CITY OF BEND

OREGON

A REPORT ON AN ENGINEERING STUDY OF THE MUNICIPAL WATER SYSTEM

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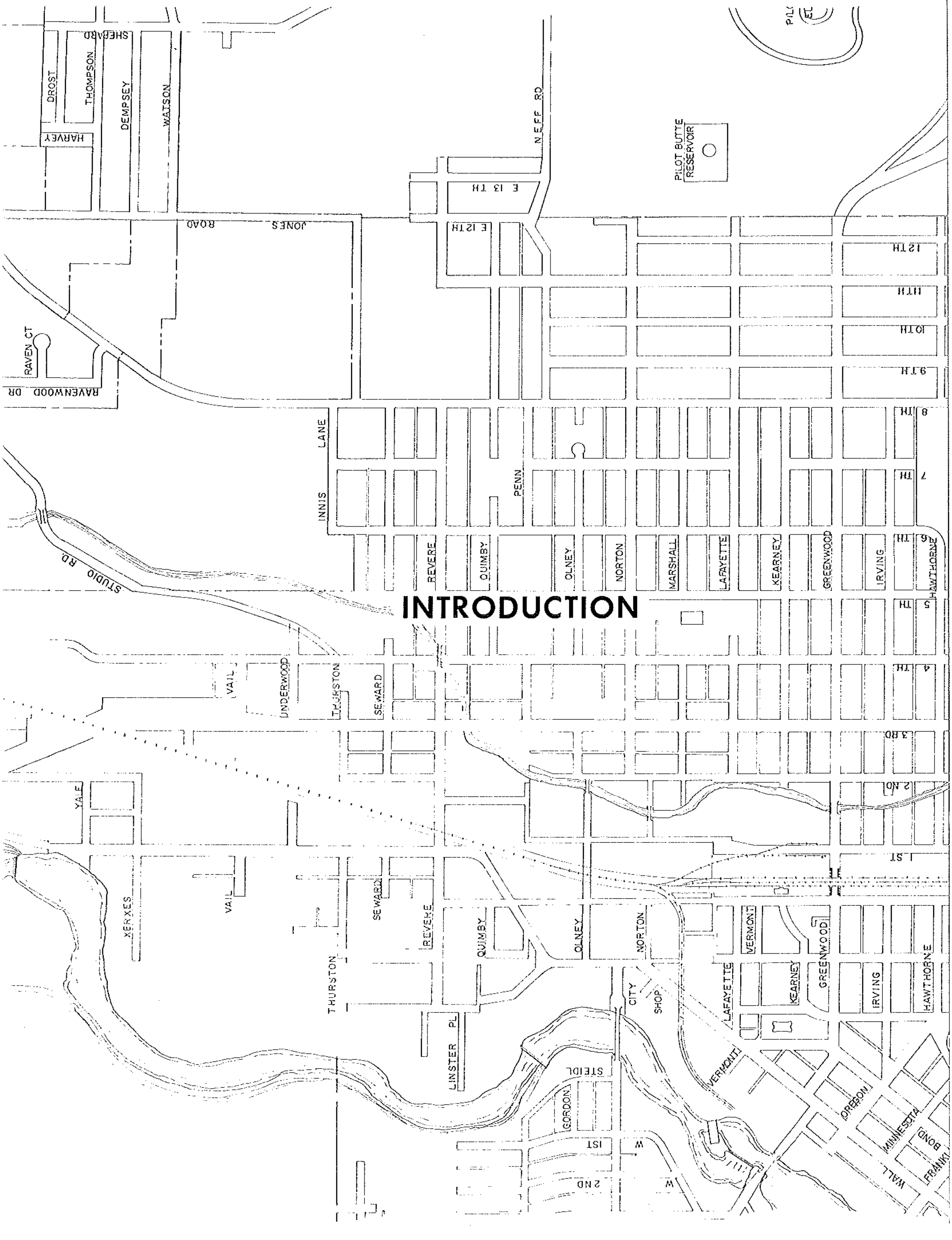
INTRODUCTION



I. INTRODUCTION

Authorization. The City Council at its meeting on 5 February 1964 directed work to proceed on the engineering study reported herein. The investigation was conducted under the terms of an agreement for engineering services dated 16 July 1963, using funds advanced by the Housing and Home Finance Agency.

Purpose. The purpose of this study is to determine methods of increasing the water supply for the City of Bend to meet the needs of the growing community for approximately 25 years into the future.

Procedure. The investigation includes establishing present and probable future water requirements, determining the capabilities of the existing water system, considering methods of improving and expanding the water facilities, estimating costs of construction and operation, outlining methods of financing, and recommending a program for orderly development of the water system.

Use of Report. In considering this report, it should be emphasized that it has been prepared on the basis of the best information available at this time. The study has, of necessity, involved some long-range forecasting. Since short-term predictions generally can be made with a higher degree of accuracy, it is essential that the preliminary analysis of plans for the future presented herein be subjected to periodic review and modification as may be indicated in the light of actual events and conditions as they occur and develop.

HISTORY OF THE WATER SYSTEM

II. HISTORY OF THE WATER SYSTEM

General. Water has played a vital role in the history of Bend, and will be an important factor in shaping the future of the City. The availability of water, its quality, and cost have a great influence on the rate and pattern of growth of any community, and this is particularly true in the case of Bend.

Prior to the founding of the City in 1905, the present site of Bend was noted as a good place to ford the Deschutes River and the last place to get good water before crossing the desert plains. To the westward-bound traveler the inviting shade of the pine trees and the abundant clear, cool water were a welcome sight. It was under the influence of the early development of irrigation and timber resources that Bend became a town.

The Original Supply. In 1905 the Bend Water, Light, and Power Company and John Steidl built the original public water system, utilizing the Deschutes River as the source of supply and laying pipelines to distribute water for domestic use and fire protection.

In the summer of 1923, the flooding of thousands of acres of wooded and meadow lands for the first time, following completion of dams at Crane Prairie Reservoir and Crescent Lake, resulted in prolific blooms of algae. Water released from reservoir storage to the Deschutes River had a disagreeable taste and odor. The Water Company made an unsuccessful attempt to secure a supply of water from Tumalo Creek, and then constructed a filter plant in an attempt to render the water palatable.

In the meantime, the State Engineer had fixed a date for hearings in the matter of adjudication of the waters of the Deschutes River and its tributaries. The City Council, impressed with the necessity of establishing the City's water rights, began an investigation of possible sources of water supply and preparation of data for submission in the adjudication proceedings.

After a personal visit by the City Council to Green Lakes, filings were made in the State Engineer's office on Green Lakes, Soda Creek, Fall River, and Spring River. These applications were held on file until the feasibility and cost of developing these various sources of supply could be determined.

The Dubuis and Redfield Report. Dubuis and Redfield, Consulting Engineers, were retained by the City in 1923 to study the water supply problem. Their report was submitted to the City in May 1924. It was a very thorough study and perceptive analysis of the water situation as it existed at that time.

They investigated and reported upon possible surface water supplies from Green Lakes, Soda Spring Creek, Tumalo Creek, Fall River, Spring River, and the Deschutes River.

Few water yield records were available for Green Lakes, and there was some indication that this source of supply might not be adequate the year around. Surveys made in 1923 showed the Lakes to lie 490 feet below the divide at Tumalo Creek, necessitating an expensive tunnel to make water from this source available by gravity for a municipal supply for Bend.

Dubuis and Redfield concluded that Soda Creek was deficient in supply, and, like Green Lakes, would require tunneling to be made available.

They reported an almost constant flow of cool, clear water from the spring-fed Fall River amounting to 115 to 122 cfs (cubic feet per second), which was considered more than adequate. However, the long distance (29 miles) from Bend and the attendant high construction costs eliminated Fall River from serious consideration at that time.

Spring River with a discharge of about 175 cfs is about 15 miles from Bend. Quality at the source was good, but backwater from the proposed Benham Falls Reservoir would cover the springs with about 40 feet of water. The consultants recommended setting aside consideration of Spring River until the idea of constructing Benham Falls Dam was definitely abandoned.

The 1924 report describes Tumalo Creek as a stream which rises on the eastern slopes of Ball Butte and Broken Top Mountain about 20 miles west of Bend, with a large part of its watershed in the Deschutes National Forest. The lowest flow recorded prior to the report was 46.5 cfs in September 1915, the mean daily flow for the same year being 83.3 cfs. The quantity and quality of this supply were judged to be more than adequate. At that time, water rights of Tumalo Creek were held jointly by the State of Oregon and the Deschutes County Municipal Improvement District.

The Deschutes River was still the source of water supply for Bend during the Dubuis and Redfield study. Treatment consisted of filtration and chlorination. The quantity of water available from the Deschutes River was sufficient, but taste and odor problems were difficult to handle by treatment methods then available.

The final selection of a source of supply lay between Tumalo Creek and the Deschutes River. Tumalo Creek had several advantages as compared to the Deschutes River. The gravity pressure of the Tumalo supply provided more reliable fire protection, since it was not affected by power outages or pump failures. Water from Tumalo Creek was of better quality than that pumped from the Deschutes. Estimated annual operation costs for the Tumalo supply were less than one-half those for the Deschutes supply, but the initial construction costs of the Tumalo supply were more than three times those for development of the Deschutes source. The total annual operation, depreciation, and interest charges were calculated by Dubuis and Redfield to be decidedly in favor of the gravity supply from Tumalo Creek, and they recommended that this source be acquired and developed.

Pursuant to this report, the City acquired the water system from the private company in 1926 and constructed a pipeline of 5 mgd (million gallons per day) capacity from Tumalo Creek to the City of Bend. The filter plant on the Deschutes was abandoned and removed. Since 1926, the municipal water supply has been obtained entirely from Tumalo Creek.

<u>Reports by John W. Cunningham and Associates.</u> A series of brief reports on the Bend water system were prepared by John W. Cunningham and Associates from 1948 to 1954.

In the first of these, in May 1948, they observed that the experience in 22 years of operation of the Tumalo supply had demonstrated the wisdom and soundness of the decision to utilize this source of supply. They commented that other sources should be considered only in case it proved impossible to get an enlargement of water rights from Tumalo Creek. They suggested that the City could always fall back on Deschutes River water, and stated that new water treatment techniques would make it possible to produce a high quality water in contrast to the results obtained with older methods in 1925. They reported the fact that the original Bend water right on Tumalo Creek amounted to 6 cfs or 3.88 mgd, and that this was subsequently augmented by the purchase of 2 cfs from users in the Tumalo irrigation project, making a right to use of 5.17 mgd in 1948. They pointed out that the low flow of Tumalo Creek at the point of diversion by Bend is adequate for any reasonable increase to meet the needs of the City, but that this must be accompanied by reduction in irrigation use, and that irrigation users must get their supply from some other source. The report recommended that the City make every effort to acquire additional water rights from Tumalo Creek up to 15 cfs. The length of the original 14- and 16-inch welded steel pipeline is given as 62,000 feet (11.75 miles), the available head as 1,150 feet, and the carrying capacity as 5.5 to 6.0 mgd. Reservoir storage in the City amounted to 3 mg (million gallons) in two steel tanks. The 1948 study showed the maximum daily use to be 420 gallons per capita. It suggested that universal metering of services might reduce water use by as much as 50 percent and that the cost of metering was only a fraction of the cost of increasing the available water supply by an equal amount. The 1948 report recommended, in addition to universal metering, construction of a 5 mg reservoir on Aubrey Butte, a cross-town high pressure main, and improvements to the water distribution system. It recommended that the construction of a storage reservoir on the north slope of Pilot Butte be deferred.

In May 1949, a supplement was issued to the May 1948 report. The City Council acted on the 1948 report by adopting an initial program of constructing the 5 mg reservoir on Aubrey Butte and a 0.5 mg reservoir on Pilot Butte. The May 1949 supplement brought cost estimates up-to-date and added further detail on some of the problems.

In July 1949, the City Council asked their consultants for a reappraisal of earlier recommendations, which resulted in a second supplemental report dated 1 August 1949. This dealt principally with reservoir sites, materials of construction, and other details, but introduced the idea of constructing, in stages, a second parallel pipe line from Tumalo Creek to the City.

A letter report, dated 7 September, 1949, considered flow conditions in sections of the original pipeline which were installed above the hydraulic gradient.

Cunningham and Associates made another report on 12 September 1950. It stated that the earlier recommendation for installation of water meters on all services had been rejected by the Council. The report mentions the fact that there are no favorable damsites on Tumalo Creek for construction of storage reservoirs to conserve excess winter runoff for summer use. This study raised the question as to whether it was necessary to construct 12 miles of pipeline to the original point of diversion when water of only slightly greater turbidity could be obtained from Tumalo Creek at a distance of only 6 miles from the City. A proposal was made for diversion at a point about 1-1/2 miles upstream from the west boundary of Shevlin Park. The water was to be carried by gravity to the City Limits, and thence pumped to the reservoirs. The plan was to use this source only in the summer months, at times of maximum demand for water and minimum turbidity in the creek. The new line was to be 16-inch diameter, 26,500 feet long, with a capacity of 3.5 mgd.

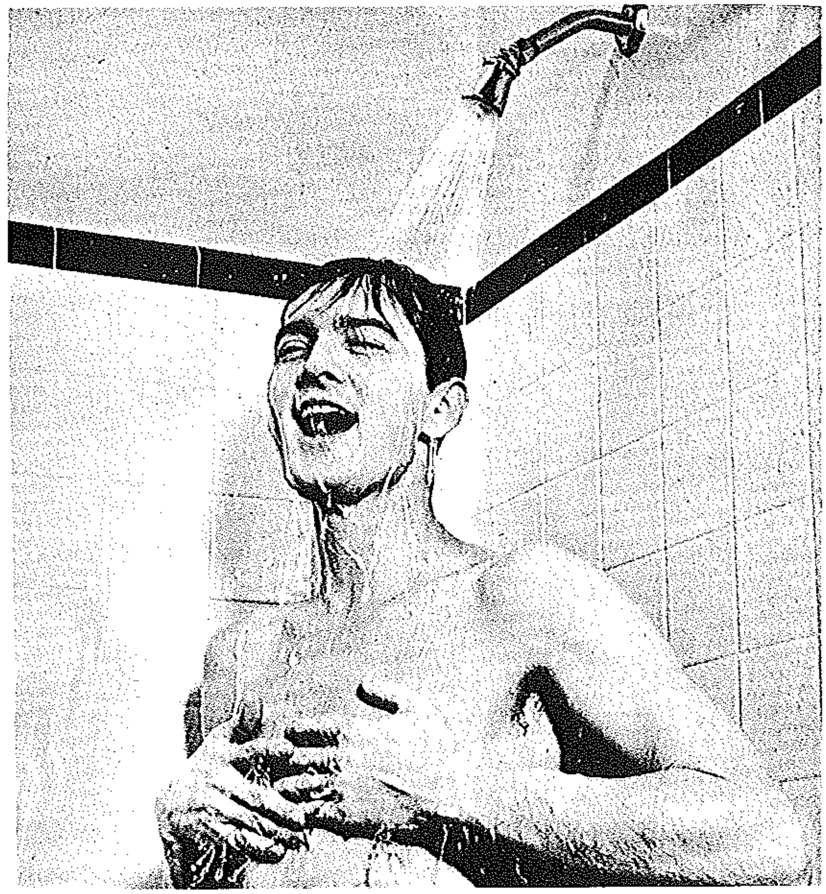
On 7 April 1953, a letter report was filed with the City preliminary to pipeline improvements for increasing the Tumalo Creek supply. The scheme for diversion above Shevlin Park had met with objection because of possible water pollution by livestock in the portion of the creek above the diversion, and the plan was eliminated when the bond issue was voted upon. In addition, the City acquired, by purchase, more water rights on Tumalo Creek in the amount of 3 cfs or 1.9 mgd, bringing the City's total water right at that time to 11 cfs or 7.1 mgd. This was greater than the capacity of the original pipeline, so that immediate construction was recommended to utilize the full water right. Consideration was given to installation of booster pumps on the existing line, but this idea was rejected because of the already high pipeline velocities and the cost of extending power lines to the booster pump locations near the upper end of the pipeline. The earlier proposal for construction of a second parallel line in stages was reiterated with the suggestion that certain sections could be constructed advantageously in the first stage of the work.

Letter reports of 16 September 1953 and 27 January 1954 were concerned with determining friction coefficients for sections of the existing pipeline, with rerouting of portions of the line which were above the hydraulic gradient.

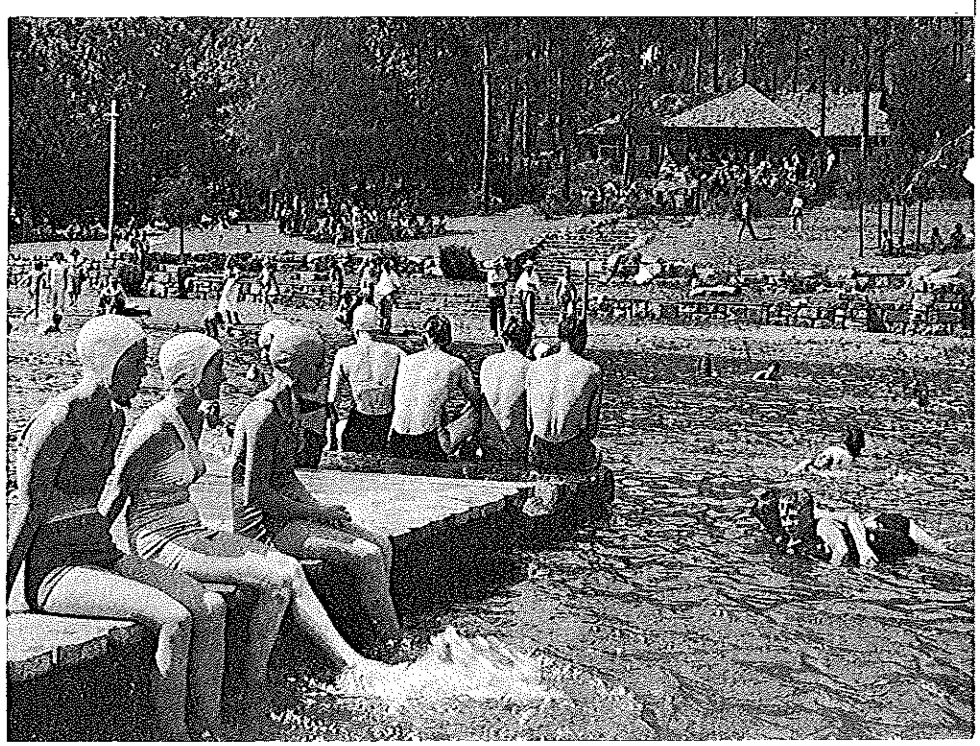
Finally, a letter of 2 January 1954 from Cunningham and Associates presented an estimate for construction of a second parallel pipeline all the way from the existing point of diversion to the City. The first section of the new 12- and 14-inch line was laid in 1954, two sections of the line were placed in service in 1956, and the line was completed in 1957. The combined capacity of the two lines is 11.1 mgd, which is just equal to the present water rights held by the City or 17.17 cfs.

A reservoir of 1-1/2 mg capacity was constructed at Pilot Butte in 1960.

Other Studies. The City Water Department made a hydraulic analysis of the water distribution system in 1958 using the McIlroy Analyzer at Washington State College. The results of this study have been the basis for elimination of several hydraulic "bottlenecks" in the system and have served as a guide in determining the proper size of new mains.



WATER USE



III. WATER USE

General. Advance planning for the Bend water system requires both a knowledge of the present situation and reasonable estimates of future conditions affecting water use.

Water supply and transmission facilities involve large capital expenditures and expansion should provide for needs twenty or more years into the future for the most economical development. Distribution mains and reservoirs can be constructed for shorter term needs since they are more readily expanded, but some estimates of future requirements are valuable in outlining an orderly program of financing improvements.

As previously pointed out, it is not necessary to make predictions of future water use with a high degree of accuracy, as construction programs can be accelerated or delayed as necessary to keep pace with actual needs.

Two methods will be used in forecasting future trends and needs. The first is based on projecting population growth and per capita water use. The second is a direct projection of water use records.

Population. Census data is tabulated below and given in Figure 1 for the period from 1910 to 1960.

CITY OF BEND - POPULATION 1910 to 1960

Year	Population	Average Increase per Year
1910	536	
1920	5,415	91.0%
1930	8,848	6.3%
1940	10,021	1.3%
1950	11,409	1.4%
1960	11,940	0.5%

In 1960 the Bend water system served a total population of approximately 13,500 including customers outside the City.

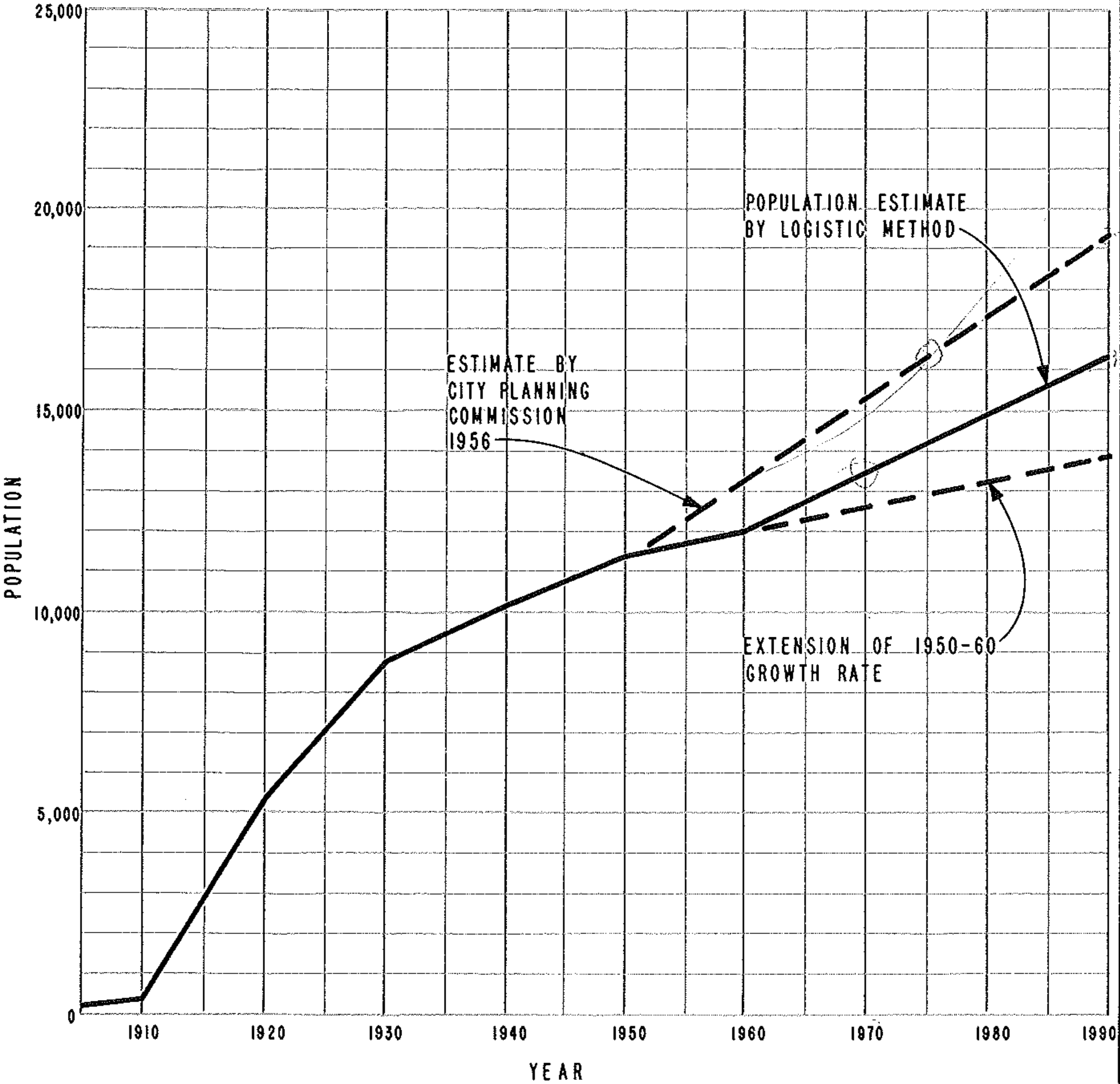


FIGURE I
CITY OF BEND, OREGON
WATER SYSTEM STUDY
CITY OF BEND
POPULATION

CORNELL, HOWLAND, HAYES & MERRYFIELD
SEATTLE CORVALLIS BOISE
CH2M

In 1956 the City Planning Commission projected a population of 17,400 for Bend in the year 1975. This is shown on Figure 1. Extending this line to 1990 would give a population of about 19,400 by the year 1990. This represents an increase of 7,500 people over the next 26 years, or an average of 288 (2.4%) per year.

The most recent reports of the Oregon Board of Census estimate a growth rate of 2.1% per year for the State as a whole for the next 15 years. In general, the rate of population growth in rural areas is less than this rate, and the rate in cities is greater. The Board of Census is predicting for Deschutes County a rate of growth much less than the average for the State.

Another method of predicting population involves the use of logistic curves. The advocates of this method claim that the logistic curve will represent with a high degree of accuracy the population changes which have occurred in most cities in the United States. It assumes that cities will reach a saturation level as population density increases, after which population densities in the densely built-up areas will remain relatively constant. It is based on past growth in the community and gives logical results when extended over considerable periods of time. Using the logistic method, the estimated population of Bend for the study period is as follows:

Year	Population
1970	13,700
1980	15,000
1990	16,300

This information is plotted on Figure 1.

The growth rate of Bend from 1950 to 1960 is the lowest in its history. If this rate is extended into the future the population of Bend in 1990 would be only 13,700 persons.

Number of Water Services. Accurate records are kept on the number of water services maintained by the Bend Water Department. The records are shown by Table 1 and Figure 2. The increase in the number of services over the years follows a more uniform course than the population data. Figure 2 shows that rate of increase in number of services is virtually constant from 1930 to 1960, as all of the figures plotted lie on or very near a straight line. Extending this line to 1990 indicates that the number of water services which might be expected at that time would be 5,850. Presently the average number of

TABLE 1

NUMBER OF WATER SERVICES *

Year	Metered	Flat Rate	Total	Bend Population	Avg. No. Persons Per Service
1928	177	2,150	2,327		
1929	187	2,204	2,391		
1930	190	2,217	2,407	8,848	3.7
1931	198	2,210	2,408		
1932	195	2,164	2,359		
1933	197	2,194	2,391		
1934	206	2,180	2,386		
1935	212	2,259	2,471		
1936	226	2,331	2,557		
1937	232	2,399	2,631		
1938	267	2,457	2,724		
1939	289	2,548	2,837		
1940	310	2,656	2,966	10,021	3.4
1941	363	2,700	3,063		
1942	357	2,626	2,983		
1943	364	2,777	3,141		
1944	382	2,638	3,020		
1945	385	2,661	3,046		
1946	412	2,952	3,364		
1947	439	2,965	3,404		
1948	479	3,105	3,564		
1949	495	3,163	3,658		
1950	510	3,216	3,726	11,409	3.1
1951	520	3,120	3,640		
1952	523	3,137	3,660		
1953	529	3,205	3,734		
1954	542	3,233	3,775		
1955	547	3,267	3,814		
1956	566	3,306	3,872		
1957	612	3,342	3,954		
1958	610	3,409	4,019		
1959	628	3,428	4,056		
1960	655	3,491	4,146	11,940	2.9
1961	660	3,522	4,182		
1962	674	3,521	4,195		
1963	711	3,596	4,307		

* As of July 1

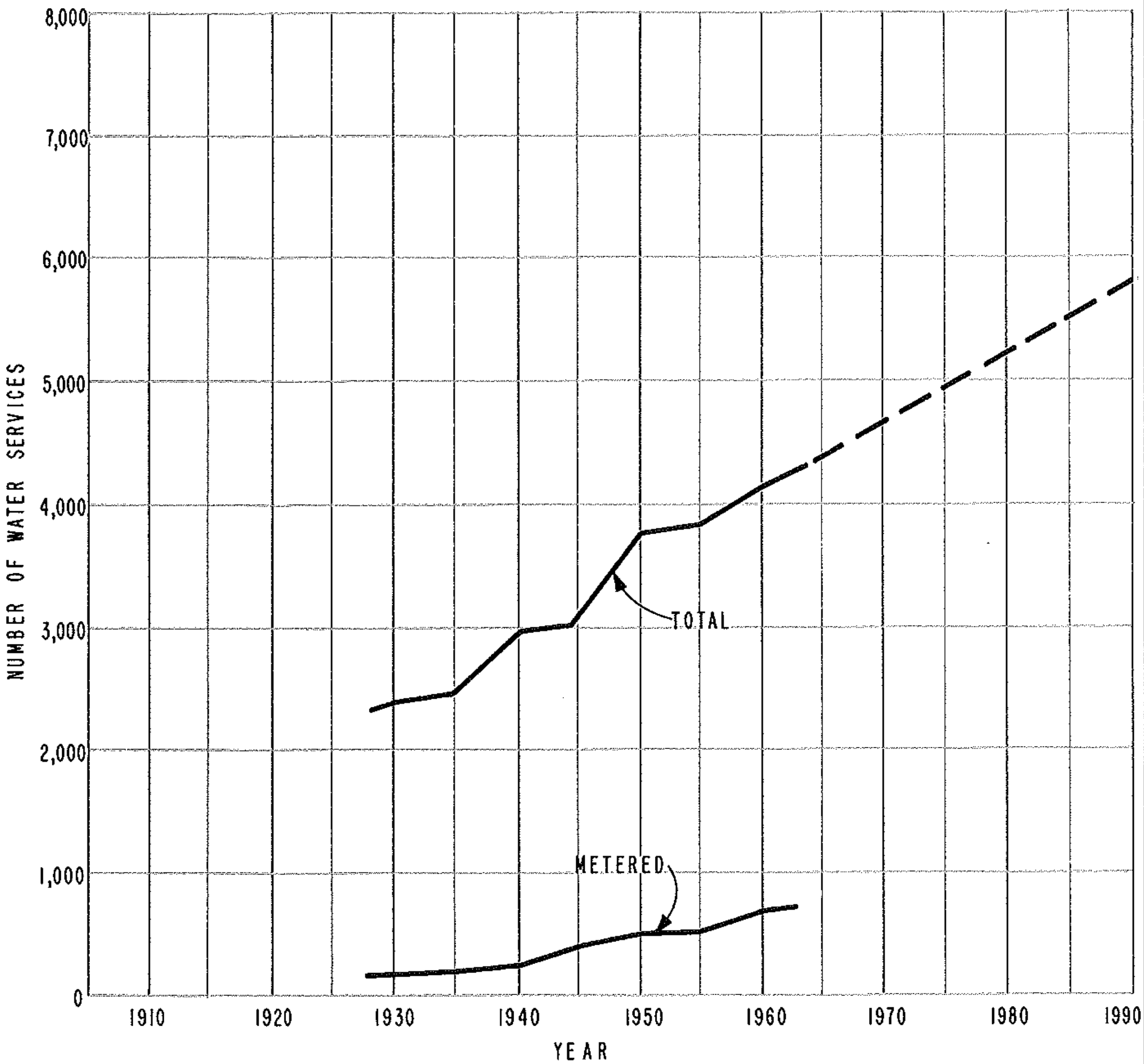


FIGURE 2

CITY OF BEND, OREGON
WATER SYSTEM STUDY

NUMBER OF WATER SERVICES BY YEARS

CORNELL, HOWLAND, HAYES & MERRYFIELD
SEATTLE CORVALLIS BOISE

CH2M

persons per service is 3.0, based on the population of the City. If this factor is applied to the 5,850 services expected in 1990, the population would be 17,550. This gives a population estimate between that of the City Planning Commission and that obtained by the logistic method.

Water Use by Months. The total water use by months for the past 31 years is shown by Table 2 and Figure 3. Water use is greatest during the summer months, May through Setpember, due primarily to the lawn sprinkling load, and to a lesser extent to the influx of tourists at this time of year. From 1933 to date, monthly water use has grown at all seasons of the year, but increased use during the summer is particularly striking. For example, in 1950 water use during the winter months varied from 40 to 50 mg (million gallons), while the maximum monthly use in July was 161 mg. In 1960, the winter use still amounted to about 40 to 50 mg per month, but more than 300 mg were used in July. Maximum monthly use almost doubled over a ten-year period even though there was no substantial increase in the winter-time use.

Annual and Daily Use. Table 3 lists the annual water use from 1933 to date both in terms of million gallons and acre-feet. Average daily use is shown for this same time period in terms of mgd (million gallons per day) and cfs (cubic feet per second). Maximum daily use is shown for the shorter period of 1947 to 1963. The data for average and maximum daily use are graphically illustrated on Figure 4. The great increase in the sprinkling load is shown very clearly by this figure. Average use has increased from about 3 mgd in the early fifties to about 4 mgd in the early sixties (33 percent gain), while the maximum daily use has increased from 6 mgd to 12 mgd (100 percent gain) in this same period. The ratio of maximum daily use to average daily use for recent years is 2.9 which again reflects the influence of lawn irrigation on water demands.

Referring again to Figure 4, the points representing average daily use from 1933 to date lie very close to a straight line of constant slope. If this line is extended to the year 1990, the average daily water use would be about 5.8 mgd. Assuming that the ratio of 2.9 will still apply in 1990, then the maximum daily use will be about 16.8 mgd.

At this point, it is of interest to compare these estimates of water use with those based on population predictions already presented. Since population records are available for the City of Bend, and are not

TABLE 2

WATER USE BY MONTHS (IN MILLION GALLONS)

YEAR	MONTH											
	J	F	M	A	M	J	J	A	S	O	N	D
1933	45.2	34.8	36.4	58.4	70.7	78.1	96.8	113.0	59.5	51.8	38.2	36.3
1934	35.6	33.1	54.1	71.7	93.4	88.8	121.1	124.7	102.6	41.6	42.9	43.0
1935	43.8	37.8	42.5	46.2	89.9	106.1	117.9	122.2	93.6	48.6	37.7	39.4
1936	35.9	32.1	37.0	51.6	84.2	88.5	123.9	124.7	71.6	59.3	41.0	40.3
1937	48.4	39.1	43.2	50.2	98.6	75.0	125.5	122.6	81.2	50.4	35.6	36.8
1938	36.4	33.5	37.0	50.3	97.8	120.4	127.5	125.8	87.4	46.9	36.5	36.0
1939	35.8	34.4	51.7	91.7	100.2	109.5	142.1	140.2	89.5	53.5	41.4	39.3
1940	35.5	33.4	46.1	61.4	103.1	119.6	122.3	128.3	58.8	45.1	44.0	48.6
1941	47.3	42.9	64.0	86.9	77.8	84.0	116.6	81.6	59.1	45.5	41.4	56.5
1942	50.8	30.0	35.2	64.3	71.3	93.5	132.5	129.9	91.9	51.1	35.2	47.4
1943	34.1	32.0	37.5	58.6	93.8	90.9	133.7	130.5	119.2	68.1	45.3	48.1
1944	45.6	44.9	50.0	68.7	125.2	97.6	144.9	143.1	102.3	69.9	46.1	45.8
1945	41.2	37.6	46.8	68.7	94.2	118.4	153.7	120.1	90.4	68.7	41.6	43.5
1946	41.7	38.0	43.6	75.1	102.8	87.0	131.5	117.5	75.2	50.9	37.6	38.7
1947	32.0	32.8	48.3	78.8	119.1	88.3	126.2	125.9	104.1	58.5	41.9	41.4
1948	40.7	39.0	39.1	52.0	80.7	75.2	150.2	120.1	96.2	53.9	43.8	45.9
1949	55.3	51.4	48.0	87.3	113.0	149.9	163.1	149.7	106.8	54.1	46.1	40.4
1950	41.5	38.9	41.1	78.2	125.2	97.5	160.7	138.3	112.1	49.7	44.0	37.8
1951	41.6	41.4	37.6	94.6	87.7	152.4	158.0	141.4	111.3	51.7	46.5	47.0
1952	47.5	43.0	46.2	98.0	120.3	97.1	157.6	145.7	108.1	85.8	51.6	50.4
1953	47.3	41.7	46.7	70.8	98.9	89.9	180.9	134.7	122.6	67.0	56.2	52.2
1954	60.6	52.4	58.9	104.9	164.7	118.6	172.6	117.7	88.5	57.7	54.0	47.6
1955	53.5	48.4	52.9	60.7	131.7	151.0	157.5	179.8	130.8	70.3	48.1	49.6
1956	51.3	51.2	51.8	90.4	115.4	111.5	196.3	173.2	135.3	82.6	53.7	48.5
1957	50.1	43.4	46.4	77.4	122.2	206.0	224.7	149.1	142.4	54.9	53.4	49.3
1958	63.6	61.9	55.9	62.1	143.1	102.7	211.0	224.3	126.1	76.4	49.4	30.4
1959	37.0	32.2	51.3	110.2	114.4	180.2	213.1	166.0	116.8	68.5	50.1	42.1
1960	44.5	23.8	51.3	80.2	116.1	233.6	301.1	224.0	162.8	80.1	49.9	41.2
1961	39.7	46.1	48.0	96.0	135.0	226.1	283.8	252.6	146.5	79.6	57.1	69.4
1962	72.8	68.4	70.6	122.2	104.2	220.9	270.4	203.1	163.7	74.0	60.5	49.5
1963	25.6	37.9	51.5	39.6	113.6	188.3	235.6	243.8	155.2	87.5	56.3	60.2

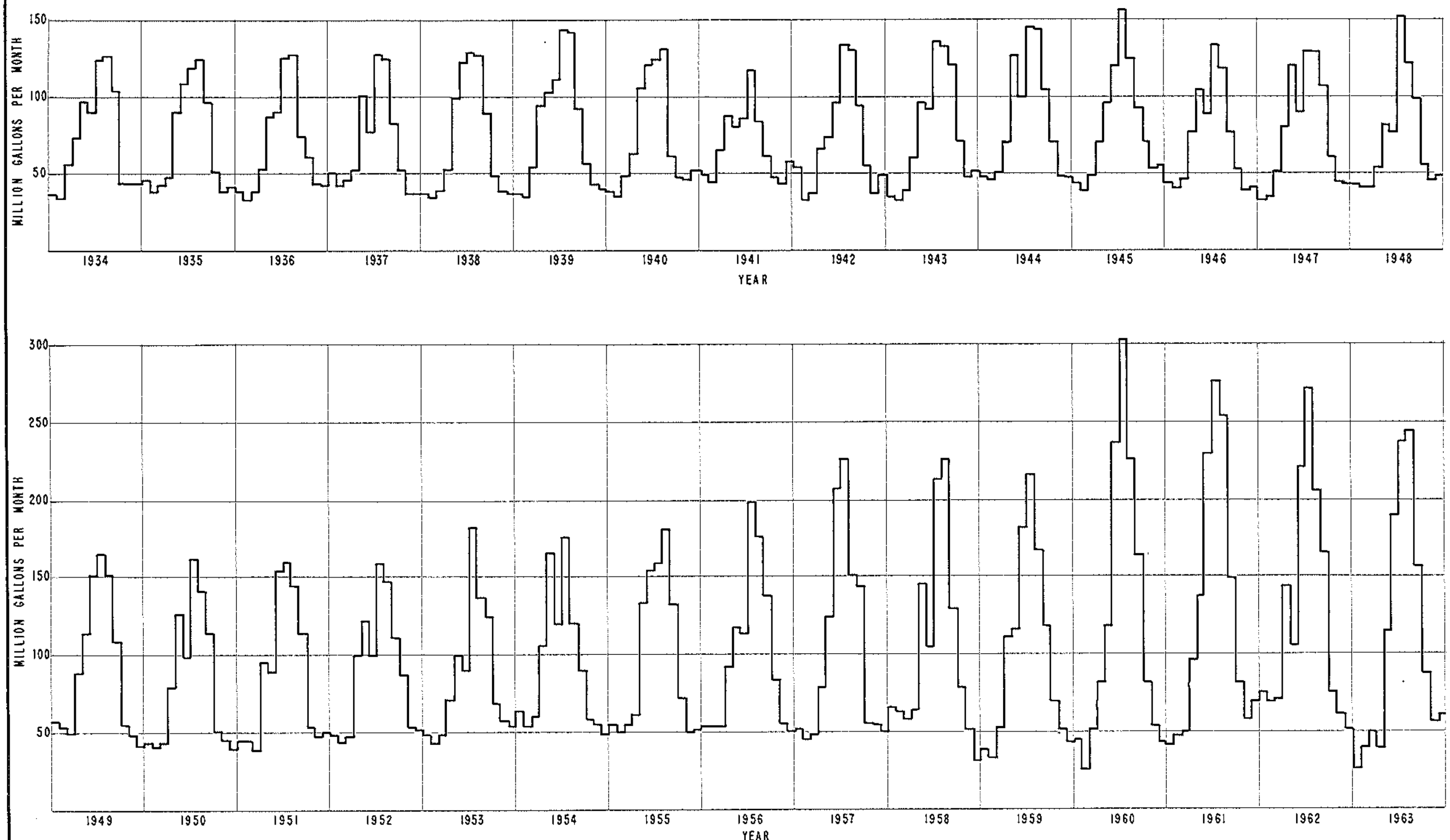


FIGURE 3
CITY OF BEND, OREGON
WATER SYSTEM STUDY
MONTHLY WATER USE BY YEARS

CORNELL, HOWLAND, HAYES & MERRYFIELD
SEATTLE PORTLAND CORVALLIS BOISE

TABLE 3

WATER USE

Year	Total Annual Water Use Million Gals.	Acre-Ft.	Average Daily Use MGD	CFS	Maximum Daily Use MGD	CFS	Ratio Max. Day / Avg. Day
1933	711	2,180	1.95	3.02			
1934	852	2,610	2.34	3.63			
1935	826	2,530	2.26	3.50			
1936	790	2,430	2.16	3.35			
1937	807	2,480	2.24	3.48			
1938	836	2,570	2.29	3.56			
1939	929	2,850	2.54	3.94			
1940	846	2,600	2.32	3.60			
1941	803	2,460	2.20	3.41			
1942	833	2,560	2.28	3.53			
1943	892	2,740	2.44	3.78			
1944	984	3,020	2.69	4.17			
1945	927	2,850	2.54	3.94			
1946	840	2,580	2.30	3.56			
1947	897	2,750	2.46	3.82	4.74	7.35	1.9
1948	837	2,570	2.29	3.55	6.10	9.45	2.6
1949	1,065		2.91	4.52	6.11	9.50	2.1
1950	865	2,660	2.38	3.69	6.03	9.32	2.5
1951	1,011	3,100	2.78	4.31	6.05	9.37	2.2
1952	1,051	3,230	2.89	4.47	6.16	9.55	2.1
1953	1,008	3,100	2.76	4.28	6.45	10.00	2.3
1954	1,044	3,210	2.87	4.45	7.22	11.20	2.5
1955	1,134	3,480	3.11	4.81	7.42	11.50	2.4
1956	1,161	3,570	3.19	4.95	7.60	11.80	2.4
1957	1,219	3,740	3.34	5.17	7.59	11.70	2.3
1958	1,208	3,710	3.31	5.13	9.07	14.10	2.7
1959	1,182	3,640	3.24	5.02	8.74	13.50	2.7
1960	1,407	4,340	3.87	6.00	11.87	18.40	3.1
1961	1,480	4,530	4.04	6.26	10.94	16.90	2.7
1962	1,480	4,550	4.06	6.30	11.74	18.20	2.9
1963	1,295	3,970	3.54	5.50	10.30	17.70	3.2

Max. Day / Avg. Day for past 17 years = 2.5, for past 6 years = 2.9

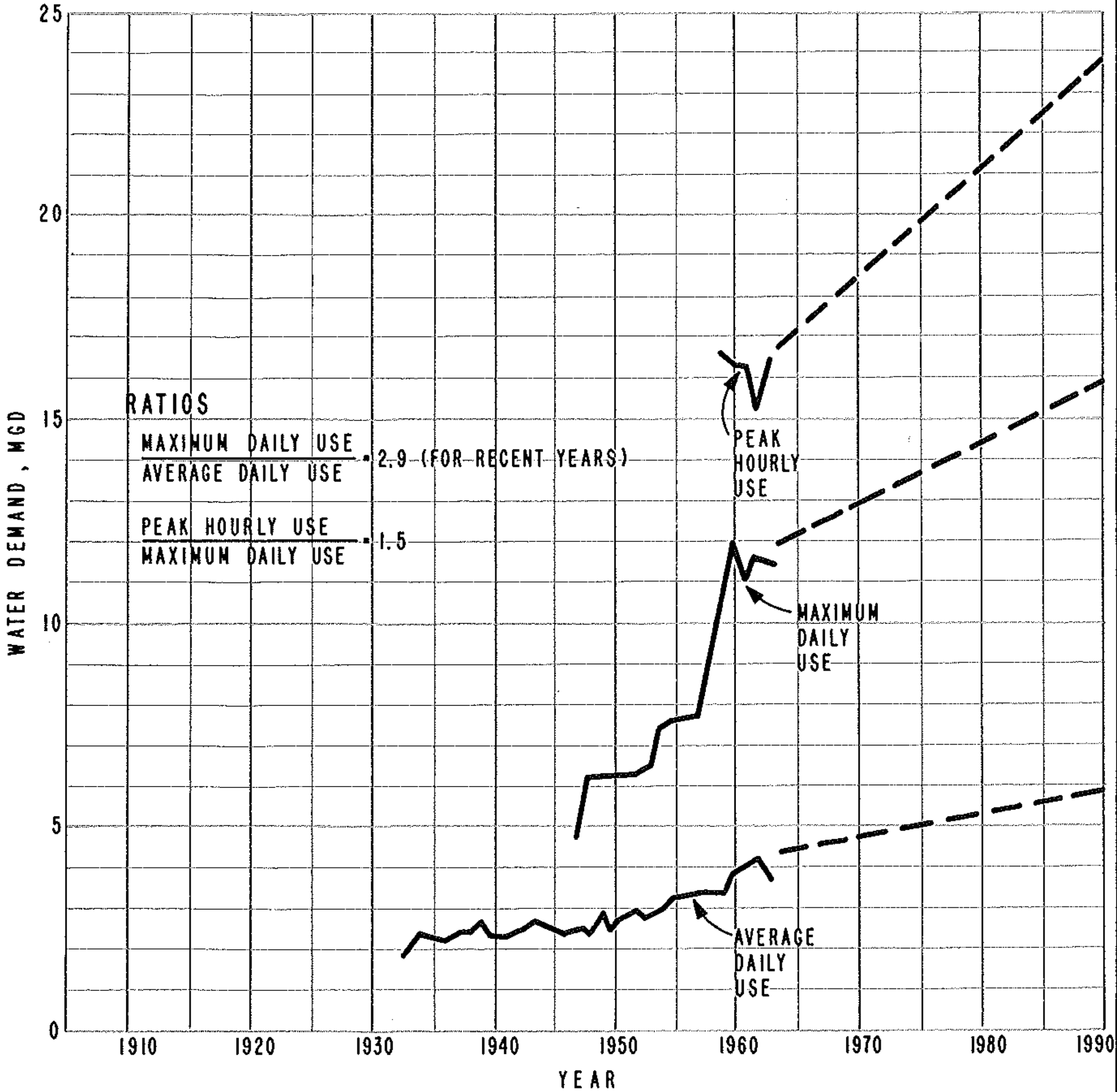


FIGURE 4

CITY OF BEND, OREGON

WATER SYSTEM STUDY

PEAK HOURLY AND MAXIMUM DAILY RATES OF WATER USE BY YEARS

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readily available for the total number of persons served by the Bend water system, it is convenient to base per capita water use on City population only. On this basis, the present average use is 340 gpcd (gallons per capita per day), and the maximum daily use is 1,000 gpcd. Using these per capita consumption figures and the City population estimate of 16,300 for the year 1990 as obtained by the logistic method, an average daily use of 5.5 mgd and a maximum daily use of 16.3 mgd are obtained as compared to 5.8 and 16.8 mgd based on direct projection of trends in water use. These estimates of future water use check within about 5 percent, which is satisfactory for the purpose of advance planning.

In considering the maximum daily use of water, it must be pointed out that lawn watering presently is restricted to alternate days. Since lawn irrigation is the largest single item of water demand on maximum days, the restriction has the effect of reducing the maximum daily demand. The imposition of more severe restrictions on lawn watering or the installation of meters on all services would tend to further reduce maximum daily demands, while the removal of the present restrictions would result in an increase in water use on days of maximum demand. The estimates of maximum daily demand presented above are based on continuation of present policies and practices in this regard.

Peak Hourly Demands. The rate of water use varies throughout the day including the days of maximum use. Table 4 and Figures 4 and 5 give data on peak hourly demands experienced in recent years. Regulation of lawn sprinkling also has an effect in reducing peak hourly demands. In Bend the peak hourly demand of record is a rate of 19.8 mgd at 10 a.m. on July 19, 1960. A peak rate of 16.6 mgd was recorded on July 23, 1959. The water demands by hours for these two days are plotted on Figure 5. The ratio of the hourly demand to the maximum daily demand is about 1.5. Water use is low from 10 p.m. to 5 a.m., increases rapidly to a peak about 10 to 11 a.m., and declines sharply from 7 to 10 p.m.

In the year 1990, peak hourly demands of 22 to 25 mgd may be expected based upon trends in water use and population growth.

Summary and Discussion. The purpose of the data presented on water use is to set some general requirements and guide lines for planning future improvement and expansion of the water system.

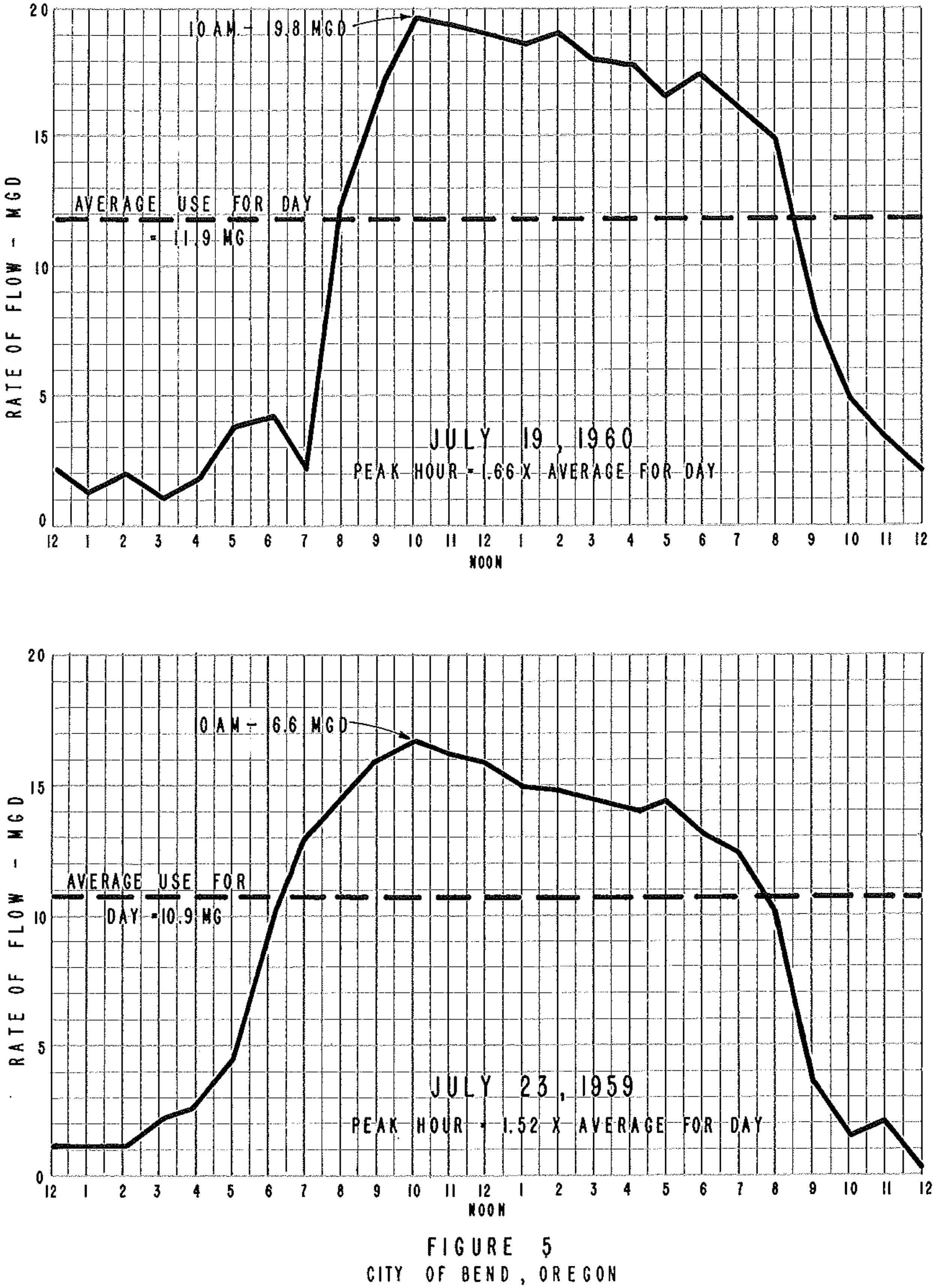

FIGURE 5
CITY OF BEND, OREGON
WATER SYSTEM STUDY
HOURLY DEMANDS FOR WATER
ON DAYS OF MAXIMUM USE

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The average daily, monthly, and annual water use figures apply principally to sizing of raw water storage or seasonal storage in the event that the use of reservoirs is considered for storing excess winter runoff for summer use.

The maximum daily use is significant for several reasons. It determines the capacity for which intake, transmission, treatment, and other production facilities must be designed. Since the maximum daily use determines the maximum rate of withdrawal from the source of supply, it is also important in connection with water rights.

TABLE 4

RATIO OF PEAK HOURLY DEMAND TO AVERAGE FOR DAY

For Maximum Day of Year, 1959-1963

Year	Day	Max. Day of Year, mg	Peak Hourly Demand, mgd	Ratio, Peak Hour / Max. Day
1963	Aug 30	10.3	16.4	1.44
1962	July 30	11.7	15.2	1.30
1961	July 12	10.9	16.2	1.50
1960	July 19	11.9	19.8	1.66
1959	July 23	10.9	16.6	1.52
				1.50

For Summer Months, 1963

Day	Max. Day of Year, mg	Peak Hourly Demand, mgd	Ratio, Peak Hour / Max. Day
May 29	7.9	13.2	1.62
June 18	9.7	15.3	1.58
July 30	10.1	14.9	1.47
Aug. 9	10.3	16.4	1.59
Sept. 6	8.8	14.7	1.67
Oct. 1	6.2	10.8	1.75
			1.61

Use $\frac{\text{Peak Hour}}{\text{Max. Day}}$ Ratio = 1.5 for future estimates

The peak hourly demand together with fire-fighting requirements are the basis for establishing the required capacity of storage reservoirs on the water distribution system and the size of distribution mains.

Table 5 summarizes average, maximum, and hourly rates of water use for the present, 1970, 1980, and 1990.

TABLE 5

SUMMARY OF FUTURE WATER USE

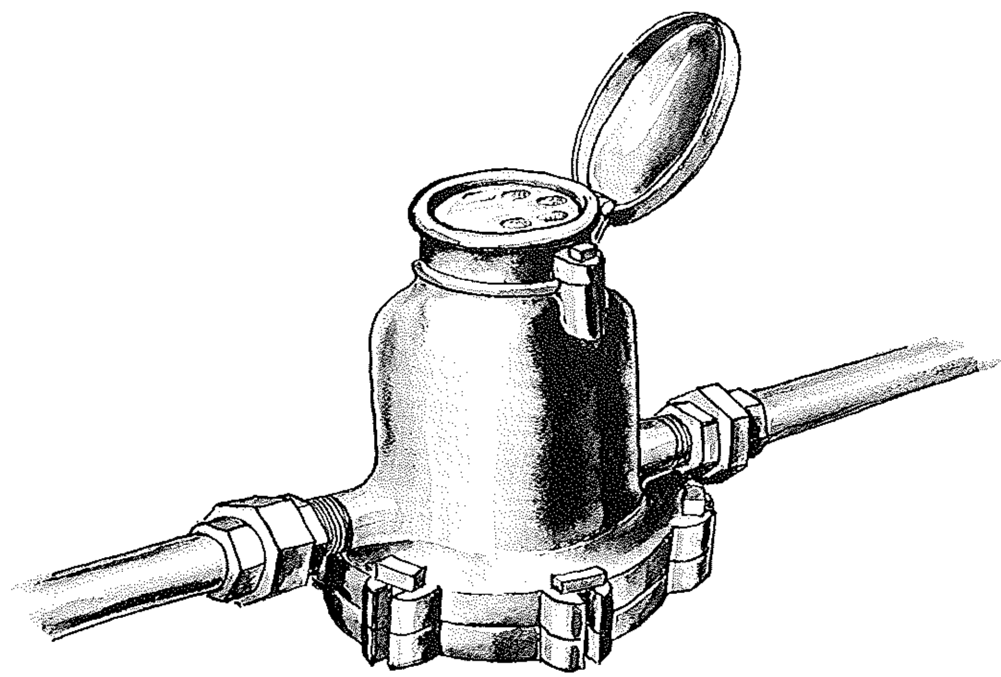
Year	Average Daily Use mgd	Maximum Daily Use mgd	Peak Hourly Demand Rate mgd
Present	4.0	11.9	16.6*
1970	4.4	12.8	19.2
1980	5.1	14.8	22.2
1990	5.8	16.8	25.2

*Exceeded on one day, July 19, 1960, when peak rate of 19.8 mgd was recorded.

In using these figures, it should be kept in mind that they are estimates. They are based on projecting historical patterns of community growth and water use, and on preserving present practices in metering and regulation of water for irrigation. There are no large water-using industries in Bend. For purposes of the report, it is assumed that the present ratio of industrial-commercial to domestic use will hold. This allows for normal industrial-commercial growth, but may require special future consideration in the event that a new large water-using industry is to be served.

The patterns and habits of water use in Bend are affected predominately by three factors: climate, soil type, and flat rates. The dry climate and porous soil combine to produce exceptionally high water requirements for proper maintenance of lawns and gardens, and the flat rates make it possible for almost everyone to use all the water necessary for this purpose. The influence of these factors on the maximum daily use and peak hourly demands overshadows other factors which might otherwise be important in predicting future water use. For example, the increased use of water by automatic washing machines, garbage grinders, and other water-using appliances is a major consideration in many cities, but in Bend, the increase which may be expected from more widespread use of these devices is relatively small compared to irrigation needs.

EFFECTS OF METERING ON WATER USE



IV. EFFECTS OF METERING ON WATER USE.

General. In Bend, commercial and industrial water accounts are individually metered but domestic services are not. Universal metering of domestic water use has never been looked upon with favor by the citizens of Bend or their City officials. Every time metering has been proposed in the past, it has been rejected. However, since major expansion of the water supply and transmission system is contemplated, it is appropriate to review the advantages and disadvantages of metering. The engineering and financial considerations are presented here, and on this basis a recommendation is made for universal metering. However, this is a policy matter which, in the final analysis, must be decided by the consumers and their elected officials. Tradition, public acceptance, and other considerations must be evaluated along with the engineering and cost data.

Comparison of Water Use in Metered and Unmetered Cities. Table 6 gives information regarding water use in four cities without meters on domestic services, in four cities with universal metering, and in one which was in the process of installing meters in 1960. Since maximum rates of water used in Bend are primarily dependent upon climate and soil type as they affect lawn irrigation requirements, cities have been selected for their similarity in this respect to Bend. There are undoubtedly variables involved other than metering, such as the industrial use of water, but in general the conditions are as comparable as it is possible to obtain.

The metered cities include Pasco, Richland, Spokane, Ellensburg. The unmetered ones are Bend, Redmond, Coeur d' Alene, and The Dalles. In 1960, the City of Medford had partially completed meter installation.

Of the nine cities, Richland, Washington and Redmond, Oregon, have the highest per capita water use rates, which are virtually equal. Redmond is unmetered while Richland is fully metered. Bend and The Dalles (unmetered) and Pasco (metered) use almost as much. The two lowest rates of use on maximum days are in metered cities. There is some indication here that water use is reduced by metering.

There is, perhaps, a better and more direct way to estimate the reduction in water use which might be obtained by installation of meters on all services, and that is the experience in other cities which have made the conversion. Richland, Washington, and Medford, Oregon, are two cities comparable to Bend which have recently installed meters on previously unmetered water systems.

TABLE 6.

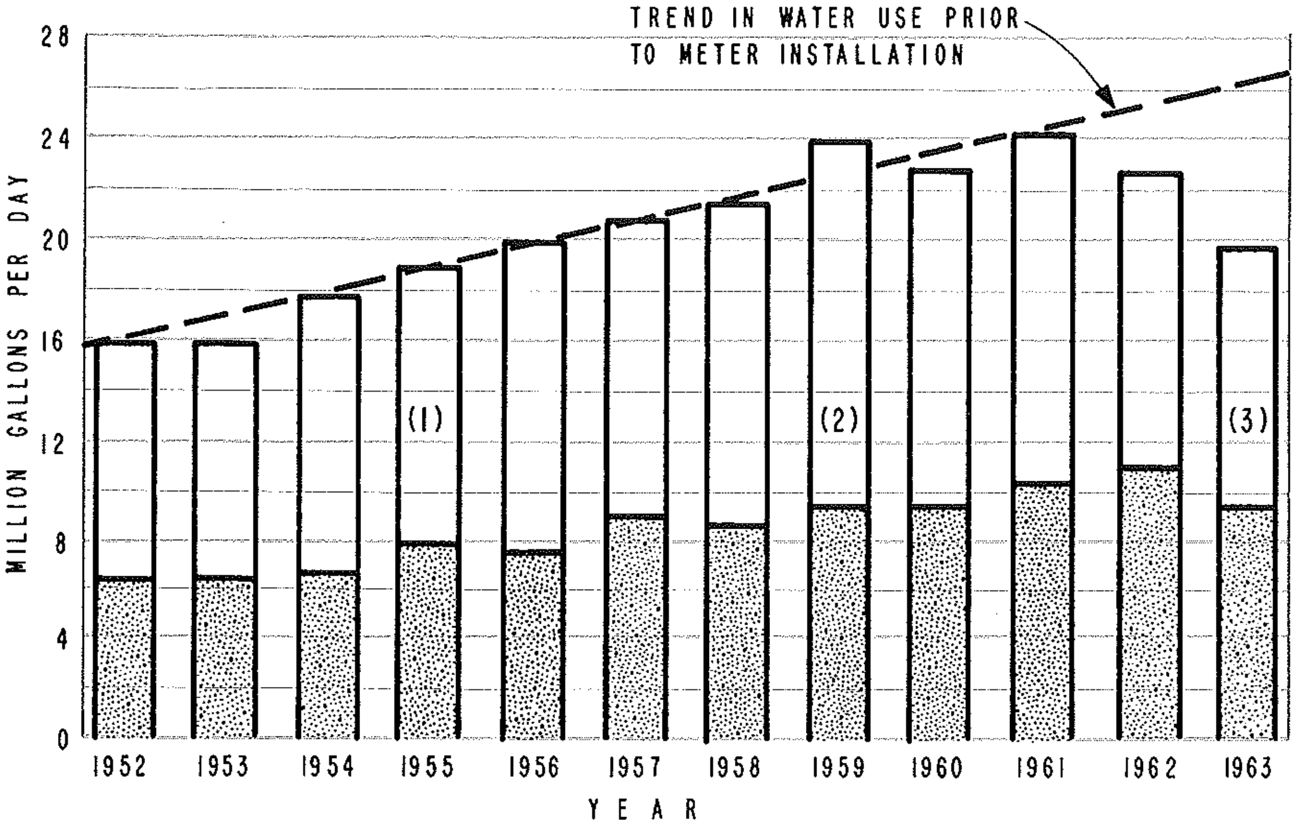
COMPARISON OF WATER USE IN BEND TO
THAT IN OTHER CITIES, 1960

City	Avg. Annual Precip. In.	Avg. Water Use gpcd	Max. Daily Use gpcd	Ratios: Max. day to Avg. day	Ratios: Peak Hour to Max. day	Domestic Use Metered
Redmond	8.51	390	1,190	3.05	1.42	No
The Dalles	13.79	420	1,050	2.50	1.20	No
Coeur d' Alene	26.43	250	975	3.90	1.53	No
BEND	13.0	340	1,000	2.90	1.50	No
Medford	19.78	300	800	2.67	1.69	Partially
Pasco	6.5	312	985	3.15	1.02	Yes
Spokane	18.69	164	465	2.82	2.73	Yes
Richland	6.31	368	1,196	3.25	1.49	Yes
Ellensburg	8.05	300	655	2.18	2.04	Yes

TABLE 7

EFFECTS OF METERING AT RICHLAND

Year	Metering	Water Use, Gallons Per Capita Per Day		
		Average Day	Maximum Month	Maximum Day
1949	BEFORE	392	912	1143
1956	BEFORE	490	1175	1268
1957	AFTER	400	858	1118
1958	AFTER	399	918	1100
1959	AFTER	366	875	1164
1960	AFTER	368	947	1196



(1) COMMENCED INSTALLATION OF METERING ON DOMESTIC SERVICE

(2) START OF MAIN METERING PROGRAM

(3) 100 % METERING ACCOMPLISHED IN MAY, 1963

FIGURE 6
CITY OF BEND, OREGON
WATER SYSTEM STUDY

MAXIMUM & AVERAGE DAILY WATER USE
IN MEDFORD, OREGON
BEFORE & AFTER UNIVERSAL METERING

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Experience at Richland. In the change from private (General Electric Administration) to municipal ownership and operation of the Richland, Washington, water system, meters were installed for the first time on all services in 1957. Good records are available to measure the effects of meters on water use. The figures are given in Table 7.

Based on the record to date, it appears that metering at Richland may have reduced average daily use by about 25 percent and maximum daily use by 5 to 15 percent.

Experience at Medford. In May 1963 the Medford Water Commission completed a program of changing from non-metered to metered rates. The program commenced in 1955, but most of the meters were installed during the period from 1959 to 1963.

The economic analysis of metering at Medford was based on an anticipated reduction of 15 percent in the maximum daily demand for water. To date, the reduction in water use has exceeded expectations, and amounts to about 25 percent. It is difficult to say just how much of the reduction in 1963 , the first year with 100 percent metering, was due to metering and how much was due to the unusually cool summer, although it can be seen from Figure 6 that some definite reduction of maximums has occurred each year since 1959. Also, there is a tendency for the reduction in water use to be greater immediately after meter installation than for following years. So that it remains to be seen at Medford what the exact extent of water savings by metering will be, although it appears now that it will be not less than the 15 percent predicted.

Experience in Other Cities. The installation of meters on all water services invariably reduces water demand. The savings range from 15 to 60 percent in different communities. The reductions come about as the elimination of water waste, and not at the sacrifice of legitimate water use. Metering provides both the means and the incentive for reduction of water waste. It makes possible the detection of leaks and faulty plumbing on the customer's premises, and by comparing the total quantity of water delivered through service meters with that measured by master meters, the water lost in the city's distribution system can also be determined. Detection and repair of leaks following meter installation have drastically reduced unaccounted for water in many water systems.

Meters have proven to be a good investment. The costs of installation and maintenance have been more than offset by reduction in water loss and savings in capital expenditures for additional supply which otherwise would have been required.

Mention of water service meters in cities with flat rates is often met with considerable, and sometimes violent, public opposition. Water department telephones are apt to be busy handling inquiries and complaints before, during, and after meter installation. In a few cases, where the necessity and advantages of metering were properly explained to the public in advance, people, at first dubious, have later given their wholehearted support to the metering.

Advantages and Disadvantages of Universal Metering. One of the principal advantages of metering is that it provides a means of equitably distributing, on the basis of use, the cost of the water system and its operation. An accurate accounting of each customer's use is accomplished. Customers receive what they pay for, and pay for what they receive. Without a means of measurement, this is not possible. The waste or misuse of water becomes the monetary responsibility of the customer and is reflected in his water bill. The thrifty or careful user is rewarded by a lower water bill, while the careless or wasteful water user must pay for his wasteful or careless habits.

Metering of a water system makes possible the accurate determination of accounted for water.

Metering is an aid in establishing an equitable and adequate water rate structure.

Often, complete metering will bring about a saving to the average user through the lower overall cost of water service by water conservation.

By installing meters, Bend may set an example of water conservation which, if followed by others, will benefit the surrounding areas as well as the City. The reduction of the presently large water losses and waste by irrigation districts near Bend could effect a substantial increase in the net water supply available for beneficial use.

Disadvantages of metering include the cost of meters, meter reading, maintenance, and bookkeeping. Sufficient savings must be made elsewhere in the system to justify their use economically.

There may also be a feeling that the sale of water through meters will deter some persons from using enough water to properly maintain lawns and gardens with a resulting loss in the neat appearance of the community. The green lawns and well-kept houses in Bend are an important part of the City's attraction to tourists, one of the principal sources of income for the community, and care should be taken to set metered water rates so as to permit adequate lawn sprinkling but to discourage water waste.

There is some slight loss of water pressure through meters, but this should be more than offset by reduced water use on the system through elimination of waste.

Some will argue that leaks can be checked by inspections and surveys, and that money spent for meters could better be spent on other water works improvements. It is true that inspectors and pitometer surveys can be used to check leakage, but in metered communities the regular determination of unaccounted-for water gives a continuous check of loss and provides a clue as to when leak location is needed. It is also true that the savings from the use of meters must exceed their costs. This can be judged by estimates of the cost of metering versus the cost of the additional supply required by an unmetered system.

Application of Meters to the Bend Water Situation. The effects of service meters on the Bend water system demand can, of course, only be estimated. The amount of City distribution system losses cannot be determined. In other systems this has ranged from as high as 50 percent to an apparently irreducible minimum of 10 percent. Also, there is no way to determine the amount of water lost in a household plumbing system through leaks or the amount of water which may be wasted due to lack of metering.

Based on the experience in other cities, a good estimate of the reduction in maximum daily water use in Bend following installation of meters would be 15 percent. On this basis, the reduction in the maximum daily demand would be equivalent to a 1.9 mgd water supply today and to a 2.5 mgd water supply in 1990.

At the present time there are 3,596 unmetered services. The estimated cost of meter installation on all of these services is $216,000.00, as compared to an estimated cost of $ 331,000.00 for development of an additional 1.9 mgd of supply from Tumalo Creek. This means that a savings of at least $115,000.00 in capital expenditures would be realized by universal metering. Meters would pay for themselves if the reduction in maximum daily water use were only 11 percent. This is the break-even point. It is almost certain that the reduction in water use will be more than 11 percent, and that there will be substantial savings to the City from their use.

From an engineering and financial standpoint then, the recommendation must be for installation of water meters on all services. It also must be recommended as a sound business practice, in which the amount of product delivered to each consumer is measured and billed accordingly.

EXPANSION OF THE TUMALO CREEK SUPPLY

V. EXPANSION OF THE TUMALO CREEK SUPPLY

Present Source. Since 1926, the City of Bend has obtained all of its municipal supply from the Bridge Creek branch and Middle Fork of Tumalo Creek. Tumalo Creek rises on the eastern slopes of Ball Butte and Broken Top Mountain about 20 miles west of Bend in a protected watershed area, most of which lies within the Deschutes National Forest. Bend is justly proud of this fine source of supply. The water is of excellent chemical quality, and the bacteriological quality is good with only chlorination treatment. The water is cool and clear, except that it is slightly turbid during periods of high run-off from the watershed. These periods occur only occasionally and are of only a few days' duration. The intake is about 1, 150 feet above the usual water level in the City's Overturf Reservoirs, and water is delivered to these reservoirs by gravity flow through 11-3/4 miles of twin transmission lines made up of 12- and 14-inch pipe. The water is screened at the inlet to the transmission lines and chlorinated at the outlet. The location of the intake and the route of the pipelines is shown on Figure 7.

A man is on duty at the intake and screen house from April to October, but the station is not regularly attended the rest of the year. The screens are manually cleaned as many as 3 or 4 times per day in May and June, but require little attention at other seasons.

The transmission lines are not designed to withstand the maximum hydrostatic pressure which would occur with closed valves at the lower end of the lines, and an overflow structure is provided about 2-1/2 miles above the outlet end for flow control and pressure regulation. The capacity of the transmission lines has been determined rather carefully on several occasions, both by calculation and by field tests. The combined capacity is 11. 1 mgd. The friction coefficient of the pipe is unusually high (Hazen-Williams C=140), indicating that the pipe is relatively free of internal corrosion and tuberculation.

The lines are located on easements, some private and some on Forest Service land.

Bend holds a total of 19 cfs (12. 35 mgd) of municipal water rights on Tumalo Creek. Only 6 cfs (3. 88 mgd) of these rights can be used throughout the year since the remainder, 13 cfs, was obtained by purchasing irrigation rights on Tumalo Creek and their use is restricted to the irrigation season from 15 April to 15 October. Some of these rights have later priorities than many others on Tumalo Creek and therefore cannot be fully exercised during those parts of the summer

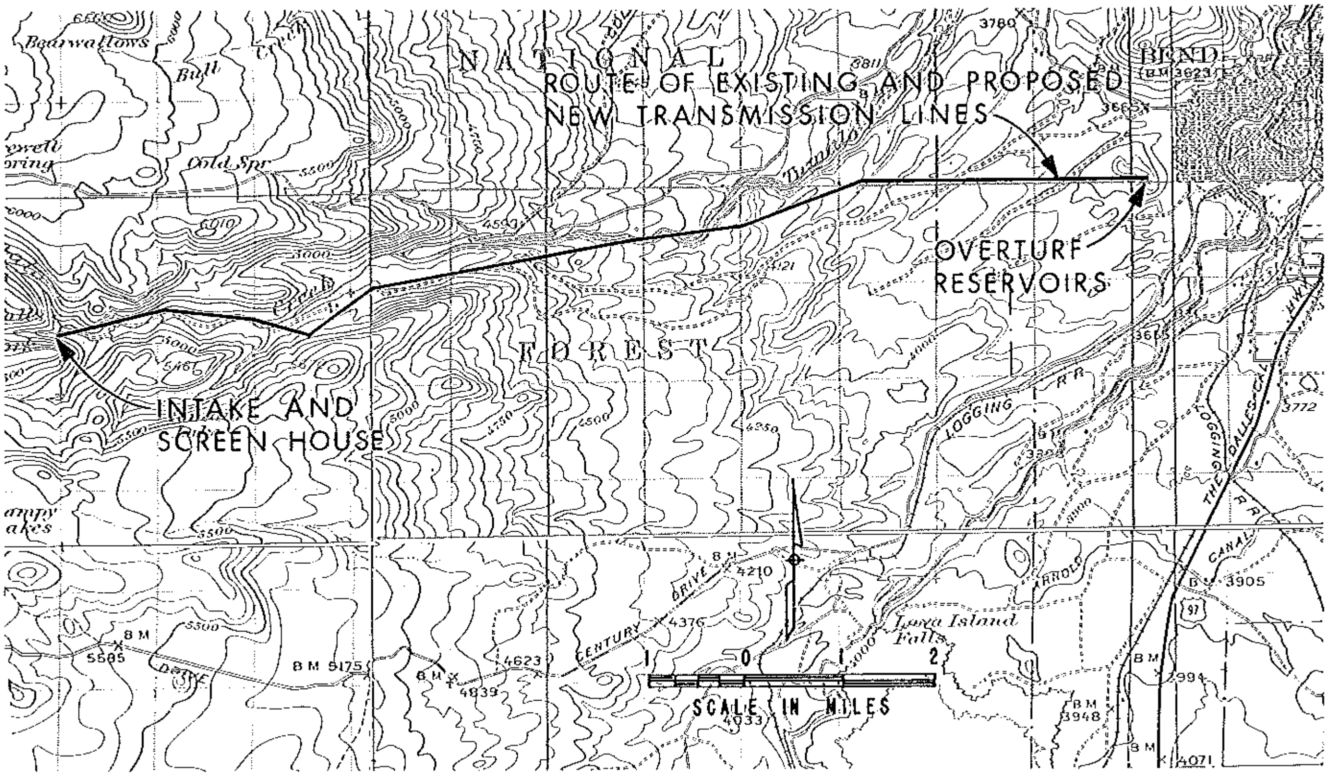

FIGURE 7
CITY OF BEND, OREGON
WATER SYSTEM STUDY

EXPANSION OF TUMALO
CREEK SUPPLY

CORNELL, HOWLAND, HAYES & MERRYFIELD
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months when flows in Tumalo Creek fall below irrigation demands. The firm water rights amount to 17.17 cfs (11.1 mgd) which is just equal to the present capacity of the transmission lines.

Increased Supply From Tumalo Creek. The minimum recorded flow in Tumalo Creek is more than adequate for the foreseeable needs of the City for additional water supply. There probably is no better source of water available, although some other sources may be less costly to develop. Minimum flows in Tumalo Creek are fully appropriated, and since there are no suitable sites for construction of seasonal storage reservoirs, further development of the Tumalo source by the City will require acquisition of additional water rights.

The water rights situation faced by the City is much the same as in 1954 at the time of the last expansion of the source of supply, except that as more water rights are acquired they may become increasingly more difficult to obtain.

It is not considered practical to develop anything less than another 5 mgd (7.75 cfs) of supply from this source, which, according to predictions, should serve the City until about 1985 barring any major new industrial use of water. This will require the acquisition of water rights, the construction of additional intake and screen facilities, and the laying of a third transmission line to the City.

Assuming that land with attached water rights is available, the cost of acquiring the necessary 7.55 cfs of additional water rights can be estimated. Water rights prior to 1908 amount to about 1 cfs per 60 acres, while later rights amount to about 1 cfs per 80 acres, so that an effort should be made to acquire the older rights. The land cost for Tumalo water averages about $300 per acre and for Deschutes water about $250 per acre. In addition, annual operation and maintenance charges of $4.50 per acre per year for Tumalo water and $4.00 per acre per year for Deschutes water must be paid to the district even though no operation and maintenance work by the irrigation district is required for delivery of water to the City's intake. If Tumalo water is purchased, the costs for another 7.75 cfs would involve a capital expenditure of about $111,400 for land, and annual operation and maintenance charges of $2,220.

The existing intake and screen chamber would need to be enlarged about 50 percent at an estimated cost of $21,200.

The third pipe could be laid on the existing right-of-way for most, if not all, of the route from the intake to the reservoirs. The line would consist of about 25,500 feet of 12-inch and 37,500 feet of 14-inch pipe, similar to the existing lines. At today's contract prices, the construction cost (only) of a third transmission line is estimated to be $585,000. This compares to the City's cost of $425,567 to build the second line in 1954-57, which would be equal to about $612,000 at today's prices, based on the increase in the Engineering News-Record Construction Cost Index during this period. The estimate of $585,000 is for the construction contract only; if a 20 percent allowance is added for engineering and contingencies, the total estimate for the third line becomes $702,000.

The estimated capital and annual costs for development of an additional 5 mgd supply from Tumalo Creek are given in Table 8.

The project does not lend itself to stage construction, as it would be necessary to parallel at least 75 percent of the length of the existing lines with the third line in order to get an increase in capacity of 2.5 mgd.

By constructing the new pipeline of 16- and 18-inch diameter pipe, rather than of 12- and 14-inch, its capacity could be doubled. This would provide standby capacity in the transmission system equal to that of one of the existing lines, and would provide either for retirement of the 1926 line when it is no longer serviceable, or for further future increase in supply from this source. The additional cost for the larger line is estimated to be $295,500, thus the line capacity could be increased 100 percent for a 42 percent increase in cost for the transmission line. All reported observations indicate that the two existing pipelines are still sound, and will serve for a number of years into the future, so that the installation of the larger line does not appear warranted. However, if a third line is to be installed, it would be worthwhile to precede its design by a more detailed and extensive examination and evaluation of the condition of the line which was laid in 1926, to verify its soundness.

TABLE 8

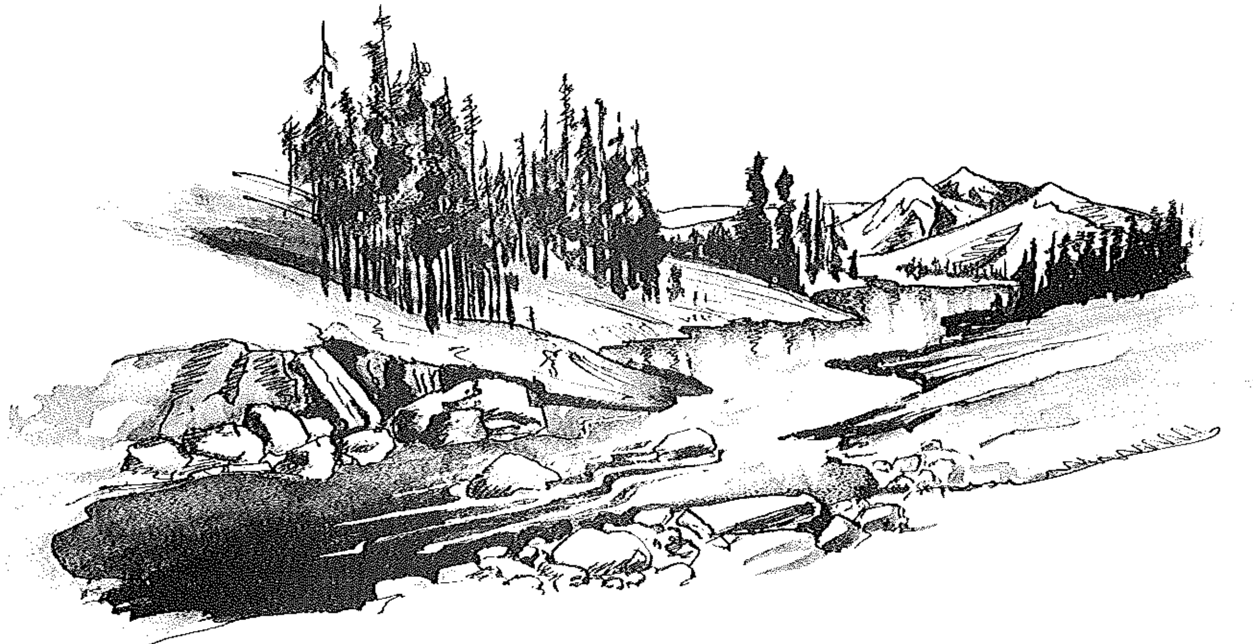
EXPANSION OF TUMALO CREEK SUPPLY
(5 mgd Additional)

CAPITAL COSTS

Water rights, 495 acres at $300	$ 148,500
Enlarging intake and screen house	21,200
Transmission line (14- and 12-inch)	702,000
Total Capital Costs	$ 871,700

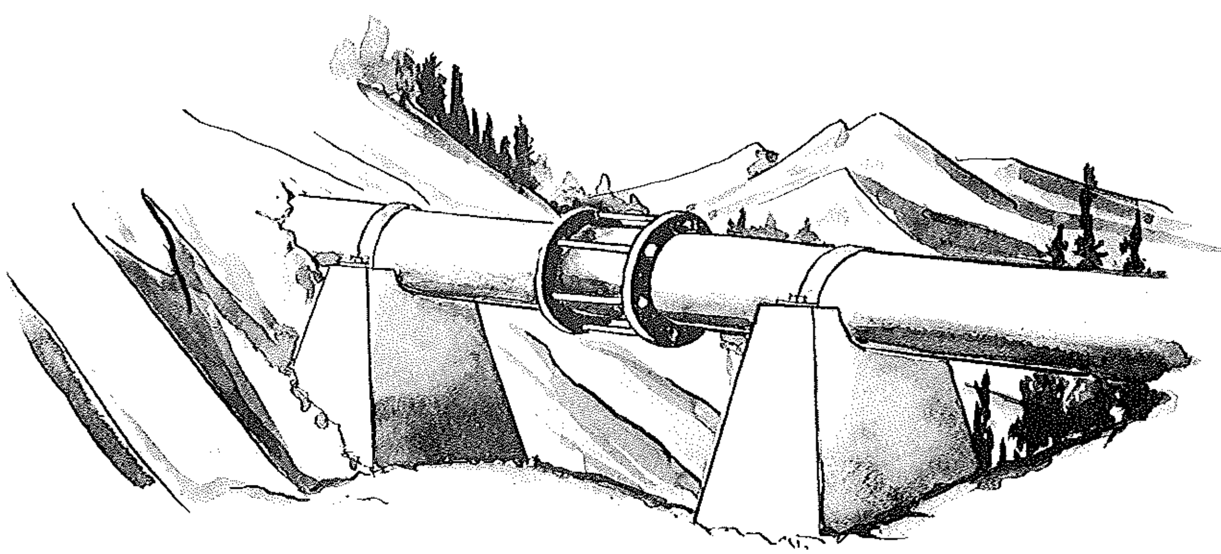
ANNUAL COSTS

Amortize capital costs (20 years at 3-1/2% on $871,700)	$ 58,840
Operation	4,500
Maintenance	1,100
Operation and Maintenance Water Rights	2,220
Total Annual Costs	$ 66,660



DEVELOPMENT OF NEW SUPPLEMENTAL

SOURCES OF SURFACE WATER SUPPLY



VI. DEVELOPMENT OF NEW SUPPLEMENTAL SOURCES OF SURFACE WATER SUPPLY

General. A reconnaissance survey and preliminary analysis eliminate from serious consideration all new surface sources of supply, except the Deschutes River and possibly Fall Creek.

Fall River and Spring River. Both of these streams are farther from the City than the present Tumalo source and involve the same water rights problems. They are also more distant from the City than known sources of well water, which can be developed more easily and at lower cost. Fall River and Spring River do not warrant further investigation at this time.

Fall Creek. Fall Creek is the outlet from the Green Lakes which lie between the South Sister and Broken Top Crater. Fall Creek discharges into Sparks Lake which has no surface outlet. There are no records of flow measurements in Fall Creek, but minimum summer flows near the source are estimated to be not less than 5 to 10 cfs, and may exceed 50 cfs late in July and early in August. Fall Creek and Green Lakes probably cannot be considered to be a part of the Deschutes River system because there is no surface connection, and since there are no existing water rights from this source, it appears that a water rights application could properly be filed by the City. At one time the Squaw Creek Irrigation District considered Green Lakes as a possible source of irrigation water along with Suttle Lake, but the project apparently has been dropped and no application has been filed. Fall Creek is a source of surface water which might be acquired without the necessity of purchasing water rights and without taking irrigated land out of production.

This source would be considerably more expensive to develop than additional water from Tumalo Creek. In addition to the third pipeline from the present intake on Bridge Creek to the City which would be required by the Fall Creek supply, a pump station and at least another 5-1/2 miles of pipeline would be necessary to carry water from Fall Creek to a point of discharge on the Middle Fork of Tumalo Creek from whence it would flow to the present intake by gravity. The surface water level in Fall Creek at Green Lakes is at Elevation 6505, which is considerably above the elevation of the Bridge Creek intake, but below the divide south of Ball Butte. The elevation of the divide is about 6,800, a 295-foot static lift from Fall Creek at Green Lakes. The total pumping head in a 16-inch line at a flow of 5 mgd would be about 470 feet. Electric power is not available in this area, so that pumps would have to be gasoline or Dieseldriven. Access to a pump station and pipeline in this location would be very difficult even for summertime operation. The supply would be frozen at other seasons.

Fall Creek does not appear to be worthy of further consideration at this time because of the high cost of development and the difficult access for construction and operation.

Figure 8 shows the location of Fall Creek and Green Lakes with respect to the existing Bridge Creek intake, and indicates a possible pipeline route along Broken Top Trail.

Table 9 gives the estimated cost of developing a 5 mgd supply from Fall Creek. The estimate does not include any special allowance for road construction which may be necessary to provide access for construction and operation of the supply.

Deschutes River. The Deschutes River is an obvious potential source of water supply for Bend, since the stream flows through the heart of the City and once served as its only source of supply. Despite the convenience of the Deschutes supply it was abandoned because of objectionable tastes and odors produced in the water by growths of algae which occurred in upstream reservoirs, particularly when they were first filled. Since the time that the Deschutes supply was abandoned, two changes have taken place. The algae food supply and hence the algae growths in the reservoirs have diminished with time, and, more importantly, new water treatment methods have been developed which can remove the objectionable tastes and odors completely with proper plant operation. With construction of a modern water treatment plant, including all the latest facilities for taste and odor control, the quality of the treated water from the Deschutes should be comparable to the present supply, except that the temperature of the water will be somewhat higher in the summer. Since the Deschutes supply would be used as the peaking or supplemental supply, and the base supply from Tumalo Creek would comprise at least two-thirds of the total, the temperature effect at the tap of using the warmer Deschutes water would not be great.

The chemical quality of the Deschutes River water is excellent and compares very well with Tumalo water from this standpoint as shown by Table 10.

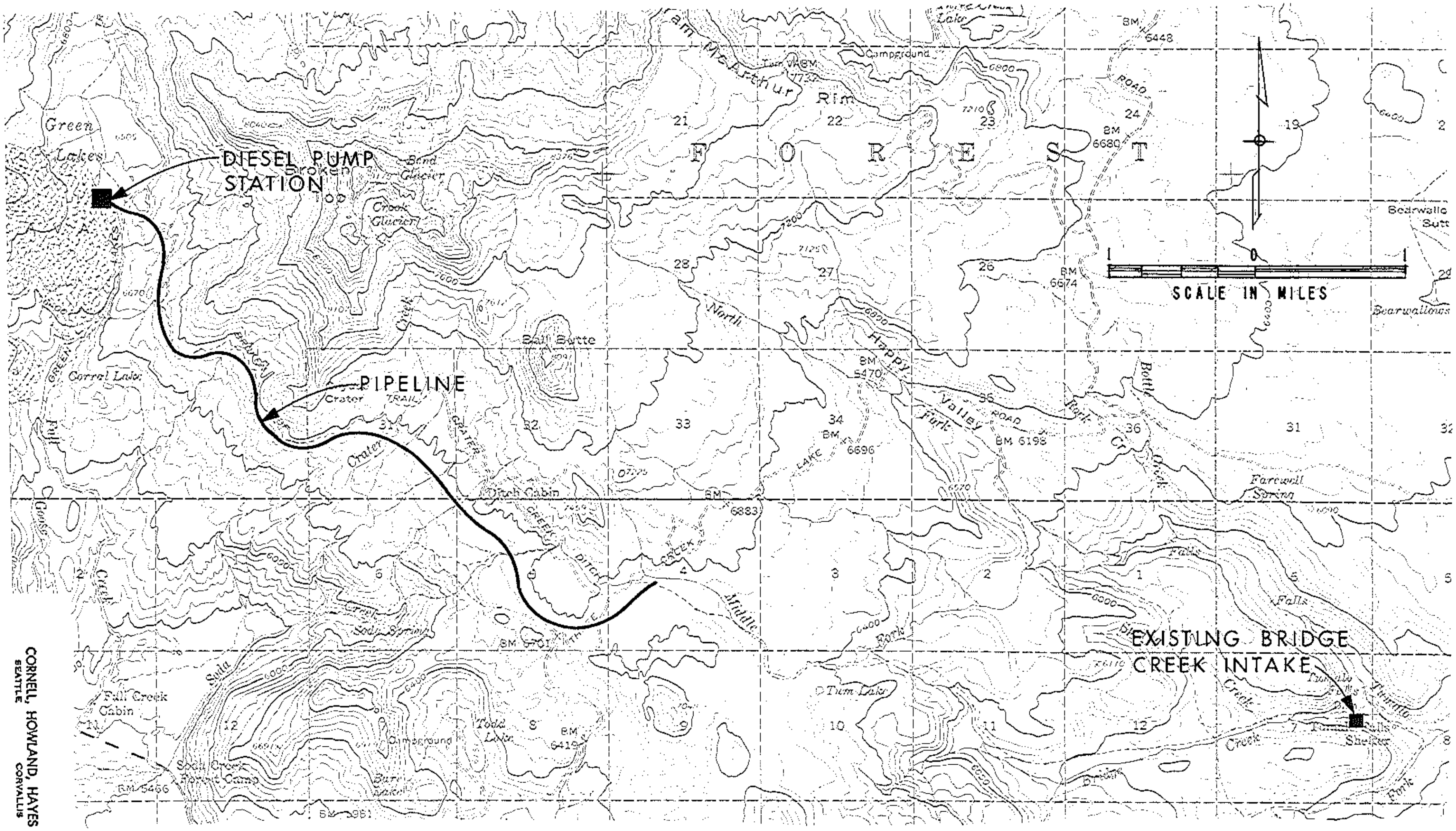


FIGURE 8

CITY OF BEND, OREGON
WATER SYSTEM STUDY

SUPPLEMENTAL SUMMER SUPPLY FROM FALL CREEK

CORNELL, HOWLAND, HAYES & MERRYFIELD
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TABLE 9

ESTIMATED COSTS FOR DEVELOPMENT OF SUPPLEMENTAL SUPPLY FROM FALL CREEK

CAPITAL COSTS

Item	Estimated Cost
Diversion structure	$ 20,000
Diesel pump station	70,000
Upper pipe line	362,000
Lower pipe line and intake	723,000
Total construction cost	$1,175,200
Engineering and contingencies	235,000
Total estimated cost	$1,410,200

ANNUAL COSTS

1966

Amortize capital costs (20 years at 3-1/2% on $1,410,200)	$ 95,190
Operation	6,800
Maintenance	1,600
Diesel fuel	4,300
Total	$107,890

1975

	$107,890
Additional fuel costs	4,300
Total	$112,190

TABLE 10

COMPARISON OF THE CHEMICAL QUALITY OF WATER FROM THE DESCHUTES RIVER AT BEND AND FROM TUMALO CREEK

	Deschutes River	Tumalo Creek
Total Solids	31	52
Total Hardness (as $CaCO_3$)	20	14.9
pH	7.0	7.4
SiO_2	20	28
Chloride	1.7	8.1
Sulfate	2.6	1.8
Bicarbonate Alkalinity	2.9	19.5

Analyses are in milligrams per liter, except pH is in standard units.

Since the Deschutes River is not a protected watershed and since it is slightly turbid at times, it will require filtration treatment. Following treatment in a filter plant, the bacteriological quality of the water would be excellent and the turbidity would be less than 0.3 units at all times, which exceeds the clarity of the present supply.

The filter plant can very readily and economically be built in stages as additional capacity is needed. This has the advantage of deferring part of the capital costs until the actual need materializes for the total increased supply. In contrast, supply development in which most of the cost is in long transmission lines, as at Tumalo, stage development is not feasible to the same extent, and capital expenditures are necessarily made for a greater period into the future. Facilities for use of Deschutes River water could conveniently be built in increments of 2.5 mgd capacity. Referring to Table 5, it is seen that each 2.5 mgd of additional capacity will fill the growing water demands on the maximum day for a period of a little more than 10 years into the future. The relatively short transmission main from the plant to the City would be built initially to carry 5 mgd.

The Deschutes River supply would be used principally as a supplemental supply to meet the peak summer water demands for lawn sprinkling. However, the plant would be built for year-around operation, so that it would be possible to use filtered, clear, Deschutes water on those rare occasions when the unfiltered Tumalo supply is cloudy and turbid from heavy runoff on the watershed.

Three possible sites for the filter plant have been considered as shown by Figure 9. Two of the sites are adjacent to the River. It is also possible to locate the filter plant at Overturf Reservoirs where it could be used for the Deschutes supply in the summer and for the Tumalo supply at other seasons. This arrangement should work out very well, since the Tumalo supply is clear during the summer when supplemental water from the Deschutes is needed, and yet the plant would be available for clarifying the Tumalo supply during the spring and fall periods of heavy runoff and cloudy water when the Deschutes supply is not required. However, there are extra costs in locating a filter plant at the Overturf site rather than adjacent to the river. About 1/2 mile of additional pipeline would be required. Also, the Deschutes supply would have to be pumped to the elevation of water in the Overturf Reservoirs which is about 90 feet higher than for direct pumpage into the City side of the pressure reducing valve at 15th and Cumberland Avenue.

As shown by Figure 9, one location for the Deschutes River intake is about one mile south of the present south City limits on the west side of the river. This places it upstream from the City and industrial areas. The other is upstream from the City, but downstream from Brooks-Scanlon. The plant and intake would be built initially to supply 2-1/2 mgd with provision for ready expansion to 5 mgd. The discharge line to the treatment plant would be sized for 5 mgd.

The design of the treatment plant would take advantage of some very recent advances in water purification which make it possible to produce water of exceptionally high quality at unusually low capital and operating costs. The treatment process is based upon principles developed by Walter Conley and Raymond Pitman of the General Electric Company for the Atomic Energy Commission at the Hanford Works near Richland, Washington. These principles have been further developed, expanded, and adopted for use in municipal water treatment plants by CH_2M for the MicroFLOC Corporation. Briefly, the process consists of the addition of alum, rapid mixing, settling, addition of a polyelectrolyte, and high-rate filtration in specially designed separation beds. Among the substantial advantages of the process are: production of water of a better and more consistent quality; lower capital costs; lower chemical and other operating costs; less space for the plant; and improved and simplified control of water quality. Coagulant dosages would be continuously predetermined by means of a pilot filter, and the quality of the finished water would be monitored by a highly sensitive turbidimeter. Means for continuous

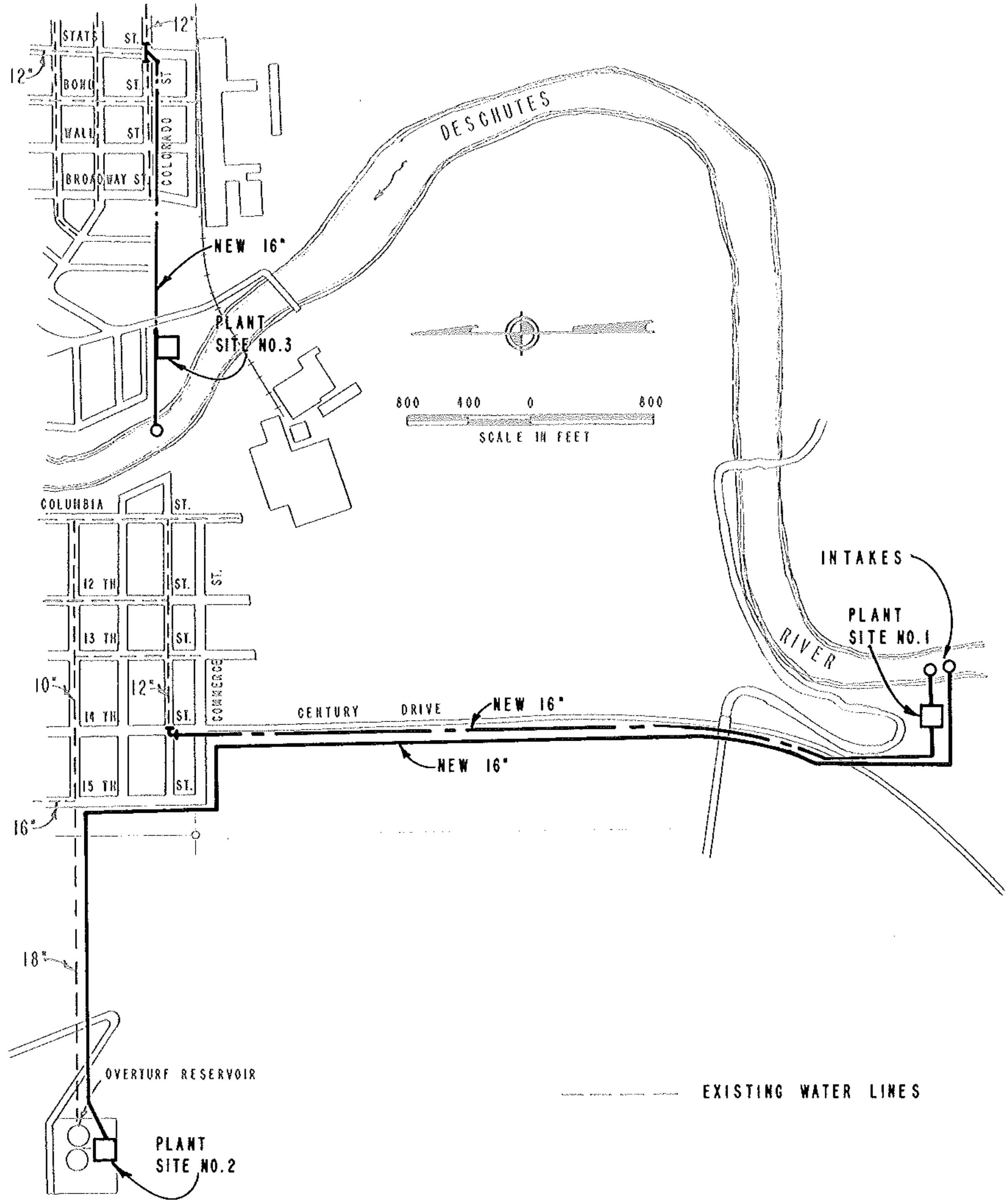

FIGURE 9
CITY OF BEND, OREGON
WATER SYSTEM STUDY

DESCHUTES RIVER SUPPLY

CORNELL, HOWLAND, HAYES & MERRYFIELD
SEATTLE PORTLAND CORVALLIS BOISE
CH2M

evaluation and control of taste and odor in raw and treated water would be provided, and facilities for three methods of taste and odor removal would be installed including activated carbon, break-point chlorination, and chlorine-dioxide. The chlorine and chlorine-dioxide "burn out" the taste and odor compounds by oxidation, while the activated carbon removes the tastes and odors by adsorption. The carbon is then removed from the water by filtration in the separation beds.

With modern water treatment equipment and proper plant operation, a high quality water unquestionably can be produced from the Deschutes River supply. Public approval of this source as a supplemental supply may depend upon how widely this fact will be accepted by residents of Bend in view of the poor experience in the early 1920's with the Deschutes River water.

Comparative capital and annual costs are shown in Table 11 for each of three plant sites.

TABLE 11

ESTIMATED COSTS OF SUPPLEMENTAL SUPPLY FROM DESCHUTES RIVER

CAPITAL COSTS

2.5 MGD CAPACITY (1966)

Item	Site 1	Site 2	Site 3
River Intake and Pumps	$ 30,000	$ 33,000	$ 30,000
Supply Line to Plant	12,500	94,000	2,500
Treatment Plant	150,000	150,000	150,000
Clearwell Storage	30,000	30,000	30,000
High Service Pump Station	37,000	34,000	37,000
Discharge Line to System	50,000	3,000	22,500
Construction Total	309,500	344,000	272,000
Engineering & Contingencies	61,900	68,800	54,400
Subtotal	$371,400	$412,800	$326,400
Water Rights, 248 acres at $250	62,000	62,000	62,000
Total Phase 1	$433,400	$474,800	$388,400

EXPANSION OF 2.5 MGD PLANT TO 5 MGD CAPACITY (1975)

River Intake and Pumps	$ 5,000	$ 8,000	$ 5,000
Treatment Plant	125,000	125,000	125,000
High Service Pump Station	8,000	5,000	8,000
Construction Total	138,000	138,000	138,000
Engineering and Contingencies	27,600	27,600	27,600
Subtotal	$165,600	$165,600	$165,600
Water Rights, 248 acres at $250	62,000	62,000	62,000
Total Phase 2	$227,600	$227,600	$227,600
TOTAL COST OF 5 MGD SUPPLY FROM DESCHUTES RIVER	$661,000	$702,400	$616,000

TABLE 11 (Cont'd)

ANNUAL COSTS

	Site 1	Site 2	Site 3
1966			
Amortize Capital (20 years at 3-1/2%)	$ 29,260	$ 32,050	$ 26,200
Operation and Maintenance, Water Rights	990	990	990
Operation	6,400	6,400	6,400
Maintenance	2,600	2,800	2,400
Power	830	1,230	830
Total	$ 40,080	$ 43,470	$ 36,820
1975			
Amortize Step No. 1	$ 29,260	$ 32,050	$ 26,200
Amortize Step No. 2	15,360	15,360	15,360
Operation	9,200	9,200	9,200
Maintenance	4,800	5,000	4,600
Power	1,220	2,030	1,220
Operation and Maintenance, Water Rights	1,980	1,980	1,980
Total	$ 61,820	$ 65,620	$ 58,560

POSSIBLE DEVELOPMENT OF A SUPPLEMENTAL WATER SUPPLY FROM WELLS

VII. POSSIBLE DEVELOPMENT OF A SUPPLEMENTAL WATER SUPPLY FROM WELLS

General. Complete detailed geological studies of the groundwater resources of the Middle Deschutes Basin have not been made. A report by Mr. Jack Sceva, Geologist for the State Engineer, based upon the best information available in 1961 is contained in the report, "Deschutes River Basin," as published by the State Water Resources Board. In the vicinity of Bend there are a few logs of shallow wells as reported to the State Engineer by water well drillers, and detailed information is available on the drilling and test pumping of a large capacity deep well by Brooks-Scanlon, Inc. The deep well was tested under the supervision of Keith E. Anderson, Consulting Geologist, and Cornell, Howland, Hayes & Merryfield. Considerable data is available from the U. S. Bureau of Reclamation as a result of their test drilling for the Benham Falls Reservoir, including a large number of holes about 15 miles south of the city and a few at Benham Falls proper.

An analysis of the information at hand does indicate the direction which the City's efforts should take in exploring the possibility of a supplemental groundwater supply.

Geology. The following is quoted from the State Water Resources Board report on the Deschutes River Basin:

> "A generalized geologic cross section taken along the Deschutes River is shown on Figure 10. Indicated here are the major formations and key locations along the river. This plot is in the form of a river profile in order to indicate approximate elevation relationships. A diagrammatic section of the major formations in the basin is shown on Figure 11 along with a table listing the nature and water-bearing characteristics of those formations.
>
> "The geology of the Deschutes River Basin consists mainly of various layers of sedimentary formations and lava flows. Permeability of these formations varies greatly and largely depends on the grain size of the rock particles, the degree of sedimentation, and the degree of fracturing.
>
> "The older rock formations are relatively dense and impermeable and should not be considered as potential sources of large groundwater supplies in the Deschutes River Basin. More recent

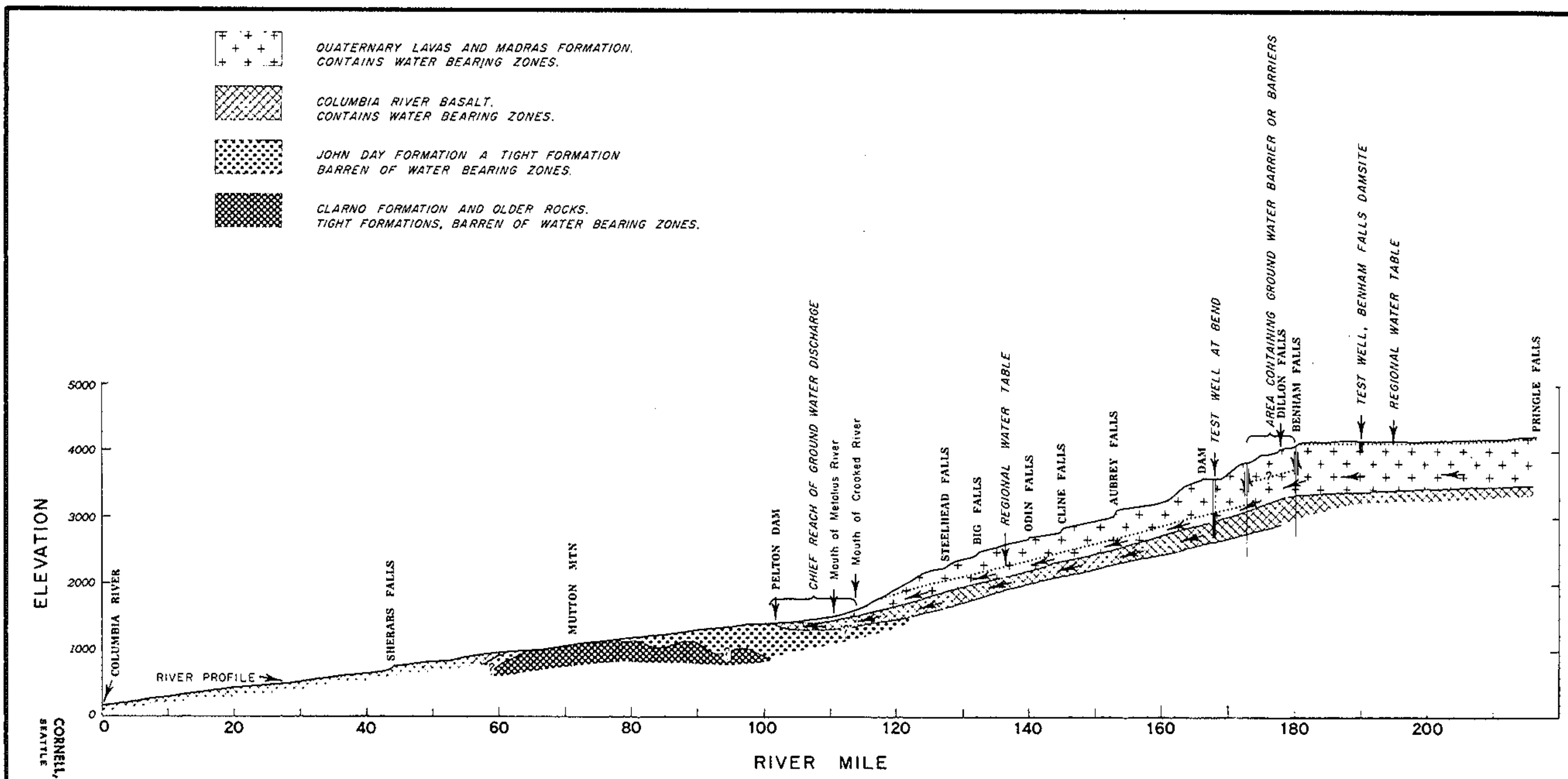

FIGURE 10

CITY OF BEND, OREGON
WATER SYSTEM STUDY

GENERALIZED GEOLOGIC CROSS SECTION ALONG THE DESCHUTES RIVER

FROM THE REPORT, "DESCHUTES RIVER BASIN"
STATE WATER RESOURCES BOARD
SALEM, OREGON, JAN. 1961

CORNELL, HOWLAND, HAYES & MERRYFIELD
SEATTLE PORTLAND CORVALLIS BOISE

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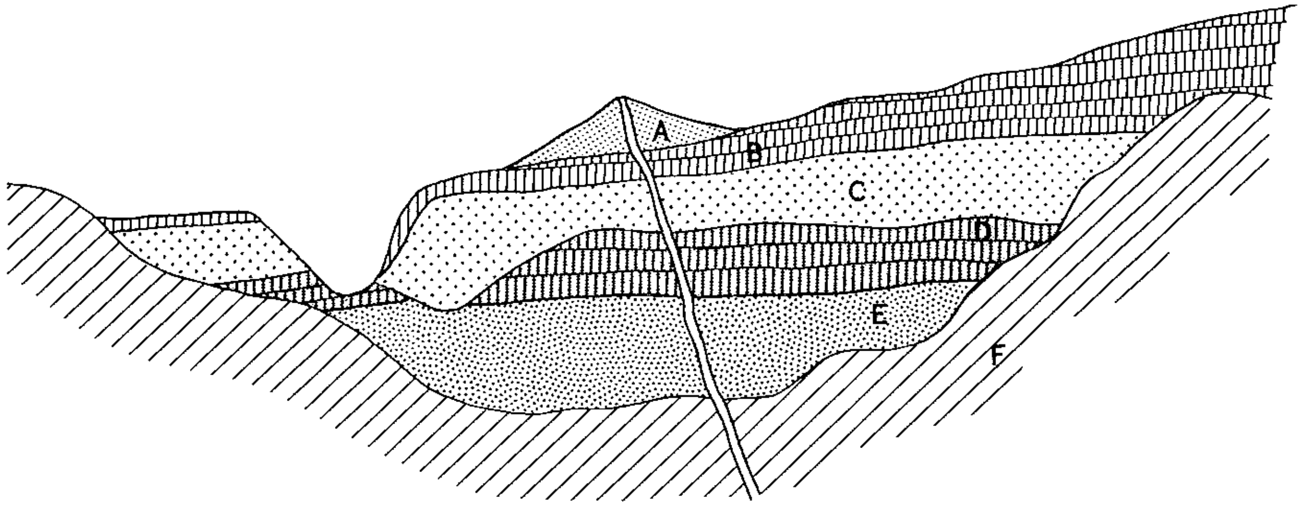


Designation in Figure	Unit Name	Character	Water-bearing Characteristics
A	Quaternary pyroclastic deposits	Chiefly cinders associated with cinder cones.	Rocks of this unit are generally well drained and not sources of ground water. Where saturated they are capable of yielding large supplies of ground water.
B	Quaternary lavas	Chiefly basaltic lava flows associated with Newberry Crater, and volcanic eruptions in the Cascade Range.	Contains numerous porous lava flows. At most places are well drained and are unproductive. Where they are saturated, they are capable of yielding moderate to large supplies of ground water.
C	Madras formation	Chiefly stratified layers of sand, silt, ash, pumice with some gravel lenses. Contains some interbedded lava flows.	This formation is in large part fine grained and not a productive aquifer. At places it contains permeable lenses of gravel that are capable of yielding moderate supplies of ground water. Some of the interbedded volcanic rocks are permeable and are capable of yielding large supplies of ground water.
D	Columbia River basalt	Series of basaltic lava flows.	Contact zones between individual lava flows serve as aquifers. This formation is generally capable of yielding moderate to large supplies of ground water.
E	John Day formation	A sedimentary formation composed of silt, sand, and volcanic ash.	The fine grained character of this formation precludes it from being a productive source of ground water.
F	Clarno formation and older rocks undifferentiated	Chiefly consolidated sedimentary rocks, volcanic rocks and associated pyroclastics.	All of these rocks are believed to be of low permeability and not capable of furnishing more than meager supplies of ground water.

FIGURE II

CITY OF BEND, OREGON
WATER SYSTEM STUDY

DIAGRAMMATIC SECTION SHOWING THE MAJOR ROCK UNITS OF THE DESCHUTES RIVER BASIN

FROM THE REPORT, "DESCHUTES RIVER BASIN"
STATE WATER RESOURCES BOARD
SALEM, OREGON, JAN. 1961

CORNELL, HOWLAND, HAYES & MERRYFIELD
SEATTLE CORVALLIS BOISE

formations and lavas contain permeable zones which are generally capable of yielding moderate to large supplies of groundwater where they lie below the regional water table.

"In some locations two and three separate water tables have been encountered because of sequences of permeable and impermeable rock formations. In some areas groundwater is pumped from the valley alluvium along streams. Confined water is sometimes found in both rock formations and recent alluvium. Artesian pressure occasionally is sufficient to raise the water above land surface.

"Figure 12 was developed to graphically illustrate what is presently known concerning the occurrence and movement of groundwater in the Deschutes Basin.

"Well logs and known water tables indicate that there is a general movement of groundwater from the area encompassing Hampton, Brothers, and Millican northward towards Bend and the confluence of the Deschutes and Crooked Rivers. Large springs in the canyon walls of the Crooked, Deschutes, and Metolius Rivers near their confluences tend to confirm this assumption.

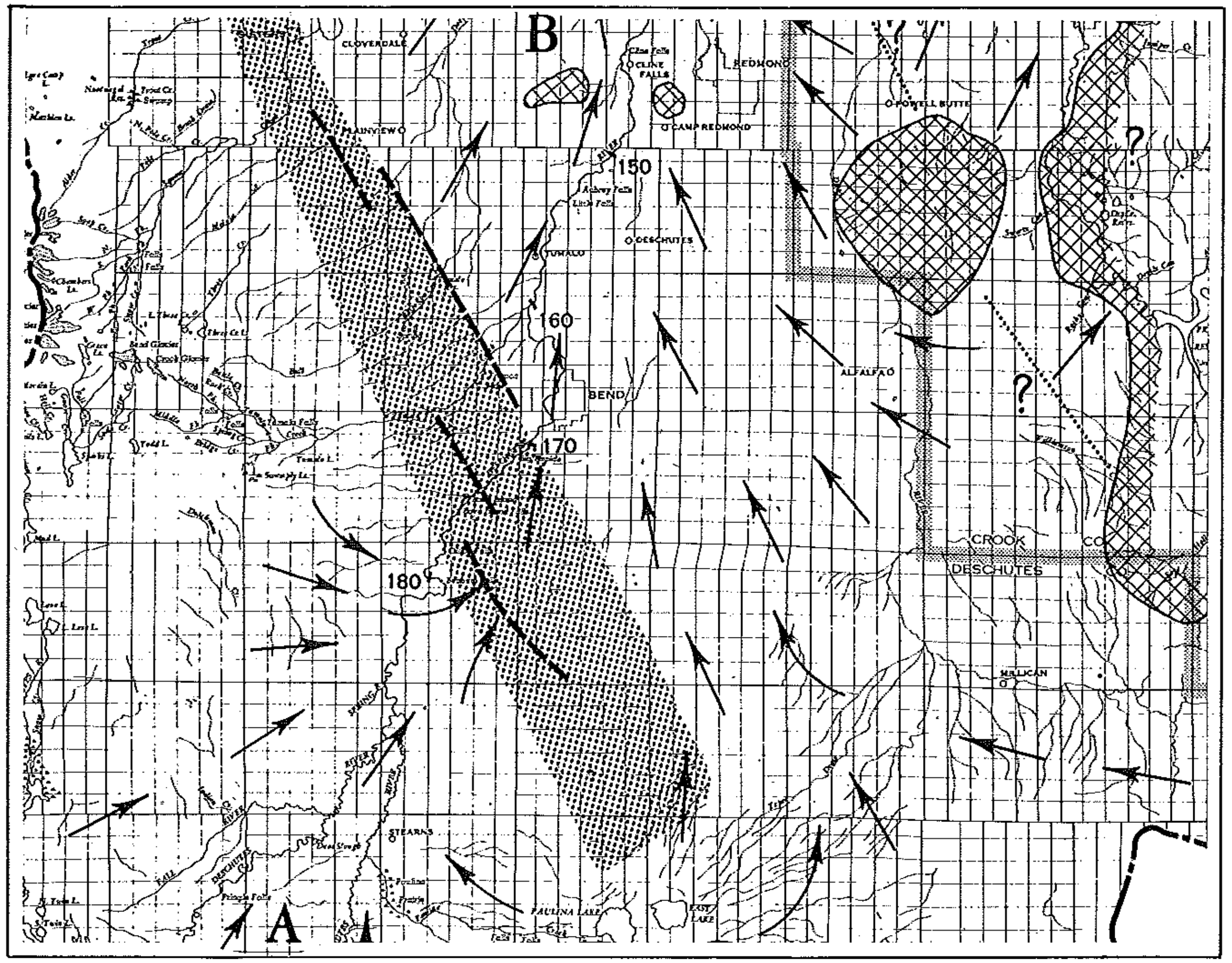
"Groundwater development between Bend and Redmond has been restricted to some degree because of the depth at which water is found. A test well at the Brooks-Scanlon mill in Bend was drilled to a depth of 900 feet. The static water level, which is believed to represent the elevation of the regional water table, was 564 feet below land surface. This well was tested at 1,300 gallons per minute (gpm) with a 7-foot drawdown. In some areas, small supplies of water have been obtained from perched zones which lie higher than the regional water table.

"Study of well logs shows the main regional water table to range in depth from 300 feet to more than 800 feet. Pump tests on these wells have varied from 3 to 1,300 gpm with the deeper wells generally showing the larger yields."

It appears from the geologic and other information at hand that three general areas might be considered for possible groundwater development.

1. Shallow wells in the immediate vicinity of Bend.

2. Deep wells near Bend.



UNDERLAIN BY ROCK FORMATIONS BARREN OF PRODUCTIVE GROUND WATER RESERVOIRS.

FAULTING MAY HAVE PRODUCED SUBSURFACE BARRIERS.

FAULT ZONE

GROUND WATER DIVIDE

GENERAL DIRECTION OF GROUND WATER FLOW

A VERY LARGE VOLUME OF WATER IN SUBSURFACE STORAGE. DEPTH OF WATER TABLE NOT WELL DEFINED.

B MODERATE TO LARGE VOLUME OF WATER IN SUBSURFACE STORAGE. WATER TABLE GENERALLY AT DEPTH GREATER THAN 250 FEET.

SCALE IN MILES

0 1 2 3 4 5 6 7 8 9 10 15

FIGURE 12
CITY OF BEND, OREGON
WATER SYSTEM STUDY
DESCHUTES DRAINAGE BASIN
GROUND WATER

FROM THE REPORT, "DESCHUTES RIVER BASIN"
STATE WATER RESOURCES BOARD
SALEM, OREGON, JAN. 1961

CORNELL, HOWLAND, HAYES & MERRYFIELD
SEATTLE PORTLAND CORVALLIS BOISE

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3. Shallow wells in the area between Lava Island Falls and Benham Falls.

Shallow Wells Near Bend. The elevation of the regional water table near Bend is about 600 to 700 feet below ground level. Above the regional water table there are numerous discontinuous perched water tables at various depths. Many existing wells draw water from these shallow aquifers for domestic and commercial use. In general, the capacity of these shallow wells ranges from 5 to 50 gpm. The areas of recharge to these perched water tables are limited, and it is doubtful that these shallow aquifers would support sustained yields sufficient for municipal water supply purposes. It is difficult and expensive to locate these aquifers, because of their spotty or discontinuous nature. A large number of wells of this capacity would be required to meet the needs of the City for additional water supply, and an extensive test drilling program would be necessary to select well locations. The costs of this type of development would be excessively high.

The spotty occurrence of these aquifers is illustrated by the four well logs, Tables 12, 13, 14, and 15 taken from the files of the State Engineer. These represent all of the recently reported drillings south of the City. Table 12 is the log of a 354-foot well which could produce as much as 40 to 50 gpm. Tables 13, 14, and 15 show dry holes of 160, 401, and 220 feet. The location of successful shallow wells above the regional water table is completely unpredictable.

The use of so-called "dry wells" for sewage disposal in and around Bend is a potential source of contamination to wells, especially to shallow wells.

In summary, shallow wells in the immediate vicinity of Bend do not appear to offer a practical solution to the City's need for additional water supply.

Deep Wells Near Bend. The regional water table lies at a depth of about 600 feet beneath the City of Bend. This great depth and the resulting high pumping lift have been deterrents to the development and use of what appears to be an abundant supply of good unappropriated water which can be made available by construction of deep wells.

The Brooks-Scanlon test well provides information which is extremely valuable in appraising the potential of a supplemental deep well supply for Bend. Brooks-Scanlon Test Well No. 1 is located about 250 feet from the left (west) bank of the Deschutes River, immediately

ORIGINAL
File Original, and Duplicate with the STATE ENGINEER, SALEM, OREGON

WATER WELL DRILLERS REPORT
STATE OF OREGON

Do Not Fill In — State Well No. 18/12-6B(1) — State Permit No. ......

(1) OWNER:
Name City of Bend
Address P. O. Box 431, Bend

(2) LOCATION OF WELL:
County Deschutes Owner's number, if any— G-177
R. F. D. or Street No.
Bearing and distance from section or subdivision corner 525.15 ft. N.69°51'31" from the S.E. corner of the N.W.¼ of the N.E.¼ Section Six, T. 18, S.R.12, E.W.M.

(3) TYPE OF WORK (check):
New well ☒ Deepening ☐ Reconditioning ☐ Abandon ☐
If abandonment, describe material and procedure in Item 11.

(4) PROPOSED USE (check):
Domestic ☐ Industrial ☐ Municipal ☒
Irrigation ☐ Test Well ☐ Other ☐

(5) EQUIPMENT:
Rotary ☐
Cable ☒
Dug Well ☐

(6) CASING INSTALLED:
Threaded ☐ Welded ☐

FROM	ft. to	ft.	Diam.	Gage or Wall
"	"	"	"	"
"	"	"	"	"
"	"	"	"	"
"	"	"	"	"
"	"	"	"	"

Type and size of shoe or well ring
Describe joint

If gravel packed

Diameter of Bore	from ft.	to ft.
	"	"
	"	"
	"	"
	"	"
	"	"

Size of gravel:

(7) PERFORATIONS:
Type of perforator used
SIZE of perforations in., length, by in.

FROM	ft. to	ft.	perf per foot	No. of rows
"	"	"	" " "	" " "
"	"	"	" " "	" " "
"	"	"	" " "	" " "
"	"	"	" " "	" " "

SCREENS:
Give Manufacturer's Name, Model No. and Size

(8) CONSTRUCTION:
Was a surface sanitary seal provided? ☐ Yes ☐ No To what depth ft.
Were any strata sealed against pollution? ☐ Yes ☐ No
If yes, note depth of strata

FROM	ft. to	ft.
"	"	"

METHOD OF SEALING

(9) WATER LEVELS:
Depth at which water was first found Dry hole ft.
Standing level before perforating ft.
Standing level after perforating ft.

Log Accepted by:
[Signed] ...... Dated ......, 19......
Owner

(10) WELL TESTS:
Was a pump test made? ☐ Yes ☒ No If yes, by whom?

Yield:	gal./min. with	ft. draw down after	hrs.
"	"	"	"
"	"	"	"

Artesian flow ...... g.p.m.
Shut-in pressure ...... lbs. per square inch.
Bailer test ...... g.p.m. with ...... ft. drawdown
Temperature of water Was a chemical analysis made? ☐ Yes ☐ No
Was electric log made of well? ☐ Yes ☐No

(11) WELL LOG:
Diameter of well, 8 inches.
Total depth 160 ft. Depth of completed well 160 ft.

Formation: Describe by color, character, size of material and structure, and show thickness of aquifers and the kind and nature of the material in each stratum penetrated, with at least one entry for each change of formation.

0ft.	to 5	ft.	Dirt
5	" 65	"	Red soft rock
65	" 74	"	Brown pumice
74	" 96	"	White pumice
96	" 116	"	Red soft rock
116	" 146	"	Gravel
146	" 160	"	Black soft rock

Ground elevation at well site 3649.50 feet above mean sea level.
Work started April 9 1956. Completed April 25 1956

Well Driller's Statement:
This well was drilled under my jurisdiction and this report is true to the best of my knowledge and belief.

NAME Lee Grimes
(Person, firm, or corporation) (Typed or printed)
Address Rte. 3, Box 26, Bend, Ore.
Driller's well number
[Signed] Lee Grimes
(Well Driller)
License No. 113 Dated 5-5, 1956

File Original and First Copy with the STATE ENGINEER, SALEM, OREGON

WATER WELL REPORT
STATE OF OREGON

State Well No. 18/13-4

State Permit No.

(1) OWNER:
Name Dale Newby
Address Bear Creek Rd.
Bend, Oregon

(2) LOCATION OF WELL:
County Deschutes Owner's number, if any—
¼ ¼ Section 4 T. 18S R. 13E W.M.
Bearing and distance from section or subdivision corner

(3) TYPE OF WORK (check):
New Well ☒ Deepening ☐ Reconditioning ☐ Abandon ☐
If abandonment, describe material and procedure in Item 11.

(4) PROPOSED USE (check):
Domestic ☐ Industrial ☐ Municipal ☐
Irrigation ☐ Test Well ☐ Other ☒

(5) TYPE OF WELL:
Rotary ☐ Driven ☐
Cable ☒ Jetted ☐
Dug ☐ Bored ☐

(6) CASING INSTALLED:
Threaded ☐ Welded ☒ 5/16
6" Diam. from 1 ft. to 5 ft. Gage
" Diam. from ft. to ft. Gage
" Diam. from ft. to ft. Gage

(7) PERFORATIONS:
Perforated? ☐ Yes ☒ No
Type of perforator used
SIZE of perforations in. by in.
perforations from ft. to ft.
perforations from ft. to ft.
perforations from ft. to ft.
perforations from ft. to ft.
perforations from ft. to ft.

(8) SCREENS:
Well screen installed ☐ Yes ☐ No
Manufacturer's Name
Type Model No.
Diam. Slot size Set from ft. to ft.
Diam. Slot size Set from ft. to ft.

(9) CONSTRUCTION:
Was well gravel packed? ☐ Yes ☐ No Size of gravel:
Gravel placed from ft. to ft.
Was a surface seal provided? ☐ Yes ☐ No To what depth? ft.
Material used in seal—
Did any strata contain unusable water? ☐ Yes ☐ No
Type of water? Depth of strata
Method of sealing strata off

(10) WATER LEVELS:
Static level ft. below land surface Date
Artesian pressure lbs. per square inch Date

Log Accepted by:
[Signed] Dale Newby (Owner) Date 3/16, 1960

(11) WELL TESTS:
Drawdown is amount water level is lowered below static level
Was a pump test made? ☐ Yes ☒ No If yes, by whom?
Yield: gal./min. with ft. drawdown after hrs.
" " " "
" " " "
Bailer test gal./min. with ft. drawdown after hrs.
Artesian flow g.p.m. Date
Temperature of water Was a chemical analysis made? ☐ Yes ☐ No

(12) WELL LOG:
Diameter of well 6 ID. inches.
Depth drilled 400 ft. Depth of completed well ft.

Formation: *Describe by color, character, size of material and structure, and show thickness of aquifers and the kind and nature of the material in each stratum penetrated, with at least one entry for each change of formation.*

MATERIAL	FROM	TO
Topsoil	0	1
Boulders - lava	1	4
Gray lava	4	69
Pink lava	69	98
Gray lava	98	133
Red cinders	133	140
Gray	140	176
Pink	176	197
Gray	197	235
Pink	235	260
Brown	260	273
Gray	273	309
Pink	309	338
Orange	338	359
Pink	359	377
Red	377	399
Gray	399	400
Well not completed		

Work started 2/16 1960 Completed 3/16 1960

(13) PUMP:
Manufacturer's Name
Type: H.P.

Well Driller's Statement:
This well was drilled under my jurisdiction and this report is true to the best of my knowledge and belief.

NAME DICK AKINS WELL DRILLING (Person, firm, or corporation) (Type or print)
Address Box 264 Prineville Oreg
Driller's well number
[Signed] Richard Akins (Well Driller)
License No. 260 Date 3/16, 1960

(USE ADDITIONAL SHEETS IF NECESSARY)

NOV 4 1960
STATE ENGINEER

File Original and First Copy with the STATE ENGINEER, SALEM, OREGON

WATER WELL REPORT
STATE OF OREGON

State Well No. 18/12E-17B

State Permit No.

(1) OWNER:
Name W.E Roats
Address Parrel Road
Bend, Oregon

(2) LOCATION OF WELL:
County Deshutes Owner's number, if any—
N.E. ¼ N.W. ¼ Section 17 T. 18-S R. 12 E W.M.
Bearing and distance from section or subdivision corner
300' E of N.W. Corner of Section 17 400' South

(3) TYPE OF WORK (check):
New Well ☒ Deepening ☐ Reconditioning ☐ Abandon ☐
If abandonment, describe material and procedure in Item 11.

(4) PROPOSED USE (check):
Domestic ☒ Industrial ☐ Municipal ☐
Irrigation ☐ Test Well ☐ Other ☐

(5) TYPE OF WELL:
Rotary ☐ Driven ☐
Cable ☒ Jetted ☐
Dug ☐ Bored ☐

(6) CASING INSTALLED: Threaded ☐ Welded ☒
6" Diam. from 0 ft. to 91' ft. Gage 15 #
" Diam. from ft. to ft. Gage
" Diam. from ft. to ft. Gage

(7) PERFORATIONS: Perforated? ☐ Yes ☒ No
Type of perforator used
SIZE of perforations in. by in.
perforations from ft. to ft.
perforations from ft. to ft.
perforations from ft. to ft.
perforations from ft. to ft.
perforations from ft. to ft.

(8) SCREENS: Well screen installed ☐ Yes ☒ No
Manufacturer's Name
Type Model No.
Diam. Slot size Set from ft. to ft.
Diam. Slot size Set from ft. to ft.

(9) CONSTRUCTION:
Was well gravel packed? ☐ Yes ☒ No Size of gravel:
Gravel placed from ft. to ft.
Was a surface seal provided? ☐ Yes ☒ No To what depth? ft.
Material used in seal—
Did any strata contain unusable water? ☒ Yes ☒ No
Type of water? Depth of strata 15 ft.
Method of sealing strata off

(10) WATER LEVELS:
Static level 338 ft. below land surface Date
Artesian pressure lbs. per square inch Date

Log Accepted by:
[Signed] W.E. Roats (Owner) Date Nov. 3, 1960

(11) WELL TESTS: Drawdown is amount water level is lowered below static level
Was a pump test made? ☐ Yes ☐ No If yes, by whom?
Yield: gal./min. with ft. drawdown after hrs.
" " " "
" " " "
Bailer test gal./min. with ft. drawdown after hrs.
Artesian flow g.p.m. Date
Temperature of water 50 Was a chemical analysis made? ☐ Yes ☒ No

(12) WELL LOG: Diameter of well 6 inches.
Depth drilled 354 ft. Depth of completed well 354 ft.

Formation: Describe by color, character, size of material and structure, and show thickness of aquifers and the kind and nature of the material in each stratum penetrated, with at least one entry for each change of formation.

MATERIAL	FROM	TO
Top Soil	0	4
76' Brown Rock	4	80
Blwe Rock	80	112
Grey Rock	112	128
Blule Rock	128	169
Brown Rock	169	203
Red Rock	203	290
Grey Rock	290	305
Bluk Rock	305	331
Red Rock	331	335
Blue Rock	335	354

Work started June 6 1960 Completed July 10 1960

(13) PUMP:
Manufacturer's Name Red Jacket
Type: Submersible H.P. 5

Well Driller's Statement:
This well was drilled under my jurisdiction and this report is true to the best of my knowledge and belief.

NAME Lloyd L. Mathers (Person, firm, or corporation) (Type or print)
Address 855 E. 7th St. Bend, Ore
Driller's well number 8
[Signed] Lloyd L. Mathers (Well Driller)
License No. 231 Date Oct. 27, 1960

(USE ADDITIONAL SHEETS IF NECESSARY)

RECEIVED
NOV 24 1961
STATE ENGINEER
SALEM, OREGON

File Original and First Copy with the STATE ENGINEER, SALEM, OREGON

WATER WELL REPORT
STATE OF OREGON

State Well No. 18/16-7

State Permit No.

(1) OWNER:
Name M.L. Schwartz
Address 240 South Beverley ~~Hills~~/Calif. Drive
Beverley Hills Calif.

(2) LOCATION OF WELL:
County Deschutes Owner's number, if any—
SE ¼ Section 7 T. 16E R. 18S W.M.
Bearing and distance from section or subdivision corner

(3) TYPE OF WORK (check):
New Well ☒ Deepening ☐ Reconditioning ☐ Abandon ☐
If abandonment, describe material and procedure in Item 11.

(4) PROPOSED USE (check):
Domestic ☐ Industrial ☐ Municipal ☐
Irrigation ☐ Test Well ☒ Other ☐

(5) TYPE OF WELL:
Rotary ☐ Driven ☐
Cable ☒ Jetted ☐
Dug ☐ Bored ☐

(6) CASING INSTALLED: Threaded ☐ Welded ☒
6" Diam. from 1ft Above ft. to 8 ft. Gage 250
" Diam. from ft. to ft. Gage
" Diam. from ft. to ft. Gage

(7) PERFORATIONS: Perforated? ☐ Yes ☒ No
Type of perforator used
SIZE of perforations in. by in.
perforations from ft. to ft.
perforations from ft. to ft.
perforations from ft. to ft.
perforations from ft. to ft.
perforations from ft. to ft.

(8) SCREENS: Well screen installed ☐ Yes ☒ No
Manufacturer's Name
Type Model No.
Diam. Slot size Set from ft. to ft.
Diam. Slot size Set from ft. to ft.

(9) CONSTRUCTION:
Was well gravel packed? ☐ Yes ☒ No Size of gravel:
Gravel placed from ft. to ft.
Was a surface seal provided? ☐ Yes ☐ No To what depth? ft.
Material used in seal—
Did any strata contain unusable water? ☐ Yes ☒ No
Type of water? Depth of strata
Method of sealing strata off

(10) WATER LEVELS:
Static level Dry Hole ft. below land surface Date
Artesian pressure lbs. per square inch Date

Log Accepted by:
[Signed] M. Schwartz (Owner) Date 11-17-61, 19

(11) WELL TESTS: Drawdown is amount water level is lowered below static level
Was a pump test made? ☐ Yes ☐ No If yes, by whom?
Yield: gal./min. with ft. drawdown after hrs.
" " " "
" " " "
Bailer test gal./min. with ft. drawdown after hrs.
Artesian flow g.p.m. Date
Temperature of water Was a chemical analysis made? ☐ Yes ☐ No

(12) WELL LOG: Diameter of well 6 inches.
Depth drilled 220 ft. Depth of completed well 220 ft.
Formation: Describe by color, character, size of material and structure, and show thickness of aquifers and the kind and nature of the material in each stratum penetrated, with at least one entry for each change of formation.

MATERIAL	FROM	TO
sand &boulders med.	0	8
clay & Boulders Large Brown	8	60
clay & Boulders med. "	60	95
sand black	95	105
clay& Boulders fine to Med.B	105	205
Clay & " small trace of Pumice Brown	205	220

Dry hole

Work started 10-19 1961. Completed 11-1-61 19

(13) PUMP:
Manufacturer's Name
Type: H.P.

Well Driller's Statement:
This well was drilled under my jurisdiction and this report is true to the best of my knowledge and belief.

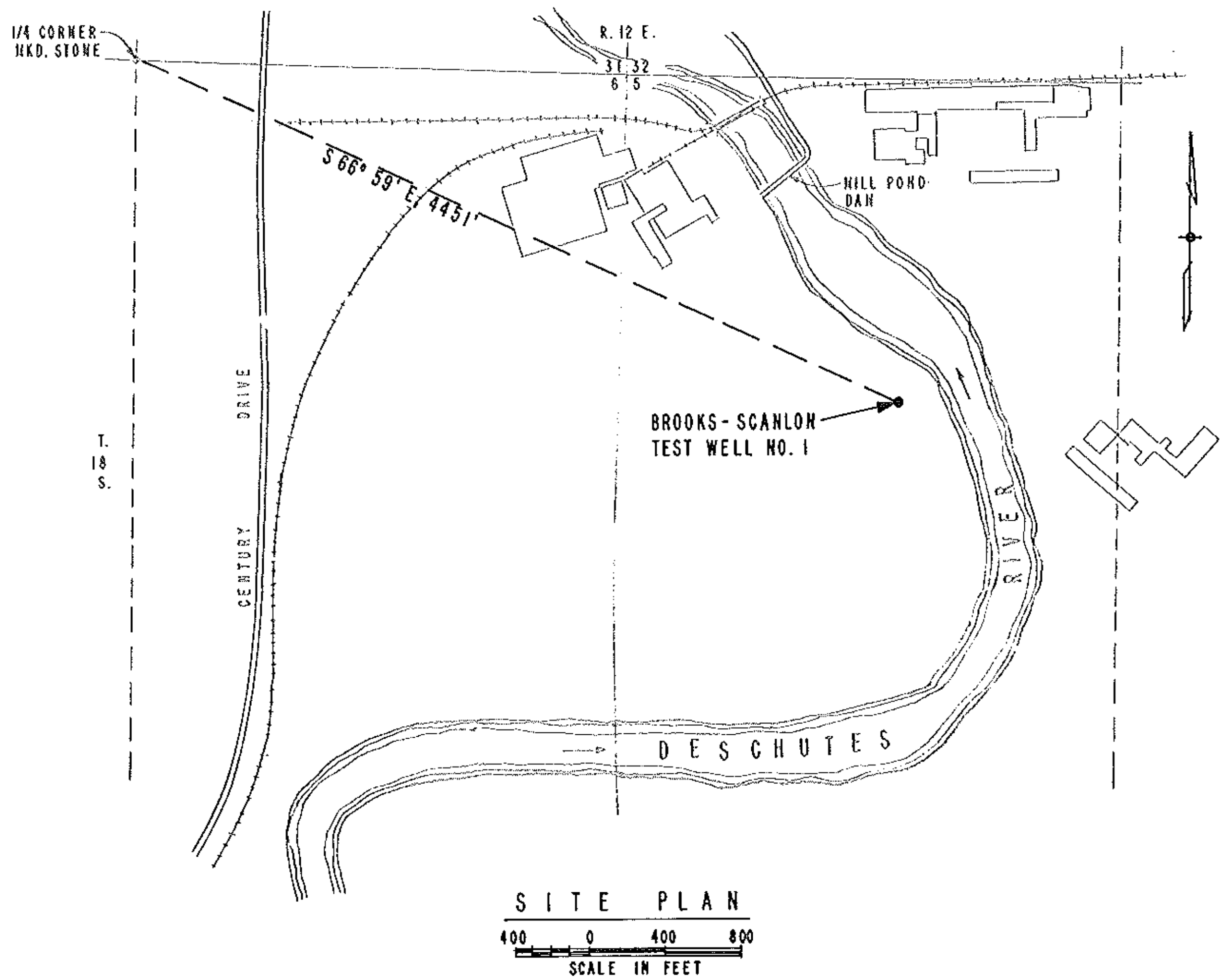
NAME Lee Grimes (Person, firm or corporation) (Type or print)
Address 26 Farell Rd. Bend Ore.

Driller's well number

[Signed] Lee Grimes (Well Driller)

License No. 113 Date 11-2-61, 19

(USE ADDITIONAL SHEETS IF NECESSARY)



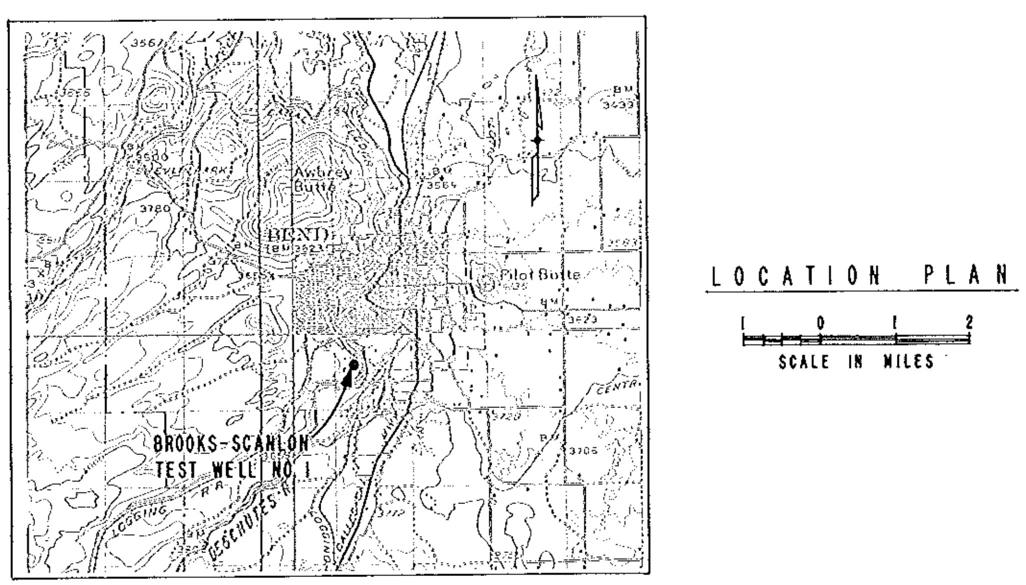


FIGURE 13
CITY OF BEND, OREGON
WATER SYSTEM STUDY

LOCATION OF BROOKS-SCANLON
TEST WELL NO. 1

CORNELL, HOWLAND, HAYES & MERRYFIELD
SEATTLE PORTLAND CORVALLIS BOISE
CH2M

south of Bend, Oregon, on the property owned by Brooks-Scanlon, Inc. (See Figure 13.) The location of the well is 4,451 feet S. 66° 59' E of the N 1/4 corner of Section 6, T18S, R12E. Ground surface elevation at the well site is approximately 3,650 feet. The well was drilled in 1956-57 by the A. M. Janssen Drilling Company of Portland, Oregon. The first drilling on the well was to a depth of 700 feet with a diameter of 6 inches, and later reaming to that depth with a 14-inch hole. At that point the well was tested. Upon completion of this initial pumping test, the well was deepened from 700 to 900 feet with a hole 12 inches in diameter. The well was again tested at the 900-foot depth. Supervision of the drilling in both stages was by E. A. Messer & Associates, Inc., an engineering firm of Portland, Oregon. A log of the well, based upon an examination of drilled cuttings by Geologist Albert A. Lewis, is given in Table 16.

TABLE 16

LOG OF BROOKS-SCANLON TEST WELL NO. 1

Depth Ft.	Description
0 - 18	River sand and gravel. Mixture various, volcanics, quartz, and feldspar.
18 - 21	Same as 0 - 18; somewhat darker in color.
21 - 25	Light gray in color; mostly pumice, some basaltic fragments.
25 - 36	Tan and gray; clay and sand, quartz, feldspar, basaltic and tuff fragments.
36 - 41	Sand and gravel; many coarse, water worn pieces, mostly volcanic material, dark colored and tuffaceous.
41 - 55	Dark colored volcanics, fragments of basalt, andesite, and tuff.
55 - 63	Dark gray to black fine-grained basaltic fragments; appears glassy; may be cindery in part.
63 - 79	Black, ground fairly fine, mostly basalt, partly tuffaceous.
79 - 84	Black, more coarse, mainly basaltic fragments, some tuffaceous.

TABLE 16 (Continued)

Depth Ft.	Description
84 - 102	Dark colored, somewhat brownish, basaltic, some pieces coarse (1/4" - 1/2"), may be cindery. Drillers log says 96 - 98 "indicated crevice, backfilling necessary."
102 - 104	Fine sand, brownish in color but has black, red, and tan fragments, probably basaltic and tuffaceous. First water test at 103 feet, pumped 10 gpm.
104 - 110	Coarse, black; some pieces 1/4" to 1/2" in diameter, mostly fine-grained basalt and tuff, some brownish in color, some pieces resicular.
110 - 120	Dark colored generally, fairly coarse, black and red pieces; basalt and tuff, perhaps some cinders; maybe some dacite or rhyolite.
120 - 137	Few very coarse porous pieces, 1" in diameter; pumiceous; other coarse pieces up to 1/2" of dark basalt and gray andesite. Some gray siltstone.
137 - 148	Coarse, cindery, brownish in color. Rock has large proportion of brown tuff and pumiceous fragments; less quantity black basaltic fragments, some siltstone.
148 - 154	Ditto, less coarse, greater proportion brown tuff.
154 - 180	Ditto, large proportion brown tuffaceous clay; less fine-grained basalt; few grains feldspar and perhaps quartz.
180 - 198	Finer; dominantly brown tuffaceous clay; few pieces black basalt, some feldspar and quartz.
198 - 200	Ditto.
200 - 215	Ditto. Very little black basalt.
215 - 234	Ditto. Numerous grains feldspar and quartz; a piece of chalcedony.
225 - 234	(within 215 - 234) Separate sample in interval 215 - 234, mostly clay, less proportion brown tuff; very little black basalt.

TABLE 16 (Continued)

Depth Ft.	Description
234 - 243	Darker; fine; very little brown tuff; dominantly black basalt, probably some tuff.
243 - 246	Porous black rock, tuffaceous and cindery; some pumice and tan and gray clay. Some coarse pieces of tuff up to 1" in diameter.
246 - 255	Black, gray, and brown sand composed of basalt, tuff, clay; some feldspar and quartz. Pump test #2 at 255 feet, 20 gpm.
255 - 270	Sand, brownish, largely composed of basalt and tuff with some grains of feldspar and quartz.
270 - 280	Ditto.
280 - 289	Ditto. Some pink tuff.
289 - 297	Fine to coarse sand. Appears to be a mixture of various volcanic and pyroclastic rock types plus mineral grains. Largest fragments are dark colored lavas, probably basalt with some lighter colored pieces of andesite and tuff. A few fragments that appear to be cindery. Mineral grains are feldspar and probably quartz.
297 - 311	Coarse, dark gray volcanic rocks, basalt and basaltic tuff; brown tuff, and some mineral grains.
311 - 323	Dominantly dark gray volcanic rock, probably andesite.
323 - 334	Coarse, up to 1", dark gray volcanic rock, probably basaltic andesite; a little brown tuff.
334 - 343	Finer dark gray basaltic or andesitic rock and tuff; some red brown grains.
343 - 346	More coarse, circa 1/4", dark gray lava, some tan, stratified clay.
346 - 352	Gray and brownish andesitic tuff, some red and brown clay. Some coarse pieces up to 3/8" but mostly 1/8" or less.

TABLE 16 (Continued)

Depth Ft.	Description
352 - 357	Dark gray lava fragments, probably andesitic in composition; also numerous fragments of fairly 'indurated' siltstone. Pump test #3 at 352 feet, 30 gpm.
357 - 364	Generally small size, gray and tan andesitic and basaltic tuffs; some clay.
364 - 370	More coarse, 1/8" to 1/2" varicolored tuffs, andesitic and basaltic. Some clay fragments.
370 - 378	Coarse, up to 1" size. Porous and pumiceous gray and brownish tuff. Some clay fragments.
378 - 387	Finer size. Dark gray and reddish tuff; some rounded black basaltic rock.
387 - 395	More coarse, black basalt and gray tuff. Some pieces of clay; some mineral fragments.
395 - 399	Largely sub-rounded fragments of medium to dark gray lava. Probably basaltic to andesitic. Also fragments of sub-rounded quartz and feldspar.
399 - 410	Black and gray volcanic tuff; considerable red and brown tuffaceous clay; few mineral grains of quartz and feldspar.
410 - 421	Ditto.
421 - 429	Finer, much slime. Large proportion of gray and reddish clay and soft tuff which made slimy sludge; some black basaltic rock.
429 - 435	Ditto.
435 - 445	Ditto, somewhat more coarse.
445 - 455	Finer, darker in color, mostly light to medium gray fragments of lava. Probably basaltic or andesitic in composition. Also numerous fragments of cream-colored tuffaceous clay. Few mineral grains.

TABLE 16 (Continued)

Depth Ft.	Description
455 - 465	Ditto. Larger proportion of clay and tuff.
465 - 473	Quite finely divided. May be greater proportion of basalt or andesite and less clay.
473 - 484	More coarse piece of gray tuff. Probably andesitic, circa 1/4". Still considerable proportion of reddish clay and slime.
484 - 497 (washed at well)	Mainly gray and brown lava and tuffs, circa 1/8". Basaltic and andesitic composition.
484 - 497 (unwashed)	Large proportion of brown slime from clay and tuff.
497 - 511	Ditto. Washed sample shows gray and brown tuff and some black basalt.
511 - 524	Large proportion of brown slime. Washed fraction shows gray and brown lava and tuff, finely ground, circa 20-mesh; some siltstone and reddish and brownish particles.
524 - 535	Ditto. Sample very finely divided. Washed fraction circa 40-mesh.
535 - 545	Ditto.
545 - 555	Ditto. Medium gray, fairly large tuffaceous siltstone. Few fragments dark gray basalt.
555 - 565	Ditto. Few mineral grains.
565 - 575	Ditto.
575 (washed at well)	Sand, sub-rounded, circa 10-mesh. Various volcanic rock types and mineral grains.
575 - 585	High proportion of slime. Sand fraction circa 20-mesh. Vari-colored volcanic rock types and clay with many mineral grains.
585 - 595	Ditto.

TABLE 16 (Continued)

Depth Ft.	Description
595 - 605	High proportion slime. Sand fraction is apparently mixture of various rock types. Larger fragments are vari-colored lavas and tuffs. Smaller grains are mostly clear and iron-stained feldspars, with probably some quartz.
605 - 615	Large proportion of slime; fine to medium grains of sand; larger fragments are rounded lava and tuff. Smaller grains are feldspar, largely iron-stained with some quartz.
615 - 625	Much more coarse. Rounded gravel pieces up to 1" in diameter, composed of basaltic and andesitic lavas and tuffs with red tuffaceous fragments and some mineral grains.
625 - 630	No sample.
630 - 640	Fine to medium size sand of various colors and rock types, up to 1/4" in diameter, mostly up to 1/8". Largely fragments finely crystalline dark gray to black basalt. Some lighter fragments with slight pinkish cast, may be andesitic in composition or possibly oxidized zone in basalt. Numerous rounded fragments of light cream to reddish pumice. Few mineral grains of feldspar, olivine, and quartz. A piece of chalcedony seen.
640 - 650	Ditto.
650 - 669	No sample.
669 - 677	Sample is smaller grain size than above. Apparently a finely crystalline basalt with large percentage of magnetite "dust." Rock is almost opaque under microscope except around edges and is slightly magnetic. Mineral grains are mostly feldspar with perhaps some quartz. Pelton basalt at bottom of Deschutes fm (Stearns?).
690 - 700	Sample almost entirely a dark gray to black, very finely crystalline, slightly magnetic basalt. Also a few slightly larger rounded fragments of light colored tuff, and a few mineral grains of clear to translucent feldspar and possibly quartz.

TABLE 16 (Continued)

Depth Ft.	Description
700 - 812	Dark gray fine-grained basalt.
812 - 902	Tuffaceous fragments, some sand and rounded nodules. Much more coarse material.

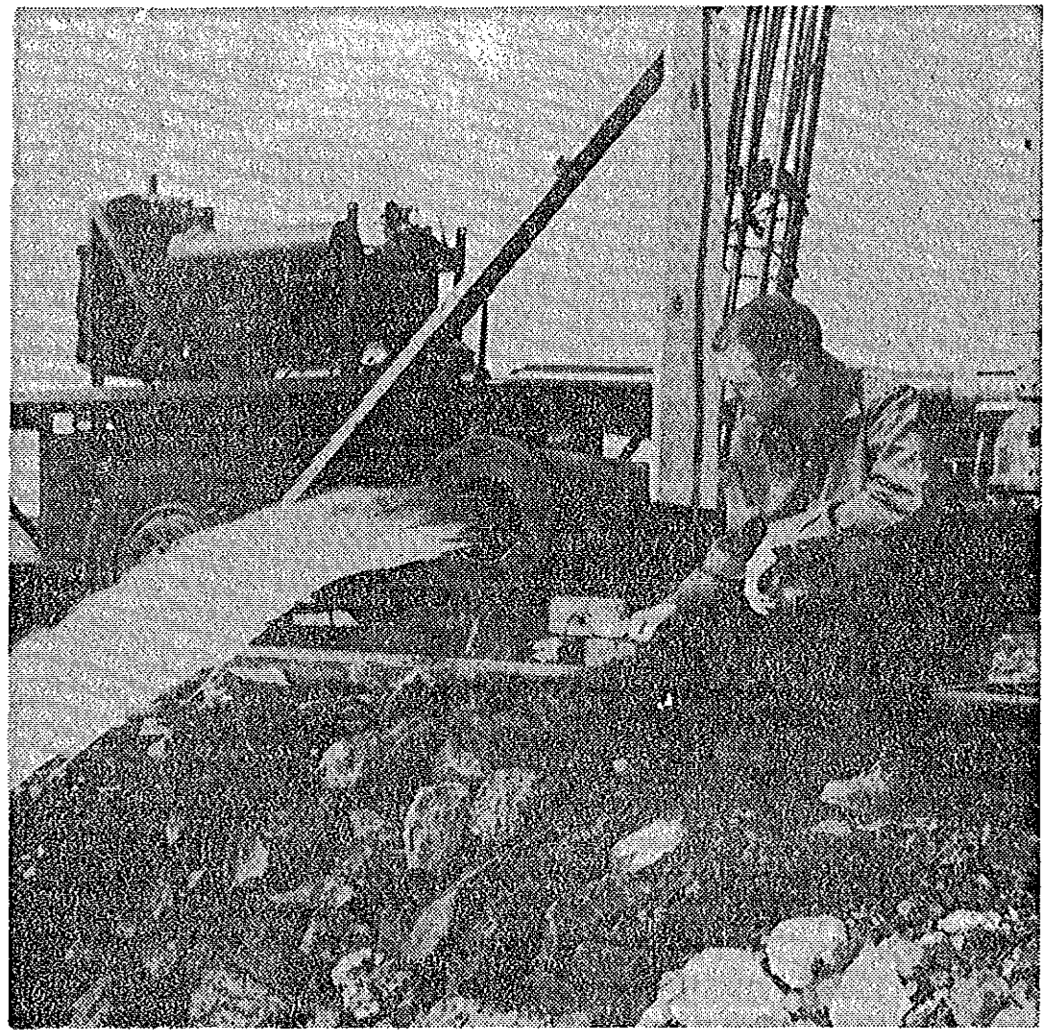
Bottom.

In 1960, two additional pumping tests were conducted for Brooks-Scanlon by Keith E. Anderson, Consulting Geologist of Boise, Idaho, in cooperation with Cornell, Howland, Hayes & Merryfield.

Based upon the information obtained during these tests, it is anticipated that future wells could be drilled in this immediate vicinity which would yield an average of at least 4.5 cfs (2,000 gpm or 2.9 mgd) each with a pumping elevation at approximately 3,020 feet above sea level. The results of the first test showed that the pump discharge approximately 1,300 gpm (2.9 cfs) with a drawdown of about 7 feet from a static elevation of about 3,045 feet above sea level. A careful examination of drawdown records during the period of the tests, together with periodic recovery measurements, indicates that the aquifer is of large areal extent and that no boundary conditions exist which would result in accelerated drawdowns in future years after continued pumping. The behavior of the water level in the well during pump and recovery periods also indicated a very high transmissibility of the formation; and from a consideration of recharge available in the area, it is believed that it would be possible to develop a total supply of at least 30 cfs (20 mgd) without depleting the groundwater resources of the immediate area.

Figure 14 is a photograph and Figure 15 is a newspaper clipping, both from the Bend Bulletin, in connection with the 1960 pumping tests.

Complete chemical analyses were made of three samples collected during the 1960 pumping tests. The results are presented in Table 17 along with the analyses made in connection with earlier tests. The water is of excellent chemical quality for municipal use. Table 18 affords a comparison of the chemical quality of the deep well water with that presently used from Tumalo Creek. The deep well water is almost equal in chemical quality to the Tumalo water and would be free of the occasional turbidity problems associated with the Tumalo supply.



OUT OF THE DEPTHS — Water pumped from a 900-foot well is pictured flowing from a big pipe in a test now in progress across the Deschutes from the Brooks-Scanlon, Inc. plant. Larry Brown of the Brooks-Scanlon staff is shown watching the 1300-gallon per minute flow. The deep well was drilled by Brooks-Scanlon in studies preliminary to the possible establishment of a pulp operation in the area. Engineers said the deep well tests are most encouraging.

FIGURE 14

CITY OF BEND, OREGON
WATER SYSTEM STUDY

NEWSPAPER PHOTO
BROOKS-SCANLON TEST WELL

CORNELL, HOWLAND, HAYES & MERRYFIELD
SEATTLE CORVALLIS BOISE

Excellent flow appears to have been tapped in drilling at mill

By Phil F. Brogan
Bulletin Staff Writer

Brooks - Scanlon, Inc., has apparently tapped an excellent flow of subterranean water in drilling a 900-foot well just across the Deschutes from its Bend plant.

This was indicated at 12:30 a.m. when a "Great Silence" came to the area as two huge diesel pumps that had been pulling water out of great depths at the rate of about 1300 gallons a minute for more than 50 hours, ceased operating.

The silence came shortly before scheduled time as the result of motor trouble, but not until after a successful drawdown test had been made.

Preliminary figures indicate that there was a total drawdown of 23 feet and 10 inches. However, in the final 24 hours of pumping there was a drawdown of the subterranean water level of only a few inches. This indicates that a constant pool had been reached.

Pumping equipment had been set in the 900 foot hole at the 600-foot level. Actually, the present bottom of the original 900-foot hole is now 880 feet, result of a slight slumping.

Drilling of the test well was started in 1956, with a six-inch hole drilled to a depth of 600 feet. Since then, the hole has been reamed several times and is now 12 inches in diameter. It is cased part of the way.

The deep-well test is being made to determine if an adequate supply of water will be available if the proposed pulp mill is constructed in the area. The hole would be reamed to 20 inches if used.

Brooks-Scanlon, Inc., officials are highly optimistic about the water picture as a result of the present test.

Plugging Planned

With the deep test completed, the hole is now to be plugged at the 730 foor level, preliminary to further pumping tests. Keith Anderson, consulting engineer from Boise, Idaho, is supervising the draw-down tests, assisted by Larry Brown of the Brooks-Scanlon staff.

While the tests are being made, water samples are taken every hour. Tests reveal a wide range of elements in the water, but apparently none that would be harmful in a pulp plant or other development. Fear was first held when a high iron test showed up, but later this lowered.

Temperature at the water is about 48 degrees.

The Interstate Pump Co. of Klamath Falls is doing the pumping. Lee Grimes, Bend, was to move in his equipment today to place the concrete plug in the well at the 730 foot level.

Above That Point?

Reason for the plugging of the well and the test above the 730 foot level is to determine whether the main source of water is above that point, If it is, the hole will remain sealed off.

The present level of the water is at 548 feet. Into this subterranean pool water is tumbling in a 300 foot "cataract."

The deep hole is on the former Shevlin-Hixon grounds on the west side of the Deschutes.

FIGURE 15
CITY OF BEND, OREGON
WATER SYSTEM STUDY
NEWSPAPER CLIPPING
BROOKS-SCANLON TEST WELL

CORNELL, HOWLAND, HAYES & MERRYFIELD
SEATTLE CORVALLIS BOISE
CH2M

TABLE 17.

SUMMARY OF WATER ANALYSIS
BROOKS-SCANLON TEST WELL NO. 1.

Sample No.	(1956-57 Pumping) A	B	(1960 Bailer Samples) 1	5	(1960 Pumping) A	B	C
Date	7-?-56	3-28-57	2-3-60	2-3-60	3-29-60	3-30-60	4-10-60
Depth	700'	900'	575'	870'	881'	881'	730'
pH	7.4	7.5	7.5	7.5	7.8	7.9	8.0
Total Dissolved Solids (Residue on Evaporation)	266	105	94	130	122	126	106
Total Volatile Solids (Loss on Ignition)	21	11	2	18	14	14	4
Total Fixed Solids (Residue after Ignition)	-	-	92	112	108	112	102
Suspended Solids (Insoluble)	-	-	155	21	-	-	-
Alkalinity (as $CaCO_3$)							
Carbonate	0	0	0	0	0	0	0
Bicarbonate	127	66	87	88	77	69	7.9
Hardness (as $CaCO_3$)	-	46.8	62	63	55	51	52
Iron (Fe) Dissolved	0.34	3.9	0.09	0.14	0.37	0.02	0.01
Iron - Insoluble	-	-	78.4	10.3	-	-	-
Manganese (Mn)	-	0.02	0.00	0.00	0.36	0.00	under .04
Sodium (Na)	-	-	13.5	12.5	-	-	-
Potassim (K)	-	-	2.9	2.7	-	-	-
Chloride (Cl)	7.2	4.0	1.7	1.8	1.9	1.9	2.4
Sulfate (SO_4)	-	3.4	Trace	Trace	1.0	1.0	3.3
Silica	-	33.7	-	-	31.0	36.0	33.2
Calcium	-	11.4	-	-	9.0	7.8	8.3
Magnesium	-	4.4	-	-	8.4	7.6	7.5
Sodium and Potassium	-	13.1	-	-	-	-	-
Aluminum	-	0.2	-	-	0.5	0.6	1.3
Fluoride	-	0.1	-	-	-	-	-
Nitrate	-	0.01	-	-	-	-	-

Note: (1) All results except pH reported in parts per million.
(2) Analysis of 2-3-60 on both the 575-foot and the 870-foor samples were run on filtered samples. Suspended solids and iron-insoluble were run on filter residue. Samples contained considerable quantity of suspended material which appeared to be casing scale.
(3) Analysis of 3-29-60 on sample collected after only a few minutes pumping; sample of 3-30-60 after nearly 24 hours pumping.
(4) Well depth on 4-10-60 was 730 ft. but analysis probably represents large proportion of water coming from greater depth.

TABLE 18

COMPARISON OF THE CHEMICAL QUALITY OF WATER FROM DEEP WELLS AT BEND AND FROM TUMALO CREEK

	(4-10-60) Deep Well	(4-19-63) Tumalo Creek
pH	8.0	7.4
Total dissolved solids	106.	52.
Alkalinity (as $CaCO_3$)		
Carbonate	0.0	0.0
Non-Carbonate	79.	19.5
Hardness (as $CaCO_3$)	52.	14.9
Calcium	8.3	3.8
Magnesium	7.5	1.3
Iron	0.01	0.2
Manganese	under 0.04	0.00
Aluminum	1.3	0.32
Sodium and Potassium	13.1*	5.0
Fluoride	0.1*	0.1
Nitrate	0.01*	0.0
Chloride	2.4	8.1
Sulfate	3.3	1.8
Silica	33.2	28.

*(3-28-57)

Analyses are in milligrams per liter (mg/l), except pH which is in standard units.

In 1960, particular attention was given to the iron content of the well water. Preliminary sampling from the well with a small bailer prior to installation of the pump sustained a previous estimate that the iron content would be low and that the reported 3.9 parts per million from an earlier investigation was in error. A number of field analyses were made for iron in addition to the tests for iron which were made as a part of the complete laboratory analyses. The results of the field tests for iron are given in Table 19. The analyses showed an iron content of only .01 or .02 parts per million, after the initial water standing in the well had been cleared out. The manganese content is also well within acceptable limits.

TABLE 19

FIELD ANALYSIS OF WATER SAMPLES
BROOKS-SCANLON, INC. TEST WELL NO. 1

Sample No.		Parts per Million Iron	pH
First test	1	0.11	
	2	0.04	
	3	0.05	
	4	0.06	
	5	0.04	
	6	0.03	
	7	0.04	7.3
Second test	8	0.14	8.65
	9	0.05	8.1
	10	0.04	8.2
	11	0.04	7.8

Hydrologic studies in the Bend area show that there should be ample recharge to the groundwater aquifers to sustain an annual withdrawal of at least 30 cubic feet per second (20 mgd) and possibly more. Much of the recharge to these volcanic rocks comes from percolation losses by surface streams and rivers in the area. These losses can be observed over most of the region around Bend, and their magnitude is sufficient to sustain yields from wells as discussed in this report.

It is recommended that any deep wells drilled by the City be similar in construction to the Brooks-Scanlon well. That is, the total depth of the well should be approximately 900 feet (below Elevation 3650, or to bottom at about Elevation 2750). Surface casings should be at least 24-inch, and the diameter of the well at 600 feet should be at least 20 inches. Below a depth of 600 feet, the diameter could be reduced to 16 inches.

The results of the pumping tests indicate that the transmissibility of the aquifer is high; and therefore, interference between wells would not be appreciable even when pumping at large rates. It is recommended, however, that a series of wells, if drilled, be located at least 1,000 to 1,500 feet apart in order that the mutual interference in pumping levels will not result in excessive pumping costs.

It has been suggested that wells be drilled to a greater depth than 900 feet in an attempt to develop additional groundwater supplies at lower elevations which might have either a higher yield or a higher static level or both. There is insufficient information on the geology and hydrology of the area to predict accurately what would be encountered if a well were to be carried 400 to 500 feet deeper. During a construction program to develop groundwater, consideration might be given to carrying the first well on down to a greater depth on an exploratory basis. It seems possible that some additional quantity of water might be obtained, but it does not appear likely that the water level would be sufficiently higher than that in the 900-foot well to warrant the cost of deeper drilling.

In locating deep wells in this area, there are three important factors to consider: (1) assurance of tapping the aquifer; (2) sanitation; and, (3) length of pipelines required to deliver the well water to the City water system. The aquifer which is to be tapped lies below the regional water table, so that from this standpoint deep wells could be located almost anywhere in the immediate vicinity of Bend. Figure 12 indicates a geologic fault a mile or so southwest of the City limits, and it is recommended that no drilling be done within 1,000 feet of this fault. There is a remote possibility that there are impermeable volcanic plugs extending upward through the aquifer and above the regional water table, and holes drilled into such plugs would be dry. However, this is just a remote possibility, and the risk is very slight. Obviously, the surest way to tap the deep aquifer is to utilize the Brooks-Scanlon test well or to drill a new well close by, since the presence of water at this location has already been demonstrated. However, the hazard of moving away from this spot is not great and such a move may well be justified by other considerations.

From the standpoint of sanitation, wells preferably should be located south of builtup areas and areas that may be developed and which use "dry wells" for waste water disposal, since the groundwater flow is from south to north. Wells should also be properly constructed by casing and grouting to exclude surface water. With these precautions, a deep well water supply which is completely safe from a bacteriological standpoint can be assured.

The third consideration is the distance of the well sites from the point of discharge into the water system, which affects the cost of construction.

The Brooks-Scanlon site is most attractive from the standpoint of being a proven source of supply. It is also very close to a good point of connection to the water distribution system. It has the disadvantage of being north of an area which is only sparsely settled now, but which may become more densely populated in the future, thus presenting the possibility that the water might be subject to contamination.

There is a large area lying about one to two miles south of Pilot Butte which is excellent from the sanitation standpoint, and which is not far from a good point of connection to the City water system. Introduction of a new source of supply at this point would strengthen the distribution grid and improve pressures in the east section of the City. The chief disadvantage of drilling in this location is that it is exploratory in nature, as no deep wells have been drilled in this area. The ground elevation is about 50 to 100 feet higher than at Brooks-Scanlon, so that the depth to the regional water table may be correspondingly greater.

All things considered, this area two miles south of Pilot Butte and 1-1/2 miles southeast of Bend is probably the best location for deep wells to serve the City. Figure 16 illustrates a supplemental source of supply from deep wells at this site. Two wells would be drilled, each to produce not less than 1,750 gpm. A 16-inch pipeline would be laid from the wells to the distribution system connecting to the 12-inch main near Pilot Butte Reservoir, or to the 12-inch main at Third and Clay Streets. Table 20 gives the estimated costs for constructing and operating this supplemental deep well supply. The total estimated cost of a 5 mgd supply from this source is $502,800. The construction could be carried out in phases. First a 6- to 10-inch pilot hole would be drilled to a depth of 700 to 1,000 feet to confirm the presence of the water and to determine the elevation of the water table. This exploratory hole would cost about $21,000 if carried to the 1,000-foot depth. Part, if not all, of this cost might be recovered if the work proceeded, but would be lost in the unexpected event that the hole was dry. If water is found, the pilot hole would then be reamed out, if possible, to the full diameter of the well and pumping tests made to determine the safe yield of the well and the capacity of the pump to be installed. According to estimates of future water use and well capacity, only one well could be needed initially. It would be used for peaking purposes only in the summer months until about 1975 when a second well would be added. Completion of the first phase of construction (2.5 mgd additional supply) would cost $330,600 including completion of the pilot hole, one well, testing, and construction of the 16-inch line to the City. Completion of a second well in 1975 would add another 2.5 mgd to the supply and would cost about $172,200.

The cost of power for pumping is based on three months' operation of one well from 1966 to 1975 and of two wells from 1975 to 1990. It is also based on a pumping level elevation of 3,025 feet above sea level.

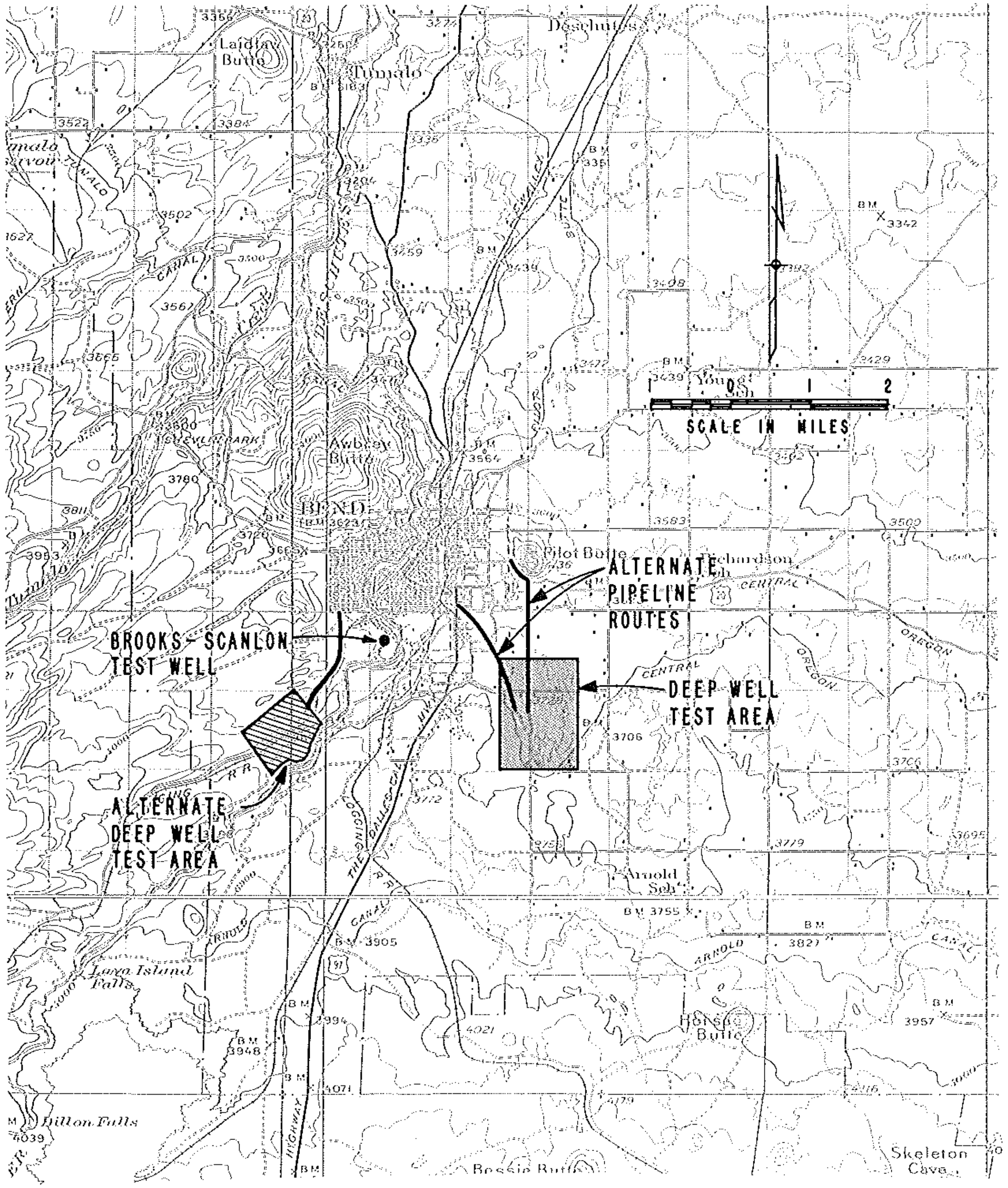


FIGURE 16

CITY OF BEND, OREGON
WATER SYSTEM STUDY

POSSIBLE SITES FOR DEVELOPMENT OF DEEP WELLS

CORNELL, HOWLAND, HAYES & MERRYFIELD
SEATTLE CORVALLIS BOISE

TABLE 20

DEEP WELL DEVELOPMENT

CAPITAL COSTS		
Step No. 1a (by 1965)		
Conduct deep well exploration	$ 21,000	
Step No. 1b (by 1966)		
Complete installation of first well	151,200	
Construct transmission line	158,400	
TOTAL		$330,600
Step No. 2 (by 1975)		
Construct second deep well		172,200
TOTAL CAPITAL COSTS		$502,800
ANNUAL COSTS		
1966		
Amortize capital (20 years at 3-1/2% on $330,600)	$ 22,320	
Operation	1,400	
Maintenance	3,400	
Power	4,600	
TOTAL		$ 31,720
1975		
Amortize Step No. 1	$ 22,320	
Amortize Step No. 2	11,620	
Operation	2,800	
Maintenance	6,400	
Power	7,470	
TOTAL		$ 50,610

This represents a lift to the surface of about 700 feet. If an additional allowance of 185 feet is made for discharge into the system, the total pumping head is 885 feet. The overall, wire-to-water efficiency of pumping is taken at 70 percent.

An alternate location for deep well testing is also shown on Figure 16. This area lies about 1-1/2 miles southwest of the City limits. It is about 1-1/2 miles from the Brooks-Scanlon test well, but on the opposite side of a fault line which passes near the southwest corner of the City. In comparing this deep well test site with the one southeast of the City, it is equally protected against any possible contamination, and is about the same distance from a good point of connection to the distribution system. The ground elevation is 75 feet lower than at the southeast location, so that less depth of test well should be required. Since the site is above the fault line, it is possible that the groundwater table may be higher, which would also reduce the depth of test hole required. However, for all practical purposes the cost of testing and developing a 5 mgd supply from deep wells at the two sites is essentially equal, and the choice between the two is not clear-cut.

Shallow Wells in the Lava Island-Benham Falls Region. Between Bend and Benham Falls there is a series of geologic faults which act as barriers to groundwater movement. South of this fault area the regional water table is at a higher elevation and much closer to the ground surface than it is north of the area and nearer the City. This is shown on Figures 10 and 12. The regional water table is at Elevation 4146 at the proposed site for Benham Falls Dam near old Camp Abbott, and is at Elevation 3045 at Brooks-Scanlon. There is little or no information concerning the elevation of the groundwater table between these points.

Tables 21, 22, and 23 are logs of wells near the old Camp Abbott site. There are no records of the capacity of the Camp Abbott wells, but judging from the 12-inch diameter of the wells and various persons' recollections, the capacity was probably in the range of 500 to 1, 200 gpm each.

The Bureau of Reclamation has drilled at various times a number of test holes in connection with the Benham Falls Reservoir project. An examination of the logs of these test holes indicates that groundwater is about 50 feet below the surface at Benham Falls, and it is likely that a shallow groundwater supply could be developed for municipal purposes at this location. Figure 17 is a geologic section at Bureau of Reclamation

Damsite "A" giving information on water levels. Development of an additional 5 mgd supply from this source is illustrated by Figure 18. It might consist of 4 wells about 200 feet deep and 12.5 miles of transmission line to the City.

TABLE 21

GROUNDWATER IN THE BEND AREA

OCCURRENCE AND USE OF GROUNDWATER

Well No. 11

Source of information:	R. J. Strasser
Drilled for:	Camp Abbott
Drilled by:	R. J. Strasser
Date:	December 1942
Location:	Camp Abbott, approximately 16 miles south of Bend and 2 miles west of U.S. Highway 97.
Elevation:	Approximately 4,200 feet above sea level
Total Depth:	124 feet
Casing:	112 to 124 feet - 12-inch diameter
Yield:	Ample

DRILLERS LOG

From	To	Description
0	33	Boulders
33	42	Black lava
42	44	Red lava
44	64	Black lava
64	69	Blue sandy lava
69	92	Red lava
92	103	Blue clay
103	112	Black lava
112	115	Clay
115	124	Black lava

TABLE 22

GROUNDWATER IN THE BEND AREA

OCCURRENCE AND USE OF GROUNDWATER

Well No. 12

Source of Information:	R. J. Strasser
Drilled for:	Camp Abbott
Drilled by:	R. J. Strasser
Date:	January 1943
Location:	Camp Abbott (Same as No. 11)
Elevation:	Approximately 4, 200 feet above sea level
Total Depth:	312 feet
Casing:	254 to 312 feet - 12-inch diameter
Aquifer:	Sand and gravel
Yield:	Ample

DRILLERS LOG

From	To	Description
0	3	Top soil
3	6	Sand, Clay
6	8	Clay
8	54	Sand and Gravel
54	63	Black lava
63	71	Gray lava
71	76	Sandy lava
76	85	Black lava
85	93	Gray sandy lava
93	95	Hard rock
95	97	Clay and Gravel
97	108	Blue lava

TABLE 22 (Continued)

From	To	Description
108	111	Red Clay
111	117	Black lava
117	120	Red lava, soft
120	131	Sandstone and black lava
131	135	Black lava
135	147	Blue lava
147	150	Sandy lava
150	165	Black lava
165	175	Clay and Gravel
175	186	Lava, sandy
186	202	Black lava, hard
202	207	Black lava, soft
207	212	Black lava, hard
212	213	Red Clay
213	222	Black lava, hard
222	231	Hard sand
231	240	Sand and lava
240	312	Sand and Gravel

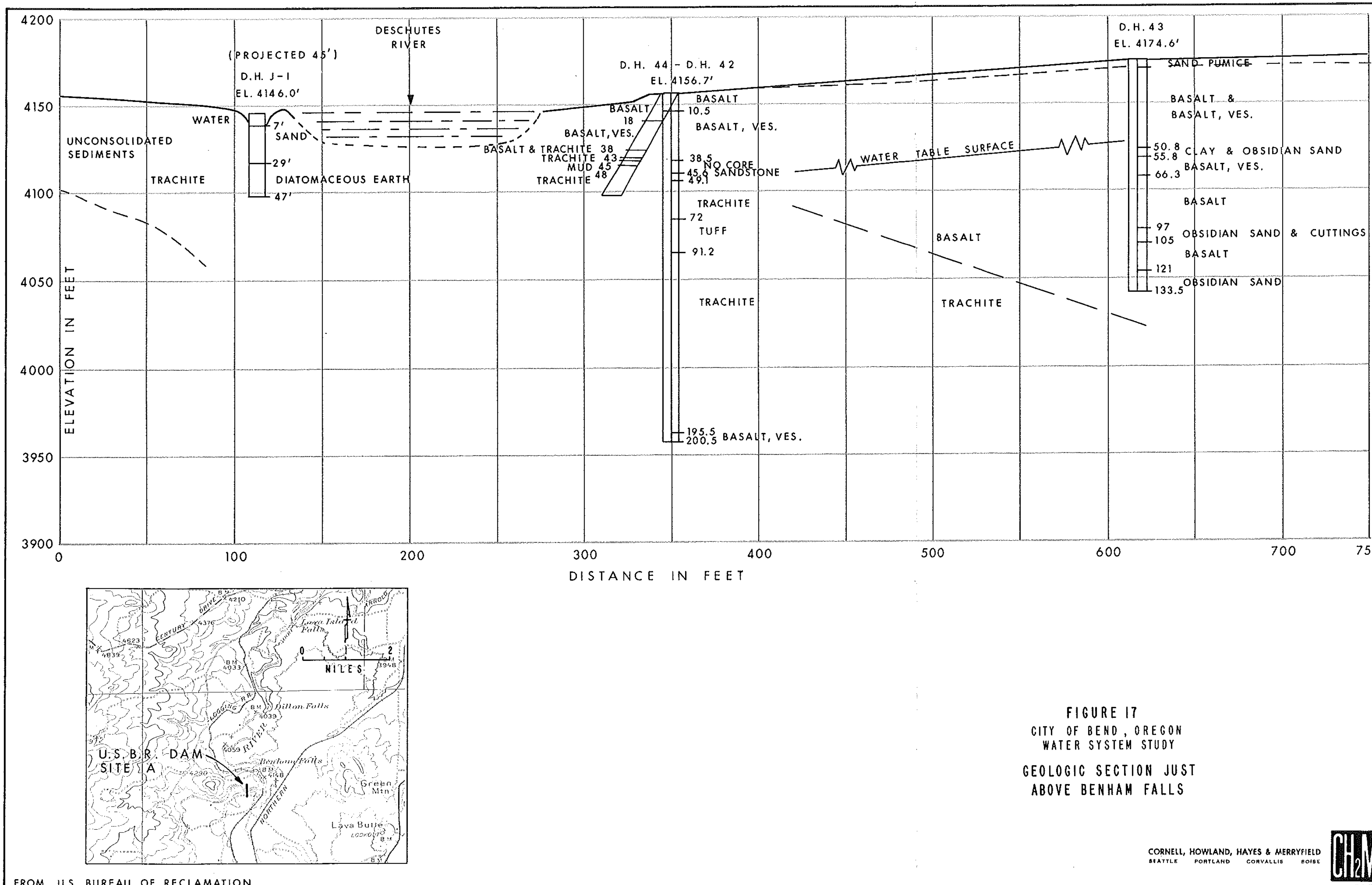


FIGURE 17
CITY OF BEND, OREGON
WATER SYSTEM STUDY

GEOLOGIC SECTION JUST ABOVE BENHAM FALLS

CORNELL, HOWLAND, HAYES & MERRYFIELD
SEATTLE PORTLAND CORVALLIS BOISE

TABLE 23

BENHAM FALLS TEST WELL

U. S. Bureau of Reclamation Test Well No. 9 located in the NW 1/4 of Section 33, T19S, R11E. The static water level in this 200-foot well was 70 feet below land surface, or at an elevation of 4,146 feet. The log of this well is as follows:

Materials	From	To
	(feet below land surface)	
Sand	0	2
Silt, with trace of sand and gravel	2	5
Sand, clay, and silt	5	10
Sandstone, fine-grained	10	11.8
Sand	11.8	18.5
Basalt, hard gray	18.5	36.5
Basalt, highly vesicular, hard, gray	36.5	43
Basalt, hard gray	43	54.6
Basalt, highly vesicular, gray	54.6	58.6
Basalt, hard gray	58.6	74.
Basalt, broken, highly vesicular, gray, possibly several thin flows	74	133
Basalt, hard gray	133	141
Basalt, broken, highly vesicular	141	159
Andesite, fine-grained, slightly vesicular	159	169
Basalt, hard, dark gray, vesicular	169	187
Andesite or basalt, slightly vesicular	187	190
Basalt, hard, vesicular	190	193
Cavity	193	195
Basalt	195	197
Cavity	197	199
Basalt	199	200

Figure 18 also shows a possible location for a well field and a tentative route for a pipeline to the City. Because the present Deschutes River channel hugs an impervious rock formation on the west side at Benham Falls, the well field is shown on the east side of the river. The pipeline would cross the river at Benham Falls and follow the logging road to the City. A shorter route to the City exists along the main line track of the Great Northern Railroad but the difficult lava cuts involved and the difficult access for construction and maintenance in the lava bed area make it less desirable and probably more costly than the other route.

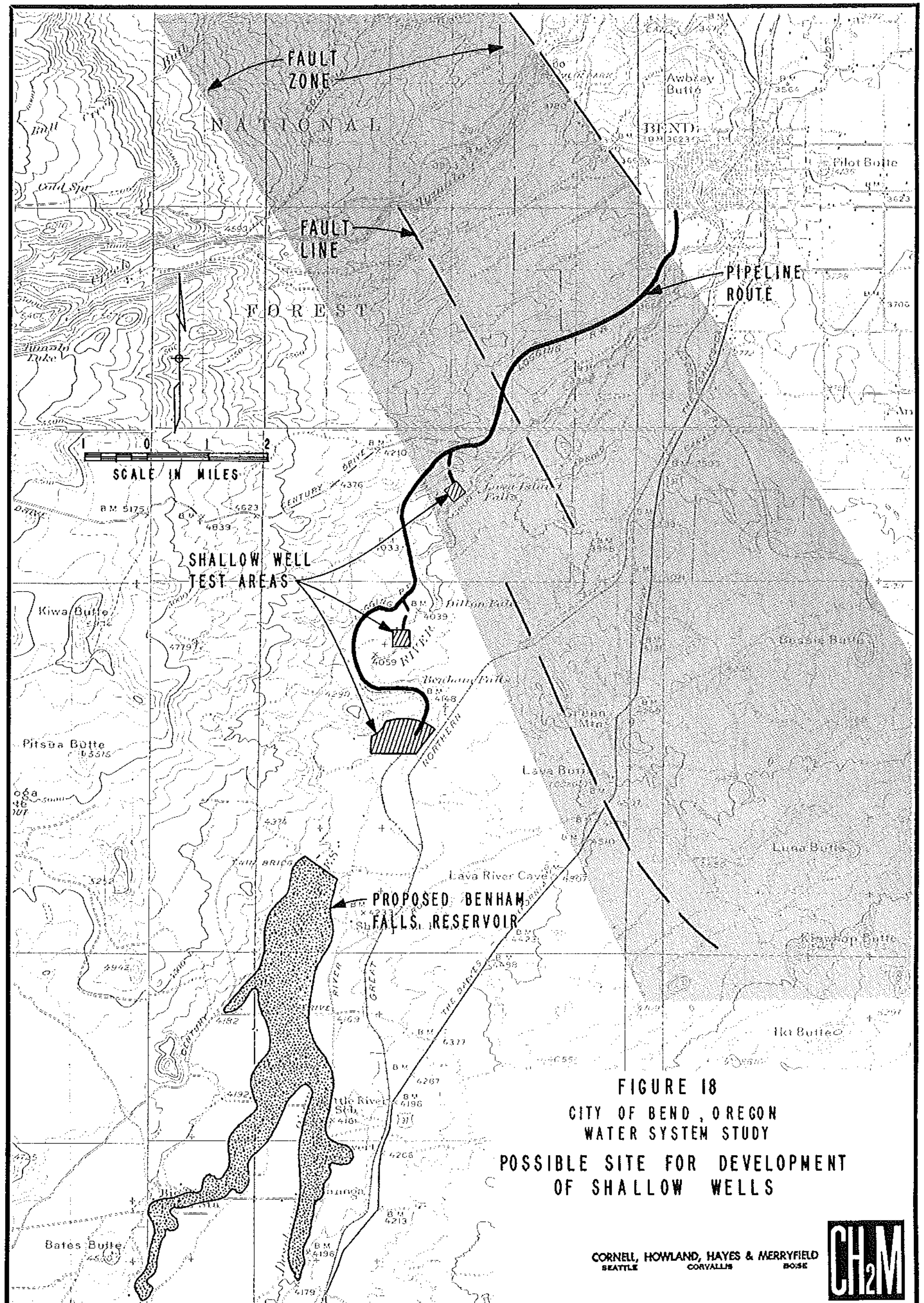


FIGURE 18

CITY OF BEND, OREGON
WATER SYSTEM STUDY

POSSIBLE SITE FOR DEVELOPMENT
OF SHALLOW WELLS

CORNELL, HOWLAND, HAYES & MERRYFIELD
SEATTLE CORVALLIS BOISE

CH2M

The estimated cost of developing a 5 mgd supply from shallow wells at the Benham Falls location is $1,162,800, as given in Table 24. The estimate includes an item for test drilling and pumping, which would be needed to prove the adequacy and quality of the supply as a firm basis for final planning and prior to actual development.

Between Benham Falls and Lava Island Falls there is a possibility that the regional water table is at some level between that at Benham Falls and that near the City, but there are no records of test holes in this area. Test drilling and pumping near Dillon Falls and Lava Island Falls might prove profitable if water is found at depths of 300 feet or less, because of the reduced length of pipeline required. If such a well field could be developed at Dillon Falls, a 5 mgd supply might be produced at a cost of about $944,500, and if such a supply could be obtained at Lava Island Falls, it would cost about $716,800. A test drilling program at all three locations is estimated to cost about $18,000, or at any single location, about $8,000.

Summary - Well Water Supply. A review and analysis of the best available information on groundwater indicates that the City can develop a satisfactory supplemental water supply from wells. The water would be equal in quality to that obtained from the present source. It appears that water rights can be obtained merely by filing an application in proper form and putting the water to beneficial use, and without the complications of purchasing existing water rights which are attendant to development of any surface water in the area.

The underground water supply in the Bend area is a valuable resource which has not been utilized. Development and use of a well water supply by the City would prove and demonstrate the availability and value of this resource, which could be a stimulus to growth in the area which is contingent upon the availability of additional water.

If the City is interested in the possibility of a well water supply, a preliminary program of test drilling and pumping should be undertaken. The cost of adequate exploratory work is high, but the potential savings are great.

Deep well exploration near the City would cost about $21,000 for a single 1,000-foot hole, or $37,000 for two at different locations.

Shallow well testing at Lava Island Falls, Dillon Falls, and Benham Falls would cost about $8,000 at any single locationor $18,000 at all three sites.

TABLE 24

ESTIMATED COSTS OF SHALLOW WELL DEVELOPMENT

CAPITAL COSTS

2.5 MGD CAPACITY (1966)

Item	Benham Falls	Dillon Falls	Lava Island Falls
Test drilling	$ 6,000	$ 6,000	$ 6,000
Two wells	54,600	69,400	69,400
Pipeline, 16-inch	825,000	612,000	430,000
Chlorination station	12,500	12,500	12,500
Miscellaneous	15,300	15,300	10,000
Construction total	$ 913,400	$715,200	$52[illegible],900
Engineering and contingencies	183,900	146,000	105,400
Total estimated cost, Step 1	$1,097,300	$861,200	$633,300

EXPANSION OF 2.5 MGD PLANT TO 5 MGD CAPACITY (1975)

Item	Benham Falls	Dillon Falls	Lava Island Falls
Two wells	$ 54,600	$ 69,400	$ 69,400
Engineering and contingencies	10,900	13,900	13,900
Total estimated cost, Step 2	$ 65,500	$ 83,300	$ 83,300

TOTAL COST OF 5 MGD SUPPLY FROM SHALLOW WELLS

	Benham Falls	Dillon Falls	Lava Island Falls
	$1,162,800	$944,500	$716,600

Annual Costs

1966	Benham Falls	Dillon Falls	Lava Island Falls
Amortize Step 1 (20 years, 3-1/2%)	$ 73,070	$ 58,130	$ 42,750
Operation	4,500	3,200	2,300
Maintenance	1,300	1,000	700
Power	600	600	500
Total	$ 79,470	$ 62,930	$ 46,250

TABLE 24 (Continued)

Annual Costs (continued)	Benham Falls	Dillon Falls	Lava Island Falls
1975			
Amortize Step 1	$ 73,070	$ 58,130	$ 42,750
Amortize Step 2	4,420	5,620	5,620
Operation	5,000	3,700	2,500
Maintenance	1,500	1,200	800
Power	900	900	700
Total	$ 84,890	$ 69,550	$ 52,370

The expenditure of $21,000 to $37,000 for test drilling could save $100,000 to $300,000 in the construction of an additional 5 mgd supply, if the search for groundwater is successful. The potential savings are the greatest for the deep well system, where the costs of exploration are the highest.

There is always the possibility that an exploratory drilling program would not reveal an adequate acceptable source of water supply, and the City should evaluate the consequences of such a failure against the possible benefits of a success before embarking on an exploratory drilling program.

Based on the best information now available, the cost of well water systems for a supply of 5 mgd is as follows:

1. Deep wells within 2 miles of Bend	$ 502,800
2. Shallow wells:	
a. At Lava Island Falls	$ 716,600
b. At Dillon Falls	$ 944,500
c. At Benham Falls	$1,162,800

Construction of a well water supply lends itself very readily to stage construction, making it possible to defer some capital expenditures for a time without increasing the total cost of the project, which is not possible with expansion of the Tumalo supply.

The principal disadvantages of a well water supply are, as already mentioned, the cost and risk of the exploration program required.

The City has made preliminary contact with Brooks-Scanlon regarding the possibility of acquiring their test hole for development as a City well. If this can be worked out, it may reduce the cost of deep well construction, and would eliminate the risk of a dry hole, since this hole has already been test pumped.

SUMMARY SOURCE OF SUPPLY

VIII. SUMMARY - SOURCE OF SUPPLY

Sources Considered. Investigation of potential sources of water supply to meet future requirements of the Bend municipal water system includes three general categories: (1) expansion of the Tumalo Creek supply; (2) development of supplemental water supply from new surface sources; and (3) development of supplemental water supply from wells. Within each of these categories are specific sources of supply offering possibilities for development which merit consideration by the City.

Tumalo Creek. The present source of supply from Tumalo Creek is excellent. The water is of very good chemical, physical, and bacteriological quality without treatment other than chorination. The water is soft, clear, and cold. There are no problems with taste and odor, and only rare and relatively minor problems with cloudiness or turbidity in the water. The water is delivered to the City by gravity flow and without pumping. Minimum stream flows are ample to meet foreseeable needs of the City.

The principal difficulty in expanding the Tumalo supply is the question of water rights. Rights must be purchased and irrigated land taken out of production to obtain additional water from this source. A second difficulty is the large initial capital investment required for increasing the supply from this source.

New Surface Water Sources. The Deschutes River and Fall Creek offer the best opportunities for development of new surface water sources to supplement the existing supply from Tumalo Creek.

The Deschutes River water would be equal in quality to the Tumalo Creek supply, subject to good operation of the filter plant which would be required The Deschutes water would be slightly warmer than Tumalo water during the summer period of use, but this effect would be minimized at consumers' taps due to the mixing of one part of Deshutes water with two parts or more of Tumalo water. The Deschutes supply involves water rights problems similar to those on Tumalo Creek. The total capital expenditures are less than for the Tumalo supply, and the Deschutes source lends itself to stage construction. Because of the need for pumping and filtration, the costs of operation and maintenance will be higher than for the Tumalo supply. The total annual costs of the Deschutes supply are less than for additional water from Tumalo.

Fall Creek is attractive as a new surface source since acquisition of water rights appears to be less difficult than for either the Tumalo or Deschutes supplies. However, the capital costs are much higher than for any of the alternates given serious consideration, which appears to eliminate it as a possible selection at this time.

Well Water Supply. Without doubt the City of Bend can develop an adequate and satisfactory supplemental water supply from wells. The quality of the water would be equal in all respects to the present supply. There should be no trouble or expense in acquiring groundwater rights in the quantity needed by the City. Wells can be developed at depths of 700 to 1,000 feet within two miles of Bend, at depths of about 100 to 200 feet at a distance of 12 miles from the City, and possibly at intermediate depths in the areas between these locations. Any development of a well supply must be preceded by an adequate program of exploratory drilling and test pumping.

In the Benham Falls-Camp Abbott area, groundwater lies at shallow depths, the cost of exploration is low, and the risk of getting a dry hole is slight. However, the construction cost at this distance from the City is not competitive with alternate schemes of development.

Within two miles of Bend, test holes would need to be 700 to 1,000 feet deep. The prospects for striking groundwater at any selected location are good, but the cost of each test hole is about $21,000, so that one or two dry holes would represent a sizeable financial loss to the City. On the other hand, a successful search for the deep well water at Bend might save the City as much as $370,000 in capital expenditures over the next ten years, and, since the deep well supply can be built in stages, the immediate capital outlay can be substantially reduced

The economics of the shallow well supply at Lava Island Falls is based on finding water at a depth less than 300 feet. Since there are no records of test holes in this area, an accurate estimate of costs at this location cannot be made until exploratory work is completed. In any event, capital costs for the initial construction are greater than for deep wells near the City, and some of the same risks are involved in test drilling, although perhaps to a lesser extent.

Comparison of Supply Sources. In comparing the various sources of supply which appear promising, there are several factors to consider including economics, risks, water rights, and public approval or acceptance.

Table 25 is a cost summary for the various sources of supply. The principal economic consideration is that of total annual costs for amortization, operation, and maintenance From this standpoint the supply sources rank in the following order:

Rank	Supply	Annual Cost 5 mgd
1	Deep wells at Bend	$50,610
2	Shallow wells at Lava Island Falls	52,370
3	Deschutes River, Site 3	58,560
4	Deschutes River, Site 1	61,820
5	Deschutes River, Site 2	65,620
6	Tumalo Creek	66,660

The deep well supply at Bend offers the greatest overall economy, but the range in annual costs for the six sources listed is not great, amounting to a maximum of about 30 percent. A second economic factor is the capital costs and the adaptability of the sources to stage construction. The deep well and Deschutes River supplies can be built in two stages of 2.5 mgd each,which permits a major part of the total capital expenditures required to be deferred until about 1975. The Tumalo Creek and Lava Island Falls projects require relatively long transmission lines which can be built more economically by use of a single pipeline for the 5 mgd capacity. This means larger capital costs for the initial construction. Arranged in order of the immediate capital outlays required for initial construction, the first six alternates are as follows:

Rank	Supply	Capital Costs Step 1
1	Deep wells at Bend	$330,600
2	Deschutes River, Site 3	388,400
3	Deschutes River Site 1	433,400
4	Deschutes River Site 2	474,800
5	Shallow wells at Lava Island Falls	633,500
6	Tumalo Creek	871,700

TABLE 25

COST SUMMARY
SOURCE OF SUPPLY AND TRANSMISSION

Description	Capital Costs			Annual Costs*	
	Step 1 (by 1966)	Step 2 (by 1975)	Total (5 mgd supply)	1966	1975
Deep Well Development	$ 330,600	$172,200	$ 502,800	$ 31,720	$ 50,610
Expansion of Tumalo Creek Supply	871,700	0	871,700	66,660	66,660
Supplemental Supply from Deschutes River					
Site 1	433,400	227,600	661,000	40,080	61,820
Site 2	474,800	227,600	702,400	43,470	65,620
Site 3	388,400	227,600	616,000	36,820	58,560
Shallow Well Development					
At Lava Island Falls	633,500	83,300	716,800	46,250	52,370
At Dillon Falls	861,200	83,300	944,500	62,930	69,550
At Benham Falls	1,097,300	65,500	1,162,800	79,470	84,890
Supplemental Supply from Fall Creek	1,410,200	0	1,410,200	107,890	112,190

*Annual costs include amortization of capital costs (principal and interest), operation, and maintenance (20 years at 3-1/2 percent).

Here the difference is substantial, with a spread of 2.5 to 1 in the size of the inital cash investment required. There is an element of risk, or at least a cost of exploration, involved in the development of the well supplies, as previously discussed. For the surface water sources, water availability can be seen and more readily measured. This situation is reversed on the matter of water rights; that is, the availability and cost of water rights for the surface supplies is not known exactly, but no difficulty or expense is anticipated for water rights from the groundwater sources.

Public approval or acceptance is often difficult to evaluate, but is seems fairly clear in this instance that, ignoring costs for the moment, the public preference for the various sources would be as follows:

Rank	Source of Supply
1	Tumalo Creek
2	Fall Creek
3	Wells
4	Deschutes River

The preference for the Tumalo Creek supply is probably quite strong in the community because of the local pride in this excellent supply and the good experience which has been enjoyed with it. The Fall Creek supply is from an area quite similar to the Tumalo supply and probably would be readily accepted, but unfortunately, the cost of development is quite high.

With proper dissemination of the facts concerning the quality of the well water, it should not be difficult to secure public approval for development of a well supply. The low annual cost of the well supply and the low cost of the initial phase of construction should aid in gaining public support for this kind of project.

It may be difficult to get public support for a water supply development on the Deschutes River, principally because of the poor experience in the 1920's, and despite the advances in water treatment which have been made since that time which should eliminate the old difficulties.

Source of Supply Recommendation. This report presents several good alternates to the City for consideration in the development of additional water supply. Actually, Tumalo Creek, the Deschutes River, deep wells at Bend, or shallow wells at Lava Island Falls could be selected, depending upon the relative importance assigned to various factors, as the differences are not great. Cost and public preference appear to be two of the most important considerations.

If the source of supply is to be selected principally on the basis of cost, the choice is clearly deep wells at Bend. However, this choice is dependent upon the successful completion of an exploratory drilling program before well development is undertaken. If a deep well water supply is located equal to that already proved near Bend, deep well development will be lowest in capital cost and total annual cost, and will require the least immediate capital outlay. The chances are good that a satisfactory site for deep well development can be found, but the chances are not 100 percent, and some element of risk is involved. If the City is willing and in a position to spend $20, 000 to $40, 000 to obtain the necessary preliminary information on a deep well supply, by conducting a test drilling program, even if the results prove to be negative, then this is the course to follow, as the potential savings are great. On the other hand, if the possibility of failure is considered an excessive or unnecessary risk, then an alternate source of supply should be selected.

The shallow well development at Lava Island Falls is attractive from an annual cost standpoint. However, the initial capital expenditure is high and, again, test drilling is a necessary prelude to actual supply development. Test drilling costs are less than for deep exploration at Bend, but the potential savings are not as great. We favor deep wells at Bend over this alternate.

Supplemental supply from the Deschutes River is third ranking from the cost standpoint. The acquisition of water rights is a difficult problem, as is the anticipated reluctance of the public to accept this source as being of satisfactory quality.

Expansion of the Tumalo Creek supply ranks next from a cost standpoint. In the past, there has been a strong public preference for the Tumalo supply, and an apparent willingness to pay a premium, if necessary, to obtain water from this source. The principal problem is the purchase of water rights.

Our evaluation of all the known factors affecting the various alternate sources of supply leads us to recommend the following procedure:

1. Investigate the question of water rights acquisition for expansion of the Tumalo Creek supply.

2. If water rights are available for additional supply from Tumalo Creek, take the necessary steps to finance the construction of another 5 mgd of supply from this source.

3. If water rights are not available for expansion of the Tumalo supply, then proceed to finance a deep well test drilling program.

4. If the deep well tests are successful make arrangements for financing the initial phase of deep well construction.

5. If the deep well tests are not successful, investigate the acquisition of water rights for the Deschutes River supply.

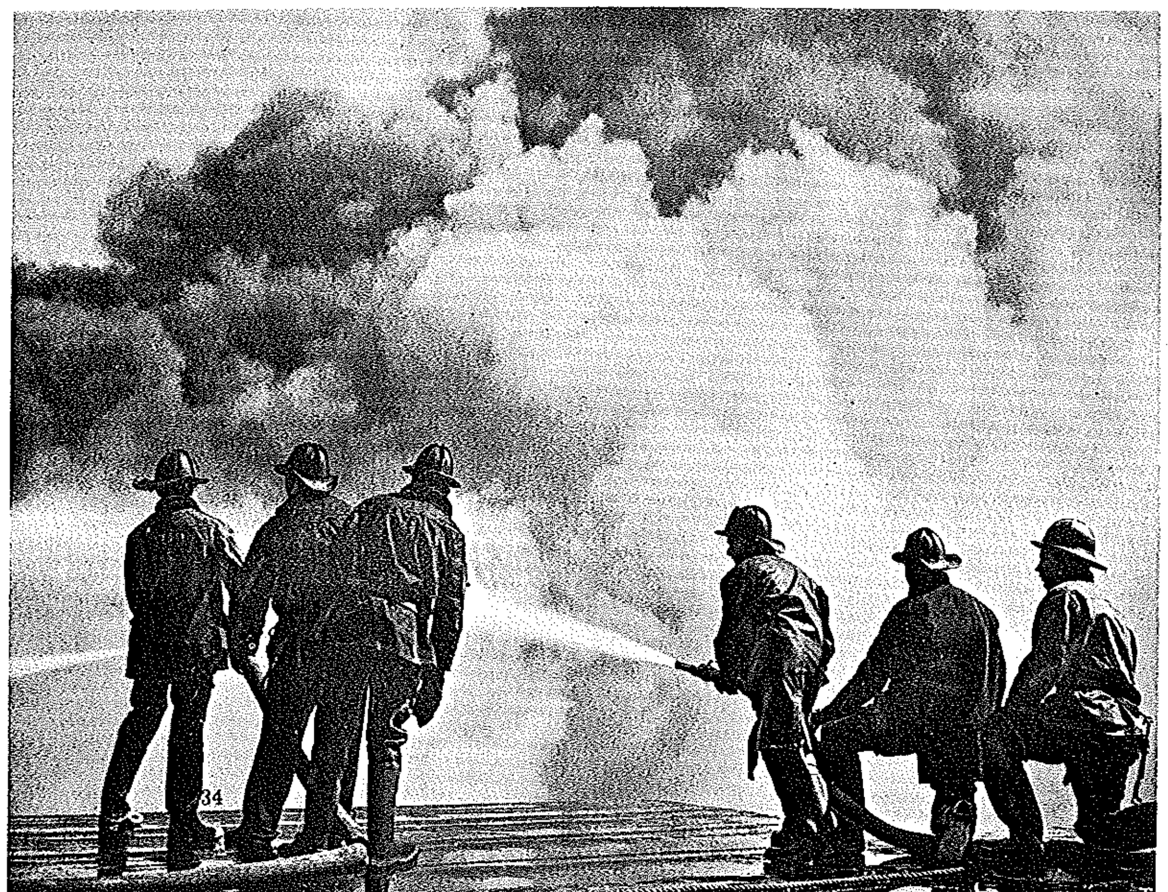
6. If water rights can be obtained for the Deschutes supply, proceed with financing and construction of the first phase of this development.

7. The fourth alternate is shallow well exploration at Lava Island Falls, followed by construction if the results of test drilling are satisfactory.

This order of preference should be reviewed both by the City Commission and by the public through presentation and thorough discussion of the information contained in this report. Although our recommendation is for expansion of the Tumalo Creek supply, deep wells at Bend, Deschutes River, and shallow wells at Lava Island Falls, in that order, any of the four is a good source which might properly be developed if they are more in accord with the wishes of the community.

It may be worthwhile to investigate further the possibility of acquiring the Brooks-Scanlon deep well for the City If this can be done, it would eliminate some of the risk and might reduce the cost of deep well development.

DISTRIBUTION, STORAGE, AND FIRE PROTECTION



IX. DISTRIBUTION, STORAGE, AND FIRE PROTECTION

Existing System. The existing distribution system for the City of Bend now provides water service at four different pressure levels. All of the central business district and a major part of the residential area are served from the first level by gravity flow from Overturf, Awbrey, and Pilot Butte Reservoirs. The location and extent of the Central District are shown on Figure 19. The capacities and elevations of the storage reservoirs are given in Table 26, and the relative elevations of reservoirs and pressure districts are shown on Figure 20. There is a total of 9.5 mg of storage on the first level system, which serves all areas lying below Elevation 3660 feet. Overturf Reservoir is connected to the first pressure level by an 18-inch pipeline through 16-inch and 10-inch pressure reducing valves located at 15th and Cumberland Streets. Awbrey Butte Reservoir is tied to the first level by a 24-inch feeder main and Pilot Butte Reservoir is connected to the gravity system by a 12-inch line.

The second pressure level extends from Elevation 3660 to 3760. The Kenwood, Fifth Street, Third Street, and Pilot Butte (or 12th and Lafayette) Districts all are within this second pressure level, which is the first pumping lift above the main gravity system. These four districts are presently widely separated, and each is served by its own pumping station. All four stations take suction from the gravity system and pump water to the second level. The Pilot Butte Station suction connection is located very near the outlet from Pilot Butte Reservoir, while the other stations withdraw their supply from feeder mains. The number and capacity of pumps in each station is given in Table 26. The Fifth Street system has 0.1 mg of storage in the Bend View tank, and the Third Street system has 0.035 mg storage in the Great Northern elevated tank. The Kenwood and Pilot Butte Districts are on direct pump pressure without storage. The Third Street and Pilot Butte stations each are equipped with one variable speed pump. All other pumps are constant speed. Overturf Reservoir is at an elevation which would serve the second level by direct gravity flow (without pressure reduction) if cross-town, high-pressure transmission lines were built to those areas. The high-pressure lines from Overturf to Awbrey Butte Reservoir and from Overturf to College Avenue Pump Station could be tapped to serve by gravity the Kenwood District and most of the Fifth Street District. As will be discussed later in more detail, it is cheaper at present to pump to the second level for the Third Street and Pilot Butte Districts than to build the necessary cross-town transmission line, although the economics may change in the future as water use increases or as the area served by these districts is expanded.

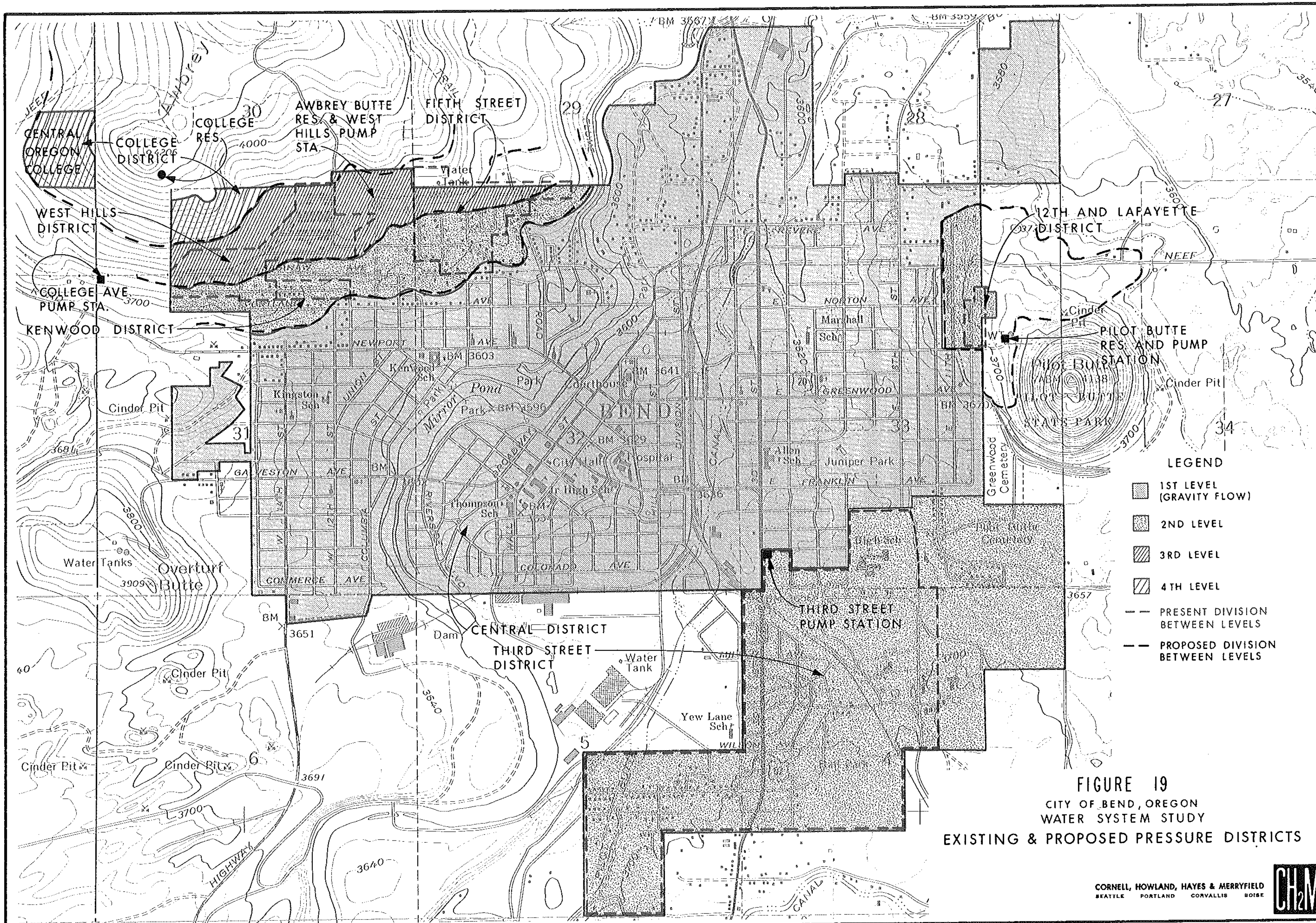


FIGURE 19
CITY OF BEND, OREGON
WATER SYSTEM STUDY
EXISTING & PROPOSED PRESSURE DISTRICTS

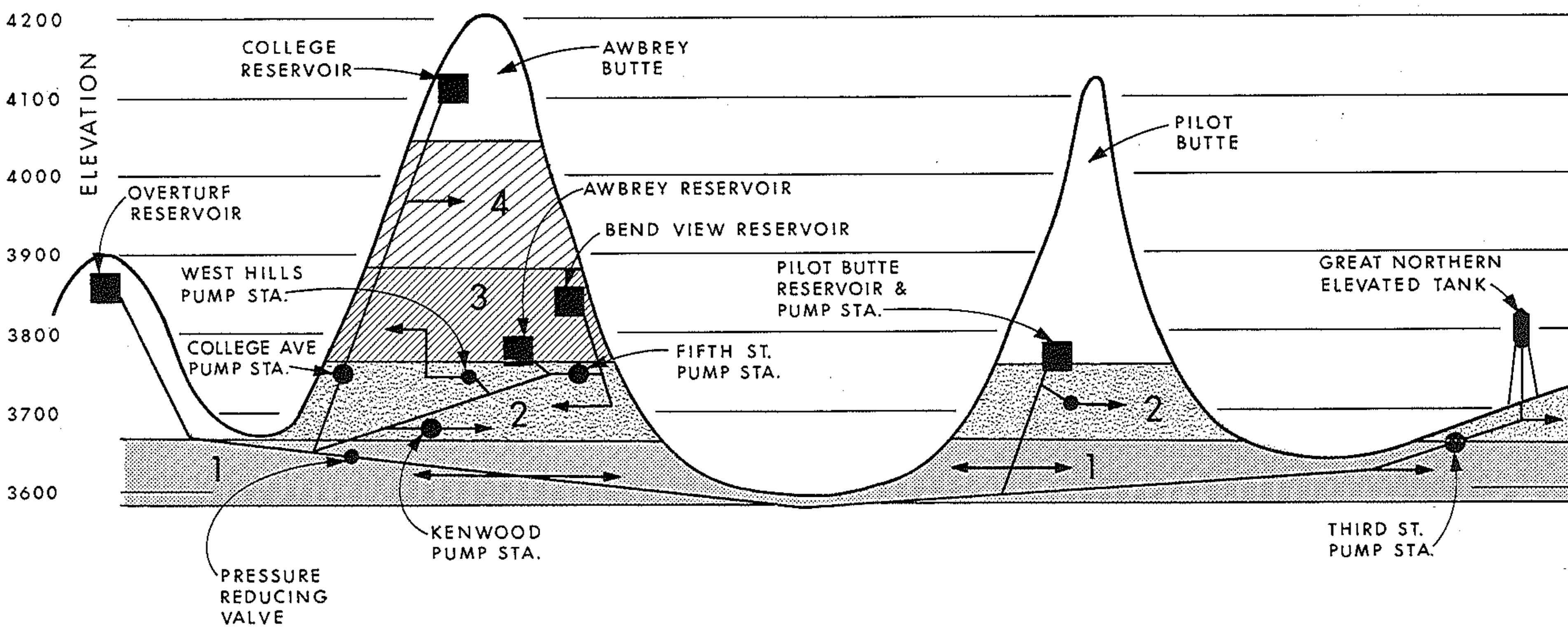


FIGURE 20
CITY OF BEND, OREGON
WATER SYSTEM STUDY

PANORAMIC DIAGRAM
SHOWING RELATIVE ELEVATIONS OF
RESERVOIRS AND PRESSURE DISTRICTS

CORNELL, HOWLAND, HAYES & MERRYFIELD
SEATTLE PORTLAND CORVALLIS BOISE

TABLE 26

EXISTING RESERVOIRS AND PUMPING STATIONS

Reservoir	Capacity, mg	Elevations		Serves
		Bottom	Overflow	Pressure Level
Overturf	3.0	3843.	3871.	1
Awbrey Butte	5.0	3775.	3795.	1
Pilot Butte	1.5	3750.	3782.	1
Great Northern	0.1	----	3814.	2
Bend View	0.035	3825.	3841.	2
College	0.5	4100.	4124.	4

Pumping Station	Pump Capacities, gpm			Serves
	No. 1	No. 2	No. 3	Pressure Level
West Hills	100	250	500	3
E. Third & Clay	1,200 (v.s.)	2,500	---	2
W. Fifth & Trenton	260	275	---	2
Kenwood	100	---	---	2
E. 12th & Lafayette	50	---	---	2
Pilot Butte	200 (v.s.)	150	1,350	2
Parallel & Brosterhouse Road	75	---	---	-
College Avenue	50	1,000	1,000	4

Pressure Level	Elevations, Feet
1	Below 3660
2	3660 to 3760
3	3760 to 3880
4	3880 to 4040

(v.s.) - variable speed pump

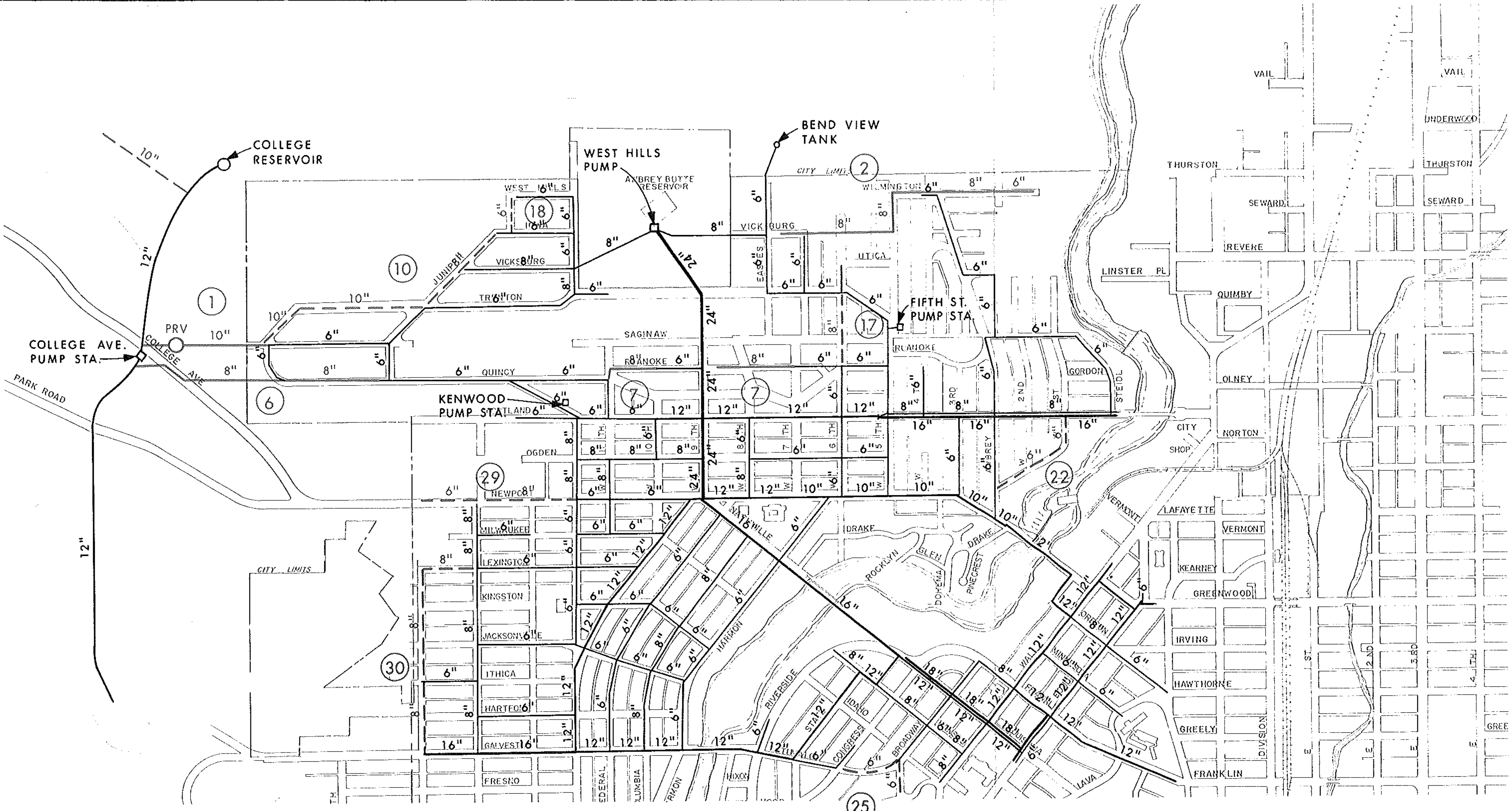
The third pressure level extends from Elevation 3760 to 3880, and presently includes one district, the West Hills District, on Awbrey Butte. The West Hills District is served by a pumping station which takes suction from the outlet pipeline of Awbrey Butte Reservoir.

The fourth pressure level serves Central Oregon College through College Avenue Pumping Station and the 0.5 mg College Reservoir. The fourth level includes ground Elevations 3880 to 4040. The pumps are supplied by a 12-inch high-pressure line from Overturf Reservoir to College Avenue. The pumps discharge to the College through a 10-inch line and to the College Reservoir through a 12-inch pipeline.

Figure 21 is a map of the water distribution system giving the location and size of water mains in the City.

The present practice is to install cement-lined cast iron rubber-ring joint pipe in all new mains, and most of the existing lines are cast iron. In general, the existing pipelines are in good condition. The soil is not aggressive, and the water is not particularly corrosive in Bend, so that the life expectancy of buried pipelines is good. This is confirmed by observation of existing lines which have been excavated at various times for one reason or another and found to be in good condition. There are still some small diameter steel lines which need to be replaced.

Hydraulic Analysis of Water Distribution System. The hydraulic performance of the existing distribution system can be determined directly by pressure surveys and hydrant-flow tests. The hydraulic performance of the system as expanded to meet anticipated future conditions can be determined by hydraulic computations. A good method of computation is that of balancing heads (or pressures) by correcting assumed flows. This method is not difficult, but it involves performance of a long series of successive mathematical approximations, and the number of calculations required is such that several days or weeks of longhand computation would be required to analyze the Bend water system. Fortunately, this type of computation is readily adaptable to solution by electronic computer, and the computer at Oregon State University was used in making this study. Certain assumptions and simplifications must be made in the computations, so a preliminary computer run was made to check the validity of these assumptions and simplifications. This was done by analysing the existing system under present flow conditions and comparing the computed pressures with actual measured pressures at the same flow rate. Pipelines smaller than 6 inches in diameter are not included in the distribution system grid used in the analysis, but the effect of lines smaller than 6 inches is taken into account indirectly in the overall friction factor used in the flow analysis. Flow records during peak demand periods indicate that the flows from Overturf, Awbry,



LEGEND

12" — EXISTING MAINS, PIPE DIAMETER IN INCHES

8" — PROPOSED MAINS, PRIORITY GROUP I

8" - - - PROPOSED MAINS, PRIORITY GROUP II

(1) PRIORITY NUMBER

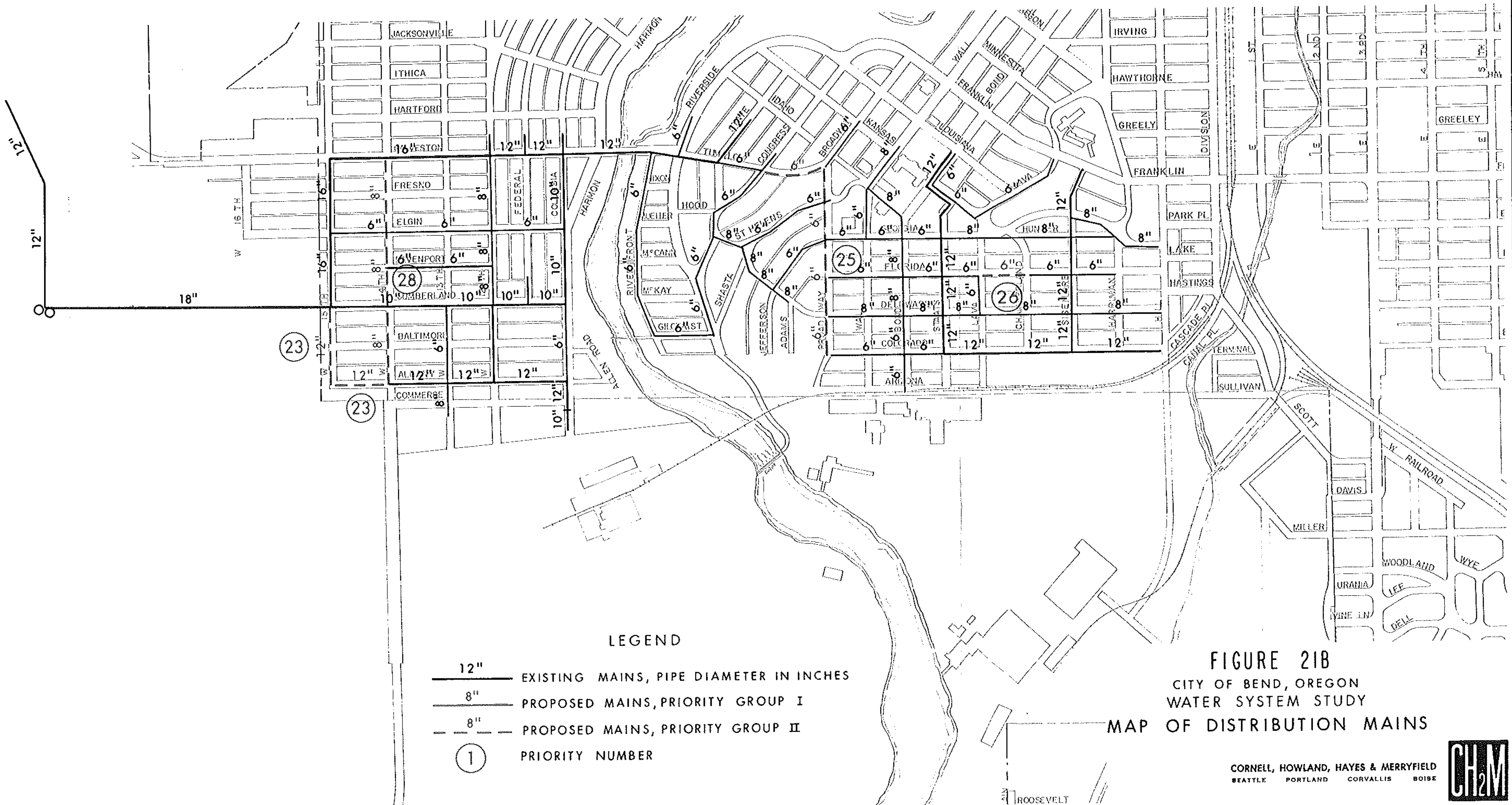
FIGURE 21A

CITY OF BEND, OREGON
WATER SYSTEM STUDY

MAP OF DISTRIBUTION MAINS

CORNELL, HOWLAND, HAYES & MERRYFIELD
SEATTLE PORTLAND CORVALLIS BOISE

CH2M



LEGEND

12" — EXISTING MAINS, PIPE DIAMETER IN INCHES

8" — PROPOSED MAINS, PRIORITY GROUP I

8" — PROPOSED MAINS, PRIORITY GROUP II

(1) PRIORITY NUMBER

FIGURE 21B

CITY OF BEND, OREGON

WATER SYSTEM STUDY

MAP OF DISTRIBUTION MAINS

CORNELL, HOWLAND, HAYES & MERRYFIELD

SEATTLE PORTLAND CORVALLIS BOISE

CH2M

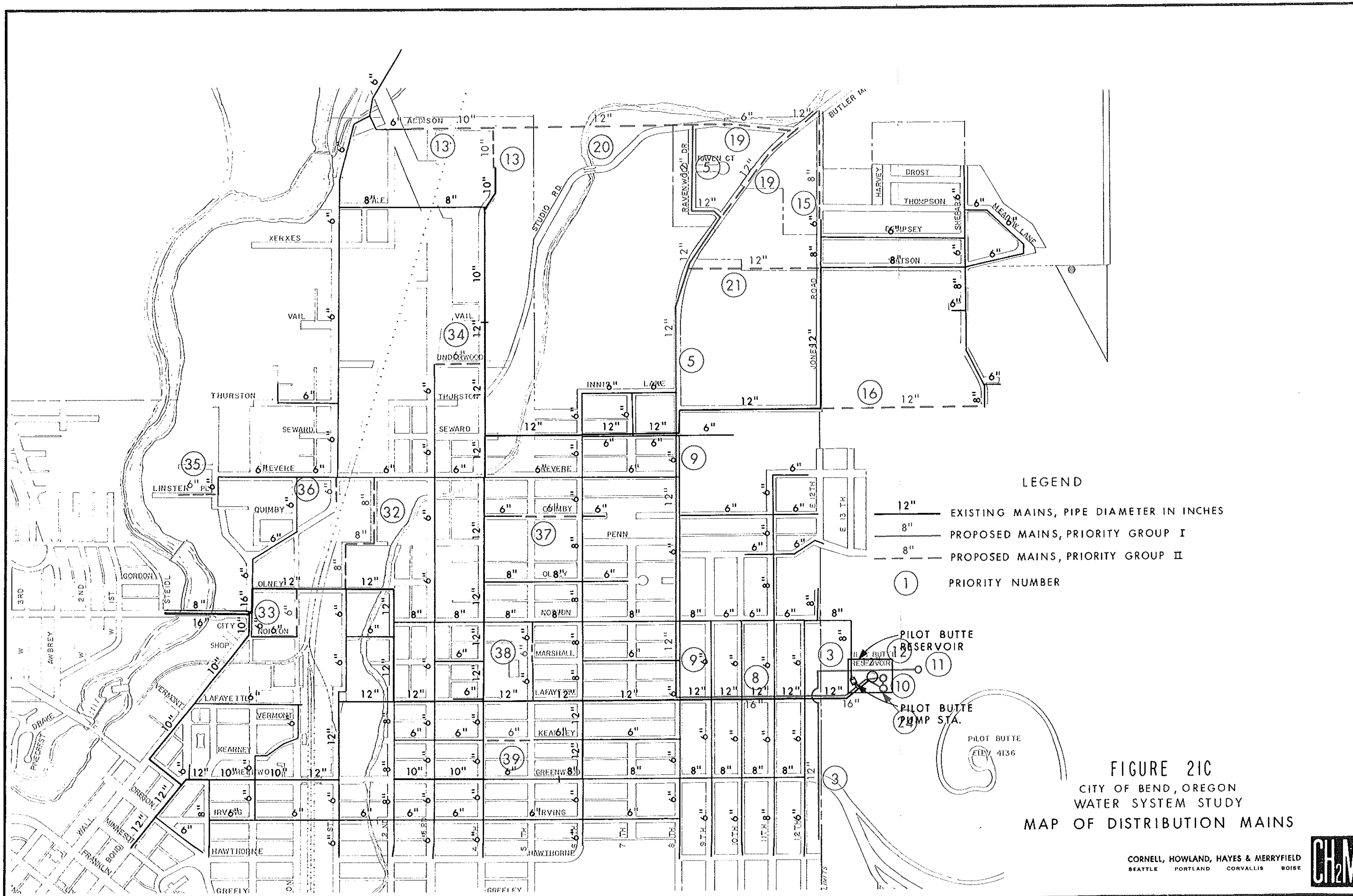


FIGURE 21C
CITY OF BEND, OREGON
WATER SYSTEM STUDY
MAP OF DISTRIBUTION MAINS

CORNELL, HOWLAND, HAYES & MERRYFIELD
SEATTLE PORTLAND CORVALLIS BOISE
CH2M

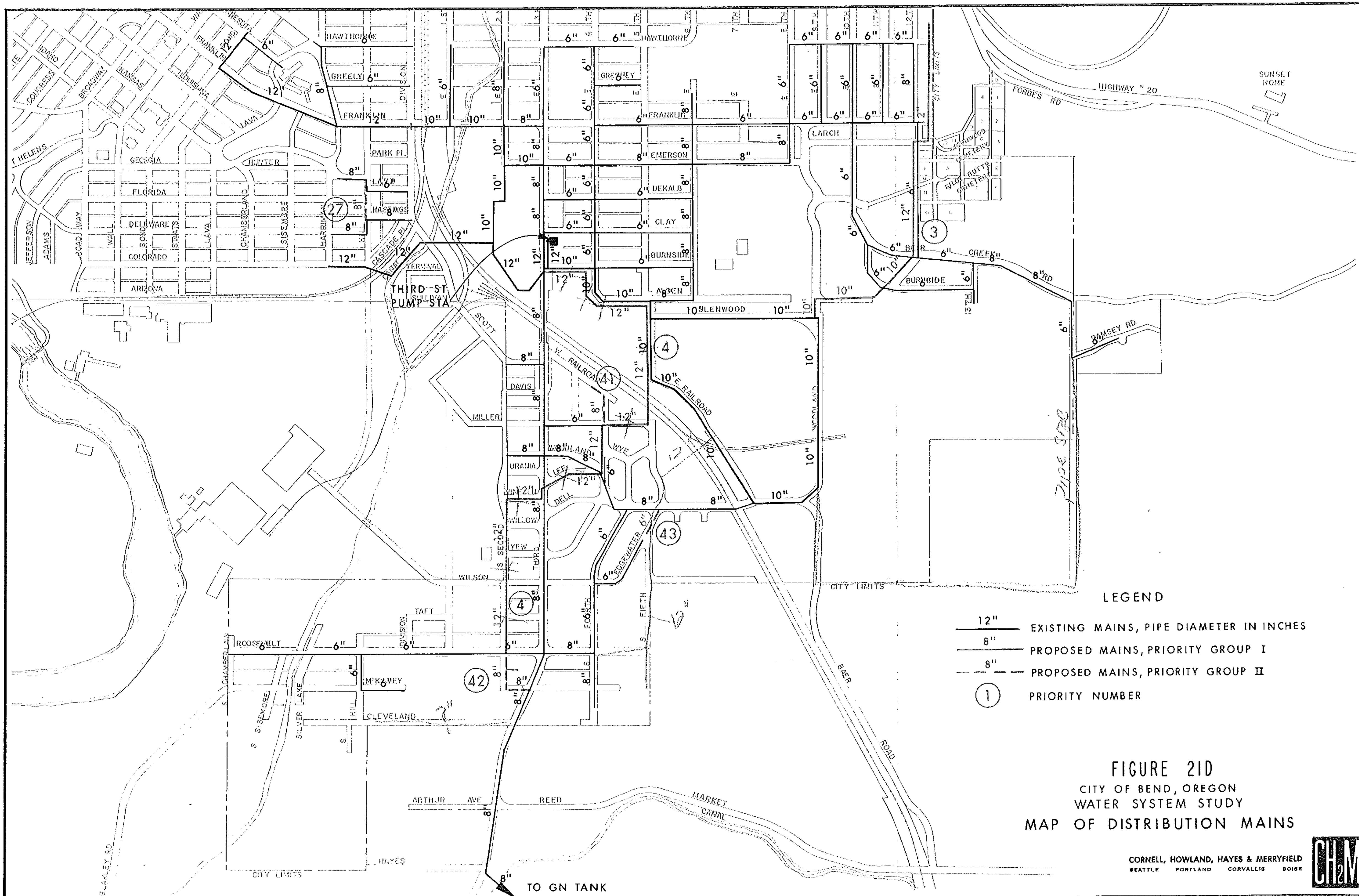


FIGURE 21D
CITY OF BEND, OREGON
WATER SYSTEM STUDY
MAP OF DISTRIBUTION MAINS

CORNELL, HOWLAND, HAYES & MERRYFIELD
SEATTLE PORTLAND CORVALLIS BOISE
CH2M

and Pilot Butte Reservoirs are approximately proportional to the storage capacity at these points of supply, and system input was so proportioned for the analyses. The area served by the Bend system was divided into a number of areas of similar usage and the water demand of each of these areas was assumed to be withdrawn at a single point. A demand rate per thousand square feet of land area was applied to each section as shown in Table 27 and the usage adjusted to conform to the present and anticipated future occupancy of the section. Full occupancy was taken at 20 people per acre.

TABLE 27

WATER DEMANDS AT FULL OCCUPANCY

Type of Use	GPD per 1,000 Square Feet	
	At Peak Hour	On Maximum Day
Commercial and Industrial	115	73
Schools and Parks	350	233
Residential	550	366

The first computer run was made for the present peak hourly flow of 16.6 mgd to be delivered by the existing water system. The results were compared to pressures recorded at nine points on the distribution system at 11:45 a.m. on 21 July 1964, when the actual flow was 16.7 mgd.

As shown in Table 28, the computed results from Run No. 1 are in excellent agreement with the actual measured pressures at the same points. This indicates that the assumed proportioning of flow from the reservoirs, the demand factors, and pipeline resistances are essentially correct, and may be used as a guide in subsequent calculations. By comparing the theoretical flow analysis and the measured pressures, the value of "C" in the Hazen-Williams formula for pipe flow was found to be approximately 100. It should be pointed out that the value of "C" is representative of the system as a whole and would not necessarily be correct for any individual pipeline. Figure 22 shows water pressures throughout the City at present peak hourly consumption of 16.6 mgd. The pressures are satisfactory.

For the present population of Bend, the required fire flow in the downtown business district is 3,500 gpm, or 5 mgd, at a residual pressure of 20 psi, and the present maximum daily demand is 11 mgd. If a fire in the business district occurs at the time of maximum daily demand, a total of 16 mgd must be supplied. This is slightly less than the present peak hourly demand of 16.6 mgd. It is evident from the results of

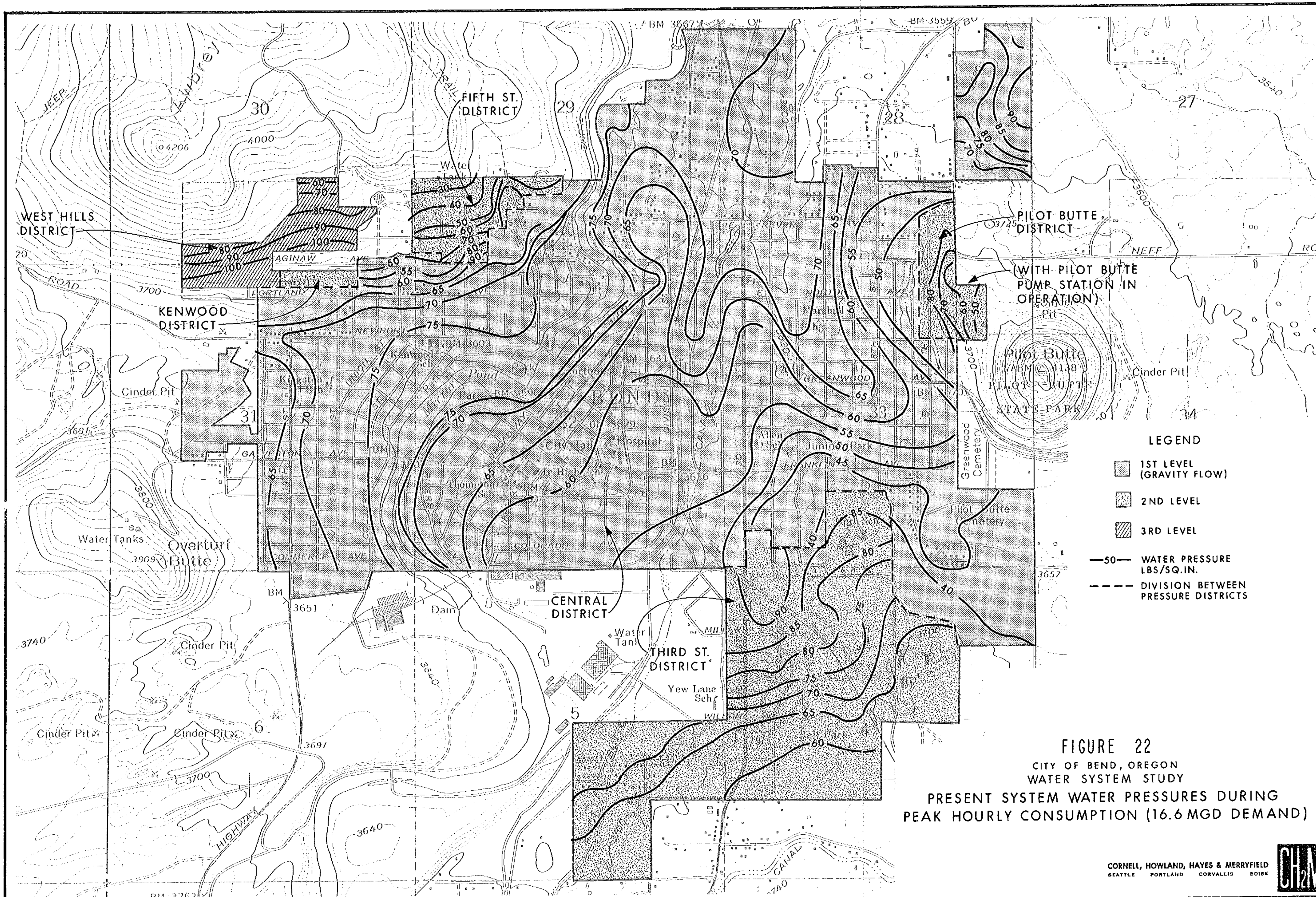


FIGURE 22

CITY OF BEND, OREGON

WATER SYSTEM STUDY

PRESENT SYSTEM WATER PRESSURES DURING PEAK HOURLY CONSUMPTION (16.6 MGD DEMAND)

TABLE 28

MEASURED AND COMPUTED WATER PRESSURES
ON DISTRIBUTION SYSTEM
UNDER VARIOUS FLOW CONDITIONS

Location	Ground Elevation (ft.)	Static Press. (psi)	Present Peak Hour Press.: Measured Press. 7/21/64 (psi)	Present Peak Hour Press.: Resid. Press. Run # 1 (psi)	Resid. Press. Run # 2 (psi)	Resid. Press. Run # 3 (psi)	Resid. Press. Run # 4 (psi)
1. Valve House--15th & Cumberland	3631	70	70	70	70	70	69
2. West 9th & Portland	3639	67	70	64	64	65	63
3. West 5th St. Pump Station	3657	59	49	51	42	51	45
4. City Shop Hydrant	3593	87	81	78	75	78	74
5. City Shop	3618	76	67	67	64	67	63
6. East 4th St. and Marshal	3627	72	60	60	56	59	55
7. Jones Rd. & Watson Drive	3584	91	82	85	72	72	74
8. East 3rd St. Pump Station	3652	61	44	44	37	51	39
9. Pilot Butte Reservoir	3748	14	10	--	--	--	--

Run # 1 1964 peak hourly demand = 16.6 mgd
Run # 2 1990 peak hourly demand = 25.2 mgd
Run # 3 1964 maximum daily demand plus 1,500 gpm industrial fire = 13.16 mgd
Run # 4 1990 maximum daily demand plus 4,000 gpm fire in business district = 22.56 mgd
Runs # 2 and # 4, for future conditions, assume the following:

1. additional 3 mg storage at Pilot Butte.
2. existing 12-inch line from Pilot Butte Reservoir west to 8th and Lafayette to be paralleled with new 16-inch line.
3. existing 6-inch line from 8th and Lafayette north to 8th and Seward to be replaced or paralleled with 12-inch line.

Run No. 1 that the water supply for fire fighting in the business district is adequate for present needs.

Fire flow requirements in residential and light industrial areas are 1,000 and 1,500 gpm, respectively. It appears that the most severe demand on the present water distribution system might be caused by a fire near the north City limits. Computer Run No. 3 was made with a 1,500 gpm (2.16 mgd) fire demand at a trailer factory in this area on a day of present maximum daily demand, or a total flow requirement of 13.16 mgd. Run No. 3 showed that the mains to this area would supply this demand at a residual pressure of 66 psi, which is more than adequate.

Runs No. 1 and No. 3 demonstrate that the present distribution system is strong and well balanced, and presently needs additions only to serve new areas, or to remedy a few localized problems, such as elimination of dead-end lines.

In considering the possible effects of placing additional loads on the water system in the future, an examination of the data from Run No. 1 and a look at Figure 22 are very helpful. The lowest pressures are in the east part of town, and it is evident that the best and cheapest way to increase the total capacity of the system is to provide additional storage on Pilot Butte and to increase the feeder main capacity to and from this storage site. Some more main capacity to the northeast from Pilot Butte is also required. Runs No. 2 and No. 4 were made for future (year 1990) loads on the system. Two main feeder lines and 3 mg of storage at Pilot Butte were added to the existing gravity system for these trials. The existing 12-inch line from Pilot Butte Reservoir to Eighth and Lafayette was paralleled with a new 16-inch line (the 2 lines are equivalent to a single 18-inch line), and the existing 6-inch line from Eighth and Lafayette to Eighth and Seward was replaced with a new 12-inch line.

Computer Run No. 2 was made for a future peak hourly demand of 25.2 mgd. The results of this run are given by Table 27 and Figure 23. With the addition of the pipelines and more storage on Pilot Butte, as described above, the gravity distribution system will handle peak hourly loads up to 25.2 mgd at about the same residual pressures as at present.

Computer Run No. 4 was made for the future maximum daily demand plus a 4,000 gpm fire in the business district, or a total flow of 22.56 mgd. From the results given in Table 27, it is seen that system pressures are are slightly lower under these conditions than at future peak hourly demands, but not significantly lower, and the expanded system will satisfactorily meet this future demand.

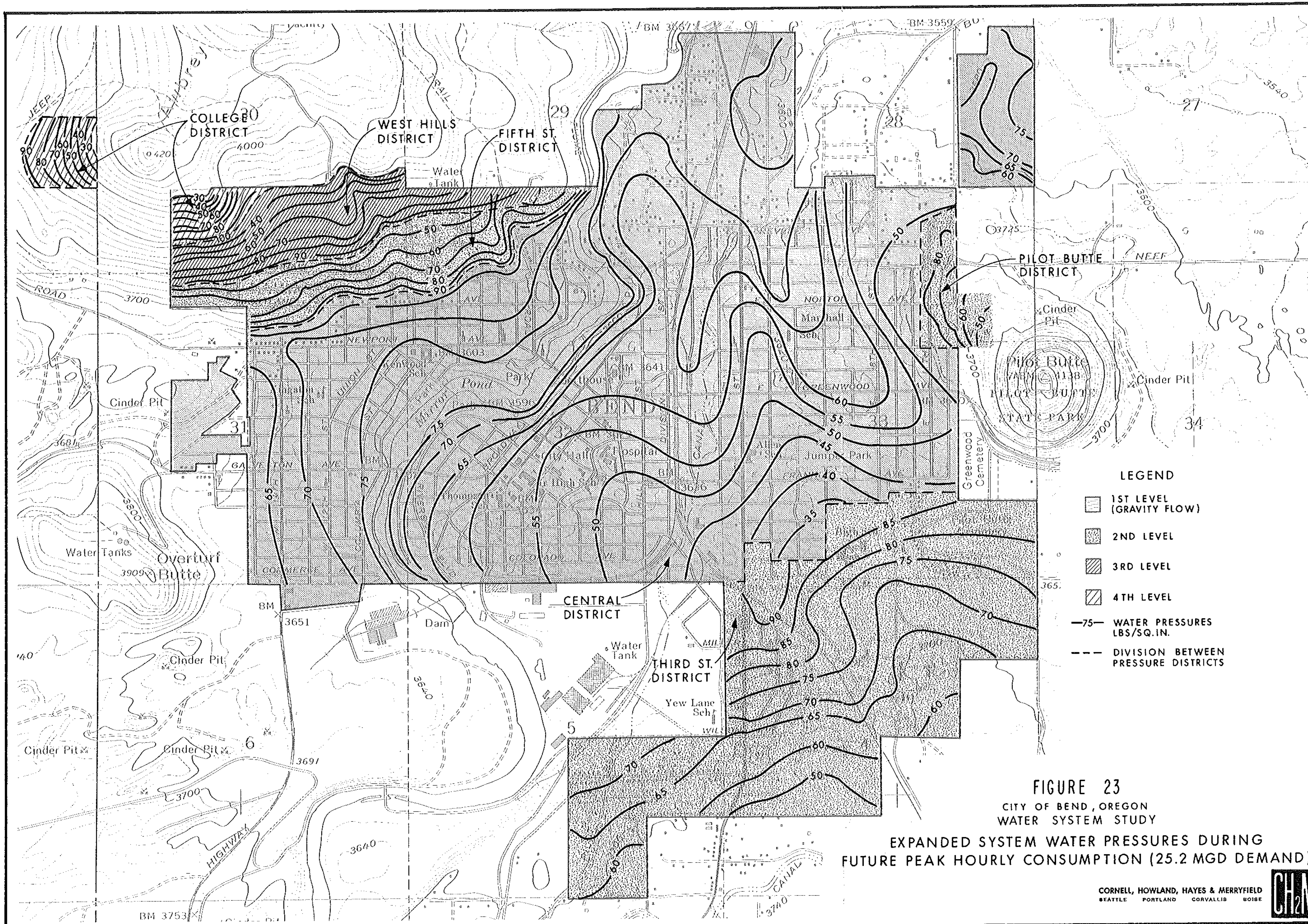


FIGURE 23

CITY OF BEND, OREGON
WATER SYSTEM STUDY

EXPANDED SYSTEM WATER PRESSURES DURING FUTURE PEAK HOURLY CONSUMPTION (25.2 MGD DEMAND)

Reservoir Storage Requirements. Distribution system storage is generally considered adequate if it provides sufficient storage for fire protection, for temporary breakdowns in the distribution system, and for water during peak demand periods. The present fire storage must supply 3,500 gpm for a duration of 10 hours, or 2.1 mg. If a breakdown occurred in one of the transmission mains during maximum daily flow conditions and required approximately 6 hours to repair, the storage required to meet this emergency would amount to 1.4 mg.

STORAGE REQUIREMENTS

	Required Storage, mg	
	Present	1990
Fire	2.1	2.4
Emergency	1.4	1.4
Peaking	5.5	8.4
Total	9.0	12.2

Peaking storage requirements are approximately one-half of the average demand for the maximum day, or equal to the area under the demand curve shown on Figure 5. This presently amounts to 5.5 mg and should reach 8.4 mg by 1990. Summation of the present individual storage requirements total 9 mg as compared to an actual present storage capacity of 9.5 mg which will be increased to 10 mg with completion of the 0.5 mg College Reservoir. Future fire storage necessary for a population of 16,300 must provide 4,000 gpm for 10 hours or 2.4 mg. By 1990, the two existing transmission lines will be paralleled with a third line or supplemented by another source, or both. However, it is logical to continue to provide at least 1.4 mg of storage to permit emergency repairs to the transmission lines or main feeder lines in the distribution system. The minimum storage required in 1990 to meet these needs totals 12.2 mg as indicated above, which requires an addition of not less than 2.2 mg of storage.

As already discussed briefly, there is considerable advantage in locating additional storage on the east side of the City. This position permits two-directional feed to the heart of the City at peak demand periods and thus reduces the size and cost of mains required to carry future flows as compared to placing the additional storage west of the Central District. There is a further advantage in adding storage at Pilot Butte in that considerable new housing development is in this direction, and it appears that building in this area may continue. We recommend that an additional 2 mg of storage on the first level system be built at Pilot Butte in two stages, one mg being added in 1970 and another one mg being constructed in 1980. Also, in about 1970, one mg of storage should be provided at Pilot Butte at a higher elevation to serve the second pressure levels in the Pilot Butte and Third Street Districts, as will be further discussed later in this report.

Fire Hydrants. The fire hydrant coverage in Bend is presently about one per 115,000 square feet of built-up area in the mercantile district, and about one hydrant per 250,000 square feet of built-up area in residential neighborhoods. The hydrant spacing gives good fire protection, and is similar to that provided in many other cities. However, the spacing is greater than that recommended by the National Board of Fire Underwriters, and deficiency points will be assessed in rating the system for fire insurance purposes. In 1950, the Oregon Insurance Rating Bureau stated in their report to the City that a reduction of 197 deficiency points could be made if hydrant spacing complied with the standard. Figure 24 shows fire hydrant locations in the City.

Expanding and Improving the Distribution System. The condition of the existing water distribution system is generally good, but there are a number of needs which require attention if the system is to keep pace with the growing demands which are being placed upon it. These needs include:

1. Planning of pressure zones.
2. Strengthening of the main grid system to meet future peak hourly demands.
3. Extension of the main grid system to newly developed areas.
4. Adequate storage at all pressure levels.
5. Correction of localized fire flow deficiencies and elimination of dead-end lines.
6. Replacement of undersized (principally 4-inch and smaller) mains and old steel lines.
7. Installation of additional fire hydrants.

Planning of Pressure Zones. Figure 19 is a map showing existing and proposed pressure districts within the area presently served by the City water system. Figure 25 is a similar map showing how these pressure districts should be expanded logically to serve new areas. It shows that large areas northeast and east of the City lie below Elevation 3660 and can be served by gravity flow from the first level system. Some areas southwest of town, along the Deschutes River, can also be served from the first level.

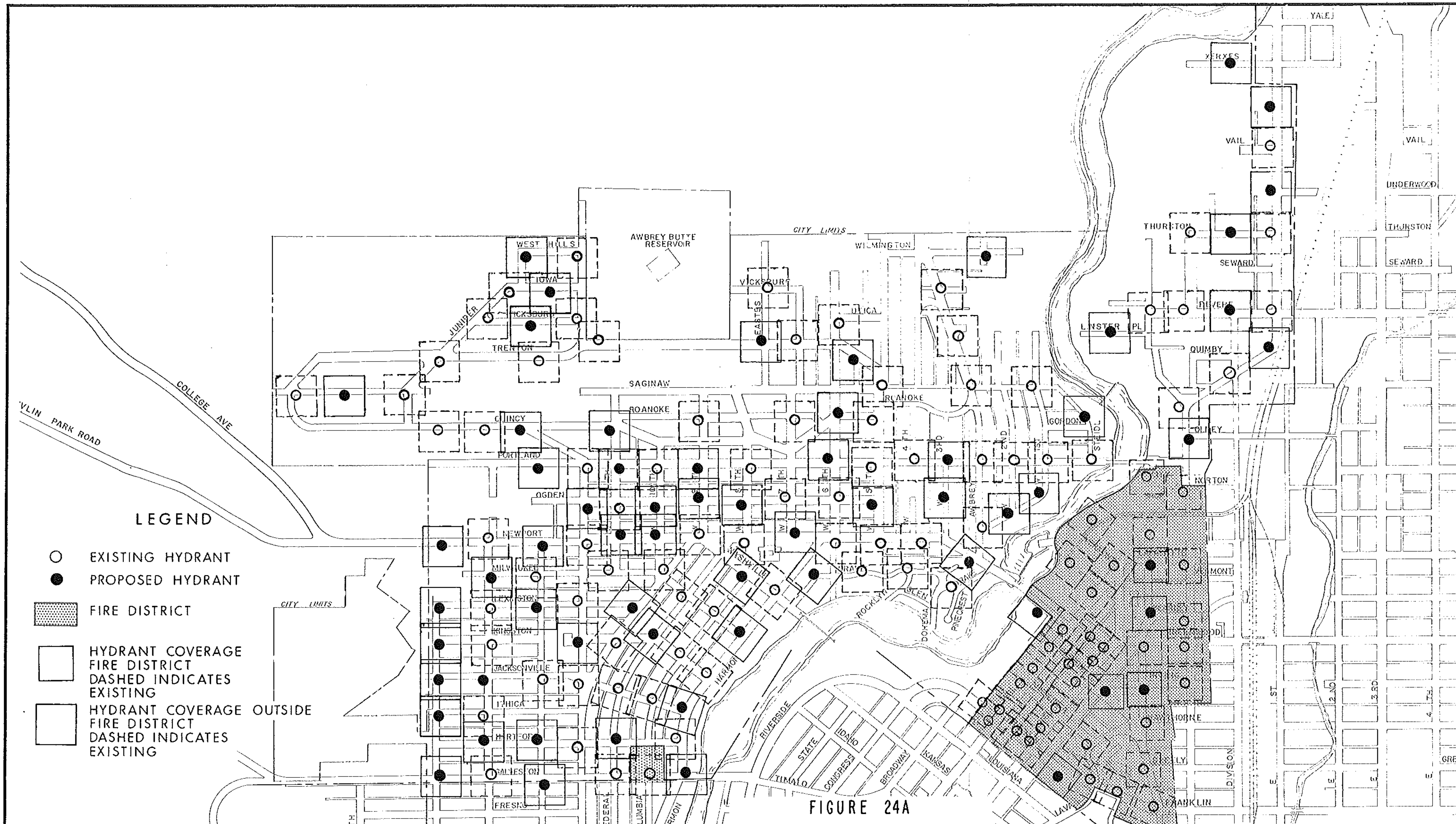


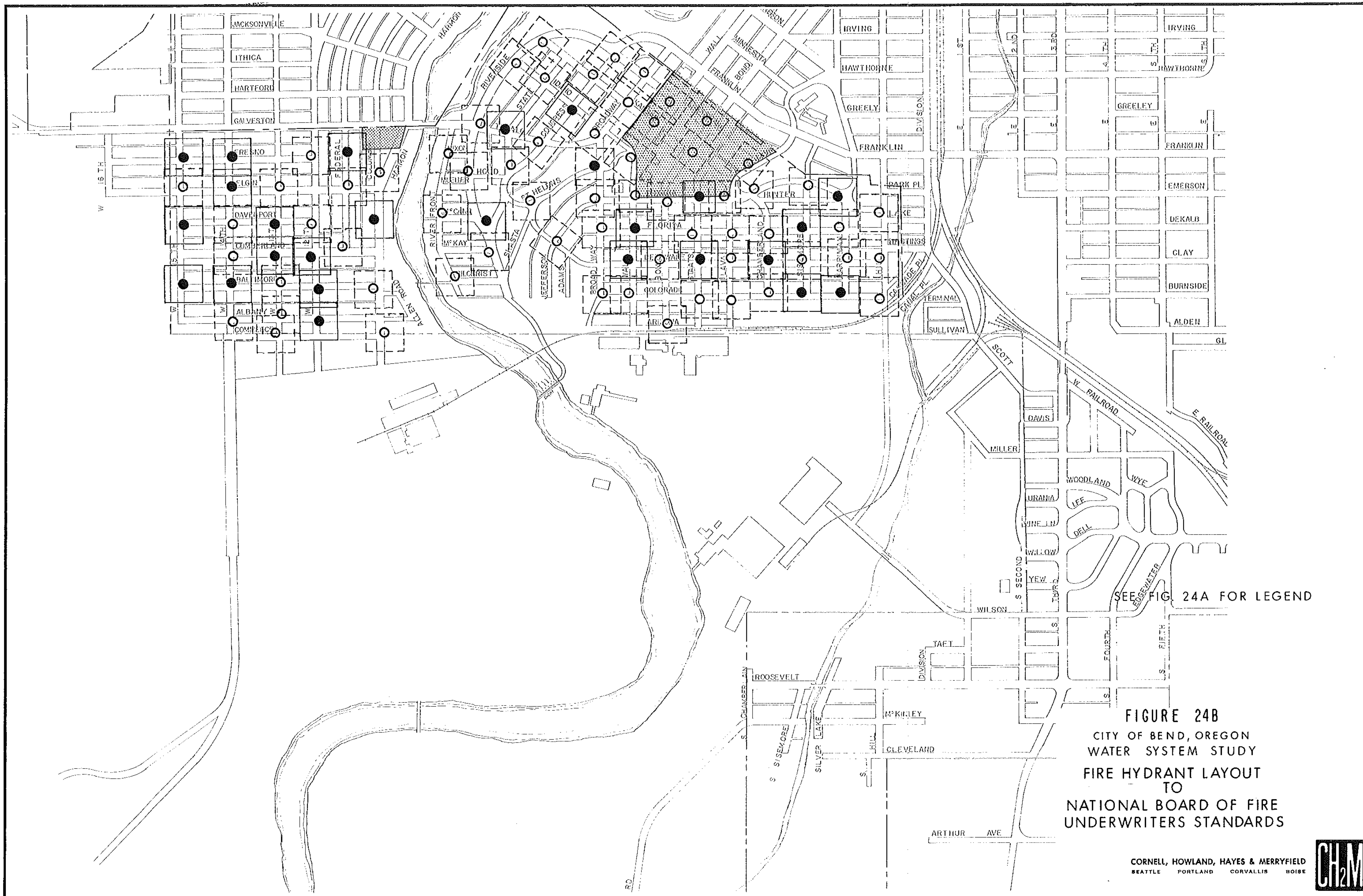
FIGURE 24A

CITY OF BEND, OREGON
WATER SYSTEM STUDY

FIRE HYDRANT LAYOUT
TO
NATIONAL BOARD OF FIRE
UNDERWRITERS STANDARDS

CORNELL, HOWLAND, HAYES & MERRYFIELD
SEATTLE PORTLAND CORVALLIS BOISE

CH2M



SEE FIG. 24A FOR LEGEND

FIGURE 24B

CITY OF BEND, OREGON
WATER SYSTEM STUDY

FIRE HYDRANT LAYOUT
TO
NATIONAL BOARD OF FIRE
UNDERWRITERS STANDARDS

CORNELL, HOWLAND, HAYES & MERRYFIELD
SEATTLE PORTLAND CORVALLIS BOISE

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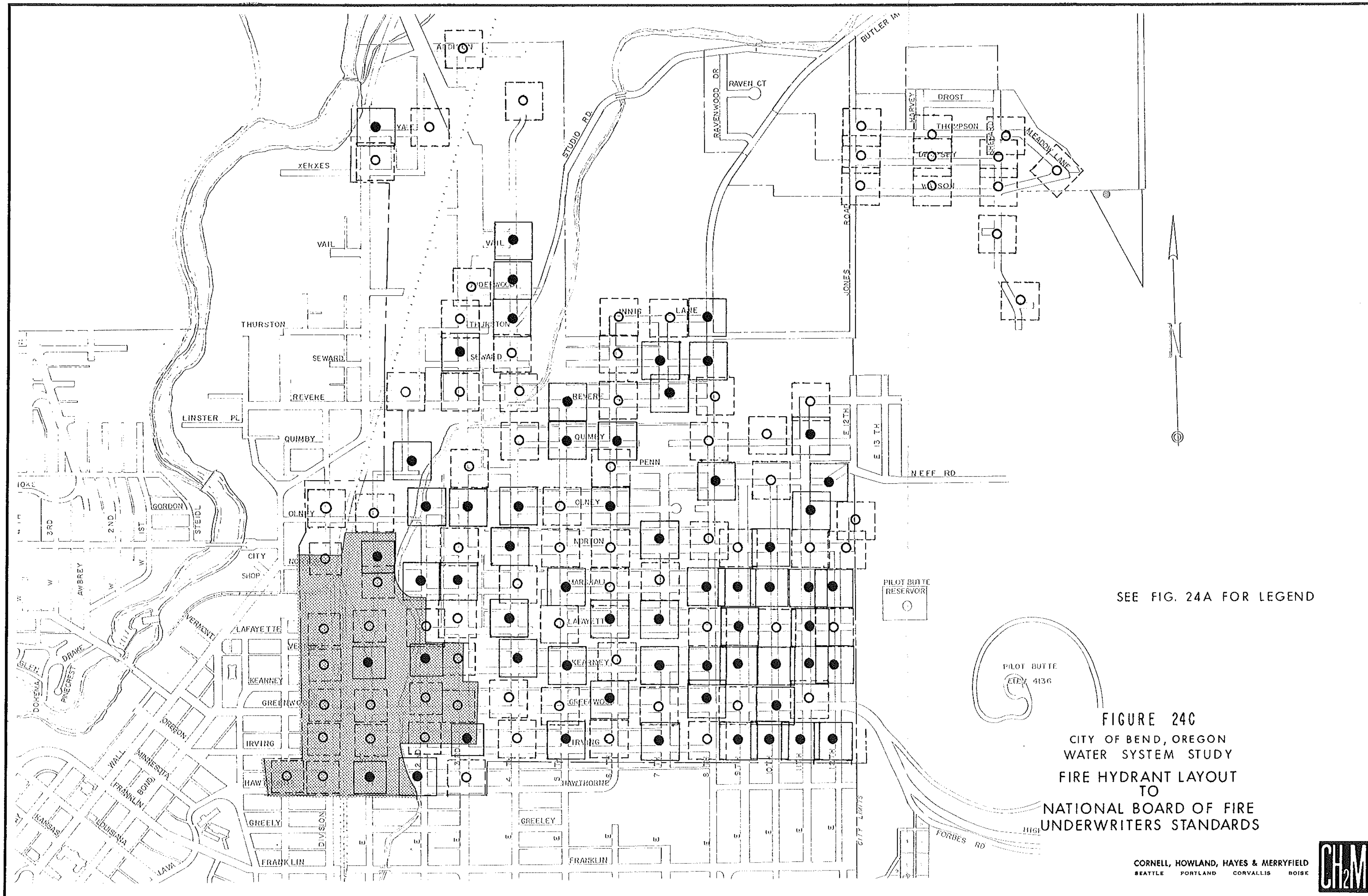
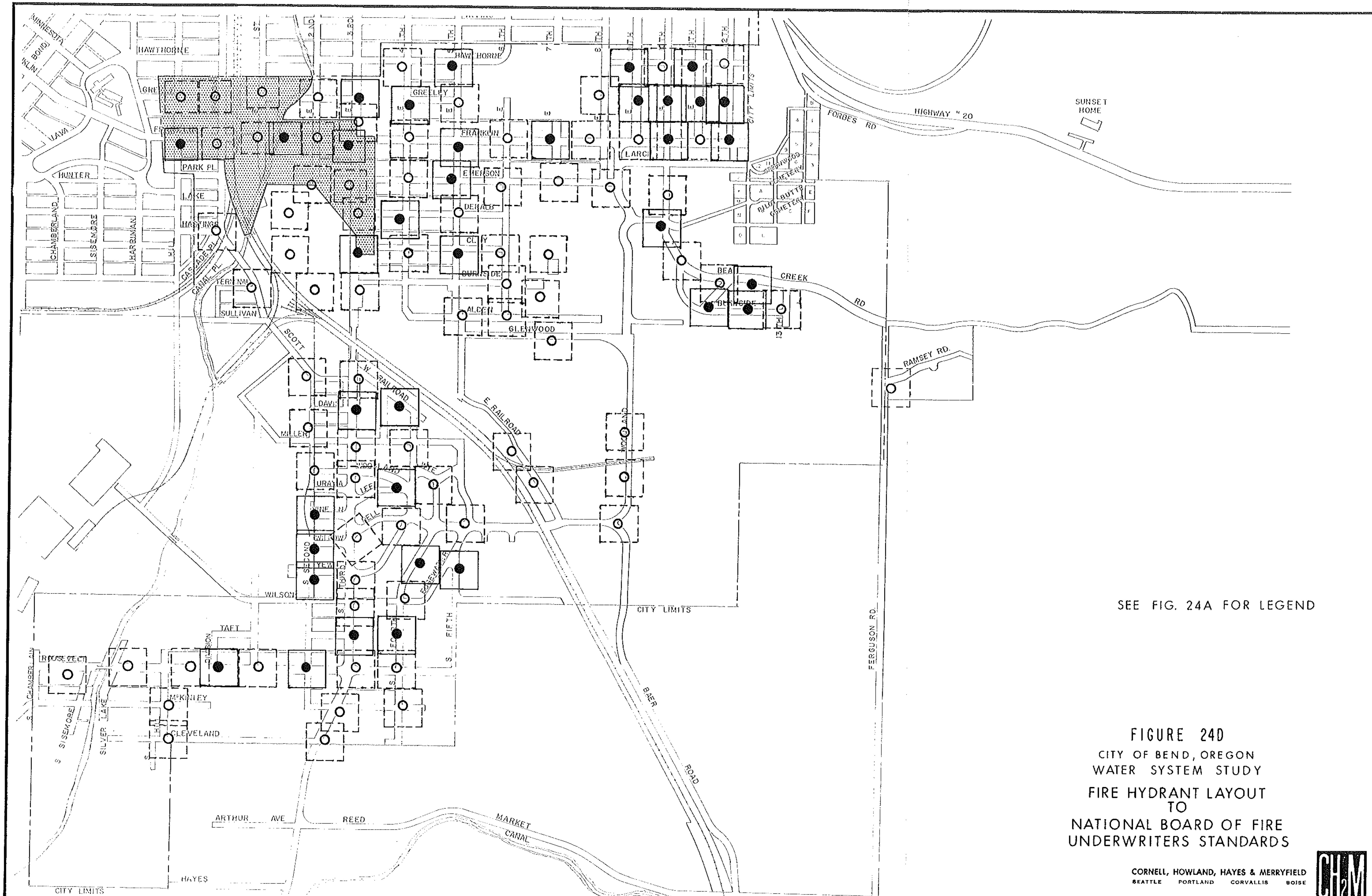


FIGURE 24C

CITY OF BEND, OREGON
WATER SYSTEM STUDY

FIRE HYDRANT LAYOUT
TO
NATIONAL BOARD OF FIRE
UNDERWRITERS STANDARDS

CORNELL, HOWLAND, HAYES & MERRYFIELD
SEATTLE PORTLAND CORVALLIS BOISE
CH2M



SEE FIG. 24A FOR LEGEND

FIGURE 24D

CITY OF BEND, OREGON
WATER SYSTEM STUDY

FIRE HYDRANT LAYOUT
TO
NATIONAL BOARD OF FIRE
UNDERWRITERS STANDARDS

CORNELL, HOWLAND, HAYES & MERRYFIELD
SEATTLE PORTLAND CORVALLIS BOISE

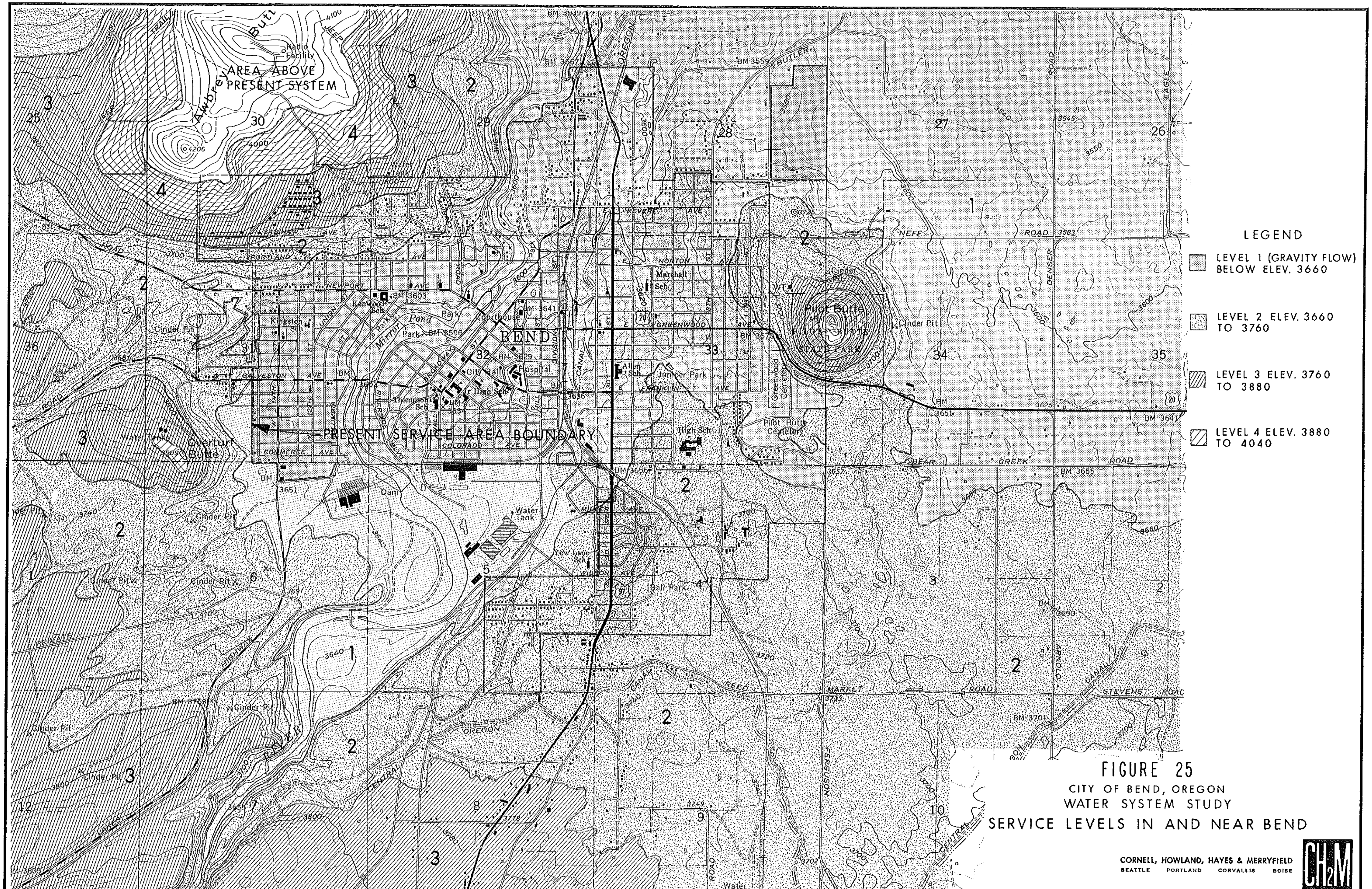


FIGURE 25
CITY OF BEND, OREGON
WATER SYSTEM STUDY
SERVICE LEVELS IN AND NEAR BEND

A large area southeast and south of Bend and a small area at the base of Pilot Butte can be served by the second level system. The southeast area is now served by the Third Street Pumping Station and the Great Northern elevated tank. The area at the base of Pilot Butte is served by the new Pilot Butte Pumping Station. As these areas grow they will merge and the two can be combined into a single pressure district. This can be done by constructing a new main between the Pilot Butte Pumping Station and feeder mains from the Third Street Pumping Station as shown on Figure 21. As suggested earlier, as this area grows, one million gallons of storage should be constructed on this system at Pilot Butte. This location will permit the use of low-cost ground level storage. It is suggested that all areas between Elevations 3660 and 3760 southeast of the City be served by this system. In addition, the residential area between the high school and Pilot Butte Cemetery and newly developed areas along and south of Bear Creek Road should be served. It would be possible to serve this area by gravity flow from Overturf Reservoir by construction of about 8,700 feet of 16-inch cross-town, high-pressure main to Third and Clay Streets. However, the cost of this main is estimated at $120,000 and unless the rate of increase in water use in this area is much greater than expected, it is more economical to pump from the first level system to serve this area. It appears that this situation will continue to prevail for the next 20 or 30 years into the future, so that the construction of the high-pressure main is not recommended.

Around Awbrey Butte, northwest of Bend, are two other areas which lie within the second level. One area is now served by the Fifth Street Pumping Station and the Bend View tank, and the other is now served by the Kenwood Pumping Station. It is recommended that these two areas be joined by construction of new mains as illustrated by Figure 21, and operated as a single system, and that any new developments in adjoining areas between Elevations 3660 and 3760 also be served by this system. At present, for at least nine months of the year, this area could be served by gravity flow without pumping from Overturf Reservoir. There are two existing high-pressure transmission lines from Overturf Reservoir, an 18-inch line to Awbrey Butte Reservoir, and a 12-inch line to College Avenue Pumping Station. The supply line to Awbrey Butte Reservoir could be tapped with an 8-inch line at Tenth and Roanoke, and connected to the second level system through a check valve. In addition, the 12-inch suction line at the College Avenue Pumping Station should be tapped with an 8-inch line and connected through a check valve and about 2,000 feet of new 8-inch main to the second level system at Juniper Street and Quincy Avenue, as shown on Figure 21. Following completion of these two taps to the lines from Overturf and installation of the necessary connections between the two sections by new mains along Roanoke Avenue, the Kenwood Pumping Station may be abandoned. The Fifth Street

Pumping Station and Bend View Tank would serve the combined districts when needed, although the pumps would operate only at times of peak demand. Power costs would be reduced by this arrangement, and the storage in Overturf Reservoir would be available to this district by gravity flow, thus improving fire protection and reliability of service to this district.

The third level system serves Elevations 3760 to 3880. The West Hills District on Awbrey Butte is presently the only district at the third level. This area is now served by the West Hills Pumping Station, which takes suction from the outlet line from Awbrey Butte Reservoir. Suction conditions can be improved and some pumping costs saved by changing this suction connection to the high-pressure inlet line to the reservoir. Presently there is no storage on the third level system. It is recommended that the third level system by connected to the new College Reservoir through the 12-inch discharge line from College Avenue Pumping Station. It will be necessary to install a pressure-reducing valve and about 1,000 feet of 10-inch pipeline to make this connection. This will make 0.5 mg of storage available to the third level system, and will provide a second feed to it. If this is done, it would be possible to abandon the West Hills Pumping Station, and to serve the West Hills District from the College Reservoir and the College Avenue Pumping Station with pressure reduction. However, this is not recommended since pumping costs would be higher. It is suggested that the West Hills Pumping Station be maintained in service, and that the connection to the fourth level (College) system be made for standby use, thus providing better fire protection and greater reliability of service.

Presently, there are low pressures at times in the upper end of the second level system along Wilmington Avenue. It is recommended that service to this area be improved by placing it on the third level system by laying a new 8-inch connecting main from Seventh and Vicksburg Streets to Wilmington Avenue. As additional adjacent land areas lying between Elevations 3760 and 3880 are developed, they should be made a part of this third level system.

Presently, the fourth level system serves only Central Oregon College, but Figure 25 shows that there are additional areas, some within the present City limits, which may be served in the future from this pressure zone. Temporarily, the College is served by direct pressure from the College Avenue Pumping Station. Service and fire protection will soon be improved by addition of the 0.5 mg College Reservoir which will float on this level. As the campus grows, it may be desirable to provide a second 10-inch connection from the College Reservoir to the upper side of the campus as shown on Figure 21.

Strengthening the Main Grid. The new mains already mentioned in Pressure Levels 2 and 3 on Awbrey Butte for reorganization of the present pressure districts will also serve to increase the capacity of the main grid system in these areas. Further strengthening of the grid will be obtained in Pressure Zone 2 by a new 8-inch main along West Sixth from Roanoke to Trenton and in Zone 3 by a 10-inch line along Trenton from Quincy to Juniper, and an 8-inch line along Juniper from Trenton to Iowa.

In the Central District, Pressure Zone 1, future water demands will require the construction of a new 16-inch line along Lafayette from Eighth Street to Pilot Butte Reservoir, and a new 12-inch main from Eighth and Lafayette along Eighth Street to Seward Avenue.

Within Pressure Zone 2 in the southeast section of the City, increased water use will require installation of a new 12-inch main from Third and Burnside to Second and Roosevelt along the route shown on Figure 21. The new 12-inch tie between the two existing Zone 2 districts in this area has been described previously under planning of pressure zones. This tie will also serve to increase the capacity of the system to serve some parts of the area.

Extension of the Main Grid System to Newly Developed Areas. Recent growth of Bend to the northeast will require a new 12-inch feeder main from Eighth and Seward along Butler Market Road and Ravenwood Drive to Studio Road at Ravenwood. Further growth to the north and northeast can be served by a line of 12- and 6-inch pipe along East Addison Avenue from Second Street to Butler Market Road, and by a 12-inch line along Butler Market Road from Ravenwood Drive to Jones Road.

As additions are made to the distribution system, gate valves should be located to provide the maximum in reliability against a failure in the pipe network. It is recommended that valves be located so that no single case of accident, breakage, or repair to the pipe system will necessitate shutdown of a length of pipe greater than 500 feet in the high-value districts or greater than 800 feet in other sections. Valves should be inspected regularly and maintained in good condition. All valves within the system should operate in the same direction.

Adequate Storage at All Pressure Levels. As previously discussed, storage at the fourth pressure (College) level will be supplied by the 500,000 gallon College Reservoir. This same reservoir will also serve the third (West Hills) level through a pressure-reducing valve and a new main.

The second pressure level at Awbrey Butte (Kenwood and Fifth Street Districts) can utilize the existing 3 mg of storage in Overturf Reservoir by construction of the recommended new tie to the high-pressure mains to College Avenue Pumping Station and Awbrey Butte Reservoir. Presently, there is only 35, 000 gallons of storage (Bend View Tank) on the Fifth Street District and none on the Kenwood District.

The second pressure level in the southeast part of town has no storage on the Pilot Butte District and only 100, 000 gallons (Great Northern Tank) on the Third Street District. When these two districts are combined by the recommended 12-inch tie, one mg of storage should be added at this level on Pilot Butte.

The present total of 9. 5 mg of storage in Overturf, Awbrey, and Pilot Butte Reservoirs on the gravity or first level system is considered adequate for the moment; but, as previously discussed, 2 mg of storage at this level should be added at Pilot Butte in the future to supply peak-hour and fire demands on the main Central District system.

Correction of Localized Fire Flow Deficiencies and Elimination of Dead-End Lines. There are a number of places in the Bend water distribution system where the laying of new mains would eliminate dead ends, complete pipe loops, and correct local fire flow deficiencies. Generally speaking, a fire hydrant on a dead-end 6-inch line cannot deliver full fire flow, but in some cases a 2-way feed through two 6-inch lines or one 8- and one 6-inch is satisfactory. In some locations, a 2-way 8-inch feed is required to produce minimum fire flows to hydrants. The elimination of dead-end lines also improves water circulation through the system. A number of suggested new mains for these purposes are shown on Figure 21. They are also included and identified in Table 29 along with other recommended water main extensions.

Replacement of Undersized Mains and Old Steel Lines. The City has a good program for replacement of water lines which have deteriorated or otherwise have become obsolete. All wood-stave pipe has been replaced with cast iron, and most of the steel lines in poor condition have been replaced. A few steel lines which are still in service will need to be replaced either because of their physical condition or because a larger capacity line is needed in the same location. The City should continue to budget money for line replacement until this program is complete.

Installation of Additional Fire Hydrants. Figure 24 shows the number and location of new fire hydrants required to meet standards of the National Board of Fire Underwriters. A total of 205 new hydrants are shown. If these were to be purchased and installed by City forces, they would represent an investment of about $360 each at present-day costs or a total of $73, 800. The cost of this improvement is substantial, and the benefits to be derived in the way of better fire protection and higher grading by the Rating Bureau must be balanced against similar benefits which might be gained by expenditures to correct other deficiencies in the total fire defenses of Bend. The value of the additional hydrants must also be balanced against that of other improvements which might be made to the water system.

A reasonable approach to eventual compliance with the hydrant spacing standard might be to install about 21 new hydrants on the existing system each year for the next ten years.

To conform to the National Board of Fire Underwriters' standards, all hydrants should have 6-inch bottom connections, two 2-1/2-inch outlets, one 4-inch pumper connection, an independent gate valve between the hydrant and the main, and should be connected to a 6-inch or larger main with a 6-inch pipe. Hydrants should be such that, when the barrel is broken off, the hydrant will remain closed.

Scheduling Water Distribution System Improvements. On Figure 21, two priority groups are noted for water main extensions. Priority Group I consists of the improvements needed to bolster the system as a whole, while Priority Group II consists principally of improvements providing benefits which are more local in nature. Table 29 lists the needed water distribution system improvements in the approximate order of priority or urgency, based on present conditions and knowledge. Undoubtedly, this order will need to be rearranged to best suit changing conditions and to meet new developments as they occur.

In summary, the cost of expanding the water distribution, storage, and fire protection facilities to meet the needs of the community until about the year 1990 are as follows:

New water mains and storage reservoirs:		
Priority Group I	$331, 320	
Priority Group II	250, 780	
Subtotal		$582, 100
Additional fire hydrants		73, 800

As already mentioned, some money should be budgeted each year for replacements of old steel lines.

TABLE 29

SCHEDULE OF DISTRIBUTION SYSTEM IMPROVEMENTS

Item No.	Description	Location	Length in Ft.	Size	Estimated Cost
		Priority Group I			
1	Main, tie College Reservoir to West Hills 3rd level system	Along Saginaw Ave. extended from College Ave., to Quincy St.	1,000	10"	$7,700
2	Main, change high areas in 5th St. district to 3rd level system	Along Vicksburg Ave., 5th St. and Wilmington Ave. from 7th St. to 2nd St.	1,550 450	8" 6"	9,000 2,160
3	Main, tie between Pilot Butte and 3rd St. districts (2nd level system)	Along East City limits and Alden Ave., from Pilot Butte Pump Sta. to Glenwood & Woodland Blvd.	3,800 1,200	12" 10"	33,800 9,250
4	Main, reinforce 2nd level system south of 3rd St. Pump Sta.	Along Burnside, 4th, Alden, 5th, Miller, Lee, Vine, and 2nd, from 3rd & Burnside to 2nd and Roosevelt	5,350	12"	52,700
5	Main, extension, 1st level system to northeast section of City	Along 8th St. & Ravenwood Dr. from Thurston Ave. to Studio Road	2,850	12"	28,000
6	Main, tie Overturf Reservoir to Kenwood (2nd level) District	Along Quincy St. extended from College Ave. to Juniper St.	1,950	8"	13,260

TABLE 29 (Cont.)

Item No.	Description	Location	Length in Ft.	Size	Estimated Cost
		Priority Group I			
7	Main, tie Kenwood and 5th St. Districts into one 2nd level district	Along Roanoke Ave. from 10th to 11th Sts. and from 7th to 9th Sts.	1,200	8"	$7,450
8	Main, reinforce 1st level system	Along Lafayette Ave. from Pilot Butte Reservoir to 8th St.	1,850	16"	23,700
9	Main, reinforce 1st level system	Along 8th St. from Lafayette to Thurston Ave.	2,640	12"	27,100
10	Reservoir on 1st level system	Pilot Butte	---	1mg	55,000
11	Reservoir on 2nd level system	Pilot Butte	---	1mg	55,000
12	Main, connect new 2nd level reservoir to system	Along Lafayette extended to reservoir site	800	12"	7,200
	Subtotal Priority Group I				$331,320
		Priority Group II			
13	Main, extension to north side of City, and complete fire loop	Along E. 4th St. to E. Addison and along Addison to E. 2nd	1,100	10"	$10,460

TABLE 29 (Cont.)

Item No.	Description	Location	Length in Ft.	Size	Estimated Cost
		Priority Group II			
14	Main, extension to northeast section of City	Along Butler Mkt. Rd. from Ravenwood to Jones Rd.	1,350	12"	$13,800
15	Main, extension and fire loop completion	Along Jones Road from Thompson Dr. to Butler Mkt. Rd.	950	8"	6,650
16	Main, extension and fire loop completion	Along Jones Rd. extended from Jones Rd. to Shepard Rd.	1,350	12"	12,200
17	Main, improve fire protection in 2nd level system	Along W. 6th St. from Roanoke to Trenton Ave.	600	8"	3,480
18	Main, improve fire protection and eliminate dead-end lines in 3rd level system	Along Trenton Ave. from Saginaw to Juniper, along Juniper from Trenton to West Hills Ave.	1,400 800 300	10" 8" 6"	10,800 4,650 1,440
19	Main, extension and fire loop completion	Along Studio Rd. from Ravenwood to Butler Mkt Rd.	950	6"	5,700
20	Main, reinforce 1st level system in north part of City	Along E. Addison Ave. extended to Ravenwood and Studio Rd.	1,850	12"	17,200
21	Main, reinforce 1st level system in northeast part of town	Along Watson Drive extended from Butler Mkt. Rd. to Jones Rd.	1,150	12"	10,350

TABLE 29 (Cont.)

Item No.	Description	Location	Length in Ft.	Size	Estimated Cost
		Priority Group II			
22	Main, improve fire protection and replace old 4" steel line	Along W. 1st St. from Awbrey to Portland Ave.	900	6"	$ 5,900
23	Main, reinforce grid in southwest part of City	Along W. 15th St. from Cumberland to Commerce, and along Commerce from 15th to 14th St.	1,100	12"	9,900
24	Reservoir, on 1st level system	Pilot Butte	---	1 mg	55,000
25	Main, reinforce grid and eliminate dead ends in south central part of town	Along Tumalo from Congress to Broadway, and along Broadway from Tumalo to Colorado Ave.	1,900	6"	11,400
26	Main, eliminate dead end	Along Florida Ave. from Lava to Chamberland St.	350	6"	2,100
27	Main, complete fire loop	Along Hill St. from Hastings to Lake Ave.	350	6"	2,100
28	Main, reinforce grid in southwest part of City, eliminate dead ends	Along W. 14th St. from Commerce to Galveston	1,750	8"	12,250

TABLE 29 (Cont.)

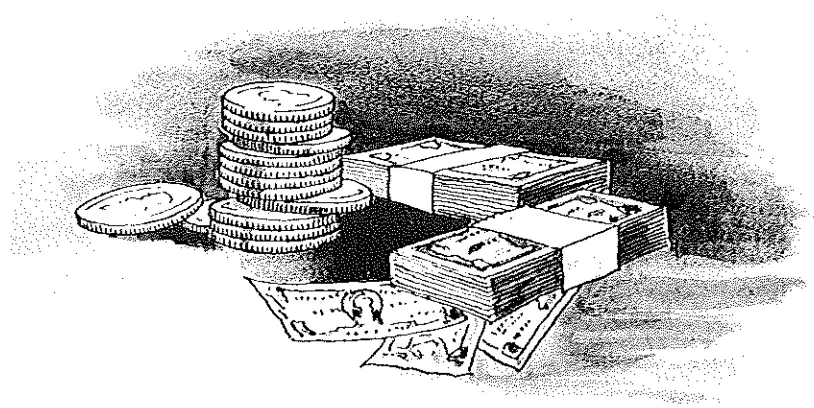
Item No.	Description	Location	Length in Ft.	Size	Estimated Cost
		Priority Group II			
29	Main, extension and elimination of dead-end line	Along Newport from 15th to 12th St.	800 500	8" 6"	$ 5,600 3,000
30	Main, reinforce grid in west part of City	Along W. 15th St. from Galveston to Lexington, and along Lexington to W. 14th St.	1,900	8"	11,000
31	Main, increase fire protection to College	From 12" main near College Reservoir to upper side of campus	600	10"	4,620
32	Main, reinforce grid in north central part of City	Along E. 1st and Lytle Sts. from Olney to Revere Ave.	1,300	8"	8,020
33	Main, eliminate dead end	Along Division St. from Norton to Olney Ave.	450	6"	2,160
34	Main, eliminate dead end	Along Underwood from E. 3rd to E. 4th St.	450	6"	2,160
35	Main, for new fire hydrant	Along Linster Place west from Harriman St.	350	6"	1,680
36	Main, for new fire hydrant	Along E. 1st St. south from Revere Ave.	250	6"	1,500

TABLE 29 (Cont.)

Item No.	Description	Location	Length in Ft.	Size	Estimated Cost
		Priority Group II			
37	Main, eliminate dead end	Along Quimby Ave. from E. 5th to E. 6th St.	500	6"	$ 2,400
38	Main, complete fire loop	Along E. 5th St. from Marshall Ave. north	250	6"	1,200
39	Main, eliminate dead end	Along Kearney Ave. from E. 4th St. to E. 5th St.	450	6"	2,160
40	Main, eliminate dead ends	Along Hawthorne Ave. from E. 5th to E. 6th St.	500	6"	3,000
41	Main, for new fire plug	Along S. 4th St. from Miller to W. Railroad	400	8"	2,320
42	Main, reinforce grid	Along S. 2nd St. and McKinley from Roosevelt to S. 3rd St.	500	8"	2,900
43	Main, complete fire loop	Along Edgewater S. of Woodland Blvd.	350	6"	1,680
	Subtotal Priority Group II				$250,780

Note: Pipeline costs include pipe in place, backfill, pavement replacement, fittings, hydrants, and valves.

FINANCIAL CONSIDERATIONS



X. FINANCIAL CONSIDERATIONS

Basis for Estimates. Cost estimates included herein for source of supply and storage improvements are based on current costs for contract work on similar projects in Oregon and include an allowance for design engineering, inspection during construction, and contingencies. Cost estimates for laying new distribution mains and installing new fire hydrants are based on the work being done by City forces and on the use of cast iron pipe. Recent cost records of the City Water Department are the source of the unit prices used in estimating the cost of distribution system improvements.

Financial Analysis. The purpose of the financial analysis is to determine whether existing water rates are adequate to support the necessary improvements to the water system.

Recommendations have been made for additions to the source of supply, storage, distribution mains, and fire hydrants. Table 30 schedules the major capital expenditures under four plans of development, designated A, B, C, and D.

Development Plan A is for expanding the Tumalo Supply for the unmetered system. Under Plan A, there would be two bond issues, one in 1966 of about $900,000 to develop another 5 mgd from the Tumalo source, and a second in 1970 of about $170,000 to construct an additional 2 million gallons of storage on Pilot Butte including the necessary connecting pipelines (8, 9, and 12) to the City. Another one million gallon storage tank ($55,000) would be built on Pilot Butte in 1980 from system revenues. The additional fire hydrants and water main extensions would also be paid for from operating revenues of the Water Department. Hydrants would be installed in 1966, and each year from 1970 through 1975 as shown by Table 30. The distribution system improvements shown on Figure 21 and Table 29 would be built during the period of 1966 to 1975 as scheduled in Table 30.

Plan B is for expanding the supply from Tumalo Creek to serve a metered system. This plan requires three bond issues, one in 1966 for about $220,000 for meter installation, a second in 1973 for the additional supply ($900,000), and a third in 1978 ($170,000) for additional storage on Pilot Butte. Scheduling and financing of the distribution system improvements, mains, and hydrants are about the same as for Plan A. The chief difference between Plans A and B is that universal metering of all water services under Plan B would reduce water use so as to permit the source of supply development and storage additions to be deferred for 7 or 8 years.

TABLE 30

SCHEDULE OF MAJOR CAPITAL EXPENDITURES
UNDER VARIOUS PLANS FOR DEVELOPMENT

		Development Plan			
		A	B	C	D
Year	Type of Improvement	Tumalo Supply	Tumalo Supply with Meters	Deep Well Supply	Deep Well Supply with Meters
1966	Supply, Step 1	$871,700*	---	$330,600*	---
	Meters	---	$216,000*	---	$216,000*
	Mains (1 & 2)	18,860	18,860	18,860	18,860
	Hydrants	7,400	7,400	7,400	7,400
	Subtotal	897,960	242,260	356,860	242,260
1967	Mains (3)	43,050	43,050	43,050	43,050
	Hydrants	0	7,400	7,400	7,400
	Subtotal	43,050	50,450	50,450	50,450
1968	Mains (4)	52,700	52,700	52,700	52,700
	Hydrants	0	7,400	7,400	7,400
	Subtotal	52,700	60,100	60,100	60,100
1969	Mains (5, 6, & 7)	48,710	48,710	48,710	48,710
	Hydrants	0	7,400	7,400	7,400
	Subtotal	48,710	56,110	56,110	56,110
1970	Storage (2 mg)	110,000*	---	110,000	---
	Mains (8, 9, & 12)	58,000*	---	58,000	---
	Mains (13 to 16)	43,110	43,110	43,110	43,110
	Hydrants	7,400	7,400	7,400	7,400
	Subtotal	218,510	50,510	218,510	50,510
1971	Mains (17 to 20)	43,270	43,270	43,270	43,270
	Hydrants	7,400	7,400	7,400	7,400
	Subtotal	50,670	50,670	50,670	50,670
1972	Mains (21, 22, 23, & 25)	37,550	37,550	37,550	37,550
	Hydrants	7,400	7,400	7,400	7,400
	Subtotal	44,950	44,950	44,950	44,950

*Financed by Bond Issue

Table 30 (cont.)

Year	Type of Improvement	Development Plan A Tumalo Supply	B Tumalo Supply with Meters	C Deep Well Supply	D Deep Well Supply with Meters
1973	Supply, Step 1	---	$871,700*	---	$330,600*
	Mains (26 to 30)	$36,050	36,050	$36,050	36,050
	Hydrants	14,800	7,400	7,400	7,400
	Subtotal	50,850	915,150	43,450	374,050
1974	Mains (31 to 36)	20,140	20,140	20,140	20,140
	Hydrants	14,800	7,400	7,400	7,400
	Subtotal	34,940	27,540	27,540	27,540
1975	Supply, Step 2	---	---	172,200	---
	Mains (37 to 43)	15,660	15,660	15,660	15,660
	Hydrants	14,600	7,200	7,200	7,200
	Subtotal	30,260	22,860	195,060	22,860
1978	Storage (2 mg)	---	110,000	---	110,000
	Mains (8, 9, & 12)	---	58,000	---	58,000
	Subtotal		168,000*		168,000*
1980	Storage (1 mg)	55,000	---	55,000	---
1983	Supply, Step 2	---	---	---	172,200
1988	Storage (1 mg)	---	55,000	---	55,000
TOTAL --Major Capital Expenditures 1966-1990=		$1,527,600	$1,743,600	$1,158,700	$1,374,700

*Financed by Bond Issue

Plans C and D are for development of a deep well supply, Plan C without meters and Plan D with meters. Again, the difference between the two is the deferment of source of supply improvements under the metered plan, Plan D.

Figure 26 is a graphic presentation of the cumulative capital expenditures under the four Development Plans further illustrating the timing and amount of the funds required.

As shown by Table 31, the City has some existing water bonds which will not be paid off until 1978, although the annual amount due drops off sharply in 1973. Because of these outstanding bonds, Plan A is the most difficult to finance since it requires a large immediate cash outlay. Since it is the most difficult plan, it was selected for detailed study as shown by Table 31.

Column 2 of Table 31 shows the estimated number of customers to be served by the system as previously determined and as illustrated by Figure 2.

The estimated annual revenue shown in Column 3 is based on the present average annual income per customer times the number of customers in Column 2. This should be a conservative estimate of income, since metered accounts will probably yield an increasing revenue per account.

Column 4 shows the estimated increase in operation and maintenance costs as the water system grows, including that required for the third Tumalo pipeline.

The amortization schedule for the outstanding water bonds is given in Column 5. The new debt service to pay off the bonds for the recommended water improvements is shown in Column 6. For simplicity, the new debt service is based on uniform payments over 20 years at 3-1/2 percent interest. Note that bonds for the additional 2 mg of storage on Pilot Butte are to be issued in 1970, that interest payments only would be made in 1971 and 1972 with principal payments being made over the final 18 years of the period. This avoids an overlap with existing payments on outstanding bonds.

Column 8 shows the estimated future capital account expenditures. The recommended water main construction and fire hydrant installations would be made during the period of 1966 to 1975 as shown in more detail in Table 30. These improvements would be paid for on a cash basis from earnings of the water department. No allowance is made

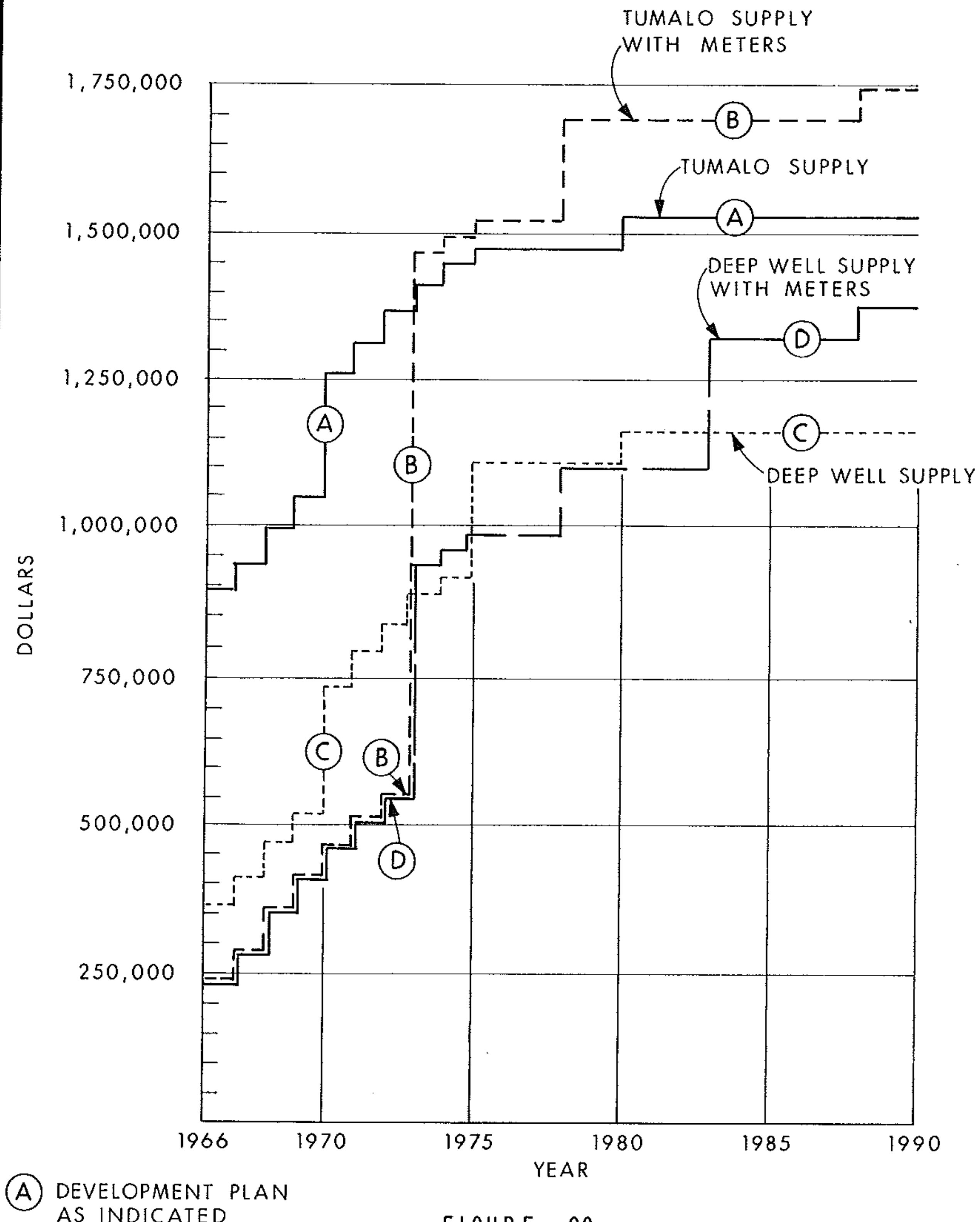


FIGURE 26

CITY OF BEND, OREGON
WATER SYSTEM STUDY
CUMULATIVE
MAJOR CAPITAL EXPENDITURES

CORNELL, HOWLAND, HAYES & MERRYFIELD
SEATTLE PORTLAND CORVALLIS BOISE

CH2M

TABLE 31

FINANCIAL ANALYSIS - DEVELOPMENT PLAN A

1 FISCAL YEAR	2 ESTIMATED NUMBER OF CUSTOMERS	3 ESTIMATED ANNUAL REVENUE	4 OPERATION & MAINTENANCE	5 EXISTING DEBT SERVICE	6 NEW DEBT SERVICE	7 TOTAL FIXED COSTS	8 NEW CONSTRUCTION	9 TOTAL ANNUAL EXPENSE	10 RESERVE FOR LINE REPLACEMENT
1964-65	4,350	$304,300	$108,796	$87,344		$196,140	$55,200	$251,340	$ 52,960
1965-66	4,410	308,700	110,600	88,000		198,600	26,260	224,860	83,810
1966-67	4,470	313,100	120,200	88,370	$58,840*	267,410	43,050	310,460	2,640
1967-68	4,530	317,500	122,000	87,692	58,840	268,532	52,700	321,232	- 3,732
1968-69	4,590	321,900	123,800	87,995	58,840	270,635	48,710	319,345	2,555
1969-70	4,650	326,300	125,600	82,200	58,840	266,640	50,510	317,150	9,150
1970-71	4,710	330,700	127,400	87,220	61,780**	276,400	50,670	327,070	3,630
1971-72	4,770	335,100	129,200	87,217	61,780	278,197	44,950	323,147	11,953
1972-73	4,830	339,500	131,000	49,155	71,140***	251,295	50,850	302,145	37,365
1973-74	4,890	343,900	132,800	48,837	71,140	252,777	34,940	287,717	56,183
1974-75	4,950	348,300	134,600	48,487	71,140	254,227	30,260	284,487	63,813
1975-76	5,010	352,700	136,400	47,105	71,140	254,645	45,000	299,645	53,055
1976-77	5,070	357,100	138,200	27,722	71,140	237,062	45,000	282,062	75,038
1977-78	5,130	361,500	140,000	27,877	71,140	239,017	50,000	289,017	72,483
1978-79	5,190	365,900	141,800		71,140	212,940	55,000	267,940	97,960
1979-80	5,250	370,300	143,600		71,140	214,740	110,000	324,740	45,560
1980-81	5,310	374,700	145,400		71,140	216,540	55,000	271,540	103,160
1981-82	5,370	379,100	147,200		71,140	218,340	55,000	273,340	105,740
1982-83	5,430	383,500	149,000		71,140	220,140	60,000	280,140	103,360
1983-84	5,490	387,900	150,800		71,140	221,940	60,000	281,940	105,960
1984-85	5,550	392,300	152,600		71,140	223,740	60,000	283,740	108,560
1985-86	5,610	396,700	154,400		71,140	225,540	60,000	285,540	111,160
1986-87	5,670	401,100	156,200		12,300	168,500	65,000	233,500	167,600
1987-88	5,730	405,500	158,000		12,300	170,300	65,000	235,300	170,200
1988-89	5,790	409,900	159,800		12,300	172,100	65,000	237,100	172,800
1989-90	5,850	414,300	161,600		12,300	173,900	65,000	238,900	175,400
1990-91	5,910	418,700	163,400			163,400	65,000	228,400	190,300

* $871,700 Bond issue for expansion of Tumalo Supply.

**
*** $168,000 Bond issue for 2/mg. additional storage on Pilot Butte with connecting pipelines, ** start interest payments, *** start principal payments.

COL. NO.

2 See Figure 2.
3 Based on number of customers with no increase in revenue per customer.

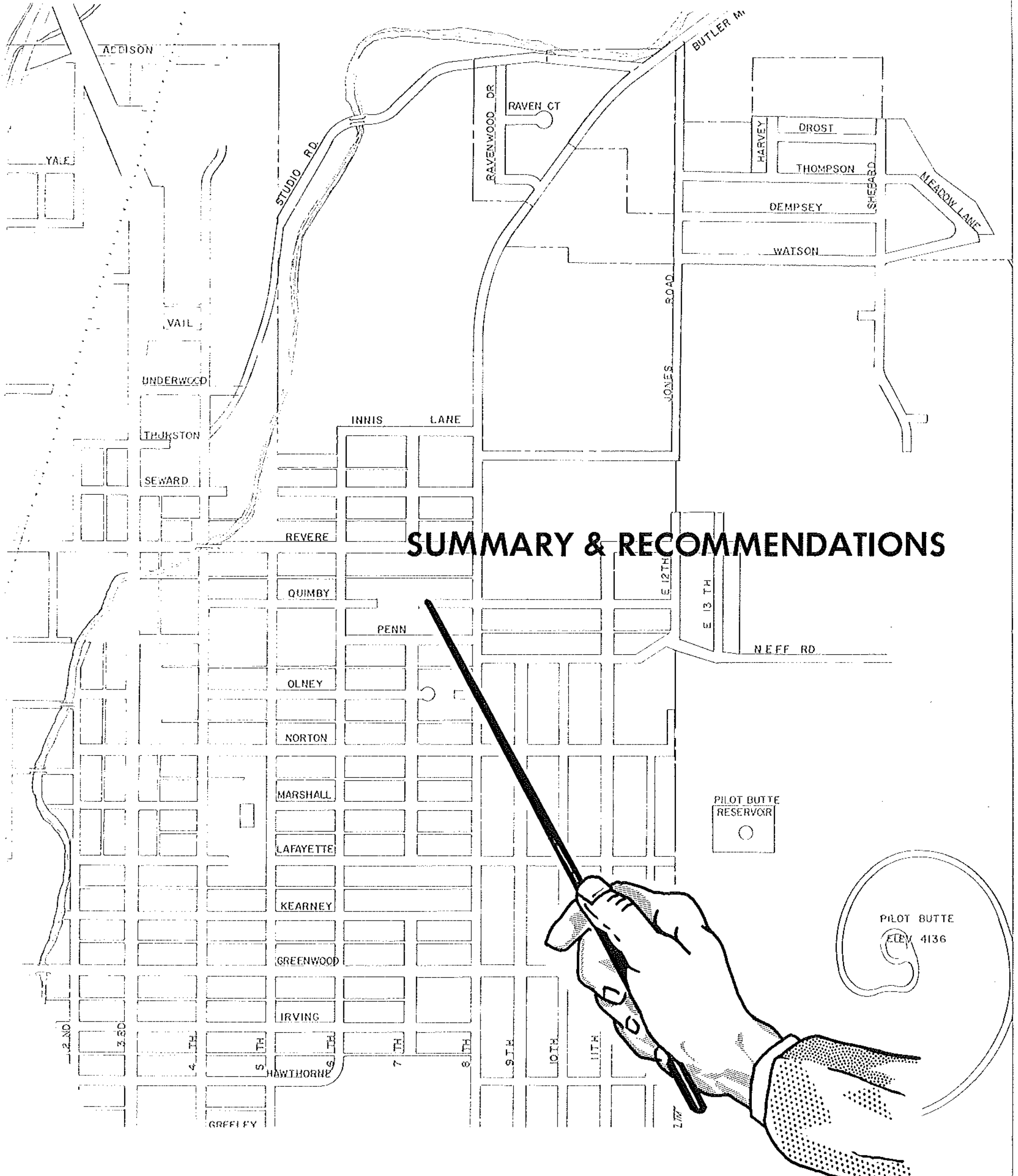
for improvements other than those tabulated, although funds are available early and late in this time period for a limited amount of other new construction. After 1975, allowance is made for new construction other than that for the major improvements specifically discussed in this report.

The figures in Column 10 are the difference between the estimated annual revenue and the total annual expense (Column 3 minus Column 9). This is the amount of revenue which can be placed each year in the Replacement and Betterment Fund. This fund is used to replace old pipelines as they become obsolete. A major item of expense which might be paid for or partially paid for from this fund is replacement or repair of the original transmission line from Tumalo Creek which may be required in the next 25 years. The critical period for financing the new work is from 1967 to 1972, as shown by Column 10. The budgeting during this period is on a rather close margin. However, if necessary, some money could be drawn from the existing Replacements and Betterments Funds to take care of any unforeseen or emergency situations.

Water Rates. From the foregoing analysis, it appears that the existing water rates are adequate to finance the improvements to the water system through the study period, and no increase in water rates is necessary. It is conceivable that substantial increases in the cost of material and labor or other inflationary trends could upset this situation, but the best information at this time indicates that the present water rates are adequate.

This conclusion is based on Plan A for development of the Tumalo Supply, but it also holds true for Plans B, C, and D and for the supplemental supply from the Deschutes River or shallow well development at Lava Island Falls if one of these alternates is selected.

SUMMARY & RECOMMENDATIONS



XI. SUMMARY OF RECOMMENDATIONS

Source of Supply. There are at least four good sources of additional water supply which may be developed by the City. Our recommendation is for expansion of the Tumalo Creek supply, or alternately, in order of preference, by construction of deep wells at Bend, use of the Deschutes River or drilling of shallow wells at Lava Island Falls. However, the City Commission and the public should review this selection by thorough discussion of the information contained in this report. If there is preliminary agreement with this order of preference, we suggest the following procedure for making the final selection:

1. Determine whether or not water rights can be purchased for expansion of the Tumalo Creek supply.

2. If water rights can be acquired, set the date for a bond election to finance the construction of 5 mgd of additional supply from this source.

3. If water rights cannot be obtained for expansion of the Tumalo supply, then make financial and other arrangements to conduct a deep well test drilling program.

4. If the deep well tests are successful, set the date for a bond election to finance the initial phase of deep well construction.

5. If the deep well tests are not successful, investigate the acquisition of water rights for the Deschutes River supply.

6. If water rights can be obtained for the Deschutes supply, proceed with financing and construction of the first phase of this development.

7. If Deschutes water rights cannot be obtained, the next alternate is shallow well exploration at Lava Island Falls, followed by construction, if the results of test drilling are satisfactory.

Distribution Mains. Based on a hydraulic network analysis of the water distribution system, a plan was developed for improving and expanding the system to keep pace with the growing needs of the community. The plan provides for some realignment and consolidation of pressure zones, strengthening of the system of trunk mains to meet future peak flows, extension of the main grid system to new areas of development, correction of local fire-flow deficiencies, and replacement of undersized and obsolete pipelines.

Details of this improvement plan are given by Figure 21, and Tables 29, 30, and 31.

Each section of proposed new main has been assigned a priority number and the mains have been divided into two general priority groups. Group I consists of the mains needed to reinforce the system as a whole, while Group II includes mains which produce local benefits.

These improvements can be financed from revenues of the Water Department on a pay-as-you-go basis. We recommend that the program be started by 1966 and completed by 1975. This program is essentially the same under any source of supply development, and the start need not await the decision on source of supply.

Storage. We recommend that three million gallons of additional storage be provided on Pilot Butte, two mg on the first level system, and one mg on the second level system. The construction can be accomplished in two stages. The first stage would provide one mg of storage on the first level and one mg of storage on the second level, plus the necessary pipeline connections to the distribution system. The first stage improvements will require a bond issue. The second stage which would add another one mg of storage on the first level system can be paid for from revenues without a bond issue. The exact timing of the storage improvements depends upon the development plan selected. (See Table 30.)

Fire Hydrants. If the fire hydrant spacing is to comply with the Standards of the National Bureau of Fire Underwriters, it will be necessary to install about two hundred additional fire hydrants throughout the City at locations shown on Figure 24. We recommend that the City consider a program to install these hydrants over the next ten years, the cost being paid from Water Department revenues.

Scheduling and Financing. To meet the anticipated needs of the City of Bend for the next twenty-five years, this report recommends the construction of a total of about one and one-half million dollars of water works improvements during the next ten years. By proper scheduling, about one-third of the total amount can be financed directly from Water Department revenues. The other two-thirds, or about one million dollars, would be raised by two or more bond issues. The bond interest and principal would be paid from water revenues, and no tax levy is necessary.

The final details of both scheduling and financing are dependent to some extent upon the source of supply selected and the decision made regarding universal metering.

Metering. We suggest that the City Commission review the pros and cons of universal metering of all water services as described in detail in Chapter IV, and confirm or change the policy in this regard.

Water Rates. The present water rates are adequate to finance operation of the Water Department and to construct the recommended improvements through the study period, and no increase in water rates is necessary.