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**CITY OF BEND**  
**WATER SYSTEM MASTER PLAN**

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## ACKNOWLEDGEMENTS



MIRROR POND — 1890's  
Photo by: Dave Swan

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The following City of Bend personnel and many others provided information and cooperated fully with the study:

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CITY OF BEND  
DESCHUTES COUNTY, OREGON

WATER SYSTEM MASTER PLAN



JULY 1980

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# GLOSSARY

AIA	-	American Insurance Association.	OD Casing	-	Outside diameter of well casing pressure zones.
Aquifer	-	A water-bearing stratum of permeable rock, sand or gravel.	PL	-	Pumping level.
BECON	-	Bend Engineering Consultants. Bend sewer project joint venture (Century West, CH2M Hill, John Carollo).	PRV	-	Pressure reducing valve.
°C	-	Degrees centrigade.	PSI	-	Pounds per square inch.
DEQ	-	Department of Environmental Quality.	RPM	-	Revolutions per minute.
DI	-	Ductile iron.	SWL	-	Static water level.
Drawdown	-	Lowering of water level.	TDH	-	Total dynamic head.
°F	-	Degrees Farenheit.			
HP	-	Horsepower.			
HUD	-	U.S. Department of Housing and Urban Development			
Hz	-	Hertz. A unit of frequency equal to one cycle per second.			
GAD	-	Gallons per acre per day.			
GPCPD	-	Gallons per capita per day.			
GPD	-	Gallons per day.			
GPM	-	Gallons per minute.			
ISO	-	Insurance Services Office.			
LID	-	Local Improvement District.			
MG	-	Million gallons.			
MGD	-	Million gallons per day.			
MSL	-	Mean sea level.			
MW	-	Mega-watt.			
NBFU	-	National Board of Fire Underwriters.			

# INTRODUCTION

## Chapter I



EARLY DAY MIRROR POND — 1920's

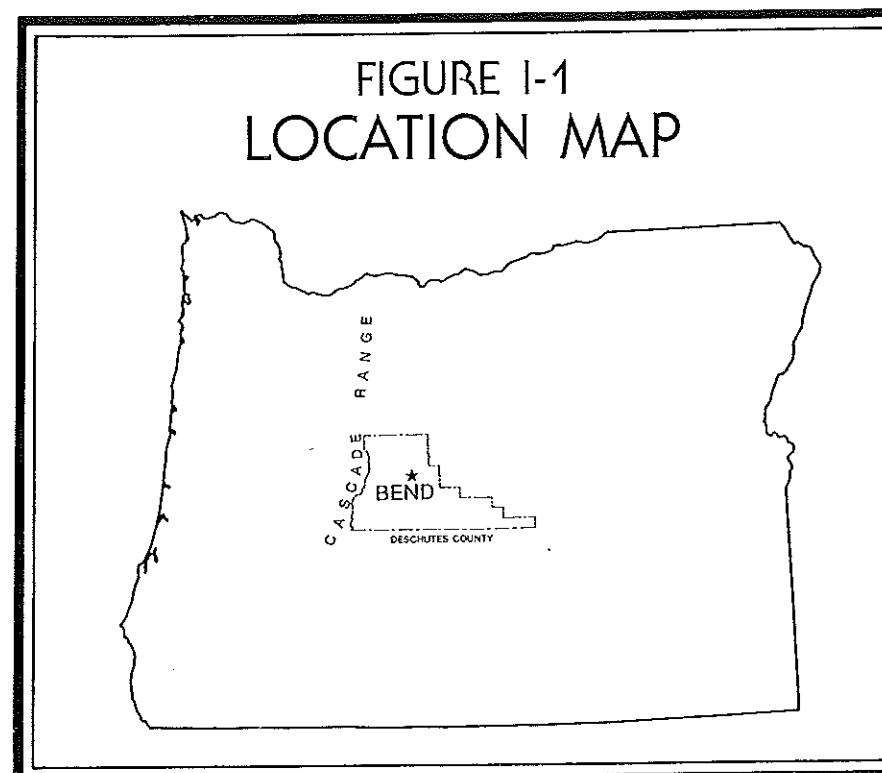
Photo by: Seward & Todd

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# INTRODUCTION

This report was prepared from an investigation authorized by the City of Bend to Century West Engineering Corporation and Central Oregon Engineering and Surveying Corporation. Its purpose is to analyze the existing water system, study alternatives for improvements to the existing system to meet present and future needs, prepare financial data and investigate methods of financing the needed improvements, including possible grant sources.

The City of Bend is located in Central Oregon, east of the Cascades (Figure I-1). Influenced by a semi-arid climate, Bend receives 12 inches of rainfall annually.



Volcanic action has created prominent landscape features with shallow, porous soils overlying thin basalt lava flows. Sitting on a plateau at 1,100 meters (3,600 feet), Bend experiences cold winters with average minimum temperatures of 30° F. An abundant snowfall in adjacent mountains has made Bend a popular ski resort area. Summer temperatures are usually dry and warm, averaging 64° F, although frost is possible

in any month of the year. Excellent fishing and hunting draw many sportsmen to the area making Bend a center for year-round recreation. The combination of these recreational activities with clear skies and fresh air has made Bend a desirable community in which to live. The City's rapid growth is expected to continue with an anticipated population of approximately 45,000 by the year 2000. It is to meet the water demands for this population that the Bend Water System Master Plan has been prepared.

## BEND WATER SYSTEM HISTORY

Bend became an incorporated city in 1905. At that time, water for its residents was supplied from the Deschutes River via the Bend Water Light and Power Company water system. The City purchased this water company in 1924 and also found it necessary to locate an alternate water source. The Deschutes River water was no longer of adequate quality due to algal growth originating in storage reservoirs located upstream.

In 1924, the engineering firm of Dubuis and Redfield recommended Tumalo Creek and its tributaries for Bend's new water source. The City purchased water rights to this creek through the Deschutes County Municipal District (now called Tumalo Irrigation District). The water travels down the Bridge Creek tributary of Tumalo Creek to an intake site where it flows through two steel pipelines capable of delivering 11½ million gallons of water per day. This water is piped 11 3/4 miles to the Overturf Reservoir located at Bend's City Limits.

## PREVIOUS STUDIES

Since 1924, the City of Bend has authorized several engineering studies to investigate various parts of their water system. The reports are as follows:

- Dubuis and Redfield Engineers, Bend, Oregon.  
A Report on the Sources of Water Supply for the City of Bend, May, 1924.
- A series of reports from John W. Cunningham and Associates, Portland, Oregon, June 1948-January, 1954.  
A Report on Improvement of Bend Waterworks System, June, 1948.

Supplement to the June, 1948 Report, May, 1949.  
Supplement Report, August, 1949.  
Supplement Report, September, 1950.

Letter, April, 1953  
Letter, January, 1954

■ McIlroy Analyzer, Washington State College, done by City Water Department, 1958.

■ Cornell, Howland, Hayes, Merryfield, Corvallis, Oregon, December 1964-September, 1968.

A Report on an Engineering Study of the Municipal Water System City of Bend, Oregon, December, 1964.

A Report on Subsurface Water Exploration at Lava Island Falls, August, 1968.

■ Robinson and Noble, Incorporated, Tacoma, Washington. Construction of Well No. 1, City of Bend, Oregon. April, 1972.

Letter, September, 1968.

■ Lee Engineering Enterprises, Oregon City, Oregon.  
South Century Drive Water Study, December, 1977.

■ Robinson and Noble, Incorporated, Tacoma, Washington.

Construction Report on City of Bend Well #2, July, 1978.

## PAST REPORT SUMMARIES

### DUBIUS AND REDFIELD

Dubuis and Redfield's 1924 report showed perceptive insight in recommending the Bridge Creek tributary of Tumalo Creek as Bend's water source. Its quality and quantity still prove to be superior to other surface water sources. Their analysis of Bend's growth also proved to be extremely accurate. They recommended that Bend's plan for the future should allow for a population of not less than 40,000 and that the present (1924) supply and equipment should be sufficient for not less than 20,000 people.

Annual cost for the Bridge Creek water source was determined by Dubuis & Redfield to be decidedly lower than the other sources they examined. Their initial recommendations included steel pipelines, fencing the complete watershed, a telephone at the headgate, construction of a diversion dam and a house for the gate tender.

Other possible water sources and their suitability investigated by Dubius and Redfield are listed in Table I-1.

### JOHN W. CUNNINGHAM AND ASSOCIATES

The first report presented by John W. Cunningham and Associates examined the Bend system in 1948. They supported Dubuis and Redfield's recommendations and reported that the only reason to consider other water sources would be from insufficient water coming from Bridge Creek. The alternate water sources studied by Cunningham and Associates are in Table I-1. Their major recommendations were: (1) the City acquire 9.6 MGD water rights from the Tumalo Irrigation District, (2) that universal metering be adopted to encourage water conservation, (3) a 5 MG reservoir be constructed on Awbrey Butte, and (4) a crosstown high pressure main be installed.

The 1949 supplement reported that construction for reservoirs on Awbrey Butte and Pilot Butte had started. A second report in 1949 introduced the idea of constructing a second pipeline from the Tumalo Creek source in order to increase capability and add reliability to the system. In 1950, Cunningham proposed a pipeline from the City to a diversion point  $1\frac{1}{2}$  miles upstream from Shevlin Park instead of running a second pipe to Tumalo Creek. This line would have

been used only in the summer. This idea was rejected by the City because of possible water pollution by livestock. The City had purchased more water rights from Tumalo Irrigation District so the earlier proposal to construct a second pipeline running parallel to the first line was recommended. The last letter in 1954 was an estimate for construction of this pipe. The two lines combined have an approximate capacity of 11-12 MGD.

### CORNELL, HOWLAND, HAYES, MERRYFIELD (CH2M)

The 1964 CH2M report's intent was to determine methods of expanding the existing water system to meet the needs of the City for approximately 25 years into the future. They examined the present system and used two methods to forecast future trends and needs; (1) projecting population growth with corresponding per capita water use and (2) a direct projection of water use records. In analyzing the present water system, CH2M listed three factors affecting patterns and habits of water use in Bend. These are: (1) dry climate, (2) porous soil type, and (3) flat rates that allow unlimited water usage. CH2M recommended metering as they estimated a 15% reduction in consumption. Suitability of alternate water sources studied by CH2M are found in Table I-1.

CH2M also examined the City of Bend's water distribution system, storage facilities and fire protection capability. They recommended additional storage on the east side of the City. The reason for this was to permit two directional flow to the center of Bend during peak demand periods. They determined that existing fire hydrant spacing supplied adequate fire protection but the spacing was greater than that recommended by the National Board of Fire Underwriters (now the ISO). Their recommendation was to install additional fire hydrants in certain critical areas. The distribution system was considered good, but needed some attention in the areas of pressure zones, expansion and strengthening of the main grid system in order to meet peak hourly demands more efficiently. CH2M provided a schedule of system improvements and estimated costs.

In August 1968, CH2M reported on subsurface exploration at Lava Island Falls. Two wells were drilled. The main aquifer in Well No. 1 was determined to be between 228 feet and 282 feet deep. Well No. 2 was in a separate aquifer located between 203 feet and 218 feet deep. The water in both wells appears to be of good quality and should produce water in excess of

500 GPM. In a September 1968 letter, further recommendations were made to confirm that Lava Island has an adequate supply of ground water in which a well field could be developed. They further stated that additional exploration should confirm this water supply. Then necessary easements for a pipeline should be obtained and land aquired for pumping facilities.

### ROBINSON AND NOBLE

The Robinson & Noble report on the construction of Well No. 1 stated that the capacity of the well should be 2,000 GPM or greater. With this discharge (2,000 GPM), the Well No. 1 aquifer should supply a long-term yield. In the future, additional wells would be expected to be able to use this same aquifer. Chemical laboratory tests indicated good quality water with an absence of suspended solids and turbidity. Robinson & Noble also felt that after the sealing of this deep well at 838 feet, there would be no possibility of bacteria contamination.

Robinson & Noble submitted a report after the drilling of Well No. 2 was completed in the Fall of 1978. They found it completely suitable for municipal use. Pumping from this well did not appear to cause interference with Well No. 1. The total depth of Well No. 2 is 800 feet and it is capable of supplying 2,000 GPM from a pumping level of 450 feet. Robinson & Noble recommended that continuous records be kept of both wells and these records be reviewed annually to determine any long-term trends or significant changes.

TABLE I-1  
ALTERNATE WATER SOURCES  
1924-1964

DUBUIS & REDFIELD — 1924		CUNNINGHAM & ASSOCIATES — 1948		CH2M — 1964	
Surface Water		Surface Water		Surface Water	
Source	<u>Suitability</u>	Source	<u>Suitability</u>	Source	<u>Suitability</u>
Deschutes River	Present filter treatment unable to handle pollution problems.	Deschutes River	Filter plant superior to 1924 possible. Not necessary if more water rights to Tumalo Creek can be purchased.	Deschutes River	Chemical and filtration treatment necessary. Public may disapprove.
Tumalo Creek	Superior quality H <sub>2</sub> O. Best source. Construction cost low.	Tumalo Creek	Superior. Purchase more H <sub>2</sub> O rights.	Tumalo Creek	Superior source. May not be possible to purchase more water rights.
Spring River	Set aside for consideration until final decision on dam at Benham Falls. If dam is built it will flood part of Spring River.			Spring River	Water rights-purchase necessary. Better sources available.
Fall River	Construction expensive.			Fall Creek	Difficult access for construction and operation. Construction expensive.
Soda Creek	Supply not dependable. Construction expensive.			Surface Water	Too far from city.
Green Lakes	Supply not dependable. Construction expensive.				
Ground Water		Ground Water		Ground Water	
Source	<u>Suitability</u>	Source	<u>Suitability</u>	Source	<u>Suitability</u>
Greater Bend Area	Broken lava under the city yields no H <sub>2</sub> O.	Greater Bend Area	No continuous H <sub>2</sub> O table at any depth. Questionable that H <sub>2</sub> O can be found in underground stream or sheets.	Greater Bend Area	Adequate and supplemental H <sub>2</sub> O available. Deep wells and shallow wells should be explored.
				Lava Island	Exploration of shallow wells should be pursued.

## SUMMARY OF RECOMMENDATIONS

The summary of recommendations in Table I-2 provides a reference list of the recommendations made in the following sections. Backup information for each recommendation and a detailed description of the recommendation are contained in the reference section listed. The cost of performing the recommended action is listed, and all other cost calculation information is in the Appendices. "N/A" is used where the recommended action could be included in normal system maintenance or the action taken would benefit other departments in the City organization and the cost to the Water Department is difficult to ascertain. All costs are in 1980 dollars.

## GENERAL RECOMMENDATIONS

The recommendations below have not been mentioned in the body of the report as they are of a general nature and do not apply to any one specific section. They apply more to future design of specific components of the system.

## DISMANTLING AND SALVAGING

Currently, the Bend Water System has numerous components that are either abandoned or are on standby and are used infrequently. The Coats Pump Station, the Bend View Reservoir, and the Fifth Street Pump Station are a few. Additionally, there are other installations that, after certain capital improvements to other areas within the system, may be able to be abandoned (e.g. Third and Clay Booster Station, Mt. Bachelor Pump Station). This equipment, when abandoned, should be dismantled and salvaged and, if possible, used in other parts of the system. If the salvagable parts do not have a place in the system, then they should be auctioned.

## INSTRUMENTATION CONTROLS AND MONITORING

The present water system does not have a centralized instrumentation, control and monitoring system. This feature would provide a continuous and immediate source of reliable information on all components of the water works system and would enable instant operational control of important units with minimum expenditure of time and effort. Reservoir low levels and overflows would be known immediately. Malfunction of electric motors or pumps would also be known at once. Pumps which are programmed to start or stop, but which fail to respond to that respective signal are instantly reported, thus avoiding unnoticed depletion or overflow of water storage. The system may also be

utilized to show information on reservoir water levels by panel display.

This is not to imply that the operator presently must travel continuously from tank to tank, for the system does have some automation; however, it is not the equivalent of a centralized monitoring and control system. Existing automation is basically level probes in reservoirs controlling well pump operation.

The control system may be operated through private wires, leased telephone cables, or by radio circuitry. The system would deliver any desired information from all critical points of the water works to a central location where it would be displayed for constant operating surveillance. Some of the pertinent information transmitted would be placed on recording devices which would enable the observer to be fully informed of the operation of the water system. This also provides a permanent and continuous record for later reference.

### MONITORING INFORMATION MAY INCLUDE:

- Water level recorder and indicator for each of the storage tanks with capacity for additional future tanks.
- Visual and audible alarm for high or low water level in each storage tank including provisions for manually silencing the audible alarm while leaving the visible alarm active until the trouble is corrected.
- Each well pump would have visual and audible alarm to signal failure of response to stop-start programming for those instances when it was programmed to start or stop, but failed to respond to this instruction. A light would indicate to the operator whether the pump was running; a manual silencer would be provided for the audible alarm while leaving the visible alarm active until the trouble is corrected.
- An automatic control with manual override for each pump would be provided at the point of central control.
- Each pumping station would have visual and audible alarm for station power failure or line failure with shut-off button for silencing the audible alarm.
- Another desirable function of an instrumentation, controls and monitoring system is the centralizing of the water meter recorders.

Thus the daily trip to each pumping station to collect flow charts and install new ones may be eliminated.

## BOOSTER PUMP STATION DESIGN CRITERIA

- Minimum of two pumps per station. Install pumps in parallel for varied operation depending on the flow required.
- Provide standby power for each pump station sized to meet fire flow requirement.
- Provide adequate signals or alarms to alert responsible department of station malfunctions. Remote alarms should be included.
- Provide clocks to indicate number of accumulated hours running time for each pump.
- Provide for master metering at each pump station.
- Make provision in manifold for possible additional discharge connections.
- Main power supply and control panels should be sized for the future capacity of the station.
- Where necessary, consider housing or enclosure facilities for each station for aesthetic reasons and for protection against vandalism.

## WELL HOUSE DESIGN CRITERIA

- Provide standby power for at least each third well pump.
- Provide clock to indicate number of hours running time for the well pump.
- Provide for master metering.
- Provide adequate space for pump and shaft removal.

TABLE I-2  
SUMMARY OF RECOMMENDATIONS

Location	Recommendation	Cost (if any)	Reference Section	Location	Recommendation	Cost (if any)	Reference Section
1980				1982			
Overturf Reservoirs	Coating surfaces	\$18,000	III Existing Water System Components	Awbrey Butte Reservoir	Joint sealing (if leakage is noticed)	\$10,000	III Existing Water System Components
College Reservoir	Coating surfaces	\$15,000	III Existing Water System Components	Third Street Pump Station	Install backup generator	\$15,000	III Existing Water System Components (ISO Evaluation portion)
Pilot Butte Reservoir No. 1	Coating surfaces	\$45,000	III Existing Water System Components				
Pilot Butte Reservoir No. 2	Spot repair	Include in normal maintenance budget	III Existing Water System Components				
West Fifth Street Pump House	Because of infrequent use, consider using mechanical components at other locations.	N/A	III Existing Water System Components				
Well #2	Install backup power with automatic transfer switch.	\$120,000	III Existing Water System Components (ISO Evaluation portion)	1983			
City-wide	Implement program to exercise valves and flush hydrants yearly.	Include in normal maintenance budget	III Existing Water System Components (ISO Evaluation portion)	Pilot Butte Reservoir No. 2	Recoating	\$20,000	III Existing Water System Components
Bridge Creek	Collect sufficient data over a five-year period to form the basis of a watershed management package.	These tests could be performed by the existing caretaker at Bridge Creek.	IV Water Sources Evaluation	Overturf to McKinley	Install second level pipe.	\$296,000	VI Hydraulic Analysis and Computer Modeling
City-Wide	Continue collecting extensive geologic and hydrologic data to improve site selection and design of future wells. Continue collecting test data on existing wells.	N/A	IV Water Sources Evaluation	S.E. Section	Install 1 MG storage tank.	\$280,000	VI Hydraulic Analysis and Computer Modeling
City-Wide	Protect City ground water source by controlling well drilling south of existing water supply wells and by limiting industrial development within a range where pollution of Bend's ground water could occur.	N/A	IV Water Sources Evaluation	S.E. Section	Install 14" pipe between new tank and Chamberlain and McKinley.	\$417,000	VI Hydraulic Analysis and Computer Modeling
City-Wide	Improve distribution system.	\$140,500 per year 1980-1985	VI Hydraulic Analysis and Computer Modeling	1985			
Cumberland St. Booster Pump Station	Construct booster pump station.	\$59,000	VI Hydraulic Analysis and Computer Modeling	City-Wide	Improve distribution system.	\$127,000 per year 1985-1990	VI Hydraulic Analysis and Computer Modeling
City Administration	Use computer modeling for future design considerations.	N/A	VI Hydraulic Analysis and Computer Modeling	City Administration	Conduct Ranney Collector Feasibility Study	\$40,000	VI Hydraulic Analysis and Computer Modeling
City Administration	Place revenue budgeted for system replacement in a reserve fund.	N/A	VIII Financial Plan				
City Administration	Provide plan and set aside funds for emergency use.	N/A	VIII Financial Plan	1986			
City Administration	Follow strong management practices, assigning the Water Department Manager responsibility for overall physical and financial department management.	N/A	VIII Financial Plan	Existing Well Field	Install Well #3.	\$725,000	VI Hydraulic Analysis and Computer Modeling
				Existing Well Field	Geologic monitoring for Well #3.	N/A (Cost included in above design and construction figure)	VI Hydraulic Analysis and Computer Modeling
				Deschutes River	Install Ranney Collectors if feasible.	\$2,376,000	VI Hydraulic Analysis and Computer Modeling
				Awbrey Butte	Install 2 MG storage tank.	\$440,000	VI Hydraulic Analysis and Computer Modeling
				1987			
				City-Wide	Storage maintenance.	\$10,000	VI Hydraulic Analysis and Computer Modeling
				1988			
				Pilot Butte	Install 1.5 MG storage tank.	\$370,000	VI Hydraulic Analysis and Computer Modeling
				Pilot Butte	Install 16" pipe between new storage tank and distribution system.	\$66,000	VI Hydraulic Analysis and Computer Modeling

TABLE I-2  
CONTINUED

<u>Location</u>	<u>Recommendation</u>	<u>Cost (if any)</u>	<u>Reference Section</u>	<u>Location</u>	<u>Recommendation</u>	<u>Cost (if any)</u>	<u>Reference Section</u>
1989	Install Well #4.	\$725,000	VI Hydraulic Analysis and Computer Modeling	1996	Install Well #7.	\$725,000	VI Hydraulic Analysis and Computer Modeling
	Geologic monitoring for Well #4.	N/A (Cost included in above design and construction figure)	VI Hydraulic Analysis and Computer Modeling		Geologic monitoring for Well #7.	N/A (Cost included in above design and construction figure)	VI Hydraulic Analysis and Computer Modeling
	Install 12" pipe between Well #4 and intersection of Greenwood and Sixth Streets.	\$60,000	VI Hydraulic Analysis and Computer Modeling		Install 1 MG storage tank.	\$280,000	VI Hydraulic Analysis and Computer Modeling
1990	Improve distribution system.	\$80,000 per year 1990-1995	VI Hydraulic Analysis and Computer Modeling	1998	Install Well #8.	\$725,000	VI Hydraulic Analysis and Computer Modeling
	Install Well #5	\$725,000	VI Hydraulic Analysis and Computer Modeling		Geologic monitoring for Well #8.	N/A (Cost included in above design and construction figure)	VI Hydraulic Analysis and Computer Modeling
	Geologic monitoring for Well #5.	N/A (Cost included in above design and construction figure)	VI Hydraulic Analysis and Computer Modeling		Install 1 MG storage tank.	\$280,000	VI Hydraulic Analysis and Computer Modeling
1991	Install 1.5 MG storage tank.	\$370,000	VI Hydraulic Analysis and Computer Modeling	General	Define methods and procedures to improve communications.	N/A	III Existing Water System Components
	Install Well #6.	\$725,000	VI Hydraulic Analysis and Computer Modeling		Consider utility division to coordinate utility expansion.	N/A	III Existing Water System Components
	Geologic monitoring for Well #6.	N/A (Cost included in above design and construction figure)	VI Hydraulic Analysis and Computer Modeling		Computerize record keeping.	N/A	III Existing Water System Components
1992	Install 1 MG storage tank.	\$280,000	VI Hydraulic Analysis and Computer Modeling	City Administration	Assign responsibility for water system expansion coordination to city engineers.	N/A	III Existing Water System Components
	Install Well #7.	\$725,000	VI Hydraulic Analysis and Computer Modeling		Provide for any new oversized facilities in reimbursement policy.	N/A	III Existing Water System Components
	Geologic monitoring for Well #7.	N/A (Cost included in above design and construction figure)	VI Hydraulic Analysis and Computer Modeling		Implement and follow preventive maintenance program.	N/A	III Existing Water System Components
1994	Install 2.5 MG storage tank.	\$475,000	VI Hydraulic Analysis and Computer Modeling	City Administration	Provide relief for developer expanding system in reimbursement policy.	N/A	III Existing Water System Components
	Install Well #8.	\$725,000	VI Hydraulic Analysis and Computer Modeling		Install fire hydrants.	\$10,000 per year 1980 - 2000	III Existing Water System Components (ISO Evaluation portion)
	Geologic monitoring for Well #8.	N/A (Cost included in above design and construction figure)	VI Hydraulic Analysis and Computer Modeling		Install water meters on all services.	\$1,250,000	V Water Meter Evaluation
1995	Replace 20% of Bridge Creek pipeline.	\$152,500 per year 1980-2000	VI Hydraulic Analysis and Computer Modeling	Bridge Creek	Determine whether City will buy utility company or allow service to continue under franchise agreement.	N/A	VII Private Water Utilities
	Improve distribution system.	\$68,000 per year 1995-2000	VI Hydraulic Analysis and Computer Modeling		Annexed Areas Served by Private Water Utilities		

# LAND USE AND CONSUMPTION

Chapter II

BOND STREET LOOKING SOUTH — 1916  
Compliments of: Bill Yates Collection



# LAND USE AND CONSUMPTION

The Land Use and Consumption section presents two kinds of information. The first kind supplies the facts, calculations and projections vital to the understanding of present and future water system design. The second type of information provides background for the facts and conclusions drawn. The reader benefits and gains necessary knowledge from both types of information.

## LAND USE

### OBJECTIVES

The issues of land use and population characteristics are of primary concern in establishing a future water service boundary. When planning and zoning policies do not guide development patterns, availability of utilities will normally be the determining factor. As planning and zoning ordinances play a more significant role in development, design and construction of adequate water and sewer utilities can be accomplished in a more logical and cost-effective fashion. Water utilities cannot be designed without oversizing or undersizing certain portions such as pipelines and storage facilities unless reliable population figures and geographic boundaries are defined. This is especially salient in a city such as Bend which has a large amount of topographical relief. If development is to bridge a large elevation gain, major capital expenditures must be made at an early date. These expenditure benefits will not fully manifest themselves until a much later point in time.

When it is possible to design for a specific population in a specific area, the costs of design and construction will be kept to a minimum while continuing to provide adequate facilities in a timely manner.

### LAND USE AND ZONING

Land outside the Bend City Limits and within the water service boundary characteristically has been

developed into residential lots ranging from approximately one-half acre to five acres in size. No apparent increase in lot size occurs as distance from the City increases. Selection of lot size appears to be a function of individual interests, availability of water, and required land area for individual sewage disposal systems rather than depending on sound urban development concepts. There are several large parcels of land in the study area which are still available for development.

Commercial and industrial development is occurring with increasing intensity along major highways in the study area. As these areas develop to the north, south and east of Bend increased demand for adjacent residential property will result. Areas such as these which have potential for more accelerated growth must be acknowledged in utility planning efforts.

Figure II-1 represents existing zoning and Figure II-2 general land use in the study area, respectively.

### PROJECTED CONDITIONS

The population density projections in Figure II-3 assume an average annual growth rate of 4.5 percent. These were determined by comparing information obtained from the Bend Planning Department, Bend Engineering Consultants (BECON) and the Deschutes County Comprehensive Plan.

Specific areas of high growth rate are difficult to predict. However, in some cases generalized predictions can be made. As mentioned above, commercial and associated residential areas will develop rapidly along the major highway corridors. Proposed subdivisions west of the Deschutes River will promote residential growth to the west.

The major influence on high density growth patterns in the study area over the next few years is the availability of the nearly completed Bend sewerage system. Historically developers who desired high density development were forced to develop on large lots due to lack of sewer service. Although the Department of Environmental Quality regulations do not specify minimum lot sizes for septic tank and drainfield systems, the construction criteria and setback requirements generally dictate a need for at least a minimum one-half acre residential lot size. In areas where connection to the sewer is possible and zoning ordinances permit, high density development will occur along with the expansion of the collection, treatment and disposal system.

### DESIGN POPULATION

Population projections for land use planning purposes are distinct from population forecasts for design purposes. Population forecasts for utility planning provide allowances for design purposes. Utility planning projections generally must be of a conservative nature to allow for unexpected future growth. It was demonstrated in the 1964 CH2M report on the Bend Municipal Water System that growth predictions based on planning considerations are not always valid for utility planning. The logistic method of prediction showed an estimated 1990 population of 15,000, which is substantially less than the current 1979 population of approximately 18,000. The 1956 estimate from the City of Bend was, in fact, substantially closer to being accurate (17,500) than was the prediction based on the logistic curve method. The 20 year design population allowance for water utility planning is illustrated by Table II-1 and will be utilized in subsequent sections of this report. Figure II-4 shows the area's projected total population trend.

TABLE II-1  
POPULATION GROWTH  
4½% PER ANNUM  
BEND AREA

Area	1980	1985	1990	1995	2000
Cooley	100	250	600	1,100	2,300
Deschutes	200	350	600	1,000	1,400
Aubrey	4,100	4,900	5,900	6,950	8,150
Pilot Butte	3,400	4,400	5,700	7,350	9,300
Central	4,000	4,100	4,200	4,300	4,400
Hamby-Ward	100	175	400	600	850
Bear Creek	2,800	3,600	4,700	6,000	7,600
Tillicum	-	200	450	700	950
Blakely	800	1,100	1,600	2,200	2,850
Century	-	500	1,000	1,600	2,800
Kingston	3,150	3,425	3,850	4,200	4,400
Total	18,650	23,000	29,000	36,000	45,000

It should be noted that regardless of the method used, the most important parameter to look at is the actual consumption. That is, if the population grows faster than predicted, consumption will rise and major capital expenditures will be needed sooner than anticipated.

## ANNEXATION CONSIDERATIONS

Development pressures have, until recently, occurred outside the City, and community water service was available in most cases. Annexation was usually not required and often not desirable to the developer. As this practice continued, the City found itself beginning to be surrounded by areas not desiring annexation but requiring other municipal services such as fire protection.

As can be seen elsewhere in this report, several privately owned and operated water systems exist outside of the City of Bend and within the water service boundary. Historically, criteria for development of the private water systems with respect to construction standards and materials has not been consistent with standards for the water system within the City. The City has been reluctant to annex areas that have water systems not compatible with the existing City system because of construction inconsistencies.

Under current policy, the City of Bend requires a consent to annexation prior to providing city sewer or water services but does not require development on the property prior to annexation. This policy will create potential for substantial geographic growth of the incorporated area in conjunction with expansion of the water and sewer utilities.

Annexation proposals in 1979, including a request by Brooks Resources to annex about 2,300 acres, will increase the geographic size of the City by over 50 percent. This increase in incorporated area is due in large part to the anticipated completion of the City sewer facilities.

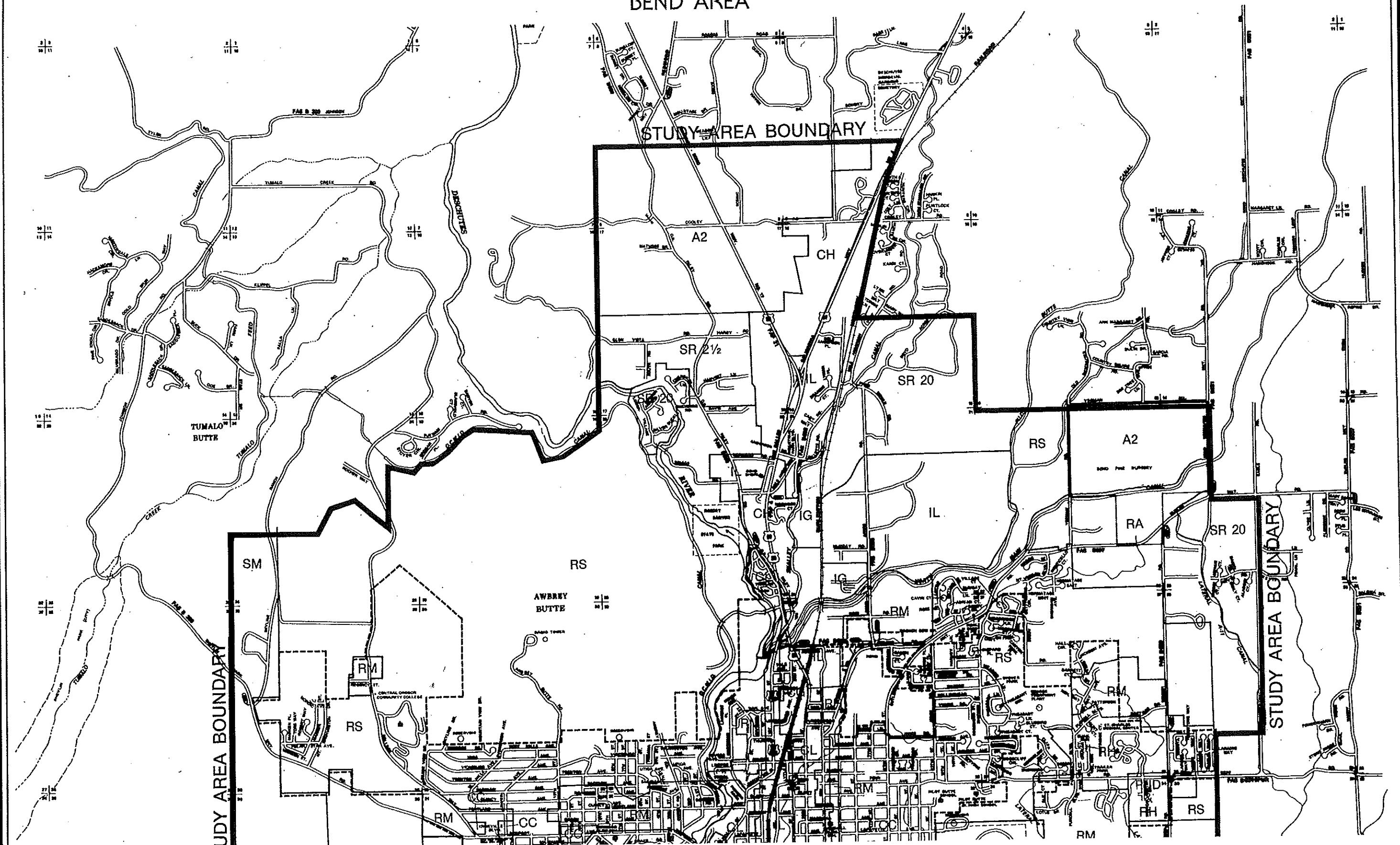
## CONCLUSIONS

A historical tendency for "uncontrolled" development is being contained or curtailed through land use and sewer and water planning efforts. Controlled urban density development is critical for effective utility planning and construction.

Currently, urban density is interspersed with low density development within the water service boundary. As the planned low density areas develop and water service is provided, cost per user should decrease. If the growth in the area is not able to be predicted, and water lines and supplies are not adequate, costs to provide additional service is high. In most cases, phased or interim service does not provide for adequate fire flows or irrigation needs. Often times pressure is inadequate for household purposes.

In order to continue sound utility planning it is essential to provide sound land use planning. In this way, the City of Bend can keep utility construction at a proper pace with development for the least expenditure of fiscal and personnel resources.

FIGURE II-1  
EXISTING ZONING  
BEND AREA



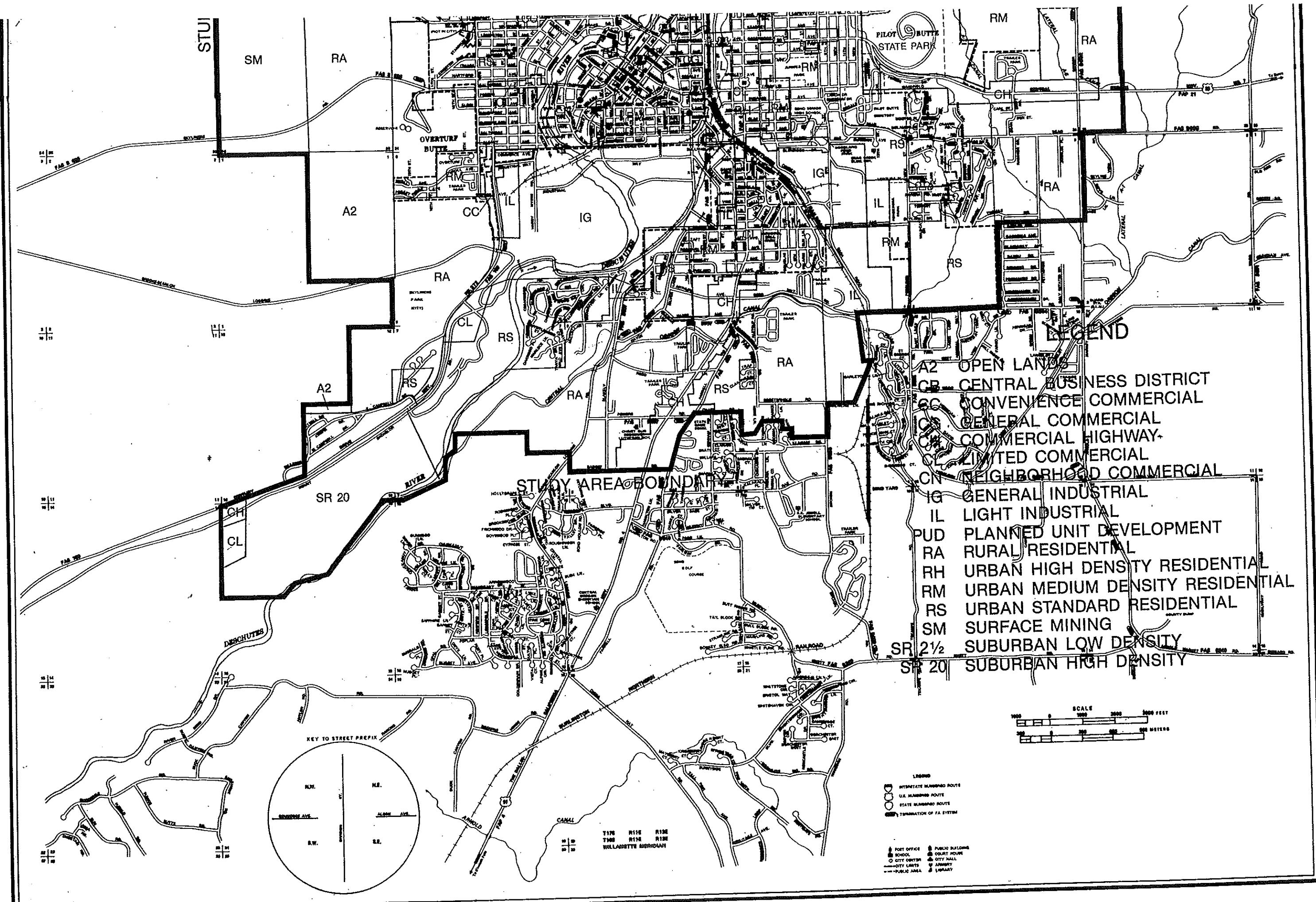


FIGURE II-3  
POPULATION DENSITY PROJECTIONS  
BEND AREA

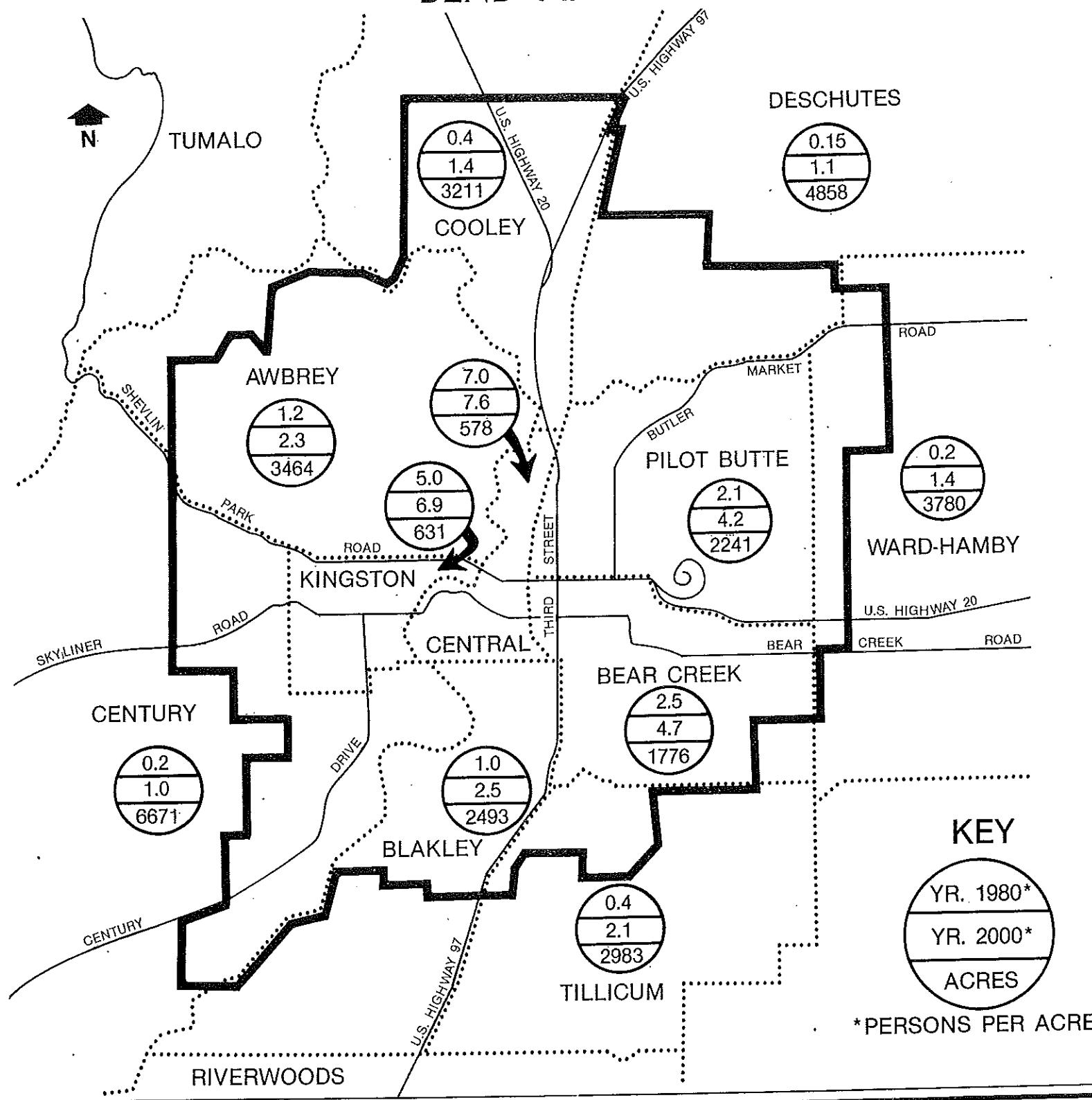
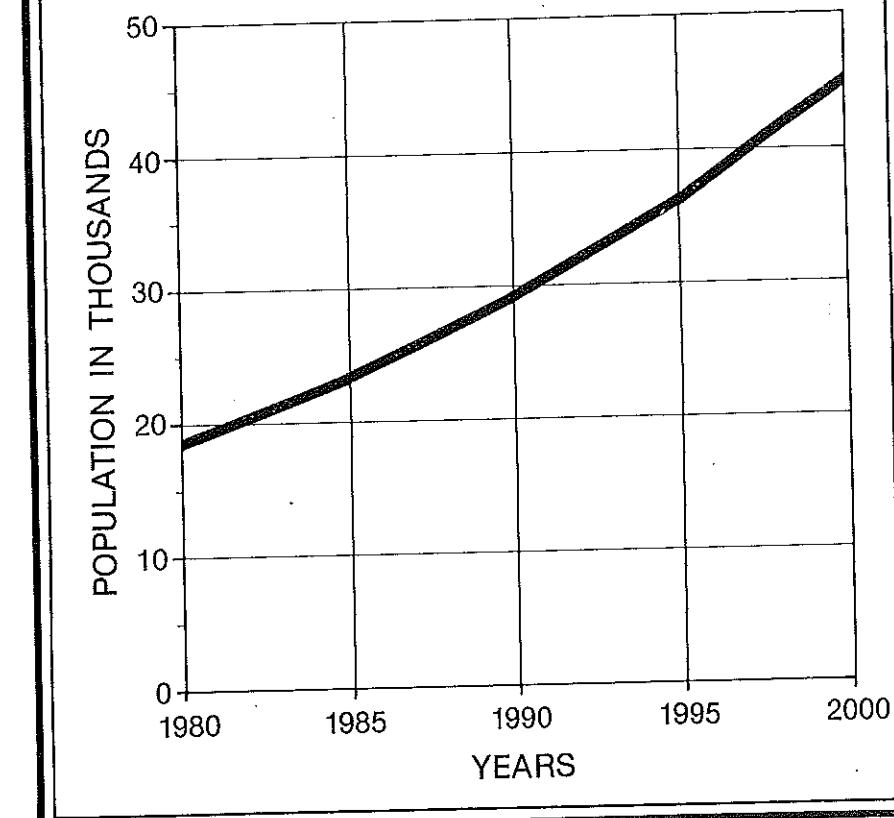


FIGURE II-4  
POPULATION GROWTH  
4 1/2 % PER ANNUM  
(1980-2000)  
BEND AREA



# CONSUMPTION

## WATER USAGE AND REQUIREMENTS

The subject of water requirements is a broad and complex one. There is the matter of basic annual requirements which vary widely--particularly by uses--such as domestic, commercial, industrial, recreational, and fire protection. Each type of usage also varies in monthly, weekly, daily, hourly and instantaneous requirements. Additionally, there are variations in each of the foregoing from year to year, due to weather conditions and other factors. Available information in the City records, together with information from adjacent and similar communities, were studied to determine the quantitative and qualitative figures and factors presented in the report.

## DOMESTIC WATER USAGE

Domestic water usage is that water used in connection with a home. This includes water used for cooking, drinking, washing, bathing, sanitary purposes, and cooling devices in the home; and water used for lawns, garden, car washing, etc., outside the home. The amount of water used for domestic purposes varies with the home and the people within it. Extensive garden or lawn areas require a substantial amount of water. Newer homes generally use more water because of additional bathrooms, garbage disposals, etc.), than older homes with limited water using facilities.

Water usage also varies with the density of development. Generally, the per capita requirement decreases as the density increases.

## COMMERCIAL WATER USAGE

The amount of water used in commercial establishments varies greatly from one place to another due to the variety in type, size, and design of the business. Comparisons of even the same type of commercial enterprises show wide variations in water usage, due to differences in equipment, method of operation, irrigated area, and cleanup procedures.

## INDUSTRIAL WATER USAGE

Industrial water usage varies even more widely than commercial usages. Each type of industrial activity is completely individual and often the quantity of water used is much more than is ordinarily realized. A reasonable basis for planning water requirements would allow about 2 MG per year per light industry, when the actual industries are not defined.

## IRRIGATION WATER USAGE

Practically all of the irrigation water requirements in the study area has been and is anticipated to be for lawns. Lawn type planting requires large volumes of water. The nature of the proposed land use plan will not diminish the quantity of water required for irrigation.

## FIRE PROTECTION USAGE

The water necessary for fire protection is more in the nature of capacity to deliver than an actual quantity of water. Water must be available at sufficient rates as required by the fire hazard conditions. Empirical formula for calculating actual required fire flow is discussed in more depth in the Existing Water System Section, ISO Evaluation.

## UNACCOUNTED-FOR WATER

The term "unaccounted-for water" includes that water which has been delivered into a water works system and has not been sold or otherwise accounted for. This includes water lost through hydrant testing, fire fighting, main flushing, leaks and slow metering. Some of these are legitimate uses of water, but the fact that they are quantitatively unknown leads to the question as to what proportion of the unaccounted-for water is actually wasted. As a result, the extent of this element is often referred to as a good index of water system operation.

With a good operation under normal circumstances, the category of unaccounted-for water should not exceed 10 percent of water production.

Since a majority of the existing Bend system is unmetered it is difficult to determine what portion of

water produced actually reaches the consumer. In light of this information (or lack of it), we have assumed that "unaccounted-for water" consists of 10 percent of all water.

## RATES OF WATER DEMAND

The rate of water demand over various time intervals is one of the major considerations in planning a water works system. The quantity of water used varies widely from one time of year to another, from day to day, and from hour to hour. Patterns of water use also vary according to the size of the service area and the type of use (e.g., domestic, commercial, industrial, etc.). The water works system must be designed with these considerations in mind.

## PAST CONSUMPTION

Historically, Bend has always had high consumption compared to other cities of similar size, mainly due to climate, flat rate fee, and the high porosity of the soil. Climate and high porosity result in large amounts of water used for lawn watering. Another section (Metering Evaluation) addresses the flat rate. In many cities, household water conservation (e.g., using water saving devices) proves quite effective. Table II-2 shows the consumption pattern Bend has followed. During the winter months which require no irrigation, consumption drops to approximately 25% of summer time consumption. Although household conservation helps reduce consumption (see Metering Evaluation Section), Bend's high consumption relates directly to lawn watering.

Table II-3 shows the peak day consumption for the last 10 years. Peak day consumption rates are used to size booster stations, storage and source facilities and in determining pipe diameters for the distribution system. Figure II-5 shows the actual demand curve for the peak day on July 17, 1979. Peaking storage is determined by measuring the area under the curve. Table II-3 shows that past peak day consumption has remained relatively constant (1970-1978) indicating that, with the City's increasing population, peak day per capita consumption has decreased. In 1979, the peak day consumption increased almost 25% from 13.82 MGD (1978) to 17.27 MGD. Two factors explain the increase: (1) the increased number of hookups (due to liberalization of the City's annexation policy) and (2) an unusually hot day. Table II-4 reflects present consumption data, providing an expansion of the 1979 data found in Table II-3.

TABLE II-2  
MONTHLY CONSUMPTION  
CITY OF BEND  
(1970-1979)

(MILLIONS OF GALLONS)

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total	Annual Average Daily Consumption
1970	97.0	97.6	108.5	146.7	252.0	257.7	327.9	329.9	190.0	131.8	80.9	73.7	2093.8	5.7
1971	110.6	91.1	69.2	148.2	226.0	205.9	330.7	290.1	161.4	94.9	66.6	64.1	1858.6	5.1
1972	67.5	64.9	73.0	106.3	197.5	258.2	332.7	286.6	175.9	96.0	70.3	86.7	1815.6	5.0
1973	72.2	57.3	75.8	144.1	235.3	302.3	348.8	328.3	170.1	93.9	68.6	70.4	1966.6	5.4
1974	72.4	64.5	75.2	96.2	186.3	317.2	305.0	323.7	244.2	127.6	75.1	82.5	1910.9	5.2
1975	88.3	80.6	81.3	80.5	222.3	264.8	301.9	251.9	209.5	100.8	71.4	70.3	1823.3	5.0
1976	76.4	75.0	80.1	94.6	223.3	232.9	321.1	166.6	192.6	125.6	77.5	81.4	1747.2	4.8
1977	82.5	74.0	85.5	199.5	147.6	273.0	340.2	296.4	169.4	101.5	78.6	72.5	1920.8	5.3
1978	73.6	66.8	101.0	93.5	154.0	257.1	272.1	255.5	144.2	145.0	85.7	80.8	1732.7	4.7
1979	103.4	88.8	97.6	98.4	229.6	323.9	349.1	266.1	210.9	172.7	94.3	86.1	1947.1	5.3

Source: Bend Water Department Records

TABLE II-3  
PEAK DAY CONSUMPTION  
CITY OF BEND  
(1968-1979)

Year	Peak Day (MGD)	Population	Per Capita
1970	13.49 (Est)	13,500	999
1971	13.64 (Est)	15,875	859
1972	12.58 (July 19)	16,401	767
1973	13.20 (July 18)	17,481	755
1974	12.96 (July 25)	18,056	718
1975	12.71 (June 12)	17,513	726
1976	12.95 (July 16)	17,723	731
1977	12.93 (July 1)	16,500	784
1978	13.82 (August 4)	18,000	768
1979	17.27 (July 17)	18,650	926

1980 15121 17263  
Source: Bend Water Department Records

TABLE II-4  
PRESENT  
CONSUMPTION DATA  
(1979)

Present Population (1979)	18,650
Number of people per dwelling unit	3
Yearly Consumption (1979)	1,947.10 MG
Maximum monthly consumption (July 1979)	349.10 MG
Maximum daily consumption (July 17, 1979)	17.27 MG
Peak hour consumption rate (July 17, 1979)	21.10 MGD
Average daily consumption (1979)	5.33 MG
Average monthly consumption (1979)	162.25 MG

At present no industrial or commercial consumers place substantial demands on the City of Bend Water System. That is, a majority of the demand placed on the system comes from the residential consumers. This percentage should remain fairly constant through the year 2000.

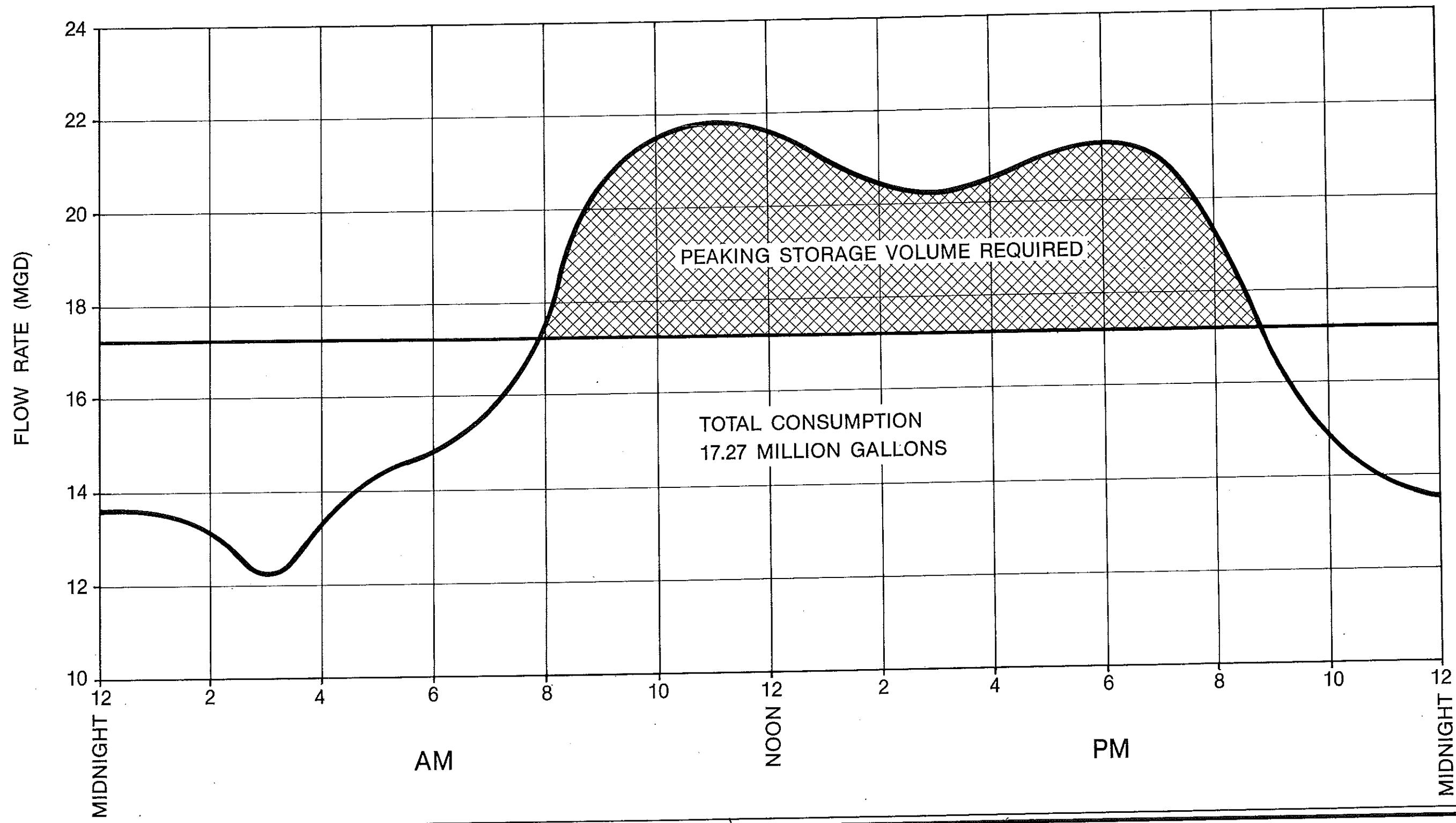
## UNIT DESIGN FACTORS

Design and planning of a water system depends largely upon the demands to be put upon it. Unit design factors have been developed from the available data and from anticipated development patterns.

Analysis of past, present and projected future water use patterns in Bend and in other cities constitute an important aspect of the development of improvement programs for water supply and distribution systems. Such projections apply estimated unit demand figures to the population and land development data.

A number of factors influence urban water requirements including climate, land use, type of service area, water quality, and water cost. Experience indicates that actual water use records for the study area provide the most reliable bases for evaluating future water needs.

FIGURE II-5  
MAXIMUM DAY CONSUMPTION  
JULY 17, 1979  
CITY OF BEND



In addition to examination of average water use by each type of a customer or land use classification, peak demand statistics determine the required hydraulic capacities of transmission, treatment, storage and distribution components of the water system.

## FUTURE WATER REQUIREMENTS

Estimates of future water demand are developed for each of the various land use classifications. Demand is expressed in terms of average annual demand, maximum monthly demand, maximum daily demand, and peak hour demand. Water requirements for fire fighting must also be established for each type of area as they frequently govern the size of the distribution mains and reservoirs.

## AVERAGE ANNUAL DEMAND

Average annual demand is expressed on a per capita basis (gpcpd) for residential areas. Estimated future average water use factors are described below for each major land use classification.

## RESIDENTIAL

For many years, domestic water use in the United States has increased at a rate of about two percent annually. This trend has resulted from two principal factors. The first factor is the popularity of water using appliances such as automatic washing machines and garbage disposals. Second, real income and standard of living generally have increased, resulting in larger homes with more adequate plumbing and with greater areas devoted to formal landscaping.

For purposes of this report, we assume that actual per capita usage will drop approximately 25 percent (see Metering Evaluation Section). Additionally, the increasing public awareness of the energy problem will undoubtedly lead to a decrease in consumption for all utilities.

## VARIATIONS IN DEMAND

The design of water system facilities requires not only determining average annual demand, but also deter-

mining the variations in demand such as maximum monthly demand, maximum daily demand and peak rate demand. The following percentages were calculated from the (1970-1979) records of the City of Bend Water Department.

■ **MAXIMUM MONTHLY DEMAND.** Maximum monthly demand, defined as the average daily demand during the month of maximum use, is important from the standpoint of supply and transmission capacities and storage requirements. Past water production records indicate that for residential areas a value of 200 percent of average annual demand can be expected. For commercial and industrial users, where seasonal effects of water use are not so pronounced, the maximum monthly use is taken as 150 percent of the average annual use.

■ **MAXIMUM DAILY DEMAND.** The demand on the maximum day is important for the proper design of storage facilities and the sizing of future source capacity and supply pipelines. For residential areas, the maximum day demand is assumed to be 300 percent of average annual demand. For commercial and industrial users, the factor used is 150 percent.

■ **PEAK HOUR DEMAND.** Peak hour demand is the greatest hourly demand and is important in the sizing of distribution system pipelines. In addition, the daily variations in demand dictate the amount of regulatory storage required to equalize the capacity of supply facilities. Residential peak rate demand is selected to be 400 percent of average annual demand. Because a great portion of the daily consumption will occur during an 8 to 10 hour period; peak rate demand for commercial and light industrial users is also assumed to be 400 percent of average annual. Heavy industrial users are assumed to operate two or three shifts. Therefore, the variations in daily demand will not be as great as for light industrial users. Consequently, the peak rate for heavy industrial users is taken at 200 percent of the average annual demand. For irrigated areas such as parks, the peak rate will be high and a factor of 350 percent is selected for those areas.

Table II-5 shows the various water demand variations used for the study.

TABLE II-5  
DEMAND VARIATIONS  
CITY OF BEND

Average Annual Demand*	100%
Maximum Monthly Demand (Industrial)	150%
Maximum Monthly Demand (Residential)	200%
Maximum Daily Demand	300%
Peak Hour Demand (Industrial)	200%
Peak Hour Demand (Parks)	350%
Peak Hour Demand (Residential)	400%

\*The average annual demand is the base demand and all other demands in the table are taken as a percent of the base.

■ **FIRE FLOW REQUIREMENTS.** In addition to providing for the various water requirements discussed above, a distribution system must be capable of supplying water for fire fighting purposes. The following design values have been selected for fire flows:

TABLE II-6  
FIRE FLOW DESIGN VALUES

	Flow	Duration
Residential districts	1000 gpm	2 Hrs.
Business districts	3000 gpm	3 Hrs.
Industrial districts	5000 gpm	5 Hrs.

All of the above listed fire flows are required continuously at a residual distribution system pressure @ 20 psi.

## SOURCE OF SUPPLY

Source capacity and supply pipelines should be able to refill the system at a rate equal to that of the maximum day flow rate. Table II-5 reflects what the maximum day flow rate is assumed to be for the planning period. These statistics assume a 25% drop in consumption by 1985 because of metering, in conjunction with a 4.5% increase in consumption per year due to population growth. Explanations of both percentages appear earlier in this section. It should be noted that these figures are assumptions, and in order to verify these assumptions flow rates should continue to be monitored carefully.

Year	Total Source Capacity Required (MGD)
1980	17.27 (Unmetered System)
1985	20.61 (Fully Metered System)
1990	25.19
1995	31.49
2000	40.48
	32.38

## STORAGE

Storage is one of the most important features of any water works system. It provides water for use in the distribution system when needed during peak demands or emergencies at much higher rates than would otherwise be economical. The economy is best exemplified by those cities that have no storage and therefore require huge pumps having a maximum capacity for both peak domestic demand and fire together with a minimum capacity for night time flow. Storage is intended for daily variations, emergencies, and fire protection. Because it is not economical, storage is not intended to compensate for long-term water shortages. Long-term storage must be provided for from an increased supply rate from the source.

■ PEAKING STORAGE is for use during the periods of peak hour demands when storage provides a

portion of the supply, serving as equalizing or peaking storage.

Peaking storage is determined from the area under the peak day demand curve and above the peak day average flow rate curve (see Figure II-5). For the Bend Water System, this area turns out to be approximately 13 percent of the peak day flow rate. An additional 5 percent was added to this percentage making a total of 18 percent to account for any fluctuations in meter recordings. Figure II-5 graphically shows the curves and area.

■ EMERGENCY STORAGE is for use in case of power outages, pipeline breaks, supply line failures, treatment plant shut-downs, and other similar emergencies.

Emergency storage is determined by envisioning unexpected situations for the City of Bend's Water System and determining what quantities of storage would be necessary to deal with them. The most critical link in the City's system is between the source intake at Bridge Creek and Overturf Reservoir. In July of 1979, an emergency situation actually occurred when the linking pipe had to be shut down for two days during the Bridge Creek fire. The following situation also could occur:

Emergency Situation (1980)

- The watershed becomes nonfunctional at 8:00 a.m. and the intake has to be shut down for 24 hours.
- Within 5 hours, the demand can be reduced to wintertime demand (approximately 25 percent of peak day demand).

Calculations

$$\frac{5}{24} \text{ Days} \times 17.27 \text{ MGD} \times 1.3 = 4.67 \text{ MG}$$

(Note: 1.3 = Peaking factor at 8:00 a.m. from Figure 1)

% of peak day flow needed for emergency

$$\text{storage} = \frac{4.67 \text{ MGD}}{17.27 \text{ MGD}} = 27\%$$

For purposes of this report, 27 percent of the peak day flow will be the assumed emergency storage required for a one day (24 hr.) emergency.

■ FIRE FLOW STORAGE readily provides water for fire fighting requirements, called fire reserve or fire storage.

Fire flow storage has been considered on an individual pressure level basis. Generally, if the zoning within the pressure level has only residential zoning, then an assumed fire flow of 1,000 GPM for two hours was used. If the zoning within the pressure level is generally commercial or industrial, then 3,000 GPM for three hours and 5,000 GPM for five hours were used respectively.

With the preceding parameters in mind, the following Table II-8 indicates storage requirements for the study area through the year 2000. The Hydraulic Analysis Section of this report will discuss actual locations and sizes of tanks.

TABLE II-8  
STORAGE REQUIREMENTS  
CITY OF BEND  
(1980-2000)

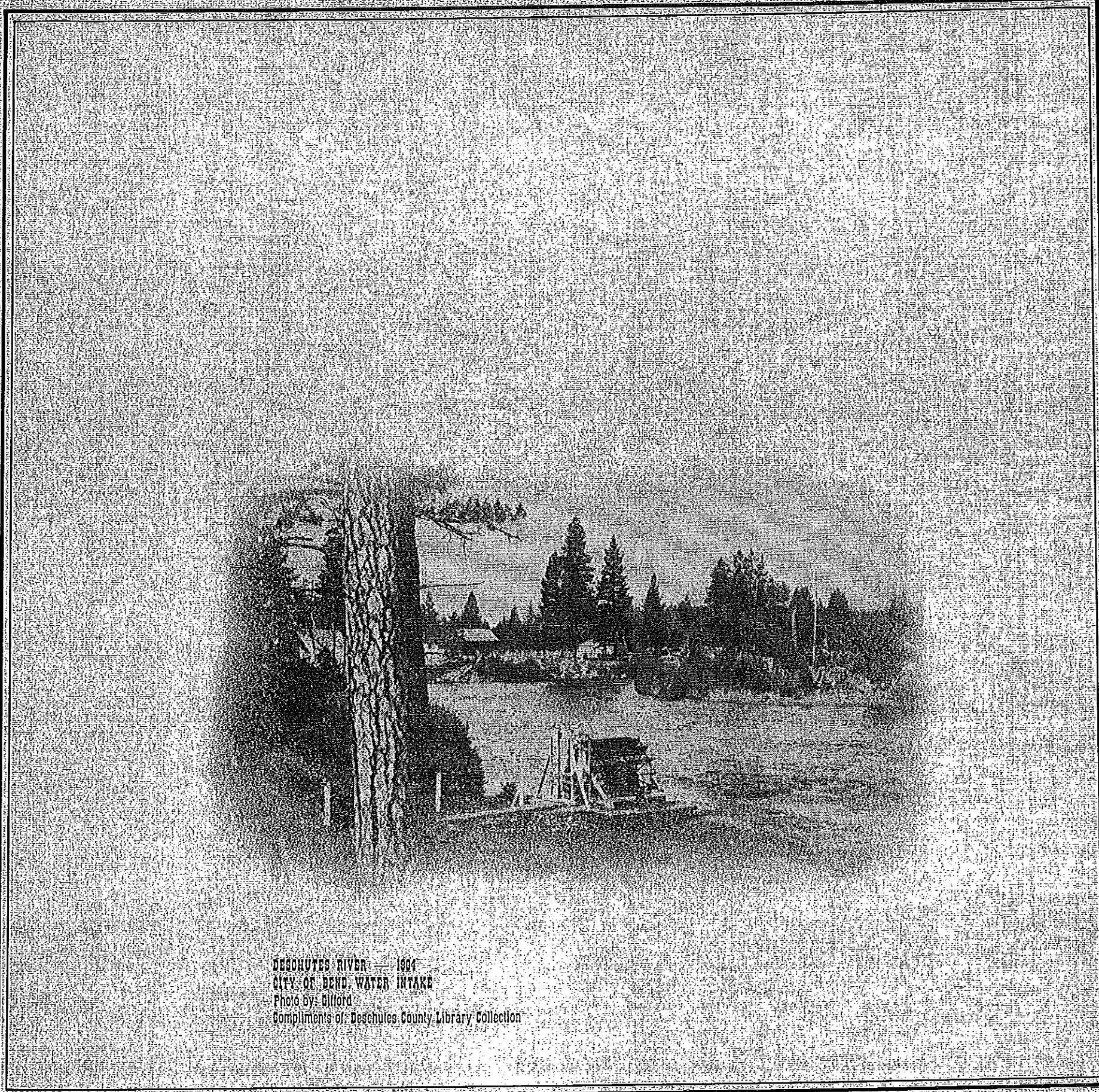
<u>Year</u>	<u>Population</u>	<u>Max. Day Flow (MGD)</u>	<u>Peak Storage (MG)</u>	<u>Emergency Storage (MG)</u>	<u>Fire Storage (MG)</u>	<u>Total Storage**** (MG)</u>	<u>Physical Volume (MG)</u>
1980	18,650	17.27	3.11	4.66	2.04**	9.82	12.26
1985*	23,000	16.49	2.97	4.45	2.04	9.46	11.82
1990	29,000	20.15	3.63	5.44	2.04	11.11	13.89
1995	36,000	25.19	4.53	6.80	2.16***	13.49	16.86
2000	45,000	32.38	5.83	8.74	2.16	16.73	20.91

\* Assumes a totally metered system as of 1985.

\*\* Assumes two simultaneous fire flows of 5,000 GPM for five hours and 3000 GPM for three hours.

\*\*\* Assumes an additional residential fire flow of 1,000 GPM for two hours.

\*\*\*\* Total storage required is 80% of the required physical volume of tanks. (ISO considers tanks 80% full for municipal grading purposes.



DESCHUTES RIVER — 1904  
CITY OF BEND WATER INTAKE

Photo by Clifford

Compliments of Deschutes County Library Collection

## EXISTING WATER SYSTEM COMPONENTS

Chapter III

# EXISTING WATER SYSTEM COMPONENTS

## STORAGE TANKS

The current total storage capacity for the City of Bend is 11.0 million gallons. The various tanks, their capacities, elevations and pressure levels served are as follows:

TABLE III-1  
WATER STORAGE  
CITY OF BEND

**TABLE III-1**  
**WATER STORAGE**  
**CITY OF BEND**

It should be noted that there are other tanks in the Bend system--principally the Bend View tank and the Great Northern tank. These tanks, because of their limited capacity and usage, were given only a cursory inspection.

Inspection of each tank was done on July 19, 1979 by Century West Engineering Corporation, Bend Water Department personnel, and a representative from Engard Coatings Corporation. Each of the tanks was inspected for structural and coating integrity.

The following is a summary of the present conditions

of each tank. Also included are recommendations and costs for maintenance and improvements.

## AWBREY BUTTE RESERVOIR

In 1954 the Awbrey Butte Reservoir was constructed to serve first level users on the City's west side. This five million gallon underground structure was fabricated with reinforced concrete and, with minimal maintenance, presently appears to be satisfactorily withstanding the elements. This low maintenance requirement can be attributed to the concrete placement and curing techniques practiced during construction. These techniques minimized honeycombing and crazing of the finished structure. In turn, this resulted in a facility of high structural integrity with minor maintenance problems when compared to the other reservoirs owned by the City.

The present area of concern in the Awbrey Butte Reservoir is located at the construction joints which were originally sealed with mastic. Since the reservoir's concrete walls are relatively impervious and non-reactive, they did not require an interior coating to prevent leakage. This has resulted in the exposure of the mastic construction joints to the high pressure water used in the reservoir's annual cleansing. Although the mastic appears to be peeling away from the joints when the cleaning takes place, noticeable leakage has not resulted from this practice. Accordingly, major repairs are not contemplated at this point in time. However, it is recommended that water levels be closely monitored to ensure that significant leakage does not occur. Should significant leakage happen, it is further recommended that the joints are sandblasted and a new sealant installed along the old construction joints.

Estimated Cost  
(If monitoring shows leakage) \$10,000  
Year 1982

## OVERTURE RESERVOIRS

Two 1.5 million gallon, uncovered, riveted steel reservoirs were constructed on Overturf Butte in 1926. This allowed the water from the Tumalo Creek transmission mains to be impounded at a location in close proximity to the City. In 1969 a vinyl coating was applied to the tanks' interiors in an effort to extend the expected life of the tanks. In a measure anticipat-

ed to reduce evaporation, contamination and other hazards, each tank was covered with a domed aluminum roof in 1970. Currently, with its three million gallon capacity, the Overturf Reservoir serves pressure levels one in the Bend business district and a major part of the City's residential area.

The July 1979 inspection of the two tanks revealed that this facility is in good to fair condition. The aluminum roofs, both inside and outside, are in excellent condition and no major maintenance requirements are anticipated in connection with them. The remaining portion of the facility requires minor maintenance in order to be restored to a satisfactory condition.

Although inspection was restricted by partially full tanks, the interiors of the tanks are regarded to be in good condition. Since these tanks were vinyl coated in 1969 a nominal number of rust spots have occurred. We recommend that these spots be eliminated by brushing to bare metal and then once again protected with a spot coating of vinyl sealant. The vinyl sealant coating should also be extended to the area which was marred in 1970 during the installation of the overflow. Any additional interior areas requiring maintenance should also be identified and corrected during the next annual inspection.

The tanks' exteriors, other than the roofs, are judged to be in fair condition. Portions of the exterior alkyd coating are reaching the point where they will require repainting by mid-1981. It is recommended that prior to this date, the tanks are completely sandblasted, reprimed and recoated with silicone enamel. This correction will continue to guarantee the soundness of the reservoir and maintain the facility's future reliability.

Estimated Cost (\$9,000/tank) \$18,000  
Year 1980

## COLLEGE RESERVOIR

The 500,000 gallon steel College Reservoir was constructed in 1964. It presently serves pressure levels two, three, and four in the vicinity of the West Hills and the Central Oregon Community College. This tank was constructed with an inorganic zinc coated roof which is currently a major maintenance problem for the facility.

The condition of the zinc coating has deteriorated to the point where large rust spots are obvious on both

the roof and the upper one foot of the shell. The unabated continuation of this saturation will result in extensive maintenance problems associated with unprotected surfaces. Until this situation is corrected, it is recommended that close attention is paid to the condition of the substrate with respect to accelerated deterioration. It is also recommended that this situation be rectified as soon as possible. Remedial measures will require complete removal of the zinc by sandblasting plus repriming and resurfacing with a vinyl coating compatible with the existing interior surfacing.

The remaining interior surfaces appear to be in good condition. The integrity of the vinyl appears to be providing adequate protection to the rest of the tank, and no maintenance problems are foreseen in this area.

In addition to the coating problem on the interior roof, the exterior surfaces appear to be in a uniformly poor condition. The entire alkyd paint system has deteriorated to a point which will require complete repainting by mid-1980. This recommendation is based on the fact that the flaking paint is exposing unprotected portions of the steel tank to the elements. Therefore, it is recommended that the exterior receives a thorough sandblasting, repriming and repainting with a durable coating, preferably of a lighter color to minimize future deterioration due to absorbed sunlight.

Estimated Cost	\$15,000
Year	1980

## PILOT BUTTE RESERVOIR NO. 1

Pilot Butte Reservoir No. 1 was constructed in 1956. This steel tank, with a 1.5 million gallon capacity, serves pressure level 1 on the City's east side. The current protective coating system, both inside and out, is deteriorating and should be replaced prior to development of any further significant maintenance problems.

The appearance of this interior vinyl coating on the floor, walls and roof indicates that the original application was completed in an unsatisfactory manner. The poor application which resulted is indicated by a dry overspray as the chief cause of the present problem.

Presently, this vinyl is judged to be in poor condition and is evidenced by considerable rust uniformly appearing throughout. It is recommended that the existing coating be removed by conventional means and a new interior vinyl coating applied.

The exterior is in a state comparable to the interior. The existing alkyd paint has deteriorated to the point where the surface is not regarded as salvagable. It is recommended that the exterior undergo a complete sandblasting, priming and painting in the near future.

Estimated Cost	\$45,000
Year	1980

## PILOT BUTTE RESERVOIR NO. 2

The 1.0 million gallon steel Pilot Butte Reservoir No. 2 was constructed in 1968. This tank is significantly younger than the Pilot Butte Reservoir No. 1, yet certain sections exhibit the need for considerable maintenance. The interior area which requires maintenance is isolated to the roof. The bulk of the exterior degradation is attributable to malicious mischief in the form of rock throwing and rifle shooting.

The interior roof is presently in poor condition as considerable rust is showing over the entire area. It is recommended that the next annual inspection include a thorough check of this portion of the tank. Major problem areas (coating failure, excessive pitting, etc.) should be repainted with vinyl as soon as possible. If these spot repairs are made, a recoating can be delayed up until early 1983. The remainder of this interior is presently in good condition.

The exterior of the tank is in good condition except for minor rock damage to the roof, extensive rock damage to the Southeast side and an occasional bullet mark on the North. The alkyd coating should be spot sandblasted, primed and painted as soon as possible to prevent substrate deterioration. It is also recommended that measures be taken to prevent further abuse as a result of past events of malicious mischief.

Estimated Cost	\$20,000
Year	1983

## BOOSTER STATIONS

### COLLEGE WAY PUMP HOUSE

This booster station is located between Shevlin Park Road and N.W. College Way in the Northwest  $\frac{1}{4}$  of Northwest  $\frac{1}{4}$  of Section 31, Township 17, Range 12, WM at an elevation of about 3,740 feet. The station, designed by CH2M Hill, is about sixteen years old, and serves the 4th and 3rd pressure level in the West Hills and Awbrey Butte area.

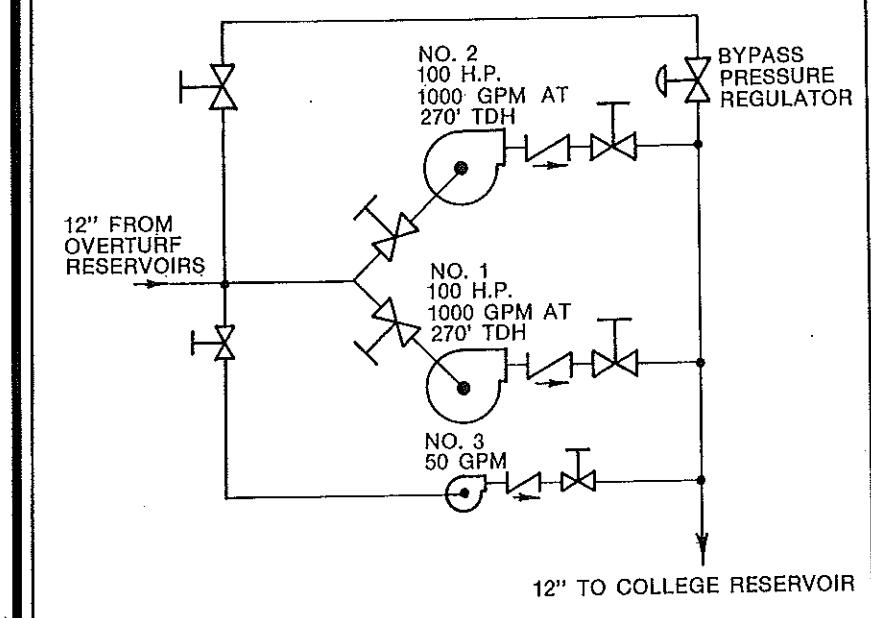
Pumping capacity is provided by two 12" Byron Jackson vertical turbine, can type pumps with a capacity of 1,000 GPM each at 270' TDH. Each pump is driven by a 100 HP, 1,770 RPM motor (440 volt, 3 phase, 60 Hz.). In addition to these pumps, a 50 GPM pump is present. This pump is used only during maintenance periods. All pumps are mounted in parallel, sharing common suction and discharge manifolding.

The booster pumps and the booster pump house have been maintained by the City and are in excellent physical condition. The compact nature of the mechanical layout and the pump house itself eliminates the possibility of adding additional pumps or mechanical components. At present, the station can produce 2,000 GPM at 270' TDH in its present form. It would be possible to increase the capacity of the pump station to 2,400 GPM at 280' TDH but this would require pump and possibly manifold changes. Flows greater than 2,400 GPM would not be recommended. The two 1,000 GPM booster pumps are controlled by pressure switches and the water level in the College Reservoir.

The area now served covers about 490 acres and could cover up to 1,200 acres within the next 20 years. The pump station is now operating close to its design capacity, so future development will require an increase in pumping capacity.

Figure III-1 schematically represents the College Way Pump House.

FIGURE III-1  
PUMP HOUSE SCHEMATIC  
COLLEGE WAY



### THIRD STREET BOOSTER PUMP STATION

This booster station is located on the southeast corner, at the intersection of 3rd Street and Clay Avenue, at an elevation of approximately 3,650 feet. The station was originally constructed about 1924, and has been updated and modernized over the years. Approximately 18 years ago, a variable speed "flowmatcher" system was installed to control the primary booster pump. The secondary booster pump is manually controlled. This booster station serves the 2nd pressure level to the southeast in the City water system.

The primary, or lead, booster system utilizes a 6" Fairbanks-Morse split case pump, rated at 2,200 GPM at 130' TDH and 1,680 RPM, which is driven by a 100 HP 1,750 RPM motor (SF505F frame). The flowmatcher system varies motor RPM to meet fluctuations in demand by maintaining the pressure just downstream of the pumps at approximately 90 PSI.

The secondary booster pump utilizes a size 5" Fairbanks-Morse split case pump rated at 750 GPM at 130' TDH and 1,750 RPM which is driven by a 50 HP, 1,770 RPM motor (RS4055 frame). Both the 100 HP and 50 HP motors are wired for 220/440 volt, 3 phase,

60 Hz. power. At present, the secondary pump cannot be used when the primary pump is on and is used for standby only.

Both booster pumps have bypass piping with a check valve and double gate valve arrangement to allow the flow of water in the event that downstream pressure is lower than upstream pressure.

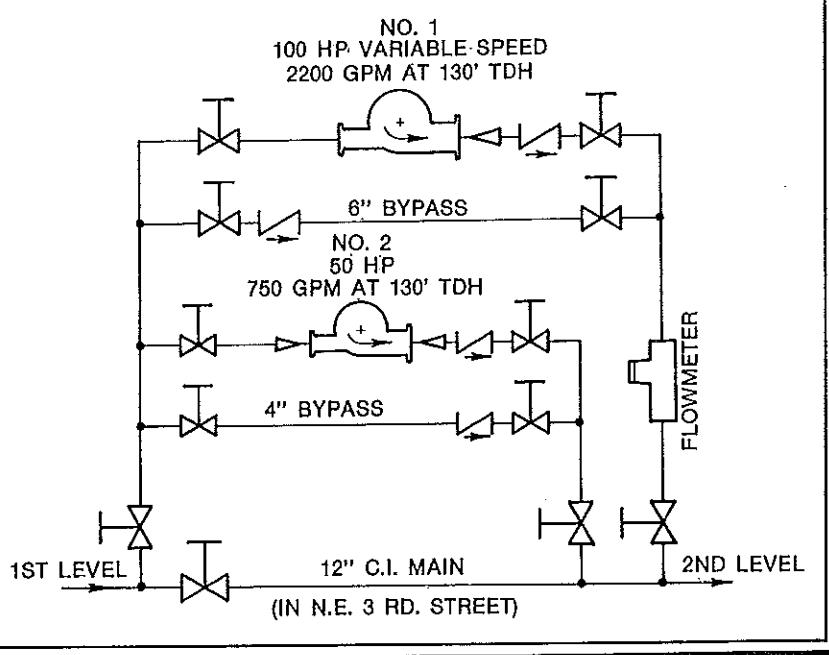
The amount of water flowing through the station is recorded on Sparling 24 hour showcase circular recorders receiving input from a No. 543 Sparling Flow Meter. Information on the operation of the pump station is relayed to, and monitored at the police station.

The booster pumps and the booster pump house have been maintained by the City and are in good physical condition. The physical size of the pump house and manifolding layout allows for good access but eliminates the possibility of adding pumping capacity to the station without a major building modification. Because of its age, this station may be considered somewhat of an antique by modern standards, but because of the high degree of maintenance and attention paid to it by the staff, it provides adequate service.

At present, this station serves an area of about 860 acres. As the City limits grow to the study area boundary in the next 20 years, this area will expand approximately to 2,465 acres. During summer peak days, demand frequently exceeds the design limits of the station, hence additional pumping capacity will be needed in the near future to keep pace with the expansion of the water system.

Refer to Figure III-2 for a schematic representation of the Third Street Booster Pump Station.

FIGURE III-2  
PUMP HOUSE SCHEMATIC  
EAST 3RD AND CLAY STREETS



at the time of inspection. Lower level pressure can be recorded on a Bristol 24 hour circular recorder and was 53 PSI at the time of inspection. A totalizing flow meter measures the amount of water pumped through the station, and a Sparling 24" circular flow recorder is present but not hooked up.

The station has been maintained by the City and appears to be in good physical condition. The layout provides good access to pumps and manifolding but the physical size of the existing pump house eliminates the possibility of adding pumps to the station. The station is adequate in performance for its role as a standby system. Since this station is used so infrequently, serious thought should be given to using the mechanical components at other locations in the system.

Figure III-3 shows the components of the West Fifth Street Pump House schematically.

## PILOT BUTTE PUMP HOUSE

This booster station is located northeast of the intersection of Lafayette Ave., and 12th Street at an elevation of 3,730 feet. The station was constructed to fill Pilot Butte No. 2 Reservoir and serve the second pressure level. Because of its close proximity to the Pilot Butte No. 1 Reservoir, which serves the first level, it has a tendency to draw down this reservoir abnormally during the station operation. For this reason, the Pilot Butte booster station is presently used only for standby purposes and is controlled manually.

Pump No. 1 is a Paco model 2DMKPG split case centrifugal with a capacity of 220 GPM at 145' TDH. The pump is driven by a 20 HP, 1,720 RPM motor (324U frame). Pump No. 2 is a Paco model 2DMKPGM split case centrifugal with a capacity of 150 GPM at 145' TDH. This pump is driven by a 20 HP, 1,760 RPM motor (286U frame). Pump No. 3 is a Paco model 8AWKPG split case centrifugal with a capacity of 1,350 GPM at 145' TDH. This pump is driven by a 75 HP 1,770 RPM motor. Pump No. 1 motor is wired for 220/440 volt, 3 phase, 60 Hz power. Pumps No. 2 and 3 motors are both wired for 208/220/440 volt, 3 phase, 60 Hz power.

Suction pressure (level 1) can be recorded on a Bristols instrument 24 hour circular recorder. Discharge pressure (level 2) can be monitored and recorded on an Ashcroft 24 hour circular recorder.

This booster station, like other stations within the system, is maintained by the City. The station is in excellent physical and mechanical condition. The design and layout of pumps and manifolding promotes excellent access and ease of maintenance. The addition of pumping capacity at this station would only detract from these features and aggravate the problem of drawing down Pilot Butte No. 1 Reservoir. Alternatives as to the status of this station should be examined so it can become a useable and valuable part of the system.

Some alternatives for increasing the effectiveness of this station in filling Pilot Butte No. 2 are:

- Reorienting the suction ring such that it draws its water from a point farther away from Pilot Butte No. 1 Reservoir.
- Relocating the station to a point closer to the west side and hence closer to its main source.
- Constructing a large transmission main across town directly to the booster station.

## WEST FIFTH STREET PUMP HOUSE

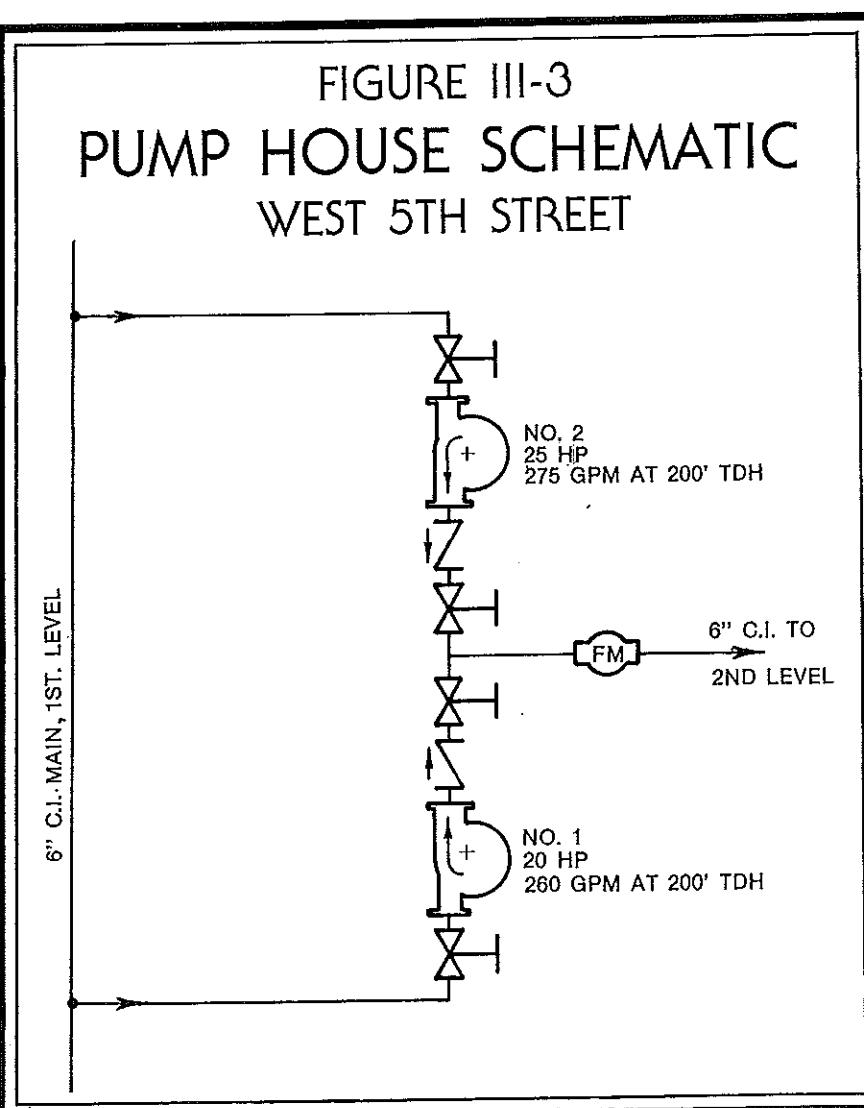
This booster station is located on the northeast corner of 5th Street and Saginaw, at an elevation of 3,660 feet. The station was originally designed to serve the first and second levels on the west side prior to construction of Awbrey Butte Reservoir. At present, it is only used as a standby system when the Awbrey Butte and/or Overturf Reservoirs are being serviced or repaired. The station is manually controlled as needed.

The primary booster pump (No. 1) is a Fairbanks-Morse 2½" split case pump rated at 260 GPM at approximately 200 TDH and 1,700 RPM. It is driven by a 20 HP motor (JE364 frame). The motor is wired for 220/440 volt, 3 phase, 60 Hz power.

The secondary booster pump (No. 2) is a Fairbanks-Morse 2" split case pump rated at 275 GPM at 230' TDH and 3,600 RPM which is driven by a 25 HP motor (10C frame). The motor is wired for 220 volt, 3 phase, 60 Hz power.

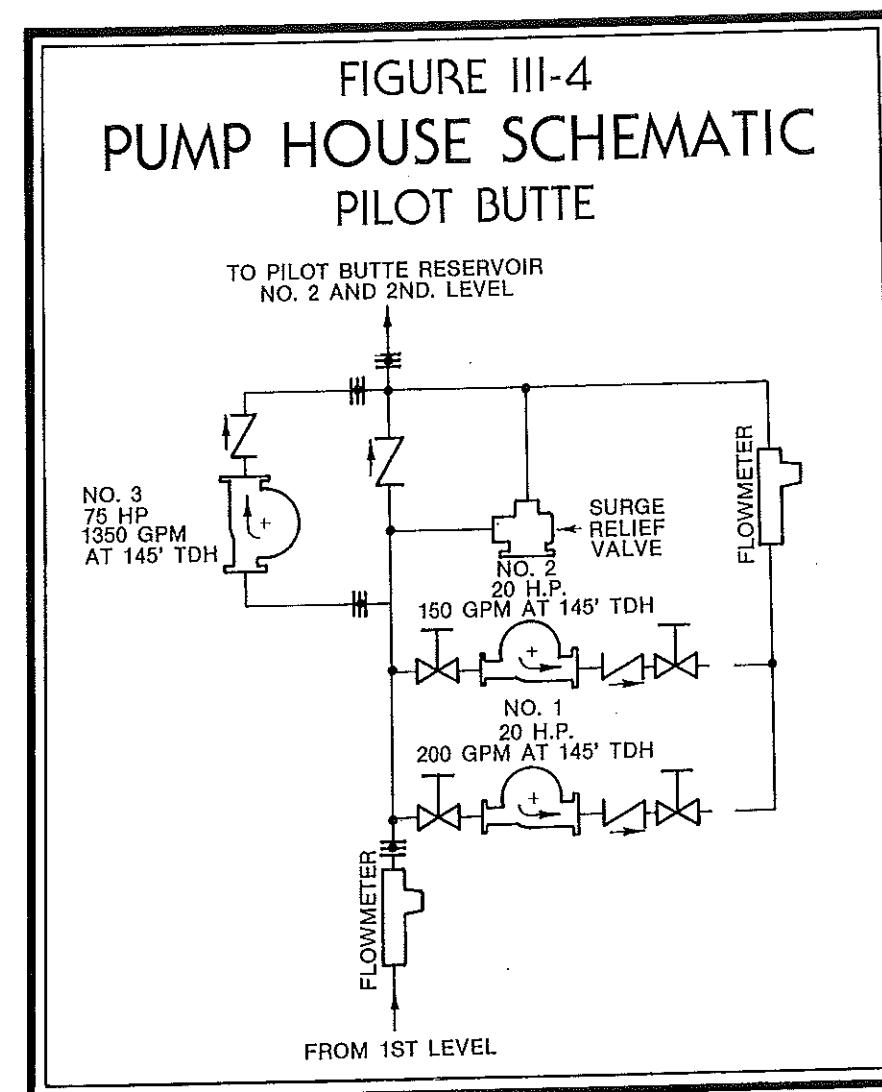
Upper level pressure can be recorded on a Smith Instrument 24 hour circular recorder and was 88 PSI

FIGURE III-3  
PUMP HOUSE SCHEMATIC  
WEST 5TH STREET



The foregoing are a few of the possibilities for modification to the station. These alternatives will be dealt with individually and in more depth in the Hydraulic Analysis section of this report.

Figure III-4 presents a schematic drawing of the Pilot Butte Pump House.



# WELLS

## CITY OF BEND WELL NO. 1

The construction of Well No. 1 started on November 5, 1971, and was completed on April 24, 1972. As Figure III-5 shows, the well has 16-inch casing to a depth of 637 feet. A 16-inch uncased hole runs from 637' to 700', and a 12-inch uncased hole runs from 700' to the bottom of the well at 900'. Test pumping of the well took place between April 5 and 6 of 1972, lasting 48 hours. Static water level at the beginning of the test was measured at 564.4'. During the test pumping, the water level fell to 568.55' at 1,840 GPM, giving a specific capacity of 438 GPM/ft. of drawdown. The details of the construction and test pumping of Well No. 1 are contained in the construction report to the City of Bend by Robinson & Noble, Incorporated, Groundwater Geologists, Tacoma, Washington 98499, dated April, 1972.

Construction of the pump house and installation of the well pump and mechanical piping was accomplished by the City of Bend, based on design drawings by Clark & Groff Engineers, Inc., Salem, Oregon. The well pump is a Byron Jackson Model 14" CGH, 8 stage submersible, 2,000 GPM at 810' TDH with a B. J. Type H submersible motor rated at 500 HP at 1,780 RPM, 2,300 volt, 3-phase, 60 hz. The pump column is 637' long and 10" in diameter. Piping between the pump house and the 16" transmission main to the distribution system is a 12" DI line containing a Sparling master flow main line meter and a 12" flanged butterfly valve.

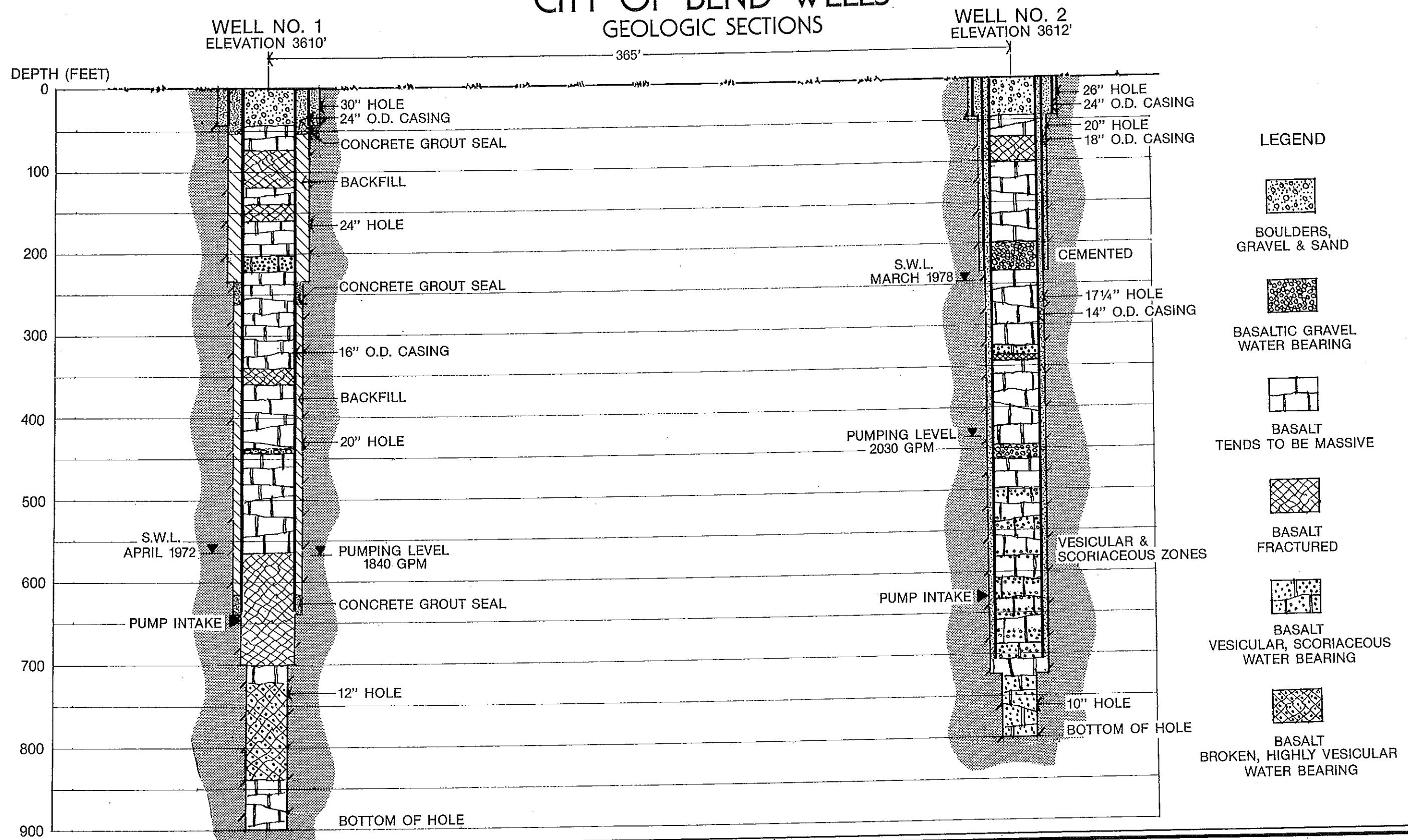
Well No. 1 is controlled manually and/or by water level in Awbrey Butte Reservoir. Typically, the well is utilized during the peak consumption months of June, July, and August to supplement the water from the City intake on Bridge Creek. The highest utilization of Well No. 1 between 1973 and the close of 1978 occurred during the summer of 1974 when 59,100,000 gallons were produced. This production of water amounted to 3% of the total annual production and 6 1/4% of the June, July, and August production. More recently, during the Bridge Creek fire in the summer of 1979, when the City intake was closed, both Well No. 1 and No. 2 provided all the water to the City, Well No. 1 producing approximately five million gallons during that period. During the period between 1973 and the end of 1979, Well No. 1 pumped almost 215 million gallons. This represents less than 2000 hours of total operation time. Figure III-5 shows Wells 1 and 2 schematically.

## CITY OF BEND WELL NO. 2

In 1977, the City of Bend obtained a grant which was used in part to construct a second deep well. These funds were provided for community drought relief by the Economic Development Administration, United States Department of Commerce. Actual construction began on October 10, 1977. The project was completed with test pumping on March 21 and 22 of 1978. As Figure III-5 shows, the well has an inner 14" OD casing from the surface to a depth of 706 feet. A 17 1/4" uncased hole runs from 706' to approximately 725' and below this point, a 10" uncased hole runs to the bottom of the well at 800'. Static water level was measured at 247' below the sounding port at the beginning of test pumping. After pumping continuously for 17 hours at 2,000 GPM, the drawdown was measured at 185', bringing the pumping level down to 432', and giving a specific capacity of 10.8 GPM/ft. of drawdown. The details of the construction and test pumping of Well No. 2 are contained in the construction report to the City of Bend by James R. Carr and Fred B. Roberts of Robinson & Noble, Incorporated, Groundwater Geologists, Tacoma, Washington 98499, dated July, 1978, summarized in Section I, Introduction.

As in the case of Well No. 1, construction of the well house and installation of Well No. 2 pump, booster pump, and mechanical piping was accomplished by the City of Bend, based on design drawings by Lee Engineering Enterprises, Oregon City, Oregon. The well pump is a Worthington, vertical line shaft turbine, model 12 HH200-15 stage with a capacity of 2,000 GPM at 650' TDH. The pump motor is a 400 HP, 1,800 RPM U. S. motor. The pump house manifolding also includes a can type vertical turbine booster pump. This pump is a Worthington model 12 HH 200-5 stage UHF pump with a capacity of 2,000 GPM at 230' TDH, powered by a 150 HP 1,800 RPM U. S. motor. Power requirements for both the well pump motor and the booster pump motor is 480 volt, 3 phase, 60 Hz. The well pump column is 600' long and 10" in diameter. The manifolding in the pump house is designed so that the booster pump can be bypassed. Well No. 2, as of January 1980, has pumped nearly 32 million gallons, representing less than 300 hours of utilization. Well #2 is also controlled manually.

FIGURE III-5  
CITY OF BEND WELLS  
GEOLOGIC SECTIONS



# CITY OF BEND ADMINISTRATION

## ORGANIZATION

The Bend Water System is managed by the Water Department, with the Public Works Director in charge of activities. The Engineering Department and Finance Director's office provide staff assistance. These various departments, working together as a team, are essential to effective management of the Water Department. Effective management requires realistic goals, based on planning, organizing, leading and controls, established by the management team.

A description of the responsibilities of each of these departments is presented to show their relation to the Water Department. Organization of the present Public Works Department and Water Department is shown on Figure III-6.

## ACCOUNTING AND RECORD KEEPING

The purpose of accounting is to record the assets of the water system, outstanding obligations, revenues derived, and costs incurred in the operation of the system. As the City grows, accounting plays a more significant role in utility management because of the large sums of long-term investments required to provide service facilities. It is the dominant basis of regulation which is used in fixing the service rate structure.

Billing, accounting and maintenance of service records are activities performed under the Finance Director's supervision. Most of these activities are performed manually. Approximately 50 percent of the Finance Director's time is allocated to the Water Department. In addition to the Finance Director, there are four full time employees assigned to Water Department accounting.

Accounting records are to be in accordance with requirements of the statutes. In addition to records prescribed by law, sufficient records must be maintained to provide internal financial control of the system.

There are approximately 6,700 customers, including 4,800 flat-rate, 1,400 metered, and 500 temporarily inactive/out of service, accounts. Each customer submits payment for service on a monthly basis. The metered customers receive bills, while the flat-rate customers are required to make payment without notice. Manually servicing these accounts on a monthly basis is a time-consuming and costly operation. Servicing delinquent accounts, maintenance of service connection records, recording advance deposits and

refunds are routine activities performed by accounting personnel.

Delinquent accounts for water service are significant. Each month notices are mailed to 20 to 25 percent of the customers. Postcard reminders are mailed at the first and second month reminding the customer to pay the bill. These notices usually result in a response from the customer and the bill is paid. Approximately 5% (250) letter notices per month are sent out at the end of three months delinquency. This notice gives the user a final date on which to pay the bill, or the water will be turned off. This procedure is the most common method of handling delinquent bills. Studies have shown that late payment penalties, early payment discounts, more or less frequent billings and advance deposit requirements have little effect on the percent of delinquent services. The threat of having water turned off is the most effective procedure for collecting late bills. In most instances bills are delinquent because people simply forget to pay them. For this reason, reminders rather than threats on the first contact are preferred. It encourages better public relations toward the City, especially in the cases of customers who have a good payment history and who only occasionally fail to pay on time. There is no magic formula for collecting money for bills owed water utilities. A system of notices, consisting of a reminder and final action is the most accepted method of handling the problem.

The cost of work performed by City crews, as a condition of a Water Service Agreement, is paid by the developer. Accounting for this labor and material requires current and accurate records to determine actual cost. Delays in processing these accounts are frequent and are caused by staff turnover or personnel shortages. Timely processing of work orders, time cards and material lists is required so that final accounting of the job can be performed, and the developer billed, or refunds made of surplus funds deposited by the developer in advance of the work.

Cost of City-purchased pipe and accessories used for normal maintenance and system improvement is significant in the water fund. Accurate records of supplies and stores must be maintained, and be readily available. Bend's records are maintained manually for supplies and stores. It is common practice to use computers to maintain these records for larger service organizations.

## ENGINEERING

Planning and design for system expansion are primary engineering responsibilities. Management of water utilities is often performed by personnel with engineering background because of the direct relation of rate setting to technical knowledge required. Con-

struction cost estimates and depreciation studies are also areas requiring engineering knowledge. The Director of Public Works is responsible for these activities in Bend's Water System.

The City Engineer's office coordinates public facilities expansion in conjunction with new development. Improvement plans showing streets, sewers, private utilities and water facilities are often combined on one plan. When all components have been reviewed and approved, the City Engineer approves the plans and accepts the bond guaranteeing construction of the required public facilities.

Water Department comments pertaining to water system expansion by private developers may be submitted to the Engineering Department, but it is more a common practice to submit them directly to the developer or his engineer. A communication breakdown can easily occur between the Water Department and the Engineering Department in this procedure, which may result in development plans being approved by the City Engineer prior to the water facilities being approved. This communication gap can result in lost time, frustration and added cost to the applicant if he has ordered material or started construction.

There is a growing need to coordinate water system expansion with other public facilities in Bend. The new sewer system, the expansion of other underground utilities and future street expansion requires coordination of all these facilities. It is anticipated that as the City grows there will have to be technical personnel added to provide coordination and expertise for the expansion of these facilities. This can be achieved by adding personnel to both the Water Department and Engineering Department, or combining all engineering activities into one department.

Accurate records of all water facilities placed in the ground must be maintained to show their location for future service connections and to provide information when there is an emergency. These records are invaluable as a tool for coordinating expansion of other underground utilities. Draftsmen maintain these records in the Water Department from plans submitted by private engineers and data obtained during construction.

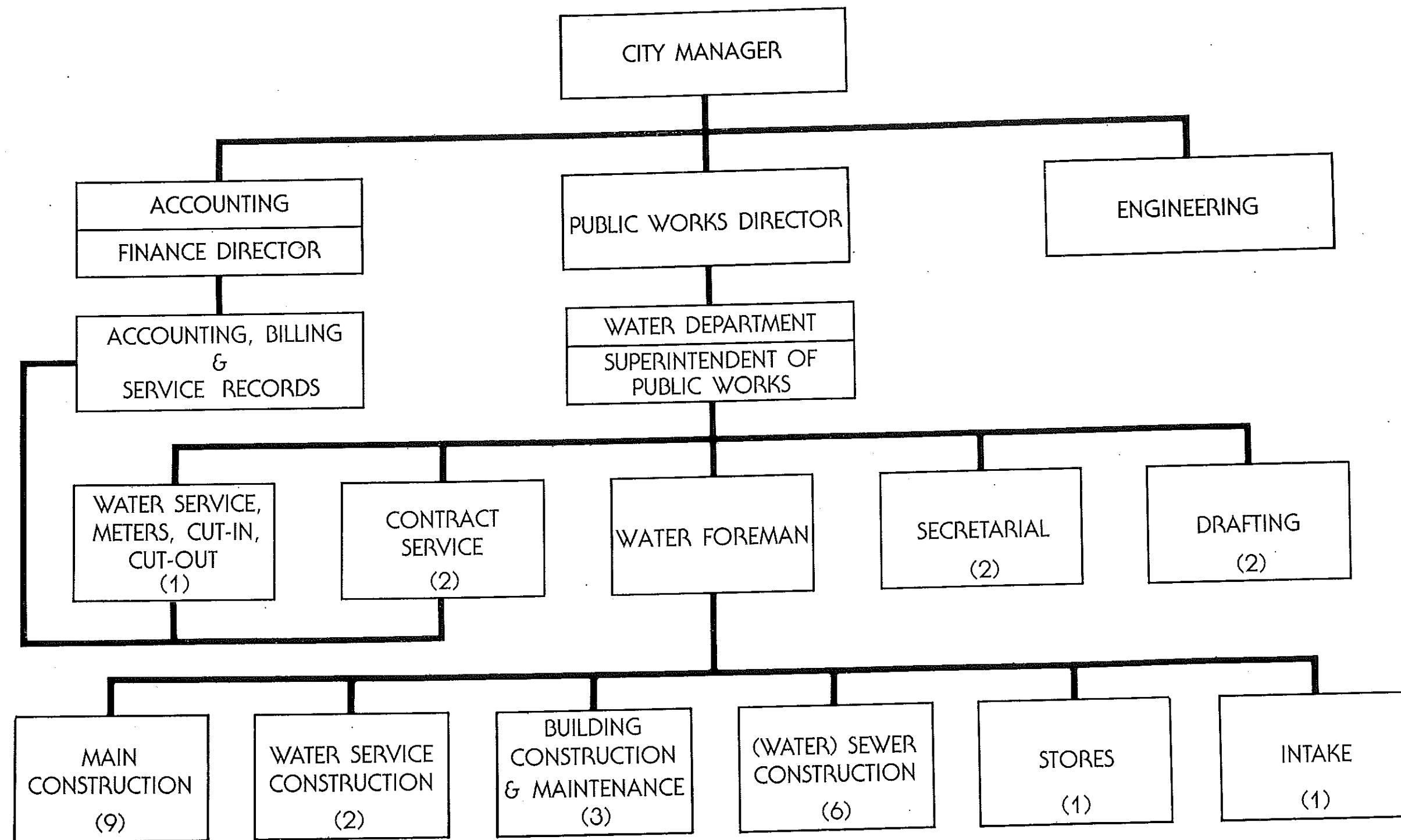
## OPERATIONS

The water system is managed by the Director of Public Works and Superintendent of Public Works.

System expansion, design review, mapping, meter reading, stores, clerical and record keeping are coordinated by the Superintendent of Public Works.

Developers and other parties interested in obtaining

FIGURE III-6  
WATER DEPARTMENT ADMINISTRATIVE STRUCTURE  
(EXISTING)  
CITY OF BEND



service from an expanded system submit plans to the Water Department or Engineering Department for review and approval. Water Service Agreements are prepared and define the terms necessary to obtain service.

Special conditions such as reimbursement terms are included in the Agreement. This phase of operations is coordinated by technical staff. It is primarily in this phase that City policy and procedures are applied.

Water system expansion agreements should be coordinated with engineering and accounting activities. Much of this work is clerical in nature, but developing cost estimates, determining benefited areas for reimbursement and coordination with other development is related to engineering review and approval.

The department maintains an inventory of pipe, fittings, hydrants, valves and other miscellaneous material for emergencies and use for services and minor improvements to the system. The store also includes inventory for other departments within the Public Works Department. A Stores Keeper is assigned full time responsibility to maintain the store. Material is stored at various locations on City property. Small items are kept in the shop and are easily controlled, but larger items are stored outside and taken from storage by the crews using the material. Recording the exact material used, the correct work order, date of use and material returned to store is not always done timely, and it is easy to "lose" material from stores. This lack of control results in delays and errors in the accounting process. Security of material stored outside is a concern of the Department.

Maps of the system are maintained by draftsmen working under supervision of the Superintendent of Public Works. Information is taken from improvement plans and actual field data, and transferred to record drawings. This data is available to maintenance personnel for quick referral in case of emergencies.

Meters are read on a monthly basis. Cut-ins and cut-outs are performed as required by the meter readers.

Office staff provides secretarial services, record keeping, drafting services, service agreement and contract preparation.

## MAINTENANCE

Maintenance is one of the keys to efficient operation. It is normally classified as breakdown maintenance or preventive maintenance. Preventive maintenance is designed to eliminate or minimize breakdown maintenance so that continuous water service can be maintained. The alternative to preventive maintenance is

to have 100 percent standby equipment and an over designed system to bring on line at time of breakdown.

Maintenance on the water system is performed by the Public Works Department and includes all work on the intake, wells, reservoirs, pumps, purification, transmission and distribution system. The Water Foreman is in direct charge of system maintenance. Maintenance of the system doesn't require the same level of staffing for the entire year. In order to retain the high level of experienced personnel for peak demand, staff is assigned to other departments within the Public Works Department on a part time basis. The goal of the department is to perform all required water system maintenance, make normal service connections, and provide system expansion to the extent possible with available manpower and equipment.

Rapid growth, system expansion and inflation have tended to reduce the level of preventive maintenance on the system. Hydrants need to be serviced on a regular basis as well as pumps and valves. Meters should also be tested for accuracy at regular intervals.

Some existing mains are old and subject to emergency repair at any time. There is a program to replace some of these older lines as money and labor become available, but demands on these resources have been high the last few years and fewer feet of mains have been replaced than originally planned.

The cost of preventive maintenance has increased rapidly during the last few years. Bend's operation and maintenance (O&M) costs for the water system have been compared with costs for various water systems in Oregon and Washington. From an examination of Table III-2 it can be seen that the City of Bend's costs, while higher than the average, are not excessive. Since this comparison does not take into account temperature and geological differences, these costs appear to be well within reason. Additionally, considering the high level of service and reliability that the Bend Water System provides, these costs may even be on the low side.

There probably isn't another system in the northwest with geological problems similar to Bend's. Many service connections in Bend require rock excavating equipment and methods not normal in other systems. Since service connection costs are included in O & M costs, it is expected that Bend's costs may be higher than other systems being compared.

Weather conditions and temperature extremes also affect maintenance costs. Low temperatures in Bend cause many pipes to freeze, resulting in increased maintenance costs. Most systems used in the comparison, except Pendleton, have more moderate temperatures than Central Oregon. The cost to repair broken pipes in freezing weather is higher than repair

costs in warmer climates, because of reduced manpower efficiency and more difficult excavation.

When Bend's O & M costs are compared to maintenance costs and conditions of other systems in the Northwest, it appears that maintenance costs are quite comparable. If added costs due to geologic and weather extremes could be quantified, Bend would probably be on the lower end of the scale rather than average when comparing maintenance costs.

## POLICY AND PROCEDURE

The City of Bend Water Department operates according to policies and procedures developed for efficiency and equalization.

### ■ WATER COMMITTEE

The City Commission relies on the Sewer and Water Committee to review and advise them on matters pertaining to the Water Department. Water Department policy is reviewed by this committee and reflects the current policy of the City. Requests for service outside the City Limits are reviewed and recommendations made to the Commission by the Committee. Major expansion proposals for the system are also brought before the committee for review.

### ■ REIMBURSEMENT POLICY

Water policy provides for the recovery of the cost of oversizing facilities when the oversized facility benefits property owners other than the person who paid the cost of constructing the line. The policy attempts to provide relief to the builder of the oversized facility. Each main extension is unique, and benefit to other property owners is not always the same as the benefit derived by the builder of the line.

## RECOMMENDATIONS

The cost of administering the Bend Water System, like most other public services, is directly related to the cost of labor. There is a relation between the optimum service provided and labor costs. The goal then, should be to obtain the greatest efficiency from the labor force to achieve optimum service. Methods and equipment must be current, and provisions made to accommodate administrative needs created by the growth of the water system.

Communication between the departments can be improved. The detrimental effect of the physical separation between Water Department administration personnel and other departments can be mitigated by formulating

TABLE III-2  
WATER SYSTEM  
OPERATION AND MAINTENANCE COMPARISON\*  
1976

CITY	O & M (\$1,000)	POPULATION	CONSUM MG/YR	MILES OF MAINS	\$/CAP	\$/MG	\$/MILE
Bend, OR.	456	20,000	1,724	143	22.80	264	3,188
Eugene, OR.	1,755	130,000	7,957	488	13.65	223	3,637
Hillsboro, OR.	299	35,000	1,185	150	8.54	252	1,993
Medford, OR.	586	56,000	5,014	215	10.46	117	2,726
Pendleton, OR.	348	15,000	1,176	124	23.20	296	2,806
Portland-Parkrose, OR.	349	14,000	638	70	24.93	545	4,971
Portland-Powell Valley, OR.	553	25,000	915	93	22.12	604	5,946
Springfield, OR.	463	24,000	1,646	56	19.29	281	8,268
Hoquiam, WA.	300	10,054	621	48	29.84	483	6,250
Mountlake Terrace, WA.	398	16,750	640	55	23.76	622	7,236
Puyallup, WA.	156	15,600	1,029	80	10.00	152	1,950
Yakima, WA.	567	46,750	2,393	231	12.13	237	2,454
Average of Comparables					15.22	251	3,565
767 Utilities in U.S.					44.28	691	5,971

\*All data for this section was supplied by 1976 AWWA operating data for water utilities.

and defining methods and procedures to control administrative needs. Some of the activities that could benefit from improved communications are:

- Labor accounting
- Inventory control and accounting
- System expansion
- Plan checking and approvals

Decisions made in relation to system expansion will be more critical as the service area develops. These decisions will become more technical and many of them may require data generated by computer. Consideration should be given to creating a utility division that would coordinate sewer and water system expansion. Personnel would include an engineer to provide the

needed technical expertise. The division would also perform utility planning, utility agreements, plan checking, mapping and engineering studies as required. It would provide close coordination with other planning and engineering functions related to new development.

Cost accounting and financial record keeping methods could be more efficient if performed by a computer. Using a computer will not necessarily reduce today's personnel labor costs, however, as the water and sewer systems expand, billing and financial record keeping will be performed with fewer people than required for a completely manual operation. Financial records will be more current and closer financial control could be achieved by a computer. Most financial record keeping required for water and sewer utilities is easily programmed into a computer. More specific capabilities and benefits should be a part of the computer feasibility study currently being considered by the City.

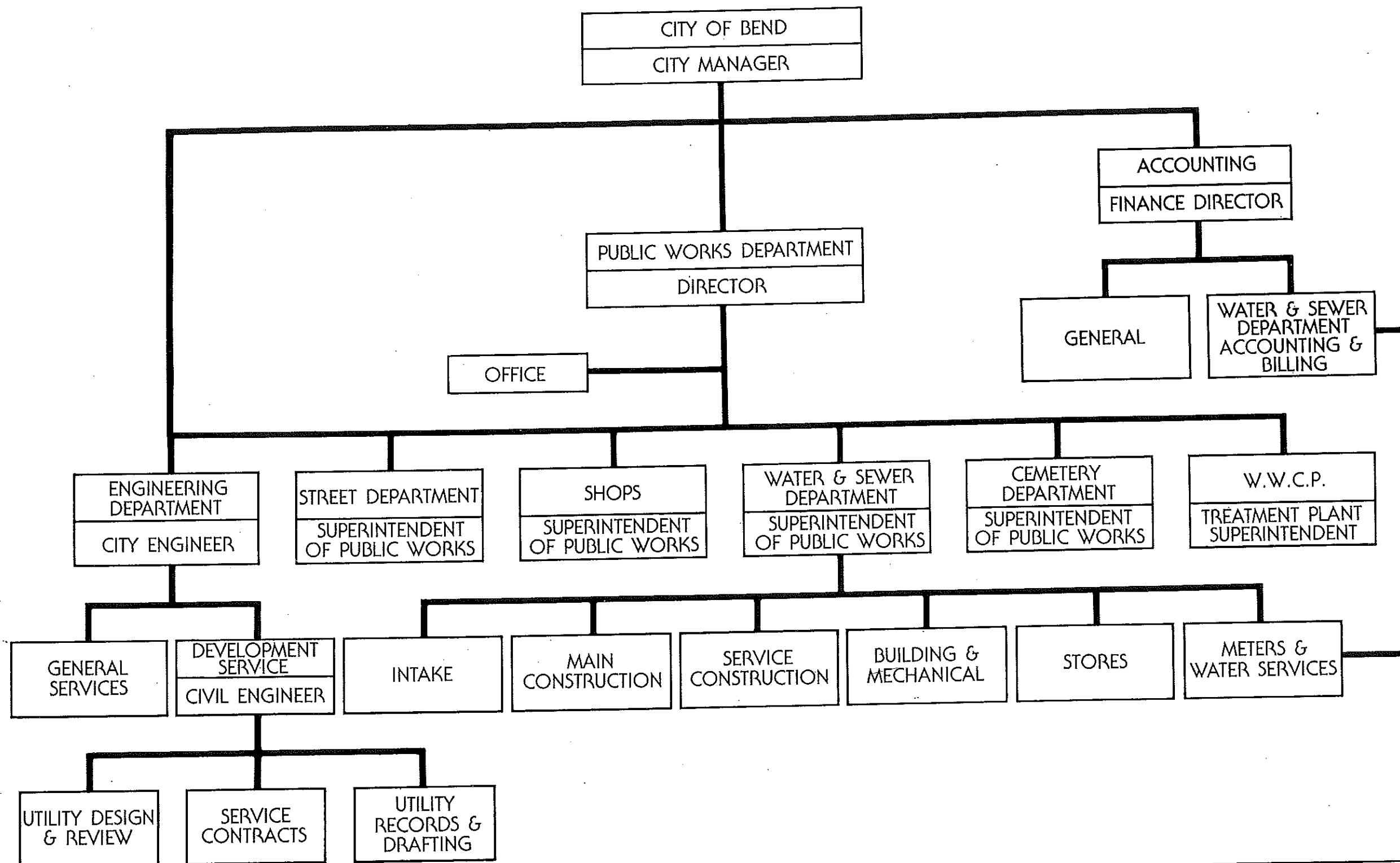
Coordination of system expansion is an engineering function and should be performed by engineering personnel. Relieving the Superintendent of Public Works of his role in this area will make more of his time available for increasing responsibilities relating to operations and maintenance of the water and sewer systems. Figure III-7 shows a possible department organization.

The City's annexation policy allows undeveloped areas to annex to the City and encourages development to City standards with City services. There will be many requests for reimbursement as the water system is extended into these new areas. The reimbursement policy should provide for any new oversized facilities when they are constructed.

The City can encourage development of the water system within the service boundary by providing assistance to developers who expand the system. There should be no "free rides" for those property owners who wait for their neighbor to construct the water system. The current reimbursement policy provides for reimbursement only when there is oversizing of the expanded system. The reimbursement policy should provide relief to the developer who expends "up-front" money for system expansion if the expansion also benefits other future users.

A preventive maintenance program for facilities should be implemented and followed closely. This program becomes more critical as consumption approaches available supply. The probability of emergencies occurring is lower when there is a good preventive maintenance program.

FIGURE III-7  
WATER DEPARTMENT ADMINISTRATIVE STRUCTURE  
(PROPOSED)



## ISO EVALUATION

The fire protection aspects of water distribution facilities are a broad field, hence, this discussion will limit itself to the Insurance Services Office evaluation of the Bend Water System.

Water utilities generally accept the need or obligation to provide water distribution systems that will be capable of conveying a reasonable amount of water to fight fires in addition to satisfying consumer requirements. Empirical formulas exist for determining arbitrary fire flow rates and duration, but no precise formulas exist to determine the exact amount of water needed to extinguish a fire. The fire flow requirement for a given fire area is the rate of flow in gallons per minute (GPM) or million gallons per day (MGD) for a given duration estimated by accepted methods for fire fighting purposes to confine a major fire to the structures within the area. Theoretically, this amount of water should control and extinguish the conflagration in the fire area under a specific set of conditions.

## HISTORY

Accepted standards of grading municipalities with reference to their fire protection capability were established in 1916 by the National Board of Fire Underwriters (NBFU). The NBFU performed fire protection survey and grading work to classify municipalities for fire insurance ratings. It emphasized fire protection in the downtown, high-value district until its last issue in 1956 when recognition was given to areas outside the central business area.

In 1956, the NBFU was combined with two other fire insurance rating organizations to become the American Insurance Association (AIA). In 1971, the municipal survey and grading work formerly performed by the NBFU and the AIA was transferred to the Insurance Services Office (ISO). The ISO presently operates in 43 states with the other states having independent fire insurance rating bureaus.

The current cycle for ISO evaluation of a city is seven to ten years. The basic thrust of an ISO evaluation is to investigate reliability and adequacy of a community's fire defenses. There are four areas of investigation: (1) water supply, (2) fire department, (3) fire service communication, and (4) fire safety control. Since this report concerns itself with the water system, the first

area (water supply) will be investigated in-depth.

Each of these areas is assigned a deficiency number related to a number of areas within each category. The following tables are taken from the Grading Schedule for Municipal Fire Protection. The various possible deficiency points that can be assigned to municipalities are shown in Table III-3.

TABLE III-3  
RELATIVE  
VALUES AND MAXIMUM  
DEFICIENCY POINTS

Feature	Percent	Maximum Points
Water Supply	39	1,950
Fire Department	39	1,950
Fire Service Communications	9	450
Fire Safety Control	13	650
	100	5,000

## BEND, 1976 RATING

Appendix III-1 shows the most current evaluation of fire protection facilities in the City of Bend (December, 1976). Protection class 4 was authorized which upgraded the previous rating of class 5. This upgrading reduced most fire insurance premiums 10-12%. Also of general interest are the deficiency points assigned to the various categories shown in Table III-4.

area (water supply) will be investigated in-depth.

Each of these areas is assigned a deficiency number related to a number of areas within each category. The following tables are taken from the Grading Schedule for Municipal Fire Protection. The various possible deficiency points that can be assigned to municipalities are shown in Table III-3.

TABLE III-4  
ISO EVALUATION  
CITY OF BEND  
1976

Category	Deficiency Points	Total Possible Deficiency Points	%
Water Supply	454 (395)*	1950	23% (20%)*
Fire Department	623	1950	32%
Fire Service Communications	105	450	23%
Fire Safety Control	373	650	57%

\*In a reference letter dated August 22, 1979, 59 deficiency points were removed because of an error in assigning the peak day flow rate. The error was noted during preparation of this Master Plan and the letter appears in Appendix III-2.

As can be seen from the above table, the water supply was responsible proportionately for the least amount of deficiency points.

## REQUIRED FIRE FLOW

The ISO uses the "Required Fire Flow" as the basis for various requirements. This value can be determined for any desired location in a municipality by the application of an empirical formula. When considering a single group or complex of buildings, the fire flow requirement will usually be based on the largest required fire flow calculated. When a group or complex covers a large area, or extends for a considerable distance, each sub-area is considered separately, in order to adequately represent the protection needed. Usually only the highest requirement calculated in a city block or sub-area is considered.

Fire flow requirements should be determined at representative locations throughout the municipality and at all locations with a potentially high fire demand rate. Note that fire flow requirements may frequently be determined for buildings or fire areas where fire flow tests are not witnessed.

The following formula is used:

$$F = 18C (A)^{0.5}$$

where

F = the required fire flow in GPM

C = coefficient related to the type of construction\*

C = 1.5 for wood frame construction

= 1.0 for ordinary construction

= 0.9 for heavy timber type buildings

= 0.8 for noncombustible construction

= 0.6 for fire-resistive construction

\*For types of construction and/or materials that do not fall within the categories given, use a coefficient reflecting the difference. Coefficients shall not be greater than 1.5 nor less than 0.6 and may be determined by interpolation. Such interpolation shall be between consecutive types of construction as listed above. Definitions of types of construction are included in the Appendix.

A = the total floor area (including all stories, but excluding basements) in the building being considered. For fire-resistive buildings consider the six largest successive floor areas if the vertical openings are unprotected; if the vertical openings are properly protected, consider only the three largest successive floor areas

One can see from the formula that the fire flow needed at a specific location depends mainly on the type of construction and the area of the building. Additional factors such as proximity or nearby buildings (exposure) and type of sprinkler system add or subtract from the required fire flow.

Since these factors are all known for existing structures, the required fire flow can be computed with a high degree of accuracy, but for proposed development, unless exact type of construction is known it would be exceedingly difficult to compute exact fire flow requirements. Hence, when designing pipelines, reservoirs, and pump stations to serve proposed developments, a worst case situation is usually assumed for sizing the above mentioned items.

## BASIC FIRE FLOW

The term "Basic Fire Flow" is the value which represents the fire potential of most large properties in the municipality, but may exclude several of the largest properties not considered as usual to the municipality. In determining the "Basic Fire Flow" consider the

required fire flow for all buildings and fire areas except those that have private protection provided by the installation of a complete, adequately supplied sprinkler system. Normally, the value used as the "Basic Fire Flow" will not be the highest required fire flow in the municipality.

## MAXIMUM DAILY CONSUMPTION

The maximum daily consumption is the usual parameter used in evaluating the water supply system. Theoretically, a system that could only deliver the maximum daily consumption rate plus the required fire flow could not meet the required fire flow during the many hours when the rate of consumption exceeds the maximum daily rate. Because it is also recognized that there are many hours when consumption is less than the maximum daily rate, the use of the maximum daily rate is considered a reasonable compromise.

Table III-5 is taken from the actual grading of the Bend Water System (as shown in the Appendix). Items 2, 3, 4, 7, 8 and 13 merit further discussion because of the high number of deficiency points assigned to them.

TABLE III-5  
WATER SUPPLY  
CITY OF BEND

Item	Assigned Deficiency Points To The Bend System
1. Adequacy of Supply Works	5
2. Reliability of Source Supply	38
3. Reliability of Pumping Capacity	61
4. Reliability of Power Supply	41
5. Condition, Arrangement, Operation, and Reliability of System Components	25
6. Adequacy of Mains	4
7. Reliability of Mains	52
8. Installation of Mains	52
9. Arrangement of Distribution System	31
10. Additional Factors and Conditions Relating to Supply and Distribution	18
11. Distribution of Hydrants	33
12. Hydrants - Size, Type and Installation	3
13. Hydrants - Inspection and Condition	56
14. Miscellaneous Factors and Conditions	35
Total	454

## ITEM 2 — RELIABILITY OF SOURCE SUPPLY

This item considers the miscellaneous factors in the source supply, especially those due to natural causes that could result in partial or complete interruption of delivery.

When the Bend grading took place in 1976, the City had only one well in service. A consideration factor for interruption of delivery was pump malfunction for this well. Now a second well is in service so a substantial number of the deficiency points should be removed.

## ITEM 3 — RELIABILITY OF PUMPING CAPACITY

This item considers the ability of the supply works to deliver the maximum daily consumption rate plus the basic fire flow for a specified time duration, with the main pump out of service.

With the new well pump in service some deficiency points in this area should also be removed.

## ITEM 4 — RELIABILITY OF POWER SUPPLY

This item considers the effect that a sustained power outage would have on the system.

The most vulnerable parts of the Bend system to a power outage at the current time are the Third Street and College Way pumping stations. Although both of these installations have somewhat of a "cushion" in that they have reservoir storage backing them up in case of mechanical problems, an electrical outage or pump breakdown of a long duration in the summer months would cause serious problems and consumption would have to be severely restricted.

With the foregoing in mind, some thought should be given to supplying these installations and the two wells with alternative energy sources. A diesel generator and/or diesel engine right angle drive are two possibilities. In order to implement this, the existing spatial limitations would have to be looked at carefully to see if the interior of the buildings would have enough room. If not, some type of all weather enclosure could be utilized on the exterior of the building.

## ITEM 7 AND 8 — RELIABILITY AND INSTALLATION OF MAINS

This item considers the most critical length of pipe and the most critical values isolated because of a break in the water system. The most critical link would be the 16" steel line coming in from the Bridge Creek source. Realistically, to improve the rating in this category, a new pipe would have to be laid from the Bridge Creek source. To do this just to improve the ISO rating may be economically unfeasible.

## ITEM 13 — HYDRANT INSPECTION AND CONDITION

The bulk of deficiency points in this item were assigned because of too long a duration between inspections. In recent years because of the rapid pace of new development, the Bend Water Department has had to sacrifice hydrant flushing and inspection in order to keep up with main installation. Every attempt should be made to flush all hydrants on a yearly basis. Aside from the obvious benefit of decreasing deficiency points, it would also increase the water department personnel's familiarity with location and operation of all hydrants.

## SUMMARY

As indicated before, the water supply section of the ISO evaluation lost fewer deficiency points proportionately than the other sections of the evaluation. Bearing this in mind, we would not recommend a specific program aimed at improving the existing rating.

Rather there are a few items (listed below) that will increase the strength of the overall system while improving the ISO rating. It should be noted that a class 4 rating for a city the size of Bend is excellent in comparison to other cities of similar size.

## RECOMMENDATIONS

- Install backup power for Well #2 with automatic transfer switch.\* Cost \$120,000
- Install diesel engine drive or backup generator at College Way pump station. Cost \$ 25,000

- Install backup generator for Third Street pump station. Cost \$ 15,000
- Implement a program such that all valves and hydrants should be exercised and flushed at least once a year.

■ Install hydrants as shown in Table III-6 at a cost of \$10,000 per year.

\*Well No. 2's primary motor is 400 HP, while Well No. 1's is 500 HP. Due to the relative infrequency of power outages, the most cost-effective alternative is to install a backup generator for Well No. 2's 400 HP motor.

TABLE III-6  
PROPOSED FIRE HYDRANT INSTALLATION SEQUENCING

COMMERCIAL AND INDUSTRIAL		RESIDENTIAL
Priority	Location	
1.	S. 2nd & Yew	51. Dekalb & 4th
2.	S. 2nd & Willow Ln.	52. 3rd between Greeley & Hawthorne
3.	Colorado & Harriman	53. 3rd & Olney
4.	Colorado & Sisemore	54. Lytle & Quimby
5.	S. 9th between Glenwood & Railroad Tracks	55. Penn between First & Lytle
6.	Woodland between S. 9th & Cinders St.	56. Deschutes Place & Olney
7.	Woodland & Cinders Sts.	57. First & Seward
8.	Cinders St. between S. 5th & Railroad Tracks	58. First & Underwood
9.	Cinders St. & S. 5th	59. Underwood between First & Railroad Tracks
10.	S. 5th between Cinders St. & Glenwood	60. Vail between First & Second
11.	S. 5th & Glenwood	61. First & Webster
12.	Glenwood between S. 5th & S. 9th	62. 2nd & Webster
13.	Glenwood between S. 5th & S. 9th	63. Century Dr. between Commerce & Knoll
14.	Glenwood between S. 5th & S. 9th	64. Century Dr. between Knoll & Simpson
15.	West Railroad St. between 2nd & 3rd (line ext.)	65. Century Dr. between Knoll & Simpson
16.	S. 3rd & Davis	66. Greenwood & 8th
17.	McKinley between S. 3rd & S. 4th	67. Greenwood & 10th
18.	2nd & Thurston	68. Galveston between 12th & 13th
19.	3rd & Seward	69. Galveston between 13th & 14th
20.	4th & Thurston	70. Newport & 10th
21.	Underwood between 3rd & 4th	71. First & Yale
22.	4th & Webster	72. Yale & Tweet Place
23.	4th St. North of Post Office	73. Tweet Place & Zenith
24.	4th St. South of Addison	74. Tweet Place & Addison
25.	4th & Addison	
26.	3rd & Vail	
27.	Burnside between 3rd & 4th	75. NW 3rd between Newport & Portland
28.	Clay between 3rd & 4th	76. NW 2nd between Portland & Saginaw
29.	2nd between Dekalb & Burnside	77. Alley between NW First & NW 2nd (end of line north of Saginaw)
30.	2nd & Dekalb	78. NW 4th & Roanoke
31.	2nd between Emerson & Franklin	79. Steidl between Gordon & Saginaw
32.	Emerson between 3rd & 4th	80. Bond between Kansas & Georgia
33.	Division & Park Place	81. Division between Wilson & Taft
34.	3rd between Emerson & Franklin	82. 5th between Roosevelt & Wilson
35.	Franklin between Bond & Lava	83. 5th & Cleveland
36.	Oregon between Irving & Harriman	84. Centennial (W: Railroad) between Miller & 5th
37.	Kearney between Hill & Division	85. Harmon & Milwaukee
38.	Franklin & Hill	86. NW 16th & Galveston
39.	Lafayette & Harriman	87. Jacksonville & Kingston
40.	Hawthorne & Hill	88. Kingston between Ithaca & Jacksonville
41.	Lafayette between 3rd & 4th	89. Portland between NW 14th & Juniper
42.	Norton between 3rd & 4th	90. Quincy between NW 11th & NW 12th
43.	3rd & Marshall	91. Quincy between NW 12th & Kenwood
44.	2nd & Marshall	92. Roanoke between NW 10th & NW 11th
45.	2nd & Kearney	93. Columbia between Cumberland & Elgin
46.	Kearney between 3rd & 4th	94. Federal & Hartford
47.	2nd & Norton	95. Butler Market between Vail Lane & Ravenwood
48.	First between Greenwood & Kearney	96. Vail & Butler Market
49.	First between Hawthorne & Irving	97. Jones between NE 12th & NE 8th
	Division between Franklin & Greeley	

# POWER GENERATION FROM THE BRIDGE CREEK SOURCE

## INTRODUCTION

The Bridge Creek water supply has an estimated capacity of 12 MGD with a pressure head potential of approximately 1,100 feet of water. These factors make the generation of hydroelectric power possible from this water source. The following investigates the economic feasibility of power generation.

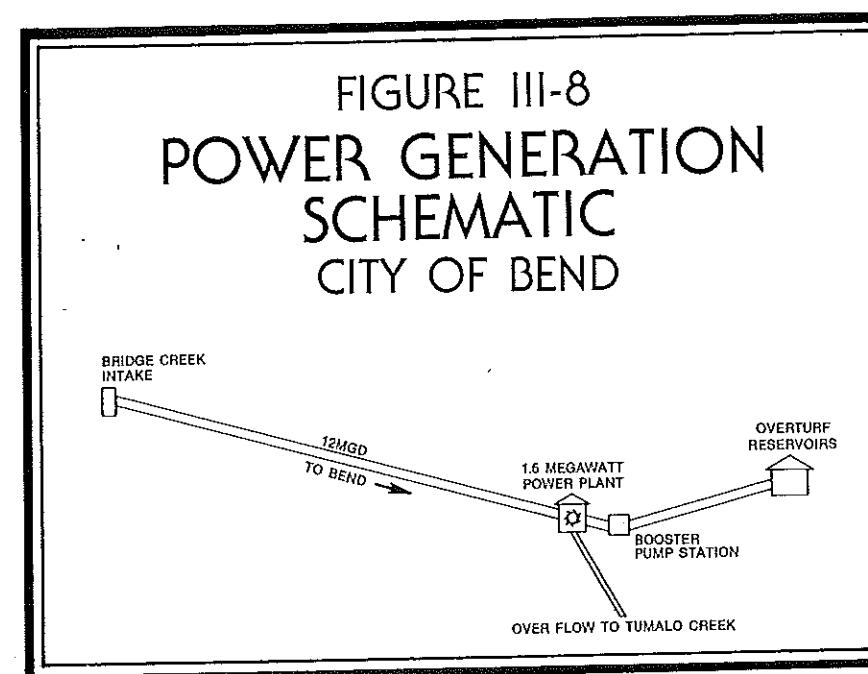
## SYSTEM CONFIGURATION

The amount of power generation possible from a hydroelectric plant is directly proportional to the water flow and pressure head entering the plant. At this time, the Bridge Creek source has an estimated capacity of 12 MGD. No pressure head is available for power generation because the existing transmission pipeline dissipates all available water elevation head through pipe friction losses. A new enlarged water transmission pipeline and a power plant would be required to produce hydroelectric power from this source.

Figure III-8 shows a general schematic of the necessary facilities for power generation. An infinite number of system configurations are possible. The system analyzed herein was designed to maximize the power producing capabilities of the source. The system proposed consists of a new 36-inch diameter transmission line from the water intake to the power plant to conserve the water elevation head, a pelton wheel type hydroelectric power plant, a booster pump station to pump the power plant tailwater to the Overturf Reservoir and a new 20-inch transmission pipeline from the booster pump station to the reservoir.

## POWER GENERATION

With the new 36-inch transmission and the power plant located near the present overflow site, approximately 1,100 feet of pressure head is available for power generation. Using the source capacity of 12 MGD and a pelton wheel type hydroelectric plant, the maximum power producing capability of the system is approximately 1.5 MEGA-watts (MW). For comparison, the



Trojan nuclear power plant generates approximately 1,200 MW at maximum capacity.

The tailwater from the power plant leaving at atmospheric pressure and at an elevation lower than Overturf Reservoir must be pumped through a new 20-inch transmission pipe to the reservoir on Overturf Butte. The booster pumping of the 12 MGD flow would require approximately 760 horsepower. The power required for this pumping is subtracted from the total power generated from the power plant. The requirement to pump the 12 MGD from the power plant to the reservoir at Overturf is assumed to occur only during periods of peak use, i.e. the six months of summer irrigation. This leaves approximately 1.0 MW/Hr of annual average power available for sale to a local power utility.

## ECONOMIC ANALYSIS

The following preliminary cost estimates are used to determine the economic feasibility of power generation from the Bridge Creek source.

## CAPITAL COSTS

36-inch transmission pipeline from the intake to power plant, 54,050 L.F.	\$ 6,705,000
20-inch transmission pipeline from the booster pump station to the reservoir, 16,675 L.F. <i>Am 18.5 6/15</i>	1,315,000
760 HP booster pump station	300,000
Pelton wheel hydroelectric power plant	<u>2,000,000</u>
Estimated Total Construction Cost	\$10,320,000
Technical Services @ 18% of Construction Cost	\$ 1,857,600
Administration @ 2% of Construction Cost	206,400
Project Contingency @ 10% of Construction Cost	1,032,000
Total Estimated Capital Cost	\$13,416,000

## ANNUAL COSTS

Plant personnel, 2 full-time	\$ 30,000
Operation and Maintenance	5,000
Total Estimated Annual Costs	\$ 35,000

## ANNUAL REVENUE

Net power available of 1.0 MW using 24-hour power generation and 365 day year.

$$\text{Power Available} = 8,760,000 \text{ KW-hr/year}$$

The current power purchase price is approximately \$0.03/KW-Hr.

$$\text{Estimated revenue from sale of power} = \$262,800/\text{Yr.}$$

*Am 1788, 400*

## BENEFIT-COST ANALYSIS

A benefit cost analysis using equivalent annual costs for all capital costs with an overall project design life of 40 years and a 12 percent return yields a benefit cost ratio of approximately 0.15. Even if capital cost items could be reduced by about one-half by including pipeline replacement costs into the water system operations and maintenance budget, the benefit cost ratio would only increase to about 0.30.

## SUMMARY AND CONCLUSION

The Bridge Creek water source could produce hydroelectric power, but at this time the project is economically unattractive with a benefit cost ratio of a 0.15 to 0.30. The estimated revenue from potential power sales do not offset the high capital costs associated with the major construction required to produce the power. The maximum amount of power generation possible from this source is approximately 1.5 MW. The current purchase price for power is approximately \$0.03 per KW/HR. For this project to have a benefit cost ratio of 1.0, based on 1980 construction costs, the purchase price for power would have to be \$0.19 per KW/HR or as much as six times the current purchase price. In the future, power cost increases may exceed construction cost increases which may make power generation from the source economically attractive. The City may want to include this option in future system planning.

1) WATER RIGHTS  
2) REV. — POWER PURCHASE PRICE



BRIDGE CREEK FALLS — 1979  
Photo by: Joyce Bork

## WATER SOURCE EVALUATION

Chapter IV

# WATER SOURCE EVALUATION

## HISTORY

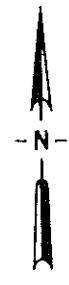
The development of a water supply system for the City of Bend has progressed through several stages. Bend became an incorporated city in 1905 with water supplied by ditches or from the Deschutes River. In 1906, using the Deschutes River, Bend Water, Light & Power Company built a system to furnish water to Bend residents for domestic water use, fire protection, and general municipal purposes. By 1923, the Deschutes River water was no longer potable. The dams at Crane Prairie and Crescent Lake were releasing the results of algal bloom into the river creating an objectionable taste and odor.

The City of Bend hired the engineering firm of Dubuis & Redfield in 1924 to prepare a report on sources of water supply for Bend's future needs. This firm recommended that Bend base its future water needs upon a population of 40,000. This population size was estimated for the year 1984. They also recommended that the acquisition of water rights on Tumalo Creek be purchased and that Tumalo Creek be used as the main source of water supply for the City of Bend. The reasons for this recommendation were (1) Tumalo Creek water was of superior quality, (2) the Tumalo Creek watershed could be controlled and protected against pollution since it was a forest reserve and (3) annual operating cost for the Tumalo source appeared to be the most economical. Bend did buy water rights amounting to 3.88 MGD and a 5 MGD pipeline was constructed connecting the City of Bend to Tumalo Creek. In 1948, water rights were increased to 5.17 MGD. By 1954, a total of 7.1 MGD were obtained necessitating construction of a second pipe parallel with the 1926 pipeline connecting Bend and Tumalo Creek. These two pipelines are shown in Appendices IV-1 and IV-2. To supplement the Tumalo source, two deep wells have been constructed. Well #1 was constructed in 1972 and Well #2 came on line in 1979. Figure IV-1 shows a schematic of Bend's present source of supply.

Alternative water sources for the City of Bend were examined by Dubuis & Redfield, Cunningham and Associates, and CH2M. Table IV-1 lists the sources and parameters evaluating their suitability.

The combination of Tumalo Creek and Wells No. 1 and 2 provide approximately 17 MGD of water for Bend's population. The projected population of Bend in the year 2000 is 45,000. Assuming that the metering program is implemented (see Metering Evaluation Section), approximately an additional 15 MGD will be required in the year 2000.

FIGURE IV-1  
PRESENT WATER SYSTEM SCHEMATIC  
CITY OF BEND



NO SCALE

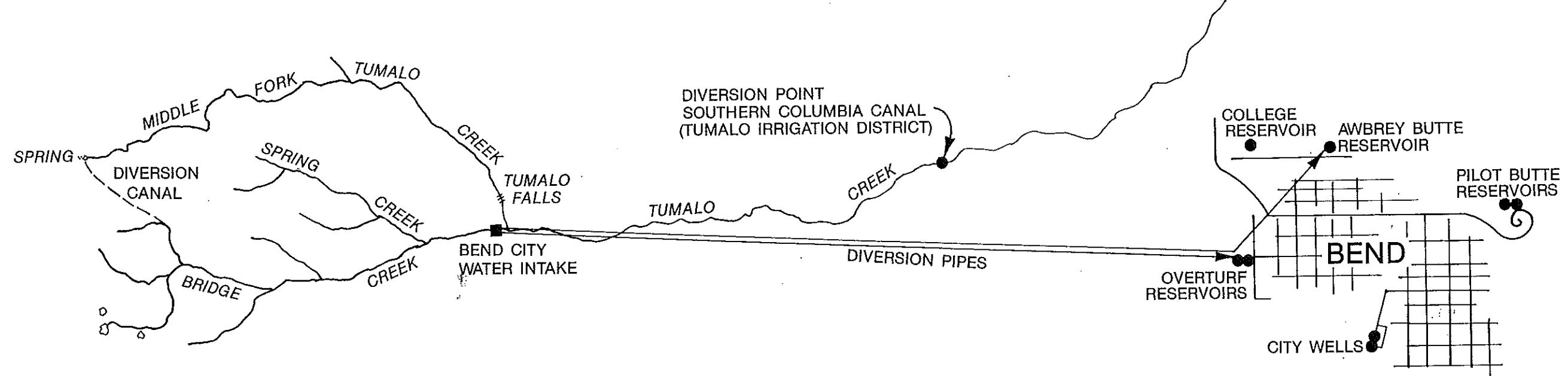


TABLE IV-1  
ALTERNATE WATER SOURCES  
1924-1964

DUBUIS & REDFIELD — 1924		CUNNINGHAM & ASSOCIATES — 1948		CH2M — 1964	
<b>Surface Water</b>					
<u>Source</u>	<u>Suitability</u>	<u>Source</u>	<u>Suitability</u>	<u>Source</u>	<u>Suitability</u>
Deschutes River	Present filter treatment unable to handle pollution problems.	Deschutes River	Filter plant superior to 1924 possible. Not necessary if more water rights to Tumalo Creek can be purchased.	Deschutes River	Chemical and filtration treatment necessary. Public may disapprove.
Tumalo Creek	Superior quality H <sub>2</sub> O. Best source. Construction cost low.	Tumalo Creek	Superior. Purchase more H <sub>2</sub> O rights.	Tumalo Creek	Superior source. May not be possible to purchase more water rights.
Spring River	Set aside for consideration until final decision on dam at Benham Falls. If dam is built it will flood part of Spring River.			Spring River	Water rights-purchase necessary. Better sources available.
Fall River	Construction expensive.			Fall Creek	Difficult access for construction and operation. Construction expensive.
Soda Creek	Supply not dependable. Construction expensive.			Surface Water	Too far from city.
Green Lakes	Supply not dependable. Construction expensive.				
<b>Ground Water</b>					
<u>Source</u>	<u>Suitability</u>	<u>Source</u>	<u>Suitability</u>	<u>Source</u>	<u>Suitability</u>
Greater Bend Area	Broken lava under the city yields no H <sub>2</sub> O.	Greater Bend Area	No continuous H <sub>2</sub> O table at any depth. Questionable that H <sub>2</sub> O can be found in underground stream or sheets.	Greater Bend Area	Adequate and supplemental H <sub>2</sub> O available. Deep wells and shallow wells should be explored.
				Lava Island	Exploration of shallow wells should be pursued.

# SURFACE WATER

## WATERSHED DESCRIPTION

The Bend watershed is located in Deschutes National Forest, 10 miles west of Bend. It comprises 7,000 acres of which 4,510 acres contribute to the domestic water supply of Bend. Bridge Creek and Spring Creek, tributaries of Tumalo Creek supply this domestic water (Figure IV-1).

Landforms found in the watershed are mostly gentle or sloping glaciated uplands. Some of the landforms are rough lava flows and a few are shield or composite volcanoes. Soil characteristics are typified in the surface area by loamy sand or sandy loam. The sub-surface layer is basically loamy sand and the deep soils when present are sandy loam or loam. The substrate is glacial till or may be composed of basalts and andesites. The watershed slope varies from 0-80%. In some areas, the Bridge Creek bank is very steep with slopes as great as 50-70% (Figure IV-2).

FIGURE IV-2  
CHANNEL STABILITY



Vegetation in the watershed is diversified and dominated by a canopy of mountain hemlock and mixed conifers (Figure IV-3). Understory consists mainly of huckleberry, manzanita, sedges and grasses. About 175 species of wildlife are supported in the watershed. These include mule deer, elk, bear and raptorial birds. Only a few fish have been sighted in Bridge Creek.

FIGURE IV-3  
WATERSHED VEGETATION  
MT. HEMLOCK AND MIXED CONIFERS



The 1926 cooperative agreement between the City of Bend and the USDA Forest Service states that the Bridge Creek area will be managed primarily for the production of domestic water. (Appendix IV-3). The Forest Service Land Management of 1978 designated the area as a "roadless area" with limited trails and no developed campsites. Recreation use is open for hikers, horseback riders, cross-country skiers and hunters. No grazing or timber harvesting has been allowed.

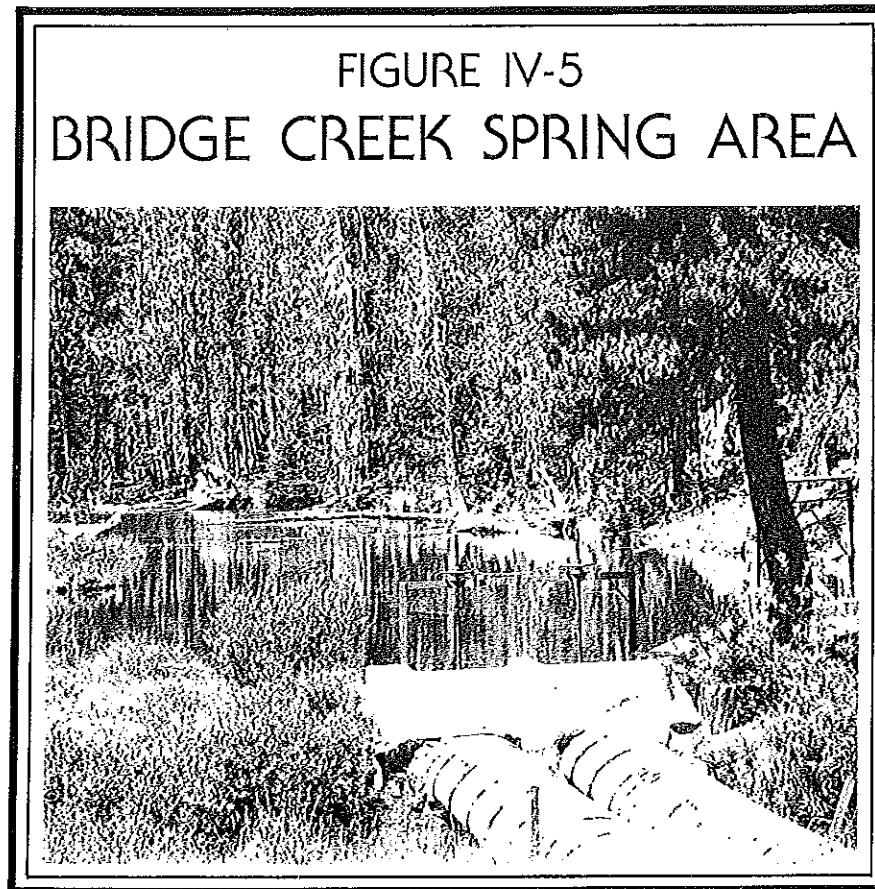
The area's designation as a roadless area has resulted in very little or no management. Large quantities of dead and dried trees have accumulated throughout much of the Bridge Creek Watershed (Figure IV-4). The dry snags contribute to high fire fuel loading in the area. Although the July 1979 fire burned parts of the area, the upper reaches of Bridge Creek still contain quantities of dried snags.

FIGURE IV-4  
WATERSHED FUEL LOAD



## EXISTING CONDITIONS OF SURFACE WATER AND SUPPLY

Water is diverted into Bridge Creek from natural springs located in the west extension of the watershed (Figure IV-5). This diversion canal maintains a clear,



fast moving flow that contributes significantly to the amount of water that moves down Bridge Creek (Figure IV-6). The intake on Bridge Creek is 1,100 feet above the water level in the Overturf Reservoirs located on the outskirts of Bend (See Figure IV-1). Figure IV-7 illustrates the spring and diversion structure.

FIGURE IV-6

## BRIDGE CREEK DIVERSION CANAL

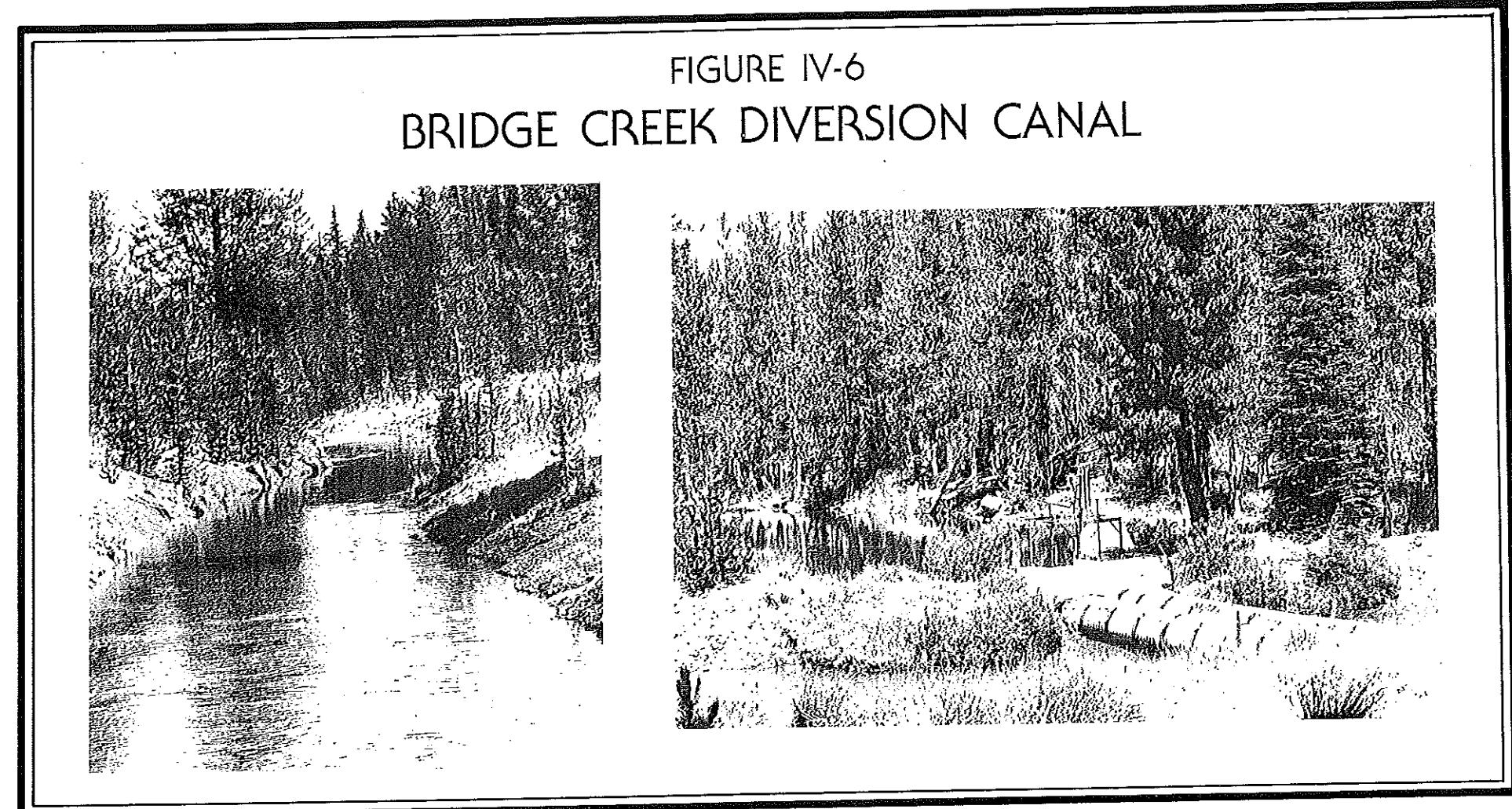
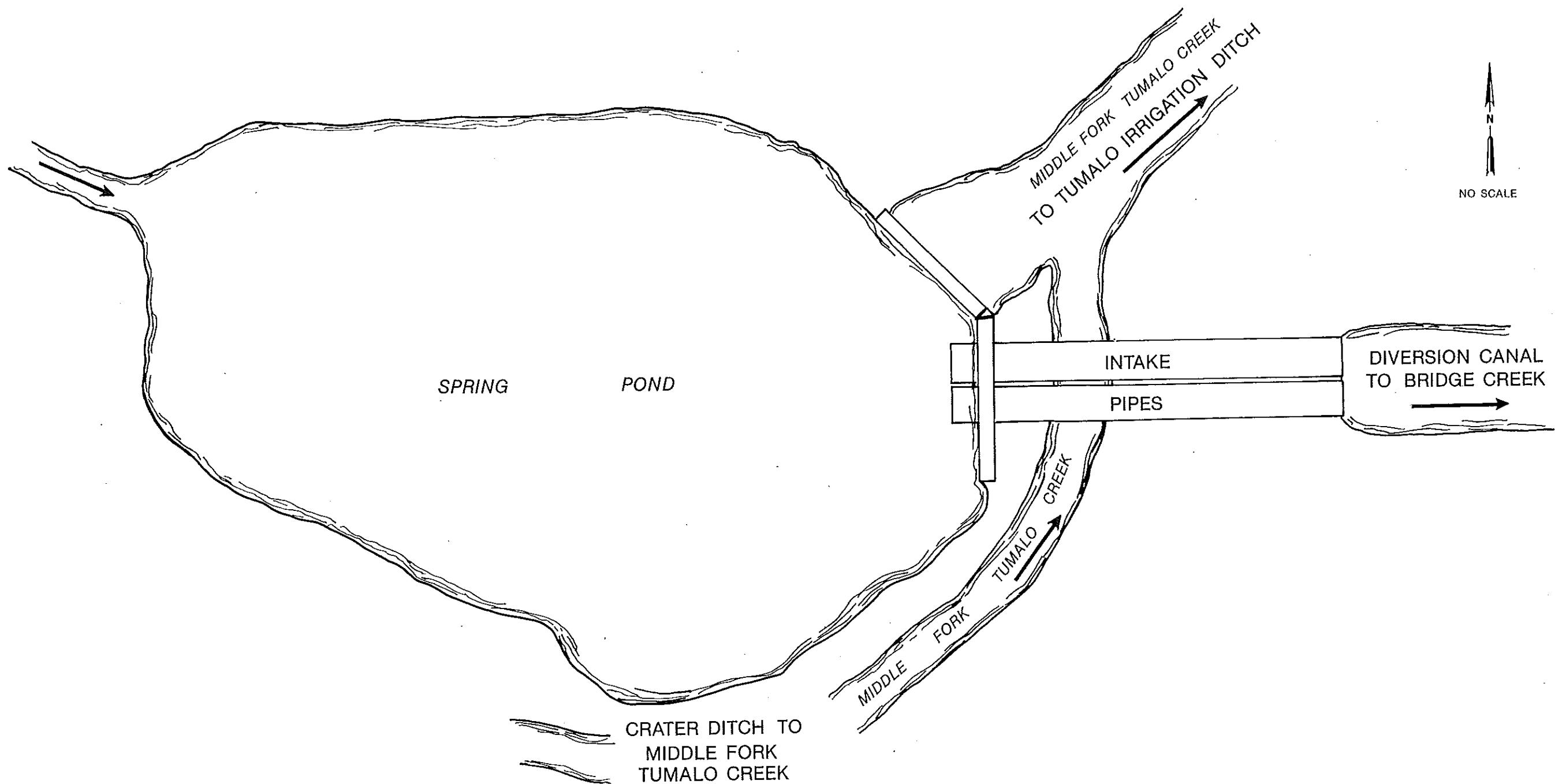


FIGURE IV-7  
BRIDGE CREEK SPRING AND DIVERSION CANAL



Water flowing from Bridge Creek is of excellent quality. Inorganic and organic tests show all elements to be well below EPA maximum allowable levels (see Table IV-2).

TABLE IV-2  
BRIDGE CREEK 1978  
INORGANIC TEST

<u>Inorganic Contaminant</u>	<u>Test Results</u>	<u>Maximum Allowable Concentrations</u>
Arsenic	0.001 mg/l	0.05 mg/l
Barium	0.05 mg/l	1.0 mg/l
Cadmium	0.005 mg/l	0.010 mg/l
Chromium	0.010 mg/l	0.05 mg/l
Flouride	0.09 mg/l	1.8 mg/l
Lead	0.010 mg/l	0.05 mg/l
Mercury	0.0006 mg/l	0.002 mg/l
Nitrate (AS N)	0.03 mg/l	10. mg/l
Selenium	0.002 mg/l	0.01 mg/l
Silver	0.005 mg/l	0.05 mg/l

## ORGANIC TEST

<u>Organic Contaminant</u>	<u>Test Results</u>	<u>Maximum Allowable Concentrations</u>
Endrine	0.0001	0.0002
Methoxychlor	0.0001	0.1
Toxaphene	0.001	0.005
2-4-D	0.001	0.1
2-4-5 TP (Silvex)	0.0001	0.01

Bacteriological counts are also low thus no treatment other than chlorination for maintaining an adequate residual in the pipelines is required. Turbidity measurements are taken daily from Bridge Creek at its entrance to Overturf Reservoir. These values are below maximum allowable EPA levels even during seasonal periods of high run off. Figure IV-8 shows the turbidity levels for 1978 which are representative of overall measurements taken from previous years.

Bridge Creek originates from several small springs. Its channel stability as measured by Deschutes National Forest Service appears to be constant and has been

evaluated between levels of fair to good except in the region directly below the diversion canal. This area is designated poor because

### ■ UPPER BANK

- The slope gradient is greater than 60%.
- Frequent mass wasting occurs nearly year long.
- Plant cover measures less than 50% density and has a shallow discontinuous root mass.

### ■ LOWER BANK

- Rock content is composed of less than 20% gravel size (1-3") rock fragments.
- There is continuous bank cutting and frequent failure of overhangs.

### ■ CHANNEL BOTTOM

- Scouring and deposition are in a continual state of flux.
- Perennial plant cover is scarce or absent.
- Greater than 65% of the channel bottom is exposed or scoured.

Figure IV-9 illustrates channel elevation and identifies contour intervals showing Bridge Creek and the diversion canal as they flow through the watershed to the city water structure.

During April, the water gates of the springs are opened approximately seven inches adding additional water flow down the diversion canal to Bridge Creek. This allows the City of Bend to meet irrigational demands that occur during the summer months. In the fall, when additional water is no longer necessary, the diversion canal is closed and all excess water flows over the weir into the middle fork of Tumalo Creek. During the summer in 1972, the City of Bend measured the water flow in the main springs and the diversion canal. No measurements were made again until late summer 1979 when Century West Engineering Corporation gaged the stream in several places. All measurements are shown in Table IV-3:

TABLE IV-3  
BRIDGE CREEK STREAM FLOW

<u>Location</u>	<u>MGD</u>	<u>Date</u>
80' above dam at spring	16.70	Late summer, 1972
At culvert below spring	10.23	Late summer, 1972
200' above the intake	16.39	Sept. 4, 1979
150' below the spring in the diversion canal	10.04	Oct. 9, 1979
250' above the intake	16.68	Oct. 9, 1979
50' below the intake weir	6.02	Oct. 9, 1979

Although these measurements do not provide a reliable data base, it appears that during the summer the main springs above the diversion ditch provides approximately 10 MGD to Bridge Creek. Bridge Creek picks up another 6 MGD from other springs along its route down through the watershed. Approximately 10-12 MGD is used by the City of Bend with 6 MGD continuing down Tumalo Creek. Since the valves are turned off at the springs on November 1, water flow measurements would change, but these measurements have not been taken.

FIGURE IV-8  
TURBIDITY AT OVERTURF RESERVOIR  
(1978)

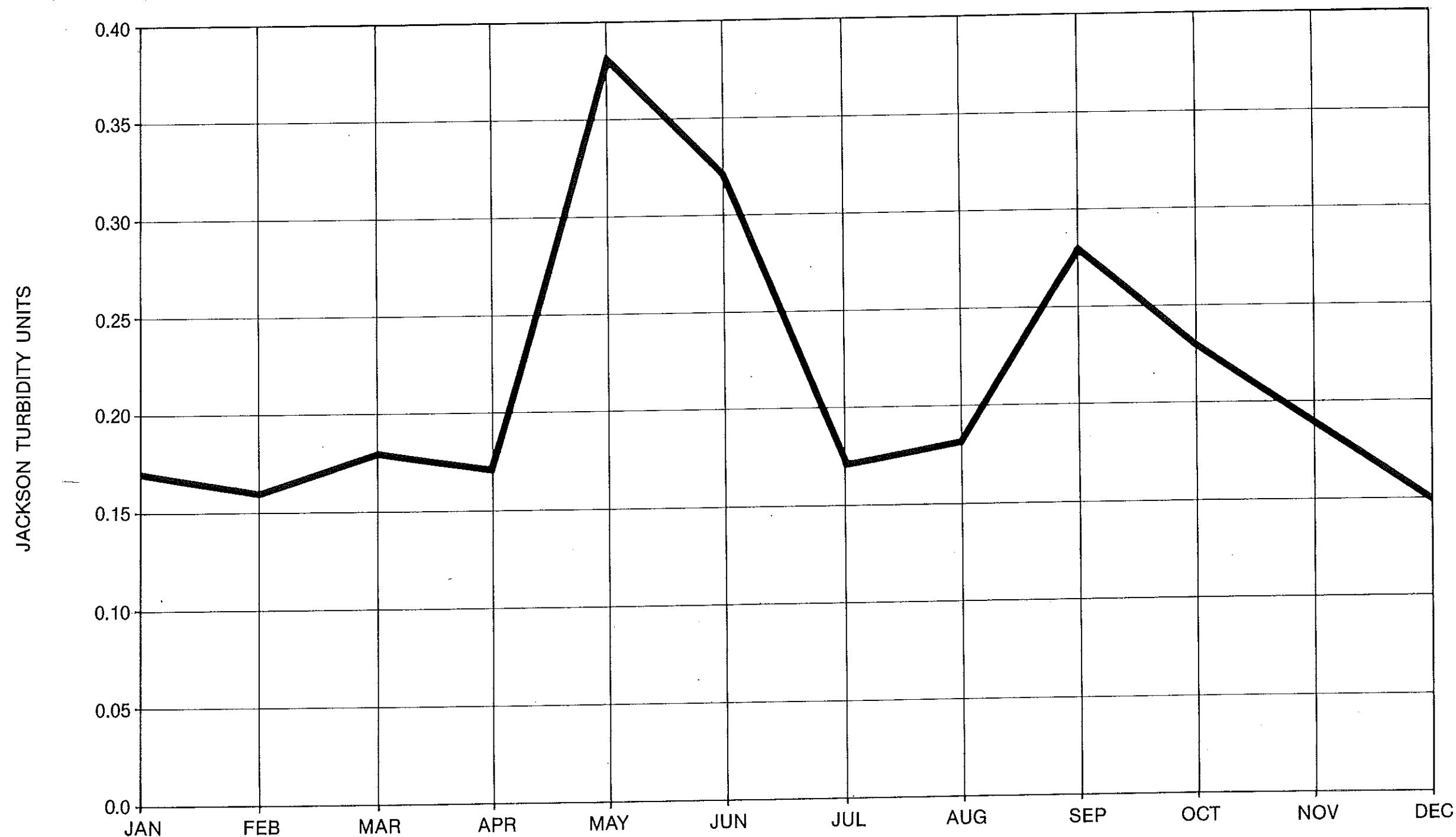
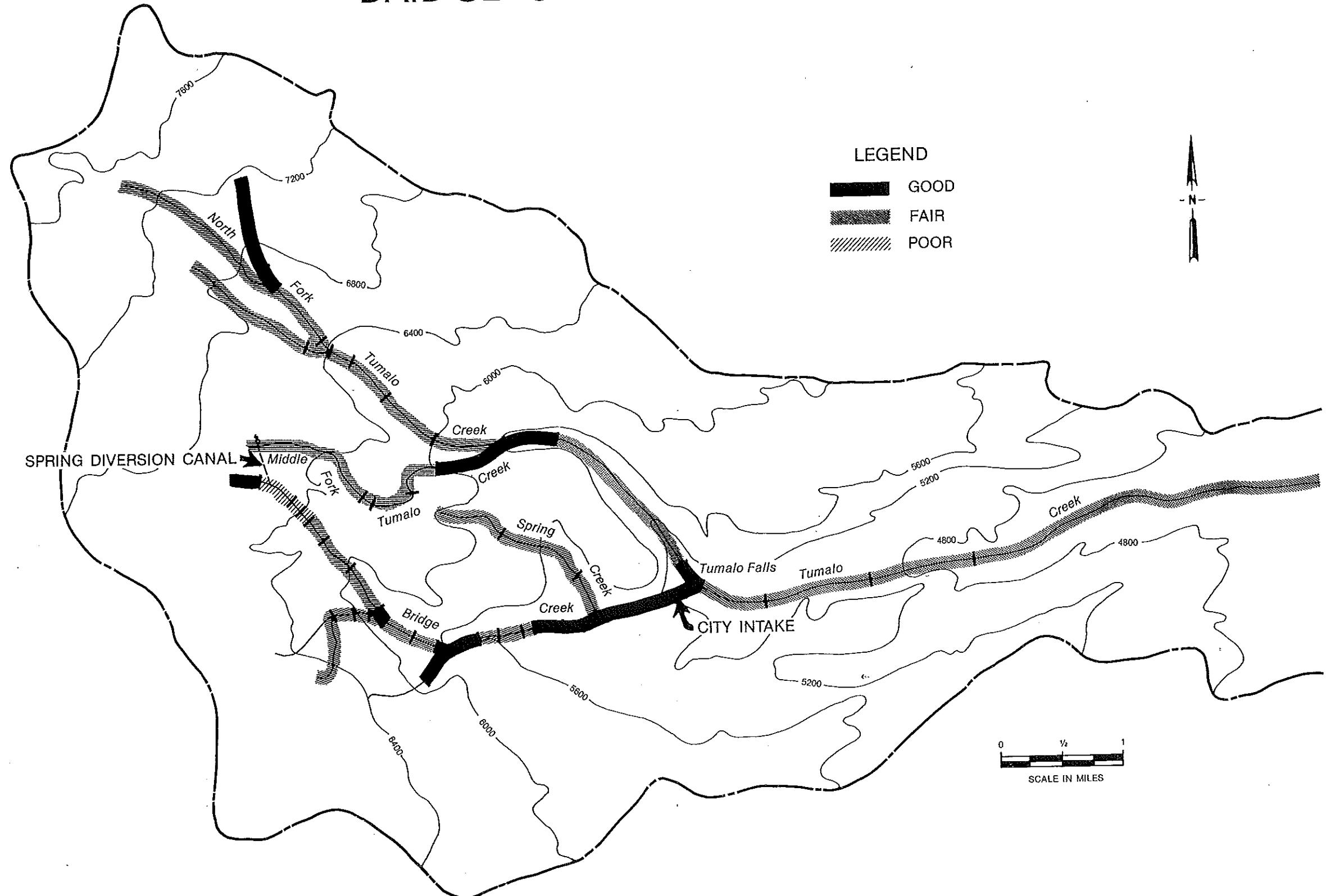
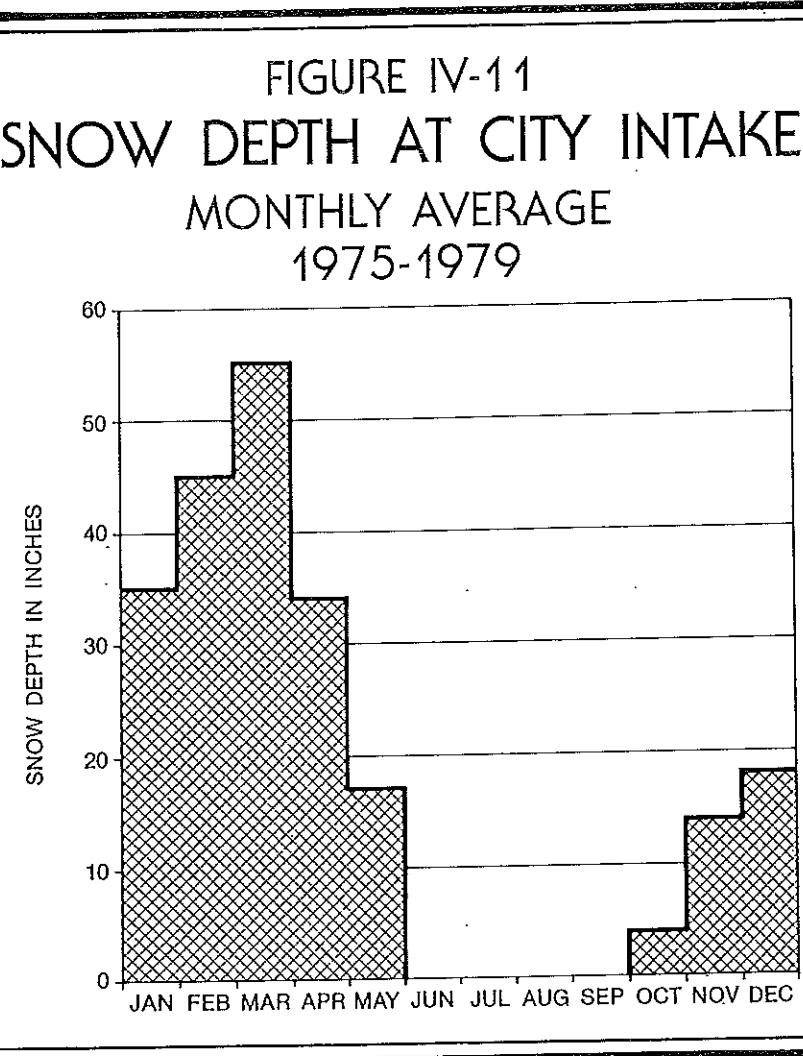
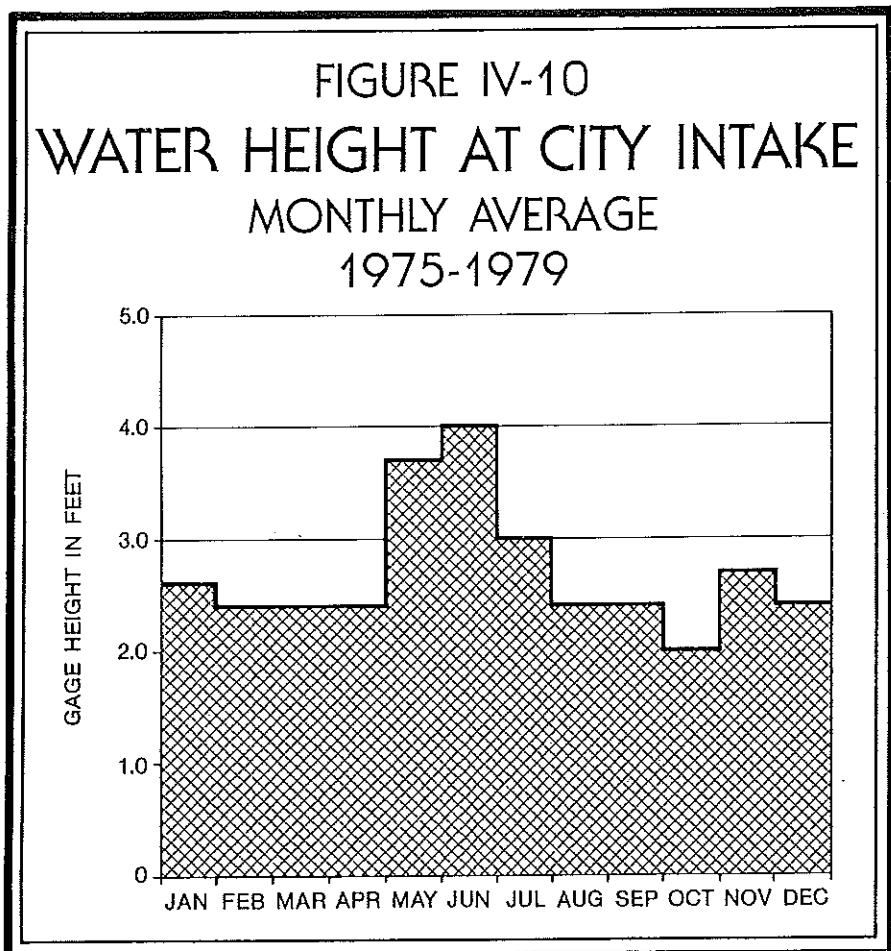


FIGURE IV-9  
BRIDGE CREEK CHANNEL STABILITY



A staff gage is located at the intake and water levels are recorded daily. Figure IV-10 shows the average levels recorded between 1975-1979. Snow level measurements are also taken near the intake building. These are shown in Figure IV-11. There is insufficient data to correlate staff gage height and snow level to stream gage measurements, this should be done to determine yearly stream fluctuations.



### EXISTING SURFACE WATER RIGHTS

In 1926, the City of Bend traded to the Deschutes River Irrigation District (now the Tumalo Irrigation District) Deschutes River rights and paid \$25,000 to obtain 3.9 MGD Tumalo Creek water rights. Throughout the years, more water rights have been purchased from the Tumalo Irrigation District (see Appendix IV-4-8).

The City of Bend now owns water rights of 13.6 MGD with the following limitations: rate of flow will be one-seventieth of one cubic foot per second per acre and the quantity of water diverted during the irrigation season (April 15-October 15) will not exceed 1.8 acre feet per acre. All water currently in Tumalo Creek appears to be appropriated. However, the quantity of water available to that drainage from the main springs is unknown.

### FUTURE SOURCE OF SURFACE WATER

Numerous surface water sources in addition to Tumalo Creek have been examined. In the past, all have been rejected because of high cost of development, poor accessibility, undependable water source or a combination of the above. Figure IV-12 shows the location of these various sources.

Reexamination of these surface water sources shows Tumalo Creek to still be the best source of potable water. Since all of the water in the Tumalo Creek drainage appears to be appropriated, the City of Bend must either purchase or condemn water rights in order to increase the amount they now own.

There are some alternatives that could be considered. The actual amount of water available from the spring that flows into the Bridge Creek diversion canal has not been determined. Only two measurements have been taken. Each diversion pipe is then opened to allow 7 inches of flow through. It is possible for each pipe to allow 12" to pass through. If a sufficient quantity of water is available then it could be possible for that water to be appropriated to the City. Another alternative would be to purchase a large farm with approximately 162 acres of existing water rights, transfer the water rights to the City and then sell the farm as dryland. This would provide an additional 3.2 MGD. A third alternative would be to bring more water into the Tumalo basin. This could be done by extending Crater Ditch or diverting other surface water into the basin. Opposition to this plan by other irrigation districts should be expected. It would be necessary for the City to buy or condemn water from the other districts before they could proceed with an interbasin conveyance.

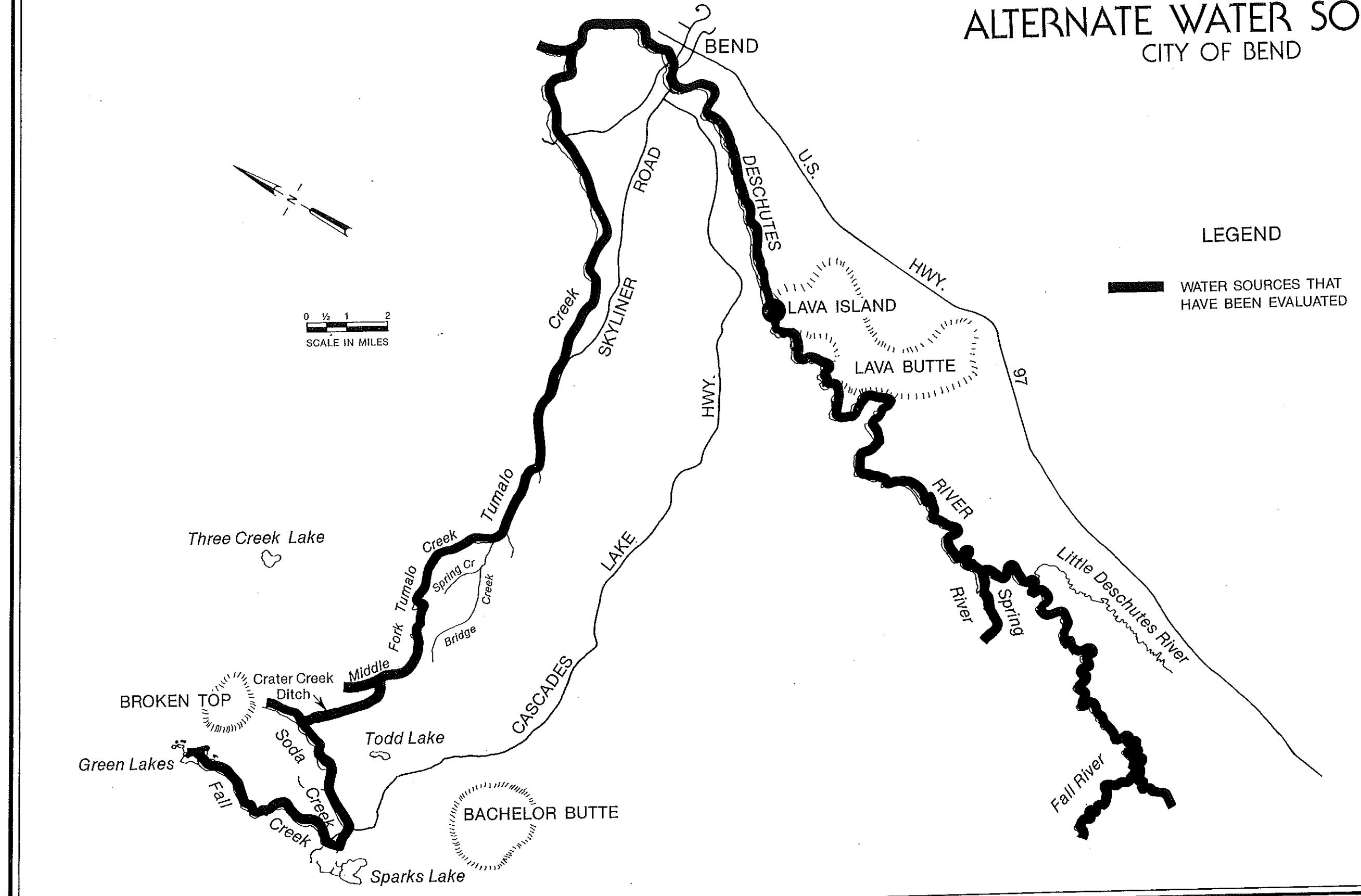
### CONCLUSION

■ The bridge tributary of Tumalo Creek is the best source of potable surface water for the City of Bend.

It appears that approximately 5-6 MGD more water could be obtained from the Bridge Creek Watershed. However, unless future studies demonstrate that more water is available than presently interpreted, Bridge Creek cannot supply the amount of water needed for the City of Bend in the year 2000. It will be necessary for other sources to supply the additional water needed.

■ Management of the Bridge Creek water supply is essential for maintaining its water quality.

FIGURE IV-12  
ALTERNATE WATER SOURCES  
CITY OF BEND



Protection of the Bend Watershed is mandatory. On July 26, 1979, a fire originated about 3/4 miles above the intake structure. Strong southeast winds spread the fire down the canyon so fortunately only 450 acres (11%) of the watershed were burned. Side slopes in this area are very steep at approximately 50-70%. As a result, both the Deschutes National Forest and the City of Bend have found it necessary to make quick decisions to prevent major erosion from taking place.

It was determined that a rain storm of moderate intensity (0.2 inches/hour) would cause extensive damage to the watershed in the burn area. The following preventive measures were taken. Rye grass seeding and fertilizing were done as soon as it was possible. A rainbird sprinkling system was used to encourage germination and root growth. Terracing with falling snags has also been done. These methods will help maintain soil on the slope so that major alteration will not occur to the water characteristics of Bridge Creek. Future management plans are now in the process of being formalized. The interim Fire Management Action Plan is shown in Appendix IV-9.

Several knowledge gaps must be filled to complete the watershed picture. Only then can a management package be designed. The following is a baseline program organized to provide this necessary data.

**PHASE I** - Determination of water available in the watershed. Measurements to be taken over five years.

■ Field measurement - Measure precipitation at five locations (each location at a different elevation).

5,600' - 6,000' - 6,400' - 6,800' - 7,200'

Objective - Analysis of data to determine potential water supply.

■ Field Measurement - Measure stream flow at Spring Creek, Bridge Creek (above intake), and flow at springs above Bridge Creek.

Objective - Determine stream yield and possibility of additional capacity from the Bridge Creek source.

■ Field Measurement - Measure snow pack and its water equivalent (five locations correlated with elevations).

Objective - Determine amount of water from snow available to watershed.

■ Field Measurement - Measure soil moisture (locations according to soil types and elevations).

Objective - Depict trends of soil moisture storage depletion.

■ Field Measurement - Calculate evapotranspiration rates.

Objective - Determine water lost to the atmosphere by way of surface evaporation of stream and soil and transpiration of plants.

■ Field Measurement - Measure forest cover density, reflectivity and interception.

Objective - Determine amount of water yield by vegetation.

# GROUND WATER

## GROUND WATER DESCRIPTION

The City of Bend lies approximately in the central portion of the Deschutes River Basin. The local relief varies considerably and there exists three prominent topographic highs; Awbrey Butte, Overturf Butte and Pilot Butte. These topographic highs represent volcanic vents from episodes of volcanism during the late Plio-Pleistocene epoch about 7.0-1.5 million years ago.

Lava flows and interbedded tuffaceous sediments are believed to underlie this area and are represented by the Clarno Formation. This formation probably underlies the Bend area at depths in excess of 2,000 feet. The John Day Formation represented by ash flows and rhyolitic tuffs is thought to overlie the Clarno Formation.

During the Miocene epoch of geologic time, a massive outpouring of basaltic lavas occurred in the Pacific Northwest and is represented by the flood basalts of the Columbia River Group. Following this massive outpouring, a series of thin basalt lava flows intermixed with ash flow tuffs, ash falls, volcanic detritus, and fluvial deposits were formed. This geologic unit is known as the Madras Formation. The Madras Formation is essentially flat lying with a gentle gradient dipping north. This formation extends to depths of at least 800 feet below the land surface in the Bend area.

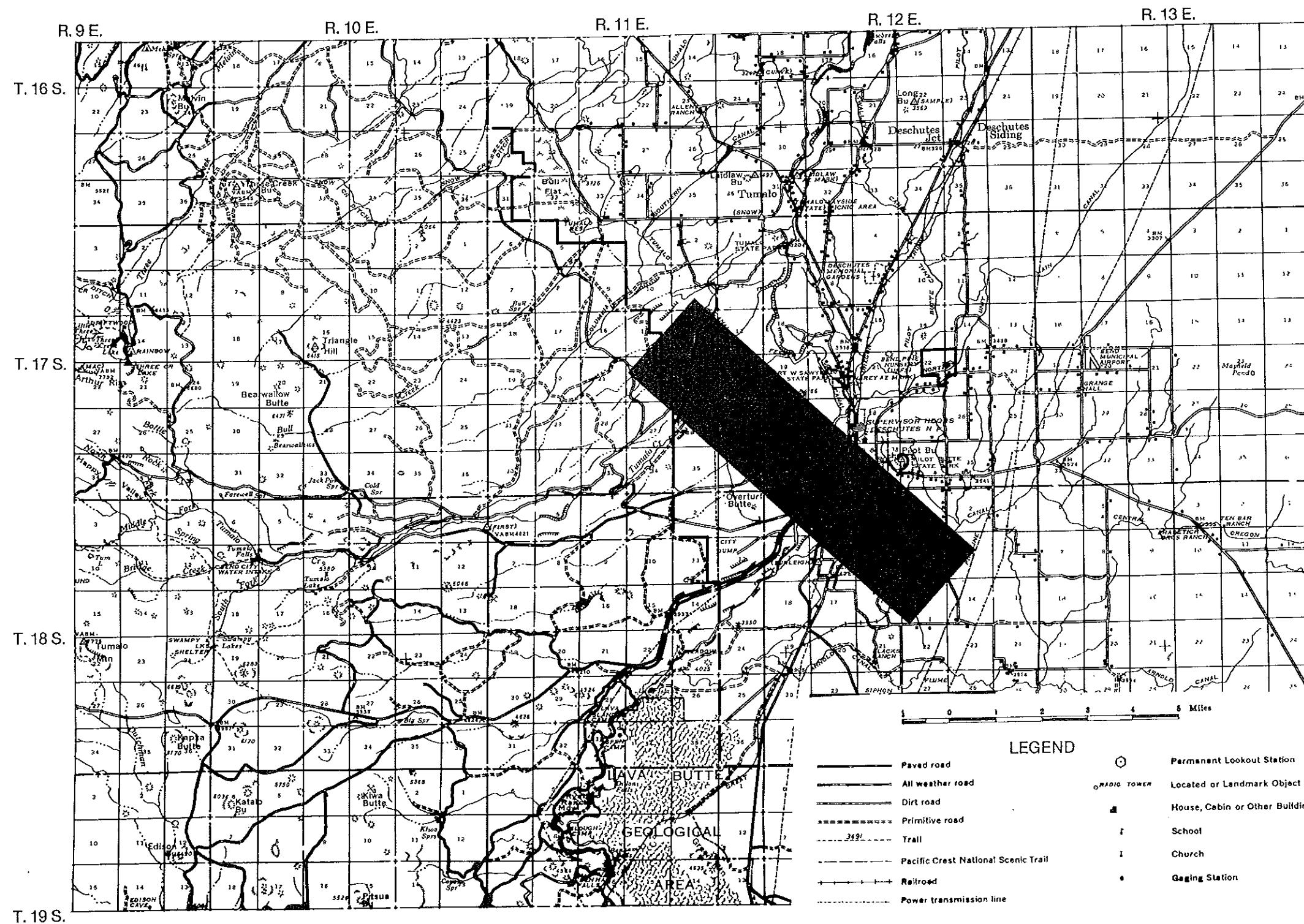
These geologic units work together in forming underlying and overlying confining beds which form aquifers and direct the movement of ground water.

Analysis of more than 100 water well driller's logs shows that possibly nine identifiable aquifers are found from the land surface down to about 1,000 feet through a series of basalt and sedimentary layers. These aquifers provide variable quantities of ground water, but in general transmissivity and permeability tend to increase with depth. This indicates that larger quantities of water probably exist at deeper levels.

The lateral extent of the aquifers is not definite and, in some cases, lateral aquifer boundaries are present in the form of various geologic structures. Faults that are likely associated with the Brothers Fault Zone have been mapped in the general Bend vicinity (Peterson and Grogh, 1974). The mapped fault traces in the City area trend northwest-southeast as indicated on

Figure IV-13. Faulting is significant to ground water conditions in the study area because there is a possibility of aquifer displacements beneath the City of Bend. Potential aquifer offsets are evidenced by variations in water levels that can indicate local, increased ground water gradients that suggest impediment to flow. Additional evidence of fault control of ground water movement in the Bend area is the difficulty encountered in correlating aquifers between the northeast part of the City and aquifers in the southwest part of the City.

FIGURE IV-13  
**BROTHERS FAULTING ZONE**  
BEND AREA



A schematic geologic cross-section from southwest Bend to northeast Bend is shown on Figure IV-14. The cross-section shows important concepts in the interpretation of ground water flow systems and the interrelationship of different permeable geologic units which form individual aquifers.

Each aquifer recognized in the Bend area is identified by different static water levels. In this report each of these aquifers has been designated alphabetically as "A" through "G" with increasing depth. The first and shallowest of these zones is aquifer "A". Aquifer "A" is confined water bearing zone with a potentiometric elevation ranging from 3,400 feet to 3,600 feet above mean sea level. At least seven wells in the Bend area obtain water from this zone. The wells utilized in this report are tabulated in Table IV-4 and the flow net is shown in Figure IV-15.

## FIGURE IV-14 GEOLOGIC CROSS SECTION SCHEMATIC BEND AREA

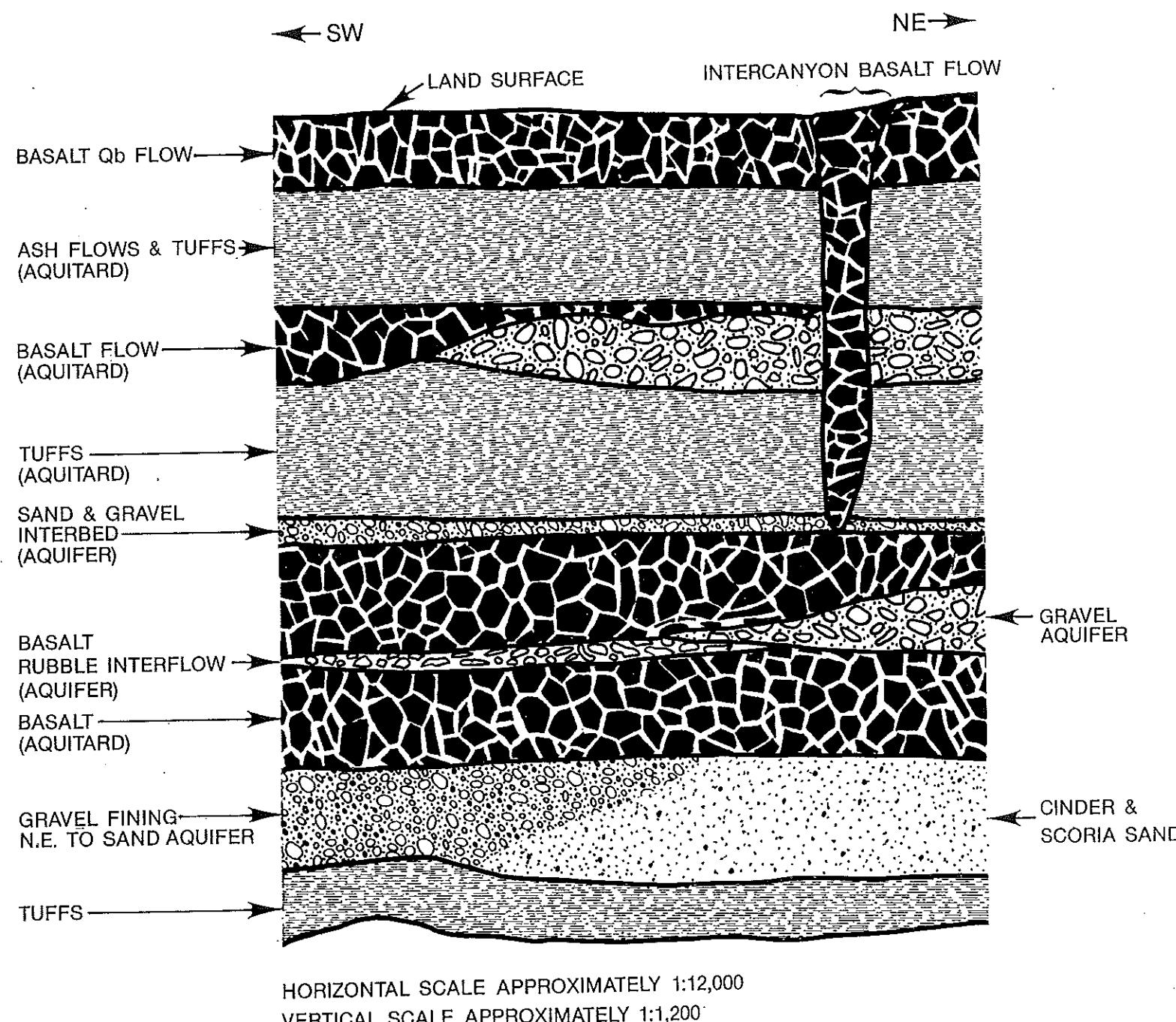


FIGURE IV-15  
AQUIFER "A"  
GROUND WATER FLOW NET

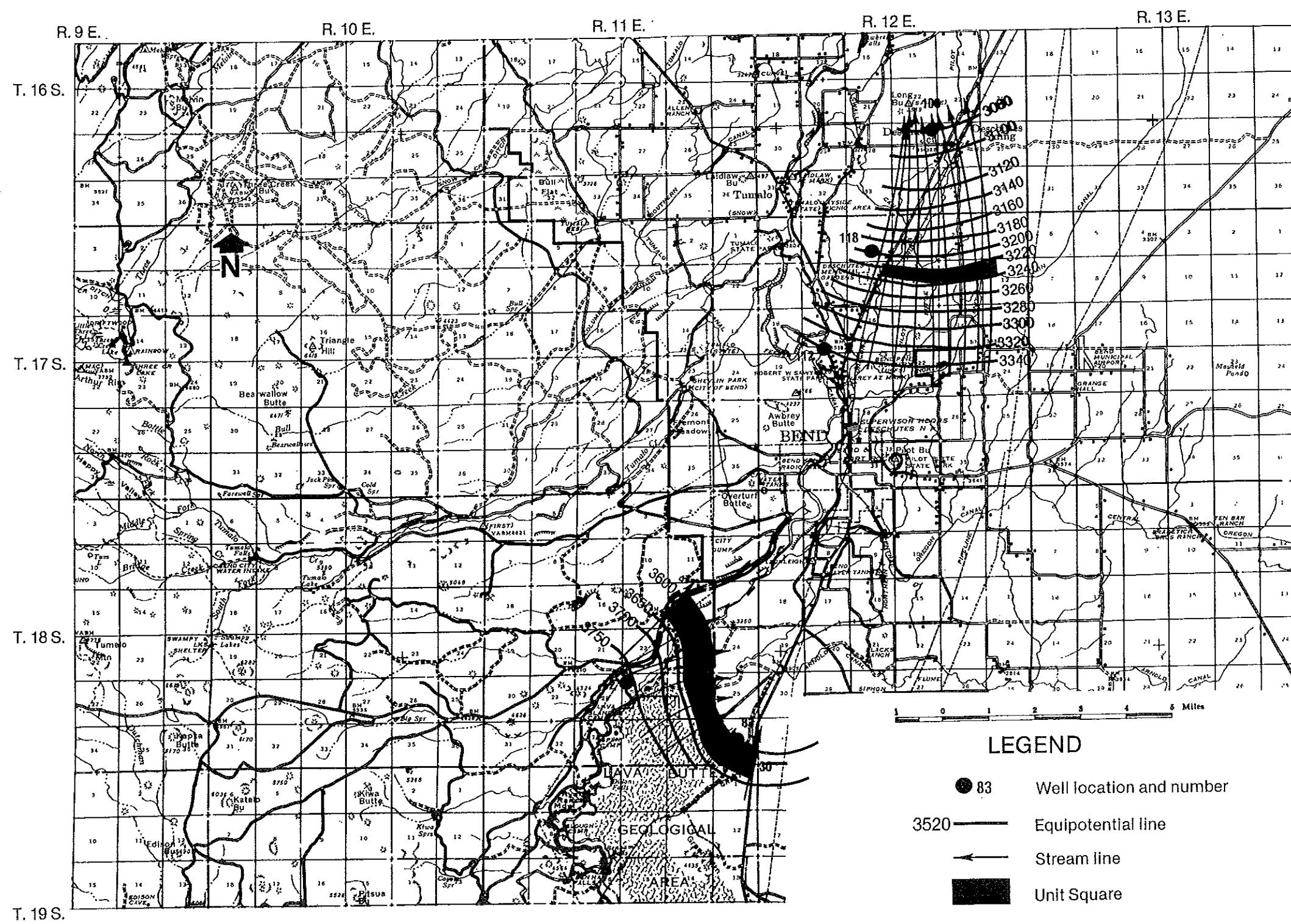


TABLE IV-4  
HYDROGEOLOGIC DATA FOR AQUIFER A  
BEND AREA

Well Code No.	Location T., R., Sec., Sub.	Total Depth (ft.)	Surface Elevation (ft. above MSL)	Static Water Level Elevation (ft. above MSL)	Date SWL Measured	Elevation of Aquifer Top (ft. above MSL)	Ft. of Head Above or Below Aquifer	Transmissivity (gpd/ft.)
30	18S, 11E, 36D	365	3970	3619	7/6/71	3619	0	10,000
52	18S, 11E, 22CD	450	4000	3755	6/18/69	3740	+15	11,300
83	18S, 11E, 36ACBD	359	3940	3600	6/5/79	3585	+15	10,000
100	16S, 12E, 26BBCD	292	3370	3119	11/9/70	3103	+16	20,200
112	17S, 12E, 17DC	194	3520	3342	8/25/62	3345	-3	30,300
117	17S, 12E, 17DA	195	3510	3350	12/14/77	3350	0	40,400
118	17S, 12E, 4D	191	3400	3224	9/19/72	3213	+11	10,100

The next deepest aquifer is aquifer "B". This aquifer has a potentiometric surface elevation ranging from 3,000 feet near Deschutes Junction to a high southwest of the Brothers Fault Zone near the Lava Butte geological area of 3,500 feet above mean sea level. Aquifer "B" serves as a major water source to certain high production wells including the City of Bend Well No.'s 1 and 2 shown on Figure IV-16. Bend's Well No. 1 penetrates aquifer "B" and extends into the underlying aquifer "C", withdrawing water from both systems. Bend's Well No. 2 penetrates only aquifer "B". More than 14 wells penetrate this aquifer and well data used to construct the flow net of aquifer "B" (Figure IV-17) is presented in Table IV-5.

TABLE IV-5  
HYDROGEOLOGIC DATA FOR AQUIFER B  
BEND AREA

Well Code No.	Location T., R., Sec., Sub.	Total Depth (ft.)	Surface Elevation (ft. above MSL)	Static Water Level Elevation (ft. above MSL)	Date SWL Measured	Elevation of Aquifer Top (ft. above MSL)	Ft. of Head Above or Below Aquifer	Transmissivity (gpd/ft.)
2	17S, 11E, 2CDCD	455	3500	3075	8/1/68	3060	+15	200
16	18S, 12E, 20BB	462	3900	3507	12/23/78	3507	0	50,000
19	18S, 12E, 27	492	4000	3530	4/22/67	3530	0	40,000
31	18S, 11E, 25DB	475	3920	3510	8/24/78	3500	+10	2,000
32	18S, 12E, 30B	434	3940	3521	3/22/67	3508	+13	40,000
33	18S, 12E, 19BDD	445	3877	3467	1/13/75	3462	+5	1,000
34	18S, 12E, 20ADAD	463	3860	3445	6/5/74	3440	+5	40,000
35	18S, 12E, 17CB	406	3840	3453	9/29/68	3447	+6	24,000
36	18S, 12E, 18AA	427	3840	3437	11/14/74	3434	+3	30,000
37	18S, 12E, 7CB	408	3780	3402	4/21/70	3400	+2	40,000
39	18S, 12E, 5BBCAD	800	3620	3378	3/21/78	2849	+524	220,000
40	18S, 12E, 5BBCDD	900	3620	3405	4/4/72	3280	+125	10,000
41	17S, 12E, 29	635	3800	3185	3/6/67	3180	+5	4,000
53	19S, 11E, 23DBD	495	3930	3510	10/11/75	3484	+26	8,000
54	18S, 11E, 19DD	445	3890	3470	11/11/78	3480	-10	36,000
55	18S, 12E, 28BD	581	4000	3445	3/16/74	3445	0	222,000
56	18S, 12E, 21ADDB	425	3810	3436	10/2/74	3433	+3	12,000
114	17S, 12E, 9BAD	435	3409	3008	4/25/78	3019	-11	1,000

FIGURE IV-16  
CITY OF BEND WELLS SCHEMATIC

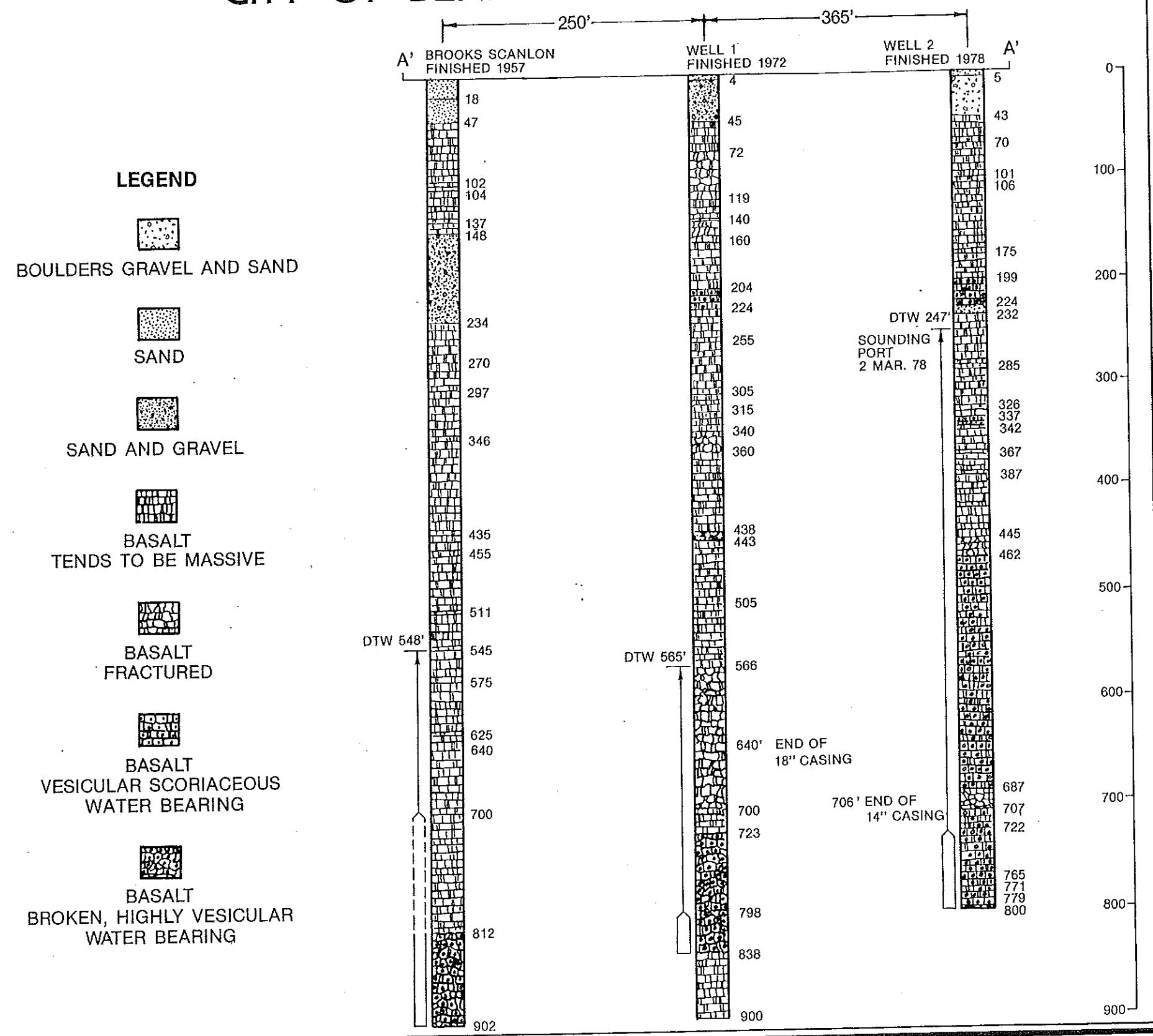
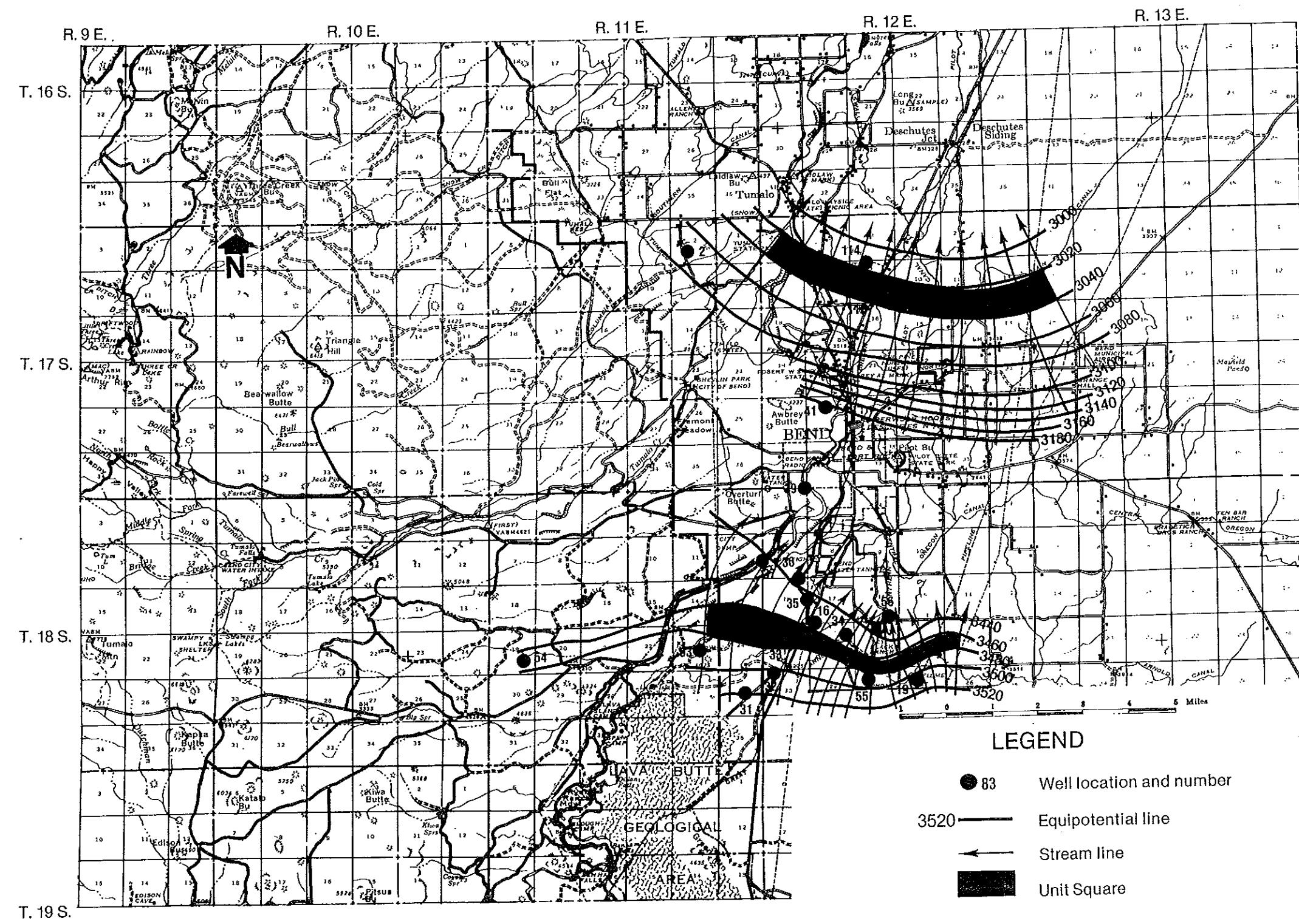


FIGURE IV-17  
**AQUIFER "B"**  
GROUND WATER FLOW NET



Aquifer "C", the third ground water flow zone in the Bend area, is the water source for some of the highest yielding wells including the 900 foot deep Bend Well No. 1. The potentiometric surface for aquifer "C" ranges from approximately 2,900 feet to 3,160 feet above mean sea level. It is not certain if Wells 20 and 40 analyzed in this study penetrate aquifer "C" north of Bend. This uncertainty is due to difficulty in interpreting the subsurface geology which indicates that south of the City of Bend, aquifers "B" and "C" occur in basalt flows, while north of the City, aquifers "B" and "C" occur in sedimentary rock. Additionally, the average hydraulic head in aquifer "C" is much greater south of the City of Bend than north of the City. Wells used in the analysis of aquifer "C" appear on Table IV-6 and the flow net is presented in Figure IV-18.

The fourth aquifer, aquifer "D", has a static water level elevation ranging from approximately 2,800 feet to 3,000 feet above mean sea level. More than a dozen domestic and commercial wells were used to construct the flow net shown on Figure IV-19. Well data for this flow net is shown on Table IV-7.

TABLE IV-6  
HYDROGEOLOGIC DATA FOR AQUIFER C  
BEND AREA

Well Code No.	Location T., R., Sec., Sub.	Total Depth (ft.)	Surface Elevation (ft. above MSL)	Static Water Level Elevation (ft. above MSL)	Date SWL Measured	Elevation of Aquifer Top (ft. above MSL)	Ft. of Head Above or Below Aquifer	Transmissivity (gpd/ft.)
3	17S, 11E, 11DDDB	700	3535	2975	7/10/78	2975	0	16,000
4	17S, 12E, 16CDB	580	3502	3025	5/24/78	2981	+44	10,000
13	16S, 11E, 34CC	610	3510	3000	8/3/78	3000	0	---
20	18S, 12E, 22ADCC	745	3825	3150	11/13/73	3005	+45	1,000
23	18S, 12E, 3DD	690	3690	3050	3/13/74	3055	-5	20,000
24	18S, 12E, 2	720	3660	3005	11/17/71	3000	+5	20,000
40	18S, 12E, 5BBDCC	900	3620	3056	4/4/72	2950	+106	100,000
46	17S, 12E, 9CD	745	3450	2946	2/20/72	2941	+5	40,000
98	16S, 12E, 26CDAC	350	3275	2936	4/30/69	2935	+1	34,000
113	17S, 12E, 20DD	490	3530	3060	11/15/74	3060	0	8,000

TABLE IV-7  
HYDROGEOLOGIC DATA FOR AQUIFER D  
BEND AREA

Well Code No.	Location T., R., Sec., Sub.	Total Depth (ft.)	Surface Elevation (ft. above MSL)	Static Water Level Elevation (ft. above MSL)	Date SWL Measured	Elevation of Aquifer Top (ft. above MSL)	Ft. of Head Above or Below Aquifer	Transmissivity (gpd/ft.)
14	16S, 11E, 35AAD	682	3385	2845	9/2/76	2788	+57	6,000
21	18S, 12E, 23BBB	785	3740	2978	8/28/75	2975	+3	14,000
28	17S, 12E, 14BDACA	571	3415	2883	6/6/78	2872	+11	20,000
46	17S, 12E, 9CD	745	3450	2865	2/20/74	2762	+103	40,000
82	17S, 13E, 19CCADB	678	3490	2892	8/20/76	2850	+42	16,000
84	17S, 13E, 30BAB	630	3500	2910	9/6/73	2900	+10	30,000
85	17S, 13E, 20ACCBB	600	3423	2893	9/10/74	2883	+10	8,000
90	17S, 13E, 27CBB	565	3430	2891	4/11/67	2890	+1	8,000
104	16S, 12E, 23B	510	3300	2830	2/8/78	2830	0	15,000
110	17S, 12E, 4AC	670	3420	2784	5/10/72	2762	+22	1,200
119	17S, 12E, 4DA	649	3400	2818	10/20/77	2820	-2	20,000
122	17S, 12E, 34B	706	3610	2934	10/16/70	2925	+9	---
123	17S, 12E, 26CC	640	3570	2950	8/25/69	2950	0	44,000
124	17S, 12E, 23DBC	637	3498	2911	2/14/74	2914	-3	24,000
125	17S, 12E, 23DB	606	3500	2911	3/14/67	2914	-3	40,000
127	17S, 12E, 23DD	601	3500	2930	2/15/70	2922	+8	30,000
129	17S, 12E, 23DAA	630	3477	2896	4/4/72	2890	+6	212,000
130	17S, 12E, 25DD	665	3560	2915	6/22/66	2913	+2	38,000
131	17S, 12E, 16ABDB	650	3450	2950	5/8/75	2840	+110	1,000

FIGURE IV-18  
AQUIFER C  
GROUND WATER FLOW NET

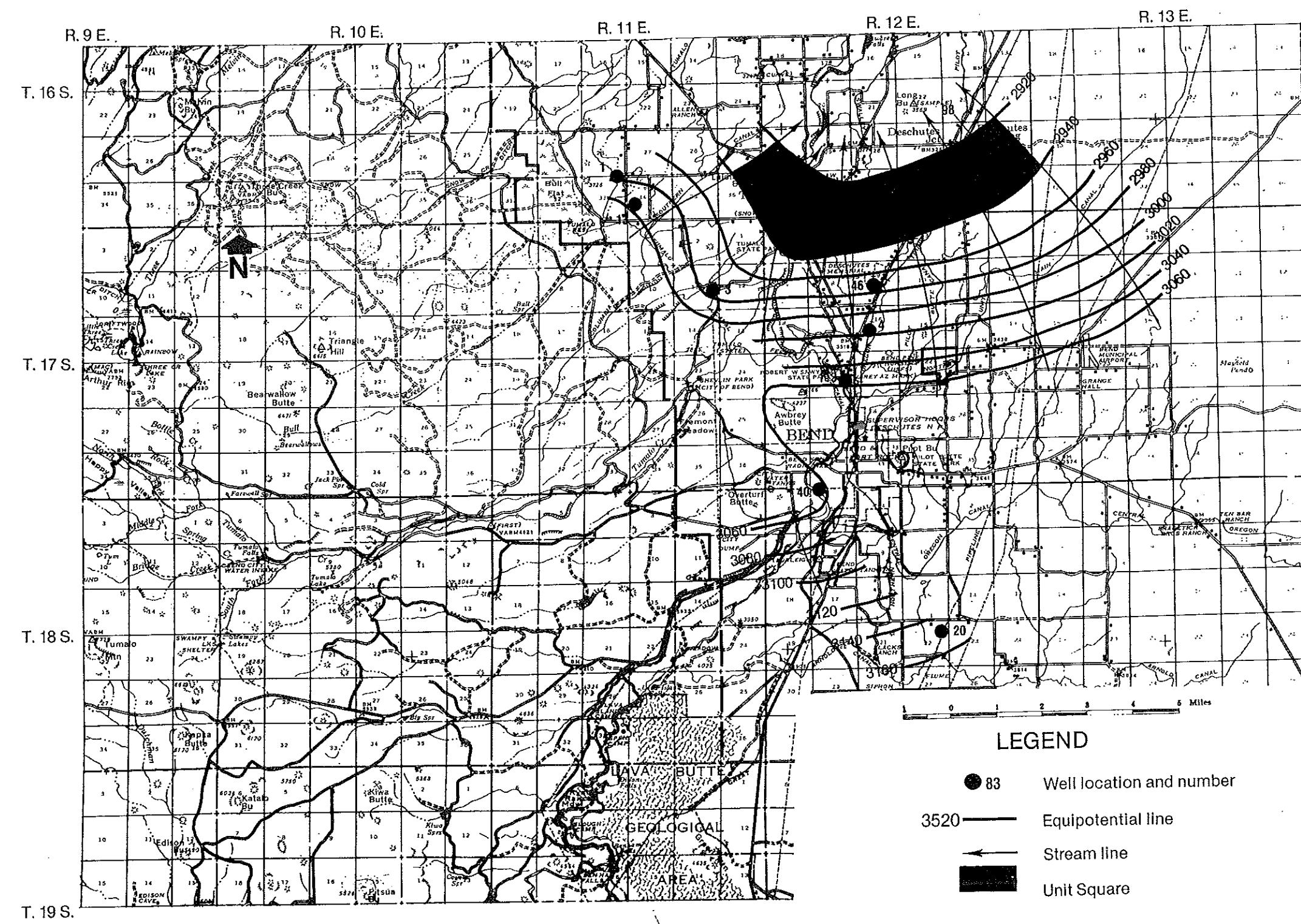
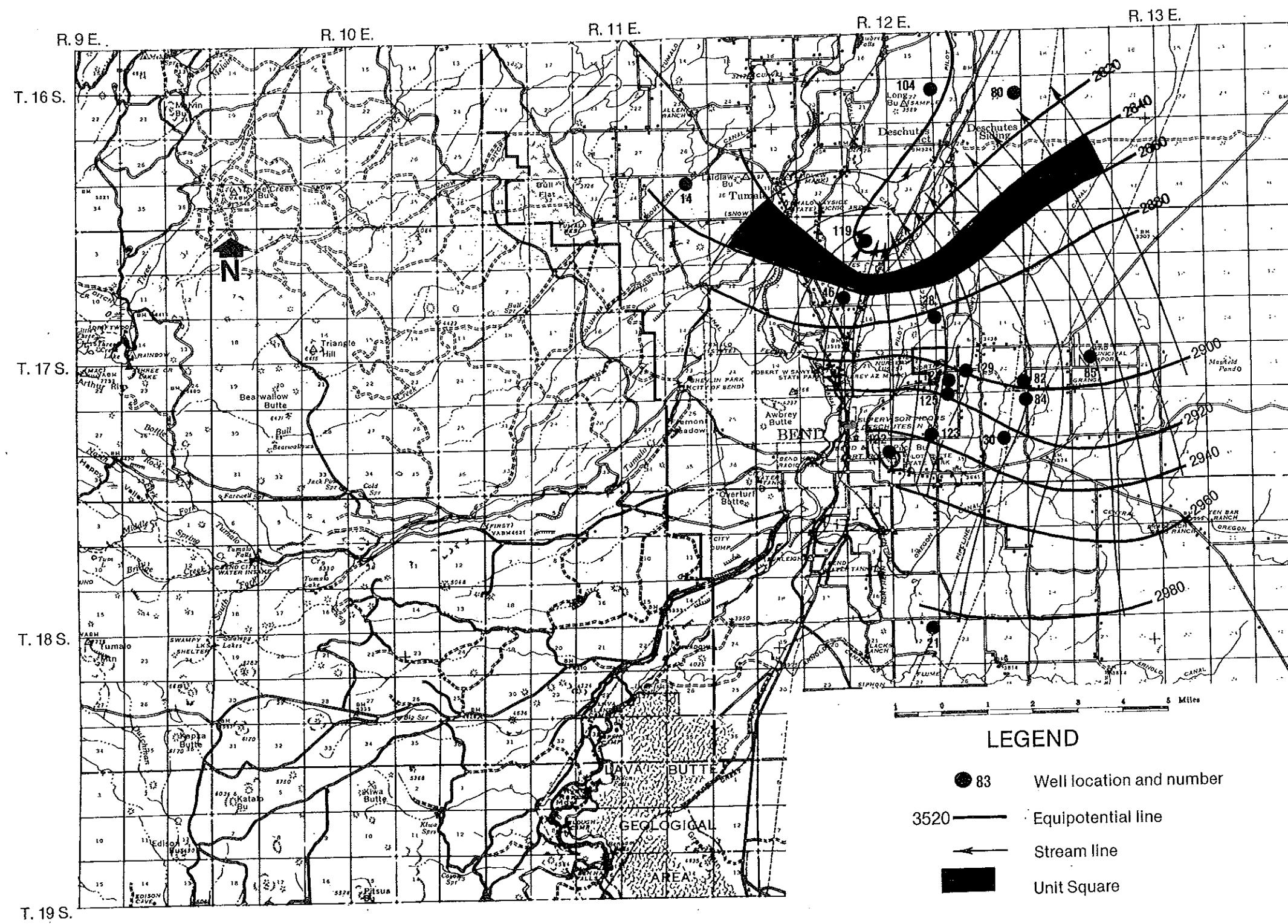


FIGURE IV-19  
AQUIFER "D"  
GROUND WATER FLOW NET



The fifth deepest aquifer is designated aquifer "E", and ranges from 2,740 feet to 2,860 feet above mean sea level. No well data was available or correlatable for aquifer "E" southwest of the City of Bend. Data used is shown in Table IV-8 and the flow net is shown on Figure IV-20.

Only four wells northeast of Bend were available for analysis of aquifer "F". The potentiometric elevation ranges from 2,680 feet to 2,760 feet which represents one of the most gentle hydraulic gradients of the nine recognizable aquifers. Figure IV-21 shows the flow net developed from the data in Table IV-9.

TABLE IV-8  
HYDROGEOLOGIC DATA FOR AQUIFER E  
BEND AREA

Well Code No.	Location T., R., Sec., Sub.	Total Depth (ft.)	Surface Elevation (ft. above MSL)	Static Water Level Elevation (ft. above MSL)	Date SWL Measured	Elevation of Aquifer Top (ft. above MSL)	Ft. of Head Above or Below Aquifer	Transmissivity (gpd/ft.)
6	16S, 11E, 24CAACA	624	3270	2775	6/18/74	2775	0	5,000
7	16S, 12E, 18ACA	560	3225	2755	3/8/74	2735	+20	14,000
10	16S, 12E, 28AB	690	3360	2750	12/2/75	2750	0	6,000
11	16S, 12E, 29DA	585	3280	2763	12/23/72	2742	+21	3,000
12	16S, 12E, 35DD	570	3285	2745	8/21/67	2735	+10	8,000
17	16S, 12E, 7BDD	525	3200	2710	12/11/78	2710	0	20,000
18	16S, 12E, 8C	485	3180	2707	2/6/69	2707	0	---
22	17S, 12E, 15BBA	750	3460	2754	12/4/73	2730	+24	12,000
27	17S, 12E, 5BC	900	3360	2763	9/20/78	2510	+253	18,000
42	17S, 12E, 20ACB	815	3540	2761	12/14/70	2756	+5	20,000
44	17S, 12E, 21ABBB	780	3510	2758	10/1/71	2750	+8	14,100
45	17S, 12E, 9ABD	735	3410	2748	7/12/72	2720	0	10,100
47	16S, 12E, 10CCABB	485	3180	2720	9/20/77	2764	+1	10,100
49	16S, 12E, 11ADDBA	440	3155	2765	12/18/78	2700	+30	2,000
51	16S, 12E, 14DDADD	530	3210	2730	6/22/73	2792	+43	---
81	17S, 13E, 16ACD	594	3375	2835	6/5/79	2837	+22	20,000
86	17S, 13E, 21AAACC	553	3355	2859	12/29/72	2860	+5	16,000
88	17S, 13E, 28DAD	600	3440	2865	12/2/73	2816	0	10,000
92	17S, 13E, 22BBBBB	573	3350	2816	2/3/76	2775	+35	10,000
93	17S, 13E, 22BCA	615	3350	2810	7/30/75	2694	+68	20,000
99	16S, 12E, 2BDDB	620	3264	2762	9/27/73	2700	+30	30,000
101	16S, 12E, 23CD	650	3320	2730	2/7/78	2700	+50	20,000
102	16S, 12E, 23CA	630	3320	2750	1/27/78	2742	+14	---
105	16S, 12E, 26BBBD	590	3270	2756	2/13/79	2752	+6	30,000
106	16S, 12E, 14B	4444	3160	2758	10/1/70	2741	0	16,000
107	16S, 12E, 12CCBC	437	3150	2741	6/24/77	2720	+42	18,000
108	16S, 12E, 30DAAAA	528	3210	2762	6/14/75	2701	+39	1,600
109	16S, 12E, 2DDCC	490	3150	2740	7/27/76	2761	0	20,000
111	17S, 12E, 20AC	815	3540	2761	12/14/70	2741	0	3,000
120	16S, 12E, 26CCD	585	3255	2741	1/12/79	2775	+5	6,000
121	17S, 12E, 28AC	800	3560	2780	9/24/71	2775	0	

FIGURE IV-20  
AQUIFER "E"  
GROUND WATER FLOW NET

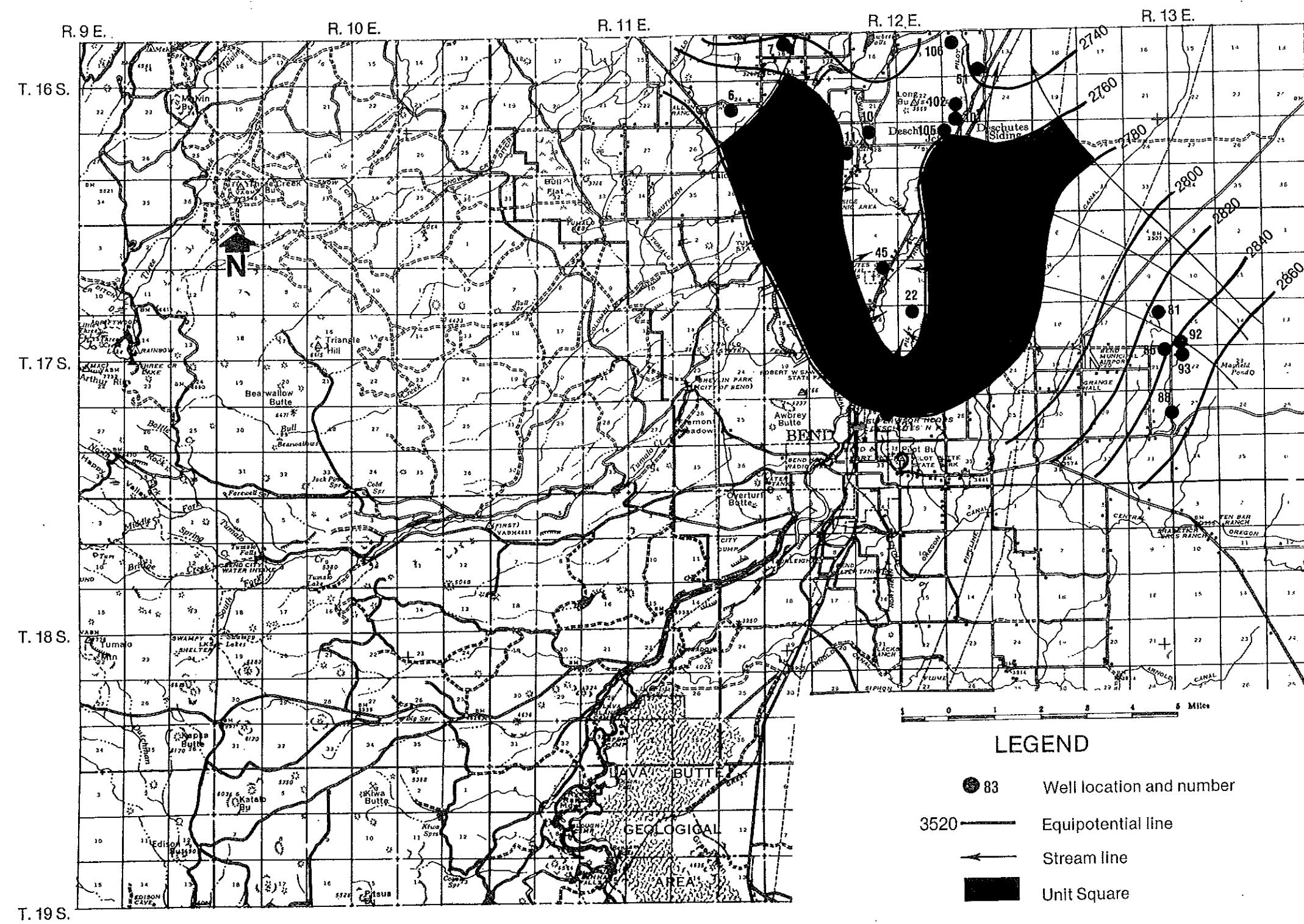
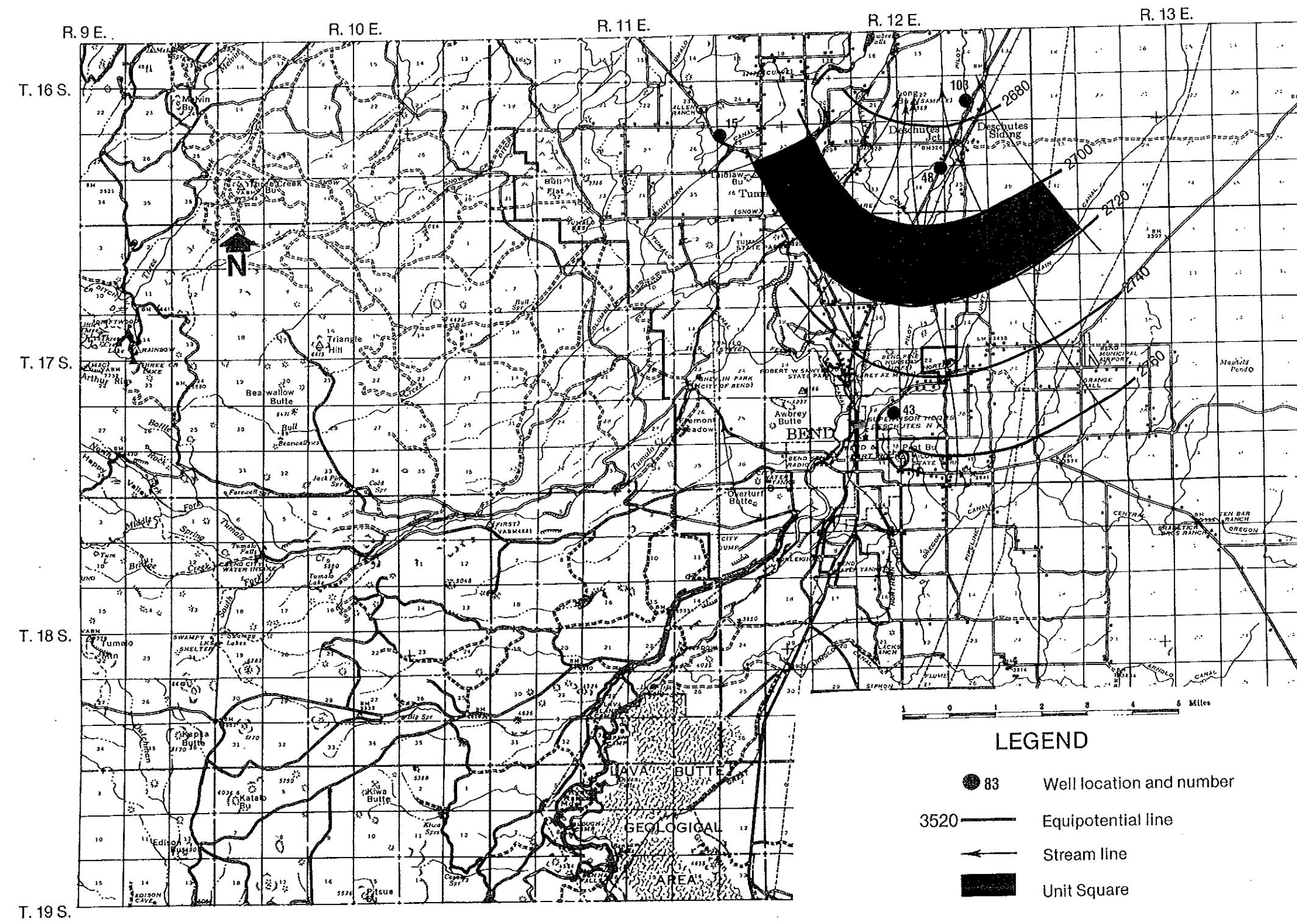


FIGURE IV-21  
AQUIFER "F"  
GROUND WATER FLOW NET



Aquifer "G", the seventh ground water flow zone in the Bend area, is the water source for only three known wells. Among the wells withdrawing ground water is the U.S. Forest Service nursery well. The flow net for aquifer G is shown on Figure IV-22.

Insufficient data was available to construct flow nets for aquifers "H" and "I". Wells analyzed for aquifers F, G, H and I are shown in Table IV-9.

## EXISTING CONDITIONS OF GROUND WATER AND SUPPLY

Large quantities of water apparently are present within the Bend area. The ground water appears to be transmitted in buried river channels and under volcanic clastic deposits. The direction of the ground water flow generally parallels the direction of the surface water flow in the Deschutes River Basin. The highest yielding ground water aquifers appear to be those associated with basalt flows, where ground water occurs in basalt rubble at the top and bottom of individual basalt flows. Some of the deep wells northeast of Bend obtain ground water from this source.

Currently, the City of Bend has two wells located in the southeast portion of the city. These wells are used as backup water sources primarily during the summer irrigation season when the Tumalo supply is not sufficient to meet the City's needs. The City wells, located near a Brooks-Scanlon well can supply approximately 5.7 MGD. City Well No. 1 was drilled in 1972 to a depth of 900 feet with a static water level 563 feet below land surface.

City Well No. 2 was drilled in 1978, 365 feet north of Well No. 1. Well No. 2 was drilled to a depth of 800 feet and a static water level 247 feet below the surface was recorded after drilling. Pump tests were performed on both the City wells and the Brooks-Scanlon well, which was drilled to 900 feet below the surface and had a static water level 563 feet below the surface. City Well No. 1 was pumped at 1,840 GPM. City Well No. 2 is 100 feet shallower than Well No. 1 and the Brooks-Scanlon well, and is in a different confined aquifer. Well No. 2 can produce 2,000 GPM with a drawdown of about 190 feet. There is no reliable pumping information for the Brooks-Scanlon well.

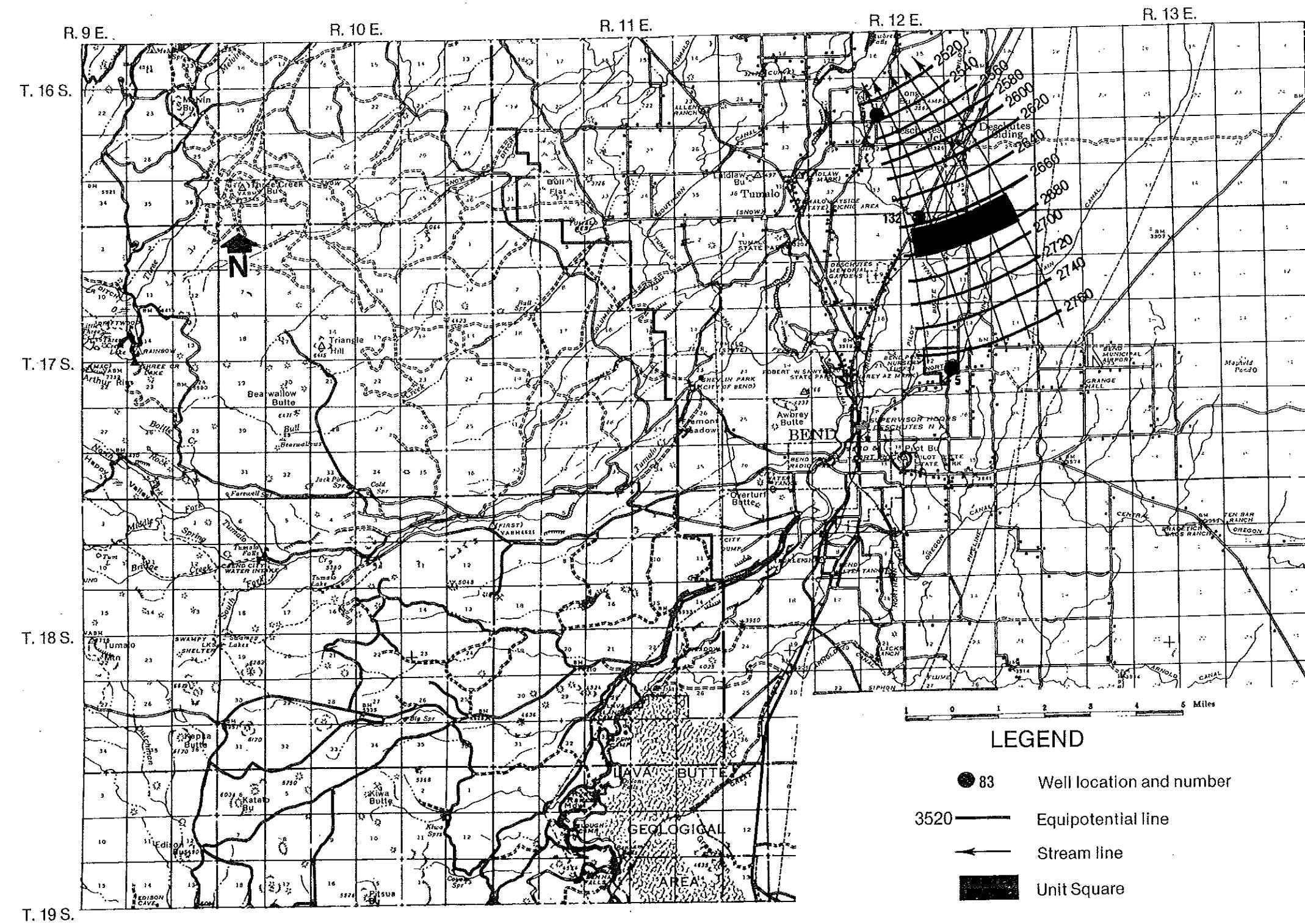
TABLE IV-9  
HYDROGEOLOGIC DATA FOR AQUIFERS F, G, H, & I  
BEND AREA

Well Code No.	Location T., R., Sec., Sub.	Total Depth (ft.)	Surface Elevation (ft. above MSL)	Static Water Level Elevation (ft. above MSL)	Date SWL Measured	Elevation of Aquifer Top (ft. above MSL)	Ft. of Head Above or Below Aquifer	Transmissivity (gpd/ft.)
15	16S, 11E, 26AAABA	695	3400	2726	8/15/69	2721	+5	14,000
43	17S, 12E, 29ACBDD	822	3570	2748	9/24/71	2770	-22	6,000
48	16S, 12E, 27DD	682	3270	2655	8/29/74	?	--	10,000
103	16S, 12E, 23BD	660	3300	2680	10/21/77	2660	+20	---
5	17S, 12E, 23BC	1057	3485	2767	2/16/77	2476	+291	292,000
9	16S, 12E, 21DC	695	3180	2530	10/3/69	2570	-40	151,000
132	17S, 12E, 3BAABA	670	3320	2660	3/31/79	2660	0	20,000
26	17S, 12E, 35CCC	622	3040	2430	7/24/75	2425	+5	10,000
25	17S, 12E, 34A	719	2947	2289	11/9/70	2277	+12	8,000

No measurable influence on the City Well No. 1 static water level was noted during the 24 hour pump test performed on Well No. 2. The lack of pumping influence in such a relatively short distance may indicate that separate aquifer systems are tapped by the two wells or that the transmissivity (resistance of rock to the movement of ground water) of the aquifer penetrated by these two wells is high enough that the cone depression created by ground water withdrawal from Well No. 2 did not extend for 365 feet to Well No. 1. Due to the static water levels for Wells No's. 1 and 2 being substantially different, it is our opinion that the two wells penetrate separate aquifers. Aquifers in lava terrain are often the pervious interflow zones between lava flows, or pervious sand/gravel deposits between lava flows, therefore it is conceivable to have isolated water bearing zones which may be under different pressure conditions. Thus, it is possible that Well No. 1 penetrated a high pressure water bearing zone isolated from underlying water bearing zones by less permeable basalts. The pressure conditions in the aquifer result in the high static water level in the well bore. City Well No. 1 was drilled an additional 100 feet deeper than Well No. 2 and may have gone through a confining medium beneath

the water bearing zone for Well No. 2 into a lower permeable water bearing zone with lower pressure conditions. Potential lower pressure conditions in a deeper water bearing zone may result in a net static water level lower than that recorded for Well No. 2 in the shallower water zone.

FIGURE IV-22  
AQUIFER "G"  
GROUND WATER FLOW NET



The general quality of the ground water in the Bend regional area is well within the present Federal Environmental Protection Agency (EPA) drinking water quality standards. The results of tests performed on ground water samples from 20 wells in the Bend-Redmond area by a local consultant indicate higher total dissolved solids values than reported by the EPA for the same sample points 12 years earlier. Test results measured in 1978 for inorganic contaminants are shown for Wells No. 1 and No. 2 in Table IV-10.

TABLE IV-10  
INORGANIC TEST 1978  
WELL NO. 1

<u>Inorganic Contaminant</u>	<u>Test Results</u>	<u>Maximum Allowable Concentrations</u>
Arsenic	0.005 mg/l	0.05 mg/l
Barium	0.00 mg/l	1.0 mg/l
Cadmium	0.000 mg/l	0.010 mg/l
Chromium	0.000 mg/l	0.05 mg/l
Flouride	0.06 mg/l	1.8 mg/l
Lead	0.000 mg/l	0.05 mg/l
Mercury	0.000 mg/l	0.002 mg/l
Nitrate (AS N)	0.40 mg/l	10 mg/l
Selenium	0.000 mg/l	0.01 mg/l
Silver	0.000 mg/l	0.05 mg/l

## WELL NO. 2

<u>Inorganic Contaminant</u>	<u>Test Results</u>	<u>Maximum Allowable Concentrations</u>
Arsenic	0.010 mg/l	0.05 mg/l
Barium	0.10 mg/l	1.0 mg/l
*Cadmium	0.010 mg/l	0.010 mg/l
Chromium	0.005 mg/l	0.05 mg/l
Flouride	0.18 mg/l	1.8 mg/l
Lead	0.010 mg/l	0.05 mg/l
*Mercury	0.001 mg/l	0.002 mg/l
Nitrate (AS N)	0.36 mg/l	10 mg/l
Selenium	0.005 mg/l	0.01 mg/l
Silver	0.010 mg/l	0.05 mg/l

A discernable degree of water quality degradation is apparent for a limited number of wells 250 feet or less in depth north of Bend. Data to indicate water quality degradation has occurred in the deeper aquifers beneath Bend is not evident.

## FUTURE SOURCE OF GROUND WATER

The City of Bend can currently supply 17 million gallons of water per day from the two city wells and the Tumalo supply. An additional 15 MGD will be required to meet the demand of the year 2000 population projection of 45,000 people if existing consumption rates continue. Additional surface water sources are indefinite at this time and it is conceivable additional water will be extracted from ground water sources.

Available test data about the hydrologic parameters of each of the identified aquifers are of a reconnaissance nature, but analysis of all the data yields general information of a relatively consistent nature. Transmissivity data is shown in Figure IV-23, and is one of the most important characteristics for determining availability of ground water.

Transmissivity readings appear to increase with depth, indicating the presence of more water. Although aquifers "B" and "C" appear to have the highest production rates based on the data available from wells located in the southwest portion of the City, aquifers "D", "E", "F", "G", "H", and "I" have tremendous potential for yielding large quantities of palatable ground water also. The presence of the Brothers Fault Zone transecting the geologic units within the Bend city limits and the close proximity of Pilot, Over-turf and Awbrey Buttes makes accurate predictions of ground water development difficult using existing data.

## CONCLUSIONS

Upon reviewing geologic and hydrologic data for the City of Bend, Oregon certain conclusions may be drawn about the ground water resource of the area. One obvious conclusion is the definite need for more precise geologic and especially hydrologic information. Data such as sampling of well cuttings, borehole logging and accurate aquifer testing of existing and new city wells would provide some of the needed information. These data should become a part of the permanent record of Bend's ground water development so that a more accurate understanding of the hydrology of the area can be used to guide site selection and design of future wells.

Although information from local pump companies suggest continuing declines in ground water levels for wells that penetrate some aquifers discussed in this report, other data indicates a sufficient quantity of ground water is available without declining water levels. This latter group of wells generally penetrate deeper aqui-

fers. Thus, if the City of Bend constructs new wells to increase its water supply source, these wells should penetrate the deeper aquifers and could be spaced and pumped at rates that will not result in "mining" ground water.

Hydrologic data from several deep aquifers indicate that future municipal wells should be between 800 and 1,100 feet deep, depending upon the elevation of the land surface at each well site. It should be anticipated that each of these wells may produce as much as 2,000 gallons per minute with acceptable amounts of drawdown.

The area of the existing Bend city wells, the east central Bend area, i.e., Juniper Park and areas northeast of the City, are favorable locations for future wells relative to water quantities and minimized well depths. Ground water resources for City development are unknown to the northwest due, in part, to the uncertain effects of the Awbrey Butte complex on the aquifer systems. Higher ground surface elevations in the areas southeast of the City may require deeper wells to reach the high yield aquifers.

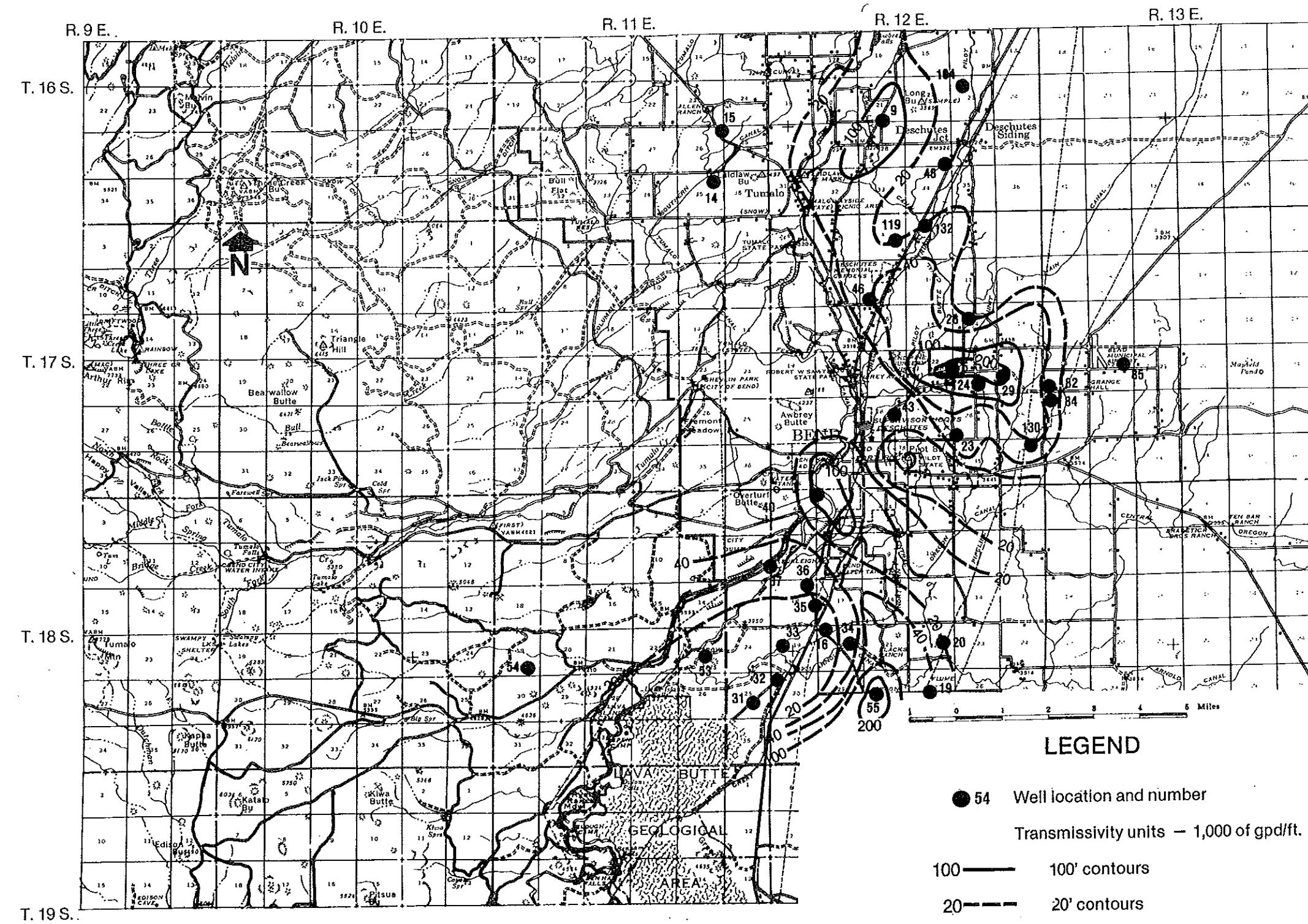
The quality of ground water in the Bend area is within current EPA drinking water quality standards. Though some discernable degradation of water quality is apparent in a limited number of wells north of Bend shallower than 250 feet, it is unlikely that quality degradation has occurred in waters of the deeper aquifer systems beneath Bend.

## RECOMMENDATIONS

Test data and geology from driller's logs show the City of Bend's ground water resource to be a viable supplement to the present subsurface and surface water supply obtained from springs near Tumalo Falls and from deep wells in the southwest corner of the City limits. Should ground water be accepted as the most feasible source for the City of Bend's future water needs, data should begin now to be collected from existing city wells and observation wells as follows:

- Take monthly readings of the volume of water withdrawn from each of the existing wells;
- Measure the depth to either static or pumping water level in each of the wells once a month;

FIGURE IV-23  
TRANSMISSIVITY MAP  
DEEP HIGH PRODUCTION AQUIFERS



■ Additionally, all new wells to be drilled by the City of Bend, data should be gathered as follows:

- During drilling, cuttings should be collected at 10-foot intervals;
- Electric borehole logs should be made of all new wells;
- Pump tests should be made to determine the efficiency and hydrologic parameters of ground water conditions in all new City wells.

In general, if additional wells are drilled near the existing City of Bend water supply wells in the southwest portion of the City, either aquifer "B" or "C" should be penetrated as the most acceptable water supply source. If, however, sites are selected in the eastern or northeastern portion of the City, then the wells should be drilled at least 900 feet to fully penetrate aquifers "G", "H" or "I".

Wells should be drilled in areas exceeding transmissivities of 40,000. The current positioning of the two City water supply wells and the Brooks Scanlon well is adverse, in that maximum interference between wells occurs. The positioning of wells is best guided by ground water flow lines shown on Figures IV-15 through 22. Municipal supply wells are best positioned roughly parallel to ground water equi-potential contours and perpendicular in ground water stream lines, which are shown on the aforementioned figures by thin lines marked by arrows. To position the wells otherwise would increase the groundwater gradient by placing wells up gradient from each other, and substantially increase the amount of drawdown, thus reducing the efficiency of each well.

Because of the importance of the ground water stream lines in the southwest portion within the City limits, the City of Bend should safeguard its ground water supply by prohibiting the drilling the many new wells which penetrate the same aquifer upgradient or approximately south, southwest of the location of the existing water supply wells. In addition, an area of concern should be the limitation of industrial development as much as five miles to the south of the water supply wells to protect them against the discharge of pollutants by injection wells, so that the quality of ground water flowing in the Bend area remains at its present high standard.

All of the above recommendations are based upon our estimate of the hydrologic characteristics of the ground water of the nine known aquifers in the Bend area.

#### REFERENCES CITED:

Tanaka, H. H., Hansen, A. J., Jr., and Skrivan, J. A., (1974), Digital-Model Study of Groundwater Hydrology, Columbia Basin Irrigation Project Area, Washington, Washington State Department of Ecology, Water Supply Bulletin 40, Olympia, Washington, 60 pages, 45 illus., 4 tables.

Peterson, Norman V., Grogh, Edward A., and Stensland, Donald E., (1976), Geology and Mineral Resources of Deschutes County, Oregon, State of Oregon, Department of Geology and Mineral Industries, Bulletin 89, Portland, Oregon, 66 pages, 60 illus., 4 maps.

## STATE AND FEDERAL REGULATIONS AND COMPLIANCES

Regulatory agencies are now examining the problems of trace organics in public drinking water. As a result, proposals are being adopted for establishing maximum contaminant levels for trihalomethanes and requiring granular activated carbon treatment for vulnerable water supplies. Measurements and treatment processes are controversial, but must be considered since requirements will need to be met in the future.

The expected requirements are as follows:

- Maximum allowable level for trihalomethane will be 0.1 mg/l.
- Community systems greater than 75,000 population will monitor trihalomethane three months after promulgation. Twenty samples a year will be tested and an annual average determined.
- Community systems 10,000-75,000 population will monitor six months after promulgation. One sample per year will need to be tested.

Since Bend's water source is in a noncontaminated area, the granular activated carbon process will not be necessary. Anticipated results from yearly tests of trihalomethane should be well below acceptable levels. If for some unforeseeable reason removal of trihalomethane is necessary, an alternate disinfectant other than chlorine will need to be used or regular water treatment will have to be modified.

## SUMMARY

Both surface water and ground water sources are available to meet the City of Bend's future water demand. The following numbers represent the present value of the initial and periodic costs of each alternative at a 9% cost of capital. Refer to Appendix IV-10 for a detailed breakdown of these costs.

### ALTERNATIVE I — DEEP WELLS

Data indicates that good quality water is available in sufficient quantities from ground water below 900 feet. Assuming a 1,000 ft. deep well, total capital cost for one well producing 2.8 MGD

Present Worth \$3,718,000

### ALTERNATIVE II — NEW 18" PIPE

Data indicates that more water exists in the Bridge Creek source than is being used. By installing a new 18" diameter pipe from Bridge Creek into town an additional 9 MGD could be supplied.

Present Worth \$5,207,000

### ALTERNATIVE III — RAW WATER STORAGE RESERVOIR

This alternative consists of building a 100 MG raw water storage reservoir at the current overflow site with a 9.5 MGD filter treatment plant to purify the water.

Present Worth \$7,296,000

### ALTERNATIVE IV — RANNEY COLLECTOR

Install a Ranney collector system along the Deschutes River. Ranney collectors function by uptaking or storing water filtered through sand near a river or any other area with a near surface water table. This alternative could provide between 9.5 and 10 MGD.

Present Worth \$3,629,000

### ALTERNATIVE V — FILTER TREATMENT PLANT

Install a filter treatment plant along the Deschutes River providing 9.5 MGD.

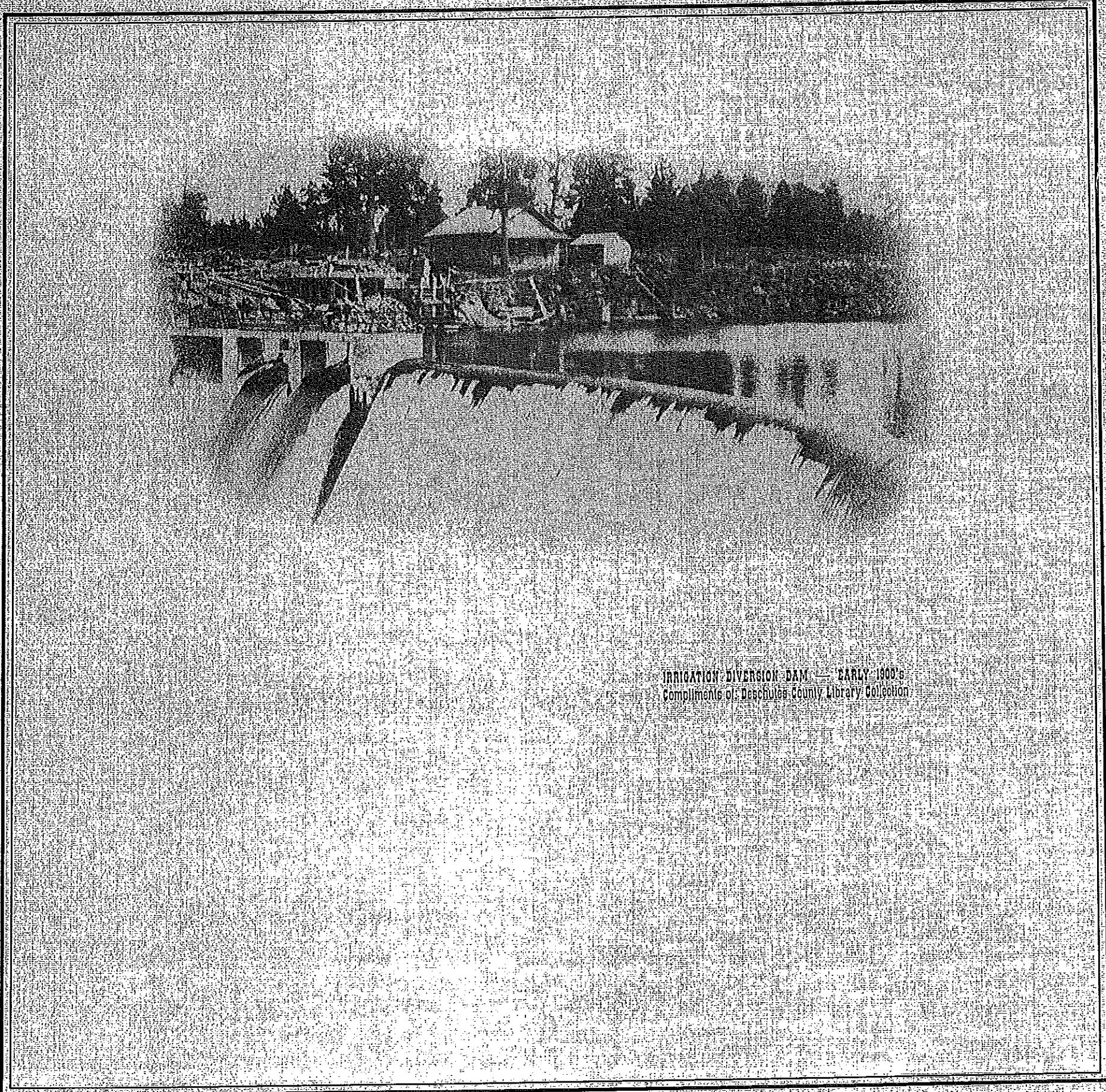
Present Worth \$5,575,000

As the Hydraulic Analysis and Land Use and Consumption sections show, the next increment of source capacity is needed in 1985-86. Prior to this time, a Ranney collector feasibility study should be undertaken. If they do prove feasible, a suitable location can be obtained and adequate water rights procured, then the Ranney collector system should be constructed. If the study does not prove Ranney collectors as a viable alternative, then deep wells should be sequenced as shown in the Hydraulic Analysis Section. For financial analysis, deep wells were assumed to be the most viable alternative.

From a present worth analysis, Alternatives I, deep wells, and IV, Ranney collectors, appear to be the most feasible solution to meeting the City's future water needs.

Wells will provide the City with 2.8 MGD per well which would allow the City to gradually increase its supply as needed. Several locations appear feasible for well development including the City's existing well field and other areas to the east and northeast. Land acquisition and ground water rights do not appear to pose any problems. Some public concern may be anticipated from towns north of Bend if large quantities of ground water were suddenly withdrawn.

Alternative IV, Ranney collectors, also appear economically feasible. Ranney collectors operate best when they are installed near rivers with large sandy deposits allowing water to seep through. The Ranney system pumps water up from the ground and distributes it into the existing water system. The filtering effect of the sand and gravel is essential for the proper operation of the system. Several areas along the Deschutes River appear to offer suitable locations for the Ranney collector. However, extensive site feasibility studies would be necessary. Land acquisition does not appear to be a problem, although water rights would have to be purchased.



IRRIGATION DIVERSION DAM — EARLY 1900's  
Compliments of Deschutes County Library Collection

## WATER METER EVALUATION

Chapter V

# WATER METER EVALUATION

## HISTORY

This section describes the history of the water meter issue and the alternatives the Bend City Commission considered. On October 17, 1979, the Commission requested that Century West analyze Alternative II in-depth. Century West did so, and at its meeting of February 20, 1980, the City Commission voted to accept Alternative II. To finance Alternative II, the City Commission voted to accept a combination of Options 1 and 3. For an explanation of the various alternatives and options, see the following text.

The City Commission adopted the recommendation of the Sewer and Water Committee to commit to metering the unmetered services and that it be accomplished in the following manner: (a) a surcharge be added to all City accounts to finance the installation of meters over a five year program, but the surcharge be held in abeyance until (b) the results are obtained by a vote of the people for general obligation bonds that would be retired by ad valorum tax. (Excerpted from the Minutes of the February 20, 1980, Bend City Commission Meeting.)

The subject of metering has been before the Bend City Commission many times in the past. John Cunningham and Associates, in an engineering report done for the City in 1948, put forth a strong argument in favor of metering. Again, in 1964, CH2M, in a master plan of the City's water system, recommended universal metering. Currently, the only consumers that are on meters are the commercial and industrial users, and the people that are using city water, but reside outside the city limits. Thus, the majority of the City's consumers (5,500± services) are on flat rates.

The repeated refusal by the City Council to meter the water system merits further discussion. Traditionally, Bend has been visioned as an oasis in a semi-arid desert. The concept of plentiful water to keep City residents' lawns green was considered essential. The overall attractiveness of the community was enhanced greatly by the appearance of the lawns. It was thought that, in order to have adequate amounts of water and also to encourage the constant watering of lawns, water should be plentiful and cheap, hence, the concept of metering was not received favorably.

This part of the Master Plan looks into all facets of the metering question. The bottom line of any engineering analysis is the most economic alternative. Looking past the economic question, there are political and social aspects of the metering issue that will have to be resolved.

## DISCUSSION

Data base for this part of the Master Plan was for calendar year 1978. Climatological data (Table V-1) indicates that 1978 was a typical year with respect to temperature and precipitation.

TABLE V-1  
CLIMATOLOGICAL DATA  
CITY OF BEND

Month	Temperature (°F) (1978)*	Precipitation (in) (1978)	Temperature (°F) (58 Yr Average)	Precipitation (in) (58 Yr Average)
January	30.3	1.81	34.2	1.33
February	34.1	1.34	36.9	0.60
March	38.6	0.94	42.5	0.89
April	44.5	0.72	42.6	2.18
May	50.7	1.13	47.1	0.82
June	57.0	1.09	58.5	1.73
July	64.3	0.48	64.2	1.12
August	62.8	0.39	62.7	1.18
September	55.6	0.52	54.4	0.89
October	48.2	0.79	50.6	0.01
November	38.6	1.58	33.3	0.95
December	32.4	1.75	28.4	1.21
Average	46.4	12.54"	46.2	12.71"

The first and most basic questions when looking at metering are how much consumption will drop, and how the additional cost for water will affect the everyday needs of the water consumers. Table V-2 indicates actual consumption rates for metered and non-metered users (flat rate) in and around the City of Bend. As can be seen, metered consumption is substantially lower than non-metered consumption.

TABLE V-2  
MONTHLY CONSUMPTION  
METERED AND  
NON-METERED CONSUMERS  
BEND AREA

Month	Non-Metered* (Gal/Service)(1978)	Metered** (Gal/Service)(1978)	% Reduction
January	9,103	6,885	24%
February	12,051	6,664	45%
March	8,912	6,933	30%
April	15,022	10,547	30%
May	40,302	11,796	71%
June	33,113	20,518	38%
July	52,743	20,914	60%
August	28,865	24,014	17%
September	18,482	10,861	41%
October	13,993	9,821	30%
November	5,650	8,419	-
December	8,543	7,622	11%

\*Based on 30 samples from Bend Water Department records and private water utility records.

\*\*Metered data supplied by the courtesy of Roats Water Company and Avion Water Company.

gal/service = ? cu. ft.

1 gal = 2.31 cubic inches

1728 cubic = 1 cu. ft.

7000 gal x 2.31 = 1728

1 cubic = (2.31) 1728

7.48 gal = 1 cubic foot

Table V-3 shows the metered and non-metered consumption on a daily per-capita basis. The reduction in consumption varies from 71 percent in the month of May to 11 percent in the month of December.

TABLE V-3  
DAILY PER CAPITA  
CONSUMPTION  
METERED AND  
NON-METERED CONSUMERS  
BEND AREA IN AND AROUND  
CITY OF BEND

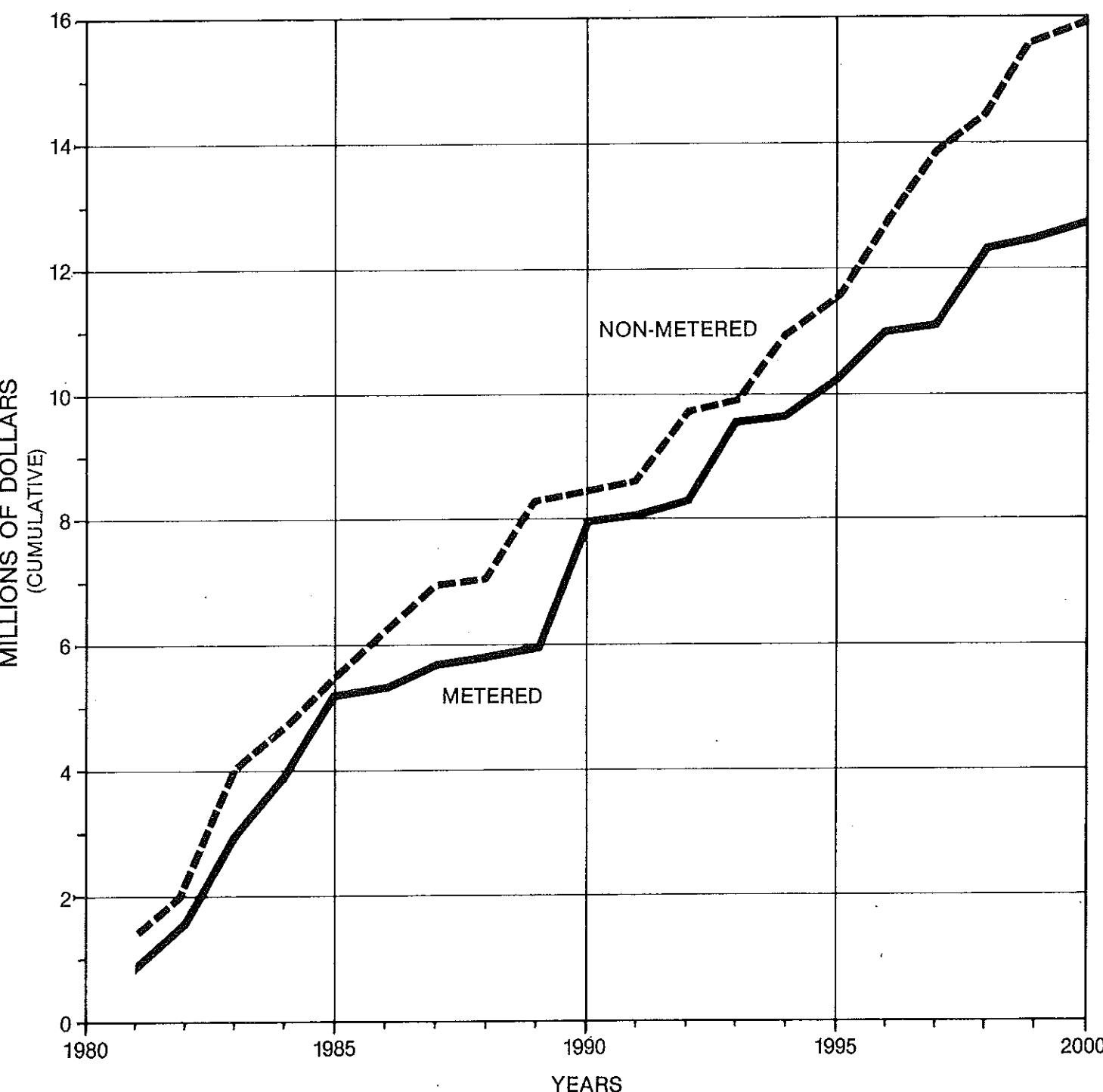
Month	Non-Metered* (Gal/Cap-Day)(1978)	Metered* (Gal/Cap-Day)(1978)
January	98	64
February	143	59
March	99	60
April	166	71
May	447	88
June	368	152
July	567	134
August	320	195
September	205	70
October	150	76
November	63	90
December	92	69
Average	226	94

\*Assumes 3.0 people/D.U.

## ADVANTAGES OF METERED WATER SERVICE

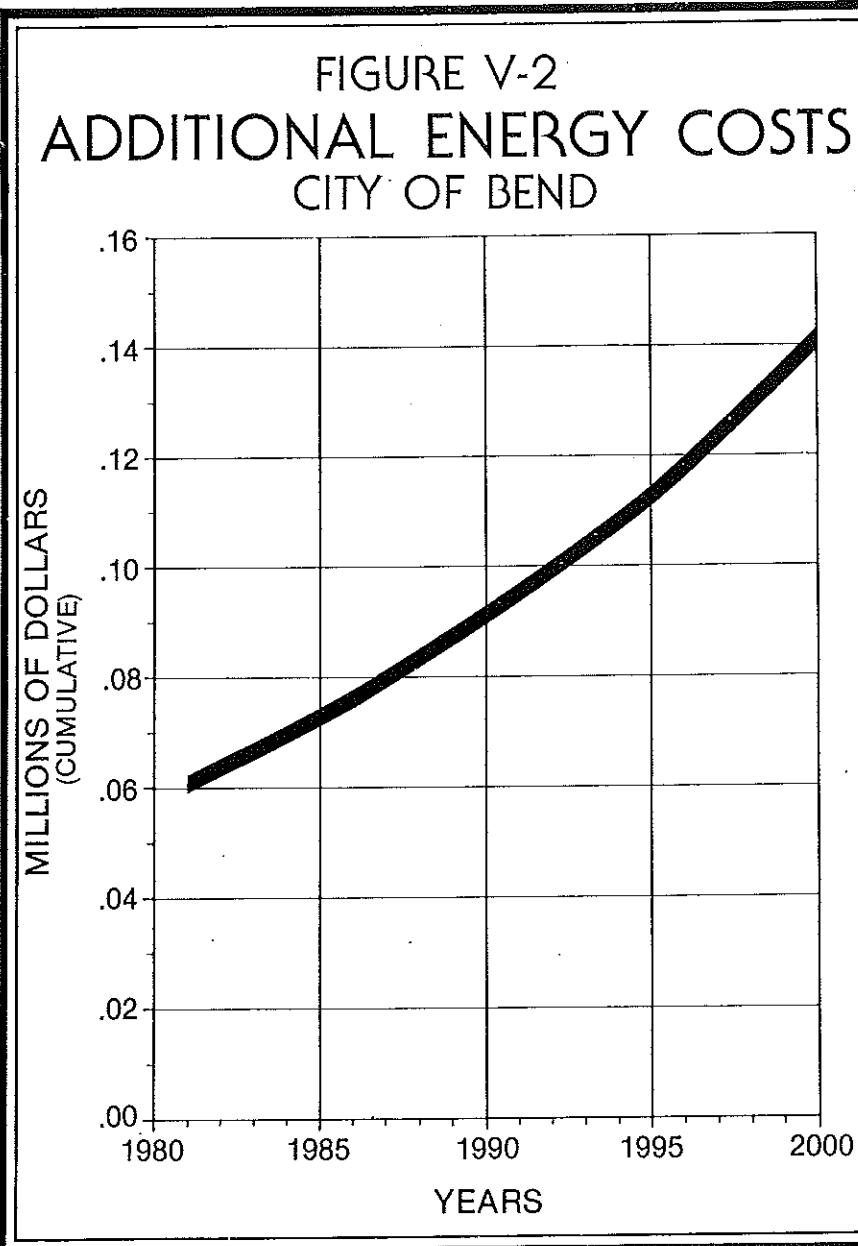
If a metering program is initiated in 1980, the economic benefits in capital expenditures are significant. Figure V-1 illustrates capital and maintenance costs for both a non-metered and metered system. The metered costs include meter installation, meter maintenance and meter replacement. The reduced outlay of capital expenditures increases each year to reach a maximum in the year 2000. Energy cost is one factor that contributes significantly to the financial difference between a

FIGURE V-1  
TOTAL CAPITAL AND MAINTENANCE COSTS  
CITY OF BEND



metered and non-metered system. Figure V-2 shows the yearly energy cost savings with a metered system. It should be noted that the above estimates (of reduction of consumption) are conservative. That is, if the reduction in consumption is greater than 25 percent, a greater savings in capital expenditures would be realized.

unaccounted-for-water problems. In a metered system, the careful consumer benefits and the careless consumer is penalized. Also, having a flat rate system penalizes the poor (since they would undoubtedly consume less water because of the expense of some water consuming appliances). In addition to the above benefits, reduced loading on the sewer system could extend its useful life much longer than initially projected.



Aside from the economic advantages of metering, there are additional benefits that can be gained. Metering would allow correlation of actual production and consumption. This information is invaluable in determining whether the distribution system has serious

## DISADVANTAGES OF METERED WATER SERVICE

There are some possible disadvantages to metering: Additional staff time will be required to read and maintain meters. Additional staff time for billing will be necessary and higher initial materials cost could also be expected.

## IMPLEMENTATION

The following are possible alternatives for the implementation of a metering program.

**ALTERNATIVE I** - Adopt a universal metering program. All new services would be metered, and existing services would be metered as soon as possible. Currently, there are approximately 4,400 services in the City that are flat rate. At \$200/service it would take approximately \$880,000 to meter all existing services.

**ALTERNATIVE II** - Meter all new services and meter existing services over a five year period. This would have the benefit of spreading the capital cost over five years. The disadvantage is that consumption will continue to increase creating capital improvements that would not be necessary if immediate metering is implemented.

**ALTERNATIVE III** - Start metering all new services, but still charge flat rates. This alternative would have the advantage that if the City, some time in the future, elects to go to metering, then part of the meters would already be installed.

**ALTERNATIVE IV** - Continue existing policy of metering new services outside the City and installing flat rate services within the City.

# FINANCING

A major consideration in implementing a program to install meters is the financing of the initial installation cost.

At their meeting of October 19, 1979, the Bend City Commission requested an in-depth financial study of Alternative II.

The following assumptions have been made in analyzing possible funding options:

- Existing City funds would not be used to finance meter installation.
- Approximately 5,500 meters need to be installed (4,800 active flat-rate + 500 inactive flat-rate + 200 cushion).
- Funds collected for water meter installation do not provide for the additional cost of maintenance or operation of the water system resulting from water meters.
- The average cost to install a meter is \$225. This cost will vary depending upon the actual method used by the City to install the meters. (e.g., one contract for the entire City, multiple small contracts, installation by City crews, etc.)
- All administrative, engineering and other cost in conjunction with the water meter installation would be additional.
- All prices are based on 1979 prices.
- The City will institute a program immediately to require all new development to install water meters during construction, and the cost for the meter would be borne by the builder.
- The estimated total capital expenditure to install 5,500 water meters is \$1,250,000.

The following methods are available to the City to fund this expenditure of \$1,250,000.

## OPTION I: RAISE EXISTING WATER RATES FOR THE NEXT FIVE YEARS

The City would raise existing water rates over the next five years to raise the required funds. At the end of each year, a construction contract would be let to install meters in one-fifth of the City or funds would be available for construction by City personnel. Payment for this work would come from funds collected to date. The money needed per year is:

$$\$1,250,000 \div 5 \text{ years} = \$250,000/\text{year}$$

Two means are available for raising the necessary funds:

- Levy a monthly surcharge on all flat-rate accounts. (Only those requiring meters pay for them.)
- Levy a monthly surcharge on all water customers. (Metered customers, inside and outside City, will benefit when overall water consumption is reduced.)

Table V-4 shows the increased water charges for a five year period for both options. A 12% inflation rate for construction is reflected in the rates over the five year period.

TABLE V-4  
OPTION I  
MONTHLY SURCHARGE

Flat-Rate Customers Only Cost per month per service (5,500 Services)	All City Water Customers Cost per month per service (6,900 Services)	Flat-Rate Customers Only Cost per month per service (5,500 Services)	All City Water Customers Cost per month per service (6,900 Services)
1980-1981	\$3.78	1980-1981	\$3.01
1981-1982	\$4.23	1981-1982	\$3.37
1982-1983	\$4.74	1982-1983	\$3.78
1983-1984	\$5.31	1983-1984	\$4.23
1984-1985	\$5.95	1984-1985	\$4.74

The monthly rates would have to be increased each year to stay current with inflation. This is in contrast with the following options that have a constant payoff rate for a number of years.

Option I would delay the completion of the water meter installation for five years which may be unacceptable. It does, however, provide a "pay as you go" program with no loans or bonds involved. At the completion of five years, the water meter rates would be initiated and the flat rate charges would be eliminated.

## OPTION II: CREATE A LOCAL IMPROVEMENT DISTRICT (LID) ENCOMPASSING THE ENTIRE CITY

The City Commission may wish to create an LID for the entire City for the specific purpose of installing water meters. This method of financing would require the Commission to hold a public hearing and a general election would be needed. The advantage of this type of funding is that the required monies would become available immediately. The water meters could be installed at once and the entire program could be activated. There would not be a five year waiting period as discussed under Option I.

It is assumed the City would sell Bancroft bonds to repay construction money. (Bond Counsel has to rule on validity.) The bonds would probably be issued for 10 years at about a 7% interest rate. The exact rate would be determined at the time of the bond sale.

Payback for the bonds would come from assessments levied against properties included in the LID. Properties included may be limited to only flat-rate customers or they could include all City water customers. A monthly surcharge would be added to City water customers outside the LID to make certain they share in costs of installing meters that represent a general benefit to everyone.

When the assessments are levied, they are due and payable. The property owner may enter into an agreement with the City to make periodic payments over the bond period. These payments could be in the form of a monthly surcharge on the water bill. The assessment can also be paid in full at any time. Table V-5 shows the monthly amounts each customer would pay based on different interest rates and the number of services obligated to retire the bonds.

TABLE V-5  
OPTION II  
MONTHLY SURCHARGE  
BANCROFT BONDS — 10 YEAR ISSUE

Cost Per Month Per Service (5,500 Services)	Cost Per Month Per Service (6,900 Services)
7% \$2.64	\$2.10
8% \$2.76	\$2.20
9% \$2.88	\$2.29

(LID Assessment = \$225) (LID Assessment = \$181)

TABLE V-6  
OPTION III  
MONTHLY SURCHARGE  
GENERAL OBLIGATION BONDS —  
20 YEAR ISSUE

Cost Per Month Per Service	
New Metered Services Only (5,500 Services)	All City Water Services (6,900 Services)
7% - \$1.75	7% - \$1.39
7½% - \$1.82	7½% - \$1.45
8% - \$1.89	8% - \$1.51
8½% - \$1.96	8½% - \$1.56
9% - \$2.04	9% - \$1.63

### OPTION III: ISSUE GENERAL OBLIGATION BONDS TO COVER INSTALLATION COSTS

Under this option, the voters would authorize the sale of general obligation bonds. A general election would be required with subsequent approval by 50% of the voters. The bond issue would probably be a 20 year payback at about 8%. Again, the exact interest rate would be determined at the time of the bond sale.

Three methods of payback for the general obligation bonds are presented.

- Increase City tax rate. Using 8% interest rate, 20 year payback, and \$393,000,000 A.V., the added tax rate is about \$0.31 per \$1,000 A.V.
- Retire the bonds by assessing all City water services. The monthly payback rates are shown in Table V-6.
- Retire the bonds by assessing only those water services that require a new meter. These monthly payback rates are also shown in Table V-6.

### OPTION IV: OBTAIN FEDERAL GRANTS TO COVER INSTALLATION COSTS

At the present time it appears that the only federal grant available to the City for water meter installation is from the Department of Housing and Urban Development (HUD). Under HUD funding, a single purpose grant in the maximum amount of \$500,000 may be used by the City for the water meter installation. The project, however, must rank high enough on HUD's priority list for funding to be considered for approval.

This grant could be combined with any of the other alternatives mentioned in this report to produce the needed \$1,250,000 revenue. If a HUD grant is secured, it probably will be designated to provide relief to low income families. Thus the rates for customers that don't receive benefit from this grant will be as shown in the other options depending upon the selected method of financing that is chosen.

According to HUD officials, all preapplications for next year's funding must be made between December 3 and December 17 of this year. If the preapplication is approved by HUD, the final application must be prepared in February 1980 and if the grant is then approved, money would be available to the City in the summer of next year. The HUD grant is a 100% grant and no local matching money would be required.

However, the HUD grant is not guaranteed to the City. The City would be required to show a need for the project and possibly designate the money to be used in the area of the City where a large number of low and moderate income families reside. The grant is an excellent solution to funding a portion of the project and should be pursued.

Other grants and federal agencies were investigated but dismissed either due to the ineligibility of the City or the ineligibility of this project. These agencies included the Farmers Home Administration (FmHA), Economic Development Administration (EDA), and the U.S. Department of Agriculture.

## SUMMARY

### OPTION I. RAISE EXISTING WATER RATES

#### Advantage

Pay as you go financing, no bonds.

#### Disadvantage

Most expensive monthly cost to consumer.  
Five years to complete meter installation.

### OPTION II. FORM CITY-WIDE LID

#### Advantage

Money available today.  
No general election required.  
Lowest overall cost.

#### Disadvantage

Ten year assessment on property.  
High administrative costs.

### OPTION III. ISSUE GENERAL OBLIGATION BOND

#### Advantage

Money available today.  
Low monthly cost to customer due to long payback period.

#### Disadvantage

Need for general election.  
Administrative costs.

### OPTION IV. OBTAIN GRANT FUNDS

#### Advantage

Federal money to pay a portion of costs.  
Money available as soon as grant approved.

#### Disadvantage

No assurance of grant funding.

# HYDRAULIC ANALYSIS AND COMPUTER MODELING

## Chapter VI



OREGON AVENUE — ABOUT 1913  
Compliments of Bill Yates Collection

# HYDRAULIC ANALYSIS AND COMPUTER MODELING

## HYDRAULIC ANALYSIS

### INTRODUCTION

Unit design factors were presented in the Land Use and Consumption section. These factors, together with population projections, determine amounts of storage, source capacity, and booster pumping required. The hydraulic analysis, coupled with the computer model, will indicate optimal locations and elevations for these facilities.

### PRESSURE LEVELS

When a water system has more than 120 feet of relief within its service area, conventionally it is divided into distinct pressure levels. These levels are designed to insure adequate pressures at high elevations, and to prevent excessive pressures at lower elevations.

The system's maximum static pressures should not exceed 100 psi. Pressures above 100 psi tend to cause consumer plumbing problems. Unavoidable system surges, like those caused by fire hydrants being quickly closed, can cause the system pressures to greatly exceed static values. The maximum pressure desired will set the lower elevation boundaries of a pressure level at a specific vertical distance below the storage reservoir's maximum water surface elevation. Since 100 psi is the pressure exerted at the base of the column of water 231 feet high, the lowest consumer at a given pressure level should not be more than 231 feet of elevation below the overflow weir of the storage reservoir.

Pressures less than 25 psi at the consumer's connection will not allow water-using appliances or equipment to function properly; the common flush-valve toilet found in most commercial establishments is a good example. To maintain a pressure of 25 psi at the customer's connection (equivalent to a column of water 58 feet high), the upper elevation boundary should be located at least 100 feet below the storage reservoir's

overflow weir. This would exert a maximum static pressure of 43 psi at the upper service level boundary. The 42-foot difference between the 100-foot minimum recommended elevation necessary and the 58 feet of head needed at the service connection is required to satisfy distribution system hydraulic requirements.

Under normal operating conditions, the water level in a reservoir may fluctuate 10 to 15 feet during the high demand season. At minimal reservoir levels, this will

leave 27 to 32 feet of the 42-foot head available to force water through the pipelines to consumers near the pressure level's upper elevation boundary.

In designing pressure levels, the number of users in each area plays an important part. Tables VI-1 through VI-5 indicate population forecasts for the study area by pressure level and by year, based on assumptions stated in the land use and consumption section.

TABLE VI-1  
POPULATION FORECAST  
BEND STUDY AREA 1980

Pressure Level	Cooley	Deschutes	Awbrey	Pilot Butte	Central	Hamby-Ward	Bear Creek	Tillicum	Blakley	Century	Kingston	Total
0	50	200		150		0						400
1	50		700	3,000	4,000	100	1,800		250		3,100	13,000
2		575		250			1,000	0	550	0	50	2,425
3		2,525									0	2,525
4		300										300
5		0									0	0
6	—	—	0	—	—	—	—	—	—	—	—	0
TOTAL	100	200	4,100	3,400	4,000	100	2,800	0	800	0	3,150	18,650

TABLE VI-2  
POPULATION FORECAST  
BEND STUDY AREA 1985

Pressure Level	Cooley	Deschutes	Awbrey	Pilot Butte	Central	Hamby-Ward	Bear Creek	Tillicum	Blakley	Century	Kingston	Total
0	75	350		725		50						1,200
1	175		800	3,400	4,100	125	2,050		275		3,300	14,225
2		725		275			1,550	200	825	200	125	3,900
3		2,550								300	300	2,850
4		450									450	450
5		275									275	275
6	—	100	—	—	—	—	—	—	—	—	—	100
TOTAL	250	350	4,900	4,400	4,100	175	3,600	200	1,100	500	3,425	23,000

TABLE VI-3  
POPULATION FORECAST  
BEND STUDY AREA 1990

Pressure Level	Cooley	Deschutes	Awbrey	Pilot Butte	Central	Hamby-Ward	Bear Creek	Tillicum	Blakley	Century	Kingston	Total
0	100	600		1,100		250					3,700	2,100
1	500		950	4,250	4,200	150	2,300		300	350	150	16,355
2			900	300			2,400	450	1,300		550	5,850
3			2,575							100		3,125
4			625									725
5			650									650
6			200									200
TOTAL	600	600	5,900	5,700	4,200	400	4,700	450	1,600	1,000	3,850	29,000

Figure VI-1 indicates existing and proposed pressure levels within the study area with their corresponding elevation ranges. As can be seen from the figure, a majority of the study area consists of base level (below 3,550 feet), first level (3,550-3,660 feet), and second level (3,660-3,760 feet).

Currently, on the west side of town, base, first, and second levels are all served by gravity from either Overturf or Awbrey Butte Reservoir. On the east side of town, gravity serves base and first level from Pilot Butte #1 and west side inputs, with second level being served from Pilot Butte #2 and from the Clay Street Booster Station. Existing pressure levels three and four in the West Hills area are served by the College Way Booster Station in conjunction with the College Reservoir. Figure VI-2 (Hydraulic Profile) shows all the inputs and the system layout.

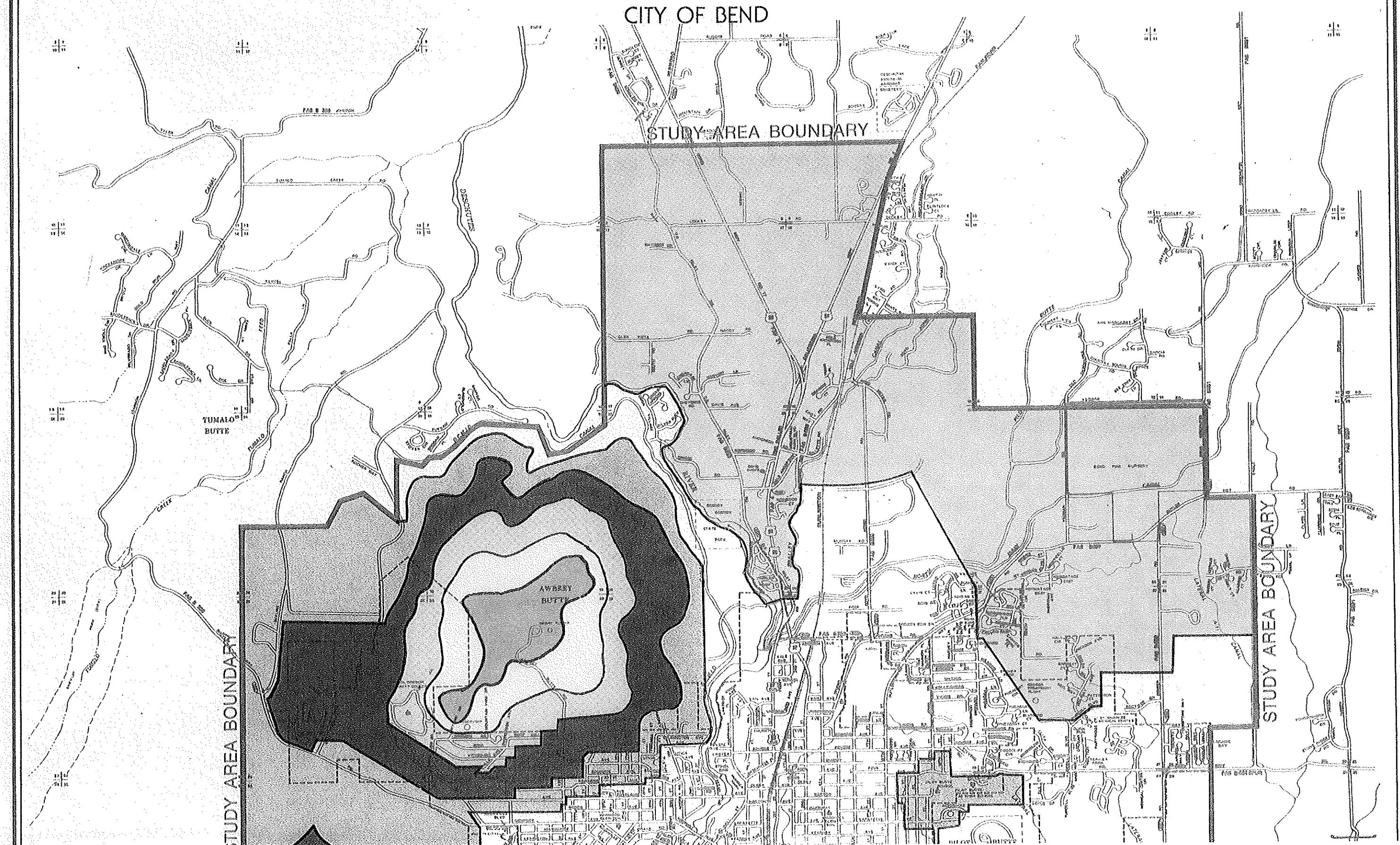
TABLE VI-4  
POPULATION FORECAST  
BEND STUDY AREA 1995

Pressure Level	Cooley	Deschutes	Awbrey	Pilot Butte	Central	Hamby-Ward	Bear Creek	Tillicum	Blakley	Century	Kingston	Total
0	100	1,000		1,575		400					4,000	3,075
1	1,000		1,100	5,450	4,300	200	2,700	700	350	550	200	19,100
2			1,150	325			3,300		1,850	850		8,075
3			2,600							200		3,450
4			900									1,100
5			900									900
6			300									300
TOTAL	1,100	1,000	6,950	7,350	4,300	600	6,000	700	2,200	1,600	4,200	36,000

TABLE VI-5  
POPULATION FORECAST  
BEND STUDY AREA 2000

Pressure Level	Cooley	Deschutes	Awbrey	Pilot Butte	Central	Hamby-Ward	Bear Creek	Tillicum	Blakley	Century	Kingston	Total
0	100	1,400		1,850		550					4,200	3,900
1	2,200		1,250	7,100	4,400	300	3,000	950	450	1,000	200	22,900
2			1,450	350			4,600		2,400	1,400		10,950
3			2,600							400		4,000
4			1,300									1,700
5			1,150									1,150
6			400									400
TOTAL	2,300	1,400	8,150	9,300	4,400	850	7,600	950	2,850	2,800	4,400	45,000

FIGURE VI-1  
EXISTING AND PROPOSED PRESSURE LEVELS



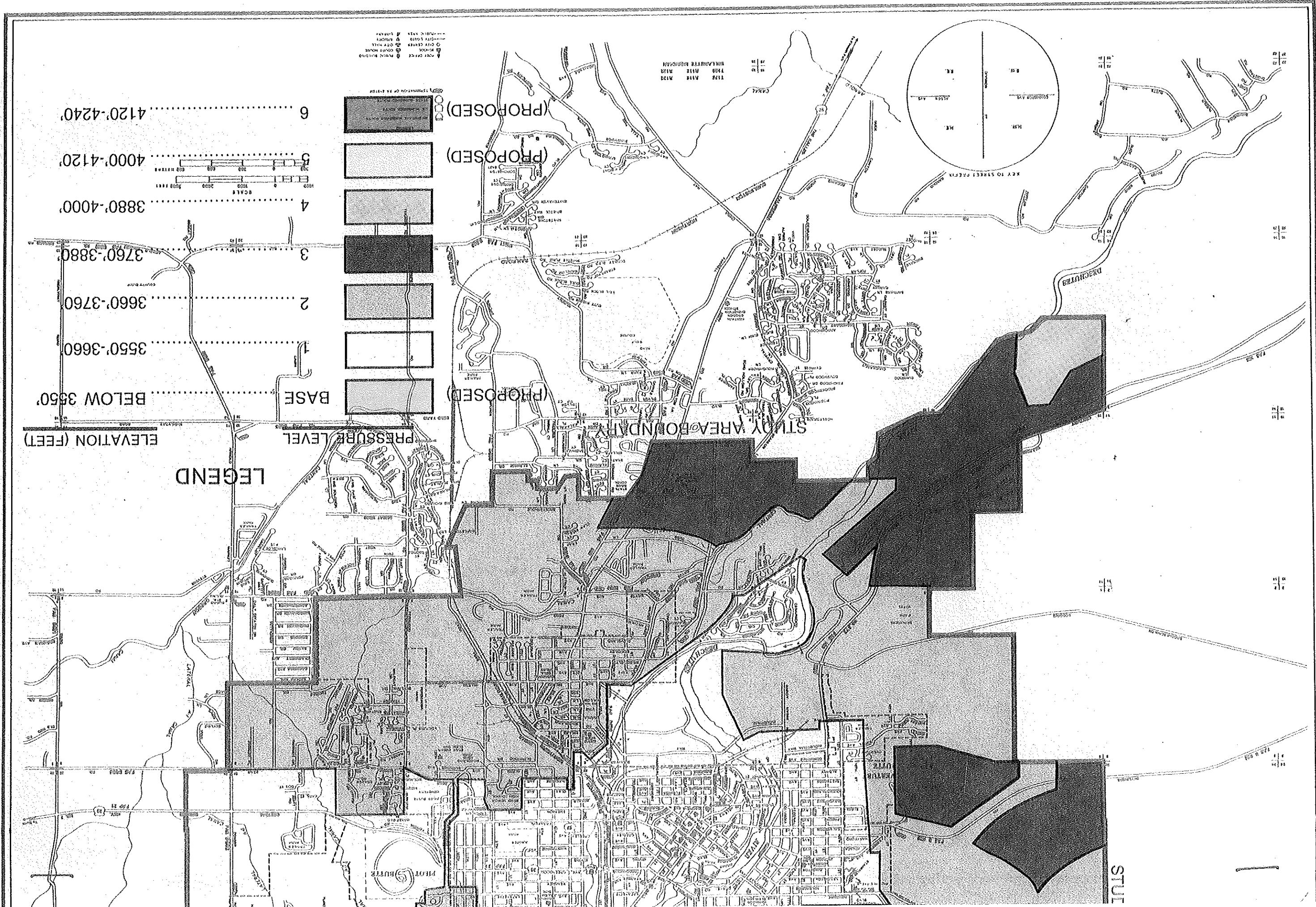
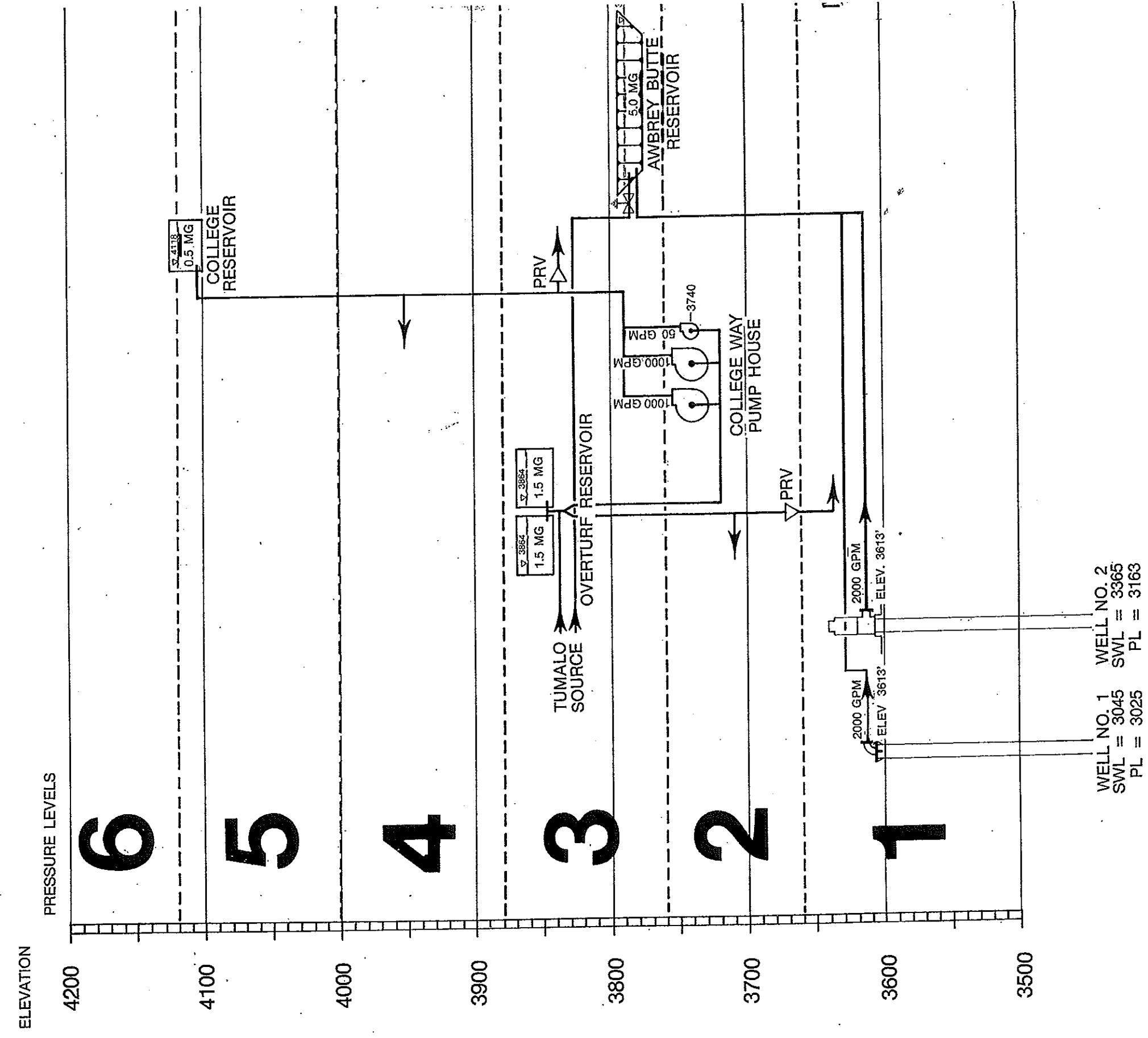
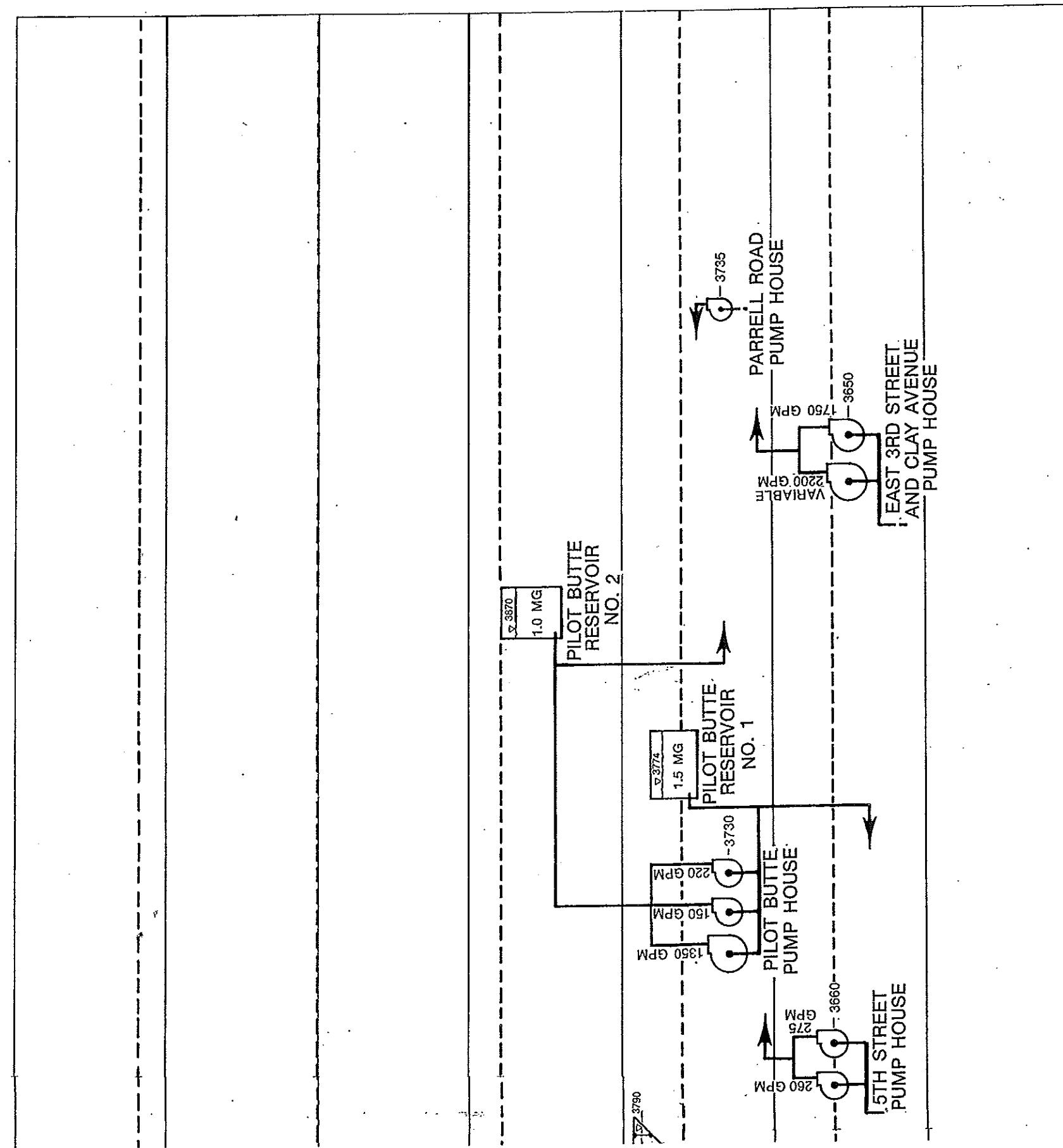


FIGURE 1  
HYDRAULIC PROFILE OF  
BEND WATER



E VI-2  
OF EXISTING FACILITIES  
TER SYSTEM



The following is a summary of the recommended improvements throughout the planning period. Tables VI-6, VI-8, and VI-9 show actual years and costs of the recommended improvements. Appendices VI-1 shows breakdowns of these costs.

## PHASE I — (1980-1985)

### SOURCE CAPACITY

Because of the proposed meter installation, the necessity for additional source capacity can be delayed until Phase II.

### STORAGE

The southeast section of town appears to be a problem area. The second level on the east side is served from the Pilot Butte Reservoir #2 and also from the Clay Street Booster Station. Reportedly, the Clay Street Booster Station runs at its design limit on many days during the summer. Additionally, maintaining Pilot Butte #2's water level is difficult because the Pilot Butte Booster Station's suction ring is close to Pilot Butte #1 and causes it to draw down to critically low levels.

Several alternatives could alleviate this situation. First, a true cross-town transmission main could be constructed. The most feasible location for this line would be from Overturf directly to Pilot Butte #2.

This should be an isolated line with no service lines or distribution mains connected to it. This alternative would have the advantage of having a direct line to Pilot Butte #2 thus increasing its refill rate on peak day, and lessening the burden on Pilot Butte #1. A second alternative would be to have a storage tank southeast of town serving second level. This tank could be filled by a direct line from Overturf. This alternative would have the advantage of supplying the southeast second level from two directions, thereby lessening the load on the Pilot Butte Reservoir. Additionally, the supply from the new reservoir would reduce the demand on the Clay Street Pump Station, possibly allowing abandonment of the flow matcher system. This could reduce power consumption and maintenance time at the station.

From an overall benefit consideration, the second alternative appears to be the most feasible at this time. The advantages for this alternative include (1) lower initial cost, (2) lower annual cost because of reduced power consumption, and (3) better compatibility with the existing system. The disadvantage

of this alternative would be the remote location of the reservoir in relation to the rest of the system, causing additional transportation time for maintenance personnel. This problem would be diminished somewhat if adequate control and instrumentation were designed into the reservoir so that day to day operation could be monitored from a central location.

It is our recommendation that this initial increment of storage be located as shown in Figure VI-3. It should be remembered that storage placed at higher elevations is still available in most cases to serve lower areas.

### DISTRIBUTION SYSTEM

The distribution system has some areas that need to be addressed. A majority of these improvements were a direct result of input from the Bend Water Department staff. Generally, the distribution system is very strong, and a majority of the pipes are 6" or larger in diameter. A concentrated effort has been made to standardize pipe material, valve and hydrant models and spacing, and pipe installation procedures. This effort has resulted in a strong distribution system capable of meeting a high percentage of the required fire flows at various locations throughout the City (see Existing System Section, ISO Evaluation).

But as with any water system, when components reach the end of their useful life, replacement becomes a necessity. The most critical links in the Bend system are the two lines from the Bridge Creek source to the Overturf Reservoirs. The original steel line was completed in 1926, and the second line was completed in 1954. Reportedly, some places on the upper three miles of the 1926 steel line are badly in need of repair. Most pipe materials have a 50 year design life. Thus, a five year replacement program for the upper 20% of the line (approximately 14,200 L.F.) is advisable. The new pipe, if possible, should be placed in the same trench as the existing pipe to minimize rock excavation. An 18" diameter pipe would make available from Bridge Creek an additional 3 to 5 MGD when the entire pipe (from the source to the Overturf Reservoir) is replaced.

Other areas that need attention are highlighted in Figure VI-3. Items 1, 2, 3 and 4 are replacement of existing pipe while item 5 is an intertie between two existing pipes. Items 1, 2, 3, and 5 are scheduled over a five year period. Item 2 consists of the original steel lines in the City center. A portion of this line will need replacement, but the exact amount is unknown. Assuming that 20% of the line needs replacement, installation should be scheduled evenly over the entire planning period (1980-2000).

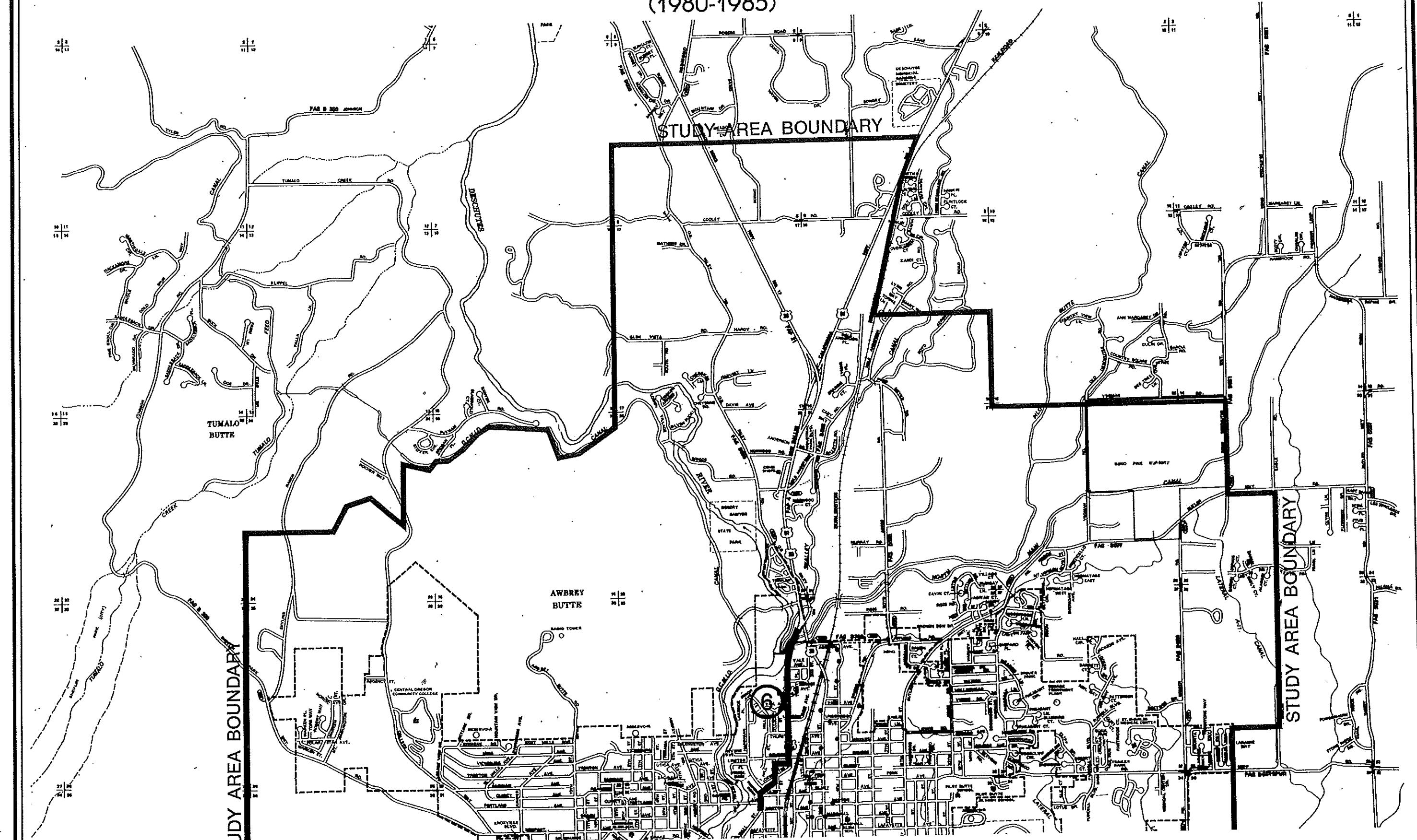
Another improvement in Phase I is hydrant installation, with 10 hydrants installed per year. Refer to the Existing System Section, ISO Evaluation for explanation. Auxiliary power for Well #2 also is included in Phase I and is discussed more fully in the Existing System Section, ISO Evaluation.

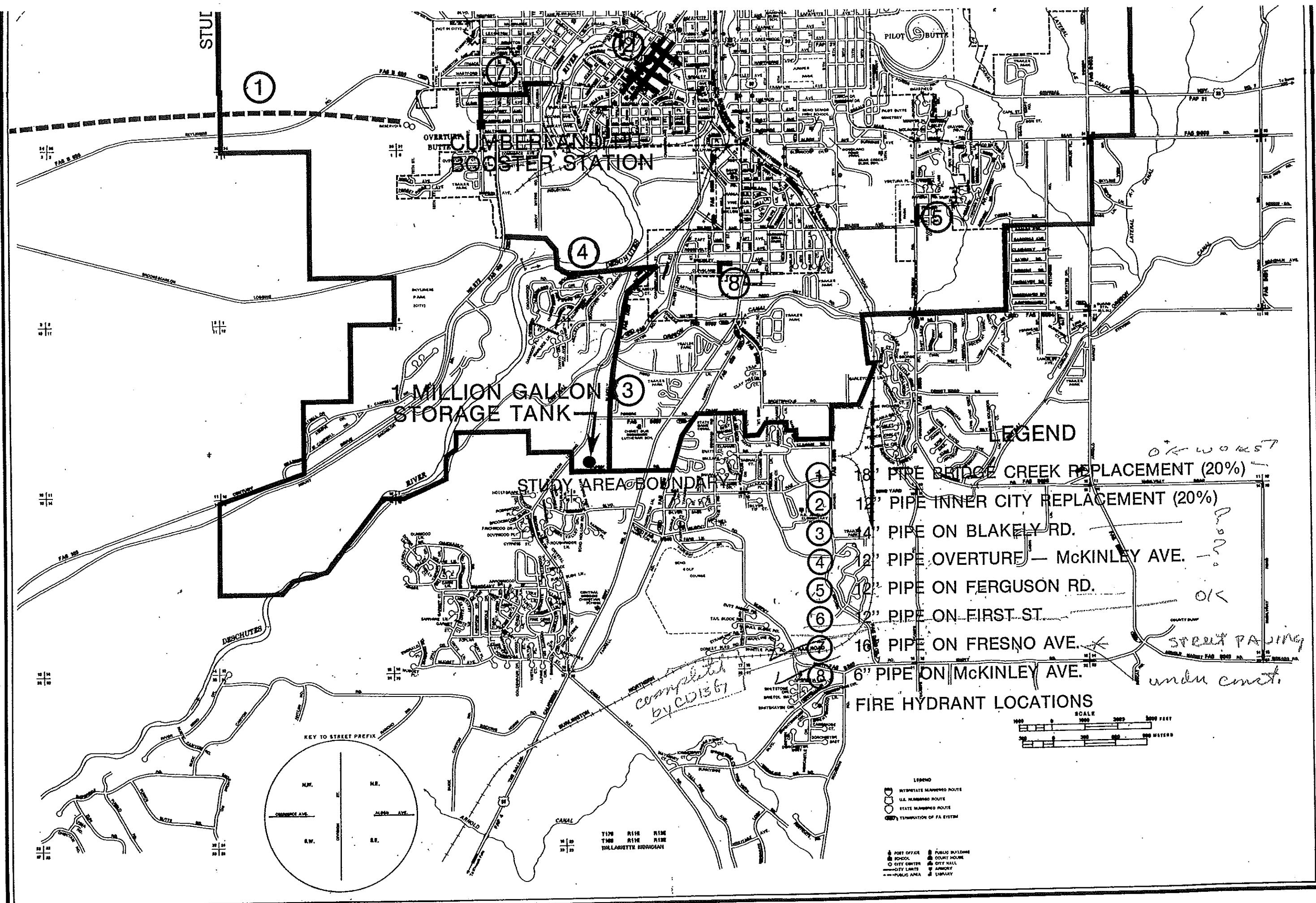
TABLE VI-6  
PHASE I  
CITY OF BEND WATER SYSTEM  
IMPROVEMENTS  
(1980 DOLLARS)

Item	Year	1980-81	1981-82	1982-83	1983-84	1984-85
Metering		1,250,000				
Storage - 1 MG Tank S.E. Section of Town					280,000	?
Pipe from Storage Tank to Chamberlain & McKinley 14" Diameter					417,000	?
Bridge Creek Replacement (Upper 20% of Line)		152,500	152,500	152,500	152,500	152,500
Hydrant Installation (10/Yr.)		10,000	10,000	10,000	10,000	10,000
Storage Maintenance (Existing tanks)		78,000	78,000	78,000	78,000	20,000
Auxiliary Power Well #2				120,000		
Cumberland Pit Booster Station				59,000		
Overturf to McKinley 2nd Level Pipe					296,000	?
Distribution System Improvements		140,500	140,500	140,500	140,500	140,500
Total		1,810,000	303,000	303,000	1,316,000	303,000
Running Total		2,113,000	2,416,000	3,732,000	4,035,000	

Installation of a booster station at Cumberland Pit is recommended. Currently, when the Bridge Creek source is shut down for maintenance or emergencies, Well #1 and/or Well #2 supply the entire source capacity for the system. Wells #1 and #2 pumps are designed

FIGURE VI-3  
PHASE I WATER SYSTEM IMPROVEMENTS  
(1980-1985)





to fill Awbrey Reservoir which supplies pressure level one. The Overturf Reservoir cannot be filled during these times. This inability to fill Overturf was especially salient during the Bridge Creek fire when the Bridge Creek source was shut down. During this period of time, the Overturf Reservoir's level was reportedly within two or three feet of the bottom of the tanks. The proposed booster station could utilize existing pumps and manifolding from some of the other pumping stations that are either on stand-by or are abandoned.

## PHASE II — (1985-1990)

### SOURCE CAPACITY

During Phase II, additional source capacity will be required as shown in Table VI-7.

TABLE VI-7  
FUTURE  
SOURCE REQUIREMENTS  
CITY OF BEND

Year	Total Source Capacity Required (MGD)
1980	17.17
1985	16.49 (Fully Metered System)
1990	20.15
1995	25.19
2000	32.38

As indicated in the Water Sources Evaluation Section, both a Ranney collector system and deep wells are feasible economic alternatives for future source capacity. In order to determine the hydraulic feasibility of Ranney collectors, it would be necessary to do some preliminary testing, preferably in 1985. Then, if the Ranney collectors prove feasible, a construction program could be implemented to install Ranney collectors, which could provide 9.5 MGD. If the collectors do not prove feasible, then deep wells should be sequenced in 1986 and 1989. Well #3 should be located in the existing well field and should be capable of providing water

to second level, hence having the capability to fill Overturf Reservoir and the new reservoir southeast of town.

Well #4 should be constructed on the east side of town in Juniper Park if land is available. Locating the well here would be advisable because it would raise the hydraulic gradient in the first level on the east side and because its close proximity to Pilot Butte #1 would help alleviate the problem of the Pilot Butte Booster Station taking water out of Pilot Butte #1 faster than it can be refilled from the system.

### STORAGE

Phase II storage should consist of a 2-MG tank on top of Awbrey Butte. This tank would serve pressure levels 6 and 5 and could serve parts of pressure level 4 if development proceeds in that area. The tank should be located at the highest elevation that is aesthetically and economically feasible so that, if possible, all lots on Awbrey Butte could be served by gravity, rather than the upper lots being served by hydropneumatic or direct booster system. The second increment of storage needed during this phase should be placed at an eastside location that is similar in elevation to Pilot Butte #1. This, together with an eastside well, would reinforce the eastside grid.

### DISTRIBUTION SYSTEM

The distribution system improvements for this phase include the following: (1) a continuation of the Bridge Creek replacement program, (2) lines from each of the new storage tanks to the existing system, (3) hydrant installation at 10 hydrants per year, and (4) various pipe replacements. The above items have already been discussed. Item 2 consists of (a) continuing the inner city replacement and, (b) miscellaneous pipe replacement and isolated branch looping. Phase II improvements are shown in Figure VI-4.

## TABLE VI-8 PHASE II

### CITY OF BEND WATER SYSTEM IMPROVEMENTS (1980 DOLLARS) 1985-1990

Item	Year	1985-86	1986-87	1987-88	1988-89	1989-90
Well #3 (located in existing well field and pumping into second level) (2.88 MG)		725,000				
Well #4 (located in Juniper Park and pumping into first level)						725,000
12" Pipe from Well #4 to intersection of Greenwood & Sixth				60,000		
Ranney Collector Feasibility Study		40,000				
Ranney collectors (alternate source capacity of 9.5 MG)			(2,376,000)			(0)
Storage-2 MG tank on top of Awbrey Butte			440,000			
Storage-1.5 MG on Pilot Butte next to Pilot Butte #1				370,000		
16" Pipe from Pilot Butte tank to distribution system-1000' L.F.					66,000	
Bridge Creek Replacement (20% of line)		152,500	152,500	152,500	152,500	152,500
Hydrant Installation (10/yr)		10,000	10,000	10,000	10,000	10,000
Storage Maintenance				10,000		
Distribution System Improvements		127,500	127,500	127,500	127,500	127,500
Total		330,000 *(330,000)	1,455,000 (310,600)	300,000 (300,000)	726,000 (726,000)	975,000 (250,000)
Running Total			1,785,000 *(3,436,000)	2,085,000 (4,000,000)	2,811,000 (4,726,000)	3,786,000 (4,976,000)

\* ( ) Totals if Ranney collector system is used.

## PHASE III — (1990-2000)

### SOURCE CAPACITY

During Phase III, four new wells, or, if the Ranney collector system is put in, three new wells, will be needed. The location of these wells is shown on Figure VI-5. Since development can follow unpredictable patterns, these locations are tentative, at best, and should be reviewed in light of actual development trend.

### STORAGE

During the ten year span, five additional tanks are recommended in order to keep up with predicted City growth. Location and timing of these tanks are also shown on Figure VI-5.

### DISTRIBUTION SYSTEM

The Bridge Creek replacement and fire hydrant programs are continued throughout Phase III. Other miscellaneous distribution system improvements are shown on Figure VI-5.

### MISCELLANEOUS

There are parts of the distribution system that will, in time, be installed by developers. Although this cost has not been put in the financial plan, size and location of important lines have been included in Figure VI-5. Additionally, some of these lines extend into areas that are presently served by private water systems, hence causing additional problems as to who will actually serve certain areas.

TABLE VI-9

### PHASE III

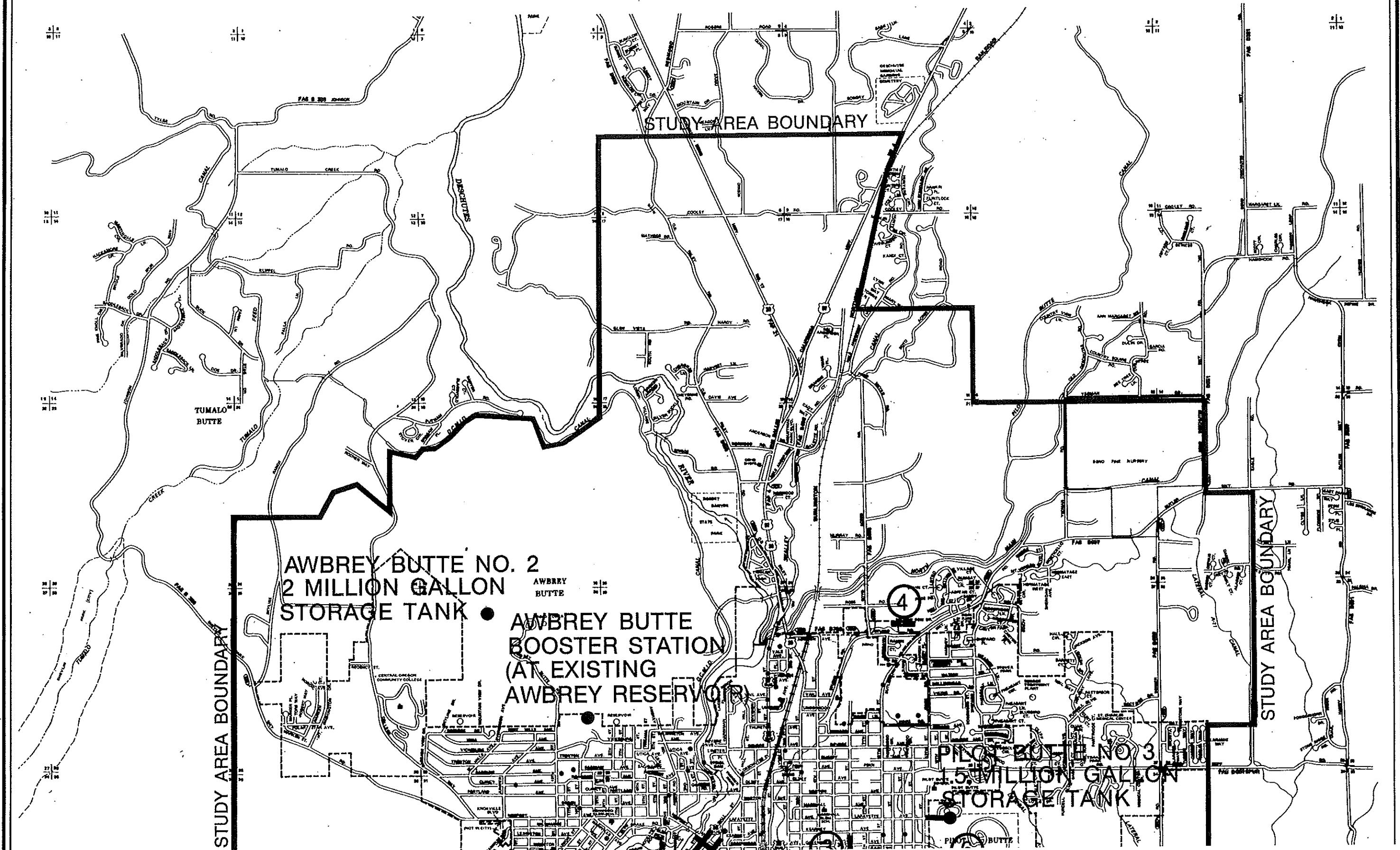
## CITY OF BEND WATER SYSTEM IMPROVEMENTS (1980 DOLLARS)

1990-1995						1995-2000								
Item	Year	1990-91	1991-92	1992-93	1993-94	1994-95	Item	Year	1995-96	1996-97	1997-98	1998-99	1999-2000	
Well #5 (either at existing well field pumping into second level or north of town pumping into first level).			725,000				Well #7 (at existing well field pumping into second level)			725,000				
Well #6 (east of town pumping into first level)					725,000		Well #8 (in Mt. Bachelor Village-Sunrise area pumping into tank in fourth level)				725,000			
Ranney collectors (alternate source capacity)*		(0)				(500,000)	Storage-1.0 MG tank on Awbrey Butte serving fourth and third levels			280,000				
Storage-1.5 MG tank on existing Overturf site		370,000					Storage-1.0 MG tank in fourth level in Mt. Bachelor Village-Sunrise area			280,000				
Storage-1.0 MG tank on Awbrey Butte serving fourth and third levels.			280,000				Bridge Creek Replacement (20% of line)	152,500	152,500	152,500	152,500	152,500		
Storage-2.5 MG tank on existing Awbrey Butte Reservoir site					475,000		Hydrant Installation (10/yr)	10,000	10,000	10,000	10,000	10,000		
Bridge Creek Replacement (20% of line)	152,500	152,500	152,500	152,500	152,500		Distribution System Improvements	68,000	68,000	68,000	68,000	68,000		
Hydrant Installation (10/yr)	10,000	10,000	10,000	10,000	10,000		Total	230,500	1,235,500	230,500	1,235,500	230,500		
Distribution System Improvements	80,000	80,000	80,000	80,000	80,000		Running Total*		1,466,000	1,696,500	2,932,500	3,163,000		
Total	242,500	1,337,500	522,500	242,500	1,442,500									
	(242,500)	(612,500)	(522,500)	(242,500)	(1,217,500)									
Running Total		1,580,000	2,102,500	2,345,000	3,787,500									
		(855,000)	(1,377,500)	(1,620,000)	(2,837,500)									

( ) \*Totals if Ranney Collector System is used.

\*Please note that the running totals for Phase III have been divided by years (1990-1995, 1995-2000) for planning reference.

FIGURE VI-4  
PHASE II WATER SYSTEM IMPROVEMENTS  
(1985-1990)



STU

1

A map of Butte, Montana, showing the locations of Overtime, Ranney, and Tangler Park. The map includes labels for Butte, OVERTIME, RANNEY, TANGER PARK, and several streets like COACHMAN AVE, INDUSTRIAL BLVD, and 10TH AVE. The map is oriented with North at the top.

WELL NO. 3 ◎

## LEGEND

18. BRIDGE CREEK REPLACEMENT (20%)

## 12" PIPPIN NECK CITY REPLACEMENT (20%)

12" PIPE FROM WELL NO. 4 TO DISTRIBUTION SYSTEM

16 PIPE ON STUDIO RD.

12" PIPE ON U.S. HWY. 20

PIPE ON FORBES BD

12" PIPE ON EERGISON

12" PIPE ON REED MKT

12. FIRE HYDRANT LOCATION

# FIRE HYDRANT LOCATIONS

# FIRE HYDRANT LOCATIONS

UNFEASIBLE - LOCATION NOT DEFINITE

- 1.00000
- INTERSTATE NUMBERED ROUTE
- U.S. NUMBERED ROUTE
- STATE NUMBERED ROUTE
- LOCAL NUMBERED SYSTEM

■ POST OFFICE	■ PUBLIC BUILDING
■ SCHOOL	■ COURT HOUSE
■ CITY CENTER	■ CITY HALL
— CITY LIMITS	■ ARMORY
— PUBLIC AREA	■ LIBRARY

T176 R118 R120  
T180 R118 R120  
1996 CASSETTE MURMUR44

ANSWER

THEORY OF THE STATE

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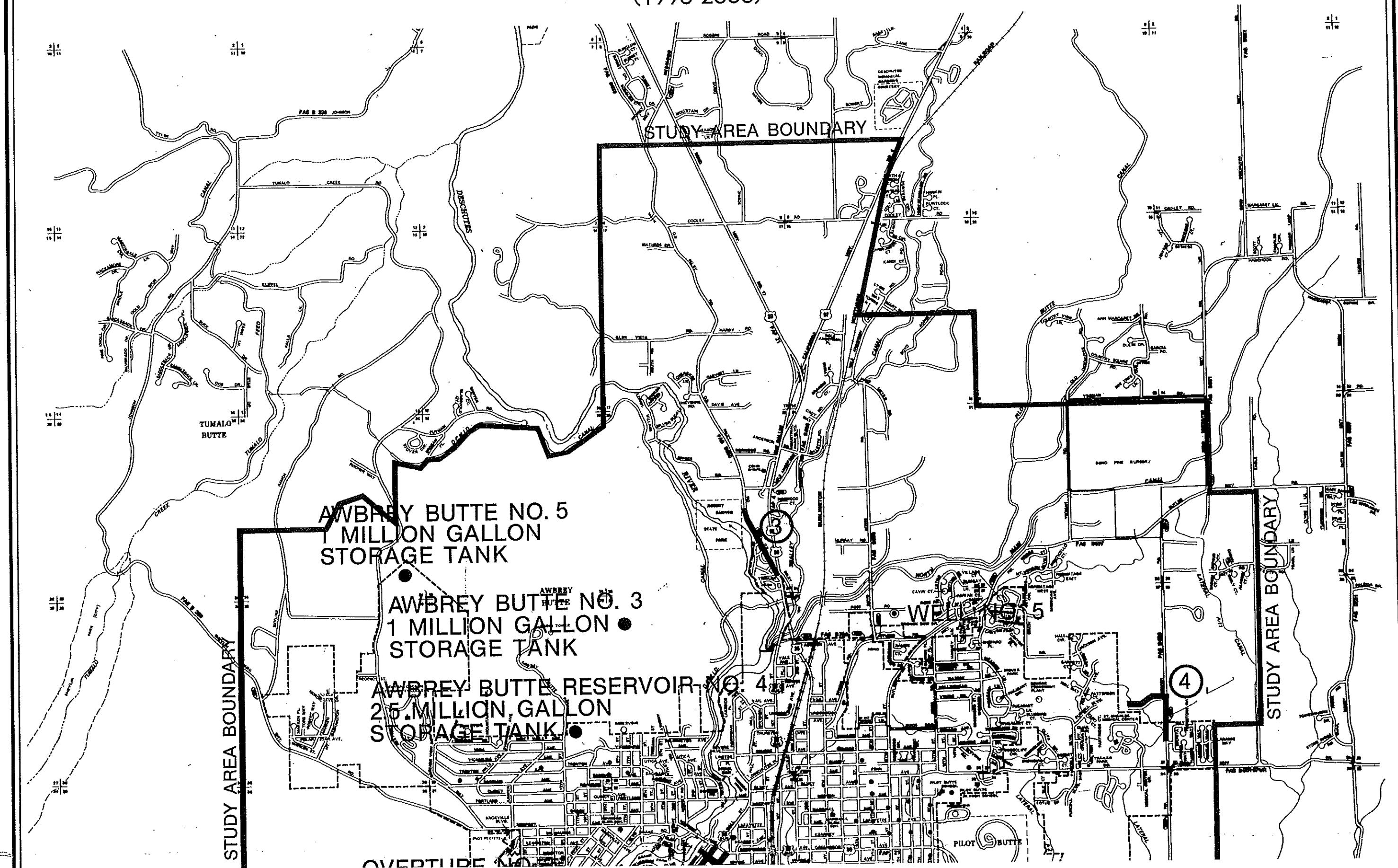
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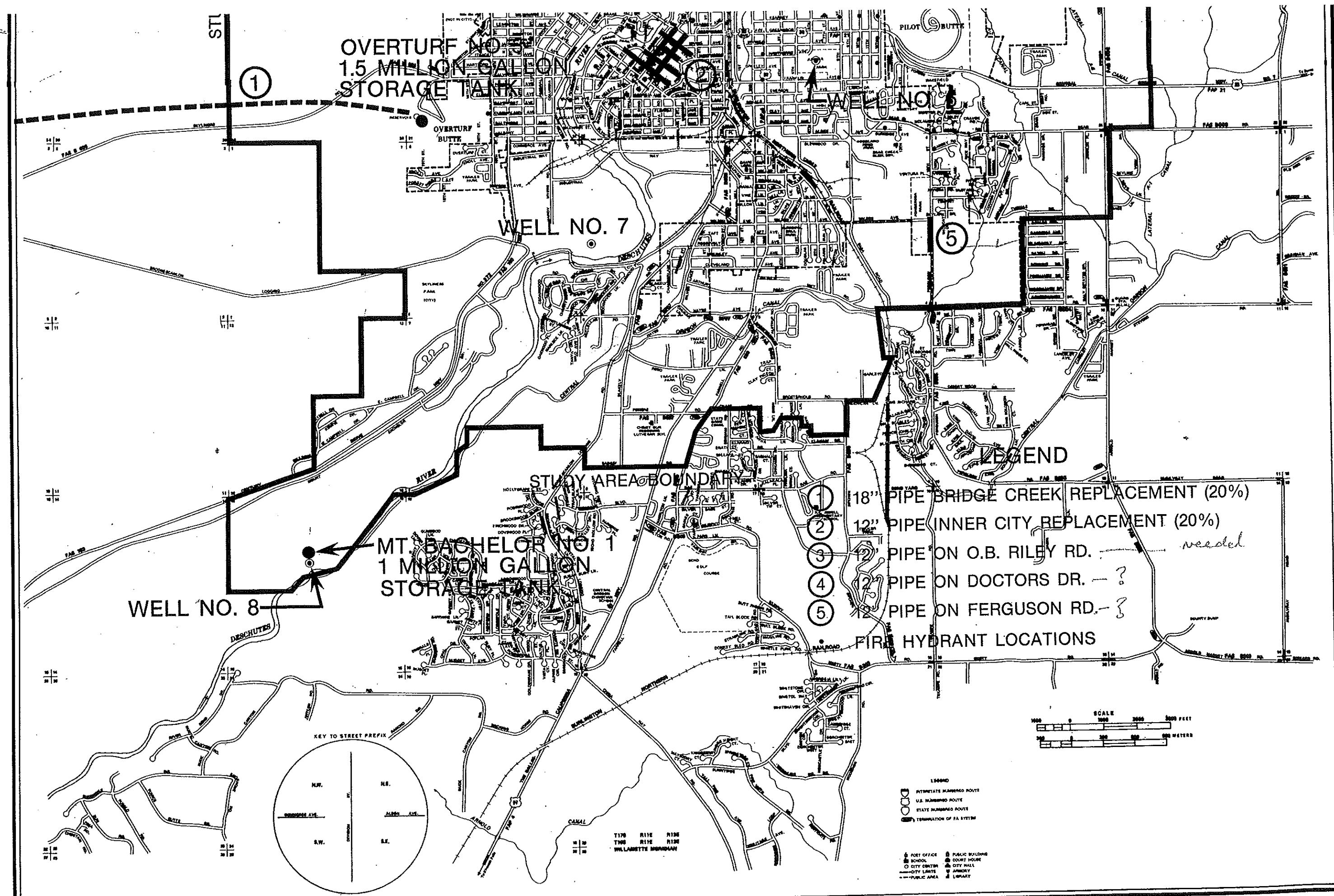
SCALE

1000 1000 2000 3000 FEET

300 300 600 600 METERS

FIGURE VI-5  
**PHASE III WATER SYSTEM IMPROVEMENTS**  
(1990-2000)





# COMPUTER MODEL

## INTRODUCTION

Computer modeling is very beneficial in water distribution system analysis and design. Bend's existing pipe network is shown in Figure VI-6. The model is a mathematical process simulating the physical properties of water in a pipe network. Flows through pipes and pressures at various locations are determined and, depending on the program used, other information can be obtained.

Bend's water system is complex in its variety of hydraulic components (i.e., well pumps, gravity feed inputs, booster pumps, elevated storage, pressure reducing valves, etc.). All of these devices in one system require a sophisticated program. For this analysis, the program WATSIM was used. WATSIM uses the most advanced mathematical procedures as well as being able to solve for the unknowns (flow and pressure) in a system as large as Bend's. In addition to WATSIM, a series of programs were written to convert the data on a printout to a contour plot of water pressure, thus giving a "picture" of the water system.

The thrust of this analysis is directed in two major areas. First, analysis of the existing system simulating peak day flows, and then superimposing fire flows in certain areas of the City, and second, the computer model can be used to aid in designing future system components for system expansion.

In evaluating the existing Bend system, a simulation of 1979's peak day was used. The actual demand curve is shown in Figure VI-7. Figure VI-8 shows peak day pressures throughout the City. As can be seen, the pressure is within tolerable limits (40-100 PSI) in virtually all locations. The peak day run was verified using the ISO field test results as shown in Table VI-10.

TABLE VI-10  
COMPUTER  
MODEL VERIFICATION  
CITY OF BEND

Location	Field Pressure (PSI)	Computer Pressure (PSI)
Harvey Lane @ Thompson Road	80	81.7
East Fifth @ Greenwood	61	61.5
East Third @ Franklin	55	58.8
Riverfront @ McCann	75	77.1
Newport @ 8th	73	77.1
Xerxes @ East First	81	85.9
East Fourth @ Seward	72	79.3
East 12th @ Norton	64	72.0
East 9th South of Glenwood	77	80.9
East 6th @ Burnside	84	85.6