	0.18
CN	Commercial Neighborhood	2,500	3	0.54*
CC	Commercial Convenience	2,500	3	0.54*
CL	Commercial Limited	2,500	3	0.54*
CG	Commercial General	2,500	3	0.54*
CBD	Industrial Park	2,500	3	0.54*
IP	Industrial Light	2,500	3	0.54*
IG	Industrial General	2,500	3	0.54*
CH	Commercial Highway	3,500	5	1.50*

* The above table presents recommended fire flow rates for distribution piping analysis. The recommended fire storage volumes for commercial and industrial areas has been calculated based on adjusted fire flow rates of 3,000 gpm and 5,000 gpm in lieu of 2,500 gpm and 3,500 gpm for the respective zones identified above.

Pump Station Pumping Capacity

Firm pumping capacity requirements vary depending on how much storage is available to the service area of the pump station and the number of pumping facilities serving the particular service area. Firm pumping capacity is defined as a station's pumping capacity with the largest pump out of service (the most severe emergency operating condition). When storage facilities serve directly by gravity the same area served by the pump station, then it is recommended that a firm pumping capacity equal to the area's maximum day demand be implemented. If a constant pressure pumping system is implemented then the firm capacity is dependent upon the size of the area served. For smaller service areas the recommended firm pumping capacity should be equal to the area's peak instantaneous demand plus fire flow. For larger service areas the firm pumping capacity could be as low as the area's maximum day demand plus fire flow. Additionally, all constant pressure pumping systems should be equipped with emergency backup power generation facilities since backup storage water is not available for these areas by gravity flow only.

The City currently uses constant pressure (continuous operation) groundwater well or booster pump station pumping, without gravity fed supply, to serve part of the Westwood area as well as Zones 2 South Bend (2SB) and 3 South Bend (3SB). This type of constant pressure system is generally recommended for relatively small residential areas of up to perhaps 50 homes where gravity fed storage is impractical or significantly more costly. However,

implementing storage for the Westwood area as well as Zones 2 South Bend (2SB) and 3 South Bend (3SB) would not come without certain challenges.

Implementing strategically located elevated storage would be one option to serve these areas by gravity. However, due to aesthetic reasons, it is understood that the City of Bend desires to avoid constructing elevated storage tanks if other reasonable alternatives are available. Upon preliminary review, it would appear that there are options for implementing ground level storage for these areas. However, such may be more costly than maintaining system pressures and providing supply through continuous pumping systems.

Summary

The criteria developed in this section are used to assess the system's ability to provide adequate water service under existing conditions and to guide improvements needed to provide service for future water needs. Planning criteria for the supply system, distribution system, service pressures, and storage and pumping facilities are presented herein. Section 5 presents the analysis of the water distribution system based on the criteria provided in this section. Section 6 identifies proposed water system improvement recommendations and presents a recommended improvement program, including project cost estimates, intended for adoption as part of the City's comprehensive Capital Improvement Plan (CIP).

SECTION 5
WATER SYSTEM ANALYSIS

General

This section presents an analysis of Bend's water system based on the water demand forecasts presented in Section 3 and the analysis criteria developed in Section 4. This section provides an overview of the City's supply system, evaluates the existing service pressures, storage and pumping capacity requirements, and presents the findings of an analysis using a computerized hydraulic network analysis program. Through evaluation and analysis, system deficiencies were identified and improvement options have been developed. Section 6 presents a recommended water system improvement program that includes prioritized recommended improvements to correct system deficiencies and provide for system expansion.

Water Demands

As presented in Section 3, water demand estimates have been developed for saturation build-out of the service area within the urban growth boundary (UGB) as well as for Tetherow and Juniper Ridge, anticipated future service areas within the proposed urban reserve areas (URA's) (see Table 5-1). For planning purposes it is assumed that saturation build-out for these areas will occur near the end of the 25 year planning period.

Table 5-1
Population Projections and Water Demand Summary

Year	Water Service Area Population	Water Demand (mgd)		
		Average Day Demand (ADD)	Maximum Day Demand (MDD)	Peak Hour Demand (5)
2005	52,941	11.3 (1)	26.9 (2)	40.7
Saturation Development(6)	103,000	30.7 (3) (6)	71.5 (4) (6)	107.3(6)

Notes:
(1) Existing Average Day Demand based on 2005 water use records.
(2) Existing Maximum Day Demand based on 2005 water use records.
(3) Average Day Demand equals the Population multiplied by the estimated average daily per capita usage for the service area (250 gpcd).
(4) Maximum Day Demand equals the Population multiplied by the estimated maximum daily per capita usage for the service area (590 gpcd).
(5) Peak Hour Demand equals 1.5 times the Maximum Day Demand
(6) Includes Juniper Ridge ADD, MDD and Peak Hour Demand of 4.8, 10.7 and 16.0 mgd, respectively.

Table 5-2, "Pressure Zone Water Demand Summary" summarizes water demand estimates for each pressure zone for the years 2005 and 2030. These water demand estimates along with the planning criteria established in Section 4 are the basis for the analysis of the existing system and the development of recommended system improvements. The capacities of recommended improvements are based on estimated maximum day demands at saturation development unless otherwise noted. This approach is intended to help avoid the need to upgrade facilities to increase capacities for higher demands, prior to the end of their useful life span.

Table 5-2
Pressure Zone Water Demand Summary

Pressure Zone	Existing (mgd)			UGB Saturation Development (mgd)		
	Average Day Demand (ADD) [1]	Maximum Day Demand (MDD) [2]	Peak Hour Demand [3]	Average Day Demand (ADD) [4]	Maximum Day Demand (MDD) [5]	Peak Hour Demand [3]
1	0.18	0.42	0.64	0.3	0.8	1.2
2	0.22	0.51	0.76	0.6	1.4	2.0
2SB	0.13	0.31	0.46	0.7	1.6	2.4
Westwood	0.07	0.09	0.14	0.4	0.9	1.4
3 [6]	0.88	2.07	3.10	2.5	6.1	9.2
3SB	0.27	0.64	0.95	0.9	2.0	3.0
4W	1.17	2.74	4.11	2.6	6.1	9.1
4E	1.89	4.45	6.67	4.9	11.5	17.3
5	4.1	10.61	15.91	7.5	17.6	26.4
6	1.80	4.23	6.34	4.8	11.2	16.9
7	0.32	0.74	1.12	0.7	1.6	2.4
Juniper Ridge	--	--	--	4.8	10.7	16.0
TOTALS	**11.3**	**26.9**	**40.7**	**30.7**	**71.5**	**107.3**

Notes: (1) Average Day Demand for existing conditions equals the population multiplied by the estimated average daily per capita usage for the service area in 2005 (216 gpcd).
(2) Maximum Day Demand for existing conditions equals the population multiplied by the estimated maximum daily per capita usage for the service area in 2005 (508 gpcd).
(3) Peak Hour Demand equals 1.5 times the Maximum Day Demand.
(4) Average Day Demand for Saturation Development equals the Population multiplied by the estimated average daily per capita usage for the service area (250 gpcd).
(5) Maximum Day Demand for Saturation Development equals the Population multiplied by the estimated maximum daily per capita usage for the service area (590 gpcd).
(6) Pressure Zone 3 Saturation Development Demands include Tetherow.

Water Supply Analysis

Currently the total existing water supply capacity for the City is approximately 38.8 mgd, with a firm capacity of approximately 31.2 mgd. Based on water demand estimates presented in Section 3, during the planning period the supply system should be expanded by approximately 40.3 mgd such that the firm capacity satisfies total maximum day demands of approximately 71.5 mgd.

The term "firm capacity" is used to refer to the reliable capacity of a water system component. In the case of the City of Bend's water supply system there are a number of sources, consisting of the groundwater wells and the surface water source. For the purposes of this report the reliable capacity, or "firm capacity", of the supply system is the total capacity of all sources minus the largest source, which in this case is the surface water source. This methodology is good practice in that it helps reduce the risks of planning a system that has insufficient capacity in the various system components, and this approach is consistent with standard engineering practices and recommendations by the American Water Works Association.

As discussed prior, for the purposes of this planning work, the City's existing surface water source is currently considered at capacity. Since planning and analysis are based on maximum day demand conditions that occur during the hot summer period this report assumes an available capacity from the surface water source of 7.6 mgd, the lowest anticipated yield for that time of year. It is understood that the City is currently conducting a water source protection study and contemplating piping raw water from the watershed to the Outback site. While surface water source expansion opportunities exist, for planning purposes, this report assumes that such expansions will provide additional supply capacity outside of the summer peak use period. Thus, supply capacity expansions presented in this plan are proposed to be implemented through the construction of new groundwater wells. However, if any contemplated surface water supply expansions increase summer water supply then such expansions may certainly be implemented in lieu of certain proposed groundwater capacity expansions. To minimize pumping costs and take full advantage of the City's existing water rights, this plan promotes maximizing the use of surface water as it is available during the wetter periods of the year.

The City reports the belief that ample quantities of groundwater are indeed broadly available and accessible throughout the City's urban planning area, as supported by prior studies. The water supply analysis presented herein assumes that groundwater sources may be developed in certain convenient locations, relative to various distribution systems facilities. By withdrawing supply water at certain strategic locations the City may avoid the need to construct high cost transmission piping that might be required with an approach that focuses on more centralized source development. Groundwater development potential may then be validated through further hydrogeologic study or proven-out through a physical test well program. This planning work does not include a comprehensive water supply study and it is suggested that the City conduct further detailed analysis of supply alternatives as the supply system is expanded. Any determined variations from assumed conditions may then be addressed through subsequent updates and revisions to this Water Master Plan Update.

Pressure Zone Analysis

General

As discussed in Section 2, Bend's distribution system is currently separated into eleven primary service areas, or pressure zones. The planning criteria developed in Section 4 established acceptable service pressure limits throughout the City. These criteria are used to determine optimal operating elevations of proposed reservoirs and to evaluate service elevations for existing and proposed pressure zones. The water distribution system analysis performed as part of this report established that certain adjustments to pressure zone boundaries should be implemented to better serve certain areas.

Westwood Service Area

When the City assumed water service responsibilities for the Westwood neighborhood in the southwesterly portion of Bend it inherited an area operating with a hydraulic grade between Zone 2 and Zone 3. While the area is at elevations consistent with the surrounding Zone 3, the water system for this area was designed with the assumption that it would continue to operate at the higher pressures between Zone 2 and Zone 3. It is recommended that the City consider conducting further study outside of this report to evaluate the potential to transition the Westwood area to the existing Zone 3 service area. This adjustment of service pressures and zones could provide both benefits and drawbacks that should be thoroughly reviewed should the City consider such a change.

As part of the recommended additional study, the City should investigate the option to implement either elevated or ground level storage to serve the Westwood area, thereby transitioning this service area from a constant pressure pumped system to a more reliable, lower maintenance gravity fed service area. The existing topography westerly of the vicinity of the Westwood area is sufficient for locating a ground level reservoir; however, since a ground level reservoir currently exists near the Westwood Pump station, upgrading the existing pump station would initially appear to be the least costly alternative to expanding service capacity in the Westwood area. This report assumes that the City would continue with the current operating scenario and pressures for the existing Westwood area.

The Westwood Pump Station is a continuously operated pump station that supplies water from the ground level Westwood Reservoir to the Westwood Service Area at a hydraulic grade between Zone 2 and Zone 3. This pump station currently serves approximately 150 residential dwelling units. A southern portion of the proposed Tetherow development is at an elevation too high to be served by the surrounding Zone 3 system. Since this area is relatively close to the Westwood area and would be adequately served at the hydraulic grade of the Westwood area, it is recommended that this area be included in the Westwood Service Area.

The Tetherow development will add approximately 300 to 350 dwelling units and commercial and retail development to the Westwood Pump Station's service area. The maximum day demand at saturation development for this proposed expanded service area is approximately 0.9 mgd (625 gpm). The pump station must also be capable of supplying fire flow demands which are 2,500 gpm in the Tetherow development. Therefore, the recommended firm pumping capacity of the Westwood Pump Station is approximately 3,125 gpm. The existing firm pumping capacity is approximately 1,490 gpm. Recommendations for expansion of the Westwood Pump Station are discussed in Section 6.

Zone 4E/Zone 5

The second recommended pressure zone boundary adjustment is for a very small area at the interface of Zone 4E and Zone 5. It is recommended that a length of piping along NE 12th Street, from NE Revere Avenue to NE Seward Avenue, be transferred to Zone 4E from Zone 5 to provide sufficient fire flows and service pressures. This adjustment is accomplished quite simply by opening and closing existing isolation valves as needed.

In the future, as the City addresses the need to replace the Overturf reservoirs, it may best serve the City to implement new storage at this site with overflow elevations at 3,880 feet to match the static hydraulic grade of Zone 4E. This would allow Zones 4W and 4E to operate as a single pressure zone, by opening an existing isolation valve on the 16-inch diameter pipeline that connects the two zones. This scenario would improve the City's ability to circulate and move water more readily between the zones, thereby, improving supply options and fire flow capacities.

Juniper Ridge Area

The Juniper Ridge area just outside the northeasterly portion of the City is anticipated to operate with either one or two separate pressure zones. One pressure zone could serve the Juniper Ridge area at a hydraulic grade somewhat lower than the existing Zone 7 hydraulic grade. Alternatively, two pressure zones could be developed, extending the existing Zone 7 northerly into the southern half of the Juniper Ridge area, and implementing an additional Zone 8 to serve the lower elevation areas in the northern half of Juniper Ridge. The ground elevations within Juniper Ridge range from approximately 3,460 feet to 3,275 feet above mean sea level.

Additional storage capacity of approximately 4.2 mg, and additional supply capacity of roughly 10.7 mgd would be needed to serve the Juniper Ridge area at ultimate build-out. For planning purposes, the required storage for the Juniper Ridge area is split between a reservoir on the Juniper Ridge site and storage capacity in a planned reservoir on Pilot Butte. This assumes that the lower elevation northerly portion of Juniper Ridge, below approximately 3,380 feet, could be served from a 2.0 MG on-site reservoir, sited at roughly 3,460 feet. The remaining 2.2 MG of storage required to serve the southerly portion of Juniper Ridge above roughly 3,380 feet in elevation is included as a portion of the capacity of the 3.5 MG Pilot

Butte VI reservoir. This scenario avoids the need for constant pressure pumping facilities to serve the Juniper Ridge area.

The recommendations presented in this plan, and incorporated into the proposed CIP, include physical pipeline connections between Juniper Ridge water facilities and the existing City facilities to support the above described storage scenario, and to facilitate integration of the Juniper Ridge area with the existing City system. These pipeline connections consist of 2,600 linear feet of 12-inch diameter pipeline along Cooley Road and 6,900 linear feet of 16-inch diameter pipeline along 18th Street. In addition to these pipelines, which help connect the Juniper Ridge area to the existing City system, further pipeline improvements within the UGB are proposed to improve system capacities to serve the southerly portion of the Juniper Ridge area, utilizing improved storage capacity on Pilot Butte.

It is proposed that as planning for the Juniper Ridge area progresses, the City conduct further study, possibly including hydraulic water system analysis, to confirm proposed improvements match well with planned development.

Former Juniper Utility Area

The former Juniper Utility area presents certain challenges regarding integration with existing City facilities. The water system in the area was recently acquired by the City of Bend and it appears that the system was not originally planned for optimum integration with the City's water system.

The pressure zones in the former Juniper Utility area, Zones 2SB and Zone 3SB, operate at hydraulic grades inconsistent with the City's existing Zones 2 and 3. Adjusting pressure zone boundaries to better match the City's existing system would, among other benefits, potentially reduce long-term capital improvement costs and simplify operations. However, such modifications would appear to introduce certain challenges regarding service pressures, system vulnerabilities, etc.

This report presents a program that maintains existing pressure zone boundaries in the former Juniper Utility area while satisfying maximum day demands plus fire flows. This approach provides the City with relatively conservative estimated capital improvement costs looking forward. It is recommended that further study be conducted outside of this report to evaluate this interest in greater detail, and to present recommendations based on more in-depth analysis.

Zone 4E/Zone 3SB

Because of certain physical characteristics of the water system as discussed above, the City is currently challenged to provide sufficient fire flows to the former Juniper Utility area. To help supplement existing flows a pressure sustaining valve should be implemented to supply water from Zone 4E to the northerly portion of this area during fire flow conditions. This

valve would operate only during conditions that would allow Zone 4E to provide water to this area that normally operates at a higher hydraulic grade than Zone 4E.

Zones 2 South Bend (2SB) and 3 South Bend (3SB)

These two zones are currently operating as constant pressure pumped service areas. While such systems are generally more costly and less reliable in the long term than gravity fed systems, it is recommended that the City conduct further study, outside of this report, to assess alternatives for implementing local storage and changing these areas to gravity fed systems.

The existing topography in the vicinity of the South Bend area would appear to require approximately two miles of transmission piping to reach a suitable elevation for locating a ground level reservoir. The costs of such piping combined with the costs of a reservoir should be compared with the costs required for constant pressure pumping at saturation development, including the additional long-term operation and maintenance costs. It is suggested that both alternatives be further evaluated during the preliminary engineering phase of the proposed additional groundwater production facilities serving this area.

Zone 7

Currently Zone 7 includes three separate areas within the current UGB, and possibly including the Juniper Ridge area, depending on how development planning proceeds. The two smaller Zone 7 areas (one adjacent to Empire Avenue and the other near 27th Street) should be considered for partial or full transfer to the adjacent Zone 6 service area. Adjacent Zone 6 service areas are at relatively similar elevations as the two Zone 7 areas. If excessive pressures are of a concern for these areas, individual pressure reducing valves (PRV's) could be implemented. The potential benefits of transferring the two Zone 7 areas to Zone 6 include improved water system looping opportunities that may help improve fire flows and help avoid water quality issues. Also, some system PRV's may be eliminated, thereby reducing maintenance costs. One key interest is to extend the Zone 6 16-inch diameter transmission main from 27th Street, along the proposed Empire Avenue Extension, through to 18th Street and then north to Juniper Ridge. Keeping this pipeline as a Zone 6 line would help in water delivery to the Juniper Ridge area, in both improved flow and pressure characteristics.

Storage Capacity Analysis

General

The storage capacity analysis evaluates the City's existing water storage capacity and determines the recommended storage volume needs for the water service area. Estimated water storage volume requirements are based on the combined storage components for operational, fire and emergency purposes.

A key assumption incorporated into the analysis for the City of Bend's water system is the premise that a certain volume of emergency storage may be allocated to the City's subsurface aquifer water supply source. This assumption assumes that during an emergency condition a sufficient volume of supply water may be withdrawn from the aquifer via existing and proposed wells until the emergency condition passes. This assumption significantly reduces the amount of reservoir "tank storage" capacity needed for the City. Further discussion and analysis associated with this interest follows.

Storage Requirements

Based on water demand forecasts presented in Section 3 and the planning criteria identified in Section 4 the total volume of required storage by the end of the planning period (year 2030) is estimated at approximately 90.8 MG (see Table 5-3, "Storage Requirements").

Table 5-3
Storage Requirements

Pressure Zone	Fire [(1)] (MG)	Operational [(2)] (MG)	Emergency [(3)] (MG)	Total Required Storage (MG)
1	0.18	0.20	0.70	**1.08**
2	0.54	0.34	1.20	**2.08**
2SB	0.54	0.40	1.40	**2.34**
Westwood	0.54	0.23	0.80	**1.57**
3	0.54	1.53	5.39	**7.46**
3SB	0.54	0.50	1.77	**2.81**
4W	0.54	1.51	5.34	**7.39**
4E	1.50	2.89	10.17	**14.56**
5	1.50	4.40	15.51	**21.41**
6	1.50	2.81	9.90	**14.21**
7	0.54	0.40	1.40	**2.34**
7JR[(4)]	1.50	2.67	9.40	**13.57**
TOTALS	**9.96**	**17.88**	**62.98**	**90.82**

Notes: (1) Fire storage is based on the largest fire anticipated for each zone.
(2) Operational storage is calculated as 0.25 X MDD for each zone.
(3) Emergency storage is calculated as 2 X ADD for each zone.
(4) For analysis purposes the Juniper Ridge area is shown separate from Zone 7.

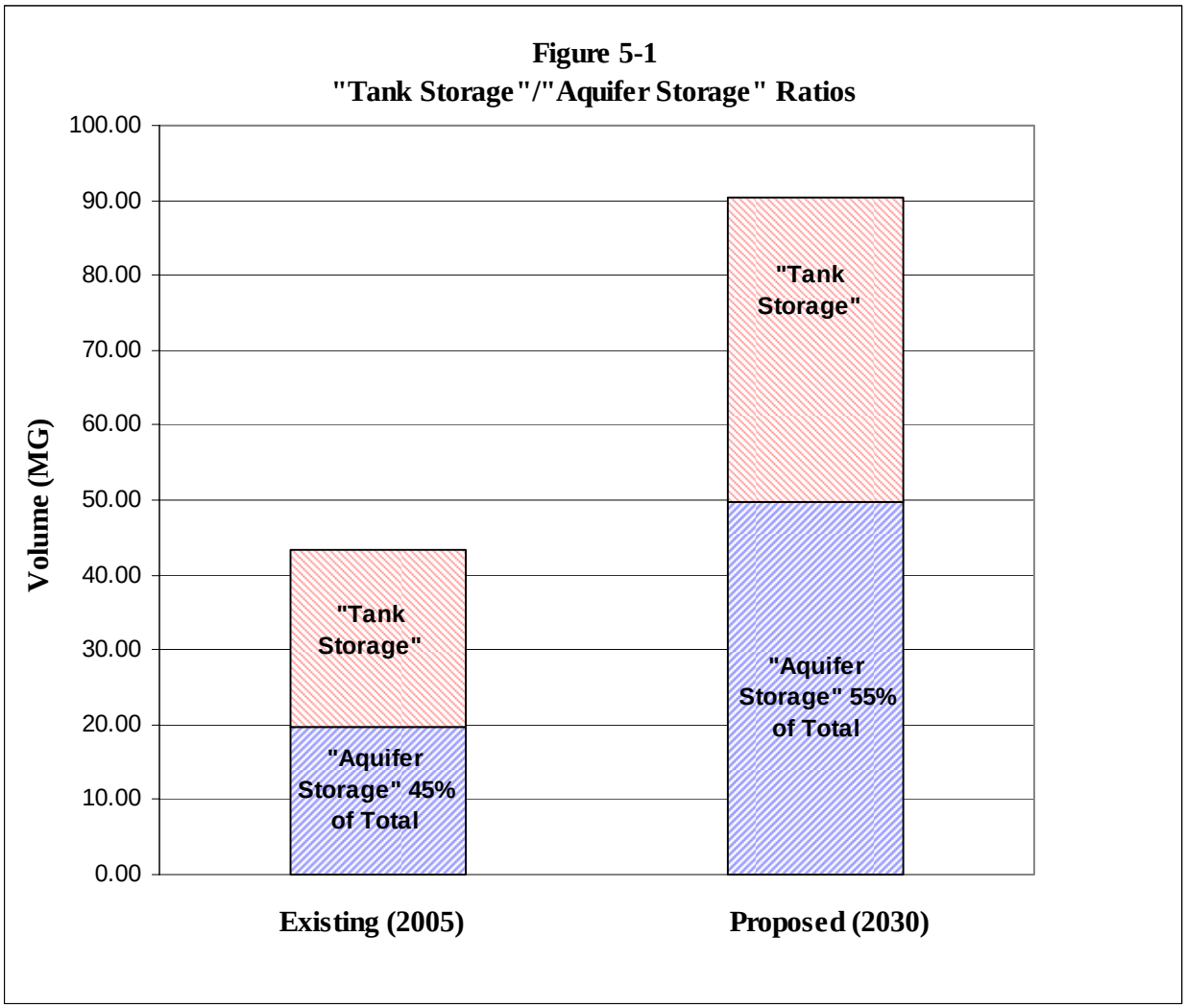
Storage Allocations ("Tank Storage" vs. "Aquifer Storage")

As mentioned previously, a key assumption incorporated into the storage analysis for the City of Bend's water system is the premise that a certain volume of emergency storage may be allocated to the City's subsurface aquifer water supply source. This idea is intended to simply reallocate some of the needed emergency storage capacity, typically provided by constructed storage tanks ("tank storage"), to the existing subsurface aquifer ("aquifer storage"). Emergency storage is that component of storage intended to provide water during emergencies such as pipeline failures, equipment failures, power outages or natural disasters. This approach results in tremendous cost savings to the City by reducing constructed "tank storage" costs. This approach also benefits the City by helping to minimize stagnation of storage water by reducing tank storage and increasing turnover of water in tanks, especially during the low use winter season.

Currently, the City allocates a significant portion of emergency storage capacity to the subsurface aquifer. For example, in the South Bend portion of the City most of the storage is

allocated to the subsurface aquifer, as tank storage is only drawn upon periodically through operation of the Murphy Pump Station when needed. Approximately 45% of the City's current total storage needs are allocated to the aquifer. This report recommends increasing that percentage to roughly 55% by the end of the 25-year planning period (see Figure 5-1, "Tank/Aquifer Storage Ratios").

Figure 5-1
"Tank Storage"/"Aquifer Storage" Ratios



As discussed above, the total volume of required storage by the end of the planning period (year 2030) is estimated at approximately 90.8 MG. As shown in Table 5-4, "Total Storage Allocations", today's storage requirements of approximately 43.3 MG are provided by existing firm "tank storage" capacity of 23.6 MG and existing "aquifer storage" capacity of approximately 19.7 MG. The firm storage capacity assumes that the City's largest storage facility, Awbrey Reservoir, is inoperable. As discussed above, the term "firm capacity" is used to refer to the reliable capacity of a water system component. The use of firm capacity for water system planning purposes is good practice in that it helps reduce the risks of planning a system that has insufficient capacity in the various system components, and this approach is consistent with standard engineering practices and recommendations by the American Water Works Association.

Approximately 47.5 MG of additional storage capacity will be required by the end of the planning period. For this additional capacity it is proposed that approximately 28.7 MG of existing well capacity be allocated as "aquifer storage" leaving a net required additional storage capacity of approximately 38.5 MG. As presented in Table 5-4, it is suggested that this needed additional capacity be provided by approximately 16.8 MG of additional "tank storage" and approximately 21.7 MG of additional well capacity ("aquifer storage"). Table 5-5 presents proposed allocations of required additional storage capacity by zone.

Table 5-4
Total Storage Allocations

		Current Storage (Year 2005) (MG)	**Future Storage (Year 2030) (MG)**
"Tank Storage"	Existing Firm Tank Storage Capacity	23.6	23.6
	Proposed Additional Tank Storage Capacity	--	**16.8**
"Aquifer Storage"	Existing Well Capacity Allocated to Storage	19.7	28.7
	Proposed Additional Well Capacity Allocated to Storage	--	**21.7**
	TOTALS	**43.3**	**90.8**

Note: (1) For planning purposes storage totals for 2005 are based on established planning level demands of 250 gpcd for Average Day Demands and 590 gpcd for Maximum Day Demands, rather than actual recorded demands for 2005.

Table 5-5
Allocations of Required Additional Storage Capacity by Zone

Pressure Zone	Total Additional Required Storage (MG)	Proposed Additional Storage (MG)	
		Proposed Additional Well Capacity	Proposed Additional "Tank Storage" Capacity
1	--	--	--
2	--	--	--
2SB	**2.34**	**2.34**	--
Westwood	--	--	--
3	--	--	--
3SB	**1.57**	**1.57**	--
4W	--	--	--
4E	**7.43**	--	**7.43**
5	--	--	--
6	**11.28**	**6.98**	**4.30**
7	**2.34**	**1.40**	**0.94**
7JR(1)	**13.57**	**9.40**	**4.17**
TOTALS	**38.53**	**21.69**	**16.84**

(1) For analysis purposes the Juniper Ridge area is shown separate from Zone 7.

The City's groundwater facilities include a high degree of redundancy and backup since there are a number of well sites, and the sites are physically separated from one another. A number of the well sites include emergency backup power generation capabilities and the City maintains some mobile power generation capabilities as well. Because this report recommends allocating a significant amount of the required emergency storage to the subsurface aquifer, emergency backup power generation capabilities should be implemented for all of the City's groundwater production sites.

Because of the understood availability of ample groundwater supply throughout the City, it is expected that the aquifer could reliably provide needed supply during the most extreme anticipated emergency scenario. As per the storage criteria presented in Section 4 the most extreme scenario is assumed to be one in which the surface water supply becomes inoperable, due to perhaps a fire in the Bridge Creek watershed. While a vulnerability assessment of the aquifer was not performed as part of this report it is acknowledged that this subsurface water supply source should not be considered immune to potential contamination or significant

depletion. However, if the aquifer were to become contaminated it is expected that the City would have sufficient time to respond and develop alternative supply sources if needed.

Through the end of the planning period (2030) the above approach, in conjunction with the demands and planning criteria identified in this report, would require minimum total additional "tank" storage capacity of approximately 11.3 MG. While it is acknowledged that risks associated with the above-described approach to storage allocation may be considered rather modest, the total recommended volume of additional "tank" storage is increased by 5.5 MG to a total of 16.8 MG as a measure to help offset such potential risks and to develop a desired reasonable balance between "tank storage" and "aquifer storage".

The total recommended additional "tank" storage volume is significantly less than the total volume required by a more conventional approach that may not allocate storage to the aquifer. The above approach allows the City to "kill two birds with one stone" by using the capacity of certain wells to satisfy both supply and storage needs. The 21.7 mgd of proposed additional well capacity intended to allocate storage to the aquifer also serves to meet planning period supply needs. In addition, the storage proposed for allocation to the aquifer is emergency storage with a peak withdrawal rate equal to the maximum day demand, not the higher rates typically required for fire suppression. Thus, the above methodology does not affect water rights interests any differently than would supply expansions for typical demand growth. As discussed above, the supply system should be expanded by approximately 40.3 mgd to meet year 2030 supply needs.

It should be noted that for the storage analysis portion of this study only, the projected population for Zone 1 has been adjusted downward. Because of the location and the development characteristics of much of Awbrey Butte that would be served by storage located in this zone, the actual population growth rate for these areas is anticipated to be somewhat slower than the average growth rate of the City. Pressure Zone 1 currently serves a population of approximately 835, and for identifying storage needs it is estimated that this zone will serve up to approximately 1,340 people by the year 2030. This estimate assumes saturation of infill development without redevelopment. However, the population projection methodology used for the other zones would result in a Zone 1 saturation development population of roughly 2,398. The Tower Rock reservoir with 1.0 million gallons of capacity will provide sufficient storage volume for the anticipated population of 1,340; however, as this planning reporting is updated in the future should it appear that the population for this area may potentially exceed 1,340 then additional storage should certainly be implemented.

Pumping Capacity Analysis

As represented in Section 4, pumping capacities should be adequate to supply the maximum day demand to the service area of the station if adequate gravity storage for the area exists. The criteria for direct pumping stations, where gravity supply is not available, are more stringent. Since mechanical equipment is subject to failure, supply capacity should be achieved with the largest pump out of service (firm capacity).

Direct pumping stations (continuously operating pumps or hydropneumatic systems without gravity storage) are normally used to supply small residential areas. Fire flow to areas served by direct pumping systems can be provided by fire pumps. These systems should be considered only for small areas where conventional supply from gravity storage is not practical or economical, or as an interim improvement until gravity service can be provided.

A brief discussion of the pumping capacity analysis by pump station is presented below, followed by Table 5-6, "Pumping Analysis Summary".

Awbrey Pump Station

The Awbrey Pump Station supplies water to Zone 1 from the Awbrey Reservoir and can supply Zone 2 through Zone 1. This pump station is the only supply to Zone 1 and therefore should be capable of supplying maximum day demands in this pressure zone. The Tower Reservoir is filled from the Awbrey Pump Station and supplies demands in excess of maximum day demands including fire flow. Maximum day demands in Zone 1 and Zone 2 at saturation development are approximately 2.15 mgd (1500 gpm). The existing firm capacity of the Awbrey Pump Station is adequate to meet the pumping capacity needs of Zone 1 and provide backup supply to Zone 2.

College Pump Station

The College Pump Station supplies water to Zone 2 from Zone 3. Zone 2 also receives water through several PRV connections from Zone 1. This pump station should be capable of supplying maximum day demands in this pressure zone without relying on supply from Zone 1. The College Reservoirs are filled from the College Pump Station and these reservoirs provide supply for Zone 2 demands that are in excess of maximum day demands including fire flow. Maximum day demands in Zone 2 at saturation development are approximately 1.36 mgd (950 gpm). The existing firm capacity of the College Pump Station is adequate to meet the pumping capacity needs of Zone 2.

Murphy Pump Station

The Murphy Pump Station supplies water to Zone 3 South Bend from Zone 4 East. Also, the Shiloh Wells pump directly into Zone 3 South Bend and a PRV connection supplies water to Zone 3 from Zone 2 South Bend. Zone 3 South Bend does not have gravity storage facilities, so the Murphy Pump Station and the Shiloh Wells must be capable of supplying maximum day demands plus fire flow to the pressure zone. The capacity of the Shiloh Wells is 2.59 mgd (1,800 gpm). The maximum day demands of Zone 3 South Bend at saturation development are approximately 2.01 mgd (1,400 gpm) and the maximum fire flow requirement for this pressure zone is 3,000 gpm. As presented above, it is recommended that approximately 1.57 mgd (1,090 gpm) of additional supply capacity be developed for this pressure zone. With the development of this supply capacity, the required firm pumping capacity of the Murphy Pump Station is the difference between the capacity of the groundwater wells and the ultimate domestic and fire flow demands, or approximately 1,510

gpm. The existing firm capacity of the Murphy Pump Station is adequate to meet the pumping capacity needs of Zone 3 South Bend.

Scott Pump Station

The Scott Pump Station supplies water from Zone 5 to Zone 4 East. The primary purpose of this pump station is to improve "turnover" in the Pilot Butte storage reservoirs during winter months when demands are low. The existing capacity of this pump station is adequate for this purpose.

Westwood Pump Station

As discussed above, the Westwood Service area should be enlarged to include certain portions of the proposed Tetherow development area. The Tetherow development will add approximately 300 to 350 dwelling units and commercial and retail development to the Westwood Pump Station's service area. The maximum day demand at saturation development for the expanded Westwood service area is approximately 0.9 mgd (625gpm). The pump station must also be capable of supplying fire flow demands which are 2,500 gpm in the Tetherow development. Therefore, the recommended firm pumping capacity of the Westwood Pump Station is approximately 3,125 gpm. The existing firm pumping capacity is approximately 1,490 gpm. Recommendations for expansion of the Westwood Pump Station are discussed in Section 6.

Table 5-6
Pumping Analysis Summary

Pump Station Facility	Existing Firm Pumping Capacity (gpm)	Saturation Development Pumping Capacity Requirement (gpm)	Recommended Additional Firm Pumping Capacity (gpm)
Awbrey Pump Station	2,400	1,500	**0**
College Pump Station	1,000	950	**0**
Murphy Pump Station	1,800	1,510	**0**
Scott Pump Station	2,500	N/A	**0**
Westwood Pump Station	1,490	3,125	**1,635**

Distribution System Analysis

General

A hydraulic network analysis computer program was used to evaluate the performance of the existing distribution system and to aid in the development of proposed system improvements. MWH Soft's H_2ONet network analysis program integrated with the AutoCAD platform was used to develop a digital base map of the water distribution system and perform analysis for

this report. The purpose of the computer network modeling is to determine pressure and flow relationships throughout the distribution system for a variety of critical hydraulic conditions. System performance and adequacy of existing facilities is then evaluated on the basis of water demand estimates developed in Section 3 and planning criteria presented in Section 4.

Hydraulic Model

The hydraulic model used to complete the hydraulic analysis of this master plan was developed by City staff and then updated by MSA. Recent system improvements have been added to the map from record drawings provided by the City. The hydraulic model was then used to perform the system analysis and to illustrate recommended improvements. The existing system is presented as Figure 1, "Existing Water System Map", in Appendix A. All pipes on Figure 1 are shown as "links" between "nodes" which represent pipeline junctions or changes in pipe size. Diameter, material type and length are specified for each pipe and approximate ground elevations are specified for each node. For drawing clarity only pipe diameters are illustrated.

Modeling Conditions

To simulate system operation under maximum usage conditions, it is necessary to determine the water usage anticipated for the highest water use day of the year. For this purpose, the maximum day demands at saturation development previously presented as part of Table 5-2, were distributed throughout the system.

The computer analysis was performed with all pressure zones simultaneously in operation and all reservoirs operating at half full. In order to use the computerized hydraulic model of the water system to assess system adequacy, several system conditions were examined. The adequacy of the system's major transmission piping to deliver water to certain portions of the City and the distribution system's ability to provide recommended fire flows throughout the City were analyzed.

All fire flow modeling was performed assuming that the system must be capable of providing the recommended fire flows while maintaining minimum pressures throughout the entire City water system of at least 20 psi.

Model Calibration

For a computer model to provide the most accurate results practical under test conditions it is essential that the model be calibrated with field conditions to reflect actual system operation. Model calibration was performed using actual measured demands distributed over the existing distribution system. Flow data from hydrant flow tests performed by City of Bend staff were compared to pressure and flow results obtained from modeled flows placed at the same locations. The Hazen-Williams roughness coefficients of the pipes and the distribution of demands from the nodes in the model were adjusted until the modeled flow test results fell within approximately ten to fifteen percent of the actual results. This is generally considered

an acceptable level of calibration for planning purposes. Based on the calibration results, a Hazen-Williams roughness coefficient or C-Factor ranging from 60 to 145 was used for all existing pipes, depending on material type and pressure zone. A C-Factor of 130 was used for all proposed pipes.

Modeling Results

Transmission System

The hydraulic analysis showed that the City's transmission system piping, or larger diameter piping (typically greater than 12-inches in diameter), is generally adequate to transmit water from the City's various water supply sources to storage reservoirs, from the storage reservoirs to the distribution system and between pressure zones. Through the analysis, two areas with inadequate transmission capacity were identified. These transmission system deficiencies are described below.

Outback Site to Pressure Zone 3

The City's surface water supply is routed to the Outback site. A major component of the City's groundwater supply source is located at the Outback site as well. Four water mains, parallel 14-inch diameter and 16-inch diameter pipes and parallel 16-inch diameter and 36-inch diameter pipes, transmit water from the Outback site to Pressure Zone 3 and to the Overturf and Awbrey Reservoirs. These transmission mains have inadequate capacity to meet future supply needs which include domestic and fire suppression flow demands for Pressure Zone 3, and supply to the Overturf Reservoirs and Awbrey Reservoir. The existing 14-inch and 16-inch diameter parallel pipes are aging steel mains and are believed to be reaching the end of their service life. For the purposes of the hydraulic analysis, it was assumed that these two mains would be replaced by a proposed 36-inch diameter main from the Outback site to the distribution system.

Rock Bluff Reservoir to Pressure Zone 4E

The Rock Bluff Reservoir provides gravity supply to Pressure Zone 4E from three existing groundwater supply wells located at the site. It is anticipated that additional storage and groundwater supply facilities will be developed at the Rock Bluff Reservoir site. Currently, a single 16-inch diameter transmission main supplies water from the Rock Bluff Reservoir site to Pressure Zone 4E. The hydraulic analysis showed that expanded transmission capacity will be needed to supply water from the Rock Bluff Reservoir site under saturation development conditions. The need for expanded transmission capacity in Pressure Zone 4E is a result of anticipated future domestic demands plus high fire suppression flow requirements in the commercial highway corridor in this area. It is anticipated that the size, timing and ultimate configuration of transmission system improvements from the Rock Bluff Reservoir site to Pressure Zone 4E will be coordinated and updated as further analysis of integrating the former Juniper Utility Company service area (Pressure Zones 3SB and 2SB) is completed.

Transmission System Improvements Summary

Transmission system improvements are proposed to increase capacity from the Outback site to Zone 3 distribution piping, and to increase capacity from the Rock Bluff reservoir site to Zone 4 East. The proposed transmission system improvements are indicated on Figure 2, "Proposed Water System Improvements Map", of Appendix A. Project cost estimates are presented in Appendix B.

Distribution System

The water system was analyzed under existing and saturation development maximum day demand conditions with fire suppression flow requirements as documented in Section 4. The major factors contributing to deficiencies in the distribution system's capacity are population growth and fire suppression requirements. A brief discussion of each of the key distribution system issues is presented below.

Population Growth

The City of Bend has in recent years experienced, and is expected to continue to experience, significant population growth. The future population growth throughout the study period is anticipated to occur as infill within the current UGB. This type of population growth will result in an increase in water demands throughout the system and can ultimately exceed the supply capacity of existing distribution system infrastructure.

With the significant recent development that has occurred within the City's water service area, the City has endeavored to evaluate, with each new development, water system improvement needs to serve existing and future customers. It is anticipated that with the verification, calibration and update of Bend's water system hydraulic model the City will be well equipped to plan for and implement future system expansions to meet the projected population growth and avoid future distribution system deficiencies.

Fire Suppression Requirements

The distribution system must be capable of maintaining acceptable system pressures while delivering peak domestic water demands and water for fire suppression. Recommended fire flow rate requirements have steadily increased to meet updated International Fire Code requirements, Insurances Services Office (ISO) audit findings, AWWA guidelines and increased development size and density within the City of Bend. The hydraulic analysis showed that a large number of the distribution system deficiencies were related to fire flow availability within older parts of the City, such as the area between the Deschutes River and Pilot Butte, and along Highway 97 and Highway 20 where major recent commercial development has occurred.

Pressures Zones 2SB and 3SB (the former Juniper Utility Company service area) also contain a large number of distribution system capacity deficiencies. As discussed in Section 2, the distribution system piping in this area largely consists of 2-inch through 6-inch diameter PVC pipe. This piping has inadequate capacity to meet domestic water demands and provide recommended fire flow capacity.

Distribution System Improvements Summary

Modeling results under maximum day demand conditions at saturation development indicate that improvements are required in order to provide recommended fire suppression flows while maintaining minimum service pressures. Fire flows were simulated throughout the study area based on the estimated fire suppression flow recommendations for land uses as presented in Section 4. The locations of proposed improvements are indicated on Figure 2, "Proposed Water System Improvements Map", in Appendix A. Pipe sizing recommendations and project cost estimates are presented in Section 6.

Summary

This section develops and presents an analysis of the City of Bend's water distribution system. The analysis found that additional water supply capacity, storage volume, pumping capacity and piping improvements are needed to adequately meet near term needs and to provide for system expansion in the future. Section 6 presents specific recommendations and a capital improvement plan that includes proposed project sequencing, phasing requirements and project cost estimates.

SECTION 6
RECOMMENDED WATER SYSTEM IMPROVEMENTS

General

This section presents recommended water system improvements for the City of Bend that provide for the correction of existing deficiencies and expansion of the distribution system to support anticipated future development. These improvements, based on the analysis and findings presented in Section 5 include proposed additional water supply capacity, storage volume, pumping capacity and piping improvements. All proposed system improvements are illustrated on Figure 2 in Appendix A, "Proposed Water System Improvements Map". Recommended water system improvements are presented for the 25-year study period (through year 2030). Recommended supply, storage and pumping improvements are shown on Figure 6-3 "Water Distribution System Hydraulic Profile".

Cost Estimating Data

An estimated project cost has been developed for each improvement project recommendation presented in this plan. Itemized project cost estimate summaries for certain proposed improvements are presented in Appendix B. Appendix B also includes a Distribution Piping Unit Project Cost Summary.

Cost estimates are based upon recent experience with construction costs for similar work in the region and assume improvements will be accomplished by private contractors. Cost estimates represent opinions of costs only, acknowledging that final costs of individual projects will vary depending on actual labor and material costs, site conditions, market conditions for construction, regulatory factors, final project scope, project schedule and other factors.

The project costs presented in this plan include estimated construction costs plus an aggregate 40 percent allowance for contingencies, engineering, administration and other project-related costs. Since construction costs change periodically, an indexing method to adjust present estimates in the future is useful. The Engineering News-Record (ENR) Construction Cost Index (CCI) is a commonly used index for this purpose. ENR provides monthly index estimates for 20 major U.S. metropolitan areas. The closest regional CCI provided by ENR is for Seattle, Washington. For purposes of future cost estimate updating, the October 2006 ENR CCI for Seattle, Washington of 8630 is referenced.

Recommended Improvements

General

Presented below are recommended water system improvements for supply, storage, pumping, and distribution system piping. The recommendations are presented by project type and size. A summary of estimated water system improvement project costs are presented in Table 6-2.

It is recommended that the City of Bend's water system capital improvement program be funded at approximately $6,800,000 annually.

Water System Planning

The City should complete updates to the Water Master Plan approximately every five years. An estimated cost of $100,000 for each update is included in the projected capital improvements program through the year 2030 for a total of $500,000. In addition, the City is required by the State of Oregon to update its Water Management and Conservation Plan (WMCP) every five to ten years. A budget estimate of $100,000 for each update is included in the Capital Improvements Program budget, assuming three updates for a total of $300,000. This report also allocates $200,000 for a water supply integrated engineering study for preliminary analysis of surface water supply improvement alternatives. It is understood that the City intends to move forward with this reporting in the short term. Thus, the total costs for water system planning through the year 2030, that are included in the Capital Improvements Program budget estimates herein, are estimated at approximately $1,000,000.

Water Supply

The water supply analysis presented in Section 5 establishes that the City must address the need for increased reliable water supply within the planning period to satisfy water demand requirements. Consistent with the City's recent expansions to the supply system, it is recommended that the City continue to pursue opportunities to develop additional groundwater supply thereby benefiting from this apparently robust available source. Specific recommendations for expansion of the supply system consist of adding new groundwater wells at strategic locations that provide the highest value to the City. However, it is understood that the City's surface water supply system is currently being studied for possible treatment and transmission improvements, and any potential opportunities for expanded surface water supply capacity should certainly be considered as well.

The water supply analysis determined that the City should expand the existing supply system, with a firm capacity of approximately 31.2 mgd, by an additional 40.3 mgd for a total firm capacity of 71.5 mgd. The project costs for groundwater production facilities are estimated at approximately $1,200,000 for each million gallons per day (mgd) of capacity (see Appendix B, Groundwater Well Project Cost Estimate Summary). Thus, the total costs for supply expansion through the year 2030 is estimated at approximately $48,360,000 (2006 dollars).

Figure 6-1, "Water Supply/Demand Schedule" presents a projected water supply and demand schedule for supply expansion through the year 2030. The "stair-step" line represents one potential approach to scheduling improvements; however, required capacity could be implemented in a number of ways to satisfy supply needs. Supply capacity expansion is shown in 1.0 to 4.0 mgd increments (one or more wells at a time); however, expansions should be implemented at increments necessary to satisfy system demands and as may be suitable for each particular project. The water demands shown in Figure 6-1 are based on an assumed consistent growth rate as required to reach the projected 2030 population presented

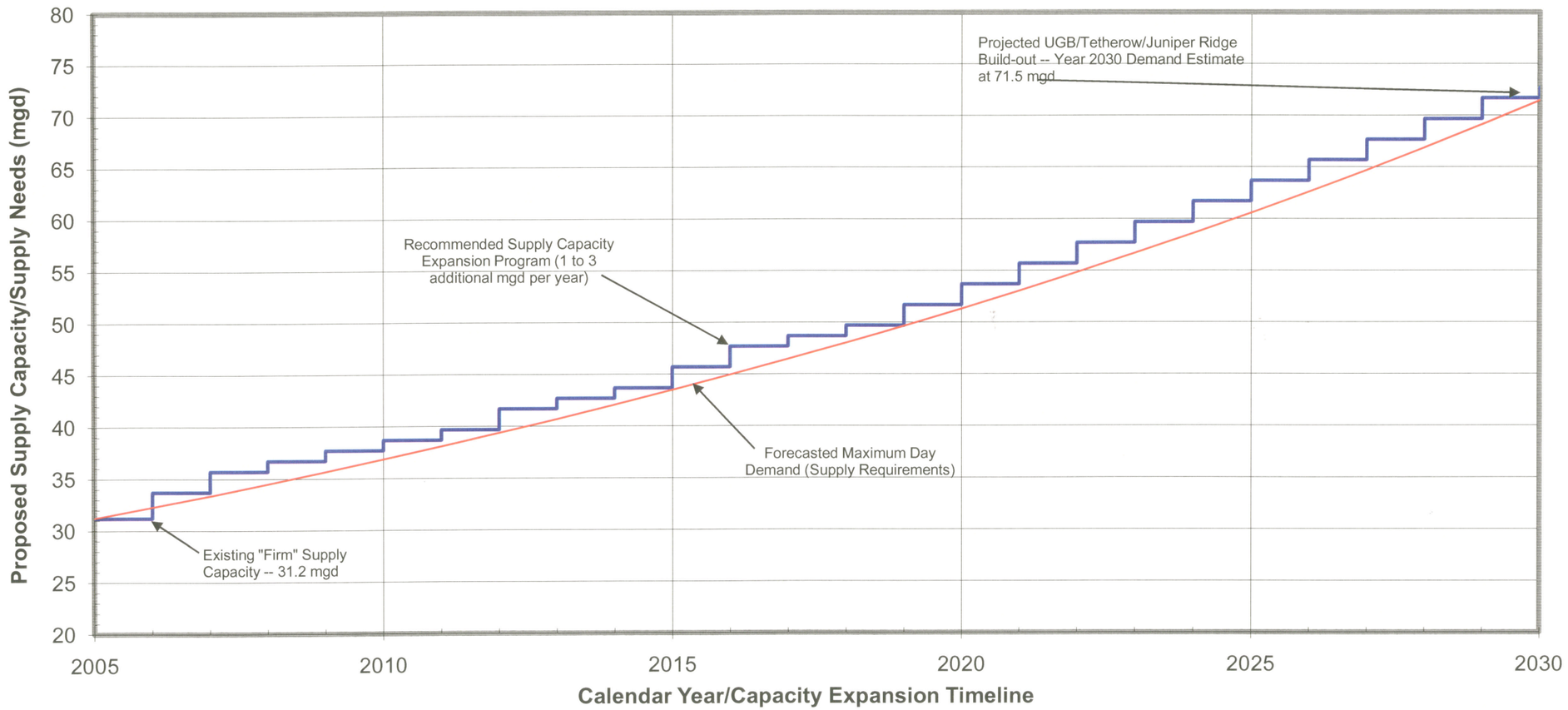
in Section 3. Both Figure 6-3, "Water Distribution System Hydraulic Profile", and Figure 2 in Appendix A, "Proposed Water System Improvements Map", identify proposed locations for new groundwater production facilities. On the graphics well symbols represent roughly 1.0 mgd each.

It is understood that of the 23 existing groundwater production wells, perhaps 10 can simultaneously be operated with emergency backup power generation facilities during a power outage. It is further understood that the City maintains several mobile emergency backup power generators and some of the wells have permanent "gen-sets" on-site. It is recommended that backup power generation facilities be implemented to provide for maximum day demands during a potential City-wide power outage. It is estimated that the project costs for implementing emergency backup power generation capabilities at the remaining existing groundwater production wells is approximately $100,000 per well, or a total of $1,300,000 (2006 dollars).

Surface Water Supply Improvements

As identified above, this report allocates $200,000 for a water supply integrated engineering study for preliminary analysis of surface water supply improvement alternatives. Existing aging raw water transmission pipelines will ultimately need to be replaced if the City continues to route water under pressure from the Bridge Creek watershed to the City. In addition, improvements may possibly include treatment facilities and power generation facilities. Once alternatives are evaluated and preliminary feasibility studies are completed then preliminary planning level cost estimates can be developed. Although the appropriate engineering studies have yet to be conducted, it is important that this Water System Master Plan Update include a rough preliminary surface water supply improvements program cost estimate for budgeting purposes. Since basic improvement concepts are very preliminary at this stage it is suggested that a budget amount of $50,000,000 be identified as a "placeholder" for preliminary Capital Improvement Program planning. This estimate should be refined as the water supply integrated engineering study is completed.

Figure 6-1
Water Supply/Demand
Schedule



Distribution Storage Reservoirs

General

As presented in Section 5 the total recommended additional "tank storage" capacity through the planning period is approximately 16.8 MG. To satisfy such storage needs it is recommended that the City construct six finished water reservoirs by the end of the 25-year planning period. Table 6-1, "Recommended Reservoir Improvement Summary" below presents a summary of the recommended storage improvements and includes project cost estimates for each proposed reservoir.

Table 6-1
Recommended Reservoir Improvement Summary

Priority	Project Description	Estimated Project Cost
1	Rock Bluff II -- 3.0 MG Reservoir	$3,750,000
2	Pilot Butte IV -- 2.3 MG Reservoir	$2,900,000
3	Pilot Butte V -- 3.0 MG Reservoir	$3,750,000
4	Juniper Ridge -- 2.0 MG Reservoir	$2,600,000
5	Pilot Butte VI -- 3.5 MG Reservoir	$4,350,000
6	Rock Bluff III – 3.0 MG Reservoir	$3,750,000
	TOTAL	**$21,100,000**

(1) Recommended reservoir storage volumes have been rounded to the nearest 0.1 MG

3.0 MG Rock Bluff II Reservoir

It is recommended that a second reservoir be constructed at the Rock Bluff site to serve pressure Zone 4E (East) with a capacity of 3.0 MG. This reservoir will provided needed storage capacity for fire suppression and operational needs as Zone 4E approaches saturation development. Supply to this reservoir will be provided through existing and proposed groundwater production wells at the Rock Bluff site. The proposed overflow elevation for the reservoir is 3,879 feet above mean sea level (msl), the same elevation as the existing Rock Bluff I Reservoir. Estimated project costs for this reservoir are approximately $3,750,000.

2.3 MG Pilot Butte IV Reservoir

A 2.3 MG reservoir serving Zones 6 and 7 is recommended for implementation on Pilot Butte. This reservoir will provide needed storage capacity as Zones 6 and 7 further develop.

This reservoir will be connected to Zone 5; thus, supply to this reservoir will be provided by supply to Zone 5, and storage for Zones 6 and 7 will be provided through connections between Zones 5, 6 and 7. The proposed overflow elevation for the reservoir is 3,782 feet above mean sea level (msl), the same elevation as the existing Pilot Butte I & III Reservoirs. Estimated project costs for this reservoir are approximately $2,900,000.

3.0 MG Pilot Butte V Reservoir

It is recommended that a 3.0 MG reservoir be constructed on Pilot Butte to serve Zones 6 and 7. This reservoir will provide needed storage capacity as Zones 6 and 7 approach saturation development. This reservoir will be connected to Zone 5; thus, supply to this reservoir will be provided by supply to Zone 5, and storage for Zones 6 and 7 will be provided through connections between Zones 5, 6 and 7. The proposed overflow elevation for the reservoir is 3,782 feet above mean sea level (msl), the same elevation as the existing Pilot Butte I & III Reservoirs. Estimated project costs for this reservoir are approximately $3,750,000.

2.0 MG Juniper Ridge Reservoir

It is recommended that a 2.0 MG reservoir be constructed in the southerly portion of the Juniper Ridge area to serve the northerly portion of this UGB expansion area at saturation development. This report assumes that the water system for the Juniper Ridge area will be connected to the water system serving other portions of the City. Supply to this reservoir will be mostly provided by proposed new groundwater production wells proposed to be located in Juniper Ridge. The proposed overflow elevation for the reservoir is approximately 3,480, so that it may serve the northerly portions of Juniper Ridge below approximately 3,380 feet above mean sea level (msl). Estimated project costs for this reservoir are approximately $2,600,000. It should be noted that this recommendation is preliminary only, and as planning for this area is finalized, demand forecasts and storage needs should be updated to reflect actual anticipated development.

3.5 MG Pilot Butte VI Reservoir

A 3.5 MG reservoir serving pressure Zones 4E, 5, 6 and 7, including the southerly portion of the Juniper Ridge area is recommended for implementation on Pilot Butte. This reservoir will be connected to Zone 4E, and is proposed to have an overflow elevation of 3,880 feet above mean sea level (msl), similar to Pilot Butte II and the existing and proposed reservoirs at the Rock Bluff site at 3,879. Storage for Zones 5, 6 and 7 will be provided through connections between Zones 4E through 7. The Estimated project costs for this reservoir are approximately $4,350,000.

3.0 MG Rock Bluff III Reservoir

It is recommended that the City consider implementing a third reservoir at the Rock Bluff site to serve pressure Zone 4E (East). The total volume of this reservoir would be 3.0 MG. The Rock Bluff III reservoir would provide needed storage capacity for fire suppression and

operational needs as Zone 4E approaches saturation development. Supply to this reservoir will be provided through existing and proposed groundwater production wells at the Rock Bluff site. The proposed overflow elevation for the reservoir is 3,879 feet above mean sea level (msl), the same elevation as the existing Rock Bluff I Reservoir, as well as the proposed Rock Bluff II Reservoir. Estimated project costs for this reservoir are approximately $3,750,000. As an alternative to implementing an additional 3.0 MG at this location the City could construct a larger tank for the Pilot Butte VI Reservoir at perhaps 4.3 MG. Further study should be conducted to identify the best site for this storage as the need approaches.

Figure 6-2, "Water Storage Requirements Schedule" presents a projected schedule of water storage needs and possible sequence of improvements through the year 2030. The "stair-step" line represents one potential approach to scheduling improvements; however, required capacity could be implemented in a number of ways to satisfy storage needs. Storage capacity expansion is shown in 1.0 to 4.0 mgd increments (one or more wells or one reservoir at a time); however, expansions should be implemented at increments necessary to satisfy system demands and as may be suitable for each particular project. As discussed in Sections 3 and 5, projected water storage needs increase from roughly 43.3 MG to roughly 90.8 MG to satisfy the needs of saturation development by the year 2030, with approximately 30.7 MG allocated to the aquifer.

Land Acquisition

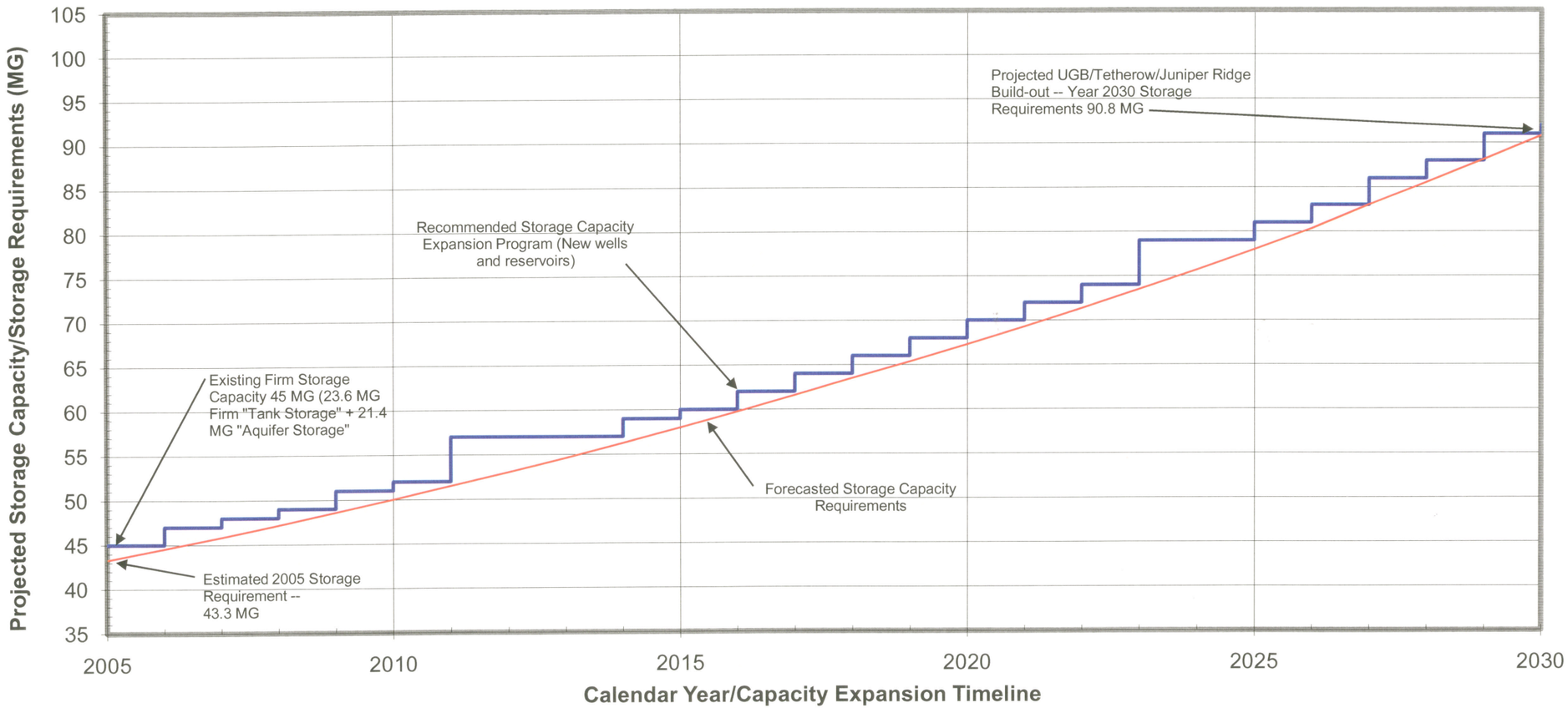
It is anticipated that some of the recommended facilities presented in this plan will require additional land to be acquired by the City. It is recommended that the City consider such additional land needs and begin any necessary acquisition process far in advance of the facility needs. For example, such land acquisition work should occur during the planning stages for the Juniper Ridge area so that development interests or other uses do not preclude construction of facilities.

With the exception of the proposed Juniper Ridge Reservoir and possibly the proposed Pilot Butte Reservoirs, it is understood that sufficient City land may be available at each of the above sites for implementing the recommended storage.

Pump Stations

In accordance with the Section 5 analyses, it is recommended that the Westwood Pump Station be upgraded. The recommended firm pumping capacity of the Westwood Pump Station is approximately 3,125 gpm. The existing firm pumping capacity is approximately 1,490 gpm; thus, this report recommends increasing the capacity of the pump station by approximately 1,635 gpm. For planning purposes it is assumed that the pump station would require complete reconstruction and it is estimated that total project costs for the pump station are approximately $2,100,000.

Figure 6-2
Water Storage/Requirements Schedule



Transmission Piping Improvements

Certain transmission piping improvements are recommended to improve transmission capacities. The recommended transmission piping improvements are shown on Figure 2 in Appendix A, "Proposed Water System Improvements Map". A list of transmission piping improvements is presented in Table B-10 in Appendix B. The total costs for transmission piping improvements through the 25-year planning period are approximately $7,680,000. While pipeline improvements up to 16-inches in diameter are proposed for integrating the Juniper Ridge area, these improvements are not categorized as transmission piping improvements by this report because they serve both distribution and transmission needs.

Distribution System Improvements

The analysis found that distribution system water line improvements are needed to improve fire flow capacities within the distribution system and also provide improved hydraulic transmission capacity and accommodate system expansion needs. Distribution system improvements are shown on Figure 2 in Appendix A, "Proposed Water System Improvements Map". The total costs for distribution piping improvements through the 25-year planning period are approximately $37,400,000. An estimated project cost is presented for each improvement in Table B-10 in Appendix B.

A pressure-sustaining valve connecting Zone 4E and Zone 3SB, located at the intersection of Chase Road and Mowich Drive, is included in the distribution system improvements. In addition a number of pressure reducing valves are proposed at various locations throughout the system. The estimated project costs for all pressure reducing/pressure sustaining valve stations is $1,080,000.

Service to Areas Outside UGB (Tetherow and Juniper Ridge)

Oregon Statewide Planning Goal No. 11 and Oregon Administrative Rules (OAR 660-0011) require facilities plans to make a clear distinction between those facilities that are required to serve areas within the UGB and those facilities needed to serve areas outside of the UGB. Two areas that are currently outside of Bend's UGB, the Tetherow area and the Juniper Ridge area, have been included within the study area of this master plan. Facilities required to serve both areas at saturation development have been identified in this report.

The Juniper Ridge area is a proposed UGB expansion area near the northeasterly boundary of the City. As identified in this plan 10.7 mgd of supply capacity and 4.2 MG of storage capacity will be needed to serve Juniper Ridge at saturation development. In addition, transmission piping improvements will be needed to properly integrate this area with the existing service area. Approximately 2,600 linear feet of 12-inch diameter piping along Cooley Road, and roughly 6,900 linear feet of 16-inch diameter piping along 18th Street are shown on Figure 2 in Appendix A. The total project costs for facilities to integrate Juniper Ridge are approximately $20,080,000, (10.7 mgd supply x $1.2M/mgd) + (storage @ $2.6M (Juniper Ridge Res.) + (2.2/3.5) x ($4.35M(portion of Pilot Butte Res. VI))) + (transmission

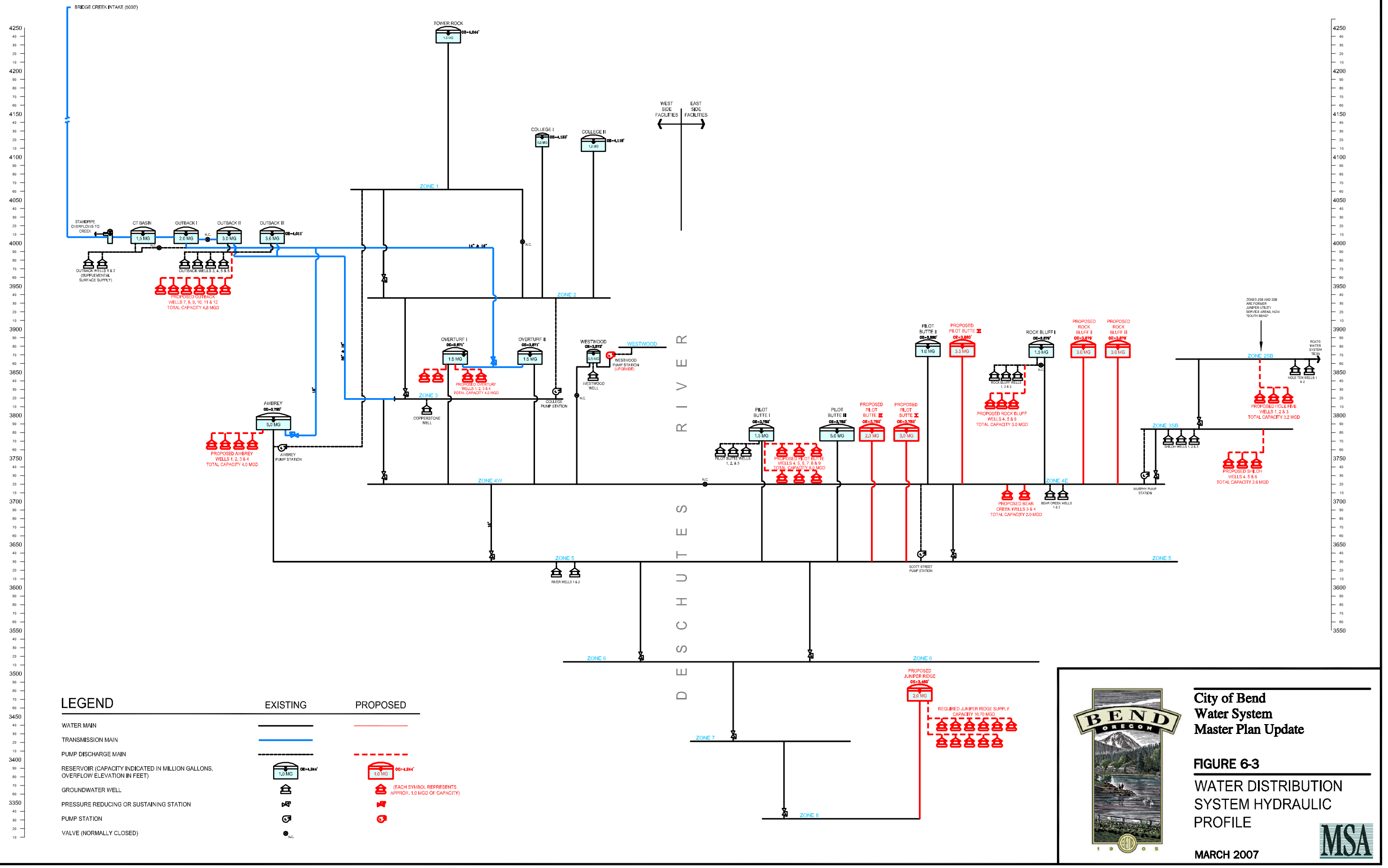
@ $1.9M). Distribution system improvements within the Juniper Ridge area are anticipated to be funded by development interests and thus are not included in the overall water system improvement cost estimates for incorporating Juniper Ridge.

Tetherow is a proposed UGB expansion area in the southwesterly portion of the City. It is anticipated that at saturation development this area will require approximately 1.3 mgd of supply capacity and 1.9 MG of storage capacity. The total project costs for these facilities are approximately $5,190,000, (1.3 mgd supply x $1.2M/mgd) + (1.9 MG storage x $1.28M/MG) + (Approx. 57% of Westwood P.S. upgrade (.57 x $2.1M)). Both transmission and distribution system improvements required to serve this area are anticipated to be funded by development interests, and thus are not included in the overall water system improvement cost estimates for incorporating the Tetherow area. Because of the location of Tetherow, supply, storage and pumping capacity improvements required for saturation development of this area are not presented as distinctly separate physical facilities in this report, but rather as "capacity expansions". This report allocates Tetherow supply capacity expansions to the Outback site (portion of the 4.8 mgd of supply improvements identified at the Outback site), and it allocates the Tetherow storage capacity expansion to the Rock Bluff site (portion of the 6.0 MG of storage improvements identified at the Rock Bluff site).

Summary

This section presents recommendations for improvements to the City's supply system, storage, pumping and distribution system. A summary of all the recommended improvements is presented in Table 6-4.

The total estimated project costs of the recommended improvements are approximately $170,000,000 over the 25-year planning horizon. It is recommended that the City's capital improvement program (CIP) be funded at approximately $6,800,000 (in 2006 dollars) annually for supply, storage, pumping and distribution system piping improvements.



LEGEND

	EXISTING	PROPOSED
WATER MAIN		
TRANSMISSION MAIN		
PUMP DISCHARGE MAIN		
RESERVOIR (CAPACITY INDICATED IN MILLION GALLONS, OVERFLOW ELEVATION IN FEET)	1.0 MG OE=4,244'	1.0 MG OE=4,244'
GROUNDWATER WELL		(EACH SYMBOL REPRESENTS APPROX. 1.0 MGD OF CAPACITY)
PRESSURE REDUCING OR SUSTAINING STATION		
PUMP STATION		
VALVE (NORMALLY CLOSED)	N.C.	

City of Bend
Water System
Master Plan Update

FIGURE 6-3

WATER DISTRIBUTION SYSTEM HYDRAULIC PROFILE

MARCH 2007

MSA

G:\05\0765\101 Model Evaluation\CAD\05-0765-101-OR-FIG 6-3.dwg Figure 6-3 4/19/07 10:16 (hcm)

Table 6-2
Summary of Estimated Water System Improvement Project Costs

Improvement Category	Project Costs, 2006 Dollars
Groundwater Supply Capacity Expansion	**$48,360,000**
Emergency Backup Power Generation Upgrades	**$1,300,000**
Surface Water Supply Improvements	**$50,000,000**
Storage Capacity Expansion	**$21,100,000**
Pumping Capacity Upgrades	**$2,100,000**
Transmission Piping Improvements	**$7,680,000**
Pressure Reducing Stations	**$1,080,000**
Water System Planning	**$1,000,000**
Distribution Piping Improvements	**$37,400,000**
GRAND TOTAL	**$170,020,000**
USE	**$170,000,000**

The recommended system improvements have been developed based on the current condition of the system and anticipated development patterns. This plan should be re-evaluated periodically to reflect factors including available budget, completed projects, actual development patterns, changes to regulatory requirements and other new information. The plan should be re-evaluated every three to five years and, as part of the re-evaluation process, annual improvements should be identified for at least the next five-year period. Financial planning work is recommended to evaluate overall water system financial needs and to identify funding options and alternatives.

APPENDIX A

FIGURE 1

City Of Bend
Water System
Master Plan Update

EXISTING WATER SYSTEM MAP

MARCH 2007

MSA
Murray, Smith & Associates, Inc.
Engineers/Planners
121 S.W. Salmon, Suite 900 Portland, Oregon 97204
PHONE 503-225-9010
FAX 503-225-9022

05-0765.101

ZONE 1
TOWER ROCK RES

ZONE 2

ZONE 3

ZONE 4 (WEST)

ZONE 4 (EAST)

ZONE 5

ZONE 6

ZONE 7

ZONE 2 (SOUTH BEND)

ZONE 3 (SOUTH BEND)

AVION WATER AREA

ROATS WATER AREA

TETHEROW

WESTWOOD

PRIVATE WATER PROVIDER

JUNIPER RIDGE

COPPER-STONE WELL

COLLEGE RES

COLLEGE P.S.

AWBREY RES/P.S.

OVERTURF RES

OUTBACK RES/WELLS

SKYLINERS RD

WESTWOOD WELL

WESTWOOD RES/P.S.

ROCK BLUFF RES/WELLS

POWERS RD

SCOTT P.S.

RIVER WELLS

PILOT BUTTE RES/WELLS

BEAR CREEK WELLS

AVION INTERTIE

SHILOH WELLS

MURPHY P.S.

HOLE TEN WELLS

US HIGHWAY 20

US HIGHWAY 97

DESCHUTES RIVER

N

800 0 800 1600
SCALE IN FEET

LEGEND

- STUDY AREA BOUNDARY
- URBAN GROWTH BOUNDARY
- PRIVATE WATER PROVIDER BOUNDARY

EXISTING FACILITIES

- RESERVOIR CAPACITY (MILLION GALLONS) OVERFLOW ELEVATION (FEET)
- PUMP STATION
- PRESSURE REDUCING/FLOW CONTROL VALVE
- GROUNDWATER WELL
- EXISTING WATER MAIN (DIAMETER IN INCHES INDICATED, COLOR VARIES BY SERVICE ZONE) — 8"

G:\05\0765\01 Water Evaluation\GIS\05-0765-101-08-FIGURE 1.dwg Figure 1 4/25/07 16:58 (hom)

FIGURE 2

City Of Bend
Water System
Master Plan Update

PROPOSED WATER SYSTEM IMPROVEMENTS MAP

MARCH 2007

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05-0765.101

DESCHUTES RIVER

PRIVATE WATER PROVIDER

AVION WATER AREA

JUNIPER RIDGE

PROPOSED JUNIPER RIDGE SUPPLY REQUIREMENT: 10.7 MGD

PROPOSED JUNIPER RIDGE RES CAP: 2.0 MG SEE NOTE 3

COPPER-STONE WELL

TOWER ROCK RES

COLLEGE RES

AWBREY RES/P.S.

COLLEGE P.S.

PROPOSED AWBREY WELLS CAP: 4.0 MGD

PROPOSED PILOT BUTTE WELLS CAP: 6.0 MGD

PROPOSED PILOT BUTTE RES II CAP: 2.3 MG, OE=3,782'

PROPOSED PILOT BUTTE RES I CAP: 3.0 MG, OE=3,782'

PROPOSED PILOT BUTTE RES III CAP: 3.5 MG, OF=3,880'

PILOT BUTTE RES/WELLS

PROPOSED OUTBACK WELLS CAP: 4.8 MGD

OUTBACK RES/WELLS

PROPOSED OVERTURF WELLS CAP: 4.0 MGD

OVERTURF RES

SCOTT P.S.

PROPOSED BEAR CREEK WELLS CAP: 2.6 MGD

BEAR CREEK WELLS

AVION INTERTIE

RIVER WELLS

WESTWOOD WELL

WESTWOOD RES/P.S. UPGRADE

TETHEROW

PROPOSED ROCK BLUFF WELLS CAP: 3.0 MGD

ROCK BLUFF RES/WELLS

PROPOSED ROCK BLUFF RES III CAP: 3.0 MG OE=3,879

PROPOSED ROCK BLUFF RES II CAP: 3.0 MG OE=3,879

ROATS WATER AREA

MURPHY P.S.

SHILOH WELLS

PROPOSED SHILOH WELLS CAP: 2.6 MGD

PROPOSED HOLE TEN WELLS CAP: 3.2 MGD

HOLE TEN WELLS

NOTES:

1. PIPING SHOWN AS EXISTING IN TETHEROW IS ANTICIPATED AS DEVELOPER-IMPLEMENTED AND NOT INCLUDED IN CITY CIP.
2. ANTICIPATED DEVELOPER IMPLEMENTED 16-INCH DIAMETER PIPELINE ALONG SE 15TH STREET SHOWN AS EDISTING.
3. TOTAL STORAGE REQUIRED FOR JUNIPER RIDGE APPROX 4.2 MG. 2.3 MG ALLOCATED TO PILOT BUTTE RESERVOIR VI.

N

800 0 800 1600
SCALE IN FEET

LEGEND

- STUDY AREA BOUNDARY
- URBAN GROWTH BOUNDARY
- PRIVATE WATER PROVIDER BOUNDARY

EXISTING FACILITIES

- EXISTING WATER MAIN (DIAMETER IN INCHES INDICATED) — 12"
- RESERVOIR — R
- PUMP STATION — P
- PRESSURE REDUCING/FLOW CONTROL VALVE
- GROUNDWATER WELL — W

PROPOSED FACILITIES

- WATER MAIN (DIAMETER IN INCHES INDICATED) — PIPE DIA 12", MAP ID D56
- RESERVOIR CAPACITY (MILLION GALLONS) OVERFLOW ELEVATION (FEET) — R
- PRESSURE REDUCING/FLOW CONTROL VALVE
- GROUNDWATER WELL — W

APPENDIX B
COST ESTIMATES FOR WATER SYSTEM IMPROVEMENTS

Appendix B contains cost estimates for recommended improvements for supply, storage, pumping, and system piping. These cost estimates are based on the Engineering News Record Construction Cost Index for Seattle, Washington of 8630 (October 2006).

Table B-1
Groundwater Well Project Cost Estimate Summary

Groundwater well project cost estimates are based on the following assumptions:
No property acquisition costs included.
Construction by private contractors.
Estimated production of approx. 1 (mgd) with standby power generation equipment.
Well constructed to a depth of approximately 750 feet below ground surface (bgs) with 16-inch diameter steel casing.
An ENR construction cost index of 8630 for Seattle, Washington (October 2006).

Item No.	Description	Estimated Project Cost[1]
1.	Mobilization	$45,000
2.	Well Construction (Drilling)	$200,000
3.	Site Work	$25,000
4.	Well House Structure	$125,000
5.	Yard Piping	$25,000
6.	Mechanical – Including Pump, Motor, Flow Meter, Control Valving and Appurtenances	$200,000
7.	Chlorination Facilities	$40,000
8.	Controls	$30,000
9.	Electrical	$65,000
10.	Landscaping/Fencing	$20,000
11.	Standby Power (Emergency Generator)	$80,000
	Total Construction	$855,000
	40% Contingency, Administration & Engineering	$342,000
	Total Project Cost	$1,197,000
	USE	$1,200,000

Notes: (1). The cost estimates presented are opinions of cost based on the assumptions stated and developed from information available at the time of the estimate. Final costs for all projects will depend on actual field conditions, on actual material and labor costs, final project scope, project implementation and other variables.

Table B-2
3.0 MG Rock Bluff II Reservoir – Welded Steel
Project Cost Estimate Summary

Reservoir project cost estimates are based on the following assumptions:

No rock excavation included.
No property acquisition costs included.
Construction by private contractors.
An ENR construction cost index of 8630 for Seattle, Washington (October 2006).

Item No.	Description	Estimated Project Cost[1]
1.	Reservoir Structure	$1,620,000
2.	Site Work	$450,000
3.	Drainage System – Including site storm drainage and reservoir overflow discharge	$75,000
4.	Access/Parking	$50,000
5.	Yard Piping	$175,000
6.	Electrical– Including reservoir telemetry	$75,000
7.	Landscaping/Fencing	$75,000
8.	Mob/Demob/Ins/Bonds	$155,000
	Total Construction	$2,675,000
	40% Contingency, Administration & Engineering	$1,070,000
	Total Project Cost	$3,745,000
	USE	$3,750,000

Notes: (1). The cost estimates presented are opinions of cost based on the assumptions stated and developed from information available at the time of the estimate. Final costs for all projects will depend on actual field conditions, on actual material and labor costs, final project scope, project implementation and other variables.

Table B-3
2.3 MG Pilot Butte IV Reservoir – Welded Steel
Project Cost Estimate Summary

Reservoir project cost estimates are based on the following assumptions:

No rock excavation included.
No property acquisition costs included.
Construction by private contractors.
An ENR construction cost index of 8630 for Seattle, Washington (October 2006).

Item No.	Description	Estimated Project Cost[1]
1.	Reservoir Structure	$1,200,000
2.	Site Work	$425,000
3.	Drainage System – Including site storm drainage and reservoir overflow discharge	$75,000
4.	Access/Parking	$35,000
5.	Yard Piping	$120,000
6.	Electrical– Including reservoir telemetry	$75,000
7.	Landscaping/Fencing	$40,000
8.	Mob/Demob/Ins/Bonds	$100,000
	Total Construction	$2,070,000
	40% Contingency, Administration & Engineering	$828,000
	Total Project Cost	$2,898,000
	USE	$2,900,000

Notes: (1). The cost estimates presented are opinions of cost based on the assumptions stated and developed from information available at the time of the estimate. Final costs for all projects will depend on actual field conditions, on actual material and labor costs, final project scope, project implementation and other variables.

Table B-4
3.0 MG Pilot Butte V Reservoir – Welded Steel
Project Cost Estimate Summary

Reservoir project cost estimates are based on the following assumptions:

No rock excavation included.
No property acquisition costs included.
Construction by private contractors.
An ENR construction cost index of 8630 for Seattle, Washington (October 2006).

Item No.	Description	Estimated Project Cost[1]
1.	Reservoir Structure	$1,620,000
2.	Site Work	$450,000
3.	Drainage System – Including site storm drainage and reservoir overflow discharge	$75,000
4.	Access/Parking	$50,000
5.	Yard Piping	$175,000
6.	Electrical– Including reservoir telemetry	$75,000
7.	Landscaping/Fencing	$75,000
8.	Mob/Demob/Ins/Bonds	$155,000
	Total Construction	$2,675,000
	40% Contingency, Administration & Engineering	$1,070,000
	Total Project Cost	$3,745,000
	USE	$3,750,000

Notes: (1). The cost estimates presented are opinions of cost based on the assumptions stated and developed from information available at the time of the estimate. Final costs for all projects will depend on actual field conditions, on actual material and labor costs, final project scope, project implementation and other variables.

Table B-5
2.0 MG Juniper Ridge Reservoir – Welded Steel
Project Cost Estimate Summary

Reservoir project cost estimates are based on the following assumptions:

No rock excavation included.
No property acquisition costs included.
Construction by private contractors.
An ENR construction cost index of 8630 for Seattle, Washington (October 2006).

Item No.	Description	Estimated Project Cost[1]
1.	Reservoir Structure	$1,000,000
2.	Site Work	$400,000
3.	Drainage System – Including site storm drainage and reservoir overflow discharge	$90,000
4.	Access/Parking	$45,000
5.	Yard Piping	$110,000
6.	Electrical– Including reservoir telemetry	$75,000
7.	Landscaping/Fencing	$35,000
8.	Mob/Demob/Ins/Bonds	$90,000
	Total Construction	$1,845,000
	40% Contingency, Administration & Engineering	$738,000
	Total Project Cost	$2,583,000
	USE	$2,600,000

Notes: (1). The cost estimates presented are opinions of cost based on the assumptions stated and developed from information available at the time of the estimate. Final costs for all projects will depend on actual field conditions, on actual material and labor costs, final project scope, project implementation and other variables.

Table B-6
3.5 MG Pilot Butte VI Reservoir – Welded Steel
Project Cost Estimate Summary

Reservoir project cost estimates are based on the following assumptions:

No rock excavation included.
No property acquisition costs included.
Construction by private contractors.
An ENR construction cost index of 8630 for Seattle, Washington (October 2006).

Item No.	Description	Estimated Project Cost[1]
1.	Reservoir Structure	$2,000,000
2.	Site Work	$500,000
3.	Drainage System – Including site storm drainage and reservoir overflow discharge	$85,000
4.	Access/Parking	$75,000
5.	Yard Piping	$130,000
6.	Electrical– Including reservoir telemetry	$70,000
7.	Landscaping/Fencing	$70,000
8.	Mob/Demob/Ins/Bonds	$175,000
	Total Construction	$3,105,000
	40% Contingency, Administration & Engineering	$1,242,000
	Total Project Cost	$4,347,000
	USE	$4,350,000

Notes: (1). The cost estimates presented are opinions of cost based on the assumptions stated and developed from information available at the time of the estimate. Final costs for all projects will depend on actual field conditions, on actual material and labor costs, final project scope, project implementation and other variables.

Table B-7
3.0 MG Rock Bluff III Reservoir – Welded Steel
Project Cost Estimate Summary

Reservoir project cost estimates are based on the following assumptions:

No rock excavation included.
No property acquisition costs included.
Construction by private contractors.
An ENR construction cost index of 8630 for Seattle, Washington (October 2006).

Item No.	Description	Estimated Project Cost[1]
1.	Reservoir Structure	$1,620,000
2.	Site Work	$450,000
3.	Drainage System – Including site storm drainage and reservoir overflow discharge	$75,000
4.	Access/Parking	$50,000
5.	Yard Piping	$175,000
6.	Electrical– Including reservoir telemetry	$75,000
7.	Landscaping/Fencing	$75,000
8.	Mob/Demob/Ins/Bonds	$155,000
	Total Construction	$2,675,000
	40% Contingency, Administration & Engineering	$1,070,000
	Total Project Cost	$3,745,000
	USE	$3,750,000

Notes: (1). The cost estimates presented are opinions of cost based on the assumptions stated and developed from information available at the time of the estimate. Final costs for all projects will depend on actual field conditions, on actual material and labor costs, final project scope, project implementation and other variables.

Table B-8
Westwood Pump Station Upgrade
Project Cost Estimate Summary

Pump station project cost estimates are based on the following assumptions:

No rock excavation included.
No property acquisition costs included.
Construction by private contractors.
An ENR construction cost index of 8630 for Seattle, Washington (October 2006).

Item No.	Description	Estimated Project Cost[1]
1.	Mobilization/Demobilization	$70,000
2.	Site Work	$75,000
3.	Structure	$325,000
4.	Yard Piping	$75,000
5.	Mechanical	$425,000
6.	Controls	$75,000
7.	Electrical	$150,000
8.	Standby Generator and Transfer Switch	$250,000
9.	Landscaping	$50,000
	Total Construction	$1,495,000
	40% Contingency, Administration & Engineering	$598,000
	Total Project Cost	$2,093,000
	USE	$2,100,000

Notes: (1). The cost estimates presented are opinions of cost based on the assumptions stated and developed from information available at the time of the estimate. Final costs for all projects will depend on actual field conditions, on actual material and labor costs, final project scope, project implementation and other variables.

Table B-9
Piping Unit Project Cost[1] Summary

Pipe Diameter	Cost per Linear Foot
8-inch	$132
10-inch	$144
12-inch	$171
16-inch	$209
18-inch	$235
24-inch	$313

Project Cost Assumptions:

Rock excavation required for the bottom two feet of trench depth
No dewatering
No property or easement acquisitions
No specialty construction included
A 40% contingency, administration and engineering allowance included
Construction by private contractors
An Engineering News Record (ENR) construction cost index CCI for Seattle, Washington of 8630 (October 2006).
Add an additional 35% for construction with rock excavation the entire depth of trench

Notes: (1). The cost estimates presented are opinions of cost based on the assumptions stated and developed from information available at the time of the estimate. Final costs for all projects will depend on actual field conditions, on actual material and labor costs, final project scope, project implementation and other variables.

Table B-10
Piping Improvements
Project Cost Estimate Summary

Distribution and Fire Flow Capacity Improvements			
Map ID	**Length (feet)**	**Size (inches)**	**Estimated Project Cost [(1)]**
D-1	2,510	12	$429,200
D-2	960	16	$218,900
D-3	390	12	$66,700
D-4	820	12	$140,200
D-5	1,780	16	$405,800
D-6	820	10	$118,100
D-7	310	12	$53,000
D-8	110	12	$18,800
D-9	2,030	10	$292,300
D-10	110	8	$14,500
D-11	1,510	12	$258,200
D-12	130	12	$22,200
D-13	590	12	$100,900
D-14	3,530	10	$508,300
D-15	1,930	12	$330,000
D-16	160	8	$21,100
D-17	950	8	$125,400
D-18	130	8	$17,200
D-19	2,110	12	$360,800
D-20	170	10	$24,500
D-21	1,100	12	$188,100
D-22	1,130	8	$149,200
D-23	570	12	$97,500
D-24	440	16	$100,300
D-25	1,670	12	$285,600
D-26	2,220	10	$319,700
D-27	150	8	$19,800
D-28	530	8	$70,000
D-29	370	8	$48,800
D-30	380	8	$50,200
D-31	210	12	$35,900
D-32	390	10	$56,200
D-33	860	8	$113,500
D-34	270	12	$46,200
D-35	420	8	$55,400
D-36	660	8	$87,100
D-37	1,000	12	$171,000
D-38	1,640	12	$280,400
D-39	800	10	$115,200
D-40	650	10	$93,600
D-41	1,300	16	$296,400

Map ID	Length (feet)	Size (inches)	Estimated Project Cost [1]
D-42	320	10	$46,100
D-43	1,,600	16	$364,800
D-44	960	8	$126,700
D-45	950	16	$216,600
D-46	500	8	$66,000
D-47	790	10	$113,800
D-48	520	10	$113,760
D-49	380	8	$50,200
D-50	1,590	12	$271,900
D-51	100	8	$13,200
D-52	1,040	10	$149,800
D-53	650	10	$93,600
D-54	1,880	16	$428,600
D-55	1,600	16	$364,800
D-56	1,980	10	$285,100
D-57	1,610	12	$275,300
D-58	2,850	10	$410,400
D-59	2,180	10	$313,900
D-60	340	8	$44,900
D-61	770	10	$110,900
D-62	1,430	8	$188,800
D-63	1,500	8	$198,000
D-64	330	8	$43,600
D-65	990	8	$130,700
D-66	1,380	8	$182,200
D-67	1,020	8	$134,600
D-68	480	8	$63,400
D-69	340	8	$44,900
D-70	120	8	$15,800
D-71	540	8	$71,300
D-72	290	8	$38,300
D-73	1,010	8	$133,300
D-74	300	10	$43,200
D-75	580	8	$76,600
D-76	1,980	8	$261,400
D-77	630	8	$83,200
D-78	310	8	$40,900
D-79	270	12	$46,200
D-80	460	12	$78,700
D-81	300	8	$39,600
D-82	320	8	$42,200
D-83	1,440	12	$246,200
D-84	510	8	$67,300
D-85	440	8	$58,100
D-86	470	8	$62,000
D-87	370	8	$48,800

Map ID	Length (feet)	Size (inches)	Estimated Project Cost [1]
D-88	420	8	$55,400
D-89	1,290	10	$185,800
D-90	150	10	$21,600
D-91	210	10	$30,200
D-92	310	8	$40,900
D-93	830	8	$109,600
D-94	200	8	$26,400
D-95	1,080	8	$142,600
D-96	580	8	$76,600
D-97	2,460	8	$324,700
D-98	1,370	10	$197,300
D-99	1,280	8	$168,960
D-100	1,250	12	$213,800
D-101	1,960	10	$282,200
D-102	2,760	16	$629,300
D-103	1,620	10	$233,300
D-104	300	10	$43,200
D-105	170	12	$29,100
D-106	250	8	$33,000
D-107	2,820	18	$723,300
D-108	780	16	$177,800
D-109	380	8	$50,200
D-110	1,230	8	$162,400
D-111	1,120	8	$147,800
D-112	2,330	12	$398,400
D-113	190	12	$32,500
D-114	400	10	$57,600
D-115	1,410	10	$203,000
D-116	3,190	8	$421,100
D-117	310	12	$53,000
D-118	420	8	$55,400
D-119	620	10	$89,300
D-120	710	8	$93,700
D-121	830	12	$141,900
D-122	1,360	8	$179,500
D-123	1,510	8	$199,300
D-124	470	8	$62,000
D-125	1,070	8	$141,200
D-126	880	8	$116,200
D-127	730	8	$96,400
D-128	250	10	$36,000
D-129	260	8	$34,300
D-130	650	8	$85,800
D-131	100	10	$14,400
D-132	340	8	$44,900
D-133	370	10	$53,300

Map ID	Length (feet)	Size (inches)	Estimated Project Cost [1]
D-134	60	8	$7,900
D-135	230	8	$30,400
D-136	320	8	$42,200
D-137	250	8	$33,000
D-138	240	8	$31,700
D-139	100	10	$14,400
D-140	390	8	$51,500
D-141	240	8	$31,700
D-142	170	8	$22,400
D-143	410	8	$54,100
D-144	630	12	$107,700
D-145	1,580	8	$208,600
D-146	330	8	$43,600
D-147	300	8	$39,600
D-148	840	10	$121,000
D-149	300	8	$39,600
D-150	180	8	$23,800
D-151	510	8	$67,300
D-152	1,880	8	$248,200
D-153	490	10	$70,600
D-154	230	8	$30,400
D-155	2,060	8	$271,900
D-156	470	10	$67,700
D-157	650	10	$93,600
D-158	160	8	$21,100
D-159	210	12	$35,900
D-160	330	8	$43,600
D-161	2,160	10	$311,000
D-162	220	10	$31,700
D-163	290	12	$49,600
D-164	450	10	$64,800
D-165	860	8	$113,500
D-166	1,010	10	$145,400
D-167	650	8	$85,800
D-168	4,430	12	$757,500
D-169	500	8	$66,000
D-170	1,750	12	$299,300
D-171	1,850	18	$474,500
D-172	550	8	$72,600
D-173	1,000	16	$173,000
D-174	3,220	12	$550,600
D-175	440	10	$63,400
D-176	2,000	8	$264,000
D-177	290	8	$38,300
D-178	1,340	8	$176,900
D-179	1,690	8	$223,100

Map ID	Length (feet)	Size (inches)	Estimated Project Cost [1]
D-180	1,750	8	$231,000
D-181	2,160	8	$285,100
D-182	950	8	$125,400
D-183*	--	--	--
D-184	1,590	16	$275,100
D-185	590	10	$85,000
D-186*	--	--	--
D-187	300	8	$39,600
D-188	280	8	$37,000
D-189	670	12	$114,600
D-190	1,460	8	$192,700
D-191	420	8	$55,400
D-192*	--	--	--
D-193	1,360	10	$195,800
D-194	3,220	10	$463,700
D-195	140	12	$23,900
D-196	180	8	$23,800
D-197	730	8	$96,400
D-198	720	10	$103,700
D-199	390	8	$51,500
D-200*	--	--	--
D-201	1,440	8	$190,100
D-202	190	8	$25,100
D-203*	--	--	--
D-204	220	24	$75,200
D-205	470	8	$62,000
D-206	1,470	12	$251,400
D-207	620	8	$81,800
D-208	1,190	12	$203,500
D-209	690	12	$118,000
D-210	380	10	$54,700
D-211	720	10	$103,700
D-212	720	8	$95,000
D-213	450	8	$59,400
D-214	460	12	$78,700
D-215	540	12	$92,300
D-216	560	12	$95,800
D-217	1,860	10	$267,800
D-218*	--	--	--
D-219*	--	--	--
D-220	1,010	10	$145,400
D-221	900	8	$118,800
D-222	1,640	10	$236,200
D-223	1,130	10	$162,700
D-224	820	10	$118,100
D-225	310	10	$44,600

Map ID	Length (feet)	Size (inches)	Estimated Project Cost [1]
D-226	1,320	10	$190,100
D-227	650	10	$93,600
D-228	1,180	8	$155,800
D-229*	--	--	--
D-230	560	8	$73,900
D-231	840	10	$121,000
D-232	800	10	$115,200
D-233	120	12	$20,500
D-234	240	8	$31,700
D-235*	--	--	--
D-236	540	8	$71,300
D-237	890	10	$128,200
D-238	1,320	10	$190,100
D-239	1,610	12	$275,300
D-240*			
D-241	380	8	$50,200
D-242	600	8	$79,200
D-243	80	8	$10,600
D-244	1,190	12	$203,490
D-245	370	10	$53,300
D-246	620	10	$89,300
D-247*	--	--	--
D-248	360	8	$47,500
D-249	280	10	$40,300
D-250	240	12	$41,000
D-251	110	8	$14,500
D-252	1,680	12	$287,300
D-253*	--	--	--
D-254*	--	--	--
D-255	690	10	$99,400
D-256	240	10	$34,600
D-257*	--	--	--
D-258*	--	--	--
D-259	170	12	$29,100
D-260	190	10	$27,400
D-261	190	10	$27,400
D-262	970	12	$165,900
D-263	160	10	$23,000
D-264*	--	--	--
D-265	110	8	$14,500
D-266*	--	--	--
D-267	680	8	$89,800
D-268	1,050	8	$138,600
D-269	430	12	$73,500
D-270	260	8	$34,300
D-271	920	12	$157,300

Map ID	Length (feet)	Size (inches)	Estimated Project Cost [1]
D-272	2,720	8	$359,000
D-273	1,530	8	$202,000
D-274	2,760	8	$364,300
D-275	750	10	$108,000
D-276	640	12	$109,400
D-277	440	12	$75,200
D-278	2,400	12	$410,400
D-279	4,100	16	$709,300
D-280	6,900	16	$1,193,700
D-281	2,600	12	$444,600
		Distribution and Fire Flow Sub-Total	$37,389,110
		USE	***$37,400,000***
Transmission Capacity Improvements			
T-1	2,490	24	$851,600
T-2	3,470	24	$1,186,700
T-3	2,060	24	$704,500
T-4	7,870	36	$4,037,300
T-5	2,260	24	$772,900
T-6	370	24	$126,500
		Transmission Capacity Sub-Total	*$7,679,500*
		USE	***$7,680,000***
		GRAND TOTAL	**$45,080,000**

* Unused numbers

Notes: (1). The cost estimates presented are opinions of cost based on the assumptions stated and developed from information available at the time of the estimate. Final costs for all projects will depend on actual field conditions, on actual material and labor costs, final project scope, project implementation and other variables.

Table B-11
Proposed Pressure Reducing Stations
Project Cost Estimate Summary

Map ID	General Location	Size (inches)	Estimated Project Cost [(1)]
PRV1	Jill	8	$90,000
PRV2	Skyline Ranch	6	$75,000
PRV3	Aurora	8	$90,000
PRV4	Brogan Pl.	8	$90,000
PRV5	Flagline	8	$90,000
PRV6	Trenton Ave.	8	$90,000
PRV7	Emkay St.	6	$75,000
PRV8	Creek Rd.	8	$90,000
PRV9	Yates Dr.	6	$75,000
PRV10	Revere Ave.	6	$75,000
PRV11	Seward	6	$75,000
PRV12	Chase Rd.	8	$90,000
PRV13	Awbrey Rd.	6	$75,000
	Total		**$1,080,000**

Notes: (1). The cost estimates presented are opinions of cost based on the assumptions stated and developed from information available at the time of the estimate. Final costs for all projects will

depend on actual field conditions, on actual material and labor costs, final project scope, project implementation and other variables.

APPENDIX C

APPENDIX C
WATER RIGHTS SUMMARY

A tabular summary of the water rights held by the City of Bend are included in this appendix. The data presented in Table C-1 is summarized from water rights information presented in the City's Water Management and Conservation Plan (Economic and Engineering Services, Inc., October 2004) and the Initial Assessment of Water Supply and Mitigation Alternatives (Newton Consultants, Inc., September 2003). This data is presented herein to provide a record of the status of the water rights held by the City for the water supply sources discussed throughout this plan.

Table C-1
City of Bend Water Rights Summary

Source Type	Facility Name	Application, Permit or Certificate	Priority Date	Authorized Pumping Rate (cfs)	Total Rate (cfs) (mgd)	Status	Comments
Groundwater	Lava Island Wells	Permit G-4435	11/8/1968	7.75	7.75 (5.01)	Permit	No development under this right completed to date.
	Outback Wells	Permit G-11380	9/7/1990	10	10 (6.46)	Permit	
	Airport Well/Bear Creek #1						T-7845 & T-7852
	River Well #1 & 2	Permit G-4946	10/31/1971	2.7	16.04 (10.36)	Permit	
	River Well #1 & 2			0.9		Certificate 68702	Partially Perfected G-4946
	Pilot Butte #1 & 2			7.57		Permit	T-7009
	Copper Stone (Awbrey Glen)					Permit	
	Bear Creek #1 & 2			4.87		Permit	T-9408
	Westwood Well	Permit G-8565	12/22/1978	2.45	2.45 (1.58)	Permit	
	Rock Bluff Wells	G-11379	6/30/1989	8	8 (5.17)	Permit	
	Pilot Butte #3						T-8342
	Bear Creek 1, 2 & 3	Application 13097	8/22/1992	12	12 (7.75)	Pending	Subject to mitigation
	Pilot Butte 1, 2 & 3	Application 13098	8/22/1992	12	12 (7.75)	Pending	Subject to Mitigation
	Total Permitted and Pending Ground Water Rate				*68.24 cfs (44.08 mgd)*		
	Total Current Permitted Ground Water Rate				**44.24 cfs (28.58 mgd)**		
Surface Water	Bridge Creek	S-49823	12/12/1983	15	15.00 (9.69)	Permit	Junior right, unavailable during irrigation season
	Tumalo Creek	Court Decree	First Priority	6	21.113 (13.64)	Decree	Unrestricted
		S-31411	9/30/1900	4.5		Certificated	Limited during summer season based on Tumalo Creek flow.
			8/5/1900	2			
			6/1/1907	0.02			
		S-31665	9/30/1900	1.314		Certificated	
			4/28/1905	0.186			
			6/1/1907	1.103			
		Transfer B-112	10/29/1913	5.99		Certificated	
	Total Permitted Surface Water Rate				*36.113 cfs (23.33 mgd)*		
	Total Reliable Surface Water Rate Available to Supply MDD				**11.72 cfs (7.6 mgd)**		

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