Rept. 42 Cost of Transporting Water By Pipeline

TEXAS
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COST OF TRANSPORTING WATER BY PIPELINE

MARCH 1967

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TEXAS WATER DEVELOPMENT BOARD

REPORT 42

COST OF TRANSPORTING WATER BY PIPELINE

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Prepared by
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for the
Texas Water Development Board

March 1967

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FOREWORD

During the preparation of the preliminary Texas Water Plan, the Water Development Board had a number of studies prepared by The University of Texas, Texas A & M University, and Texas Technological College. Other investigations were prepared by the staff, or under contract with various consultants. A number of these reports have been published heretofore by the Board.

To facilitate numerous staff analyses comparing the cost of transporting water from alternative sources to a given point, the Board had this report prepared by Lockwood, Andrews and Newnam, Inc., Consulting Engineers, Houston, Texas. The information and results contained in the report should provide assistance to engineers, cities, water districts, and numerous agencies when considering costs of transporting water.

Publication of this report is a continuation of the Board's policy of providing the widest possible distribution of information obtained during the preparation of the preliminary Plan.

In addition to the basic report, Lockwood, Andrews and Newnam, Inc., has provided an Addendum containing examples in use of the report, and also two appendices containing computer print-outs and other data. The Addendum and Appendix A are included in this volume. Appendix B, which contains the Fortran source program and voluminous computer outputs, remains unpublished but is available for reference in the files of the Texas Water Development Board.

Texas Water Development Board

Joe G. Moore, Jr.

Joe G. Moore, Jr.
Executive Director

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COST CHARTS

(Cost of transporting water by pipeline)

Chart No.	Peak Factor	Growth Rate
1	1.00	0%
2	1.00	10%
3	1.00	6%
4	1.00	3%
5	1.25	0%
6	1.25	10%
7	1.25	6%
8	1.25	3%
9	1.50	0%
10	1.50	10%
11	1.50	6%
12	1.50	3%
13	1.75	0%
14	1.75	10%
15	1.75	6%
16	1.75	3%
17	2.00	0%
18	2.00	10%
19	2.00	6%
20	2.00	3%

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APPENDIX B

(Unpublished; available in files of Texas Water Development Board)

Part I, Fortran Print-Out and Input Data

Part II, Supplementary Data (Output B)

Part III, Output AA (Partial rerun of Output A with different interest rates and amortization periods)

C O S T O F T R A N S P O R T I N G

W A T E R B Y P I P E L I N E

SUMMARY

Authorization

This study was authorized by the Texas Water Development Board to provide the Board with a tool to assist in developing a State Water Plan. The data developed are generalized for use as such a tool. However, the computer program developed is such as to permit its later use in determining cost for specific projects.

Range Covered

Charts and printed output provide construction costs and water costs for the following ranges:

Average delivery rates: 2 MGD to 1,000 MGD (12 rates tabulated).
Pipe line length: 10 miles to 500 miles (9 lengths tabulated).
Peak factors: 1.0, 1.25, 1.50, 1.75, 2.0. (This is the ratio of maximum delivery date to the average annual delivery rate.)
Growth rates: 0, 3%/yr, 6%/yr, 10%/yr. (This is the rate at which the average annual use increases each year until the rated average delivery rate is reached.)
Static head slopes: 0, 4 ft/mi, 8 ft/mi, 12 ft/mi.

Cost Factors Included

Construction costs include pipeline cost (based on use of concrete cylinder pipe) and pump station costs. They include an allowance of 25% for engineering and contingencies. Right-of-way costs must be added to the costs given herein. No costs are included for the source of supply, for the extra cost of a pump station located in a reservoir at the beginning of a pipeline, or for terminal storage at the end. Cost of intermediate storage tanks or ponds is included, as is the cost of control and telemetering equipment for automatic, unattended operation of pump stations.

Water costs are computed on a present worth basis and represent the uniform rate at which water would have to be sold to repay the construction cost and pay the pumping costs, for the interest rate and amortization period assumed (4% and 40 years).

Water costs shown on the charts and in the output must be increased for right-of-way costs and for operating costs other than power. The procedure for doing this is set forth in this report.

Other Assumptions

The basic assumptions are:

Interest rate = 4.0% (Except for output AA - See below).
Amortization period = 40 years.
Pipe friction factor (Manning's n) = 0.011.
Maximum pump efficiency = 0.85.
Power cost (for over 500 KW per station) = $19.00/KW/Yr + 0.55¢/KWH.

Output

Output in 4 forms is obtained as follows:

Output A: Print-out of costs for each combination of the delivery rates, lengths and other factors used [Appendix A, Part I]. This print-out shows construction cost and water cost, for the most economical diameter and the most economical number of pump stations. (All data for 4% and 40 years.)

Output B: Print-out of costs for selected combinations of delivery rates, lengths and other factors [Appendix B, Part II]. This print-out shows cost data and maximum head per pump station for the range of diameter investigated for each combination. (All data for 4% and 40 years.)

Output C: Graphic charts [page 39] showing the same data as output A. These are useful for interpolating between the values of delivery rate, length and other parameters shown in output A.

Output AA: This is a partial repeat of output A for other interest rates and amortization periods [Appendix B, Part III].

Conclusions and Comments

Experience in developing these data and the analysis of the result indicates that:

1. Despite necessary approximation in input data and procedures, the results should be of entirely adequate accuracy for planning purposes.

2. By introducing various refinements (as subroutines in the program), the computer program could be used to develop costs for specific projects with almost any accuracy desired.

3. The output data reveal several facts of considerable interest, namely:

   a. The economical pipe diameter for a given peak factor and growth rate depends almost solely on the delivery rate. It is almost independent of the length of pipeline or static head.

   b. The maximum head per pump station, for the most economical pipe size and number of pump stations, is seldom much more or much less than 230 feet. This corresponds to 100 psi, the minimum pressure class assumed for most sizes of the concrete cylinder pipe used as a basis for the pipe cost data.

   c. The cost curves show a break in slope and curvature at a point corresponding to about 39 inches pipe diameter. This is apparently due to a break in the pipe cost curves at about this diameter. This break in the cost curves results from the fact that a different and more costly manufacturing process is used above about 39 inches diameter.

4. If water is to be sold at a higher price than the cost as determined herein (so as to provide for reserve or contingencies) a better "return on investment" may sometimes be secured by using a pipe diameter somewhat smaller than the "economical diameter" as determined herein.

PURPOSE AND SCOPE

For Use as a Planning Tool

Cost data developed in this study, and the charts which show these data, are intended primarily for use as a tool in planning water resource development. For this reason, the studies are generalized to a very great degree. Many factors and details which would require consideration in the design of a particular project have either been eliminated from the study, or have been covered by arbitrary or average allowances. The factors which have been eliminated from consideration are those which would be peculiar to particular regions of the state (such as topographic and soils conditions that would materially add to the cost), or which are not a direct function of the quantity of water to be transported (such as right-of-way cost and operation and maintenance costs). The latter costs cannot be neglected even in a planning study; hence the data developed herein will require modification for these factors in any use of the data.

Other Uses

It is anticipated that other uses than as a planning tool may be made of the data developed herein and/or the computer program from which the data was obtained. A complete print-out of the data shown on the charts is contained in Appendix A, together with a description of the program. Adjustments for some of the factors excluded from the analysis can be made merely by reference to this print-out data, with the aid of procedures described in this report. Additional print-out data can be obtained merely by rerunning the program with certain specified changes in the input commands.

The computer program is further arranged to permit its later use as a tool in preliminary design of specific pipeline projects after a basic plan has been established. For such use, additional types of input data would be specified, and certain subroutines would be called in. These would introduce refinements in the analysis and permit inclusion of factors which have been excluded or approximated in the present study.

Range Covered

The output data, and the charts which accompany this report, cover a range which should accommodate virtually any reasonable water pipeline project in Texas. The range of the various variables is as follows:

Average delivery capacity - 2 mgd to 1,000 mgd.
Pipeline lengths - 10 miles to 500 miles.
Peak factors - 1.0, 1.25, 1.50, 1.75, and 2.0.
Growth rates - 0, 3% per year, 6% per year, and 10% per year.
Static head slopes - 0, 4 ft per mile, 8 ft per mile, and 12 ft per mile.

Limited Detail

The amount of detail included in these studies has been limited, consistent with the intended use of the data, and as required to present the output data in manageable form. For the same reason, the results have been plotted on logarithmic coordinate paper. The number of curves plotted on each chart, and the number of points on each curve, were selected so as to be consistent with the requirements of this type of a coordinate plotting system. The amount of detail covered in the input data was also limited to the expected requirements of plotting the curves with reasonable accuracy.

Output

The primary output data is presented in two forms. One of these (sometimes called "Output C") is a set of 20 charts--one chart for each combination of peak rate and growth factor. The left-hand side of each chart presents the construction cost of pipeline project and the cost of water, for a static head slope equal to zero; that is, for a level profile. The right-hand side of each chart shows adjustment factors for other static head slopes than zero.

The other form of the output data is a tabulation which is included in Appendix A. This tabulation is a print-out from the computer and shows all of the data from which the charts were prepared--it is designated as "Output A".

Appendix B contains several pages of tabulation designated as "Output B". These tabulations are additional or supplementary to those in Output A. Output A shows the data for the most economical pipeline diameter for each of the delivery rates, lengths of pipeline, and other factors studied. Output B shows similar data for the complete range of diameters considered in order to obtain the most economical diameter. The computer program is such as to permit a complete print-out of Output B; however, this would have required over 1,000 pages of computer print-out. It does not appear that Output B will be of use

except in certain specific cases. Hence only a limited number of print-outs are included in this report. These were prepared primarily as a check on the process of selecting the most economical pipeline diameter.

Appendix B also includes comparative print-outs similar to Output A for varying interest rates and amortization periods. These are denoted as "Output AA".

Exclusions

Specifically, the factors which were excluded from consideration in these studies are as follows:

(1) Cost of pipeline right-of-way.

(2) The additional cost (over that of a typical "booster" station) of a pump station intake structure, such as may be required at the reservoir end of a pipeline.

(3) The cost of terminal storage at the terminal end of the pipeline (such as will normally be required for pipelines operated at low peak factors).

(4) The cost of maintenance and replacement, and of operation costs, other than pumping.

(5) The cost of variations in pipeline alignment from a uniform profile gradient (however, both pipeline and pump station costs have been increased by a factor of 25% to allow for engineering, contingencies and cost factors not specifically included in the analysis).

In addition, no provision has been made for a deferment of pumps or pump stations, during the early years of operation, for pipelines in which a growth factor is included.

DESCRIPTION OF INPUT DATA AND BASIC ASSUMPTIONS

Peak Factors and Growth Rates

Peak Factor.--This term, as used herein, represents the ratio of the maximum rate of delivery for the pipeline to the average annual rate of delivery. This annual average is the rated capacity listed in the output data.

Growth Rate.--This term, as used herein, represents the rate of increase in average annual delivery of water during the early stages of operation of the pipeline. A zero growth rate indicates that the pipeline will be used at its rated capacity beginning with the first year of operation.

Details of Application.--The peak factor as used here is a function of the pipeline and pumping facilities. It is only indirectly related to the peak factor for the city or industry which is being supplied. If the latter peak factor is greater than the pipeline peak factor, terminal storage will be

needed to supply the difference. In any specific case the charts developed herein can be used, in conjunction with the estimated cost of terminal storage, to determine the most economical peak factor for the pipeline.

Where the growth rate is other than zero, the pipeline will be operated at less than its rated capacity during the growth period. In such case a pipeline designed for a peak factor greater than unity could be operated at a unity peak factor, or some intermediate value, during the growth period. However, efficient operation during this period will probably involve deferment of pumps or pump stations, bypassing of intermediate pump stations, or similar measures. Such procedures cannot readily be generalized, and they may result in a value of the peak factor during the growth period which is nearly the same as the value after the pipeline is operating at capacity. Hence it is assumed herein that the peak factor remains constant during the growth period. Furthermore, a higher peak factor generally results in a lower operating efficiency. The assumption of a higher peak factor than may actually occur will partially account for the reduction in efficiency which may occur when operating a pipeline greatly below its design capacity (due to reduced head on the pumps).

Pipe Costs

The pipe costs used as input data to the program are listed in Table I. These costs are based on cost information for prestressed concrete cylinder pipe, obtained from the Gifford-Hill-American Concrete Pipe Company, and developed by them for the purposes of this program. The information so furnished was extended and extrapolated to cover the range required for this study. Laying costs were estimated on the basis of average conditions in non-urban areas. The assumed laying cost for each diameter of pipe is shown in Fig. 1. As previously stated, the sum of pipe costs and estimated laying cost was increased by 25% to allow for engineering and contingencies. It is believed that this allowance will cover cost items not specifically estimated, such as road and stream crossings, anchorages at bends in the pipeline, and devices to control water hammer to a reasonable amount.

The use of concrete pipe as a basis for estimating pipeline costs is not intended in any way to suggest a preference on the part of the Texas Water Development Board for this type of pipe as compared with other types. Selection was made purely for convenience, because of the ready availability of cost data for a wide range of sizes, and because the pressure classes are well determined, and the diameters standardized. These factors permitted the use of these data in the computer program with a minimum of difficulty. It is believed that the results so obtained will provide conservative cost estimates for planning purposes.

Manufacturing experience for this type of pipe is essentially limited to pipe 12 ft in diameter or less, and no cost information was received for larger pipe. Cost input data for larger sizes was extrapolated for this study, and the resulting output data must be considered as approximate.

Water Hammer

In line with current recommendations of the AWWA for prestressed concrete cylinder pipe, no specific allowance for water hammer is made in these studies.

It is assumed that pump stations will be appropriately designed to limit water hammer to very low values, and that air-vacuum valves and/or surge tanks will be installed on the pipelines as required to eliminate dangerous surges following unanticipated pump stoppage.

Pipe Friction

Friction losses in the pipe are based upon use of the Mannings Formula, assuming n = 0.011. This value is approximately equivalent to a Hazen Williams Coefficient C = 140, a common value for large concrete pipelines, provided they are properly installed and maintained. The Mannings formula is more convenient for use in the various formulas required herein, and it is probably more applicable, with a single value, to a large range of pipe diameters.

Economical Pipe Diameters

Fig. 2 shows the economical pipe diameter plotted against the peak delivery rate (Average rate x peak factor). Two curves are shown, for peak factors equal to 1.0 and 2.0, respectively.

Pump Plant Costs

Previous experience, in conjunction with additional rough estimates made for this study, indicated that the cost of the pumping plants would constitute a relatively small portion of the total cost in the majority of the pipeline projects--at least where a pipe of the most economical diameter is used. For this reason, extreme refinement in development of pump plant costs did not appear warranted. Pump plant costs were introduced into the program in the form of formulas designed to cover the range of delivery rates involved and the heads associated with most economical pipe diameters for the greatest part of the range covered. The formulas contain factors to allow for variations in pump plant costs with peak factors and static head slopes. Where a growth rate is involved, the pump plant cost is that required to deliver the full capacity of the pipeline after the end of the growth period.

The formulas were developed from cost data for typical pump plants of several capacities[1/] and for a considerable range of pump and motor sizes.

Preliminary analysis showed that the head range for economical diameter is fairly limited--generally from about 220 feet to 250 feet. Under the circumstances the following general formula is appropriate:

$$CPST = \frac{CK1 \times Q\ Max}{E3} + \frac{CK2 \times Q\ Max \times H\ Max}{E4 \times E1}$$

[1/] Taken from data furnished by the U.S. Bureau of Reclamation for pump plants on the Canadian River Project in West Texas.

Where: CPST = Pump station cost
CK1 and CK2 are cost factors
E3 and E4 are factors described below
Q Max and H Max are maximum delivery rate and corresponding head
E1 is the normal pumping efficiency.

In this formula the first term represents cost of pumps, valves, piping, structure, and forebay storage. All of these are generally proportional to the delivery rate. The second term represents the cost of motors and electrical facilities--these are generally proportional to horsepower, which in turn is proportional to Q x H.

The factor E3 represents the additional pump installation required to permit efficient pumping at times when the delivery rate is relatively low, and for cases where the peak factor is high and the static head low. In the present analysis it is assumed that special pumps are provided for such conditions--these being additional to the pumps required for maximum delivery. If Q Max and Q Min are the maximum and minimum delivery rates:

$$E3 = \frac{Q\ Max}{Q\ Min + Q\ Max} = \frac{1}{1 + \frac{Q\ Min}{Q\ Max}} \qquad (1)$$

The factor E4 represents the additional motor and electrical installation for the additional pumps discussed above. In this case if Hs = 0:

$$HP \text{ for } Q\ Min = K \times Q\ Min \times H\ Min = K \times Q\ Min \left(\frac{Q\ Min}{Q\ Max}\right)^2 H\ Max$$

$$= \left(\frac{Q\ Min}{Q\ Max}\right)^3 \text{ Max HP}$$

$$E4 = \text{Ratio } \frac{\text{Req'd HP}}{\text{Total HP}} = \frac{1}{1 + \left(\frac{Q\ Min}{Q\ Max}\right)^3}$$

(K = Horsepower conversion factor[2/])

Assuming Q Min = rQAV (QAV = Average delivery rate in MGD)

Q Max = PKF x QAV (PKF = Peak factor)

$$\frac{Q\ Min}{Q\ Max} = \frac{r}{PKF}$$

$$E4 = \frac{1}{1 + \left(\frac{r}{PKF}\right)^3} \qquad (2)$$

[2/] Actual value of K not required for use in the final formula.

Values of E3 and E4 are estimated as follows (Hs = 0):

	E3	E4
PKF = 1.75, r = 0.75, r/PKF = .43----------	.70	.92
PKF = 2.0, r = 0.70, r/RKF = .35----------	.74	.96

For PKF $\leq$ 1.5, E3 and E4 are both assumed equal to 1.00.

Values of E3 and E4 for HS> 0 are estimated and given in Table II-B.

More specifically the pump station cost formula becomes:

$$CPST = QAV \times \left(PKF \times \frac{CK1}{E3} + \frac{CK2 \times H\ Max}{E1 \times E4} \right) \quad (3)$$

Where QAV = Average delivery required
PKF = Peak factor
CK1, CK2 = Cost factors defined below
E1, E3, and E4 = efficiencies as previously discussed
H Max = Head at maximum delivery rate

Fig. 3 shows the results of plotting pump costs, motor costs and pump plant costs to obtain CK 1 and CK 2. Values of the latter are shown by the heavy lines, which have the following general formulas:

$$CK\ 1 = a(Q\ Max)^b \quad (4)$$

$$CK\ 2 = c(Q\ Max)^d$$

Values of a, b, c and d, as obtained from Fig. 3 are shown in Table II-A.

Note that CK 1 and CK 2 are shown as having constant values for Q Max > 350 MGD. Up to this point a typical pump station will have 3 or 4 pumps, and pump capacities increase as Q Max increases. Available data indicate that for pump capacities greater than about 60,000 gpm (capacity of 4 pumps = 350 MGD) the cost of pumps plus motor will no longer decrease further with increasing capacity. Hence it is assumed that pump station capacities above 350 MGD will be obtained by increasing the number of pumps.

Values of CK 1 and CK 2 plotted on Fig. 3 include a 25% allowance for engineering and contingencies. They also include cost of automatic control and telemetering equipment.

It should be noted that the formula as developed herein for pump station cost can be considered reliable only for a head range in the neighborhood of 200 to 250 feet. This range will generally correspond to the pumping head for most economic size of pipe and most economic number of pump stations.

Efficiencies

The input data includes four efficiency factors for use in pumping and pump station costs as follows:

E1 - Efficiency of pumps at maximum head and capacity.

E2 - Average operating efficiency of pumping over full range of delivery rates.

E3 - } Factors (not actually efficiencies) previously discussed in
E4 - } connection with pump station cost.

Efficiency E1 is used in connection with the KW portion of pumping cost, and as a part of the factor to determine the motor and electrical facility component of pump station cost. Efficiency E2 is used in connection with the KWH portion of the pumping cost.

Efficiency E1 has a relatively small variation and is assumed equal to 0.85 throughout this study. Values of the other efficiencies were estimated for the range of peak factors and static head slopes and are listed in Table II-B.

Figs. 4, 5, 6 and 7 are duration of pumping curves for the several peak factors involved. For reference they are plotted against a duration of use curve developed from water use data for the city of Austin for the period 1959 - 1965. The above charts were used to estimate the average operating efficiencies shown in Table II-B.

Interest Rate and Amortization Period

As agreed with the Texas Water Development Board, the charts and the outputs A, B and C were based upon an assumed interest rate of 4% and an amortization period of 40 years. The effect of using other interest rates is discussed later on.

Power Costs

Assumed power costs used in estimating the cost of pumping were obtained from published schedules of several Texas electric utilities, supplemented by conversations with representatives of one of these utilities regarding probable rates which would be applicable to large pumping installations.

The pumping cost formula contains two factors representing cost of power--one a cost per maximum kilowatt during each year and the second a cost per kilowatt hour. Hence the formula is,

$$\text{Annual Pumping Cost} = C1 \times \text{Max KW(in a year)} + C2 \times \text{KWH/Yr} \qquad (5)$$

Power cost factors assumed for this study are:

For installations equal to or less than 500 KW:

C1 = \$3000/Yr (independent of the Max KW)

C2 = 1.00 ¢/KWH

For installations over 500 KW:

C1 = $19.00/KW/Yr

C2 = 0.55 ¢/KWH

In selection of values of C1 and C2, each pump station is considered as a separate installation.

The above values of C1 and C2 are average values for each of the ranges indicated. Within each range they approach the weighted average cost of electric energy for the group of electric utilities considered and for the probable range of load factors. The weighted average for the group of utilities was obtained by assigning weight factors to each rate schedule as follows:

Utility	Weight factor
Texas Power and Light Co.	4
Texas Electric Service Co.	3
Gulf States Utilities	2
Central Power and Light Co.	1
West Texas Utilities	1
Southwest Public Service Co.	1
Lower Colorado River Authority	1
Total of weight factors	13

These weight factors were assumed in accordance with an assumed distribution of probable pipeline locations in a State Water Plan.

Analysis of results indicates that water costs will generally change only 3 or 4% for changes in power costs up to 15 to 25%.

Two facts regarding actual power costs were brought out in conversation with the power company representatives:

1. For large installations (above about 5,000 to 10,000 KW per pump station), more favorable power costs can be obtained if the pump station installation includes the substation, and if power is taken at transmission voltage.

2. For many pump stations in isolated areas, power costs may increase due to the need for amortizing the power companies investment in the transmission lines required to serve the pump station.

Criterion

The basic criterion for determining the cost of water in this study is that if all the water delivered were sold at this cost, the revenues would be sufficient to pay the annual pumping cost and to amortize the investment in the pipeline and pumping stations over the amortization period.

Since one of the omitted factors in this analysis is the cost of operating and maintaining the project, it is evident that an increment of cost for this purpose would have to be added to the cost shown on the charts and listed in the output data. A procedure for making this adjustment is discussed in a subsequent section of this report.

As discussed and agreed upon with the Texas Water Development Board staff prior to starting this study, the actual computation of the cost of water in this study is determined by the "present worth" method. It is believed that this gives the most reliable index of comparative costs on a generalized basis, and is directly applicable to projects which would be financed through the Texas Water Development Board.

Comparison of Possible Methods of Computing Water Costs

In general, there are three possible ways in which the cost of water could be stated, as follows:

(1) The Annual Cost Basis.

(2) Capitalized Cost Basis.

(3) Present Worth Basis.

The application and essential differences between the three methods are shown by the illustrative example in Tables III-A, III-B and III-C. Table III-A shows the application of the three methods to the case of a project in which the use of the facility is uniform throughout the period of amortization. Furthermore, the assumed basis for retiring of capital costs is a uniform series of equal payments throughout the amortization period. For these conditions the three methods of computing costs of water give exactly the same results.

Analysis by the present worth basis involves a concept of present worth not commonly considered in discussions of this factor. This concept is the "present worth of water used". This expression merely signifies the quantity obtained by multiplying the average annual use of water by the present worth factor. The result is stated in millions of gallons, rather than in dollars as is customarily the case in present worth statements; this number of million gallons, multiplied by the cost per million gallons, will equal the present worth of the revenues obtained from the sale of water at this rate.

Table III-B shows the application of the three methods to the case where the use of the facility has a growth rate of 10%. In this case the use gradually increases over the first 10 years of the amortization period and reaches the design capacity at the end of the 10th year. In such case the annual cost (based on a uniform series of payments for interest and amortization) is very high the first year, and gradually diminishes. From the 10th year onward the annual cost is the same as that obtained in Table III-A. For the case shown by Table III-B, the unit cost obtained on a present worth basis is about 10% higher than that obtained on a capitalized basis.

The analysis shown in Table III-C covers the same condition as illustrated in Table III-B, with the difference that it is assumed that no amortization payments would be made for the first 5 years, but that interest would be paid during this period. Under this procedure the annual cost for the first 5 years would be considerably reduced over that shown in Table III-B. The unit cost computed on a capitalized basis would be increased somewhat, but that computed on the present worth basis would be unchanged.

It is essentially because the cost of water obtained by the present worth basis is unaffected by the method of amortization that this method has been adopted for the purposes of this study. It is evident that, for the specific case illustrated in Tables III-B and III-C, it would probably not be feasible to make a charge for water delivered during the first 2 or 3 years sufficient even to pay the interest. If water were to be sold at a uniform rate throughout the amortization period it would be necessary to obtain supplementary funds during the growth period to make up for the difference between the annual costs and the revenues. This can be done in several manners, including the levying of a tax, the funding of interest and deferment of amortization payments, or the provision of a reserve fund in the initial financing sufficient to pay the deficiencies in the interest payments during the first several years. The method used would affect the cost of water if the analysis is made on a capitalized basis; but it will not affect the cost of water on a present worth basis (because the present worth of any series of payments to amortize a debt is equal to the amount of the debt).

Present Worth Formulas

The basic formula for determining cost of water on a present worth basis is as follows:

$$\text{Cost of Water} = \frac{\text{Total Investment Cost + Present Worth of Pumping Costs}}{\text{Present Worth of Water Delivered}}$$

or in mathematical terms:

$$WC = \frac{CPL + CPST + \int_0^N \text{Present Worth } (C1 \times KW + C2 \times KWH/Yr)}{365 \int_0^N (Q\ Avg \times \text{Present Worth Factor})} \qquad (6)$$

Where WC = Water cost in $/MG

CPL = Pipeline Investment Cost

CPST = Pump Station Investment Cost

N = No. of Years for Amortization

C1 = Power Cost in $/KW/Yr

KW = Maximum Kilowatts in a year

C2 = Power Cost in $/KWH

Q Avg = Average Annual Delivery, MGD

Table IV shows the formulas for present worth of water delivered and of pumping cost.

OUTLINE OF COMPUTER PROGRAM

An abbreviated summary of the computer program is shown in Table V; a detailed block diagram for the program is given in Appendix A, and a print-out of the Fortran expression of this block diagram is in Appendix B.[3/]

Basically the purpose of the program is first to obtain the most economical pipe diameter, and the most economical number of pump stations, for the specified conditions, and then print out the project cost and water costs for the most economical diameter. The results obtained from the computer are shown in both printed and graphical form. Provisions for printing the supplementary output for other diameters considered are included.

Input Data

The input data for this program consists of three types of information, namely:

1. Cost information for the various sizes and pressure classes of pipe, for the constants to be used in obtaining the cost of pumping and the cost of pumping plants.

2. Values of several other factors which are used throughout the computations. Some of these could have been included with the program, but are listed as input data to facilitate later change in these values, in case the program is to be rerun later for other uses than the output desired in these studies. These factors include: the assumed pumping efficiencies, the interest rate, the amortization period, the static head slopes used, the specified peak rates and growth rates and the assumed friction coefficient for the pipe.

3. The third class of input data consists of several indexes to regulate the internal operation of the program. One set of these specifies the types of printed output required, and in case of Output B, the particular conditions for which the printed output shall appear. Another index permits the program

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[3/] Both block diagram and program print-out include a "best fit" line plotting subroutine not finally used for this report.

to be rerun with different interest rates and amortization periods. Still another index is inserted to permit later use of the program with adjustments for conditions such as the following:

(1) Variations in the topography such as to cause an irregular profile of the pipeline.

(2) Cost of right-of-way.

(3) Variable pipe laying costs.

(4) Deferment of pumps or pump stations.

(5) An initial rate of water delivery different from that assumed in the generalized program.

(6) Addition of costs for operation, maintenance and replacement.

In the present study the input values for the index to provide for the above six factors is zero; this value eliminates consideration of these factors in operation of the program. If it is later desired to rerun the program and include some or all of these factors, the corresponding index can be given a value of one, which will then activate this portion of the program. Additional matrices will be needed to provide values of the input for the several factors, and subroutines will be required for insertion in the program to cover the operations needed to take these factors into account. These subroutines have not been written as part of the present study.

Formats for Input and Output

The printed outputs shown in the appendices illustrate the format of the output.

Also included in the appendices are print-outs of all of the input data; these show the required format for incorporation of the data. An index to the card numbers on which the various input items are located is found on Table VI.

Reuse of Program

As may be seen from the above discussion, the program is designed to provide maximum flexibility and reuse of the program for other conditions than those on which the present study is based. By suitable changes in the input data it is possible to vary the conditions to be analyzed and the constants and assumptions used in the analysis. By activating portions of the program which were not used in this study, it is also possible to include a number of factors which were not included in the present study. It will however be necessary to develop the subroutines for inclusion of these factors.

DISCUSSION OF COST CHARTS

On each of Charts 1 to 20 inclusive the average delivery rate appears on the vertical scale and cost or cost factors on the horizontal scale.

Water costs for zero static head are shown for a number of pipeline lengths. Values for intermediate lengths can be interpolated easily, if it is noted that water cost is nearly proportional to pipeline length.

Construction costs per mile vary only slightly with the length of line, and curves are shown only for lengths of 10 miles and 100 miles. The latter curve will generally apply for lengths greater than 100 miles.

Economical pipe diameter in inches is indicated by the numbers adjacent to each plotting point for water costs.

The correction factors for the various static head slopes vary slightly with the length of line, but for lengths greater than 60 miles this variation is small. The correction factors shown apply to such lengths--values for shorter lengths can be obtained from Output A in Appendix A.

The upper dashed portions of the various curves are for pipe diameters greater than 144 inches. Pipe cost data for diameters larger than this were obtained by extrapolation, and the results must be considered as approximate. The lower portions (below 2 MGD) are also shown dashed, because 2 MGD was the minimum delivery rate for which plotting points were computed.

The curves for construction cost and construction cost correction factors do not correspond exactly with the printed output in all cases. Some erratic plotting points have been skipped. Such points generally correspond to pipe diameters which give only slightly smaller water costs than the next smaller diameter. It is obvious that in any actual project the next smaller diameter would generally be used in such cases. This is because the criterion of minimum water cost may not always be adequate for selection of most economical pipe diameter. In most cases water will probably be sold at a rate somewhat above the actual cost, in order to provide a reserve, or to allow for contingencies. If so, a better "return on investment" can sometimes be secured if the pipeline diameter is somewhat smaller than the diameter for which water cost is a minimum. The extent to which a smaller diameter will provide a larger return on investment will depend upon the "mark-up", of selling price over cost of water, and can be determined by reference to Output B in Appendix B.

The Fortran Program printed out in Appendix B includes provisions which program the plotter to draw the water cost and construction cost curves for zero static head. One set of output charts were so plotted. On those charts the curves for each length of pipeline were drawn in as a straight line--this being the "best fit" line for the plotted points. The best fit was determined by a "least squares" subroutine. However, it was found that the plotted points showed several systematic departures from the straight line, especially for points corresponding to about 39-inch pipe diameter. Pipe cost curves have a break at this diameter due to a change in the manufacturing process for concrete cylinder pipe. For this reason it appeared that the straight lines of best fit were not the best expression of the data, and the broken curves as shown on the charts were plotted instead. The best fit and line plotting portion of the Fortran program were not used in the final plotting.

RULES FOR MODIFYING RESULTS FROM CURVES

As previously stated, certain cost components were omitted from the costs determined herein. Discussed below are the procedures for modifying the results obtained from the curves, both for such omitted factors and for certain changes in the basic assumptions.

The modifications discussed in this section are intended for use in planning studies. In any actual design it would probably be better to modify the input data and rerun the program.

Correction for Right-of-Way Costs

Assuming this cost can be determined as an average number of dollars per mile, the correction to the construction cost to obtain the project cost will be a simple addition to the construction costs as shown by the curves.

The correction to water cost per 1000 gallons can be obtained from the following formula:

$$\Delta WC = \frac{RWC \times L}{QAvg \times PWF \times 3650} \qquad (7)$$

Where ΔWC = Increased water cost, ¢/1000 gal

RWC = Right-of-way cost, $/mi

L = Length in miles

QAvg = Average delivery rate, MGD

PWF = Present worth factor (as shown on each page in Part I of Appendix A)

Correction for Operating Costs (Other than Power)

Water costs as plotted and shown on the output sheets include only the power cost component of operating costs. To this must be added a correction for operating salaries, maintenance and replacement. A suggested procedure for determining such costs is given in Appendix A.

Assuming that the operating costs other than power can be expressed as a uniform amount in dollars per year throughout the period of amortization, the correction to water cost for this cost component can be obtained by the following formula:

$$\Delta WC = \frac{OPC \times 19.79}{QAvg \times PWF \times 3650} \qquad (8)$$

Where OPC = operating cost in $/Yr, and other terms are as defined for equation (7).

(The factor of 19.79 is the present worth of an annuity of $1/Yr)

Correction for Change in Interest Rate or Amortization Period

Examination of Table IV shows that interest rate and amortization period appear in several of the basic formulas. For this reason there is no simple way to modify the results for a change from the assumed interest rate or amortization period. The only really satisfactory method of determining the effect of such a change is to change the output data and rerun the printed output.

This was done for a limited range of the several variables and the results are included in the appendices.

Critical examination of these results led to some approximate generalizations. First it was found that peak factor and pipeline length have an insignificant effect on the variation of water cost with interest rate and amortization period. Next it was found that the rated capacity of the pipeline has a relatively small effect on this variation, so long as growth rate and static head slope are held constant. Hence it is possible to plot up a family of curves showing a "Correction Factor" for water cost, for the range of interest rates and amortization periods investigated. Fig. 8 shows such a plotting. The meaning and use of the so-called "Correction Factor" is noted on the chart.

Fig. 8 is really three separate families of curves--one family for each amortization period. Each line in a family represents one combination of growth rate and static head slope. Only a limited number of combinations were plotted, in order to avoid confusion in the results.

Approximate interpolation of intermediate combinations is possible--for more precise values it will be necessary to refer to the printed results in the appendices.

For interpolating between different amortization periods for a given interest rate, an auxiliary family of curves, in which the correction factor is plotted against the amortization period, will be helpful. Such a family can be obtained quite readily merely by "transversing" the curves in Fig. 8 for the interest rate desired.

The approximate incremental water cost due to changes in interest or amortization rate can be found by selecting a percentage from Fig. 8 (or computing one with the aid of Appendix B) and by using the following formula:

$$\Delta WC = \frac{(\text{Water Cost for } 4\% - 40 \text{ Years}) \times \text{Correction Factor}}{100} \qquad (9)$$

(Note that ΔWC can be either positive or negative.)

ILLUSTRATIONS

CONTENTS OF ILLUSTRATIONS

ILLUSTRATIONS

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TABLE II-A	Values of Pump Station Cost Factors
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COST CHARTS

COST OF TRANSPORTING WATER BY PIPELINE

Chart No.	Peak Factor	Growth Rate
1	1.00	0%
2	1.00	10%
3	1.00	6%
4	1.00	3%
5	1.25	0%
6	1.25	10%
7	1.25	6%
8	1.25	3%
9	1.50	0%
10	1.50	10%
11	1.50	6%
12	1.50	3%
13	1.75	0%
14	1.75	10%
15	1.75	6%
16	1.75	3%
17	2.00	0%
18	2.00	10%
19	2.00	6%
20	2.00	3%

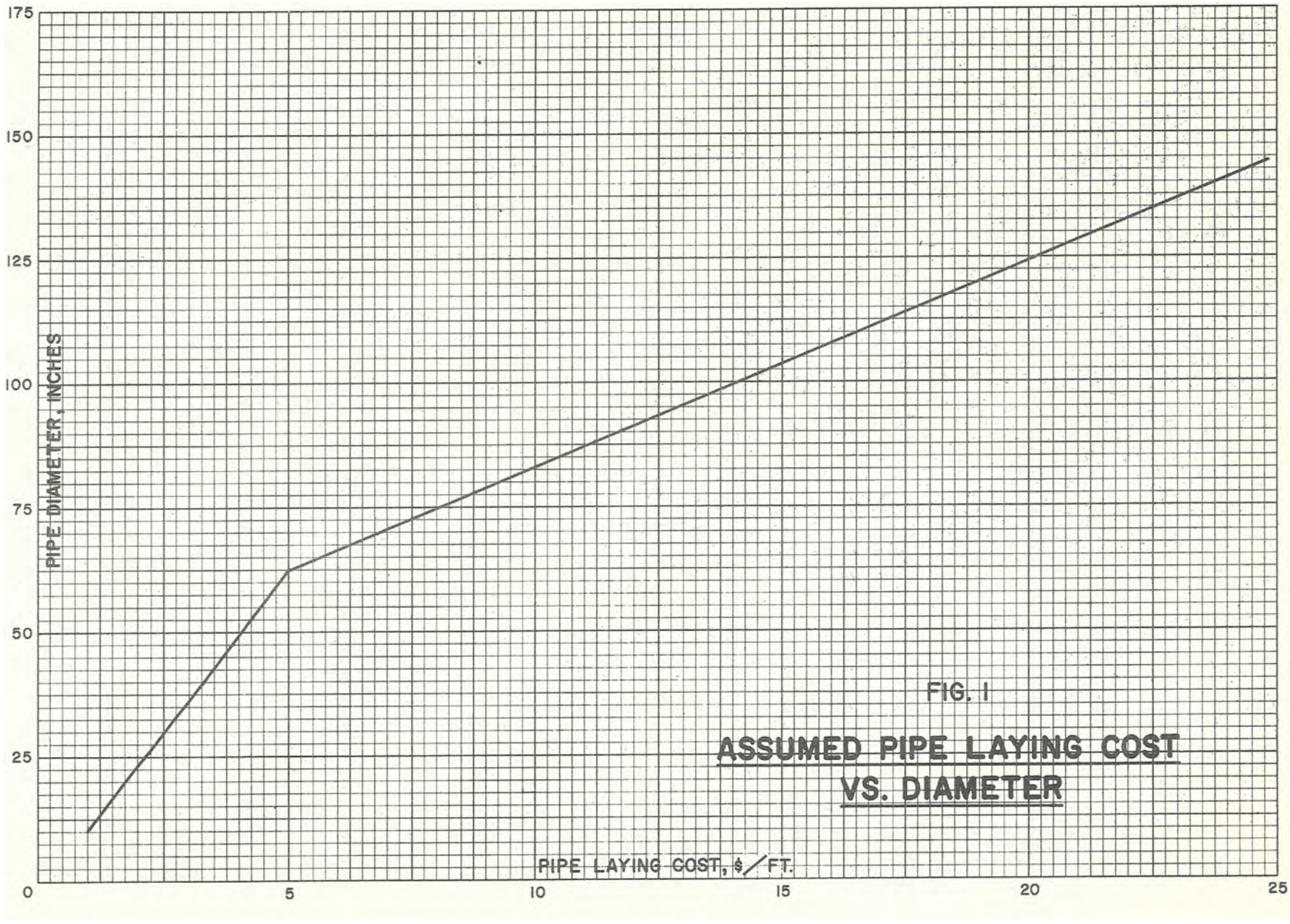


FIG. 1

ASSUMED PIPE LAYING COST VS. DIAMETER

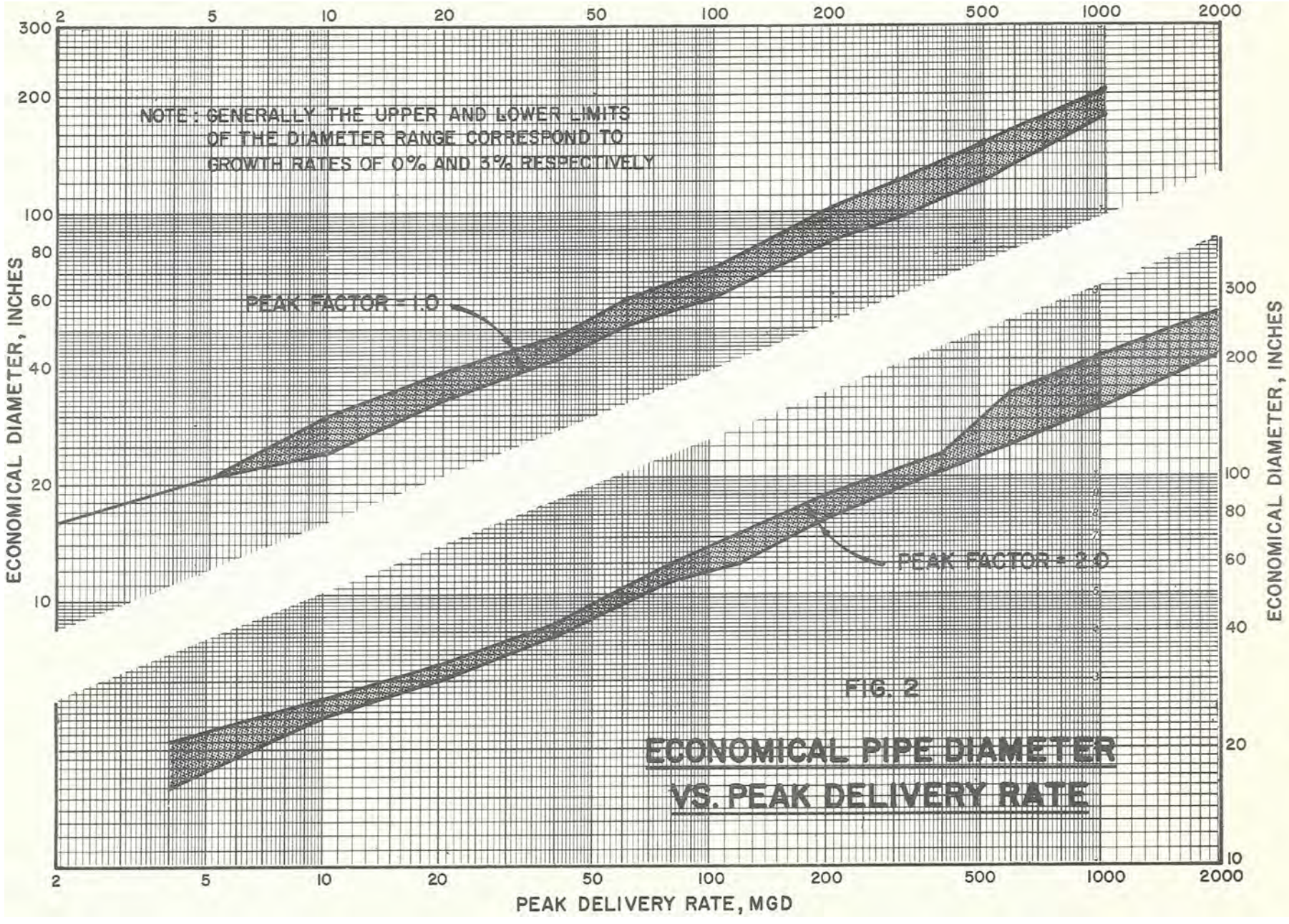


FIG. 2

ECONOMICAL PIPE DIAMETER VS. PEAK DELIVERY RATE

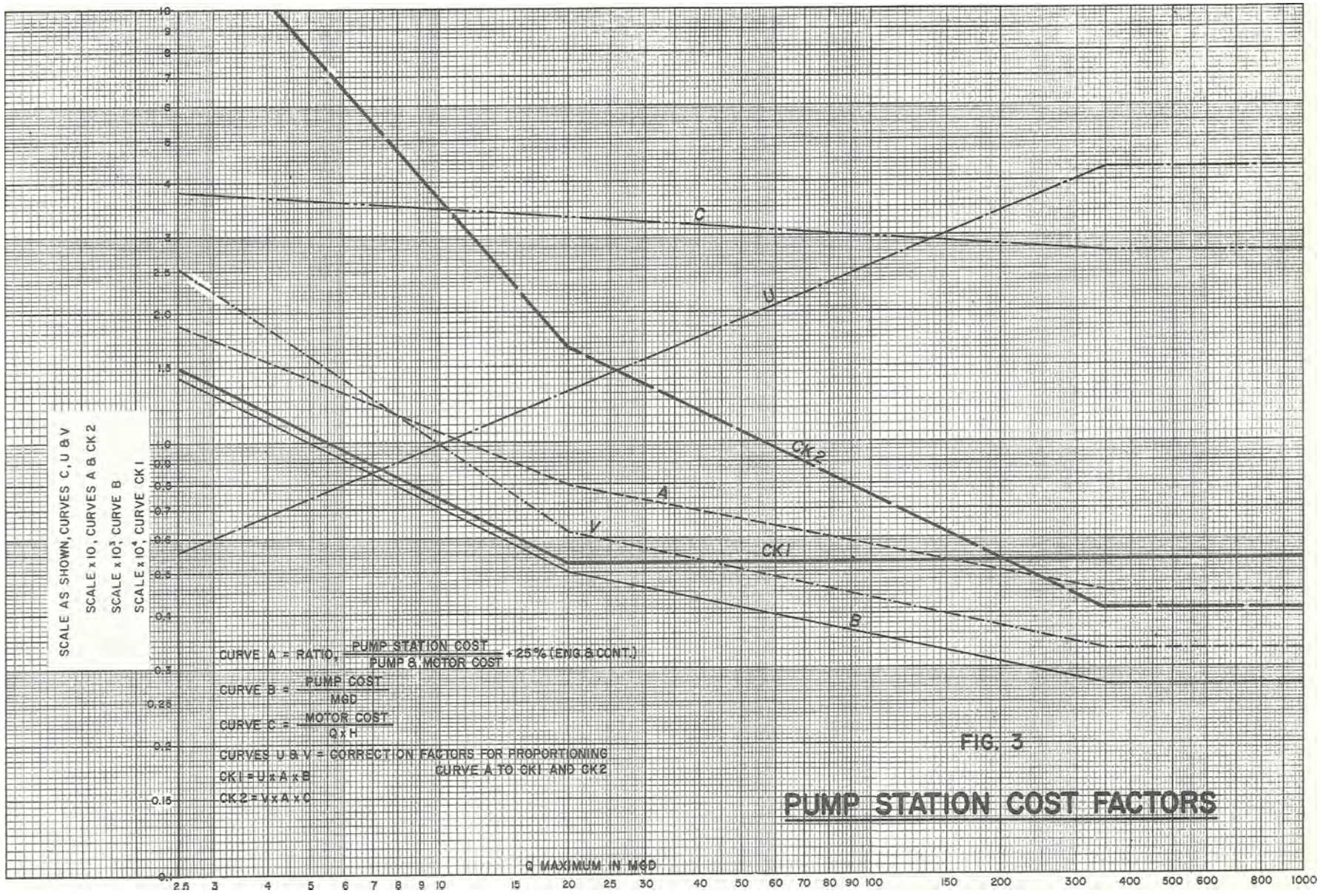


FIG. 3

PUMP STATION COST FACTORS

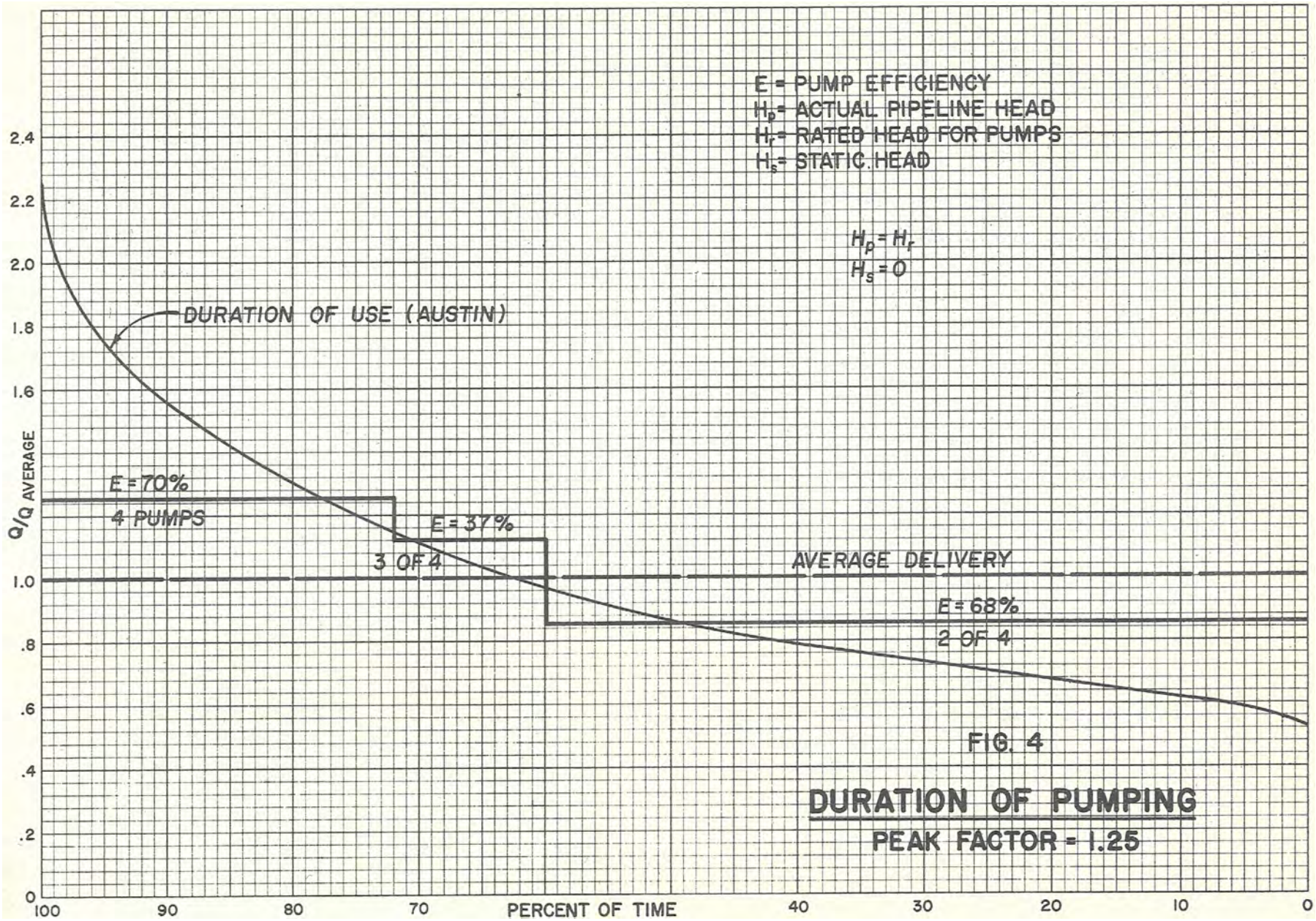


FIG. 4

DURATION OF PUMPING

PEAK FACTOR = 1.25

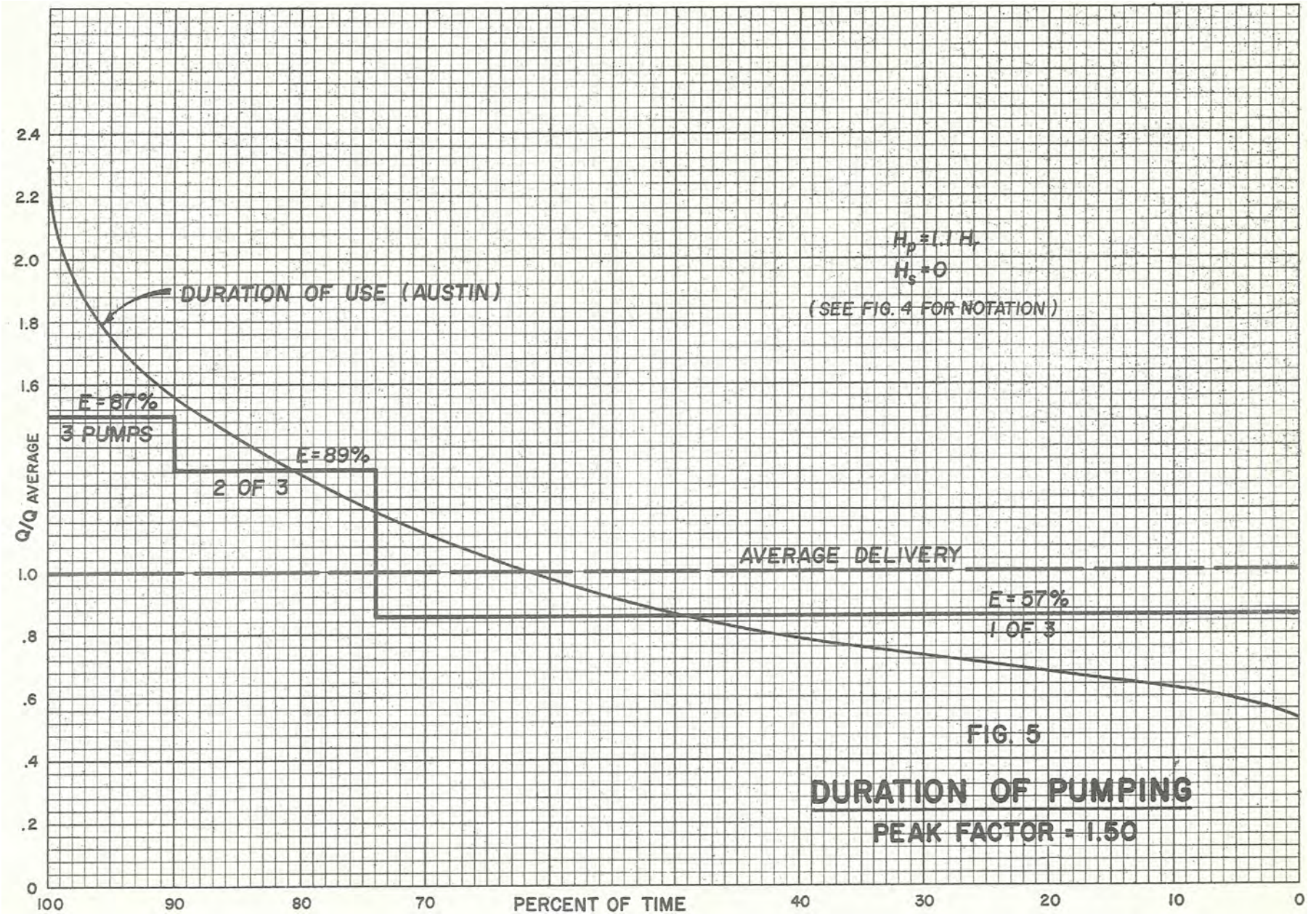


FIG. 5

DURATION OF PUMPING

PEAK FACTOR = 1.50

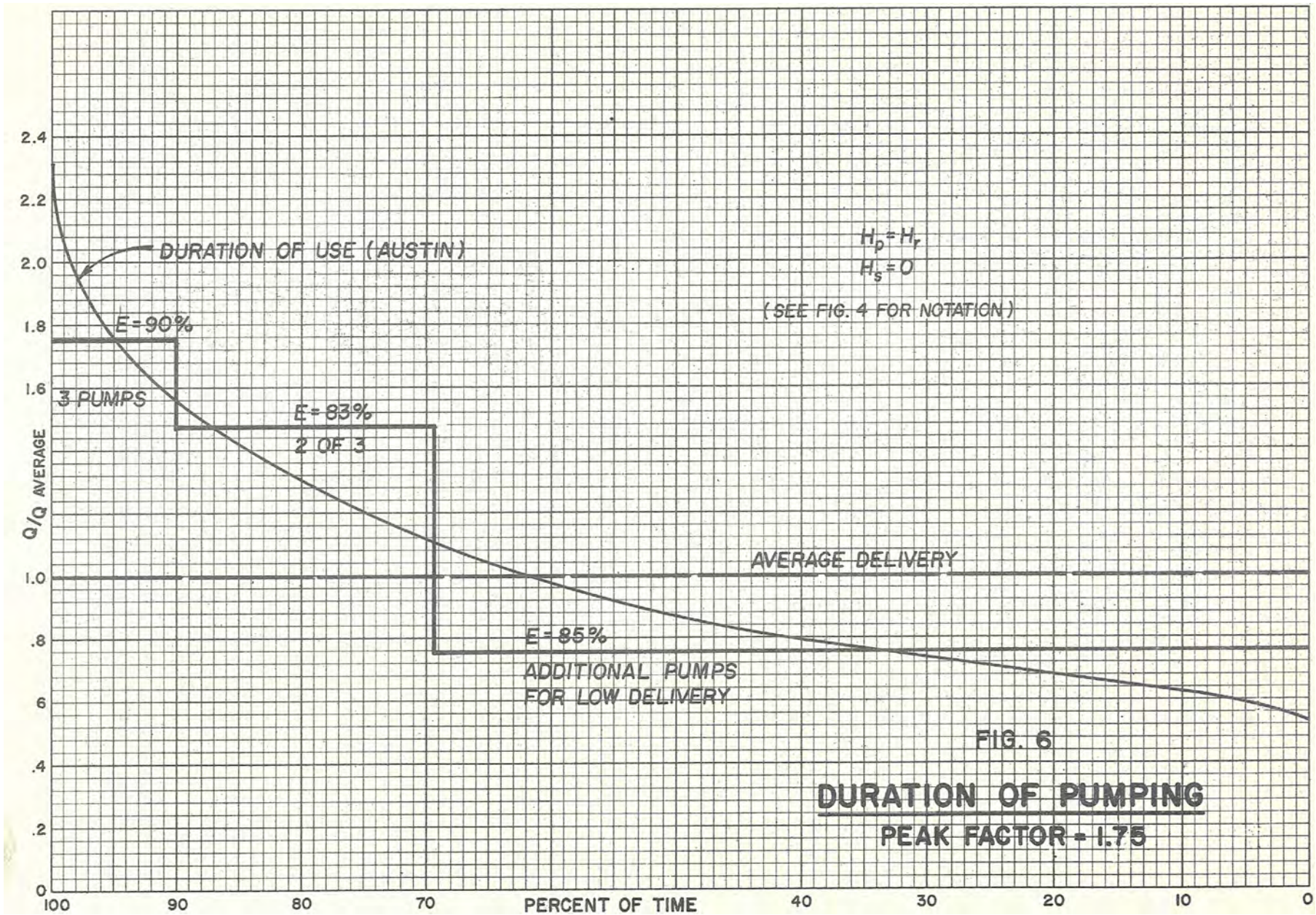


FIG. 6

DURATION OF PUMPING

PEAK FACTOR = 1.75

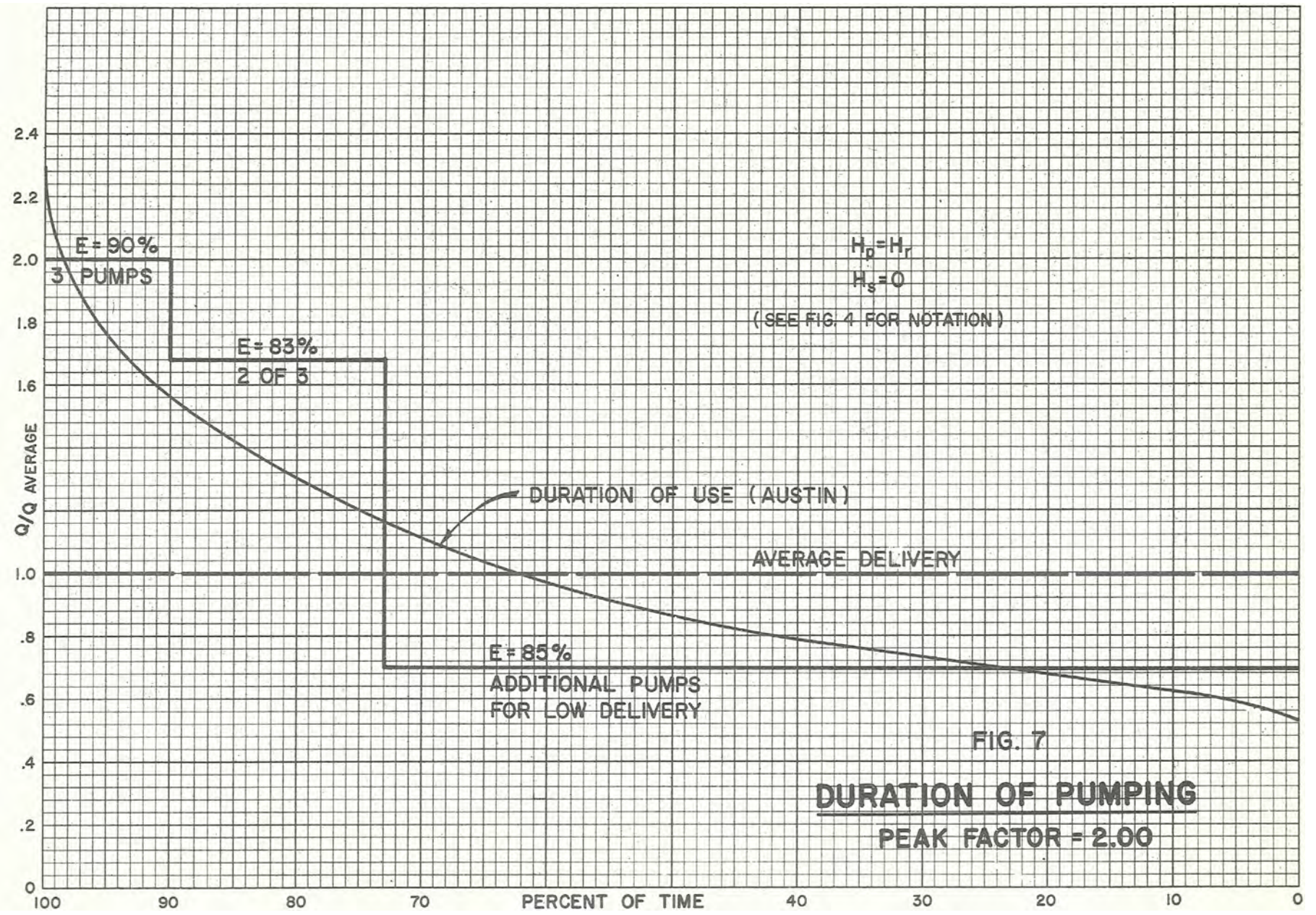
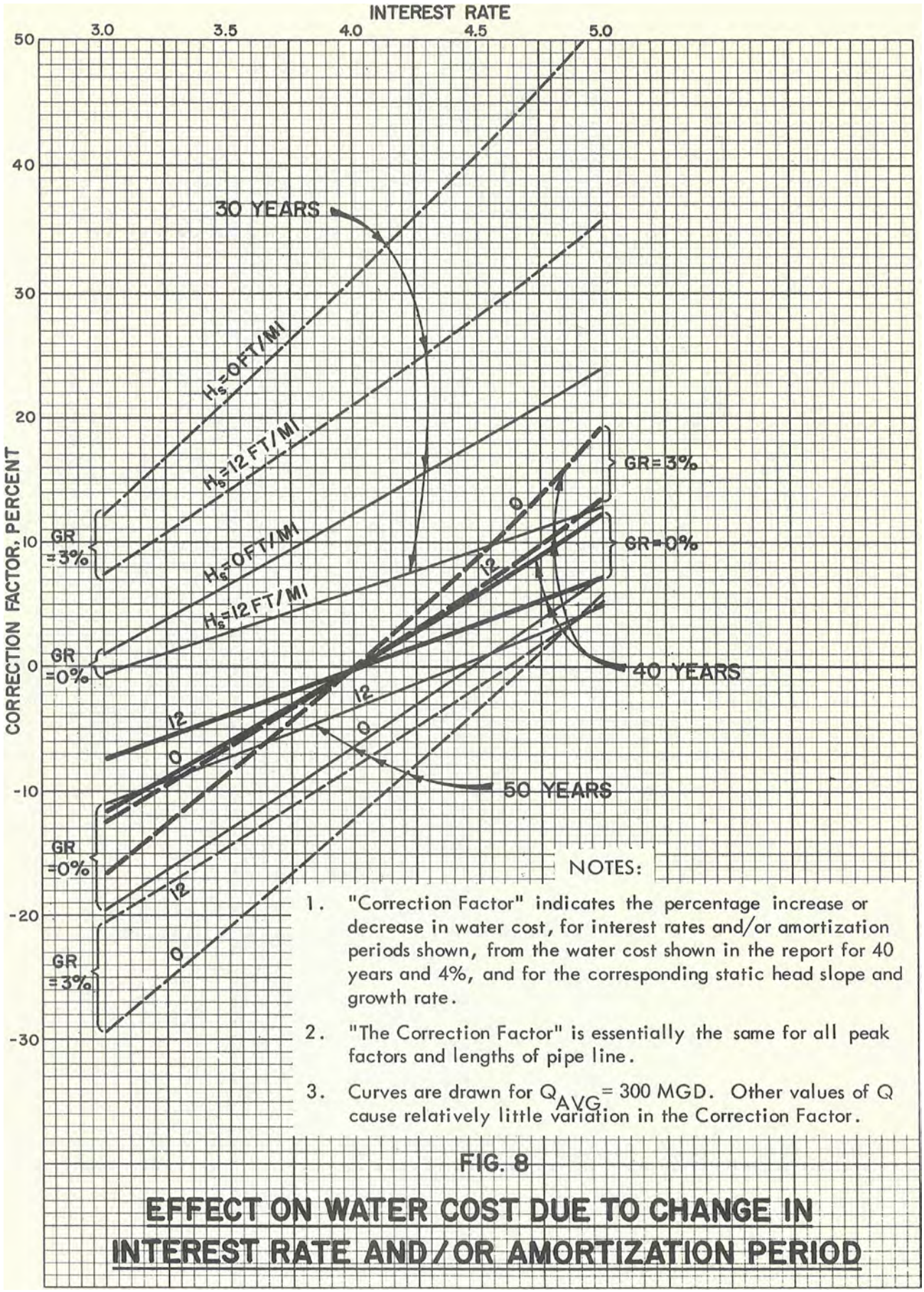


FIG. 7

DURATION OF PUMPING

PEAK FACTOR = 2.00



NOTES:

1. "Correction Factor" indicates the percentage increase or decrease in water cost, for interest rates and/or amortization periods shown, from the water cost shown in the report for 40 years and 4%, and for the corresponding static head slope and growth rate.
2. "The Correction Factor" is essentially the same for all peak factors and lengths of pipe line.
3. Curves are drawn for $Q_{AVG.}$ = 300 MGD. Other values of Q cause relatively little variation in the Correction Factor.

FIG. 8

EFFECT ON WATER COST DUE TO CHANGE IN INTEREST RATE AND/OR AMORTIZATION PERIOD

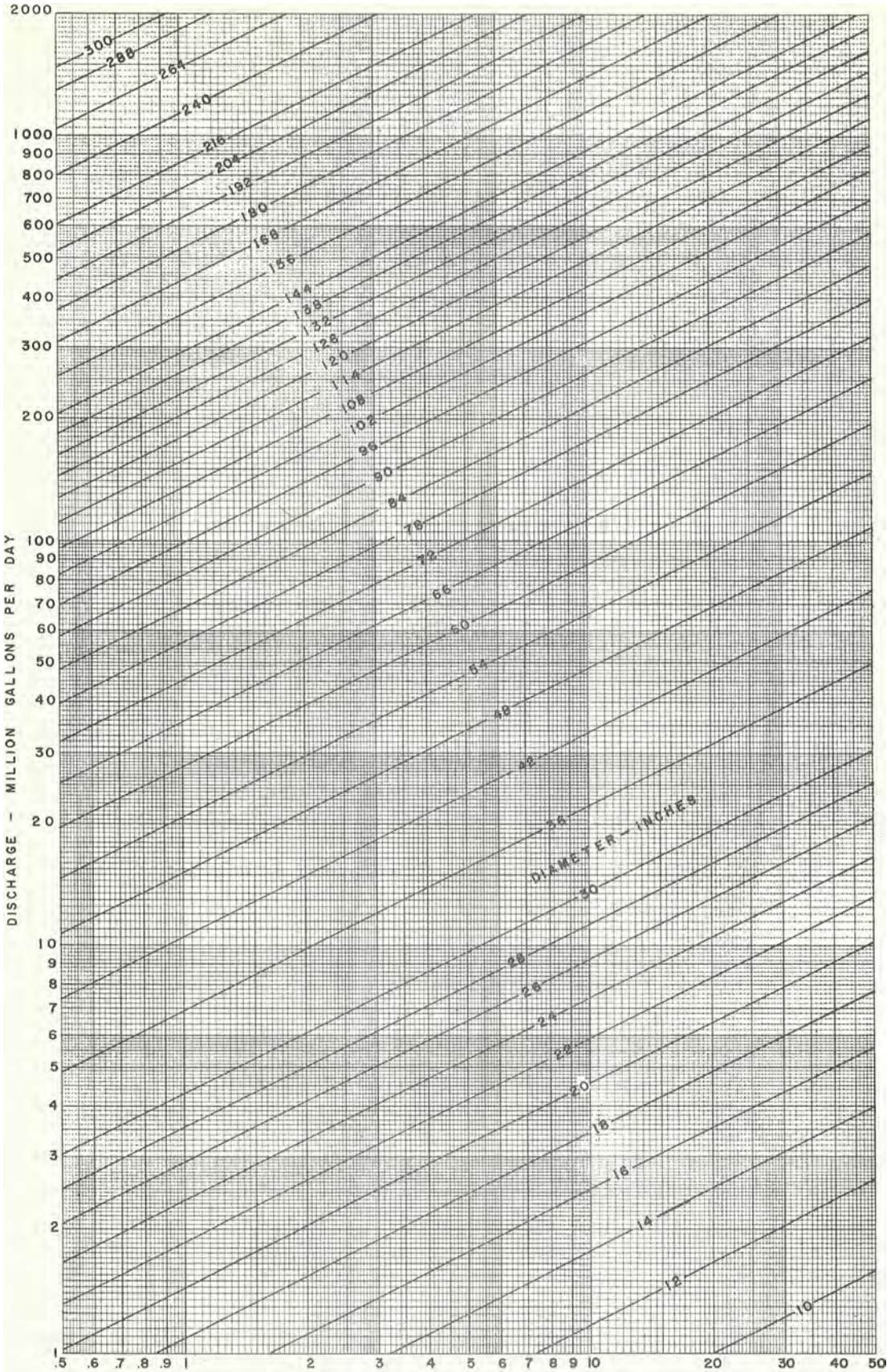


FIG. 9

SOLUTION OF MANNING FLOW FORMULA FOR n = 0.011

TABLE I

ASSUMED PIPE COSTS PER MILE

(In place, including 25% for engineering and contingencies)

Thousands of Dollars

	Diameter inches	100 psi	150 psi	200 psi	250 psi	300 psi
1.	10	--	--	27.6	31.8	36.0
2.	12	--	--	36.4	41.5	46.6
3.	14	--	--	45.3	51.2	57.2
4.	16	--	47.3	54.1	60.8	67.5
5.	18	--	55.3	62.9	70.5	78.1
6.	20	--	63.4	71.8	80.3	88.7
7.	21	58.5	67.3	76.2	85.0	93.9
8.	24	69.2	79.4	89.6	99.7	109.9
9.	27	80.0	91.4	102.8	114.3	125.7
10.	30	90.8	103.4	116.1	128.8	141.4
11.	33	101.4	115.1	128.8	142.4	156.1
12.	36	112.2	127.9	143.7	159.4	175.2
13.	39	122.9	140.8	158.6	176.4	194.2
14.	42	143.8	162.9	182.0	201.0	220.1
15.	45	164.7	185.0	205.3	225.6	245.9
16.	48	185.6	207.1	228.6	250.2	271.7
17.	51	206.5	229.2	252.0	274.8	297.5
18.	54	227.3	251.3	275.3	299.3	323.3
19.	57	248.2	273.4	298.7	323.9	349.2
20.	60	269.1	295.6	322.0	348.5	375.0
21.	66	316.9	351.9	387.0	422.0	457.0
22.	72	364.7	408.3	451.9	495.5	539.1
23.	78	412.5	464.6	516.8	569.0	621.2
24.	84	460.3	521.0	581.7	642.5	703.2
25.	90	508.1	577.4	646.7	716.0	785.3
26.	96	559.1	639.8	720.4	801.1	881.8
27.	102	610.2	702.2	794.2	886.2	978.2
28.	108	661.1	764.5	867.9	971.3	1075.
29.	114	712.1	826.9	941.7	1056.	1171.
30.	120	763.1	889.3	1015.	1142.	1268.
31.	126	814.2	951.7	1089	1227.	1364.
32.	132	865.2	1014.	1163.	1312.	1461.
33.	138	916.2	1076.	1237.	1397.	1557.
34.	144	967.2	1139.	1310.	1482.	1654.
35.	150	1018.	1201.	1384.	1567.	1750.
36.	156	1069.	1264.	1458.	1652.	1847.
37.	162	1120.	1326.	1532.	1737.	1943.
38.	168	1171.	1388.	1605.	1823.	2040.
39.	174	1222.	1451.	1679.	1908.	2136.
40.	180	1273.	1513.	1753.	1993.	2233.
41.	186	1324.	1576.	1827.	2078.	2329.
42.	192	1375.	1638.	1900.	2163.	2426.
43.	204	1477.	1763.	2048.	2333.	2618.
44.	216	1579.	1887.	2195.	2503.	2811.
45.	238	1681.	2012.	2343.	2674.	3004.
46.	240	1784.	2137.	2490.	2844.	3197.
47.	252	1886.	2262.	2638.	3014.	3390.
48.	264	1988.	2387.	2786.	3184.	3583.
49.	276	2090.	2512.	2933.	3354.	3776.
50.	288	2192.	2636.	3081.	3525.	3969.

TABLE II-A

VALUES OF PUMP STATION COST FACTORS

$$CK1 = a\ Q_{max}^{b}$$

$$CK2 = c\ Q_{max}^{d}$$

Range of Qmax

Factor	$Q \leq 20$ mgd	20 mgd $< Q \leq 135$ mgd	$Q > 135$ mgd
a	23,580	5,200	5,321
b	-0.4949	0.0009	0.0
c	515.7	72.0	4.1
d	-1.1407	-0.4882	0.0

TABLE II-B

VALUES OF EFFICIENCY FACTORS

PKF	Static head slope=0			Static head slope=4			Static head slope=8			Static head slope=12		
	E2	E3	E4	E2	E3	E4	E2	E3	E4	E2	E3	E4
1.00	0.85	1.00	1.00	0.85	1.00	1.00	0.85	1.00	1.00	0.85	1.00	1.00
1.25	.71	1.00	1.00	.80	1.00	1.00	.83	1.00	1.00	.83	1.00	1.00
1.50	.59	1.00	1.00	.76	1.00	1.00	.81	1.00	1.00	.82	1.00	1.00
1.75	.55	.70	.92	.75	.85	.96	.80	1.00	1.00	.81	1.00	1.00
2.00	.44	.74	.96	.72	.87	.98	.79	1.00	1.00	.81	1.00	1.00

TABLE III-A

EFFECT OF ALTERNATE METHODS OF STATING WATER COSTS

Uniform Use

Cost	= $10,000,000	Interest Rate	= 4%
Annual Operating Cost	= $ 300,000	Amortization Period	= 40 Yrs
Annual Water Use	16,000 MG		

(1) ANNUAL COST BASIS:

Capital Recovery Factor	= 0.05052	=> Amortization	=	$505,200 per year
		Operating Cost	=	300,000
		Total Annual Cost	=	$805,200
		=> Cost per MG	=	$50.50

(2) CAPITALIZED BASIS:

Interest and Principal in 40 yrs	=	$505,200 x 40
Operation Cost in 40 yrs	=	300,000 x 40
Total Cost in 40 yrs	=	$805,200 x 40
Water Used in 40 yrs	=	$ 16,000 x 40
=> Cost per MG	=	$ 50.50

(3) PRESENT WORTH BASIS:

Initial Investment	=	$10,000,000
P.W. of Operating Cost=19.793 x 300,000	=	5,940,000
Total Present Worth Cost	=	$15,940,000
P.W. of Water Used=19.793 x 16,000		316,000 MG
=> Cost per MG	=	$50.50

TABLE III-B

EFFECT OF ALTERNATE METHODS OF STATING WATER COSTS

Gradually Increasing Use for 10 Yrs

Year	Q/Q_{10}	$(Q/Q_{10})^2$	$\sum$	(1): Annual Cost Basis					Present Worth		
				Prin. & Int.	Operat.*	Total Cost	Water Used	$/MG	Factor	Op. Cost	Water
1	.05	.0025	.05	505,200	7,500	512,700	800	641.	.9615	7,200	770
2	.15	.0225	.17	do	25,500	530,700	2,400	221.	.9246	23,600	2,220
3	.25	.0625	.31	do	46,500	551,700	4,000	138.	.8890	41,400	3,560
4	.35	.1225	.47	do	70,500	575,700	5,600	103.	.8548	60,200	4,780
5	.45	.2025	.65	do	97,500	602,700	7,200	83.7	.8219	80,100	5,910
6	.55	.3025	.85	do	127,500	632,700	8,800	72.0	.7903	100,800	6,950
7	.65	.4225	1.07	do	160,500	665,700	10,400	64.0	.7599	121,800	7,900
8	.75	.5625	1.31	do	196,500	701,700	12,000	58.5	.7307	143,500	8,770
9	.85	.7225	1.57	do	235,500	740,700	13,600	54.5	.7026	165,200	9,560
10	.95	.9025	1.85	do	277,500	782,700	15,200	51.5	.6756	187,400	10,270
$\sum$					1,245,000		80,000			931,200	60,690
11	1.00	1.00	2.00	do	300,000	805,200	16,000	50.50			

(2) CAPITALIZED BASIS:

Interest and Principal in 40 yrs = 40 x 505,200 = $20,208,000
Operation Cost 1st 10 yrs = 1,245,000
Operation Cost last 30 yrs = 30 x 300,000 = 9,000,000
Total Cost in 40 yrs = $30,453,000
Water Used 1st 10 yrs = 80,000 MG
Water Used last 30 yrs = 30 x 16,000 = 480,000 MG
Total Water Used in 40 yrs = 560,000 MG
=> Cost = 30,453,000/560,000 = 54.40$/MG

(3) PRESENT WORTH BASIS:

Initial Investment = $10,000,000
P.W. of Operating Cost 1st 10 yrs = 931,200
P.W. of Operating Cost last 30 yrs
= 300,000 x .6756 x 17.292 = 3,500,000
Total Present Worth Cost = $14,431,200
P.W. of Water Used 1st 10 yrs = 60,690 MG
P.W. of Water Used last 30 yrs
= 16,000 x .6756 x 17.292 = 187,000 MG
Total Present Worth of Water = 247,690 MG

=> Cost = 14,431,200/247,690 = 58.20$/MG

*Assuming $\frac{1}{2}$ proportional to Q, and $\frac{1}{2}$ proportional to Q^2.

TABLE III-C

EFFECT OF ALTERNATE METHODS OF STATING WATER COSTS

Same as III-B. Paying Interest Only for 5 Yrs

(1) ANNUAL COST BASIS:

Year	Interest	Principal and Interest	Operating Cost	Total Cost	$/MG
1	400,000	--	7,500	407,500	510.
2	400,000	--	25,500	425,500	178.
3	400,000	--	46,500	446,500	112.
4	400,000	--	70,500	470,500	84.1
5	400,000	--	97,500	497,500	69.1
6	--	535,800	127,500	663,300	75.4
7	--	535,800	160,500	696,300	67.0
8	--	535,800	196,500	731,300	61.0
9	--	535,800	235,500	771,300	56.7
10	--	535,800	277,500	812,300	53.5
$\sum$	--	--	1,245,000	--	--
11	--	535,800	300,000	835,800	52.20

(2) CAPITALIZED BASIS:

Interest 1st 5 yrs = 5 x 400,000	= $	2,000,000
Interest and Principal 35 yrs = 35 x 535,800	=	18,750,000
Operating Cost 1st 10 yrs	=	1,245,000
Operating Cost last 30 yrs = 30 x 300,000	=	9,000,000
Total Cost in 40 yrs	= $	30,995,000

Water Used in 40 yrs = 560,000 MG

=> Cost = 55.30$/MG

(3) PRESENT WORTH BASIS:

P.W. of Interest 1st 5 yrs = 400,000 x 4.452	= $	1,784,000
P.W. of Interest and Principal 35 yrs = 535,800 x 18.665 x 0.8219	=	8,220,000
P.W. of Operating Cost 1st 10 yrs	=	931,200
P.W. of Operating Cost last 30 yrs = 300,000 x 17.292 x 0.6756	=	3,500,000
Total Present Worth Cost	= $	14,435,200

Present Worth of Water = 247,690 MG

=> Cost = 58.20$/MG

TABLE IV

PRESENT WORTH FORMULAS

Present Worth of Water Delivered:

$$P.W.W.D. = 365 \times Q_{avg} \left[(\text{Growth Rate}) \times \int_o^{t_1} \frac{t \times dt}{(1+i)^t} + t_1 \int^{t_n} \frac{dt}{(1+i)^t} \right]$$

Present Worth of Pumping Cost:

$$P.W.P.C. = 0.1309 \times K \times (Q_{avg})^3 \times A \times \left[(\text{Growth Rate})^3 \times \int_o^{t_1} \frac{t^3 \times dt}{(1+i)^t} + \int_{t_1}^{t_n} \frac{dt}{(1+i)^t} \right]$$

$$+0.1309 \times H_{st} \times Q_{avg} \times B \left[(\text{Growth Rate}) \times \int_o^{t_1} \frac{t \times dt}{(1+i)^t} + \int_{t_1}^{t_n} \frac{dt}{(1+i)^t} \right]$$

In the above equations:

$$\int_o^{t_1} \frac{t \times dt}{(1+i)^t} = \left. \frac{-t \times \ln(1+i) - 1}{[\ln(1+i)]^2 \times (1+i)^t} \right|_{t=0}^{t=t_1}$$

$$= \frac{1.0}{[\ln(1+i)]^2} - \frac{t_1 \times \ln(1+i) + 1.0}{[\ln(1+i)]^2 \times (1+i)^{t_1}}$$

$$\int_{t_1}^{t_n} \frac{dt}{(1+i)^t} = \left. \frac{-1.0}{\ln(1+i) \times (1+i)^t} \right|_{t=t_1}^{t=t_n}$$

$$= \frac{1.0}{[\ln(1+i)] \times (1+i)^{t_1}} - \frac{1.0}{[\ln(1+i)] \times (1+i)^{t_n}}$$

$$\int_o^{t_1} \frac{t^3 \times dt}{(1+i)^t} = \left. - \frac{t^3 \times [\ln(1+i)]^3 - 3 \times t^2 \times [\ln(1+i)]^2 - 6 \times t \times \ln(1+i) - 6.0}{\ln(1+i)^4 \times (1+i)^t} \right|_{t=0}^{t=t_1}$$

$$= \frac{6.0}{[\ln(1+i)]^4} - \frac{[t_1 \times \ln(1+i)]^3 + 3[t_1 \times \ln(1+i)]^2 + 6[t_1 \times \ln(1+i)] + 6.0}{[\ln(1+i)]^4 \times (1+i)^{t_1}}$$

$$K = 4.66 \times (n)^2 \times (\text{Length}) \left(\frac{\text{Diameter}}{12} \right)^{-16/3}$$

$$A = [(\text{Peak Factor})^3 \times (C1)/E1] + [8760 \times (C2)/E2]$$

$$B = [(\text{Peak Factor}) \times (C1)/E1] + [8760 \times (C2)/E2]$$

E1= Efficiency for Max KW

E2= Efficiency for KW-Hr

TABLE V

SUMMARY OF COMPUTER PROGRAM

COST OF TRANSPORTING WATER BY PIPELINE

1. Read input data: Pipe costs, constants for computing pump station cost, interest rate, amortization time, power cost constants, friction factor, pump efficiency, specified lengths, pressure classes, diameters and minimum pressure class for each diameter, efficiencies or factors used in pumping cost and pump station cost calculations, specified peak factors, growth rates, static head slopes, and flows with range of diameters and lengths.

2. Select Peak Factor and Growth Rate for First Chart: Print captions for output print-out, including present worth factor for amount of water delivered.

3. Select first specified flow and length.

4. For static head slope = Zero:
   Compute investment cost and water cost for all specified diameters, and for increasing numbers of pump stations, until number which gives minimum water cost is reached.

5. Print, for most economical diameter and number of pump stations, the following output "A":

   a. Most economical diameter
   b. Most economical number of pump stations
   c. Corresponding project cost per mile
   d. Corresponding water cost per 1000 gal

6. If called for, print, for all other specified diameters, the following output "B":

   a. Diameter
   b. Most economical number of pump stations
   c. Maximum head per pump station
   d. Pipeline cost per mile
   e. Pump station cost per mile
   f. Project cost per mile
   g. Present worth of pumping cost per mile
   h. Water cost per 1000 gal

7. Repeat steps 4, 5 and 6 for all specified flows and lengths.

8. Plot water cost and project cost* (items 5c and 5d).

9. Repeat steps 4, 5, 6 and 7 for other specified static head slopes.

10. Repeat steps 2 to 9 for other peak factors and growth rates.

11. If called for, repeat steps 2 to 10 for other interest rates and amortization periods.

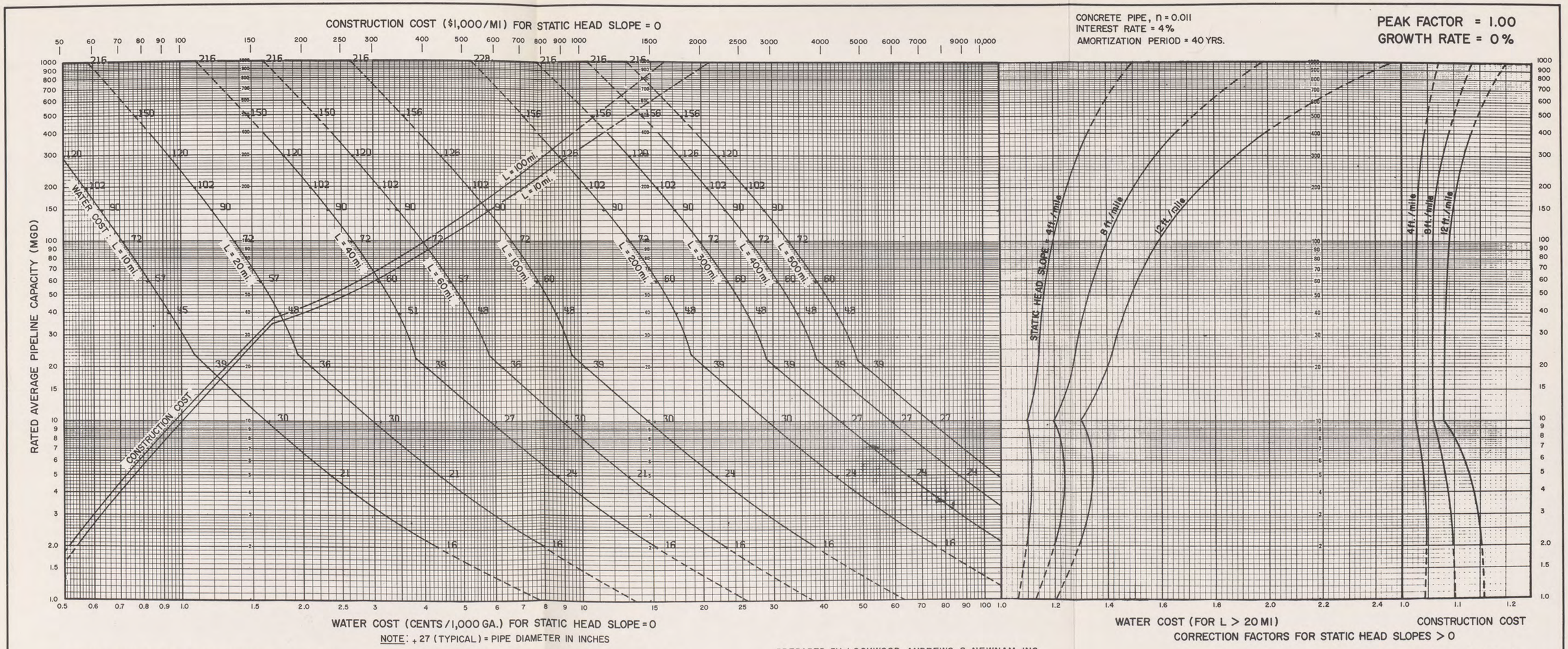
---

*On the charts as finally prepared, project cost was not plotted by computer and only the plotting points for water cost were so plotted.

TABLE VI

PROGRAM INPUT FOR FINAL RUN (INDEX TO INPUT DATA CARDS)

Card Index	Last Card No.	Description of Data
		FOR OUTPUT "A"
10	001	ND = Number of Diameters.
		NPCS = Number of Pressure Classes.
		NL = Number of Lengths.
		NQR = Number of Discharge ranges to compute Pump Station Cost.
20	050	PIPEC = Pipe Cost in $1000 per mile.
30	003	QR, CKA, CKB, CRC, CKD = Discharge and constants to compute Pump Station Cost.
40	001	RI = Interest Rate.
		TN = Amortization Period in years.
		C11 = Cost of Power in $ per max. Kw.
		C22 = Cost of Power in ¢ per Kw-hr.
		FRN = Friction factor (Manning's "n").
		E1 = Efficiency.
		IRTX = Indicator for changing the above values.
50	001	PIPEL = Pipe Lengths in miles.
51	001	PRCLS = Pressure Classes in psi.
52	004	D = Diameters in inches.
53	004	DMINP = Minimum pressure class of each diameter in psi.
60	001	NPKF = Number of Peak Factors.
		NGRR = Number of Growth Rates.
		NSHD = Number of Static Head Slopes.
		NQ = Number of Discharges.
		A,B = Indicators for printing Outputs "A" and "B".
		C = Indicator for plotting charts.
		IDX = Indicator for using future subroutine.
70	005	E = Efficiencies for pumping cost and for pump station cost.
80	001	PKF = Peak Factors.
81	001	GR = Growth Rates.
82	001	STHDS = Static Head Slopes in feet per mile.
90	012	Q, MIND, MAXD, MINL, MAXL = Average Discharge in MGD and number of the minimum and maximum diameter and length.
		FOR OUTPUT "B"
960	01	NPKF, NGRR, NSHD, NQ, A, B, C, IDX (See Card Index 60)
970	02	E (See Card Index 70)
980	01	PKF (See Card Index 80)
981	01	GR (See Card Index 81)
982	01	STHDS (See Card Index 82)
990	04	Q, MIND, MAXD, MINL, MAXL (See Card Index 90)
	96	TOTAL NUMBER OF INPUT CARDS -- (OUTPUTS A & B)
94	(002 First Card) (010 Last Card)	Same data as shown on Card 40001 with additional values of RI and TN for use in Output AA.



TEXAS WATER DEVELOPMENT BOARD - COST OF TRANSPORTING WATER BY PIPELINE

PREPARED BY LOCKWOOD, ANDREWS & NEWNAM, INC.
CORPUS CHRISTI · HOUSTON · VICTORIA, TEXAS

CHART NO. 1

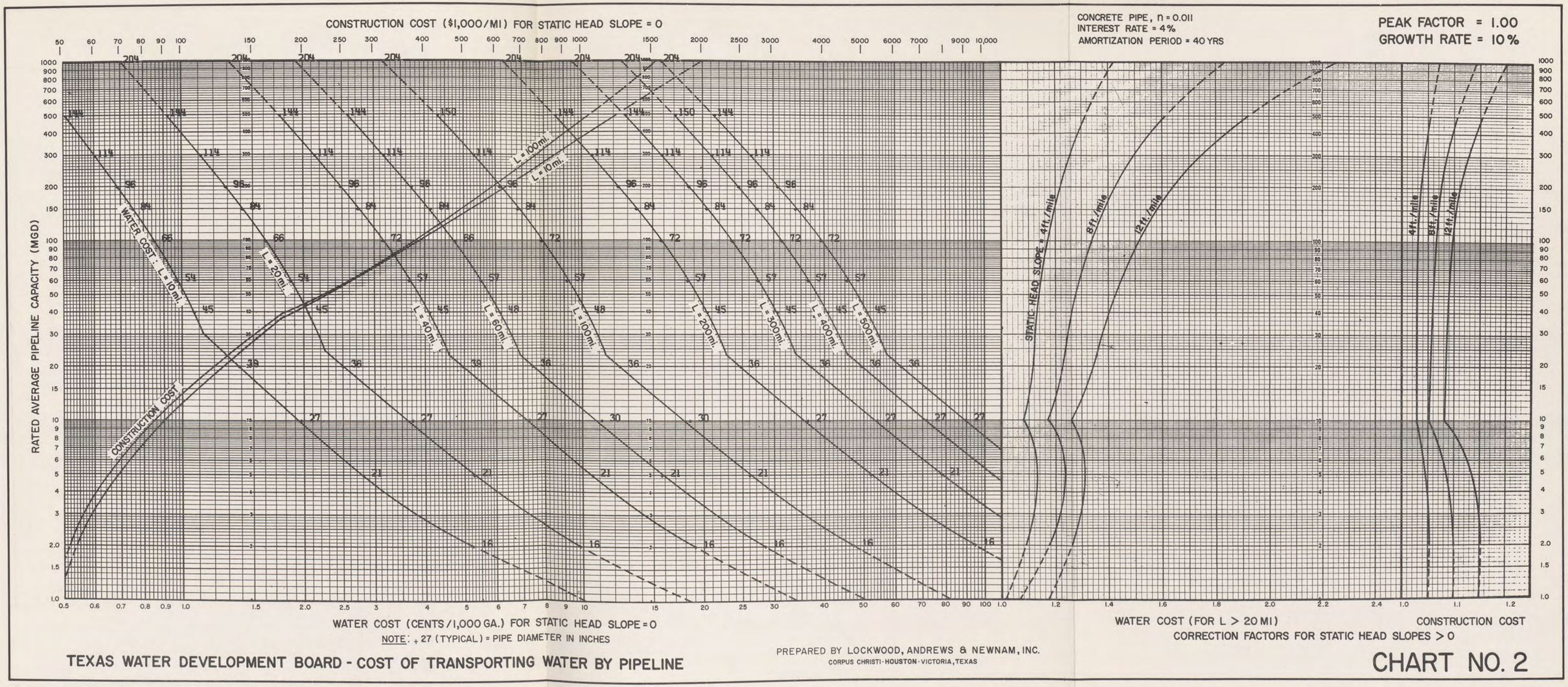


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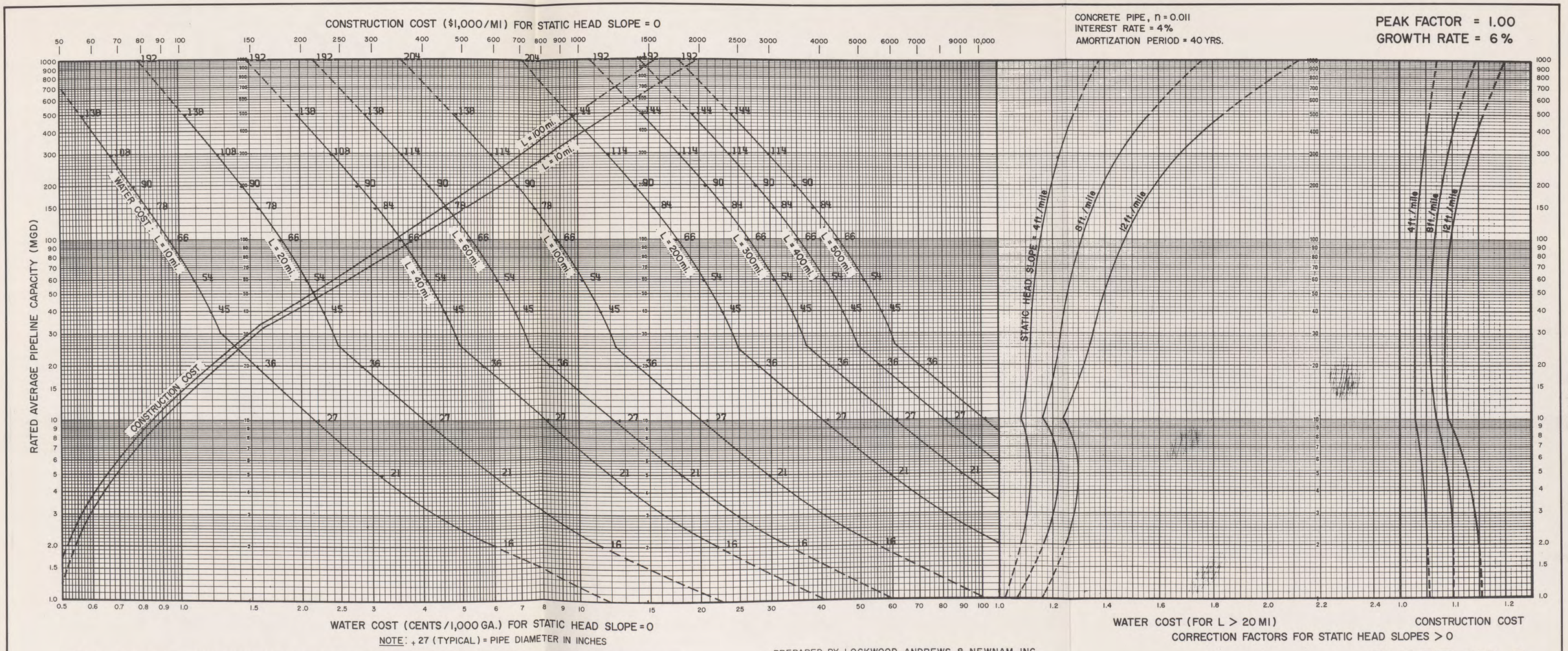
CHART NO. 2



NOTE: + 27 (TYPICAL) = PIPE DIAMETER IN INCHES

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CHART NO. 3

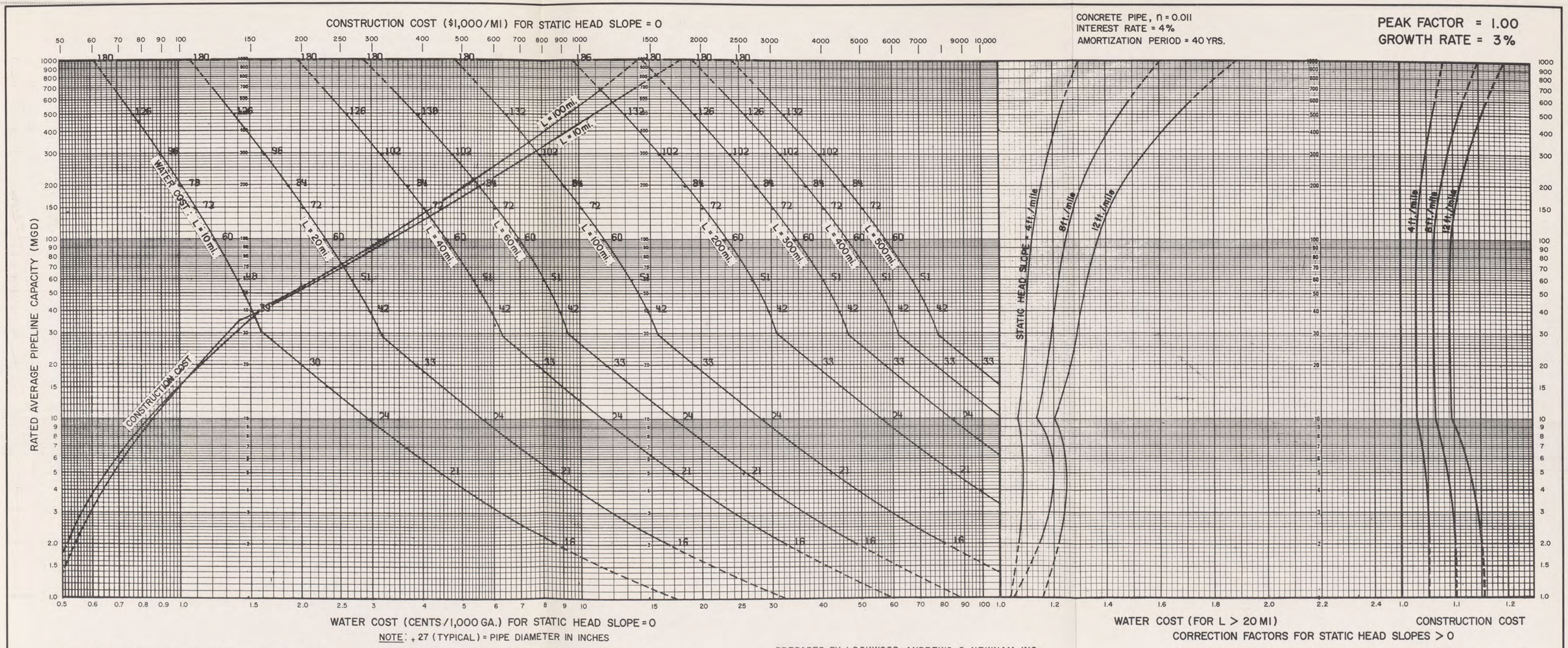

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CHART NO. 4

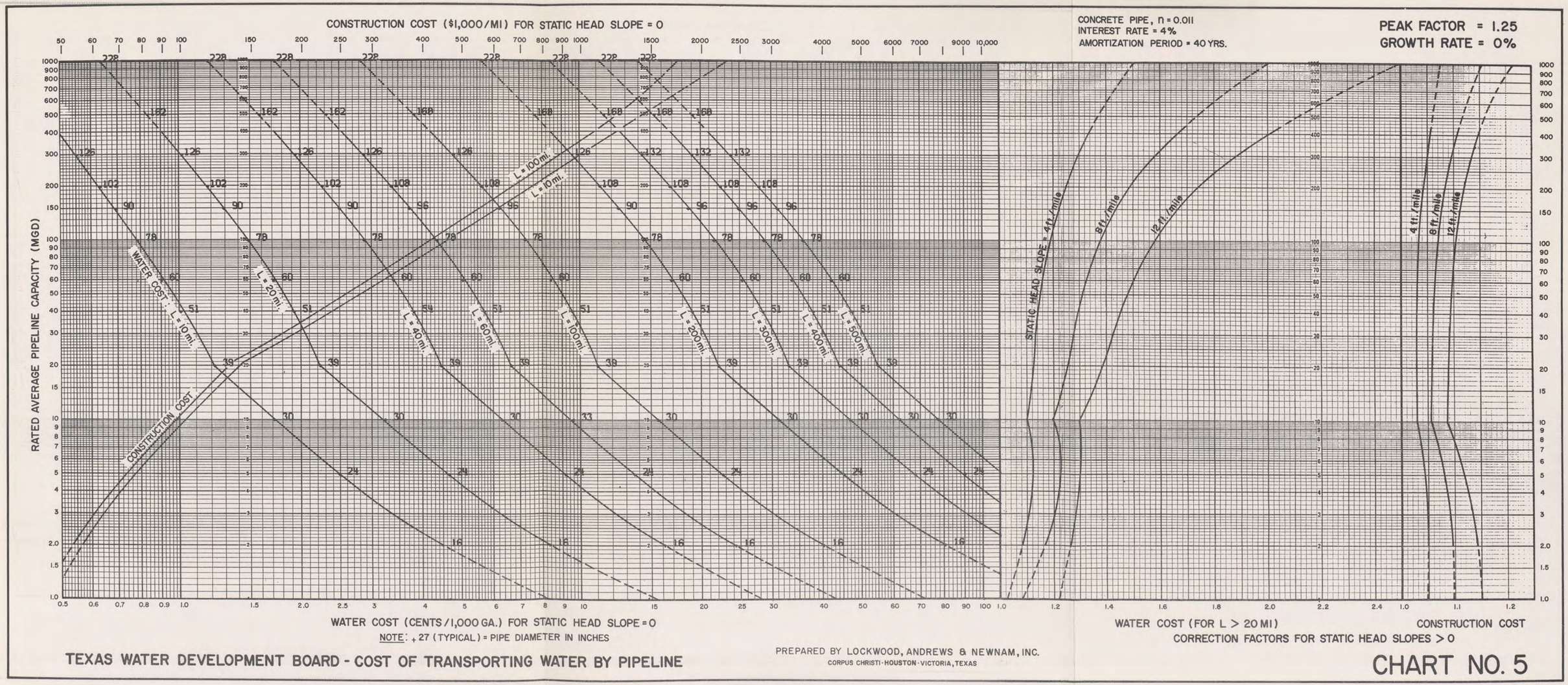

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CHART NO. 5

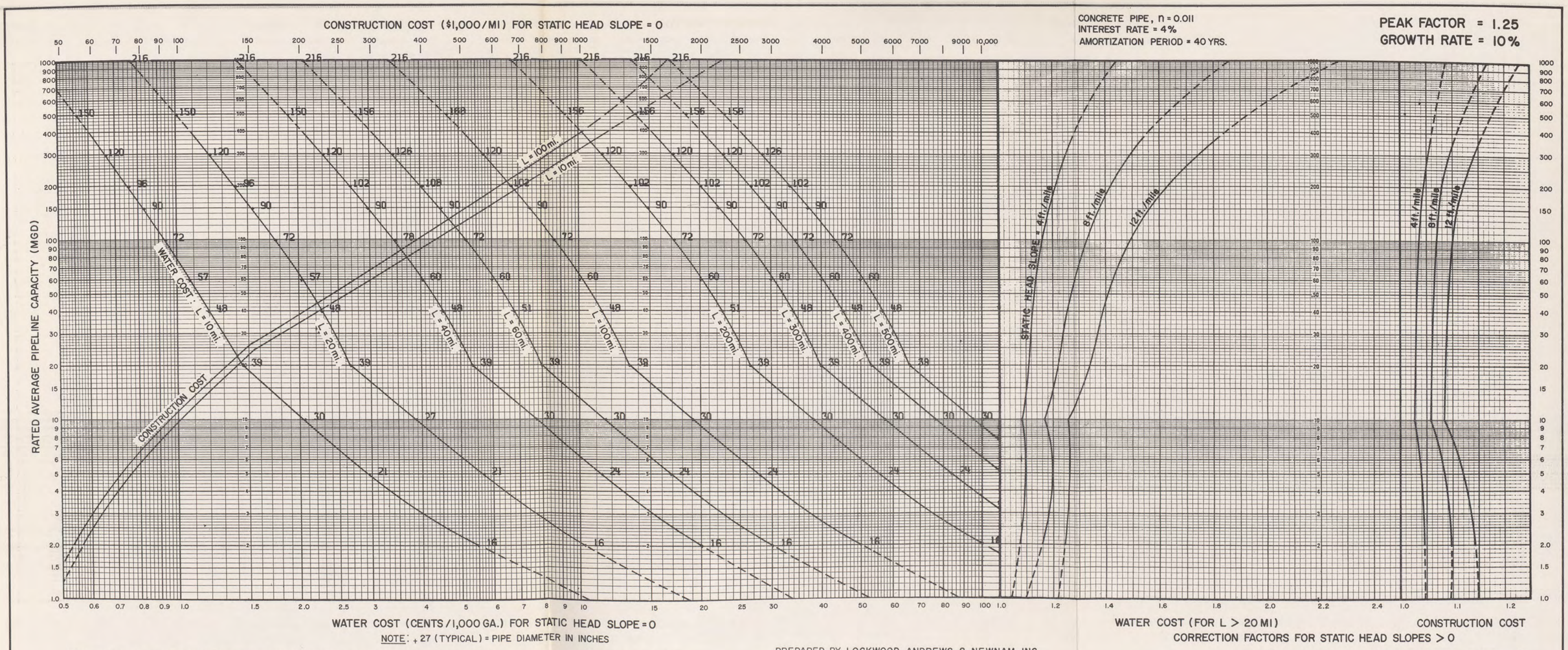

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CHART NO. 6

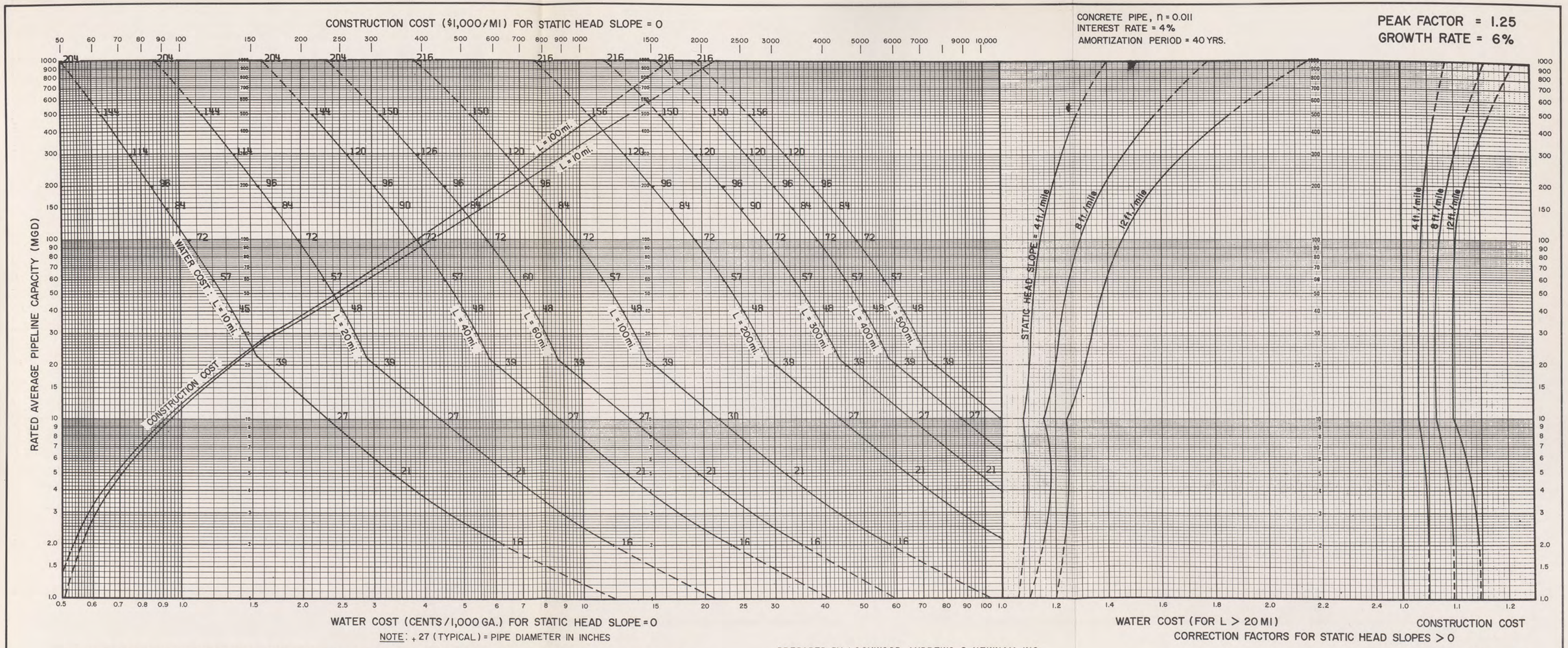

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CHART NO. 7

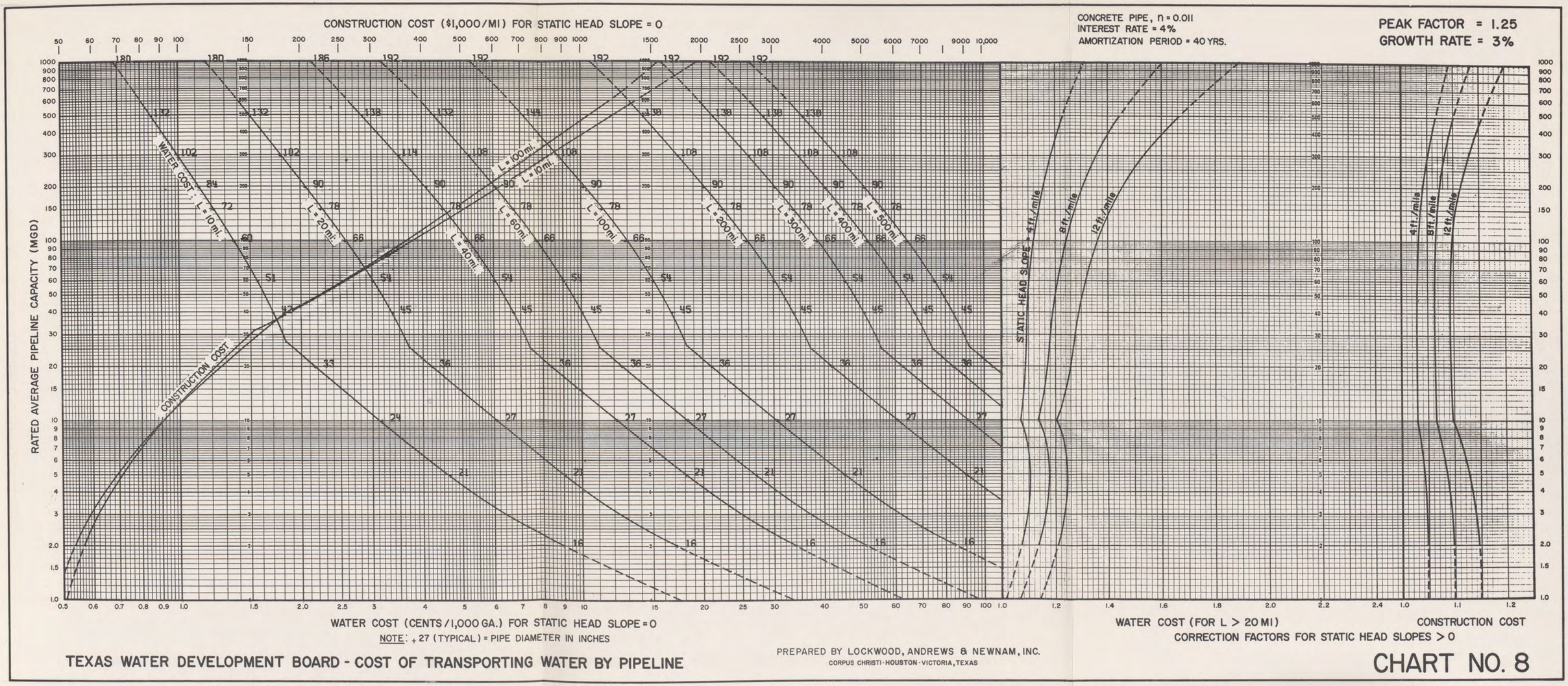

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CHART NO. 8

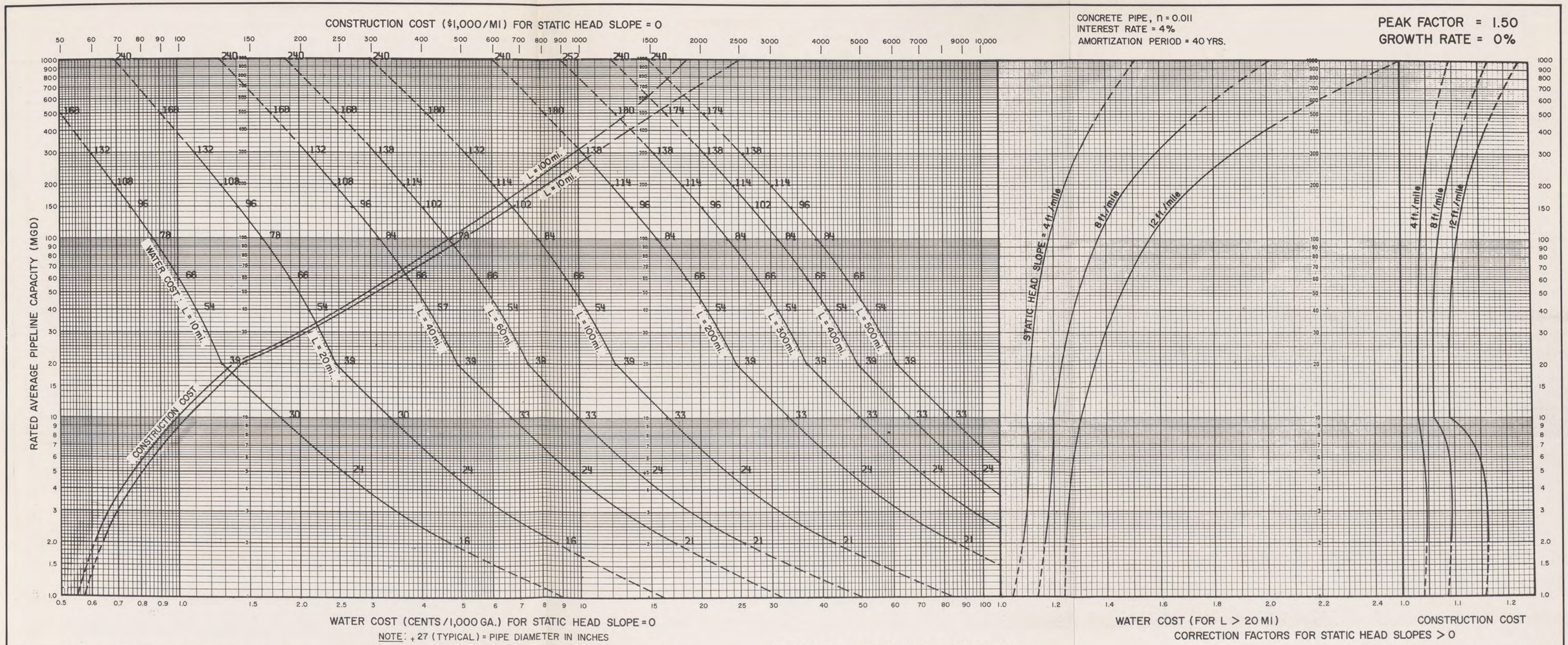

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CHART NO. 9

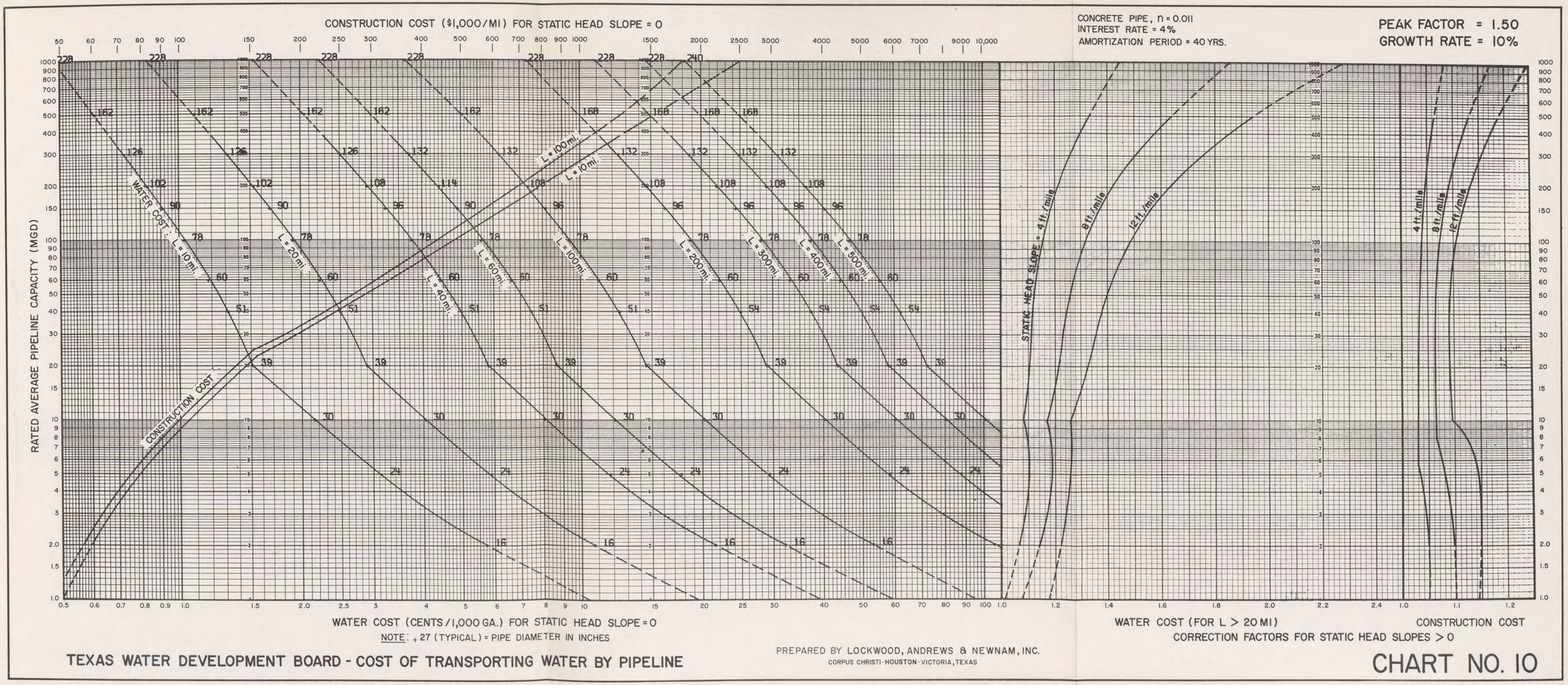

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CHART NO. 10

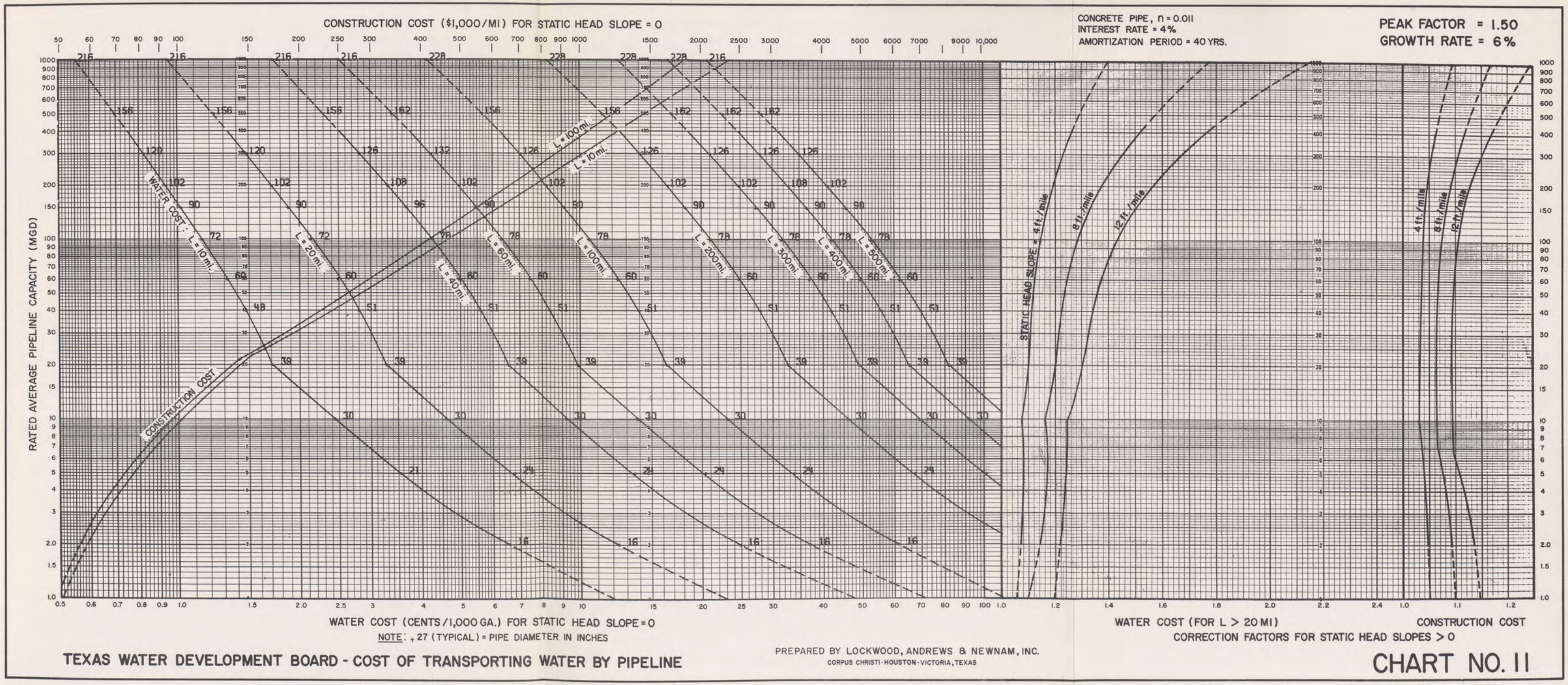

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CHART NO. 11

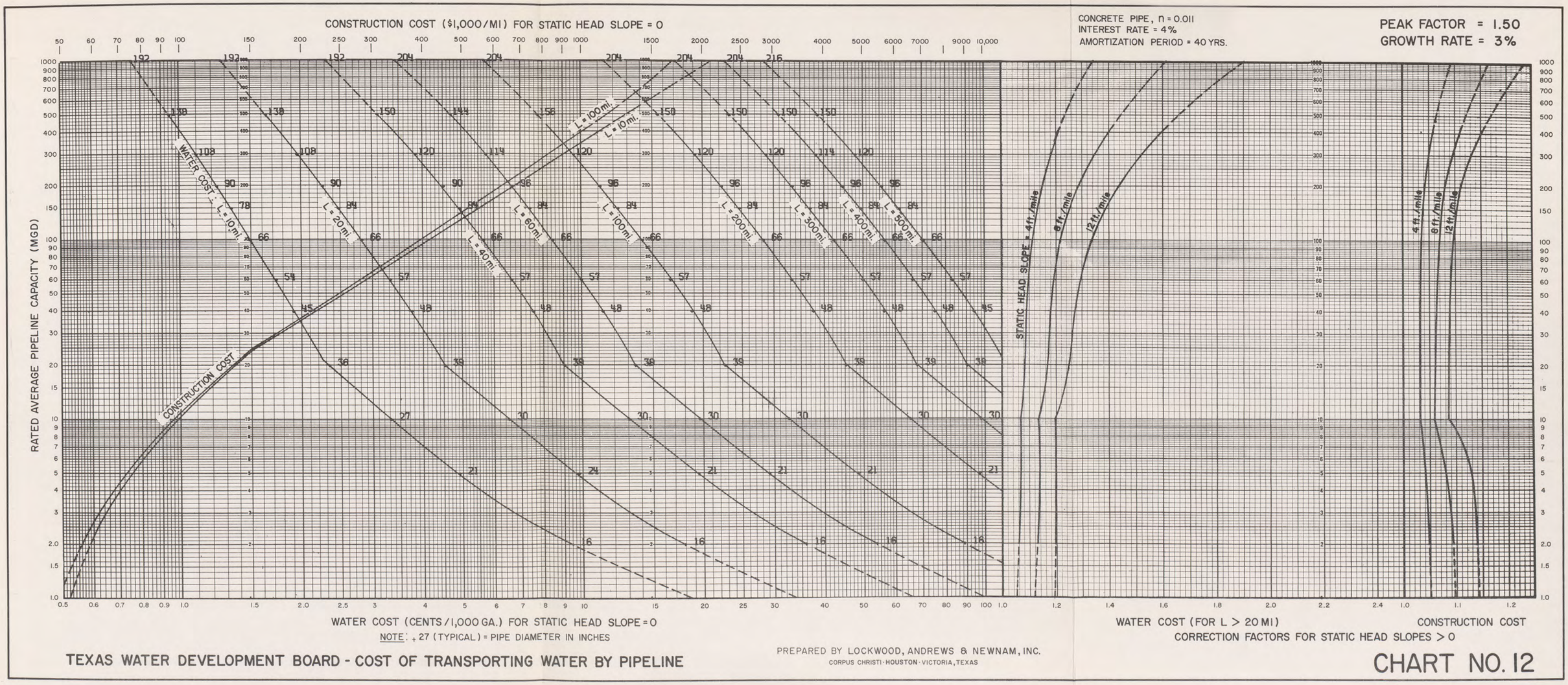

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CHART NO. 12

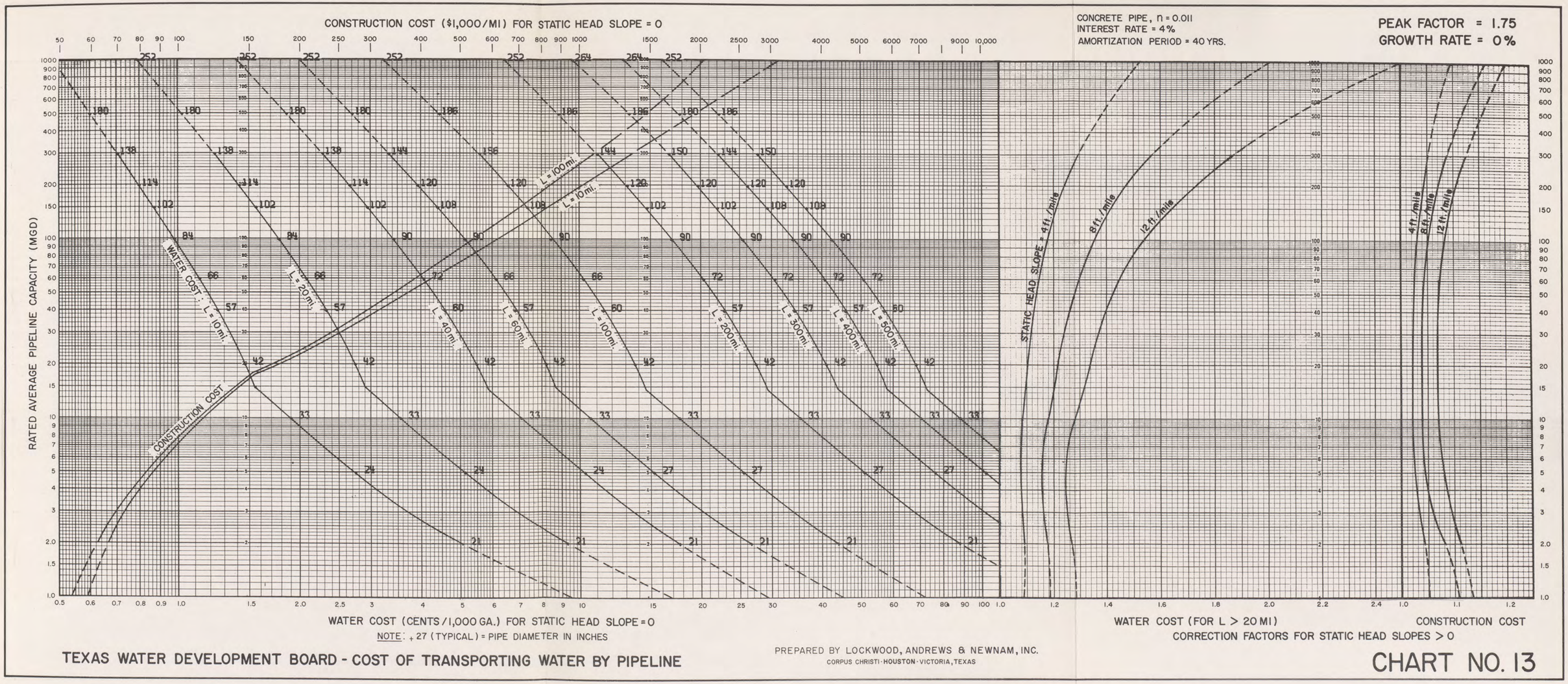

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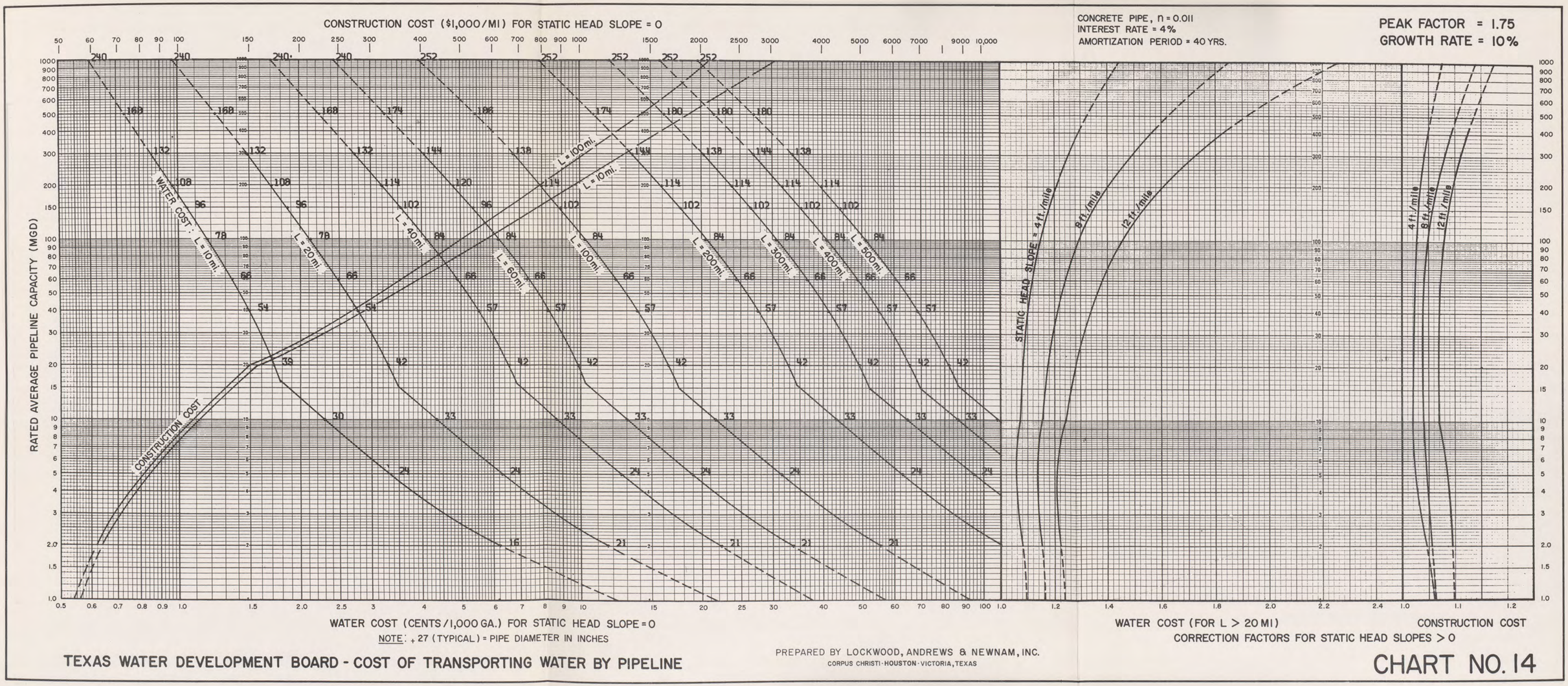
CHART NO. 13



NOTE: + 27 (TYPICAL) = PIPE DIAMETER IN INCHES

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TEXAS WATER DEVELOPMENT BOARD - COST OF TRANSPORTING WATER BY PIPELINE

CHART NO. 14

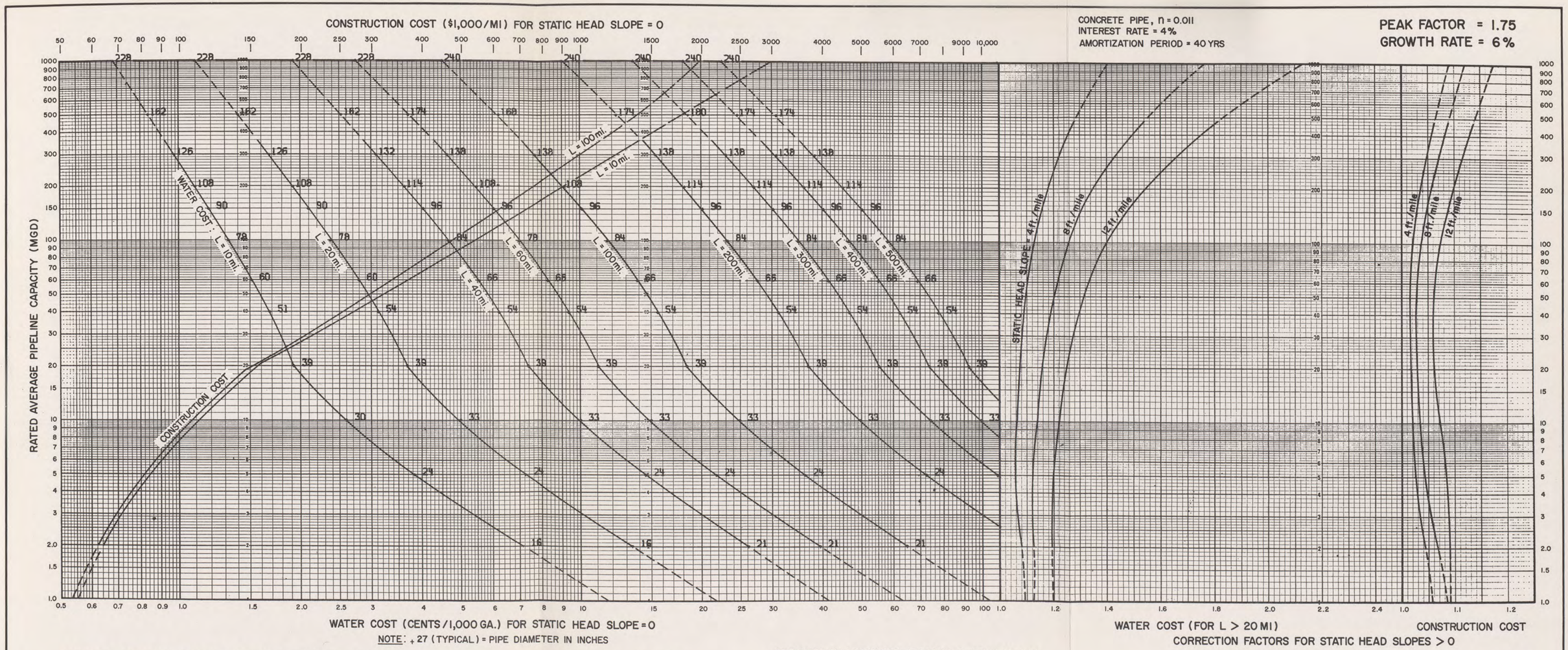

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CHART NO. 15

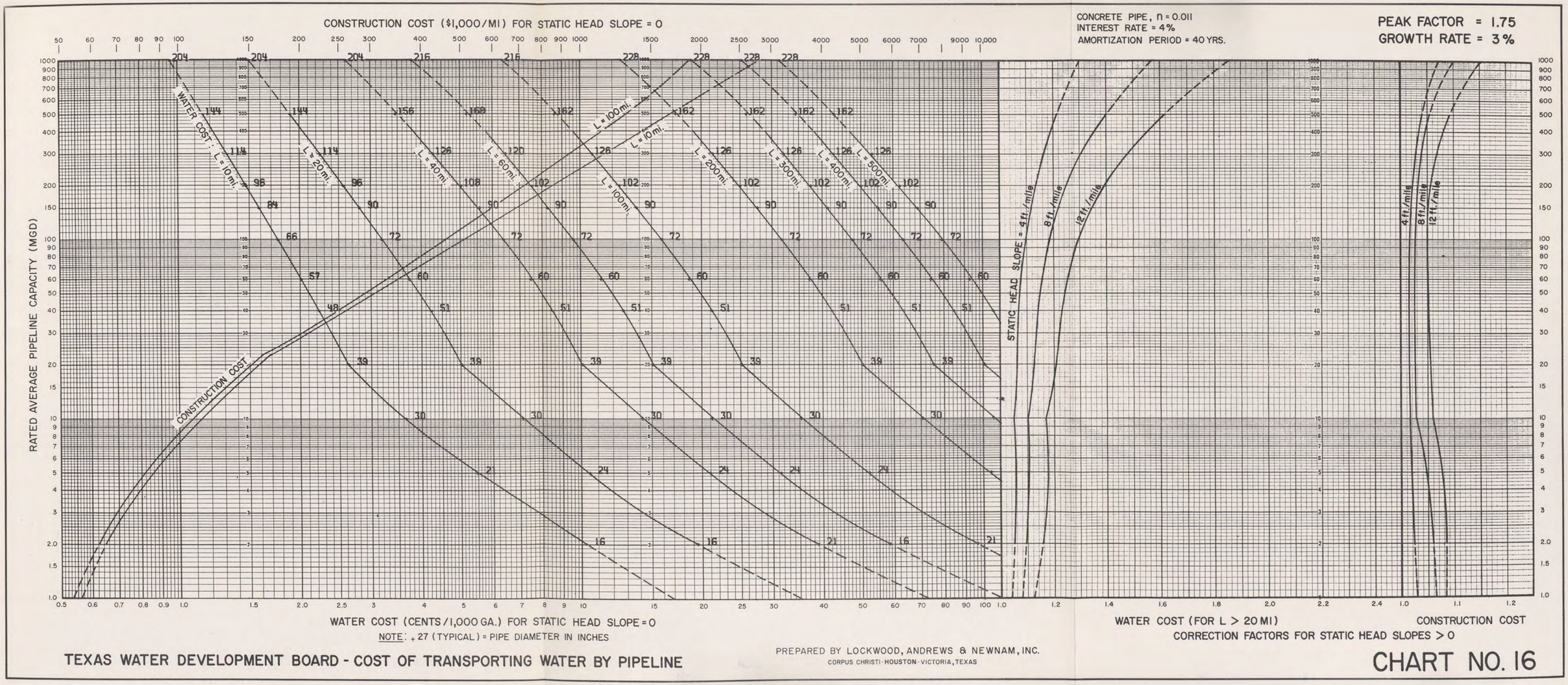

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CHART NO. 16

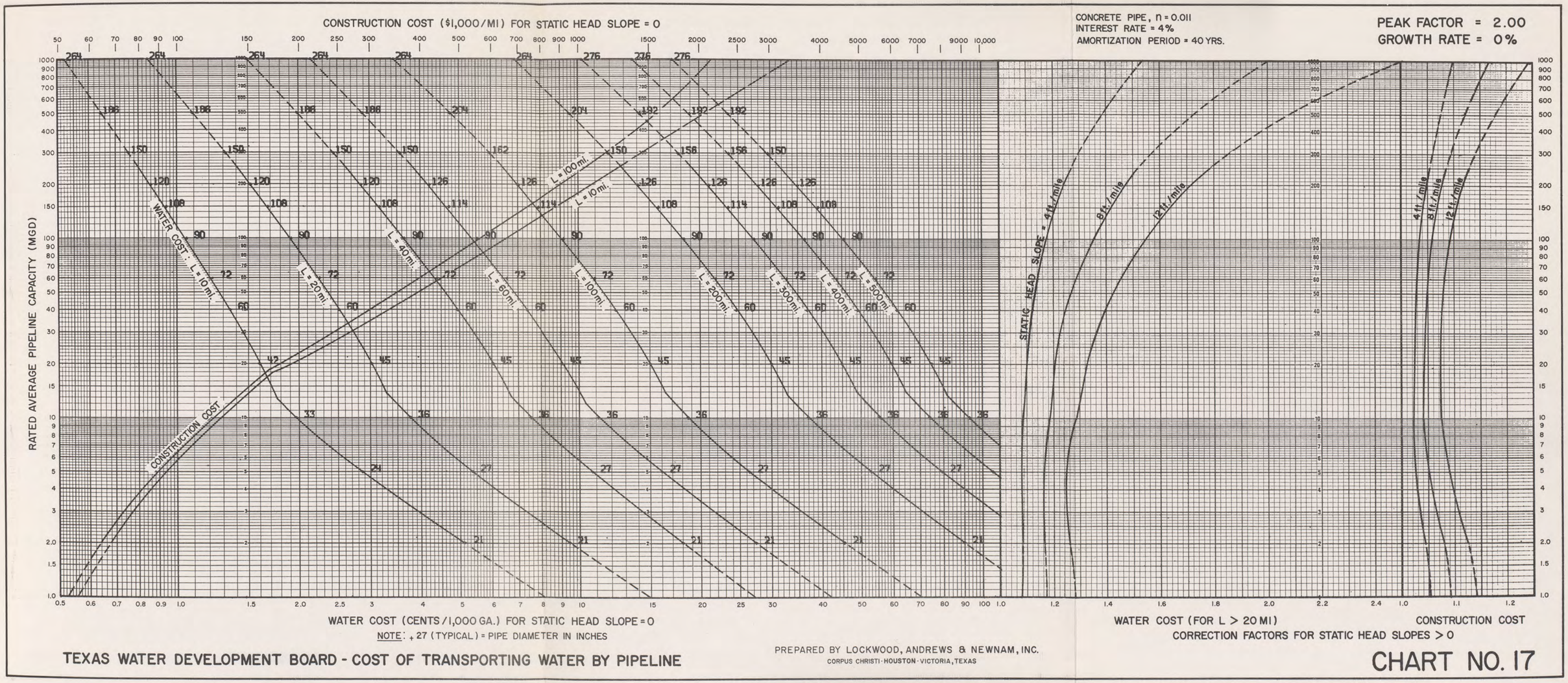

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CHART NO. 17

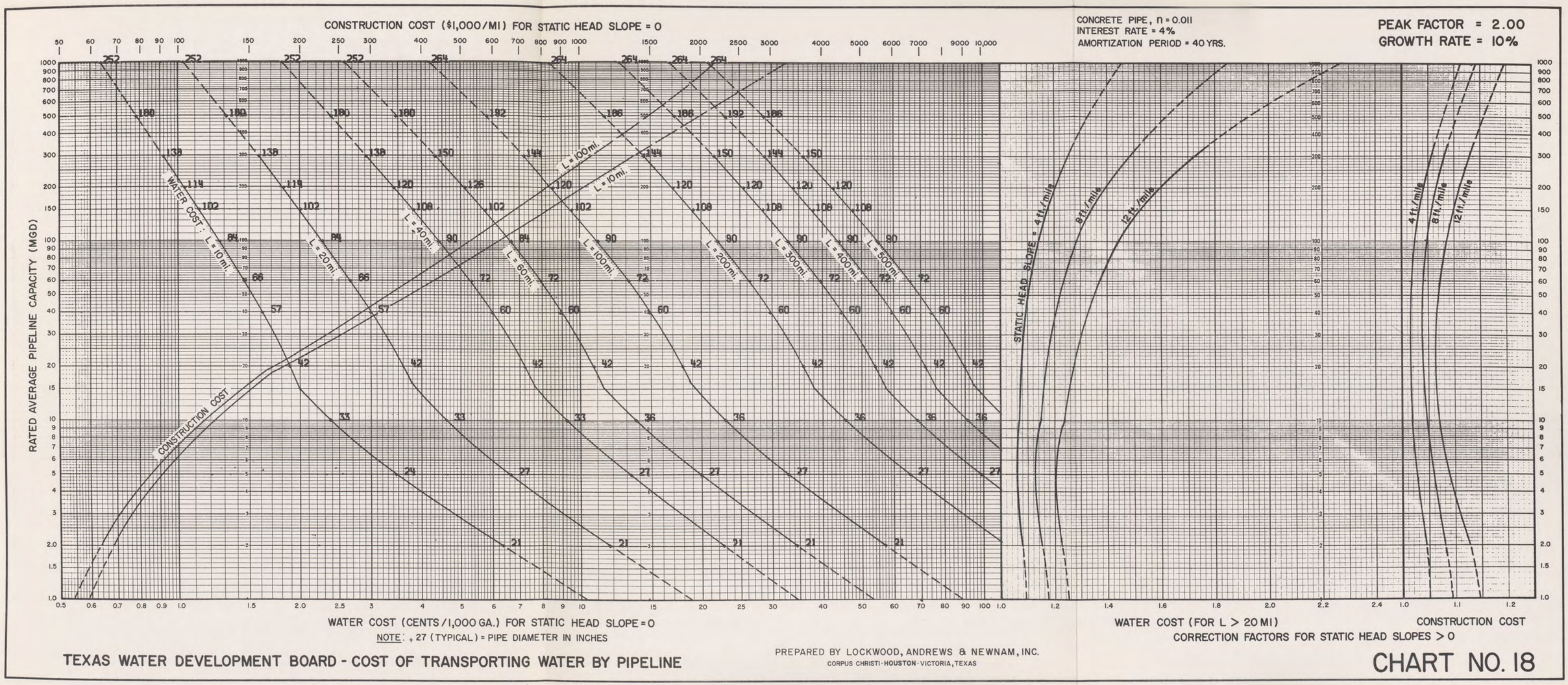

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CHART NO. 18

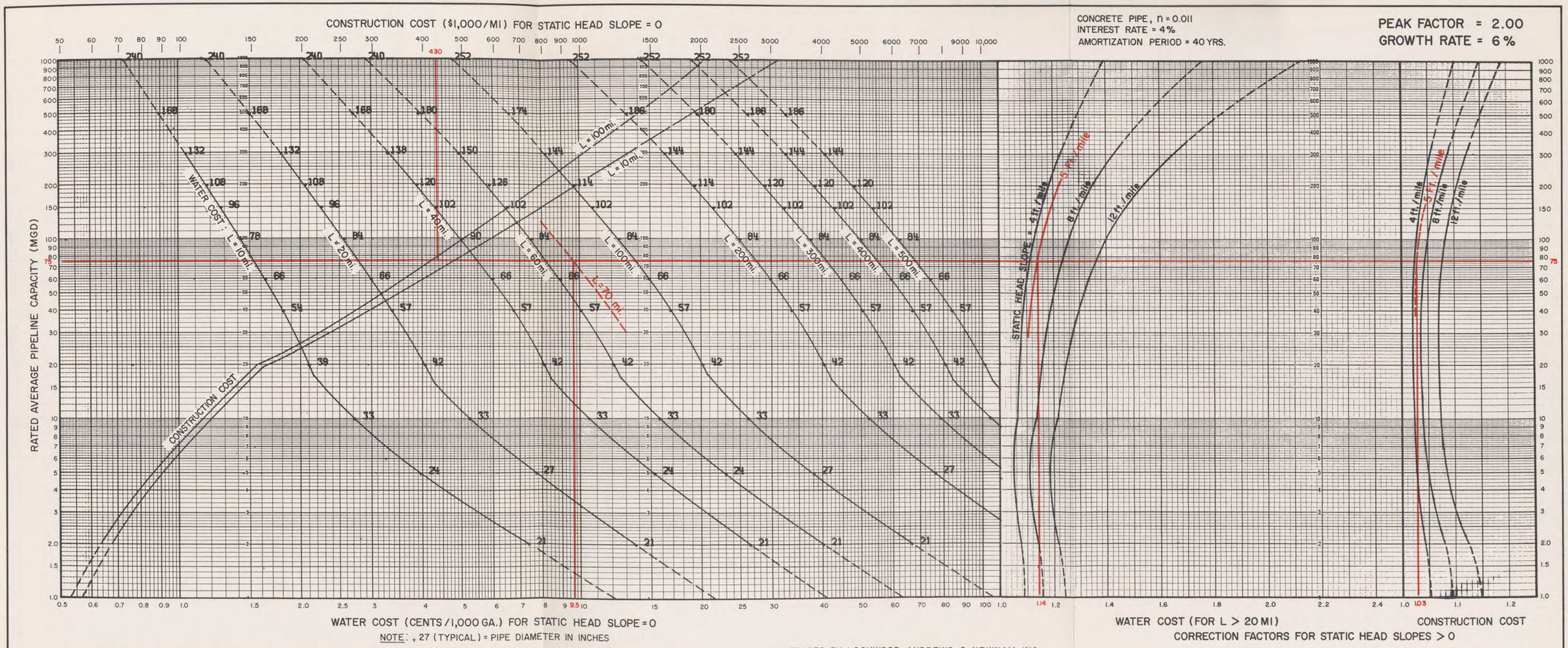

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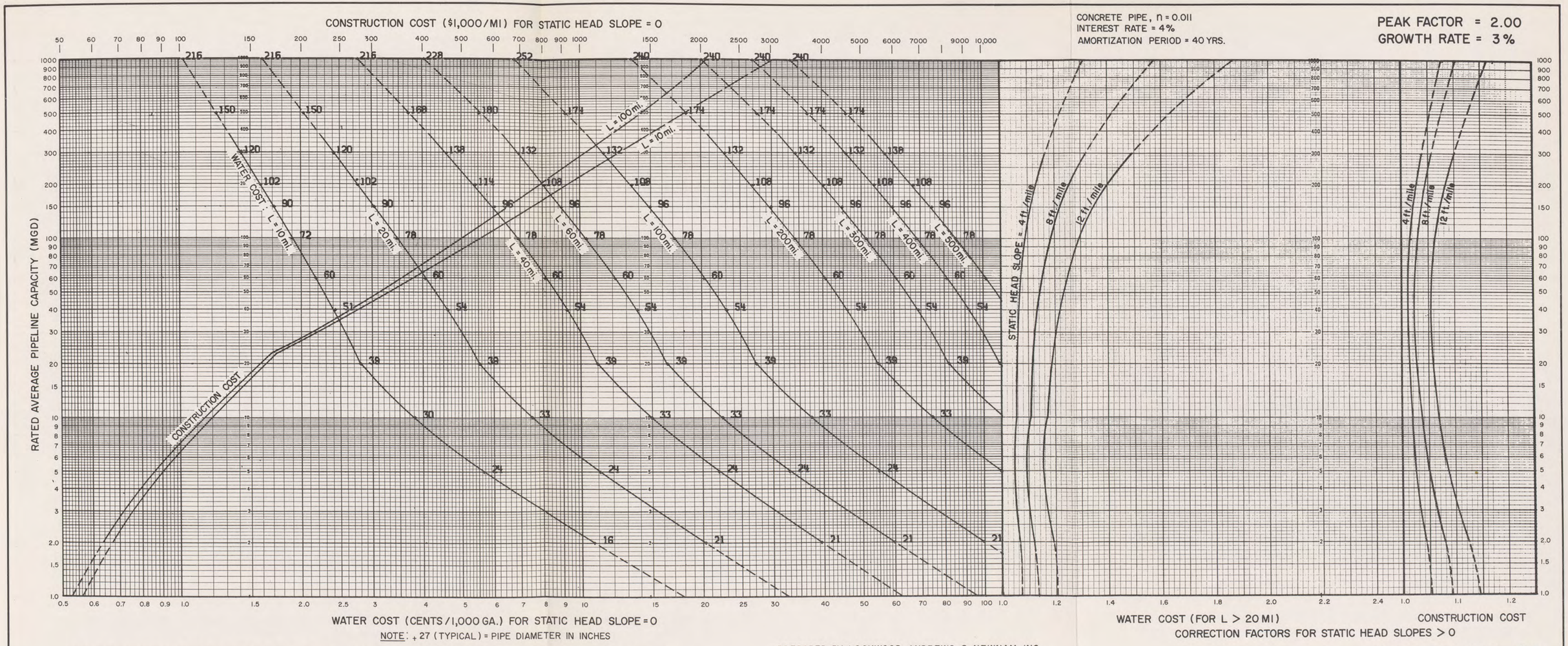
CHART NO. 19

Example shown in red is described in the Addendum.



TEXAS WATER DEVELOPMENT BOARD - COST OF TRANSPORTING WATER BY PIPELINE

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CHART NO. 20

ADDENDUM

ILLUSTRATIVE EXAMPLES IN USE OF REPORT

I. APPLICATION OF CHARTS 1-20 (INTEREST RATE 4%, AMORTIZATION PERIOD 40 YEARS)

A. Given the following data:

1985 water requirement ---------- 225 MGD

1969 water requirement
(limit of existing supplies) ---------- 150 MGD

1985 requirement from new source ---------- 75 MGD

Distance to new source, 70 miles.

Elevation of terminal storage, 350 ft above elevation of source.

Ratio, $\frac{\text{max. monthly use}}{\text{average annual use}}$ = 2.0 (peak factor).

Interest rate = 4.0% - amortization period 40 years.

The procedure in determining costs can be described in a series of steps as follows:

1. Assume pipeline to be designed for 1985 requirement.
(Second pipeline to be added after 1985)

Then growth rate = $\frac{1}{16}$ = 6.25%.

2. Assume pipeline to be operated at same peak factor as that of the load, or 2.0.

3. Go to Chart No. 19 (peak factor = 2.0; growth rate = 6.0%).

a. For 75 MGD on left scale, interpolate for L = 70 miles.
Read on lower scale, water cost = 9.5¢/1000 gal (static head = 0).

b. For 75 MGD on left scale, read on construction cost curve, for 70 miles interpolated, construction cost = $430,000/mi (Hs = 0).

c. Since peak delivery rate = 2.0 x 75 = 150 MGD, from Fig. 2, the economical diameter is 72 inches. This can also be estimated from Chart No. 19.

4. Static head slope = 350/70 = 5.0 ft/mile.

From right side of Chart No. 19, interpolate for 5 ft/mi, and read for 75 MGD the following corrections for static head:

For water cost, correction factor = 1.14.

For construction cost, correction factor = 1.03.

5. Then construction cost = $430,000 x 70 x 1.03 = $31 million.

Water cost = 9.5 x 1.14 = 10.8¢/1000 gal.

This example is illustrated on Chart No. 19 in red.

B. For closer interpolation of the Static Head Slope Correction Factors, a correction chart, Fig. 1, at the end of this Addendum, may be used in the following procedure.

1. Place the base line of the correction chart on the Rated Average Pipeline Capacity, or 75 MGD for above, on the right-hand part of Chart No. 19.

2. Project the intersection of the static head slopes of 4 ft, 8 ft, and 12 ft to their respective horizontal line on the correction chart.

3. Connect these points with a line, and read the correction factors. For the above example with a static head slope of 5 feet, the results are as shown on Fig. 2 at the end of this Addendum, and as follows:

Water cost correction factor = 1.145

Construction cost correction factor = 1.03

This chart is also used for the extrapolation of correction factors for static head slopes greater than 12 feet per mile. For example, if the static head slope were 20 feet per mile, the correction factors would be as follows:

Water cost correction factor = 1.62

Construction cost correction factor = 1.157

For short pipelines with very steep static head slopes, an extrapolation can be made by changing the left hand scale and drawing a line parallel to the plotted line. Thus for a static head slope of 35 feet per mile the water cost correction factor would be 2.10. For long pipelines, correction factors for additional static head slopes need to be computed to give a better plot of the extended line.

C. For interpolation of Peak Factor

Water cost and construction cost may be interpolated for Peak Factors other than those given in Charts 1-20 in the following manner. If in the above example, the peak factor were 1.9 instead of 2.0, merely read the cost figures from the charts for peak factors of 1.75 and 2.0 and add the proportional difference to the cost for a peak factor of 1.75.

For example:

From Chart 19--peak factor 2.0

Water cost (static head = 0) = 9.5¢/1000 gal

Water cost correction factor (5 ft/mi) = 1.14

Water cost = 10.8¢/1000 gal

From Chart 15--peak factor 1.75

Water cost (static head = 0) = 8.8¢/1000 gal

Water cost correction factor (5 ft/mi) = 1.16

Water cost = 10.2¢/1000 gal

Then water cost for peak factor 1.9 is

$$10.2 + \left(\frac{0.15}{0.25}\right)(10.8 - 10.2) = 10.56¢/1000 \text{ gal}$$

D. For Interpolation of Growth Rate

Water cost and construction cost may be interpolated for growth rates other than those given in Charts 1-20, in the following manner. Assume that in the above example the 75 MGD was not required until 1989. Thus the growth rate would be

$$\frac{1}{1989-1969} = \frac{1}{20} \text{ or } 5\%.$$

1. Read costs from Charts 17, 18, 19, and 20. (Peak factor = 2.0; and growth rates of 0%, 10%, 6%, and 3%, respectively.)

2. Plot cost versus a scale of the reciprocal of the growth rate, and join points by a curve as shown in Fig. 3 of this Addendum.

3. Read the cost for a growth rate of 5%.

For the example above, the water costs are respectively:

Growth Rate	Water Cost (Static Head = 0)	Water Cost Correction Factor (5 ft/mi)	Water Cost (5 ft/mi)
0%	6.9¢/1000 gal	1.195	8.25¢
10%	8.5¢/1000 gal	1.16	9.8 ¢
6%	9.5¢/1000 gal	1.14	10.8 ¢
3%	13.1¢/1000 gal	1.10	14.4 ¢

For a growth rate of 5% the water cost is 11.35¢/1000 gal.

II. INTERPOLATION FOR INTEREST AND AMORTIZATION PERIODS OTHER THAN 4% AND 40 YEARS

Example:

To find correction factor for 5% interest rate, 5% growth rate, and 35 year amortization period, use the following procedure with Fig. 8 of the report:

1. Interpolate and draw in lines 1a and 1b, illustrated on Fig. 4 of this Addendum, for static head slopes for 5 ft/mile and for growth rates of 3% and 0% for 30 years and 1c and 1d for 40 years. This is interpolated on straight

line basis from 0-12. Five ft/mile would be 5/12 or 0.42 of space from 0 slope to 12 ft/mile slope. (For static head slope of 9 ft/mile, ratio would be 9/12 or 0.75.)

2. Interpolate for growth rate of 5% between lines established in step 1. To get the interpolation ratio, divide 3% growth rate by the desired growth rate. Therefore, for this case, the interpolation ratio of distance is 3/5 or 0.6 from 0% growth rate towards 3% growth rate. Use this ratio to draw curves 2a and 2b for the amortization periods of 30 and 40 years, respectively (with a growth rate of 5% and a static head slope of 5 ft/mile). (For growth rate of 10% the ratio for interpolation ratio would be 3/10 or 0.3.)

3. Interpolate between the curves 2a (30 years) and 2b (40 years) using the square root of the difference for the interpolation ratio. In this case, the interpolation ratio is $\sqrt{5/10} = 0.71$. This is used to plot curve 3.

4. Then read on curve 3 the correction factor for 5% interest rate, in this case 19%. Therefore, the correction factor for 5% interest rate, 5% growth factor, and 35 year amortization period is 1.19 times the water cost read on Charts 1-20 for desired peak factors and the interpolated growth rate of 5%.

III. CHANGING UNIT COSTS OR ADDING COSTS EXCLUDED FROM COMPUTER PROGRAM

This example will be an extension of Example I. The additional problem assumed will be as follows:

1. Adjust costs for an increase of 10% in pipe costs.

2. Adjust costs for an increase of 20% in pump station costs.

3. Add costs due to a right-of-way cost of $5,000 per mile.

4. Add costs due to an annual operation and maintenance cost of $25,000 for the entire pipe plus $5,000 per pump station.

5. Add costs due to 20% higher power costs. It is assumed that none of the adjustments will affect the optimum size of pipe and number of pump stations.

A. Adjustment for Higher Pipe and Pump Station Unit Costs

1. From previous example the economical pipe diameter is 72 inches.

2. The following data is obtained for Appendix B, pages 22 and 28, for a growth rate of zero and a diameter of 72 inches.

Page	Growth Rate	Q MGD	L Mi	HS Ft/Mi	No. of Pumping Stations	H Max per Segment	*Pipe Press. Class	Pipe Cost $1000/Mi	Pump Station Cost $1000/Mi	*Pump Station Cost $1000/Station
22	0.0	60	60	0	2	218	100	364.7	35.7	1070
22	0.0	60	60	12	4	289	150	373.4	60.7	910
22	0.0	60	100	0	3	242	150	366.7	32.8	1090
22	0.0	60	100	12	6	321	150	376.9	56.5	940

* Rederived.

3. From page 28 of Appendix B it is seen that all data remain unchanged for corresponding conditions in a growth rate of 3%. Hence, it is assured that growth rate will not affect these adjustments.

4. For 60 MGD and 60 miles, the total friction head, from the above data, is 218 x 2 = 436 feet. In the Manning Formula, friction-slope varies as V^2, and hence as Q^2 for the same diameter. Hence, for 75 MGD and 70 miles,

$$Hf = \left(\frac{75}{60}\right)^2 \times 436 \times \frac{70}{60} = 800 \text{ feet}$$

and $HS = 70 \times 5 = \underline{350}$ feet.

Hence, H Max = 1150 feet.

5. Since the 60 MGD, 60 miles case is closest to this example, assume 4 pump stations making the head per pump station $\frac{1150}{4} = 287$ feet.

Then pipe cost/mile = $373,400 approximately

and pump station cost/mile $= \frac{4 \times 910}{70} = 52.0$

6. Now the effect of a 10% increase in pipe cost is to add

$$0.1 \times \$373,400 = \$37,340 \text{ per mile.}$$

7. The effect of a 20% increase in pump station costs is to add

$$0.2 \times \$52,000 = \$10,400/\text{Mi.}$$

8. The construction cost from the previous example, adjusted in both increases, is

$$\$31,000,000 + 70(\$37,340 + \$10,400) =$$

$$\$31,000,000 + \$3,340,000 = \$34.34 \text{ million.}$$

9. The present worth factor for a peak factor of 2.0, growth rate of 6%, is 13.41 (from Appendix A, Part I, page 99).

By formula (7) on page 17 of the report, the increased water cost for an increased construction cost of $3.34 million is

$$WC = \frac{\$3,340,000}{75 \times 13.4 \times 3650} = 0.9¢/1000 \text{ gal.}$$

Hence, the adjusted water cost for these two increases is

$$10.8 + 0.9 = 11.7¢/1000 \text{ gal.}$$

B. Adjustment for Right-of-Way and O&M Costs

This is described on pages 17 and 18 of the report.

1. For a right-of-way cost of $5000 per mile, the increased construction cost is 70 x $5000 = $350,000 and the $31 million in the original example would be $31.35 million.

2. The increased water cost to reflect the above right-of-way cost is, by formula (7),

$$WC = \frac{\$350,000}{75 \times 13.41 \times 3650} = 0.10¢/1000 \text{ gal.}$$

3. An O&M cost of $25,000 + $5,000 per pump station represents a total annual operation cost of $25,000 + (4 x $5,000) = $45,000.

By formula (8) the added water cost is

$$WC = \frac{\$45,000 \times 19.79}{75 \times 13.41 \times 3650} = 0.24¢/1000 \text{ gal.}$$

4. The water cost for the original example adjusted for the above right-of-way and O&M costs (but not for the increased unit prices) would be 10.8 + 0.10 + 0.24 = 11.14¢/1000 gal.

C. Adjustment for Higher Power Costs

1. By using the relations in formula (7), page 17 of the report, and the present worth,

PW of water cost = water cost/1000 gal x Q avg X PWF x 3650, or for the given example

PW of water cost = 10.8 x 75 x 13.41 x 3650 = $39.9 million.

2. Referring to the present worth formula, page 13 of the report,

PW of pumping costs = PW of water cost - total investment cost

or PW of pumping cost = 39.9 - 31.0 = $8.9 million.

and using the relation in formula (8), page 17,

$$WC = \frac{0.2 \times \$8,900,000}{75 \times 13.41 \times 3650} = 0.5¢/1000 \text{ gal.}$$

3. Hence, the water cost with a 20% increase in power cost is

$10.8 + 0.5 = 11.3¢/1000$ gal.

IV. ECONOMICS OF TERMINAL STORAGE

This example will illustrate an application of the report data to a related problem. The conditions assumed will be the same as for Example 1.

1. Assume in Example 1 that a peak factor of 2.0 is required with little or no terminal storage, and that the duration of use curve is as shown in Figs. 4, 5, 6, and 7 in the report.

The pumping curve on Fig. 7 was deliberately drawn above the duration of use curve for 3 and 2 pumps, because doing this made the water costs conservatively high. The portion of the use curve below the maximum capacity (3 pumps) can be fitted very closely by varying the number of pumps in service at short intervals. Such operation will require very little terminal storage.

2. The only large need for terminal storage will be for the part of the use curve above the maximum capacity of the pumps and pipeline. From Figs. 4, 5, and 6, this amount is approximately as follows:

Fig.	Peak Factor	Approximate Area* Above Maximum Capacity Q/Q Avg. x % of Time	Required Volume in MG (for time of one year)
--	1.00	1/3 x 1.25 x .37 = .155	.155 x 75 x 365 = 4250 MG
4	1.25	1/2 x 1.0 x .16 = .08	.08 x 75 x 365 = 2190 MG
5	1.50	1/2(.75 x 08 + .16 x .09) = .037	.037 x 75 x 365 = 1010 MG
6	1.75	1/2 x .05 x .04 = .01	.01 x 75 x 365 = 240 MG

* Could also be planimetered with greater accuracy than as determined above.

3. Assume for Case A that terminal storage can be provided at $600 per million gallons (approximately $200 per acre-foot). Assume also that the terminal storage is 15 feet deep and that net reservoir evaporation is 3 feet per year; hence, that annual evaporation loss will be 20% of the total storage volume.

4. Then the costs for water delivered can be found as follows (following the same procedure as for Example I for other peak factors). The correction to water costs per 1000 gallons for the addition of terminal storage facilities is computed on the basis of equation (7), page 17 of the report.

Peak Factor	Terminal Storage Cost $ Million	Pipeline Cost $ Million	Project Cost Million	Water Costs ¢/1000 gal		
				From Charts	Add for Terminal Reservoir	Cost of Water Delivery
1.0	2.55	20.6	23.2	7.9	0.7	8.6
1.25	1.31	24.0	25.3	8.8	0.4	9.2
1.50	0.60	26.1	26.7	9.5	0.2	9.7
1.75	0.15	29.2	29.35	10.0	0.1	10.1
2.0	0	31.0	31.0	10.8	0	10.8

To the above costs, an additional cost must be added for the evaporation loss. This is computed as follows:

$$\Delta WC(¢/1000\ gal) = \frac{Evap.Loss(MG) \times (Water\ Cost\ at\ Source + Water\ Del.Cost)(¢/1000)}{Q\ Avg\ (MGD) \times (365)}$$

Assuming that the average cost of water at the source is 10¢/1000 gallons, the total water cost for terminal storage is:

Peak Factor	Water Costs ¢/1000 gallons, CASE A		
	Delivered	Add for Evaporation	Total Water Cost
1.0	8.6	0.6	9.2
1.25	9.2	0.3	9.5
1.50	9.7	0.1	9.8
1.75	10.1	0	10.1
2.0	10.8	0	10.8

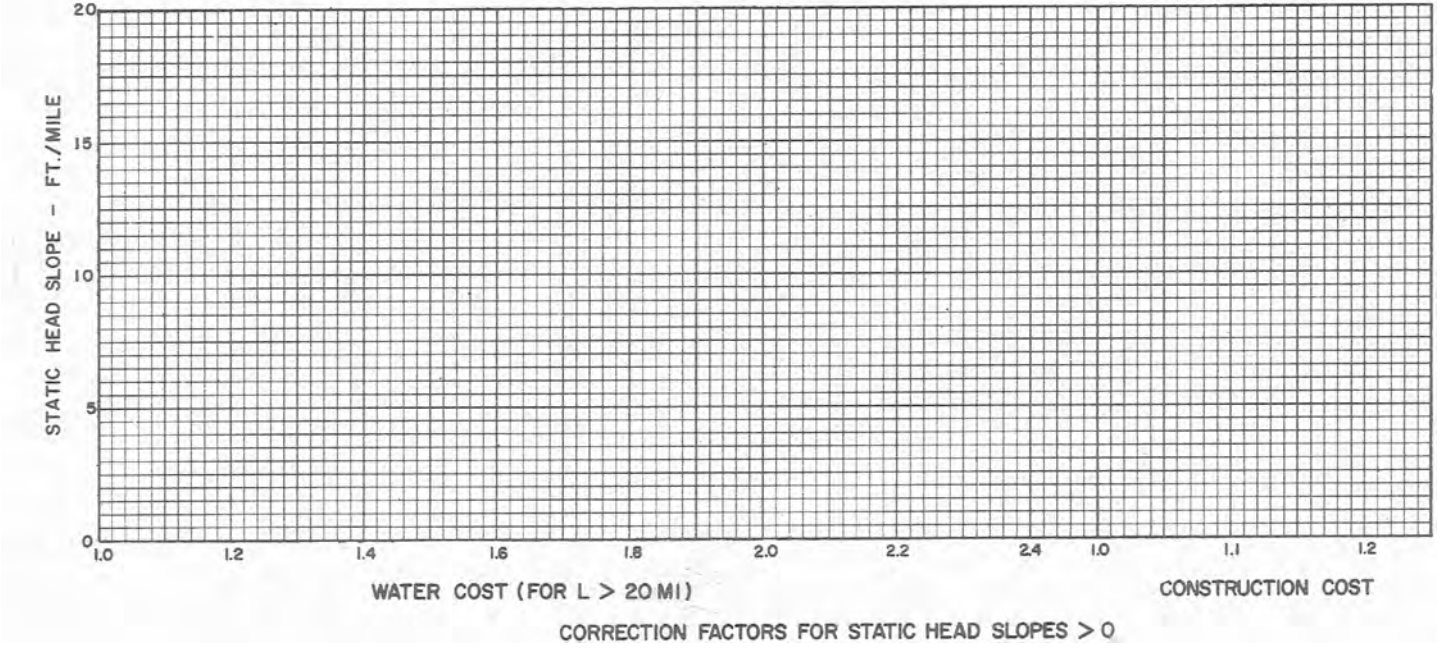
Clearly, the terminal reservoir for unity peak factor operation is justified.

5. If the unit cost assumed above for terminal storage were doubled (Case B), or tripled (Case C), the cost would be as follows (including the evaporation loss).

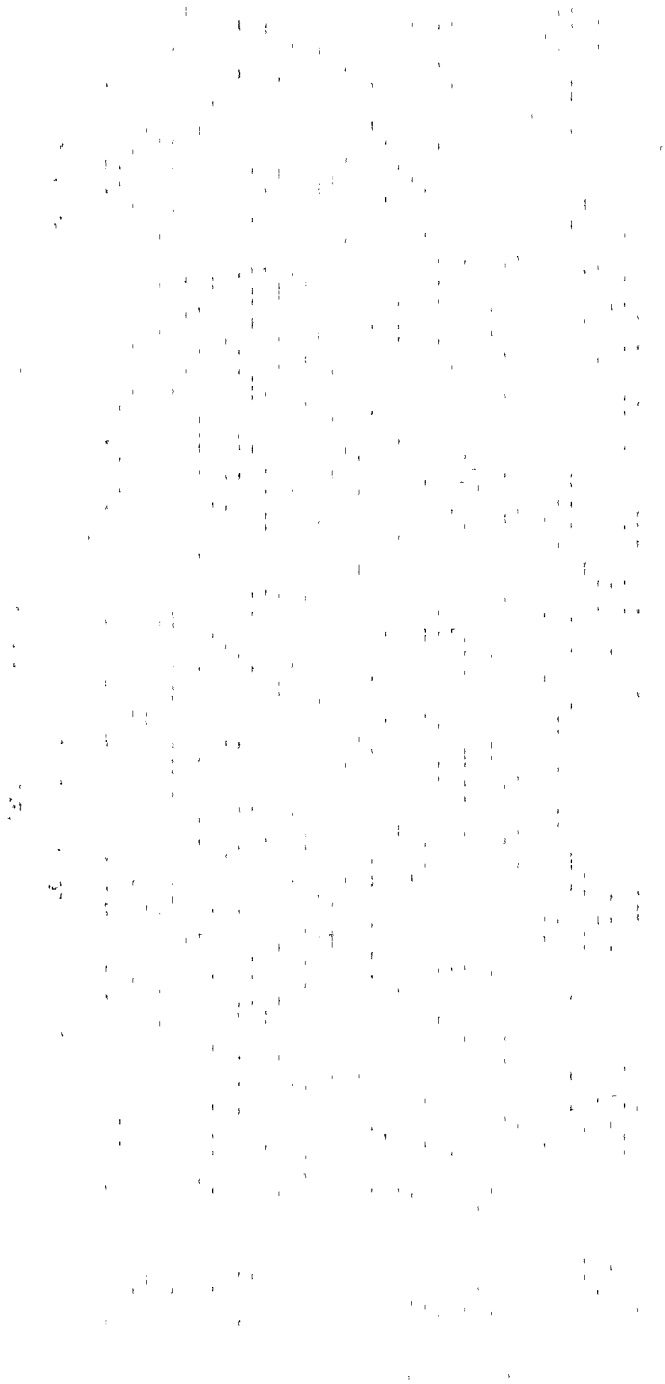
Peak Factor	CASE B Terminal Storage $1200/MG		CASE C Terminal Storage $1800/MG	
	Project Cost $ Million	Total Water Cost ¢/1000 Gal	Project Cost $ Million	Total Water Cost ¢/1000 Gal
1.0	25.7	9.9	28.3	10.6
1.25	26.6	9.9	27.9	10.3
1.50	27.0	10.0	27.6	10.2
1.75	29.5	10.2	29.6	10.3
2.0	31.0	10.8	31.0	10.8

It appears that a peak factor of either 1.0 or 1.25 should be used for Case B, and one of 1.50 for Case C.

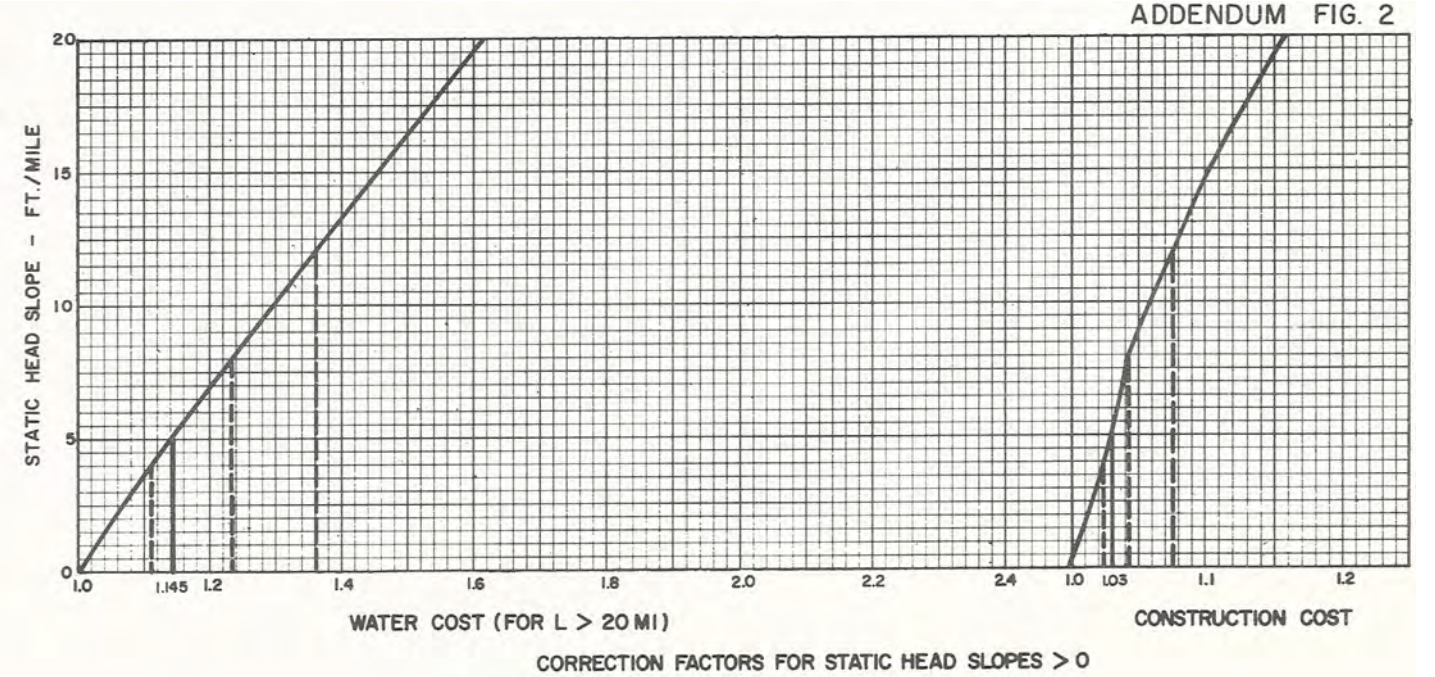
ADDENDUM FIG. 1



CORRECTION FACTORS FOR STATIC HEAD SLOPES > 0

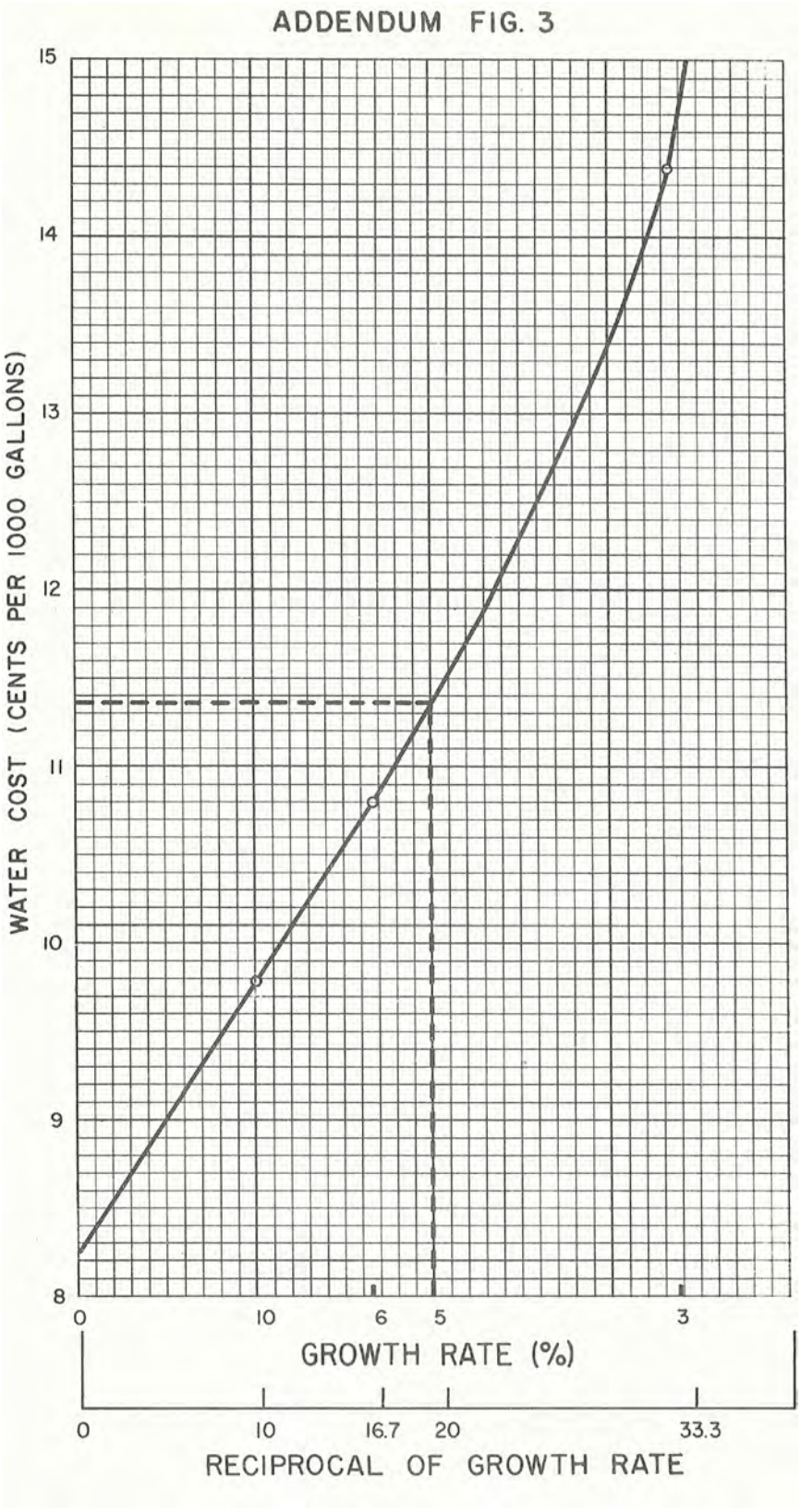


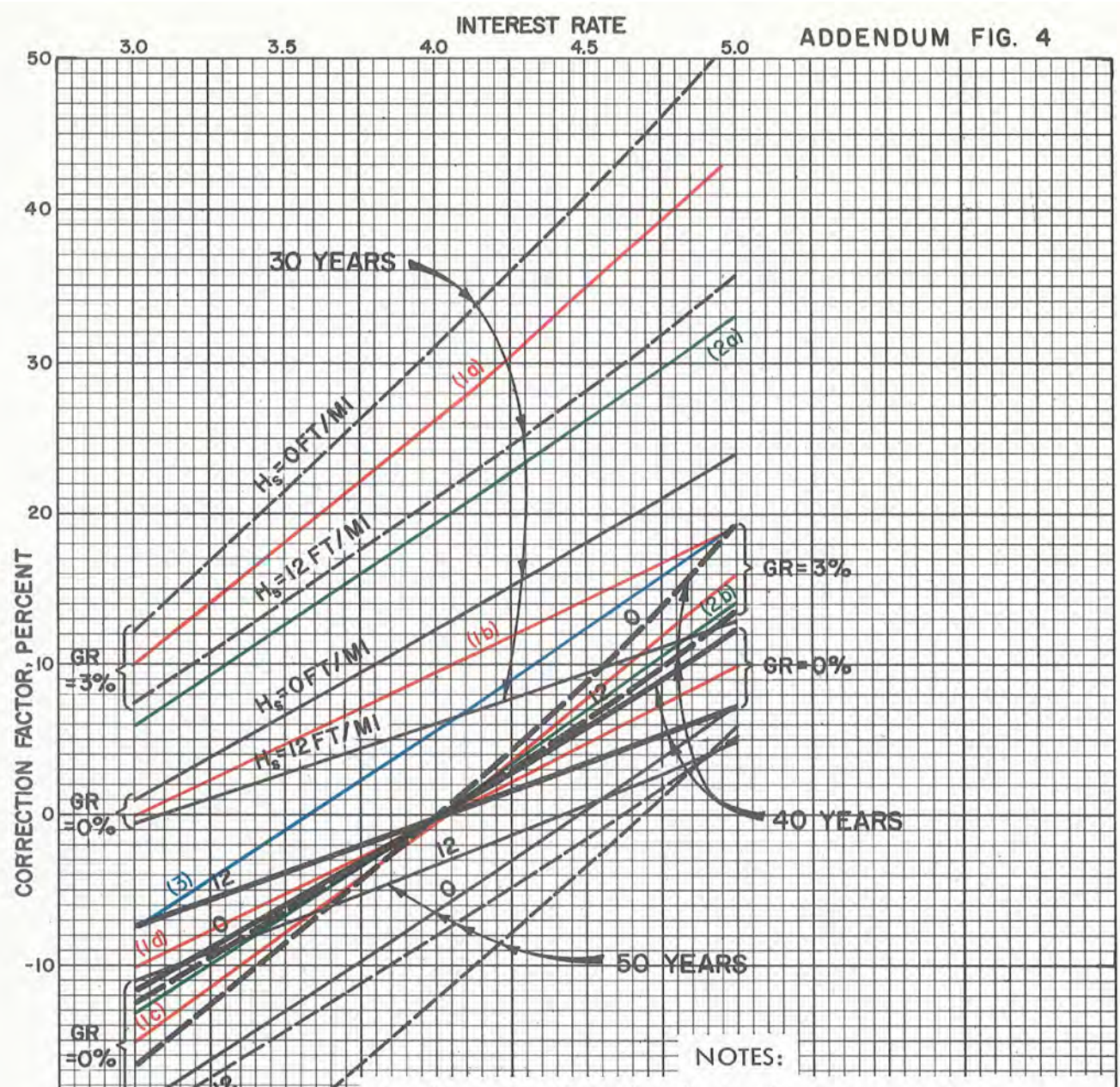
ADDENDUM FIG. 2



CORRECTION FACTORS FOR STATIC HEAD SLOPES > 0

EXAMPLE IN USE OF ADDENDUM FIG. 1


ADDENDUM FIG. 3
WATER COST (CENTS PER 1000 GALLONS)
15
14
13
12
11
10
9
8
0
10
6
5
3
GROWTH RATE (%)
0
10
16.7
20
33.3
RECIPROCAL OF GROWTH RATE



NOTES:

1. "Correction Factor" indicates the percentage increase or decrease in water cost, for interest rates and/or amortization periods shown, from the water cost shown in the report for 40 years and 4%, and for the corresponding static head slope and growth rate.
2. "The Correction Factor" is essentially the same for all peak factors and lengths of pipe line.
3. Curves are drawn for Q_{AVG} = 300 MGD. Other values of Q cause relatively little variation in the Correction Factor.

EXAMPLE IN USE OF FIG. 8

APPENDIX A

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PART I

PRINTOUT OF DATA USED FOR CHARTS
(OUTPUT A)

TEXAS WATER DEVELOPMENT BOARD — LOCKWOOD, ANDREWS AND NEWNAM, INC. PROGRAM

COST OF DELIVERING WATER BY PIPELINE - MOST ECONOMICAL DIAMETER

PEAK FACTOR = 1.00 GROWTH RATE = 0.00 INTEREST RATE = 0.040 AMORTIZATION PERIOD = 40YRS PRESENT WORTH FACTOR = 20.19

FLOW	LENGTH	STATIC HEAD SLOPE = 0				STATIC HEAD SLOPE = 4				STATIC HEAD SLOPE = 8				STATIC HEAD SLOPE = 12			
MGD	MILES	DIA.	NO. PS	C.C. ($/MI	W.C./CT/TG	DIA.	NO. PS	C.C. RATIO	W.C. RATIO	DIA.	NO. PS	C.C. RATIO	W.C. RATIO	DIA.	NO. PS	C.C. RATIO	W.C. RATIO
2	10	16	1	54.0	4.30	16	1	1.041	1.069	16	1	1.081	1.138	16	1	1.122	1.207
2	20	16	1	52.4	7.97	16	1	1.042	1.075	16	1	1.084	1.149	16	1	1.132	1.229
2	40	16	1	51.5	15.30	16	1	1.062	1.095	16	2	1.102	1.197	16	2	1.150	1.280
2	60	16	1	51.0	22.80	16	2	1.045	1.099	16	2	1.112	1.199	16	3	1.147	1.289
2	100	16	2	51.4	37.94	16	3	1.049	1.095	16	4	1.101	1.193	16	5	1.154	1.291
2	200	16	4	51.4	75.89	16	6	1.049	1.095	16	8	1.101	1.193	16	10	1.154	1.291
2	300	16	6	51.4	113.83	16	9	1.049	1.095	16	12	1.101	1.193	16	15	1.154	1.291
2	400	16	7	51.4	151.38	16	12	1.049	1.098	16	16	1.101	1.196	16	21	1.150	1.293
2	500	16	9	51.3	189.08	16	15	1.051	1.099	16	20	1.103	1.197	16	26	1.152	1.294
5	10	21	1	68.2	2.35	21	1	1.028	1.085	21	1	1.057	1.171	21	1	1.085	1.256
5	20	21	1	65.5	4.39	21	1	1.045	1.104	21	1	1.102	1.218	24	1	1.264	1.339
5	40	24	1	72.7	8.71	21	2	0.942	1.112	21	2	0.994	1.227	21	3	1.021	1.339
5	60	21	2	65.9	13.06	21	3	1.038	1.112	21	4	1.079	1.226	21	4	1.131	1.337
5	100	24	2	72.4	21.62	21	5	0.945	1.120	21	7	0.979	1.234	21	6	1.035	1.346
5	200	24	4	72.4	43.23	24	7	1.043	1.119	24	11	1.079	1.236	21	13	1.031	1.346
5	300	24	6	72.4	64.85	24	11	1.039	1.117	24	16	1.079	1.234	21	19	1.032	1.346
5	400	24	8	72.4	86.47	24	15	1.040	1.118	24	21	1.081	1.235	21	25	1.032	1.346
5	500	24	10	72.4	108.08	24	18	1.040	1.117	21	13	1.127	1.248	21	16	1.159	1.330
10	10	30	1	100.7	1.65	30	1	1.017	1.104	30	1	1.035	1.209	30	1	1.052	1.313
10	20	30	1	96.9	3.11	30	1	1.018	1.110	27	1	0.984	1.149	30	1	1.098	1.245
10	40	27	1	91.4	6.03	30	1	1.123	1.100	27	2	1.043	1.186	30	2	1.165	1.285
10	60	30	2	95.7	9.15	27	2	0.992	1.094	27	3	0.996	1.173	30	3	1.113	1.271
10	100	30	3	95.4	15.19	27	4	0.969	1.077	30	4	1.086	1.175	30	5	1.116	1.276
10	200	30	3	99.2	29.97	27	8	0.932	1.091	30	8	1.044	1.191	27	13	0.985	1.290
10	300	27	8	90.3	44.80	27	12	1.024	1.095	27	16	1.052	1.194	30	16	1.175	1.294
10	400	27	11	87.9	59.51	27	16	1.028	1.099	27	21	1.057	1.199	27	26	1.087	1.300
10	500	27	14	87.8	74.32	27	20	1.029	1.100	27	26	1.059	1.201	27	33	1.087	1.300
20	10	39	1	135.7	1.16	33	1	0.876	1.111	33	1	0.887	1.218	39	1	1.035	1.246
20	20	36	1	120.8	2.10	39	1	1.092	1.104	39	1	1.125	1.237	39	2	1.163	1.375
20	40	39	1	127.7	4.07	39	2	1.033	1.140	39	2	1.064	1.278	39	3	1.079	1.402
20	60	36	2	119.8	6.26	39	3	1.101	1.111	39	4	1.129	1.241	39	5	1.157	1.372
20	100	39	3	129.2	10.21	39	4	1.022	1.130	39	6	1.050	1.265	39	8	1.079	1.401
20	200	39	5	127.7	20.34	39	8	1.026	1.134	39	12	1.054	1.269	39	15	1.079	1.402
20	300	39	7	127.5	30.47	39	12	1.027	1.135	39	17	1.055	1.270	39	23	1.082	1.405
20	400	39	10	127.7	40.68	39	16	1.026	1.134	39	23	1.052	1.268	39	30	1.079	1.402
20	500	39	12	127.6	50.81	39	20	1.027	1.134	39	29	1.053	1.269	39	38	1.081	1.404
40	10	45	1	191.1	0.93	48	1	1.113	1.113	48	1	1.124	1.243	48	1	1.136	1.373
40	20	48	1	200.0	1.75	48	1	1.011	1.138	48	1	1.047	1.295	48	1	1.085	1.454
40	40	51	1	214.6	3.49	48	2	0.942	1.145	48	2	0.976	1.303	48	3	0.996	1.450
40	60	48	2	196.5	5.19	48	3	1.029	1.153	48	4	1.058	1.307	48	5	1.087	1.460
40	100	48	3	196.0	8.64	48	5	1.031	1.155	48	6	1.062	1.310	48	8	1.089	1.462
40	200	48	6	196.0	17.28	48	10	1.031	1.155	48	13	1.059	1.308	48	16	1.089	1.462
40	300	48	9	196.0	25.92	48	14	1.030	1.154	48	19	1.060	1.309	48	24	1.089	1.462
40	400	48	12	196.0	34.56	48	19	1.029	1.154	48	26	1.059	1.308	48	33	1.089	1.462
40	500	48	15	196.0	43.20	48	24	1.029	1.154	48	32	1.059	1.308	48	41	1.089	1.462
60	10	57	1	203.9	0.82	57	1	1.010	1.146	57	1	1.019	1.291	57	1	1.029	1.437
60	20	57	1	208.2	1.57	57	1	1.010	1.152	60	1	1.104	1.315	60	1	1.136	1.483
60	40	60	1	200.2	3.08	57	2	0.967	1.176	60	2	1.057	1.341	60	3	1.085	1.512
60	60	57	2	203.0	4.64	60	2	1.099	1.167	60	3	1.126	1.335	60	4	1.155	1.503
60	100	60	2	217.7	7.69	60	4	1.029	1.171	60	5	1.059	1.344	60	7	1.086	1.513
60	200	60	4	217.7	15.37	60	8	1.029	1.171	60	11	1.056	1.341	60	14	1.086	1.513
60	300	60	6	217.7	23.06	60	11	1.029	1.171	60	16	1.057	1.342	60	21	1.086	1.513
60	400	60	9	217.5	30.73	60	15	1.028	1.171	60	22	1.057	1.342	60	29	1.086	1.513
60	500	60	11	217.3	38.39	60	19	1.028	1.171	60	28	1.058	1.343	60	36	1.087	1.514
100	10	72	1	421.4	0.71	72	1	1.008	1.165	72	1	1.017	1.331	72	1	1.025	1.496
100	20	72	1	395.3	1.36	72	1	1.009	1.174	72	1	1.031	1.358	72	1	1.063	1.550
100	40	72	1	382.3	2.65	72	2	1.044	1.205	72	2	1.066	1.394	72	3	1.096	1.590
100	60	72	2	388.0	4.01	72	2	1.026	1.190	72	3	1.054	1.382	72	4	1.084	1.575
100	100	72	2	383.3	6.63	72	4	1.027	1.192	72	5	1.063	1.391	72	7	1.092	1.585
100	200	72	5	382.3	13.23	72	8	1.030	1.195	72	11	1.063	1.392	72	14	1.095	1.589
100	300	72	7	381.4	19.82	72	12	1.032	1.197	72	17	1.064	1.394	72	22	1.097	1.591
100	400	72	9	381.0	26.40	72	16	1.033	1.198	72	22	1.066	1.396	72	29	1.099	1.593
100	500	72	11	380.7	32.98	72	20	1.034	1.199	72	28	1.066	1.396	72	37	1.100	1.594
150	10	90	1	594.4	0.63	90	1	1.005	1.184	90	1	1.010	1.367	90	1	1.015	1.551
150	20	90	1	550.5	1.19	90	1	1.005	1.195	90	1	1.011	1.389	90	1	1.048	1.611
150	40	90	1	530.6	2.31	90	1	1.035	1.225	90	2	1.049	1.433	90	2	1.087	1.661
150	60	90	1	523.9	3.43	90	2	1.031	1.224	90	3	1.062	1.448	90	4	1.093	1.672
150	100	90	2	520.6	5.74	90	3	1.030	1.222	90	5	1.056	1.442	90	6	1.091	1.668
150	200	90	3	522.6	11.41	90	7	1.036	1.229	90	10	1.065	1.451	90	13	1.097	1.676
150	300	90	5	523.9	17.16	90	10	1.031	1.224	90	15	1.062	1.448	90	20	1.093	1.672
150	400	90	6	522.6	22.83	90	13	1.032	1.225	90	20	1.065	1.451	90	26	1.097	1.676
150	500	90	8	523.4	28.57	90	16	1.031	1.224	90	25	1.063	1.449	90	33	1.095	1.674
200	10	102	1	719.7	0.58	102	1	1.005	1.201	102	1	1.011	1.402	102	1	1.016	1.602
200	20	102	1	666.4	1.08	102	1	1.006	1.214	102	1	1.012	1.428	102	1	1.050	1.670
200	40	102	1	639.6	2.09	102	1	1.034	1.245	102	2	1.054	1.478	102	2	1.094	1.728
200	60	102	1	631.0	3.10	102	2	1.034	1.247	102	3	1.068	1.495	102	4	1.103	1.742
200	100	102	2	634.5	5.20	102	3	1.027	1.241	102	5	1.062	1.488	102	6	1.098	1.735
200	200	102	3	627.2	10.32	102	6	1.036	1.249	102	10	1.071	1.498	102	13	1.104	1.745
200	300	102	4	629.4	15.49	102	9	1.036	1.249	102	14	1.070	1.497	102	19	1.105	1.745
200	400	102	6	629.2	20.65	102	13	1.036	1.249	102	19	1.070	1.497	102	26	1.104	1.745
200	500	102	7	628.1	25.77	102	16	1.037	1.250	102	24	1.071	1.498	102	33	1.107	1.748
300	10	120	1	962.0	0.50	120	1	1.006	1.230	120	1	1.012	1.461	120	1	1.019	1.691
300	20	120	1	844.2	0.94	120	1	1.007	1.248	120	1	1.014	1.496	120	1	1.055	1.772
300	40	120	1	790.3	1.80	120	1	1.083	1.277	120	2	1.064	1.556	120	2	1.107	1.843
300	60	120	1	774.0	2.66	120	2	1.041	1.289	120	3	1.082	1.577	120	4	1.122	1.866
300	100	120	1	833.5	4.42	120	3	0.986	1.288	120	5	1.030	1.583	120	6	1.068	1.871
300	200	120	2	833.5	8.84	120	6	0.986	1.288	120	9	1.029	1.581	120	13	1.066	1.869
300	300	120	4	780.7	13.24	120	9	1.042	1.291	120	14	1.085	1.583	120	19	1.127	1.874
300	400	120	4	833.5	17.68	120	12	0.986	1.288	120	19	1.026	1.578	120	26	1.066	1.869
300	500	120	7	769.8	22.08	120	15	1.041	1.290	120	24	1.083	1.581	120	32	1.125	1.871
500	10	150	1	1290.1	0.42	150	1	1.007	1.275	150	1	1.015	1.550	150	1	1.022	1.826
500	20	150	1	1157.1	0.77	150	1	1.008	1.301	150	1	1.017	1.602	156	1	1.098	1.928
500	40	150	1	1089.6	1.47	156	1	1.082	1.322	150	2	1.079	1.681	156	2	1.165	2.022
500	60	150	1	1068.4	2.17	150	2	1.051	1.354	150	3	1.101	1.709	156	3	1.189	2.056
500	100	150	1	1100.5	3.57	150	3	1.012	1.366	156	4	1.104	1.723	156	6	1.149	2.079
500	200	150	2	1100.5	7.13	156	5	1.053	1.362	156	9	1.102	1.722	156	12	1.149	2.079
500	300	150	3	1100.5	10.70	156	8	1.049	1.359	156	13	1.099	1.719	156	18	1.149	2.079
500	400	150	4	1100.5	14.26	156	11	1.051	1.361	156	17	1.100	1.720	156	24	1.149	2.079
500	500	150	5	1100.5	17.83	156	13	1.048	1.359	156	22	1.100	1.719	156	30	1.149	2.079
1000	10	210	1	2110.0	0.33	216	1	1.009	1.353	216	1	1.018	1.707	216	1	1.027	2.060
1000	20	210	1	1852.0	0.58	216	1	1.010	1.397	216	1	1.021	1.794	216	1	1.055	2.211
1000	40	210	1	1717.0	1.10	216	1	1.011	1.423	216	2	1.100	1.912	216	2	1.136	2.357
1000	60	210	1	1674.0	1.61	216	2	1.064	1.478	216	2	1.110	1.939	216	3	1.166	2.410
1000	100	210	1	1639.2	2.63	216	2	1.073	1.492	216	4	1.125	1.967	216	4	1.191	2.454
1000	200	210	1	1716.8	5.26	216	5	1.015	1.483	216	8	1.077	1.969	216	8	1.140	2.456
1000	300	210	2	1821.4	7.83	216	7	1.068	1.492	216	12	1.137	1.985	216	12	1.204	2.476
1000	400	210	3	1823.8	10.46	216	10	1.064	1.492	216	16	1.134	1.980	216	16	1.201	2.471
1000	500	210	4	1820.3	13.09	216	12	1.064	1.487	216	20	1.132	1.978	216	20	1.199	2.467

TEXAS WATER DEVELOPMENT BOARD — LOCKWOOD,ANDREWS,AND NEWNAM,INC. PROGRAM

COST OF DELIVERING WATER BY PIPELINE - MOST ECONOMICAL DIAMETER

PEAK FACTOR = 1.00 GROWTH RATE = 0.10 INTEREST RATE = 0.040 AMORTIZATION PERIOD = 40YRS PRESENT WORTH FACTOR = 15.78

FLOW MGD	LENGTH MILES	STATIC HEAD SLOPE = 0 DIA.	NO.	PS	C.C.TS/MI	W.C.CT/TG	STATIC HEAD SLOPE = 4 DIA.	NO.	PS	C.C.RATIO	W.C.RATIO	STATIC HEAD SLOPE = 8 DIA.	NO.	PS	C.C.RATIO	W.C.RATIO	STATIC HEAD SLOPE = 12 DIA.	NO.	PS	C.C.RATIO	W.C.RATIO
2	10	16	1		54.0	5.25	16	1		1.041	1.069	16	1		1.081	1.135	16	1		1.122	1.201
2	20	16	1		52.4	9.84	16	1		1.042	1.071	16	1		1.084	1.141	16	1		1.132	1.216
2	40	16	1		51.5	19.04	16	1		1.062	1.090	16	2		1.102	1.180	16	2		1.150	1.257
2	60	16	1		51.6	28.45	16	2		1.045	1.088	16	2		1.112	1.183	16	3		1.147	1.262
2	100	16	2		51.4	47.27	16	3		1.049	1.087	16	4		1.101	1.176	16	5		1.154	1.266
2	200	16	4		51.4	94.55	16	6		1.049	1.087	16	8		1.101	1.176	16	10		1.154	1.266
2	300	16	6		51.4	141.82	16	9		1.049	1.087	16	12		1.101	1.176	16	16		1.150	1.265
2	400	16	7		51.4	188.75	16	12		1.049	1.089	16	16		1.101	1.178	16	21		1.150	1.266
2	500	16	9		51.3	235.72	16	15		1.051	1.090	16	20		1.103	1.179	16	26		1.152	1.267
5	10	21	1		66.2	2.80	21	1		1.028	1.079	21	1		1.057	1.157	21	1		1.085	1.235
5	20	21	1		65.5	5.27	21	1		1.045	1.096	21	1		1.102	1.202	21	2		1.129	1.312
5	40	21	2		65.5	10.55	21	2		1.045	1.096	21	3		1.079	1.197	21	3		1.132	1.300
5	60	21	2		65.9	15.76	21	3		1.038	1.100	21	4		1.079	1.202	21	4		1.131	1.305
5	100	21	4		65.0	26.04	21	6		1.046	1.109	21	7		1.091	1.211	21	7		1.145	1.316
5	200	21	8		65.0	52.08	21	11		1.045	1.106	24	11		1.202	1.243	21	13		1.148	1.316
5	300	21	12		65.0	78.12	24	11		1.158	1.136	21	22		1.087	1.210	21	19		1.150	1.316
5	400	21	16		65.0	104.16	24	15		1.158	1.137	24	21		1.204	1.243	21	25		1.150	1.316
5	500	21	20		65.0	130.20	24	18		1.159	1.137	21	13		1.256	1.261	21	16		1.292	1.335
10	10	27	1		91.7	1.97	27	1		1.019	1.092	27	1		1.038	1.184	27	1		1.057	1.275
10	20	27	1		87.9	3.73	30	1		1.123	1.111	27	1		1.084	1.133	27	1		1.145	1.243
10	40	27	1		91.4	7.28	30	1		1.123	1.115	27	2		1.043	1.162	27	2		1.101	1.275
10	60	30	2		95.7	11.15	27	2		0.992	1.073	27	3		0.996	1.138	27	3		1.052	1.248
10	100	30	3		95.4	18.51	27	4		0.969	1.054	27	5		0.999	1.142	27	6		1.030	1.231
10	200	27	5		91.4	36.38	27	8		1.012	1.073	27	10		1.043	1.162	27	13		1.070	1.248
10	300	27	8		90.3	54.03	27	12		1.024	1.084	27	16		1.052	1.171	27	19		1.083	1.261
10	400	27	11		89.9	71.77	27	16		1.028	1.088	27	21		1.057	1.176	27	26		1.087	1.265
10	500	27	14		89.8	89.62	27	20		1.029	1.089	27	26		1.059	1.178	27	33		1.087	1.266
20	10	39	1		135.7	1.38	33	1		0.876	1.057	33	1		0.887	1.149	36	1		0.965	1.211
20	20	36	1		120.8	2.50	36	1		1.019	1.107	39	1		1.125	1.231	36	2		1.084	1.343
20	40	39	1		127.1	4.96	36	2		0.964	1.116	36	3		0.992	1.232	39	3		1.079	1.345
20	60	36	2		119.8	7.45	36	3		1.028	1.114	36	4		1.055	1.229	36	5		1.083	1.344
20	100	36	4		119.7	12.40	39	4		1.094	1.114	36	7		1.053	1.228	36	9		1.085	1.345
20	200	36	7		119.3	24.72	36	11		1.031	1.117	36	14		1.057	1.231	36	17		1.087	1.348
20	300	36	11		119.4	37.11	36	16		1.028	1.115	36	21		1.057	1.231	36	26		1.086	1.347
20	400	36	14		119.3	49.45	36	21		1.028	1.115	36	28		1.057	1.231	36	35		1.086	1.348
20	500	36	18		119.3	61.82	36	26		1.029	1.116	36	35		1.057	1.231	36	43		1.087	1.348
40	10	45	1		191.1	1.07	45	1		1.012	1.115	45	1		1.023	1.229	45	1		1.035	1.344
40	20	45	1		180.7	2.06	48	1		1.119	1.132	45	1		1.068	1.272	45	2		1.095	1.403
40	40	45	2		180.7	4.11	48	2		1.119	1.132	45	3		1.057	1.264	45	3		1.089	1.399
40	60	48	2		196.5	6.16	48	3		1.029	1.135	45	4		0.974	1.269	45	5		1.002	1.402
40	100	48	3		196.0	10.24	45	6		0.944	1.134	45	7		0.976	1.271	45	9		1.004	1.405
40	200	45	9		179.6	20.48	45	12		1.030	1.134	45	15		1.063	1.270	45	18		1.095	1.405
40	300	45	13		179.3	30.67	45	18		1.032	1.135	45	23		1.065	1.271	45	28		1.097	1.407
40	400	45	17		179.3	40.89	45	24		1.032	1.135	45	31		1.065	1.271	45	37		1.098	1.407
40	500	45	21		179.4	51.15	45	30		1.031	1.135	45	38		1.064	1.271	45	47		1.097	1.406
60	10	54	1		264.4	0.97	54	1		1.010	1.125	54	1		1.021	1.240	54	1		1.031	1.374
60	20	54	1		248.8	1.86	57	1		1.089	1.135	57	1		1.120	1.281	57	1		1.154	1.430
60	40	57	1		262.5	3.66	57	2		1.032	1.151	57	2		1.061	1.298	57	3		1.088	1.445
60	60	57	2		263.0	5.50	57	3		1.030	1.149	57	3		1.059	1.297	57	4		1.086	1.443
60	100	57	3		261.9	9.14	57	4		1.032	1.151	57	6		1.060	1.298	57	7		1.091	1.447
60	200	57	6		261.9	18.27	57	9		1.028	1.148	57	12		1.060	1.298	57	15		1.091	1.447
60	300	57	8		261.5	27.37	57	13		1.031	1.150	57	18		1.062	1.300	57	23		1.092	1.449
60	400	57	11		261.2	36.46	57	18		1.032	1.151	57	25		1.063	1.301	57	31		1.094	1.451
60	500	57	14		261.1	45.60	57	22		1.031	1.150	57	31		1.062	1.300	57	39		1.093	1.450
100	10	66	1		376.3	0.85	66	1		1.010	1.140	66	1		1.019	1.281	66	1		1.029	1.421
100	20	66	1		350.2	1.61	66	1		1.014	1.151	72	1		1.164	1.314	72	1		1.200	1.481
100	40	72	1		382.3	3.15	66	2		0.929	1.177	72	2		1.066	1.343	72	3		1.096	1.513
100	60	66	2		342.9	4.76	72	2		1.157	1.168	72	3		1.188	1.335	72	4		1.222	1.503
100	100	72	2		383.3	7.90	72	4		1.027	1.166	72	5		1.063	1.340	72	7		1.092	1.508
100	200	72	5		382.3	15.76	72	8		1.030	1.169	72	11		1.063	1.340	72	14		1.095	1.512
100	300	72	7		381.4	23.60	72	12		1.032	1.171	72	17		1.064	1.342	72	22		1.097	1.514
100	400	72	9		381.0	31.44	72	16		1.033	1.172	72	22		1.066	1.344	72	29		1.099	1.516
100	500	72	11		380.7	39.27	72	20		1.034	1.173	72	28		1.066	1.345	72	37		1.100	1.517
150	10	84	1		543.7	0.75	84	1		1.005	1.155	84	1		1.011	1.310	84	1		1.016	1.465
150	20	84	1		503.8	1.41	84	1		1.006	1.165	84	1		1.025	1.342	84	1		1.056	1.528
150	40	84	1		483.9	2.73	84	2		1.047	1.205	84	2		1.067	1.387	84	2		1.099	1.579
150	60	84	2		490.5	4.15	84	2		1.024	1.184	84	3		1.053	1.371	84	4		1.083	1.561
150	100	84	2		484.3	6.84	84	4		1.030	1.190	84	5		1.066	1.386	84	7		1.097	1.577
150	200	84	5		483.9	13.66	84	8		1.031	1.191	84	11		1.064	1.385	84	14		1.098	1.578
150	300	84	7		482.5	20.45	84	12		1.034	1.194	84	17		1.067	1.388	84	22		1.101	1.582
150	400	84	9		481.9	27.23	84	16		1.035	1.195	84	22		1.069	1.389	84	29		1.103	1.584
150	500	84	11		481.5	34.02	84	19		1.035	1.196	84	28		1.069	1.390	84	36		1.104	1.585
200	10	96	1		669.7	0.69	96	1		1.006	1.169	96	1		1.012	1.339	96	1		1.017	1.508
200	20	96	1		618.5	1.29	96	1		1.006	1.182	96	1		1.021	1.370	96	1		1.057	1.577
200	40	96	1		589.9	2.48	96	1		1.049	1.223	96	2		1.067	1.421	96	2		1.105	1.636
200	60	96	1		590.3	3.72	96	2		1.032	1.209	96	3		1.066	1.421	96	4		1.102	1.633
200	100	96	2		584.6	6.15	96	4		1.043	1.220	96	5		1.077	1.432	96	7		1.112	1.646
200	200	96	4		584.6	12.30	96	7		1.038	1.216	96	10		1.077	1.432	96	14		1.112	1.646
200	300	96	6		584.6	18.44	96	11		1.037	1.215	96	16		1.076	1.430	96	21		1.112	1.646
200	400	96	8		584.6	24.59	96	14		1.038	1.216	96	21		1.075	1.431	96	28		1.112	1.646
200	500	96	10		584.6	30.74	96	18		1.036	1.214	96	27		1.075	1.431	96	35		1.112	1.646
300	10	114	1		877.4	0.60	114	1		1.007	1.193	114	1		1.013	1.386	114	1		1.020	1.579
300	20	114	1		797.6	1.12	114	1		1.007	1.209	114	1		1.019	1.422	114	1		1.061	1.660
300	40	114	1		757.7	2.14	114	1		1.049	1.252	114	2		1.073	1.483	114	2		1.117	1.732
300	60	114	1		746.2	3.17	114	2		1.045	1.251	114	3		1.089	1.502	114	4		1.133	1.752
300	100	114	2		749.7	5.30	120	3		1.096	1.249	114	5		1.084	1.496	114	6		1.128	1.746
300	200	114	4		749.7	10.61	114	7		1.040	1.246	114	10		1.084	1.496	114	13		1.128	1.746
300	300	114	5		746.2	15.85	114	10		1.045	1.251	114	15		1.089	1.502	114	20		1.133	1.752
300	400	114	7		745.7	21.13	114	14		1.045	1.252	114	20		1.090	1.503	114	27		1.133	1.753
300	500	114	9		746.5	26.43	114	17		1.043	1.250	114	26		1.088	1.501	114	34		1.132	1.751
500	10	144	1		1240.8	0.51	144	1		1.008	1.230	144	1		1.016	1.460	144	1		1.023	1.689
500	20	144	1		1107.8	0.92	144	1		1.009	1.253	144	1		1.017	1.505	144	1		1.063	1.789
500	40	144	1		1041.3	1.75	150	1		1.077	1.287	144	2		1.082	1.585	144	2		1.131	1.883
500	60	144	1		1019.1	2.59	144	2		1.053	1.307	144	3		1.106	1.613	144	3		1.155	1.917
500	100	150	1		1085.6	4.32	144	3		1.003	1.300	144	5		1.058	1.609	144	5		1.105	1.912
500	200	144	3		1014.6	8.59	144	6		1.054	1.308	150	9		1.148	1.614	144	9		1.160	1.923
500	300	144	4		1012.8	12.87	144	9		1.055	1.310	144	14		1.109	1.618	144	14		1.162	1.926
500	400	150	5		1057.3	17.17	150	11		1.051	1.308	150	18		1.102	1.616	150	25		1.154	1.924
500	500	144	7		1012.0	21.43	150	14		1.096	1.308	150	23		1.152	1.618	150	31		1.206	1.927
1000	10	204	1		2018.5	0.40	204	1		1.010	1.293	204	1		1.019	1.586	204	1		1.029	1.878
1000	20	204	1		1756.5	0.70	204	1		1.011	1.331	204	1		1.022	1.662	204	1		1.061	2.018
1000	40	204	1		1619.4	1.32	204	1		1.017	1.359	204	2		1.106	1.779	204	2		1.148	2.159
1000	60	204	1		1575.1	1.93	204	2		1.069	1.411	204	2		1.122	1.809	204	3		1.181	2.211
1000	100	204	1		1539.6	3.15	204	3		1.082	1.429	204	4		1.142	1.839	204	4		1.205	2.252
1000	200	204	2		1539.6	6.31	204	5		1.070	1.419	204	8		1.142	1.839	204	8		1.205	2.252
1000	300	204	3		1539.6	9.46	204	8		1.070	1.419	204	13		1.140	1.838	204	12		1.205	2.252
1000	400	204	4		1539.6	12.62	204	10		1.070	1.419	204	17		1.140	1.837	204	17		1.205	2.252
1000	500	204	5		1539.6	15.77	204	13		1.068	1.417	204	21		1.140	1.838	204	21		1.205	2.252

TEXAS WATER DEVELOPMENT BOARD — LOCKWOOD, ANDREWS AND NEWNAM, INC. PROGRAM

COST OF DELIVERING WATER BY PIPELINE - MOST ECONOMICAL DIAMETER

PEAK FACTOR = 1.00 GROWTH RATE = 0.06 INTEREST RATE = 0.040 AMORTIZATION PERIOD = 40YRS PRESENT WORTH FACTOR = 13.41

FLOW	LENGTH	STATIC HEAD SLOPE = 0				STATIC HEAD SLOPE = 4				STATIC HEAD SLOPE = 8				STATIC HEAD SLOPE = 12			
MGD	MILES	DIA.	NO. PS	C.C.T&S/MI	W.C.LT/TG	DIA.	NO. PS	C.C. RATIO	W.C. RATIO	DIA.	NO. PS	C.C. RATIO	W.C. RATIO	DIA.	NO. PS	C.C. RATIO	W.C. RATIO
2	10	16	1	54.0	6.02	16	1	1.041	1.068	16	1	1.081	1.133	16	1	1.122	1.196
2	20	16	1	52.4	11.37	16	1	1.042	1.069	16	1	1.084	1.136	16	1	1.132	1.208
2	40	16	1	51.5	22.08	16	1	1.062	1.088	16	2	1.102	1.170	16	2	1.150	1.244
2	60	16	1	51.6	33.05	16	2	1.045	1.082	16	3	1.099	1.173	16	3	1.147	1.247
2	100	16	2	51.4	54.88	16	3	1.049	1.082	16	4	1.101	1.166	16	5	1.154	1.251
2	200	16	4	51.4	109.76	16	6	1.049	1.082	16	8	1.101	1.166	16	10	1.154	1.251
2	300	16	6	51.4	164.64	16	9	1.049	1.082	16	12	1.101	1.166	16	16	1.150	1.250
2	400	16	7	51.4	219.22	16	12	1.049	1.083	16	16	1.101	1.168	16	21	1.150	1.250
2	500	16	9	51.3	273.73	16	15	1.051	1.085	16	20	1.103	1.169	16	26	1.152	1.252
5	10	21	1	68.2	3.17	21	1	1.028	1.075	21	1	1.057	1.149	21	1	1.085	1.221
5	20	21	1	65.5	6.00	21	1	1.045	1.091	21	1	1.102	1.193	21	2	1.129	1.291
5	40	21	2	65.5	12.00	21	2	1.045	1.091	21	3	1.079	1.184	21	3	1.132	1.282
5	60	21	2	65.9	17.97	21	3	1.038	1.093	21	4	1.079	1.188	21	5	1.120	1.283
5	100	21	4	65.0	29.66	21	6	1.046	1.102	21	7	1.091	1.198	21	9	1.132	1.295
5	200	21	8	65.0	59.33	21	11	1.045	1.099	24	11	1.202	1.247	21	18	1.132	1.295
5	300	21	12	65.0	88.99	21	17	1.043	1.098	21	22	1.087	1.197	21	27	1.132	1.295
5	400	21	16	65.0	118.66	24	15	1.158	1.148	24	22	1.202	1.247	21	36	1.132	1.295
5	500	21	20	65.0	148.32	24	18	1.159	1.148	21	13	1.256	1.268	21	16	1.292	1.338
10	10	27	1	91.7	2.21	27	1	1.019	1.086	27	1	1.038	1.170	27	1	1.057	1.254
10	20	27	1	87.9	4.20	27	1	1.038	1.104	27	1	1.084	1.135	27	1	1.145	1.240
10	40	27	1	91.4	8.30	27	2	0.999	1.118	27	2	1.043	1.148	27	2	1.101	1.255
10	60	27	3	87.9	12.60	27	2	1.079	1.076	27	3	1.084	1.135	27	3	1.145	1.240
10	100	27	4	87.4	20.83	27	4	1.058	1.062	27	5	1.091	1.144	27	6	1.125	1.228
10	200	27	5	91.4	41.50	27	8	1.012	1.065	27	10	1.043	1.148	27	13	1.070	1.226
10	300	27	8	90.3	61.62	27	12	1.024	1.076	27	16	1.052	1.157	27	19	1.083	1.240
10	400	27	11	89.9	81.83	27	16	1.028	1.081	27	21	1.057	1.162	27	26	1.087	1.244
10	500	27	14	89.8	102.19	27	20	1.029	1.082	27	26	1.059	1.164	27	33	1.087	1.245
20	10	36	1	126.1	1.56	33	1	0.942	1.037	33	1	0.955	1.121	36	1	1.038	1.194
20	20	36	1	120.8	2.83	36	1	1.019	1.097	36	1	1.063	1.216	36	2	1.084	1.314
20	40	36	2	120.8	5.65	36	2	1.019	1.097	36	3	1.049	1.203	36	3	1.080	1.310
20	60	36	2	119.8	8.42	36	3	1.028	1.105	36	4	1.055	1.210	36	5	1.083	1.315
20	100	36	4	119.7	14.03	36	5	1.029	1.106	36	7	1.053	1.208	36	9	1.085	1.316
20	200	36	7	119.3	27.96	36	11	1.031	1.108	36	14	1.057	1.212	36	17	1.087	1.319
20	300	36	11	119.4	41.97	36	16	1.028	1.106	36	21	1.057	1.211	36	26	1.086	1.318
20	400	36	14	119.3	55.93	36	21	1.028	1.106	36	28	1.057	1.212	36	35	1.086	1.319
20	500	36	18	119.3	69.92	36	26	1.029	1.106	36	35	1.057	1.212	36	43	1.087	1.319
40	10	45	1	191.1	1.19	45	1	1.012	1.104	45	1	1.023	1.209	45	1	1.035	1.313
40	20	45	1	180.7	2.28	45	1	1.031	1.125	45	1	1.068	1.254	45	2	1.095	1.375
40	40	45	2	180.7	4.57	45	2	1.031	1.125	45	3	1.057	1.245	45	3	1.089	1.370
40	60	45	3	180.7	6.85	45	3	1.031	1.125	45	4	1.060	1.247	45	5	1.089	1.370
40	100	45	4	179.9	11.38	45	6	1.028	1.123	45	7	1.063	1.250	45	9	1.094	1.375
40	200	45	9	179.6	22.72	45	12	1.030	1.124	45	15	1.063	1.251	45	18	1.095	1.376
40	300	45	13	179.3	34.03	45	18	1.032	1.126	45	23	1.065	1.252	45	28	1.097	1.379
40	400	45	17	179.3	45.37	45	24	1.032	1.126	45	31	1.065	1.252	45	37	1.098	1.379
40	500	45	21	179.4	56.74	45	30	1.031	1.125	45	38	1.064	1.252	45	47	1.097	1.378
60	10	54	1	264.4	1.09	54	1	1.010	1.113	54	1	1.021	1.226	54	1	1.031	1.339
60	20	54	1	248.8	2.07	54	1	1.018	1.124	54	1	1.051	1.261	54	1	1.090	1.403
60	40	54	1	248.8	4.13	54	2	1.019	1.125	54	2	1.052	1.262	54	3	1.081	1.396
60	60	54	2	248.8	6.13	54	3	1.031	1.136	54	4	1.063	1.273	54	4	1.092	1.408
60	100	54	4	248.8	10.22	54	5	1.031	1.136	54	7	1.062	1.273	54	6	1.091	1.407
60	200	54	7	248.0	20.40	54	11	1.033	1.138	54	14	1.065	1.275	54	12	1.093	1.410
60	300	54	11	244.8	30.56	54	16	1.033	1.139	54	21	1.067	1.277	54	18	1.095	1.412
60	400	54	15	244.8	40.79	54	21	1.033	1.138	54	28	1.066	1.276	54	24	1.094	1.410
60	500	54	18	244.7	50.95	54	27	1.033	1.138	54	35	1.066	1.277	54	30	1.095	1.411
100	10	66	1	376.3	0.95	66	1	1.010	1.128	66	1	1.019	1.255	66	1	1.029	1.383
100	20	66	1	350.2	1.79	66	1	1.014	1.138	66	1	1.048	1.293	66	1	1.086	1.450
100	40	66	1	346.9	3.54	66	2	1.024	1.147	66	2	1.058	1.303	66	3	1.092	1.457
100	60	66	2	346.9	5.27	66	3	1.036	1.158	66	3	1.071	1.315	66	4	1.102	1.469
100	100	66	3	344.5	8.81	66	5	1.031	1.153	66	5	1.066	1.310	66	6	1.094	1.461
100	200	66	7	342.3	17.53	66	10	1.037	1.159	66	10	1.072	1.316	66	12	1.101	1.469
100	300	66	10	342.9	26.33	66	15	1.036	1.158	66	14	1.070	1.315	66	18	1.099	1.467
100	400	66	14	342.3	35.06	66	21	1.037	1.159	66	19	1.072	1.316	66	23	1.101	1.468
100	500	66	17	342.0	43.85	66	26	1.036	1.158	66	24	1.072	1.316	66	29	1.100	1.467
150	10	78	1	497.7	0.84	78	1	1.006	1.139	78	1	1.012	1.279	78	1	1.017	1.418
150	20	78	1	457.8	1.57	78	1	1.006	1.149	78	1	1.041	1.321	84	1	1.162	1.493
150	40	84	1	483.9	3.08	78	2	0.952	1.176	78	2	0.985	1.351	78	3	1.017	1.526
150	60	78	2	444.5	4.61	78	3	1.036	1.176	78	3	1.072	1.352	78	4	1.104	1.524
150	100	78	3	445.1	7.70	84	4	1.120	1.173	78	5	1.071	1.350	78	6	1.099	1.520
150	200	84	5	483.9	15.38	84	8	1.031	1.174	84	11	1.064	1.350	78	12	1.011	1.521
150	300	84	7	482.5	23.02	84	12	1.034	1.176	84	17	1.067	1.353	78	17	1.013	1.524
150	400	84	9	481.9	30.66	84	16	1.035	1.178	84	22	1.069	1.355	78	23	1.015	1.526
150	500	84	11	481.5	38.30	84	19	1.035	1.178	84	28	1.069	1.355	78	28	1.015	1.526
200	10	90	1	620.4	0.77	90	1	1.006	1.152	90	1	1.012	1.305	90	1	1.019	1.457
200	20	90	1	567.2	1.43	90	1	1.007	1.164	90	1	1.036	1.346	90	1	1.070	1.533
200	40	90	1	544.7	2.77	90	2	1.048	1.203	90	2	1.079	1.391	90	2	1.115	1.584
200	60	90	2	549.5	4.18	90	2	1.037	1.193	90	3	1.069	1.381	90	4	1.105	1.572
200	100	90	3	545.9	6.93	90	4	1.038	1.194	90	6	1.075	1.388	90	6	1.110	1.579
200	200	90	5	544.7	13.84	90	9	1.039	1.195	90	12	1.078	1.390	90	11	1.110	1.580
200	300	90	8	542.4	20.69	90	13	1.041	1.198	90	18	1.082	1.395	90	16	1.115	1.585
200	400	90	11	543.3	27.62	90	17	1.040	1.197	90	24	1.080	1.393	90	21	1.113	1.583
200	500	90	13	543.2	34.52	90	22	1.040	1.196	90	30	1.081	1.393	90	27	1.113	1.584
300	10	108	1	828.3	0.68	108	1	1.007	1.173	108	1	1.014	1.345	108	1	1.021	1.518
300	20	108	1	748.5	1.25	108	1	1.008	1.188	114	1	1.086	1.387	108	1	1.069	1.600
300	40	108	1	708.6	2.39	114	1	1.121	1.239	114	2	1.147	1.450	108	2	1.129	1.673
300	60	114	1	748.2	3.57	114	2	1.045	1.229	114	3	1.089	1.457	108	3	1.072	1.682
300	100	114	2	744.7	5.97	108	4	0.985	1.225	114	5	1.084	1.452	108	5	1.067	1.675
300	200	114	4	744.7	11.94	114	7	1.040	1.224	114	10	1.084	1.452	108	10	1.067	1.675
300	300	114	5	748.2	17.84	114	10	1.045	1.229	114	15	1.089	1.457	108	15	1.072	1.682
300	400	114	7	745.7	23.77	114	14	1.045	1.229	114	20	1.090	1.458	108	20	1.073	1.683
300	500	114	9	746.5	29.74	114	17	1.043	1.227	114	26	1.088	1.457	108	25	1.072	1.681
500	10	138	1	1191.7	0.57	138	1	1.008	1.205	138	1	1.016	1.409	138	1	1.024	1.614
500	20	138	1	1058.7	1.04	138	1	1.009	1.226	138	1	1.023	1.456	138	1	1.069	1.712
500	40	138	1	996.2	1.97	144	1	1.092	1.271	138	2	1.092	1.536	138	2	1.140	1.807
500	60	138	1	973.0	2.91	138	2	1.057	1.281	138	3	1.113	1.561	138	3	1.163	1.836
500	100	138	2	978.4	4.87	144	3	1.092	1.273	138	5	1.106	1.553	138	5	1.156	1.827
500	200	144	3	1014.6	9.67	144	6	1.054	1.280	144	9	1.109	1.562	138	10	1.115	1.638
500	300	144	4	1012.8	14.49	144	9	1.055	1.282	144	14	1.109	1.563	138	14	1.116	1.840
500	400	144	6	1014.6	19.35	144	12	1.054	1.280	144	19	1.107	1.560	138	19	1.114	1.838
500	500	144	7	1012.0	24.13	144	16	1.056	1.283	144	24	1.109	1.563	138	23	1.117	1.841
1000	10	192	1	1920.1	0.45	192	1	1.010	1.260	192	1	1.020	1.519	192	1	1.030	1.779
1000	20	192	1	1654.1	0.80	192	1	1.012	1.295	192	1	1.023	1.590	192	1	1.069	1.914
1000	40	192	1	1521.0	1.48	204	1	1.083	1.331	192	2	1.113	1.707	192	2	1.163	2.055
1000	60	192	1	1476.7	2.17	192	2	1.073	1.375	192	2	1.136	1.741	192	3	1.197	2.106
1000	100	204	1	1539.6	3.58	192	3	1.018	1.379	192	4	1.088	1.757	192	5	1.148	2.127
1000	200	204	2	1539.6	7.15	204	5	1.070	1.378	192	9	1.087	1.756	192	9	1.145	2.124
1000	300	192	4	1459.0	10.73	192	9	1.074	1.379	192	13	1.147	1.757	192	13	1.207	2.123
1000	400	192	5	1454.5	14.27	204	10	1.132	1.382	192	18	1.151	1.761	192	17	1.210	2.128
1000	500	192	6	1451.9	17.81	204	13	1.132	1.382	192	23	1.152	1.764	192	22	1.213	2.132

TEXAS WATER DEVELOPMENT BOARD — LOCKWOOD, ANDREWS AND NEWNAM, INC. PROGRAM
COST OF DELIVERING WATER BY PIPELINE - MOST ECONOMICAL DIAMETER
PEAK FACTOR = 1.00 GROWTH RATE = 0.03 INTEREST RATE = 0.040 AMORTIZATION PERIOD = 40YRS PRESENT WORTH FACTOR = 8.92

FLOW MGD	LENGTH MILES	STATIC HEAD SLOPE = 0 DIA.	NO. PS	C.C. FS/MI	W.C. CT/TG	STATIC HEAD SLOPE = 4 DIA.	NO. PS	C.C. RATIO	W.C. RATIO	STATIC HEAD SLOPE = 8 DIA.	NO. PS	C.C. RATIO	W.C. RATIO	STATIC HEAD SLOPE = 12 DIA.	NO. PS	C.C. RATIO	W.C. RATIO
2	10	16	1	54.0	8.63	16	1	1.041	1.065	16	1	1.081	1.126	16	1	1.122	1.184
2	20	16	1	52.4	16.53	16	1	1.042	1.064	16	1	1.084	1.124	16	1	1.132	1.190
2	40	16	1	51.5	32.34	16	1	1.062	1.081	16	2	1.102	1.150	16	2	1.150	1.217
2	60	16	1	51.6	48.53	16	2	1.045	1.071	16	3	1.099	1.149	16	3	1.147	1.216
2	100	16	2	51.4	80.49	16	3	1.049	1.072	16	4	1.101	1.147	16	5	1.154	1.222
2	200	16	4	51.4	160.98	16	6	1.049	1.072	16	8	1.101	1.147	16	11	1.151	1.222
2	300	16	6	51.4	241.47	16	9	1.049	1.072	16	12	1.101	1.147	16	16	1.150	1.220
2	400	16	7	51.4	321.79	16	12	1.049	1.073	16	17	1.100	1.148	16	21	1.150	1.220
2	500	16	9	51.3	401.73	16	15	1.051	1.074	16	21	1.102	1.149	16	26	1.152	1.222
5	10	21	1	68.2	4.45	21	1	1.028	1.066	21	1	1.057	1.129	21	1	1.085	1.190
5	20	21	1	65.5	8.48	21	1	1.045	1.080	21	1	1.102	1.171	21	2	1.129	1.248
5	40	21	2	65.5	16.96	21	2	1.045	1.080	21	3	1.079	1.157	21	3	1.132	1.244
5	60	21	3	65.5	25.44	21	3	1.045	1.080	21	4	1.085	1.160	21	5	1.127	1.241
5	100	21	4	65.0	41.99	21	6	1.046	1.087	21	7	1.091	1.169	21	9	1.132	1.251
5	200	21	8	65.0	83.98	21	11	1.045	1.084	21	15	1.088	1.168	21	18	1.132	1.251
5	300	21	12	65.0	125.97	21	17	1.043	1.083	21	22	1.087	1.167	21	27	1.132	1.251
5	400	21	16	65.0	167.96	21	23	1.044	1.084	24	22	1.202	1.252	21	36	1.132	1.251
5	500	21	20	65.0	209.95	21	28	1.044	1.083	24	27	1.202	1.251	18	25	1.235	1.327
10	10	24	1	84.5	2.98	24	1	1.021	1.070	24	1	1.054	1.150	24	1	1.089	1.232
10	20	24	1	84.5	5.71	24	1	1.057	1.092	27	1	1.129	1.154	27	1	1.191	1.251
10	40	24	2	84.5	11.41	24	2	1.057	1.092	24	3	1.059	1.133	24	3	1.106	1.215
10	60	24	3	84.5	17.12	24	4	1.026	1.064	24	4	1.073	1.146	24	5	1.094	1.204
10	100	24	5	84.5	28.53	24	6	1.034	1.071	24	7	1.067	1.140	24	9	1.090	1.201
10	200	24	10	84.5	57.06	24	13	1.027	1.064	24	15	1.059	1.133	24	18	1.090	1.201
10	300	24	16	84.1	85.23	24	20	1.031	1.068	24	23	1.064	1.138	24	27	1.095	1.206
10	400	24	21	84.1	113.70	24	26	1.031	1.068	24	31	1.063	1.137	24	36	1.094	1.206
10	500	24	27	84.0	142.00	24	33	1.032	1.069	24	39	1.064	1.138	24	45	1.096	1.207
20	10	30	1	110.1	4.00	33	1	1.080	1.062	33	1	1.094	1.130	33	1	1.118	1.207
20	20	33	1	113.4	3.86	33	1	1.040	1.094	33	2	1.062	1.174	33	2	1.085	1.253
20	40	33	2	113.4	7.72	33	3	1.025	1.081	33	3	1.060	1.171	33	4	1.085	1.253
20	60	33	3	113.4	11.58	33	4	1.028	1.084	33	5	1.056	1.168	33	6	1.085	1.253
20	100	33	6	113.0	19.24	33	7	1.029	1.085	33	9	1.057	1.170	33	10	1.089	1.257
20	200	33	11	112.7	38.40	33	15	1.031	1.087	33	18	1.060	1.172	33	21	1.091	1.259
20	300	33	17	112.6	57.57	33	22	1.030	1.086	33	27	1.061	1.173	33	32	1.091	1.260
20	400	33	22	112.7	76.80	33	29	1.030	1.086	33	36	1.060	1.172	33	43	1.091	1.259
20	500	33	28	112.5	95.89	33	37	1.031	1.087	33	45	1.061	1.174	33	54	1.092	1.260
40	10	39	1	155.6	1.51	39	1	1.024	1.094	39	1	1.053	1.193	39	1	1.078	1.288
40	20	42	1	165.9	2.97	42	1	1.040	1.111	39	2	0.988	1.211	39	2	1.012	1.307
40	40	42	2	165.9	5.93	42	3	1.029	1.101	42	3	1.062	1.206	42	3	1.090	1.307
40	60	42	4	165.7	8.89	42	4	1.032	1.104	42	4	1.063	1.207	39	6	1.013	1.309
40	100	42	6	164.9	14.75	42	8	1.035	1.107	42	7	1.068	1.212	42	8	1.097	1.314
40	200	42	12	164.9	29.51	42	15	1.035	1.107	39	17	0.988	1.212	39	19	1.016	1.313
40	300	42	18	164.9	44.26	42	23	1.035	1.107	42	20	1.068	1.212	39	29	1.016	1.313
40	400	42	25	164.8	59.00	42	31	1.035	1.107	39	34	0.988	1.212	39	38	1.016	1.313
40	500	42	31	164.7	73.70	42	39	1.036	1.107	39	42	0.989	1.213	39	48	1.017	1.314
60	10	48	1	227.8	1.40	48	1	1.012	1.091	48	1	1.027	1.185	48	1	1.052	1.287
60	20	51	1	230.0	2.69	51	1	1.037	1.117	48	2	1.017	1.231	48	2	1.042	1.337
60	40	51	2	230.0	5.38	48	3	0.980	1.114	48	3	1.006	1.221	48	3	1.033	1.329
60	60	51	3	230.0	8.07	48	4	0.978	1.112	48	4	1.004	1.220	48	5	1.032	1.328
60	100	51	5	230.0	13.45	48	6	0.976	1.110	48	7	1.003	1.219	48	8	1.030	1.327
60	200	51	10	230.0	26.89	48	12	0.976	1.110	48	14	1.003	1.219	48	16	1.030	1.327
60	300	51	15	230.0	40.34	48	17	0.976	1.110	48	21	1.003	1.219	48	24	1.030	1.327
60	400	51	20	230.0	53.79	48	23	0.975	1.110	48	28	1.003	1.219	48	32	1.030	1.327
60	500	51	25	230.0	67.23	48	29	0.975	1.110	48	34	1.003	1.219	48	40	1.030	1.327
100	10	60	1	333.2	1.22	60	1	1.011	1.102	60	1	1.021	1.204	60	1	1.039	1.312
100	20	60	1	310.7	2.30	60	1	1.029	1.122	60	1	1.067	1.253	60	1	1.104	1.382
100	40	60	2	310.7	4.60	60	2	1.029	1.122	60	2	1.067	1.253	60	3	1.092	1.373
100	60	60	3	310.7	6.90	60	3	1.029	1.122	60	4	1.063	1.250	60	4	1.092	1.372
100	100	60	4	310.0	11.47	60	5	1.031	1.124	60	6	1.063	1.250	60	7	1.093	1.374
100	200	60	8	310.0	22.94	60	10	1.031	1.124	60	12	1.063	1.250	60	14	1.093	1.374
100	300	60	12	310.0	34.42	60	15	1.031	1.124	60	18	1.063	1.250	60	22	1.093	1.374
100	400	60	16	310.0	45.89	60	20	1.031	1.124	60	25	1.062	1.249	60	29	1.093	1.374
100	500	60	20	310.0	57.36	60	25	1.031	1.124	60	31	1.062	1.249	60	36	1.093	1.374
150	10	72	1	452.7	1.09	72	1	1.006	1.109	72	1	1.013	1.218	72	1	1.020	1.328
150	20	72	1	412.8	2.02	72	1	1.033	1.140	72	1	1.068	1.281	72	1	1.103	1.422
150	40	72	2	412.8	4.04	72	2	1.033	1.140	72	2	1.068	1.281	72	3	1.097	1.417
150	60	72	3	412.8	6.07	72	3	1.033	1.140	72	3	1.068	1.281	72	4	1.090	1.412
150	100	72	5	412.8	10.11	72	5	1.033	1.140	72	6	1.063	1.277	72	7	1.092	1.413
150	200	72	9	412.5	20.21	72	9	1.032	1.139	72	11	1.062	1.277	72	13	1.092	1.414
150	300	72	14	412.3	30.31	72	14	1.033	1.140	72	17	1.062	1.277	72	20	1.092	1.413
150	400	72	19	412.3	40.40	72	18	1.033	1.140	72	22	1.063	1.277	72	27	1.091	1.413
150	500	72	24	412.2	50.50	72	22	1.033	1.140	72	28	1.062	1.277	72	34	1.092	1.414
200	10	78	1	531.6	1.01	78	1	1.007	1.118	78	1	1.015	1.237	84	1	1.104	1.359
200	20	84	1	522.1	1.86	84	1	1.019	1.138	84	1	1.051	1.288	84	1	1.094	1.446
200	40	84	1	518.0	3.70	84	2	1.027	1.146	84	2	1.060	1.296	84	3	1.101	1.455
200	60	84	2	512.3	5.50	84	3	1.039	1.157	84	3	1.071	1.309	84	4	1.107	1.463
200	100	84	4	511.4	9.15	84	5	1.040	1.159	84	5	1.073	1.311	84	6	1.105	1.461
200	200	84	8	511.4	18.30	84	11	1.040	1.158	84	10	1.073	1.311	84	12	1.105	1.461
200	300	84	11	510.6	27.41	84	16	1.042	1.160	84	15	1.075	1.313	84	18	1.106	1.464
200	400	84	15	510.1	36.52	84	22	1.043	1.161	84	20	1.076	1.314	84	24	1.107	1.465
200	500	84	19	509.9	45.64	84	27	1.043	1.161	84	25	1.077	1.314	84	30	1.108	1.465
300	10	96	1	732.9	0.89	96	1	1.008	1.134	96	1	1.016	1.267	96	1	1.024	1.401
300	20	96	1	653.1	1.62	102	1	1.081	1.158	102	1	1.123	1.332	102	1	1.167	1.508
300	40	102	1	677.3	3.19	102	2	1.042	1.179	102	2	1.083	1.357	102	2	1.126	1.536
300	60	102	2	673.7	4.76	102	3	1.048	1.185	102	3	1.089	1.363	96	4	1.070	1.539
300	100	102	3	670.3	7.90	102	4	1.052	1.189	102	5	1.094	1.369	96	6	1.073	1.544
300	200	102	6	670.3	15.80	102	9	1.050	1.187	102	9	1.093	1.368	102	11	1.129	1.542
300	300	102	9	670.3	23.70	102	14	1.049	1.186	102	13	1.093	1.368	96	19	1.071	1.543
300	400	102	12	670.3	31.60	102	19	1.049	1.186	102	18	1.093	1.368	102	22	1.129	1.542
300	500	102	15	670.3	39.49	102	24	1.049	1.186	102	22	1.092	1.367	102	28	1.129	1.543
500	10	126	1	1095.6	0.77	126	1	1.009	1.156	126	1	1.018	1.311	126	1	1.026	1.467
500	20	126	1	964.6	1.37	126	1	1.010	1.174	126	1	1.048	1.373	126	1	1.091	1.576
500	40	126	1	909.0	2.61	126	2	1.070	1.234	126	2	1.110	1.442	126	2	1.156	1.655
500	60	138	1	973.0	3.93	126	2	0.990	1.219	126	3	1.037	1.434	126	3	1.080	1.646
500	100	132	2	941.0	6.51	132	4	1.056	1.224	126	5	1.072	1.444	126	5	1.116	1.657
500	200	132	4	941.0	13.02	126	9	1.019	1.223	126	9	1.070	1.442	126	11	1.113	1.654
500	300	126	8	905.1	19.48	126	13	1.060	1.226	126	13	1.111	1.445	126	16	1.155	1.657
500	400	126	11	903.2	25.92	132	15	1.098	1.227	126	17	1.113	1.447	126	21	1.158	1.661
500	500	132	11	935.7	32.38	132	19	1.059	1.228	126	21	1.074	1.448	126	27	1.118	1.662
1000	10	180	1	1823.5	0.62	180	1	1.011	1.194	180	1	1.021	1.387	180	1	1.032	1.581
1000	20	180	1	1557.4	1.07	180	1	1.012	1.223	180	1	1.028	1.450	180	1	1.079	1.707
1000	40	180	1	1424.4	1.97	180	1	1.057	1.281	180	2	1.124	1.570	180	2	1.179	1.849
1000	60	180	1	1380.0	2.88	180	2	1.081	1.308	180	2	1.156	1.611	180	3	1.217	1.901
1000	100	180	2	1397.8	4.85	180	3	1.071	1.297	180	4	1.141	1.592	180	5	1.202	1.880
1000	200	180	3	1419.2	9.65	180	7	1.055	1.303	180	7	1.122	1.598	180	9	1.180	1.885
1000	300	180	5	1380.0	14.39	180	10	1.081	1.308	180	11	1.154	1.609	180	14	1.213	1.898
1000	400	180	7	1384.5	19.24	180	13	1.078	1.305	180	14	1.150	1.604	180	18	1.209	1.892
1000	500	180	8	1383.3	24.03	180	17	1.078	1.305	180	17	1.151	1.605	180	23	1.209	1.893

TEXAS WATER DEVELOPMENT BOARD — LOCKWOOD, ANDREWS, AND NEWNAM, INC. PROGRAM

COST OF DELIVERING WATER BY PIPELINE - MOST ECONOMICAL DIAMETER

PEAK FACTOR = 1.25 GROWTH RATE = 0.00 INTEREST RATE = 0.040 AMORTIZATION PERIOD = 40YRS PRESENT WORTH FACTOR = 20.19

FLOW MGD	LENGTH MILES	STATIC HEAD SLOPE = 0 DIA.	NO. PS	C.C.T$/MI	W.C.CT/TG	STATIC HEAD SLOPE = 4 DIA.	NO. PS	C.C. RATIO	W.C. RATIO	STATIC HEAD SLOPE = 8 DIA.	NO. PS	C.C. RATIO	W.C. RATIO	STATIC HEAD SLOPE = 12 DIA.	NO. PS	C.C. RATIO	W.C. RATIO
2	10	16	1	56.2	4.49	16	1	1.038	1.060	16	1	1.076	1.123	16	1	1.114	1.189
2	20	16	1	54.3	8.32	16	1	1.039	1.065	16	1	1.081	1.135	16	1	1.143	1.226
2	40	16	1	54.0	16.16	16	2	1.045	1.097	16	2	1.086	1.169	16	2	1.148	1.263
2	60	16	2	53.7	24.31	16	2	1.059	1.084	16	3	1.093	1.166	16	3	1.156	1.260
2	100	16	3	53.5	40.29	16	4	1.047	1.084	16	5	1.096	1.172	16	6	1.145	1.265
2	200	16	6	53.5	80.58	16	8	1.047	1.084	16	10	1.096	1.172	16	12	1.145	1.265
2	300	16	8	53.7	120.73	16	12	1.044	1.085	16	15	1.093	1.174	16	18	1.142	1.266
2	400	16	11	53.5	160.64	16	16	1.048	1.087	16	20	1.097	1.176	16	25	1.143	1.269
2	500	16	14	53.5	200.79	16	20	1.048	1.087	16	25	1.097	1.176	16	31	1.144	1.269
5	10	24	1	78.4	2.49	21	1	0.930	1.067	21	1	0.954	1.141	24	1	1.072	1.233
5	20	24	1	75.4	4.65	24	1	1.025	1.080	24	1	1.080	1.189	21	1	1.095	1.265
5	40	24	1	73.6	9.15	24	2	1.022	1.097	24	2	1.078	1.208	21	2	1.093	1.285
5	60	24	2	74.4	13.62	24	3	1.039	1.106	24	4	1.077	1.214	21	3	1.110	1.295
5	100	24	3	74.2	22.60	24	5	1.041	1.111	24	6	1.084	1.219	21	5	1.113	1.301
5	200	24	6	74.2	45.19	24	9	1.044	1.110	21	8	1.092	1.229	21	10	1.113	1.301
5	300	24	9	74.2	67.79	24	14	1.040	1.108	21	12	1.092	1.229	21	15	1.113	1.301
5	400	24	12	74.2	90.39	21	13	1.063	1.152	21	16	1.092	1.229	21	20	1.113	1.301
5	500	24	15	74.2	112.99	21	17	1.054	1.144	21	21	1.083	1.220	21	25	1.113	1.301
10	10	30	1	102.8	1.72	30	1	1.017	1.089	30	1	1.033	1.184	27	1	0.986	1.218
10	20	30	1	98.6	3.23	30	1	1.026	1.102	30	1	1.072	1.161	30	1	1.127	1.282
10	40	30	1	100.4	6.31	33	1	1.124	1.128	30	2	1.053	1.190	30	3	1.073	1.285
10	60	33	1	100.2	9.59	33	2	1.018	1.090	30	3	0.977	1.175	30	4	1.000	1.273
10	100	30	3	99.1	15.60	30	4	1.036	1.103	30	6	1.057	1.195	30	7	1.090	1.302
10	200	30	6	99.1	31.20	30	9	1.028	1.096	30	12	1.057	1.195	30	15	1.087	1.300
10	300	30	9	99.1	46.80	30	14	1.026	1.094	30	18	1.057	1.195	30	23	1.086	1.299
10	400	30	12	99.1	62.41	30	19	1.024	1.093	30	25	1.055	1.193	30	31	1.085	1.299
10	500	30	16	98.6	77.65	30	23	1.032	1.100	30	31	1.061	1.199	30	39	1.091	1.304
20	10	39	1	134.6	1.22	36	1	0.950	1.086	39	1	1.025	1.154	39	1	1.038	1.264
20	20	39	1	133.1	2.23	39	1	1.021	1.118	39	1	1.066	1.258	39	2	1.089	1.387
20	40	39	2	133.1	4.46	39	2	1.021	1.118	39	3	1.051	1.246	39	3	1.084	1.383
20	60	39	2	132.2	6.65	39	3	1.028	1.124	39	4	1.057	1.252	39	5	1.087	1.387
20	100	39	4	131.8	11.06	39	5	1.031	1.127	39	7	1.057	1.253	39	9	1.090	1.390
20	200	39	7	131.6	22.10	39	11	1.030	1.125	39	14	1.059	1.254	39	17	1.091	1.391
20	300	39	11	131.3	33.10	39	16	1.030	1.126	39	21	1.061	1.256	39	26	1.092	1.392
20	400	39	15	131.4	44.17	39	21	1.030	1.126	39	28	1.060	1.255	39	35	1.090	1.391
20	500	39	18	131.2	55.14	39	27	1.031	1.127	39	35	1.062	1.257	39	44	1.092	1.393
40	10	51	1	237.6	1.01	51	1	1.011	1.120	51	1	1.021	1.244	51	1	1.032	1.374
40	20	51	1	224.5	1.93	51	1	1.014	1.128	51	1	1.050	1.277	51	1	1.089	1.436
40	40	54	1	237.8	3.83	51	2	0.958	1.138	51	2	0.992	1.288	51	3	1.016	1.437
40	60	51	2	220.8	5.71	51	3	1.031	1.143	51	4	1.063	1.290	51	5	1.094	1.444
40	100	51	4	221.9	9.56	51	5	1.026	1.139	51	7	1.058	1.285	51	8	1.088	1.438
40	200	51	7	220.6	19.03	51	10	1.032	1.144	51	14	1.064	1.291	51	17	1.095	1.445
40	300	51	10	220.8	28.57	51	15	1.031	1.143	51	20	1.063	1.290	51	25	1.094	1.444
40	400	51	14	220.6	38.06	51	21	1.032	1.144	51	27	1.063	1.290	51	34	1.095	1.445
40	500	51	17	220.6	47.57	51	26	1.032	1.143	51	34	1.063	1.290	51	43	1.095	1.445
60	10	60	1	314.0	0.90	60	1	1.010	1.133	60	1	1.020	1.270	60	1	1.029	1.415
60	20	60	1	294.5	1.72	60	1	1.010	1.140	60	1	1.044	1.302	60	1	1.078	1.472
60	40	60	1	290.8	3.40	60	2	1.023	1.151	60	2	1.057	1.315	60	3	1.088	1.484
60	60	60	2	287.9	5.06	60	3	1.033	1.160	60	4	1.067	1.325	60	4	1.097	1.494
60	100	60	3	288.6	8.45	60	5	1.031	1.158	60	6	1.065	1.322	60	6	1.092	1.489
60	200	60	7	288.6	16.90	60	10	1.031	1.158	60	13	1.065	1.322	60	12	1.093	1.490
60	300	60	10	287.9	25.30	60	15	1.033	1.160	60	20	1.067	1.325	60	17	1.094	1.492
60	400	60	13	287.6	33.70	60	20	1.035	1.161	60	26	1.069	1.326	60	23	1.096	1.493
60	500	60	16	287.8	42.15	60	25	1.034	1.161	60	33	1.068	1.325	60	28	1.095	1.492
100	10	78	1	482.9	0.79	78	1	1.008	1.156	78	1	1.017	1.313	78	1	1.025	1.476
100	20	78	1	450.3	1.49	78	1	1.009	1.165	78	1	1.032	1.343	78	1	1.064	1.536
100	40	78	1	434.0	2.88	78	2	1.047	1.201	78	2	1.071	1.384	78	3	1.103	1.582
100	60	78	2	437.4	4.37	78	2	1.028	1.184	78	3	1.057	1.370	78	4	1.089	1.565
100	100	78	2	436.0	7.23	78	4	1.027	1.185	78	5	1.066	1.379	78	7	1.097	1.575
100	200	78	5	434.0	14.41	78	8	1.032	1.189	78	11	1.068	1.382	78	14	1.102	1.581
100	300	78	7	432.9	21.57	78	12	1.034	1.191	78	17	1.069	1.384	78	22	1.105	1.584
100	400	78	9	432.3	28.74	78	16	1.036	1.193	78	23	1.071	1.386	78	29	1.106	1.586
100	500	78	11	432.6	35.94	78	20	1.035	1.192	78	28	1.070	1.385	78	37	1.105	1.585
150	10	90	1	612.7	0.69	90	1	1.006	1.174	90	1	1.012	1.348	90	1	1.018	1.531
150	20	90	1	562.9	1.29	90	1	1.006	1.186	90	1	1.030	1.386	90	1	1.061	1.601
150	40	90	1	537.9	2.50	90	2	1.053	1.229	90	2	1.078	1.436	90	2	1.110	1.669
150	60	96	1	579.2	3.73	96	2	1.037	1.224	90	3	1.001	1.442	90	3	1.031	1.666
150	100	96	2	582.5	6.25	90	4	0.957	1.216	90	5	0.995	1.436	90	5	1.025	1.658
150	200	90	5	537.9	12.49	90	8	1.037	1.216	90	11	1.076	1.434	90	10	1.110	1.659
150	300	96	5	579.2	18.66	90	12	0.963	1.221	90	17	0.998	1.441	90	16	1.031	1.666
150	400	96	7	580.0	24.91	90	16	0.961	1.220	90	23	0.997	1.439	90	21	1.030	1.664
150	500	96	9	580.5	31.15	90	20	0.961	1.219	90	29	0.996	1.437	90	26	1.029	1.663
200	10	102	1	749.2	0.63	102	1	1.006	1.191	102	1	1.013	1.382	102	1	1.019	1.581
200	20	102	1	682.6	1.18	102	1	1.007	1.206	108	1	1.087	1.417	102	1	1.064	1.660
200	40	102	1	649.4	2.27	108	1	1.122	1.249	108	2	1.143	1.474	102	2	1.118	1.726
200	60	108	1	687.6	3.36	108	2	1.039	1.247	108	3	1.079	1.493	108	4	1.120	1.747
200	100	108	2	692.1	5.62	102	4	0.974	1.247	108	5	1.073	1.485	102	5	1.049	1.738
200	200	108	3	690.0	11.22	108	7	1.039	1.247	108	10	1.076	1.488	108	13	1.117	1.742
200	300	108	5	687.6	16.78	108	10	1.039	1.247	108	15	1.079	1.493	108	20	1.120	1.747
200	400	108	7	688.8	22.41	108	13	1.038	1.246	108	20	1.078	1.491	108	27	1.118	1.744
200	500	108	8	686.8	27.94	108	17	1.042	1.250	108	25	1.081	1.494	108	33	1.122	1.749
300	10	126	1	1020.2	0.55	126	1	1.007	1.223	126	1	1.014	1.443	126	1	1.021	1.672
300	20	126	1	920.5	1.02	126	1	1.008	1.243	126	1	1.016	1.483	126	1	1.062	1.763
300	40	126	1	870.6	1.94	132	1	1.091	1.283	126	2	1.074	1.552	126	2	1.123	1.845
300	60	126	1	853.9	2.87	126	2	1.047	1.290	126	3	1.095	1.576	126	4	1.144	1.874
300	100	126	2	860.6	4.81	132	3	1.089	1.283	126	5	1.087	1.566	126	6	1.136	1.862
300	200	126	3	855.2	9.57	132	6	1.096	1.289	126	10	1.094	1.574	126	13	1.143	1.871
300	300	132	4	896.9	14.32	126	10	0.997	1.292	126	15	1.043	1.579	126	20	1.089	1.877
300	400	132	5	895.2	19.06	126	13	0.999	1.294	126	20	1.045	1.581	126	27	1.091	1.880
300	500	132	6	895.6	23.84	126	16	1.000	1.294	126	25	1.044	1.581	126	33	1.091	1.879
500	10	162	1	1460.4	0.46	162	1	1.008	1.270	162	1	1.017	1.534	162	1	1.025	1.808
500	20	162	1	1294.1	0.84	162	1	1.009	1.299	162	1	1.019	1.592	162	1	1.061	1.923
500	40	162	1	1211.0	1.58	168	1	1.062	1.332	162	2	1.089	1.683	162	2	1.134	2.032
500	60	162	1	1183.3	2.33	162	2	1.057	1.361	162	3	1.114	1.715	162	3	1.161	2.072
500	100	168	1	1210.7	3.84	162	3	1.024	1.369	162	4	1.083	1.730	162	5	1.134	2.095
500	200	168	2	1210.7	7.67	162	6	1.024	1.369	162	9	1.078	1.726	162	9	1.134	2.095
500	300	168	3	1210.7	11.51	168	8	1.056	1.368	162	14	1.080	1.727	162	13	1.134	2.095
500	400	168	4	1210.7	15.34	162	11	1.024	1.369	162	18	1.078	1.726	162	17	1.134	2.095
500	500	168	5	1210.7	19.18	162	14	1.022	1.367	162	23	1.078	1.725	162	22	1.134	2.095
1000	10	228	1	2356.3	0.36	228	1	1.010	1.349	216	1	0.979	1.687	216	1	0.989	2.036
1000	20	228	1	2023.7	0.64	228	1	1.012	1.399	216	1	0.975	1.784	228	1	1.061	2.205
1000	40	228	1	1857.4	1.18	228	1	1.013	1.429	216	2	1.062	1.921	228	2	1.156	2.374
1000	60	228	1	1802.0	1.73	228	1	1.073	1.491	228	2	1.126	1.951	228	3	1.192	2.436
1000	100	228	1	1757.7	2.82	228	2	1.087	1.512	228	4	1.150	1.989	228	4	1.216	2.483
1000	200	228	2	1757.7	5.63	228	5	1.070	1.498	228	8	1.150	1.989	228	8	1.216	2.483
1000	300	228	3	1757.7	8.45	228	7	1.074	1.501	228	12	1.150	1.989	228	12	1.216	2.483
1000	400	228	3	1741.0	11.18	228	10	1.081	1.510	228	16	1.161	2.005	228	16	1.227	2.503
1000	500	228	4	1744.4	13.99	228	12	1.080	1.509	228	21	1.157	2.001	228	20	1.225	2.499

TEXAS WATER DEVELOPMENT BOARD — LOCKWOOD, ANDREWS AND NEWNAM, INC. PROGRAM

COST OF DELIVERING WATER BY PIPELINE - MOST ECONOMICAL DIAMETER

PEAK FACTOR = 1.25 — GROWTH RATE = 0.10 — INTEREST RATE = 0.040 — AMORTIZATION PERIOD = 40YRS — PRESENT WORTH FACTOR = 15.78

FLOW	LENGTH	STATIC HEAD SLOPE = 0				STATIC HEAD SLOPE = 4				STATIC HEAD SLOPE = 8				STATIC HEAD SLOPE = 12			
MGD	MILES	DIA.	NO. PS	C.C.$/MI	W.C./CT/TG	DIA.	NO. PS	C.C. RATIO	W.C. RATIO	DIA.	NO. PS	C.C. RATIO	W.C. RATIO	DIA.	NO. PS	C.C. RATIO	W.C. RATIO
2	10	16	1	56.2	5.47	16	1	1.038	1.061	16	1	1.076	1.121	16	1	1.114	1.184
2	20	16	1	54.3	10.26	16	1	1.039	1.063	16	1	1.081	1.129	16	1	1.143	1.216
2	40	16	1	54.0	20.06	16	2	1.045	1.087	16	2	1.086	1.154	16	2	1.148	1.243
2	60	16	2	53.7	30.09	16	2	1.059	1.082	16	3	1.093	1.154	16	3	1.156	1.244
2	100	16	3	53.5	49.93	16	4	1.047	1.078	16	5	1.096	1.160	16	6	1.145	1.245
2	200	16	6	53.5	99.85	16	8	1.047	1.078	16	10	1.096	1.160	16	12	1.145	1.245
2	300	16	8	53.7	149.76	16	12	1.044	1.078	16	15	1.093	1.160	16	18	1.142	1.245
2	400	16	11	53.5	199.20	16	16	1.048	1.081	16	20	1.097	1.163	16	25	1.143	1.247
2	500	16	14	53.5	248.94	16	20	1.048	1.081	16	25	1.097	1.163	16	31	1.144	1.247
5	10	24	1	71.0	2.96	24	1	1.026	1.064	24	1	1.053	1.132	24	1	1.093	1.218
5	20	24	1	69.6	5.67	24	1	1.110	1.081	24	2	1.074	1.180	24	1	1.186	1.242
5	40	24	1	75.6	11.32	24	2	1.022	1.084	24	3	0.995	1.174	24	2	1.093	1.245
5	60	24	2	74.4	16.81	24	3	1.039	1.095	24	4	1.014	1.185	24	3	1.110	1.258
5	100	24	3	74.2	27.91	24	5	1.041	1.099	24	6	1.084	1.195	24	5	1.113	1.263
5	200	24	6	74.2	55.81	24	9	1.044	1.099	24	13	1.079	1.193	24	10	1.113	1.263
5	300	24	9	74.2	83.72	24	14	1.040	1.096	21	12	1.092	1.200	21	15	1.113	1.263
5	400	24	12	74.2	111.62	24	19	1.039	1.096	21	16	1.092	1.200	21	20	1.113	1.263
5	500	24	15	74.2	139.53	21	17	1.054	1.123	21	21	1.083	1.191	21	25	1.113	1.263
10	10	30	1	102.8	2.06	27	1	0.938	1.079	27	1	0.954	1.159	27	1	0.986	1.177
10	20	27	1	93.0	3.88	27	1	1.048	1.093	30	1	1.137	1.160	27	2	1.090	1.251
10	40	30	1	100.4	7.72	27	2	0.970	1.100	30	2	1.053	1.167	30	3	1.073	1.249
10	60	30	2	98.2	11.62	27	4	0.973	1.080	30	3	1.076	1.163	30	4	1.101	1.249
10	100	30	3	99.1	19.08	30	4	1.036	1.092	30	6	1.057	1.172	30	7	1.090	1.266
10	200	30	6	99.1	38.16	30	9	1.028	1.085	30	12	1.057	1.172	30	15	1.087	1.264
10	300	30	9	99.1	57.24	30	14	1.026	1.083	30	18	1.057	1.172	30	23	1.086	1.263
10	400	30	12	99.1	76.32	30	19	1.024	1.082	30	25	1.055	1.170	30	31	1.085	1.262
10	500	30	16	98.8	94.94	30	23	1.032	1.089	30	31	1.061	1.176	30	39	1.091	1.268
20	10	39	1	139.6	1.45	36	1	0.950	1.061	39	1	1.025	1.141	39	1	1.038	1.237
20	20	39	1	133.1	2.68	39	1	1.021	1.103	39	1	1.066	1.229	39	2	1.089	1.340
20	40	39	2	133.1	5.36	39	2	1.021	1.103	39	3	1.051	1.216	39	3	1.084	1.336
20	60	39	2	132.2	7.99	39	3	1.028	1.110	39	4	1.057	1.222	39	5	1.087	1.340
20	100	39	4	131.8	13.29	39	5	1.031	1.113	39	7	1.057	1.223	39	9	1.090	1.343
20	200	39	7	131.6	26.54	39	11	1.030	1.111	39	14	1.059	1.225	39	17	1.091	1.345
20	300	39	11	131.3	39.75	39	16	1.030	1.112	39	21	1.061	1.226	39	26	1.092	1.346
20	400	39	15	131.4	53.03	39	21	1.030	1.112	39	28	1.060	1.225	39	35	1.090	1.345
20	500	39	18	131.2	66.21	39	27	1.031	1.113	39	35	1.062	1.227	39	44	1.092	1.346
40	10	48	1	218.6	1.19	48	1	1.011	1.101	48	1	1.023	1.207	48	1	1.034	1.320
40	20	48	1	205.5	2.27	48	1	1.036	1.125	48	1	1.074	1.257	48	2	1.100	1.388
40	40	48	2	205.5	4.55	48	2	1.036	1.125	48	3	1.065	1.249	48	3	1.094	1.381
40	60	51	2	220.8	6.81	48	4	0.962	1.124	48	4	0.991	1.251	48	4	1.016	1.380
40	100	48	5	205.5	11.36	48	6	1.033	1.122	48	8	1.065	1.249	48	7	1.093	1.380
40	200	51	7	220.6	22.69	48	13	0.961	1.123	48	16	0.992	1.252	48	14	1.018	1.382
40	300	48	14	205.0	34.02	48	19	1.034	1.123	48	24	1.068	1.252	48	20	1.095	1.382
40	400	48	19	204.9	45.34	48	26	1.035	1.124	48	32	1.069	1.252	48	27	1.096	1.383
40	500	48	24	205.0	56.70	48	32	1.034	1.123	48	41	1.068	1.252	48	33	1.095	1.382
60	10	57	1	295.0	1.07	57	1	1.010	1.112	57	1	1.021	1.228	57	1	1.031	1.352
60	20	57	1	275.4	2.03	60	1	1.080	1.124	60	1	1.116	1.268	60	1	1.153	1.418
60	40	60	1	290.6	4.03	60	2	1.023	1.134	60	2	1.057	1.278	57	3	1.031	1.425
60	60	60	2	287.9	6.00	60	3	1.033	1.143	60	4	1.067	1.288	57	4	1.037	1.434
60	100	60	3	288.6	10.02	60	5	1.031	1.140	60	6	1.065	1.285	60	6	1.092	1.431
60	200	60	7	288.6	20.05	60	10	1.031	1.141	60	13	1.065	1.286	57	13	1.034	1.431
60	300	60	10	287.9	30.01	60	15	1.033	1.143	57	16	1.010	1.288	57	19	1.036	1.433
60	400	60	13	287.6	39.98	60	20	1.035	1.144	57	21	1.010	1.284	57	25	1.037	1.435
60	500	60	16	287.8	50.00	60	25	1.034	1.143	57	26	1.010	1.288	57	32	1.036	1.434
100	10	72	1	437.9	0.94	72	1	1.009	1.130	72	1	1.018	1.262	72	1	1.027	1.401
100	20	72	1	405.2	1.76	72	1	1.013	1.140	72	1	1.049	1.302	72	1	1.089	1.474
100	40	78	1	434.0	3.47	72	2	0.946	1.155	72	2	0.980	1.319	72	3	1.012	1.489
100	60	72	2	395.4	5.17	72	3	1.038	1.163	72	3	1.075	1.328	72	4	1.108	1.497
100	100	72	3	397.4	8.66	72	5	1.033	1.158	72	5	1.070	1.323	72	6	1.100	1.489
100	200	72	7	395.4	17.24	72	10	1.038	1.163	72	10	1.075	1.328	72	12	1.105	1.495
100	300	72	10	395.4	25.86	72	15	1.038	1.163	72	14	1.075	1.328	72	18	1.105	1.495
100	400	72	14	395.4	34.49	72	20	1.038	1.163	72	19	1.075	1.328	72	23	1.104	1.494
100	500	72	17	394.9	43.07	72	25	1.039	1.164	72	23	1.076	1.329	72	29	1.106	1.496
150	10	90	1	612.7	0.83	84	1	0.931	1.144	84	1	0.937	1.290	84	1	0.943	1.444
150	20	90	1	562.9	1.54	84	1	0.928	1.157	90	1	1.030	1.331	90	1	1.061	1.517
150	40	90	1	537.9	2.97	84	2	0.971	1.202	90	2	1.078	1.383	90	2	1.110	1.576
150	60	90	2	540.2	4.51	90	2	1.029	1.182	90	3	1.061	1.365	90	3	1.093	1.556
150	100	90	2	542.9	7.49	90	4	1.027	1.181	90	5	1.068	1.372	90	5	1.100	1.564
150	200	90	5	537.9	14.86	90	8	1.037	1.190	90	11	1.076	1.381	90	10	1.110	1.576
150	300	90	7	536.3	22.23	90	12	1.040	1.193	90	17	1.078	1.384	90	16	1.114	1.580
150	400	90	10	537.9	29.71	90	16	1.037	1.190	90	23	1.075	1.381	90	21	1.110	1.576
150	500	90	12	536.9	37.08	90	20	1.039	1.192	90	29	1.077	1.383	90	26	1.112	1.579
200	10	96	1	700.3	0.76	96	1	1.007	1.158	96	1	1.014	1.318	96	1	1.021	1.486
200	20	96	1	633.8	1.40	96	1	1.008	1.171	102	1	1.108	1.363	102	1	1.146	1.568
200	40	102	1	649.4	2.69	96	2	0.983	1.221	102	2	1.081	1.420	102	2	1.118	1.634
200	60	108	1	687.6	4.07	102	2	0.986	1.206	102	3	1.021	1.411	102	3	1.056	1.624
200	100	102	2	648.3	6.72	102	4	1.040	1.210	102	5	1.083	1.422	102	5	1.120	1.637
200	200	102	4	648.3	13.45	102	8	1.040	1.210	102	11	1.080	1.420	96	11	1.051	1.635
200	300	102	7	647.2	20.14	102	12	1.042	1.212	102	16	1.083	1.423	96	17	1.053	1.638
200	400	102	9	646.1	26.82	102	15	1.042	1.213	102	22	1.084	1.424	96	22	1.054	1.640
200	500	102	11	645.4	33.49	102	19	1.043	1.213	102	28	1.085	1.425	96	27	1.055	1.641
300	10	120	1	971.0	0.67	120	1	1.007	1.186	120	1	1.015	1.370	120	1	1.022	1.561
300	20	120	1	871.3	1.22	120	1	1.008	1.203	120	1	1.029	1.415	120	1	1.069	1.651
300	40	120	1	821.4	2.32	120	1	1.060	1.255	120	2	1.092	1.486	120	2	1.134	1.734
300	60	126	1	853.9	3.44	126	2	1.047	1.252	120	3	1.050	1.498	120	3	1.091	1.748
300	100	120	2	812.3	5.74	120	4	1.057	1.255	120	5	1.104	1.499	120	5	1.147	1.750
300	200	120	4	812.3	11.47	120	7	1.055	1.253	120	11	1.103	1.498	120	10	1.147	1.750
300	300	120	6	812.3	17.21	120	11	1.052	1.251	120	16	1.103	1.498	120	15	1.147	1.750
300	400	120	8	812.3	22.95	120	15	1.051	1.250	120	22	1.103	1.498	120	20	1.147	1.750
300	500	126	8	852.6	28.67	120	19	1.002	1.252	120	27	1.050	1.499	120	24	1.092	1.750
500	10	150	1	1362.4	0.56	150	1	1.009	1.222	150	1	1.018	1.441	150	1	1.027	1.669
500	20	150	1	1196.1	1.01	150	1	1.010	1.248	156	1	1.061	1.496	150	1	1.072	1.780
500	40	150	1	1113.0	1.90	156	1	1.089	1.294	156	2	1.140	1.587	150	2	1.152	1.889
500	60	156	1	1134.0	2.79	156	2	1.060	1.312	156	3	1.119	1.618	150	3	1.131	1.926
500	100	168	1	1210.7	4.68	156	3	0.989	1.299	156	5	1.048	1.606	150	5	1.059	1.912
500	200	156	3	1126.5	9.26	156	6	1.061	1.314	156	9	1.122	1.623	156	9	1.175	1.934
500	300	156	4	1129.6	13.90	156	9	1.060	1.313	156	14	1.120	1.621	150	14	1.134	1.931
500	400	156	6	1126.5	18.52	156	12	1.061	1.314	156	19	1.120	1.621	150	19	1.135	1.933
500	500	156	7	1125.2	23.09	156	16	1.064	1.317	156	24	1.123	1.625	150	23	1.138	1.937
1000	10	216	1	2257.7	0.44	204	1	0.968	1.287	204	1	0.978	1.566	204	1	0.989	1.854
1000	20	216	1	1965.1	0.77	204	1	0.962	1.330	204	1	0.975	1.651	216	1	1.068	2.010
1000	40	216	1	1758.8	1.42	216	1	1.027	1.369	204	2	1.067	1.785	216	2	1.169	2.174
1000	60	216	1	1703.4	2.08	204	2	1.022	1.423	216	2	1.138	1.819	216	3	1.207	2.234
1000	100	216	1	1659.1	3.38	216	3	1.095	1.445	216	4	1.168	1.859	216	4	1.234	2.281
1000	200	216	2	1659.1	6.76	216	5	1.089	1.439	216	8	1.168	1.859	216	9	1.234	2.281
1000	300	216	3	1659.1	10.14	216	8	1.084	1.435	216	13	1.167	1.859	216	13	1.232	2.279
1000	400	216	4	1659.1	13.53	216	11	1.085	1.436	216	17	1.167	1.859	216	17	1.232	2.279
1000	500	216	5	1659.1	16.91	216	13	1.086	1.437	216	22	1.167	1.859	216	21	1.231	2.278

TEXAS WATER DEVELOPMENT BOARD — LOCKWOOD, ANDREWS AND NEWNAM, INC. PROGRAM

COST OF DELIVERING WATER BY PIPELINE - MOST ECONOMICAL DIAMETER

PEAK FACTOR = 1.25 GROWTH RATE = 0.06 INTEREST RATE = 0.040 AMORTIZATION PERIOD = 40YRS PRESENT WORTH FACTOR = 13.41

FLOW MGD	LENGTH MILES	STATIC HEAD SLOPE = 0 DIA.	NO. PS	C.C. FT/MI	W.C.C.T/TG	STATIC HEAD SLOPE = 4 DIA.	NO. PS	C.C. RATIO	W.C. RATIO	STATIC HEAD SLOPE = 8 DIA.	NO. PS	C.C. RATIO	W.C. RATIO	STATIC HEAD SLOPE = 12 DIA.	NO. PS	C.C. RATIO	W.C. RATIO
2	10	16	1	56.2	6.27	16	1	1.038	1.060	16	1	1.076	1.120	16	1	1.114	1.180
2	20	16	1	56.3	11.84	16	1	1.039	1.062	16	1	1.081	1.125	16	1	1.143	1.210
2	40	16	1	56.0	23.25	16	2	1.045	1.081	16	2	1.086	1.146	16	2	1.148	1.232
2	60	16	2	53.7	34.81	16	2	1.059	1.080	16	3	1.093	1.148	16	4	1.143	1.232
2	100	16	3	53.5	57.79	16	4	1.047	1.075	16	5	1.096	1.152	16	6	1.145	1.233
2	200	16	6	53.5	115.58	16	8	1.047	1.075	16	10	1.096	1.152	16	12	1.145	1.233
2	300	16	9	53.5	173.37	16	12	1.047	1.075	16	15	1.096	1.152	16	19	1.143	1.233
2	400	16	11	53.5	230.66	16	16	1.048	1.077	16	20	1.097	1.155	16	25	1.143	1.234
2	500	16	14	53.5	288.24	16	20	1.048	1.077	16	25	1.097	1.155	16	31	1.144	1.235
5	10	21	1	71.0	3.34	21	1	1.026	1.062	21	1	1.053	1.127	21	1	1.093	1.209
5	20	21	1	69.6	6.44	21	1	1.055	1.088	21	2	1.074	1.169	21	1	1.186	1.242
5	40	21	2	69.6	12.88	21	3	1.031	1.077	21	3	1.080	1.164	21	2	1.186	1.242
5	60	21	4	69.1	19.31	21	4	1.046	1.080	21	4	1.093	1.164	21	3	1.196	1.243
5	100	21	6	68.8	31.99	21	7	1.047	1.086	24	6	1.170	1.191	21	5	1.200	1.251
5	200	21	12	68.8	63.98	21	15	1.044	1.084	24	13	1.164	1.186	21	10	1.200	1.251
5	300	21	18	68.8	95.97	24	14	1.122	1.098	21	12	1.179	1.193	21	15	1.200	1.251
5	400	24	12	74.2	128.97	24	19	1.039	1.089	21	16	1.092	1.184	21	20	1.113	1.241
5	500	24	15	74.2	161.21	24	24	1.040	1.090	21	21	1.083	1.175	21	25	1.113	1.241
10	10	27	1	94.7	2.32	27	1	1.018	1.069	27	1	1.036	1.143	27	1	1.070	1.165
10	20	27	1	93.0	4.39	27	1	1.048	1.090	30	1	1.137	1.167	27	2	1.090	1.235
10	40	27	2	93.0	8.77	27	2	1.048	1.090	27	3	1.062	1.154	27	4	1.090	1.235
10	60	27	3	93.0	13.16	27	4	1.029	1.073	27	5	1.059	1.152	27	6	1.090	1.235
10	100	30	3	99.1	21.93	27	7	0.963	1.072	27	8	0.994	1.153	27	10	1.023	1.236
10	200	27	11	92.5	43.67	27	14	1.032	1.076	27	17	1.064	1.157	27	20	1.096	1.241
10	300	27	17	92.3	65.41	27	21	1.034	1.078	27	26	1.065	1.158	27	30	1.098	1.243
10	400	27	22	92.5	87.34	27	28	1.032	1.076	27	35	1.063	1.156	27	41	1.096	1.240
10	500	27	28	92.4	109.07	27	36	1.032	1.076	27	43	1.065	1.157	27	51	1.097	1.242
20	10	39	1	139.6	1.64	36	1	0.950	1.046	36	1	0.962	1.127	39	1	1.038	1.219
20	20	39	1	133.1	3.05	39	1	1.021	1.095	39	1	1.066	1.211	39	2	1.089	1.312
20	40	39	2	133.1	6.10	39	2	1.021	1.095	39	3	1.051	1.198	39	3	1.084	1.308
20	60	39	2	132.2	9.09	39	3	1.028	1.101	39	4	1.057	1.204	39	5	1.087	1.312
20	100	39	4	131.8	15.12	39	5	1.031	1.104	39	7	1.057	1.205	39	9	1.090	1.315
20	200	39	7	131.6	30.19	39	11	1.030	1.103	39	14	1.059	1.206	39	17	1.091	1.316
20	300	39	11	131.3	45.21	39	16	1.030	1.103	39	21	1.061	1.208	39	26	1.092	1.318
20	400	39	15	131.4	60.33	39	21	1.030	1.103	39	28	1.060	1.207	39	35	1.090	1.316
20	500	39	18	131.2	75.31	39	27	1.031	1.104	39	35	1.062	1.209	39	44	1.092	1.318
40	10	48	1	200.5	1.33	45	1	1.013	1.089	45	1	1.027	1.185	48	1	1.128	1.294
40	20	48	1	205.5	2.54	48	1	1.036	1.118	48	1	1.074	1.241	48	2	1.100	1.360
40	40	48	2	205.5	5.07	48	2	1.036	1.118	48	3	1.065	1.233	48	3	1.094	1.354
40	60	48	3	205.5	7.61	48	4	1.033	1.116	48	4	1.065	1.233	48	4	1.092	1.353
40	100	48	5	205.5	12.68	48	6	1.033	1.115	48	8	1.065	1.233	48	7	1.093	1.354
40	200	48	9	205.3	25.35	48	13	1.032	1.115	48	16	1.066	1.234	48	14	1.094	1.355
40	300	48	14	205.0	37.97	48	19	1.034	1.116	48	24	1.068	1.236	48	20	1.095	1.356
40	400	48	19	204.9	50.60	48	26	1.035	1.117	48	32	1.069	1.237	48	27	1.096	1.357
40	500	48	24	205.0	63.28	48	32	1.034	1.116	48	41	1.068	1.236	48	33	1.095	1.356
60	10	57	1	293.0	1.20	54	1	0.948	1.102	54	1	0.959	1.206	57	1	1.031	1.320
60	20	57	1	273.4	2.27	57	1	1.026	1.122	57	1	1.058	1.250	57	1	1.096	1.390
60	40	57	2	273.4	4.54	57	2	1.026	1.122	57	2	1.058	1.250	57	3	1.088	1.384
60	60	60	2	287.9	6.78	57	3	0.982	1.126	57	3	1.011	1.255	57	4	1.037	1.386
60	100	57	4	273.1	11.26	57	6	1.034	1.129	57	6	1.066	1.258	57	6	1.095	1.392
60	200	57	8	273.1	22.53	57	12	1.034	1.129	57	11	1.065	1.257	57	13	1.093	1.390
60	300	57	13	272.8	33.76	57	18	1.035	1.130	57	16	1.066	1.258	57	19	1.093	1.390
60	400	57	17	272.8	44.99	57	24	1.036	1.130	57	21	1.066	1.259	57	25	1.095	1.392
60	500	57	21	272.7	56.25	57	30	1.036	1.130	57	26	1.066	1.258	57	32	1.094	1.391
100	10	72	1	437.9	1.05	66	1	0.911	1.116	66	1	0.920	1.234	72	1	1.027	1.362
100	20	72	1	405.2	1.97	72	1	1.013	1.128	72	1	1.049	1.278	72	1	1.089	1.436
100	40	72	1	400.0	3.90	72	2	1.025	1.139	72	2	1.061	1.290	72	3	1.096	1.446
100	60	72	2	395.4	5.79	72	3	1.038	1.152	72	3	1.075	1.304	72	4	1.108	1.459
100	100	72	3	397.4	9.69	72	5	1.033	1.147	72	5	1.070	1.299	72	6	1.100	1.451
100	200	72	7	395.4	19.30	72	10	1.038	1.152	72	10	1.075	1.304	72	12	1.105	1.457
100	300	72	10	395.4	28.95	72	15	1.038	1.152	72	14	1.075	1.304	72	18	1.105	1.457
100	400	72	14	395.4	38.60	72	20	1.038	1.152	72	19	1.075	1.304	72	23	1.104	1.456
100	500	72	17	394.9	48.20	72	25	1.039	1.153	72	23	1.076	1.305	72	29	1.106	1.458
150	10	84	1	567.1	0.93	84	1	1.006	1.130	84	1	1.013	1.262	84	1	1.019	1.400
150	20	84	1	517.2	1.72	84	1	1.009	1.142	84	1	1.046	1.308	84	1	1.084	1.484
150	40	90	1	537.9	3.36	84	2	0.971	1.169	84	2	1.005	1.339	84	3	1.042	1.518
150	60	84	2	501.3	5.03	84	3	1.041	1.172	84	3	1.079	1.342	84	4	1.113	1.518
150	100	84	3	504.0	8.42	84	5	1.036	1.167	84	5	1.073	1.336	84	6	1.104	1.508
150	200	84	7	502.3	16.79	84	10	1.039	1.170	84	10	1.077	1.340	84	12	1.107	1.512
150	300	90	7	536.3	25.14	84	15	0.974	1.172	84	14	1.008	1.342	84	17	1.036	1.514
150	400	84	13	502.0	33.56	84	20	1.040	1.171	84	19	1.077	1.340	84	23	1.107	1.512
150	500	84	17	501.3	41.91	84	25	1.042	1.172	84	23	1.078	1.342	84	29	1.109	1.514
200	10	96	1	700.3	0.85	96	1	1.007	1.144	96	1	1.014	1.288	96	1	1.021	1.438
200	20	96	1	633.8	1.57	96	1	1.008	1.156	96	1	1.043	1.336	96	1	1.082	1.525
200	40	96	1	612.7	3.05	96	2	1.042	1.189	96	2	1.079	1.373	96	2	1.119	1.568
200	60	96	2	611.6	4.56	96	3	1.044	1.190	96	3	1.081	1.375	96	4	1.120	1.570
200	100	96	3	607.2	7.56	96	4	1.049	1.195	96	5	1.089	1.384	96	6	1.124	1.576
200	200	96	6	607.2	15.12	96	9	1.046	1.193	96	9	1.088	1.383	96	11	1.122	1.574
200	300	96	9	607.2	22.67	96	14	1.045	1.192	96	13	1.088	1.383	96	17	1.123	1.575
200	400	96	12	607.2	30.23	96	18	1.046	1.193	96	18	1.088	1.383	96	22	1.122	1.574
200	500	96	15	607.2	37.79	96	23	1.045	1.192	96	22	1.088	1.383	96	27	1.122	1.574
300	10	114	1	922.7	0.75	114	1	1.008	1.164	114	1	1.016	1.328	114	1	1.024	1.499
300	20	114	1	822.9	1.36	114	1	1.009	1.180	120	1	1.090	1.381	114	1	1.083	1.595
300	40	120	1	821.4	2.61	114	2	1.011	1.235	120	2	1.092	1.444	114	2	1.085	1.669
300	60	120	1	853.9	3.92	120	2	1.006	1.222	120	3	1.050	1.442	114	3	1.044	1.666
300	100	120	2	812.3	6.46	120	4	1.057	1.235	120	5	1.104	1.458	114	5	1.097	1.685
300	200	120	4	812.3	12.92	120	7	1.055	1.233	120	11	1.103	1.457	114	11	1.094	1.682
300	300	120	6	812.3	19.38	120	11	1.052	1.231	120	16	1.102	1.457	114	16	1.093	1.681
300	400	120	8	812.3	25.84	120	15	1.051	1.230	120	22	1.103	1.457	114	21	1.093	1.681
300	500	120	10	812.3	32.30	120	19	1.052	1.231	120	27	1.102	1.457	114	26	1.093	1.681
500	10	144	1	1314.3	0.63	144	1	1.009	1.197	144	1	1.018	1.391	144	1	1.028	1.593
500	20	144	1	1148.2	1.13	144	1	1.011	1.220	150	1	1.068	1.446	144	1	1.079	1.703
500	40	144	1	1085.1	2.13	150	1	1.103	1.276	150	2	1.151	1.538	144	2	1.163	1.812
500	60	150	1	1089.0	3.14	150	2	1.063	1.285	150	3	1.126	1.565	144	3	1.137	1.844
500	100	150	2	1096.4	5.26	150	3	1.092	1.282	150	5	1.118	1.556	144	5	1.130	1.833
500	200	150	3	1120.5	10.49	150	7	1.026	1.282	150	10	1.086	1.561	144	10	1.098	1.839
500	300	150	5	1089.0	15.70	150	10	1.063	1.285	150	15	1.126	1.565	150	14	1.176	1.843
500	400	150	7	1088.0	20.92	150	14	1.065	1.286	150	20	1.127	1.566	150	19	1.177	1.845
500	500	150	7	1120.2	26.17	150	17	1.028	1.284	150	25	1.090	1.565	150	23	1.138	1.843
1000	10	204	1	2180.3	0.50	204	1	1.011	1.253	204	1	1.022	1.500	204	1	1.033	1.756
1000	20	204	1	1826.9	0.87	204	1	1.013	1.293	204	1	1.026	1.578	204	1	1.076	1.905
1000	40	204	1	1661.7	1.60	216	1	1.087	1.342	204	2	1.129	1.712	204	2	1.184	2.067
1000	60	204	1	1600.2	2.33	204	2	1.084	1.385	204	2	1.153	1.750	204	3	1.224	2.127
1000	100	216	1	1657.1	3.84	204	3	1.039	1.395	204	4	1.119	1.776	204	4	1.185	2.156
1000	200	216	2	1657.1	7.68	204	6	1.039	1.395	204	7	1.117	1.774	204	9	1.179	2.150
1000	300	216	3	1657.1	11.51	204	9	1.039	1.395	204	10	1.116	1.773	204	13	1.177	2.148
1000	400	216	4	1657.1	15.35	204	12	1.039	1.395	204	13	1.116	1.773	204	18	1.179	2.150
1000	500	216	5	1657.1	19.19	204	15	1.039	1.395	204	16	1.116	1.773	204	22	1.177	2.148

TEXAS WATER DEVELOPMENT BOARD — LOCKWOOD, ANDREWS, AND NEWNAM, INC. PROGRAM
COST OF DELIVERING WATER BY PIPELINE - MOST ECONOMICAL DIAMETER
PEAK FACTOR = 1.25 — GROWTH RATE = 0.03 — INTEREST RATE = 0.040 — AMORTIZATION PERIOD = 40YRS — PRESENT WORTH FACTOR = 8.92

FLOW MGD	LENGTH MILES	STATIC HEAD SLOPE = 0 DIA.	NO.	PS	C.C.(A/M)	W.C.(T/T)	STATIC HEAD SLOPE = 4 DIA.	NO.	PS	C.C. RATIO	W.C. RATIO	STATIC HEAD SLOPE = 8 DIA.	NO.	PS	C.C. RATIO	W.C. RATIO	STATIC HEAD SLOPE = 12 DIA.	NO.	PS	C.C. RATIO	W.C. RATIO
2	10	16	1		56.2	8.98	16	1		1.038	1.059	16	1		1.076	1.115	16	1		1.114	1.170
2	20	16	1		54.3	17.18	16	1		1.039	1.058	16	1		1.081	1.116	16	1		1.143	1.196
2	40	16	1		54.0	33.97	16	2		1.045	1.070	16	2		1.086	1.129	16	2		1.148	1.209
2	60	16	2		53.7	50.74	16	3		1.051	1.074	16	3		1.093	1.134	16	4		1.143	1.207
2	100	16	3		53.5	84.30	16	4		1.047	1.068	16	5		1.096	1.137	16	6		1.145	1.209
2	200	16	6		53.5	168.61	16	8		1.047	1.068	16	10		1.096	1.137	16	12		1.145	1.209
2	300	16	9		53.5	252.91	16	12		1.047	1.068	16	15		1.096	1.137	16	19		1.143	1.208
2	400	16	11		53.5	336.74	16	16		1.048	1.069	16	20		1.097	1.139	16	25		1.143	1.208
2	500	16	14		53.5	420.73	16	20		1.048	1.070	16	25		1.097	1.139	16	31		1.144	1.209
5	10	21	1		71.0	4.66	21	1		1.026	1.057	21	1		1.053	1.114	21	1		1.093	1.187
5	20	21	1		69.0	9.06	21	1		1.055	1.084	21	2		1.074	1.146	21	2		1.115	1.220
5	40	21	2		69.0	18.11	21	3		1.031	1.066	21	3		1.080	1.145	21	3		1.122	1.220
5	60	21	4		69.1	27.04	21	5		1.042	1.075	21	5		1.085	1.149	21	5		1.129	1.226
5	100	21	6		68.8	44.84	21	8		1.043	1.077	21	9		1.086	1.153	21	5		1.200	1.252
5	200	21	12		68.8	89.69	21	15		1.044	1.077	24	13		1.164	1.202	21	10		1.200	1.252
5	300	21	18		68.8	134.53	21	23		1.042	1.076	24	19		1.165	1.203	21	15		1.200	1.252
5	400	21	24		68.8	179.37	24	19		1.121	1.124	24	26		1.164	1.202	21	20		1.200	1.252
5	500	21	30		68.8	224.22	24	24		1.122	1.125	21	21		1.168	1.194	21	25		1.200	1.252
10	10	24	1		91.1	3.16	24	1		1.031	1.059	24	1		1.061	1.122	27	1		1.113	1.158
10	20	27	1		93.0	6.10	27	1		1.048	1.082	24	2		1.040	1.163	27	2		1.090	1.200
10	40	27	2		93.0	12.20	27	2		1.048	1.082	27	3		1.062	1.133	27	4		1.090	1.200
10	60	27	3		93.0	18.30	27	4		1.029	1.064	27	5		1.059	1.131	27	6		1.090	1.200
10	100	27	5		93.0	30.50	27	7		1.027	1.062	27	8		1.060	1.132	27	10		1.090	1.200
10	200	27	11		92.5	60.72	27	14		1.032	1.067	27	17		1.064	1.136	27	20		1.096	1.206
10	300	27	17		92.3	90.93	27	21		1.034	1.069	27	26		1.065	1.137	27	30		1.098	1.208
10	400	27	22		92.3	121.43	27	28		1.032	1.067	27	35		1.063	1.135	27	41		1.096	1.206
10	500	27	28		92.4	151.65	27	36		1.032	1.067	27	43		1.065	1.136	27	51		1.097	1.207
20	10	33	1		125.3	2.16	33	1		1.019	1.067	36	1		1.089	1.140	36	1		1.112	1.217
20	20	36	1		125.7	4.20	36	1		1.041	1.093	36	2		1.068	1.174	36	2		1.091	1.253
20	40	36	2		125.7	8.40	36	3		1.029	1.081	36	3		1.063	1.168	36	4		1.091	1.253
20	60	36	3		125.7	12.60	36	4		1.030	1.082	36	5		1.060	1.166	36	6		1.091	1.253
20	100	36	6		125.6	20.97	36	7		1.028	1.081	36	9		1.059	1.165	36	10		1.092	1.254
20	200	36	11		125.0	41.75	36	14		1.034	1.086	36	18		1.065	1.171	36	21		1.097	1.259
20	300	36	17		125.2	62.72	36	22		1.031	1.084	36	27		1.063	1.169	36	32		1.095	1.257
20	400	36	22		125.0	83.49	36	29		1.032	1.085	36	36		1.065	1.171	36	42		1.097	1.259
20	500	36	28		125.1	104.47	36	36		1.031	1.084	36	45		1.064	1.170	36	53		1.095	1.258
40	10	42	1		183.9	1.71	42	1		1.026	1.084	42	1		1.052	1.172	42	1		1.075	1.264
40	20	45	1		192.6	3.37	42	2		0.980	1.100	42	2		1.005	1.189	42	2		1.026	1.282
40	40	45	2		192.6	6.73	42	3		0.969	1.090	42	3		1.004	1.188	42	4		1.026	1.282
40	60	45	4		191.9	10.07	42	5		0.976	1.096	42	5		1.003	1.188	42	6		1.030	1.286
40	100	45	6		192.2	16.80	42	8		0.973	1.093	42	9		1.001	1.186	42	10		1.029	1.284
40	200	45	13		191.9	33.56	42	15		0.973	1.093	42	17		1.002	1.187	42	20		1.030	1.285
40	300	45	20		191.9	50.33	42	23		0.972	1.093	42	26		1.001	1.187	42	30		1.030	1.286
40	400	45	26		191.9	67.13	42	31		0.972	1.093	42	35		1.001	1.186	42	39		1.030	1.285
40	500	45	33		191.9	83.89	42	38		0.972	1.093	42	44		1.001	1.186	42	49		1.030	1.285
60	10	51	1		259.4	1.56	51	1		1.012	1.081	51	1		1.033	1.173	51	1		1.055	1.271
60	20	54	1		260.0	3.01	54	1		1.031	1.103	54	1		1.071	1.217	51	2		1.053	1.320
60	40	54	2		260.0	6.02	54	2		1.031	1.103	51	3		1.013	1.203	51	3		1.044	1.312
60	60	54	3		260.0	9.03	51	4		0.985	1.101	51	4		1.016	1.206	51	5		1.042	1.311
60	100	54	5		260.0	15.05	51	6		0.986	1.102	51	7		1.015	1.204	51	8		1.043	1.311
60	200	54	11		259.6	30.08	51	13		0.985	1.101	51	15		1.013	1.203	51	17		1.043	1.311
60	300	54	17		259.8	45.11	51	19		0.984	1.101	51	22		1.014	1.204	51	26		1.043	1.312
60	400	54	22		259.8	60.16	51	25		0.984	1.101	51	30		1.013	1.203	51	34		1.043	1.311
60	500	54	28		259.8	75.19	51	32		0.985	1.101	51	37		1.013	1.203	51	43		1.043	1.311
100	10	60	1		355.3	1.37	60	1		1.016	1.092	60	1		1.037	1.193	60	1		1.056	1.298
100	20	66	1		364.8	2.57	66	1		1.032	1.118	66	1		1.071	1.243	66	1		1.110	1.372
100	40	66	2		364.8	5.14	66	2		1.032	1.118	66	2		1.071	1.243	66	3		1.098	1.362
100	60	66	3		364.8	7.72	66	3		1.032	1.118	66	4		1.068	1.240	66	4		1.097	1.361
100	100	66	4		364.8	12.86	66	5		1.033	1.118	66	6		1.064	1.236	66	7		1.095	1.360
100	200	66	8		364.8	25.72	66	10		1.033	1.118	66	12		1.064	1.236	66	14		1.095	1.360
100	300	66	11		364.7	38.58	66	15		1.033	1.118	66	18		1.064	1.236	66	21		1.095	1.360
100	400	66	15		364.8	51.44	66	19		1.032	1.117	66	24		1.064	1.236	66	28		1.095	1.360
100	500	66	19		364.8	64.30	66	24		1.032	1.117	66	30		1.064	1.236	66	35		1.095	1.360
150	10	72	1		480.5	1.22	72	1		1.008	1.097	72	1		1.024	1.205	78	1		1.113	1.317
150	20	78	1		472.9	2.24	78	1		1.036	1.135	78	1		1.073	1.271	78	1		1.110	1.413
150	40	78	2		472.9	4.48	78	2		1.036	1.135	78	2		1.073	1.271	78	3		1.105	1.409
150	60	78	3		472.9	6.73	78	3		1.036	1.135	78	3		1.073	1.271	78	4		1.098	1.403
150	100	78	5		472.9	11.21	78	5		1.036	1.135	78	6		1.068	1.267	78	7		1.100	1.404
150	200	78	10		472.9	22.42	78	9		1.034	1.132	78	11		1.067	1.266	78	13		1.099	1.404
150	300	78	15		472.9	33.64	78	14		1.034	1.133	78	17		1.066	1.265	78	20		1.098	1.403
150	400	78	20		472.9	44.85	78	18		1.034	1.132	78	23		1.066	1.265	78	27		1.098	1.403
150	500	78	25		472.9	56.06	78	23		1.034	1.133	78	28		1.066	1.265	78	34		1.098	1.402
200	10	84	1		610.0	1.12	84	1		1.008	1.108	84	1		1.016	1.219	84	1		1.034	1.345
200	20	90	1		588.2	2.05	90	1		1.026	1.138	90	1		1.059	1.281	90	1		1.103	1.440
200	40	90	2		588.2	4.11	90	2		1.026	1.138	90	2		1.059	1.281	84	3		1.043	1.437
200	60	90	2		577.6	6.08	90	3		1.041	1.152	90	3		1.074	1.298	90	4		1.113	1.453
200	100	90	4		575.4	10.10	90	4		1.043	1.154	90	5		1.079	1.302	90	6		1.115	1.456
200	200	90	8		575.4	20.21	90	8		1.043	1.154	90	10		1.079	1.302	90	12		1.115	1.456
200	300	90	12		575.4	30.31	90	12		1.043	1.154	90	15		1.079	1.302	90	19		1.114	1.455
200	400	90	16		575.4	40.41	90	16		1.043	1.154	90	20		1.079	1.302	90	25		1.113	1.454
200	500	90	20		575.4	50.52	90	20		1.043	1.154	90	26		1.078	1.302	90	31		1.113	1.454
300	10	102	1		824.8	1.00	102	1		1.009	1.124	102	1		1.017	1.250	102	1		1.026	1.381
300	20	102	1		730.0	1.79	108	1		1.080	1.157	108	1		1.123	1.325	102	1		1.124	1.504
300	40	114	1		779.4	3.52	108	2		1.011	1.176	108	2		1.052	1.347	102	2		1.053	1.529
300	60	108	2		748.2	5.24	108	3		1.053	1.183	108	3		1.095	1.355	102	4		1.090	1.532
300	100	108	3		751.3	8.77	108	4		1.049	1.178	108	5		1.091	1.350	108	6		1.131	1.526
300	200	108	7		746.6	17.44	108	8		1.055	1.185	102	11		1.052	1.357	108	12		1.138	1.534
300	300	108	10		748.2	26.21	108	11		1.053	1.183	108	14		1.093	1.353	108	17		1.136	1.532
300	400	108	14		748.6	34.89	108	15		1.055	1.185	108	19		1.096	1.356	108	23		1.137	1.533
300	500	108	17		747.5	43.66	108	18		1.054	1.183	108	24		1.095	1.355	108	29		1.135	1.531
500	10	132	1		1221.2	0.85	126	1		0.974	1.148	126	1		0.983	1.295	126	1		0.993	1.448
500	20	132	1		1054.9	1.50	132	1		1.014	1.171	132	1		1.061	1.369	138	1		1.140	1.575
500	40	138	1		1027.1	2.85	132	2		1.042	1.235	132	2		1.089	1.443	138	2		1.171	1.661
500	60	132	2		1000.8	4.30	138	2		1.095	1.220	132	3		1.118	1.432	138	3		1.201	1.648
500	100	144	2		1057.8	7.14	138	4		1.034	1.223	138	4		1.087	1.438	132	6		1.105	1.654
500	200	138	5		1027.1	14.24	138	8		1.065	1.227	132	9		1.085	1.440	132	11		1.136	1.658
500	300	138	8		1023.4	21.29	138	13		1.068	1.231	132	14		1.090	1.445	132	17		1.138	1.661
500	400	138	11		1025.1	28.46	138	17		1.065	1.228	132	18		1.086	1.441	132	23		1.135	1.658
500	500	138	13		1024.4	35.52	138	22		1.067	1.230	132	23		1.088	1.443	132	28		1.137	1.661
1000	10	180	1		1974.0	0.68	180	1		1.012	1.188	180	1		1.024	1.372	180	1		1.037	1.563
1000	20	180	1		1641.4	1.17	180	1		1.015	1.221	186	1		1.074	1.456	186	1		1.121	1.708
1000	40	186	1		1520.4	2.13	192	1		1.098	1.297	186	2		1.159	1.592	186	2		1.210	1.868
1000	60	192	1		1533.9	3.16	192	2		1.084	1.308	192	2		1.162	1.604	186	3		1.199	1.889
1000	100	192	2		1533.4	5.27	192	3		1.086	1.310	186	4		1.135	1.598	186	5		1.200	1.890
1000	200	192	4		1533.4	10.53	192	7		1.083	1.308	186	8		1.135	1.598	186	10		1.200	1.890
1000	300	192	6		1533.4	15.80	192	10		1.084	1.308	186	11		1.134	1.597	186	15		1.200	1.890
1000	400	192	7		1527.5	20.99	192	14		1.088	1.312	186	15		1.136	1.600	186	19		1.204	1.896
1000	500	192	9		1523.6	26.18	192	17		1.091	1.316	186	19		1.140	1.605	186	24		1.207	1.900

TEXAS WATER DEVELOPMENT BOARD — LOCKWOOD, ANDREWS AND NEWNAM, INC. PROGRAM

COST OF DELIVERING WATER BY PIPELINE = MOST ECONOMICAL DIAMETER

PEAK FACTOR = 1.00 GROWTH RATE = 0.00 INTEREST RATE = 0.040 AMORTIZATION PERIOD = 40 YRS PRESENT WORTH FACTOR = 20.19

FLOW MGD	LENGTH MILES	STATIC HEAD SLOPE = 0 DIA.NO.PS	C.C.FS/MI	W.C.CT/TG	STATIC HEAD SLOPE = 4 DIA.NO.PS	C.C.RATIO	W.C.RATIO	STATIC HEAD SLOPE = 8 DIA.NO.PS	C.C.RATIO	W.C.RATIO	STATIC HEAD SLOPE = 12 DIA.NO.PS	C.C.RATIO	W.C.RATIO
2	10	16 1	58.6	4.71	16 1	1.035	1.049	16 1	1.071	1.107	16 1	1.106	1.168
2	20	16 1	58.5	8.74	16 1	1.040	1.056	16 1	1.098	1.137	16 1	1.162	1.227
2	40	21 1	61.2	17.33	16 2	0.961	1.065	16 2	1.015	1.147	16 3	1.042	1.231
2	60	21 1	60.9	25.86	16 3	0.966	1.080	16 3	1.020	1.162	16 4	1.054	1.245
2	100	21 2	61.0	42.99	16 5	0.964	1.074	16 6	1.007	1.155	16 6	1.058	1.238
2	200	21 3	60.8	85.29	16 10	0.967	1.082	16 12	1.010	1.164	16 12	1.061	1.248
2	300	21 5	60.9	128.28	16 15	0.966	1.080	16 18	1.009	1.161	16 17	1.063	1.244
2	400	21 6	60.8	170.58	16 20	0.967	1.082	16 25	1.008	1.164	16 23	1.063	1.247
2	500	21 7	60.8	212.96	16 25	0.968	1.084	16 31	1.008	1.165	16 28	1.065	1.249
5	10	24 1	80.3	2.58	24 1	1.023	1.063	24 1	1.046	1.134	24 1	1.068	1.211
5	20	24 1	77.0	4.82	24 1	1.046	1.087	24 1	1.099	1.189	24 1	1.162	1.262
5	40	24 2	77.0	9.63	24 2	1.046	1.087	24 3	1.073	1.183	24 2	1.162	1.262
5	60	24 3	77.0	14.45	24 3	1.046	1.087	24 4	1.080	1.184	24 3	1.162	1.262
5	100	24 4	77.1	23.93	24 6	1.032	1.089	24 4	1.132	1.191	24 5	1.161	1.269
5	200	24 9	76.7	47.82	24 12	1.037	1.090	24 8	1.138	1.192	24 10	1.167	1.271
5	300	24 13	76.6	71.56	24 9	1.114	1.121	24 12	1.140	1.195	24 15	1.168	1.274
5	400	24 17	76.6	95.43	24 12	1.113	1.121	24 16	1.139	1.194	24 20	1.167	1.273
5	500	24 21	76.7	119.36	24 16	1.102	1.112	24 20	1.137	1.194	24 25	1.166	1.273
10	10	30 1	105.1	1.79	30 1	1.016	1.069	30 1	1.032	1.155	30 1	1.052	1.202
10	20	30 1	101.0	3.35	33 1	1.096	1.077	33 1	1.145	1.191	30 2	1.095	1.288
10	40	33 1	103.0	6.68	33 2	1.010	1.080	30 3	0.984	1.192	33 3	1.075	1.288
10	60	33 2	102.5	9.85	33 3	1.030	1.098	33 4	1.060	1.200	33 5	1.090	1.305
10	100	33 3	102.6	16.46	33 5	1.027	1.095	33 7	1.059	1.199	33 8	1.088	1.304
10	200	33 6	102.6	32.92	33 10	1.027	1.095	33 13	1.057	1.197	33 17	1.087	1.303
10	300	33 10	102.5	49.24	33 15	1.030	1.098	33 20	1.060	1.200	33 25	1.090	1.305
10	400	33 13	102.4	65.61	33 20	1.031	1.099	33 27	1.061	1.201	33 33	1.091	1.307
10	500	33 16	102.4	81.98	33 25	1.031	1.099	33 33	1.060	1.201	33 42	1.091	1.307
20	10	39 1	144.3	1.28	39 1	1.013	1.092	39 1	1.027	1.196	39 1	1.045	1.311
20	20	39 1	137.1	2.46	39 1	1.046	1.119	39 2	1.081	1.244	39 2	1.100	1.363
20	40	39 2	137.1	4.92	39 3	1.038	1.114	39 3	1.070	1.235	39 4	1.100	1.363
20	60	39 3	137.1	7.38	39 4	1.033	1.110	39 5	1.066	1.233	39 6	1.100	1.363
20	100	39 5	137.1	12.29	39 7	1.033	1.110	39 8	1.068	1.234	39 10	1.100	1.363
20	200	39 10	137.1	24.58	39 14	1.033	1.110	39 17	1.066	1.233	39 20	1.100	1.363
20	300	39 16	137.0	36.86	39 21	1.033	1.110	39 26	1.066	1.233	39 31	1.100	1.363
20	400	39 21	136.9	49.11	39 27	1.034	1.111	39 34	1.067	1.234	39 41	1.101	1.364
20	500	39 26	136.8	61.37	39 34	1.034	1.111	39 43	1.068	1.234	39 51	1.102	1.365
40	10	54 1	204.4	1.11	54 1	1.010	1.112	54 1	1.021	1.231	54 1	1.031	1.356
40	20	54 1	204.0	2.11	54 1	1.018	1.123	54 1	1.051	1.265	54 1	1.090	1.419
40	40	54 1	202.3	4.19	54 2	0.964	1.129	54 2	0.996	1.273	54 3	1.023	1.419
40	60	54 2	203.0	6.26	54 3	1.031	1.134	54 4	1.063	1.277	54 4	1.092	1.424
40	100	54 4	203.0	10.44	54 5	1.031	1.134	54 7	1.062	1.277	54 6	1.091	1.423
40	200	54 7	203.0	20.84	54 11	1.033	1.136	54 14	1.065	1.279	54 12	1.093	1.426
40	300	54 11	204.0	31.22	54 16	1.033	1.137	54 21	1.067	1.281	54 18	1.095	1.428
40	400	54 15	204.0	41.66	54 21	1.033	1.136	54 28	1.066	1.280	54 24	1.094	1.427
40	500	54 18	204.1	52.05	54 27	1.033	1.136	54 35	1.066	1.281	54 30	1.095	1.428
60	10	66 1	267.4	1.00	60 1	0.890	1.123	60 1	0.899	1.252	60 1	0.908	1.389
60	20	66 1	265.9	1.89	66 1	1.010	1.135	66 1	1.040	1.291	66 1	1.074	1.456
60	40	66 1	266.0	3.71	66 2	1.033	1.157	66 2	1.064	1.316	66 3	1.095	1.481
60	60	66 2	265.1	5.56	66 3	1.033	1.157	66 3	1.064	1.316	60 4	0.971	1.478
60	100	66 3	266.0	9.24	66 4	1.036	1.160	66 6	1.067	1.319	66 6	1.098	1.485
60	200	66 6	266.0	18.48	66 9	1.032	1.156	66 12	1.067	1.319	60 13	0.976	1.484
60	300	66 9	266.0	27.72	66 14	1.033	1.158	66 18	1.067	1.319	60 20	0.976	1.484
60	400	66 11	266.1	36.92	66 18	1.033	1.158	66 25	1.067	1.320	60 26	0.977	1.485
60	500	66 14	266.1	46.10	66 23	1.035	1.159	66 31	1.069	1.321	60 33	0.978	1.486
100	10	78 1	447.7	0.86	78 1	1.006	1.141	78 1	1.012	1.289	78 1	1.017	1.444
100	20	78 1	457.0	1.61	78 1	1.006	1.151	78 1	1.041	1.330	78 1	1.077	1.518
100	40	84 1	483.9	3.13	78 2	0.952	1.187	78 2	0.985	1.373	78 3	1.017	1.565
100	60	78 2	444.5	4.73	78 3	1.036	1.177	78 3	1.072	1.360	78 4	1.104	1.549
100	100	84 2	484.3	7.82	84 4	1.030	1.184	78 5	0.984	1.372	78 6	1.010	1.559
100	200	84 5	483.9	15.63	84 8	1.031	1.185	78 9	0.985	1.373	78 12	1.011	1.560
100	300	84 7	482.5	23.39	84 12	1.034	1.188	78 14	0.988	1.376	78 17	1.013	1.563
100	400	84 9	481.9	31.15	84 16	1.035	1.189	78 18	0.989	1.377	78 23	1.015	1.565
100	500	84 11	481.5	38.92	84 19	1.035	1.190	84 28	1.069	1.378	78 28	1.015	1.566
150	10	96 1	664.6	0.76	96 1	1.006	1.168	96 1	1.013	1.337	96 1	1.019	1.513
150	20	96 1	624.9	1.41	96 1	1.007	1.181	96 1	1.033	1.378	96 1	1.066	1.589
150	40	96 1	593.0	2.70	96 2	1.058	1.228	96 2	1.085	1.433	96 2	1.120	1.653
150	60	102 1	637.6	4.06	96 2	0.980	1.221	96 3	1.012	1.432	96 3	1.045	1.652
150	100	102 2	638.3	6.77	96 4	0.970	1.213	96 5	1.011	1.431	96 5	1.043	1.650
150	200	96 5	595.0	13.52	96 8	1.041	1.215	96 11	1.083	1.432	96 11	1.119	1.653
150	300	96 7	594.7	20.28	96 12	1.042	1.215	96 17	1.083	1.432	96 16	1.120	1.653
150	400	102 7	635.5	26.99	96 16	0.975	1.217	96 23	1.013	1.434	96 21	1.048	1.656
150	500	96 12	593.6	33.76	96 20	1.043	1.217	96 29	1.084	1.433	96 26	1.121	1.655
200	10	108 1	826.3	0.69	108 1	1.007	1.184	108 1	1.014	1.370	108 1	1.021	1.563
200	20	108 1	743.5	1.28	108 1	1.008	1.200	114 1	1.086	1.413	108 1	1.069	1.647
200	40	108 1	700.6	2.45	114 1	1.121	1.251	114 2	1.147	1.476	108 2	1.129	1.720
200	60	114 1	746.2	3.63	114 2	1.045	1.249	114 3	1.089	1.493	108 3	1.072	1.740
200	100	114 2	744.1	6.07	108 4	0.985	1.245	114 5	1.084	1.487	108 5	1.067	1.733
200	200	114 4	744.1	12.13	114 7	1.040	1.244	114 10	1.084	1.487	108 10	1.067	1.733
200	300	114 5	746.2	18.13	114 10	1.045	1.249	114 15	1.089	1.493	108 15	1.072	1.740
200	400	114 7	745.1	24.16	114 14	1.045	1.249	114 20	1.090	1.494	108 20	1.073	1.741
200	500	114 9	746.5	30.23	114 17	1.043	1.247	114 26	1.088	1.492	108 25	1.072	1.739
300	10	132 1	1113.4	0.80	132 1	1.008	1.217	132 1	1.016	1.431	132 1	1.023	1.652
300	20	132 1	993.1	1.10	132 1	1.009	1.238	132 1	1.023	1.478	132 1	1.068	1.750
300	40	132 1	933.8	2.09	138 1	1.095	1.284	132 2	1.089	1.555	132 2	1.137	1.841
300	60	138 1	983.0	3.09	132 2	1.006	1.293	132 3	1.056	1.579	132 3	1.102	1.870
300	100	132 2	921.8	5.18	138 3	1.095	1.286	132 5	1.103	1.571	132 5	1.151	1.860
300	200	138 3	957.0	10.27	132 7	1.008	1.296	132 10	1.060	1.584	132 10	1.107	1.876
300	300	138 4	980.0	15.42	138 9	1.051	1.296	132 15	1.059	1.583	132 14	1.105	1.874
300	400	144 6	959.0	20.54	132 14	1.008	1.296	138 19	1.102	1.584	132 19	1.106	1.876
300	500	138 7	956.0	25.62	138 16	1.054	1.299	132 26	1.062	1.587	132 24	1.109	1.880
500	10	168 1	1381.3	0.51	168 1	1.009	1.264	168 1	1.018	1.521	168 1	1.027	1.785
500	20	168 1	1381.7	0.90	168 1	1.010	1.296	168 1	1.021	1.583	168 1	1.068	1.909
500	40	168 1	1282.0	1.70	174 1	1.071	1.336	168 2	1.100	1.684	168 2	1.151	2.031
500	60	168 1	1249.7	2.50	168 2	1.065	1.365	168 2	1.130	1.720	168 3	1.182	2.075
500	100	180 1	1320.8	4.12	168 3	1.001	1.374	174 4	1.097	1.736	168 5	1.118	2.097
500	200	180 2	1320.8	8.24	168 6	1.001	1.374	174 9	1.093	1.732	168 9	1.115	2.094
500	300	180 3	1320.8	12.36	168 9	1.001	1.374	174 13	1.094	1.733	168 13	1.115	2.094
500	400	174 5	1281.2	16.48	174 11	1.064	1.373	174 18	1.127	1.733	168 18	1.150	2.095
500	500	174 6	1277.2	20.57	174 14	1.064	1.374	174 23	1.129	1.735	168 22	1.151	2.097
1000	10	240 1	2595.3	0.40	228 1	0.973	1.344	228 1	0.984	1.671	228 1	0.995	2.007
1000	20	240 1	2170.4	0.69	228 1	0.988	1.398	228 1	0.981	1.776	240 1	1.066	2.191
1000	40	240 1	1940.9	1.27	240 1	1.017	1.436	240 1	1.123	1.926	240 2	1.173	2.378
1000	60	240 1	1930.4	1.85	240 1	1.080	1.501	240 2	1.139	1.963	240 3	1.213	2.448
1000	100	240 1	1877.2	3.01	240 2	1.097	1.526	240 4	1.170	2.009	240 4	1.236	2.497
1000	200	240 2	1877.2	6.02	240 5	1.081	1.513	240 8	1.170	2.009	240 8	1.236	2.497
1000	300	252 2	1949.5	9.01	240 8	1.046	1.521	240 12	1.127	2.014	240 12	1.190	2.504
1000	400	240 4	1877.2	12.04	240 10	1.081	1.513	240 17	1.170	2.008	240 16	1.236	2.497
1000	500	240 4	1881.2	14.94	240 13	1.093	1.526	240 21	1.180	2.023	228 21	1.198	2.515

TEXAS WATER DEVELOPMENT BOARD — LOCKWOOD, ANDREWS, AND NEWNAM, INC. PROGRAM

COST OF DELIVERING WATER BY PIPELINE - MOST ECONOMICAL DIAMETER

PEAK FACTOR = 1.50 GROWTH RATE = 0.10 INTEREST RATE = 0.040 AMORTIZATION PERIOD = 40YRS PRESENT WORTH FACTOR = 15.78

FLOW	LENGTH	STATIC HEAD SLOPE = 0				STATIC HEAD SLOPE = 4				STATIC HEAD SLOPE = 8				STATIC HEAD SLOPE = 12			
MGD	MILES	DIA.	NO.	PS	C.C./M	W.C.RATIO	DIA.	NO.	PS	C.C.RATIO	W.C.RATIO	DIA.	NO.	PS	C.C.RATIO	W.C.RATIO	DIA.	NO.	PS	C.C.RATIO	W.C.RATIO
2	10	16	1	58.6	5.73	16	1	1.035	1.051	16	1	1.071	1.107	16	1	1.106	1.165				
2	20	16	1	58.5	10.74	16	1	1.040	1.057	16	1	1.098	1.135	16	1	1.162	1.221				
2	40	16	2	58.5	21.49	16	2	1.040	1.057	16	2	1.098	1.135	16	3	1.128	1.208				
2	60	16	2	57.0	32.10	16	3	1.032	1.061	16	3	1.090	1.140	16	4	1.126	1.213				
2	100	16	4	56.1	53.01	16	5	1.048	1.071	16	6	1.094	1.147	16	7	1.140	1.224				
2	200	16	8	56.1	106.02	16	10	1.048	1.071	16	12	1.094	1.147	16	14	1.140	1.224				
2	300	16	12	56.1	159.03	16	15	1.048	1.071	16	19	1.091	1.146	16	22	1.137	1.224				
2	400	16	16	56.1	212.04	16	20	1.048	1.071	16	25	1.091	1.146	16	29	1.138	1.224				
2	500	16	20	56.1	265.05	16	26	1.046	1.071	16	31	1.092	1.146	16	37	1.137	1.224				
5	10	24	1	80.3	3.14	21	1	0.953	1.051	21	1	0.991	1.125	24	1	1.068	1.193				
5	20	24	1	77.0	5.90	24	1	1.046	1.084	24	1	1.099	1.178	24	1	1.162	1.250				
5	40	24	2	77.0	11.80	24	2	1.046	1.084	24	3	1.073	1.167	24	2	1.162	1.250				
5	60	24	3	77.0	17.70	24	3	1.046	1.084	24	4	1.080	1.169	24	3	1.162	1.250				
5	100	24	4	77.1	29.39	24	6	1.032	1.081	24	7	1.077	1.173	24	5	1.161	1.255				
5	200	24	9	76.7	58.64	24	12	1.037	1.083	21	13	1.064	1.187	24	10	1.167	1.258				
5	300	24	13	76.6	87.78	21	16	1.039	1.125	24	12	1.140	1.191	24	15	1.168	1.261				
5	400	24	17	76.6	117.09	21	22	1.034	1.121	21	26	1.065	1.189	24	20	1.167	1.260				
5	500	24	22	76.6	146.42	24	16	1.103	1.115	21	32	1.066	1.190	24	25	1.168	1.260				
10	10	30	1	105.1	2.15	30	1	1.016	1.066	30	1	1.032	1.142	30	1	1.052	1.185				
10	20	30	1	101.0	4.04	33	1	1.096	1.091	33	1	1.145	1.195	30	2	1.095	1.260				
10	40	30	2	101.0	8.07	33	2	1.096	1.091	30	3	1.067	1.172	30	4	1.095	1.260				
10	60	30	3	101.0	12.11	30	4	1.031	1.081	30	5	1.063	1.169	30	6	1.095	1.260				
10	100	30	5	101.0	20.18	30	7	1.029	1.079	30	9	1.064	1.169	30	10	1.095	1.260				
10	200	30	11	100.9	40.31	30	14	1.030	1.080	30	17	1.063	1.169	30	21	1.095	1.261				
10	300	30	16	100.8	60.39	30	21	1.032	1.081	30	26	1.064	1.170	30	31	1.096	1.262				
10	400	30	21	100.7	80.47	30	28	1.033	1.082	30	35	1.065	1.171	30	41	1.098	1.263				
10	500	30	26	100.7	100.62	30	35	1.032	1.082	30	43	1.065	1.170	30	52	1.097	1.262				
20	10	39	1	144.3	1.51	39	1	1.013	1.083	39	1	1.027	1.174	39	1	1.045	1.274				
20	20	39	1	137.1	2.90	39	1	1.046	1.113	39	2	1.081	1.225	39	2	1.100	1.329				
20	40	39	2	137.1	5.80	39	3	1.038	1.106	39	3	1.070	1.216	39	4	1.100	1.329				
20	60	39	3	137.1	8.70	39	4	1.033	1.102	39	5	1.066	1.213	39	6	1.100	1.329				
20	100	39	5	137.1	14.50	39	7	1.033	1.102	39	8	1.066	1.214	39	10	1.100	1.329				
20	200	39	10	137.1	29.01	39	14	1.033	1.102	39	17	1.066	1.213	39	20	1.100	1.329				
20	300	39	16	137.0	43.49	39	21	1.033	1.102	39	26	1.066	1.213	39	31	1.100	1.330				
20	400	39	21	136.9	57.95	39	27	1.034	1.103	39	34	1.067	1.214	39	41	1.101	1.331				
20	500	39	26	136.8	72.40	39	34	1.034	1.103	39	43	1.068	1.214	39	51	1.102	1.331				
40	10	51	1	243.7	1.32	51	1	1.011	1.093	51	1	1.022	1.194	51	1	1.035	1.303				
40	20	51	1	230.8	2.49	51	1	1.037	1.118	51	1	1.075	1.245	51	2	1.105	1.374				
40	40	51	2	230.8	4.99	51	2	1.037	1.118	51	3	1.069	1.241	51	3	1.096	1.366				
40	60	51	3	230.8	7.48	51	4	1.035	1.116	51	4	1.067	1.239	51	4	1.094	1.364				
40	100	51	5	230.8	12.47	51	6	1.036	1.117	51	6	1.066	1.238	51	7	1.094	1.364				
40	200	54	7	243.8	24.94	51	13	0.972	1.117	51	12	1.001	1.239	51	14	1.027	1.365				
40	300	54	11	244.8	37.36	51	20	0.973	1.118	51	17	1.002	1.240	51	21	1.029	1.367				
40	400	54	15	244.8	49.85	51	26	0.972	1.117	51	23	1.001	1.239	51	27	1.027	1.365				
40	500	54	18	244.7	62.28	51	33	0.973	1.118	51	28	1.001	1.240	51	34	1.028	1.366				
60	10	60	1	323.2	1.18	60	1	1.010	1.103	60	1	1.021	1.215	60	1	1.031	1.333				
60	20	60	1	301.7	2.22	60	1	1.031	1.125	60	1	1.063	1.260	60	1	1.098	1.404				
60	40	60	2	301.7	4.43	60	2	1.031	1.125	60	2	1.063	1.260	60	3	1.094	1.401				
60	60	60	2	301.5	6.65	60	3	1.031	1.125	60	3	1.064	1.261	60	4	1.089	1.397				
60	100	60	4	300.9	11.06	60	5	1.034	1.127	60	6	1.064	1.262	60	7	1.094	1.402				
60	200	60	9	300.4	22.10	60	9	1.034	1.128	60	11	1.064	1.261	60	13	1.093	1.402				
60	300	60	14	300.2	33.13	60	13	1.034	1.128	60	16	1.065	1.262	60	20	1.094	1.402				
60	400	60	18	300.4	44.19	60	17	1.034	1.128	60	22	1.064	1.261	60	26	1.093	1.402				
60	500	60	23	300.3	55.22	60	22	1.034	1.128	60	27	1.064	1.262	60	33	1.093	1.402				
100	10	78	1	497.7	1.03	72	1	0.915	1.120	72	1	0.921	1.244	72	1	0.928	1.375				
100	20	78	1	459.8	1.91	78	1	1.006	1.131	78	1	1.041	1.289	78	1	1.077	1.455				
100	40	78	1	447.3	3.77	78	2	1.025	1.149	78	2	1.061	1.310	78	3	1.095	1.476				
100	60	78	2	444.5	5.60	78	3	1.036	1.159	78	3	1.072	1.321	78	4	1.104	1.486				
100	100	78	3	443.1	9.34	78	5	1.035	1.158	78	5	1.071	1.320	78	6	1.099	1.482				
100	200	78	6	443.1	18.69	78	10	1.035	1.158	78	9	1.070	1.320	78	12	1.099	1.482				
100	300	78	10	444.5	27.99	78	15	1.036	1.159	78	14	1.072	1.321	78	17	1.100	1.483				
100	400	78	13	443.8	37.28	78	19	1.038	1.160	78	18	1.074	1.323	78	23	1.102	1.485				
100	500	78	16	443.5	46.57	78	24	1.038	1.161	78	23	1.075	1.324	78	28	1.102	1.485				
150	10	90	1	638.3	0.91	90	1	1.007	1.137	90	1	1.014	1.279	90	1	1.020	1.428				
150	20	90	1	570.4	1.67	90	1	1.010	1.150	90	1	1.047	1.328	90	1	1.087	1.515				
150	40	90	1	549.0	3.23	90	2	0.978	1.190	90	2	1.014	1.374	90	2	1.053	1.567				
150	60	90	2	551.0	4.88	90	3	1.045	1.182	90	3	1.084	1.365	90	4	1.121	1.554				
150	100	90	3	601.0	8.16	96	4	1.031	1.180	90	5	1.004	1.362	90	6	1.035	1.547				
150	200	90	5	595.0	16.17	96	8	1.041	1.190	90	9	1.014	1.373	90	12	1.046	1.560				
150	300	90	7	594.7	24.25	96	12	1.042	1.190	90	14	1.014	1.373	90	17	1.045	1.560				
150	400	90	10	595.0	32.35	96	16	1.041	1.190	90	19	1.014	1.373	90	23	1.044	1.559				
150	500	90	12	595.0	40.37	96	20	1.043	1.192	90	23	1.015	1.375	90	29	1.046	1.562				
200	10	102	1	760.1	0.83	102	1	1.007	1.152	102	1	1.015	1.307	102	1	1.022	1.469				
200	20	102	1	700.3	1.52	102	1	1.008	1.165	108	1	1.104	1.359	108	1	1.142	1.559				
200	40	108	1	708.0	2.92	102	2	0.996	1.219	108	2	1.091	1.421	108	2	1.129	1.631				
200	60	114	1	740.2	4.40	108	2	0.998	1.209	108	3	1.036	1.413	108	3	1.072	1.622				
200	100	108	2	712.3	7.32	108	4	1.036	1.202	108	5	1.085	1.414	102	6	1.065	1.622				
200	200	108	5	708.6	14.58	108	8	1.042	1.208	108	11	1.090	1.420	102	11	1.068	1.627				
200	300	108	7	708.9	21.80	108	12	1.046	1.212	108	17	1.093	1.424	102	17	1.073	1.633				
200	400	108	9	709.0	29.04	108	16	1.047	1.213	108	23	1.095	1.426	102	22	1.073	1.634				
200	500	108	11	709.2	36.36	108	20	1.045	1.211	108	28	1.092	1.423	102	28	1.071	1.631				
300	10	126	1	1064.9	0.73	126	1	1.008	1.180	126	1	1.016	1.358	126	1	1.024	1.543				
300	20	126	1	945.1	1.32	126	1	1.009	1.199	126	1	1.036	1.411	126	1	1.075	1.640				
300	40	126	1	885.3	2.50	132	1	1.112	1.258	126	2	1.106	1.489	126	2	1.148	1.730				
300	60	132	1	920.9	3.72	132	2	1.052	1.252	126	3	1.064	1.499	126	3	1.104	1.743				
300	100	132	2	921.8	6.21	126	4	1.009	1.250	126	5	1.062	1.497	126	5	1.102	1.740				
300	200	132	4	921.8	12.43	132	7	1.048	1.249	126	11	1.062	1.497	126	10	1.102	1.740				
300	300	132	5	920.9	18.62	126	12	1.010	1.252	126	17	1.064	1.499	126	15	1.104	1.743				
300	400	132	7	919.8	24.72	132	14	1.055	1.256	126	22	1.069	1.506	126	20	1.110	1.750				
300	500	132	9	917.9	30.93	132	17	1.055	1.255	126	28	1.068	1.504	126	25	1.108	1.748				
500	10	162	1	1532.7	0.61	156	1	0.978	1.218	156	1	0.988	1.431	156	1	0.997	1.650				
500	20	162	1	1353.1	1.09	156	1	0.975	1.246	162	1	1.024	1.489	162	1	1.074	1.770				
500	40	162	1	1283.3	2.04	168	1	1.084	1.299	162	2	1.107	1.590	162	2	1.161	1.890				
500	60	162	1	1200.1	2.99	162	2	1.069	1.317	162	3	1.138	1.627	162	3	1.193	1.934				
500	100	162	2	1213.4	5.03	168	3	1.089	1.307	162	5	1.125	1.612	162	5	1.180	1.916				
500	200	168	3	1242.0	9.97	168	6	1.064	1.318	162	10	1.099	1.627	162	9	1.150	1.931				
500	300	168	4	1238.2	14.90	162	10	1.037	1.322	162	15	1.105	1.634	162	14	1.155	1.939				
500	400	168	6	1242.0	19.95	162	13	1.034	1.318	162	20	1.099	1.627	162	18	1.150	1.931				
500	500	168	7	1238.1	24.87	162	17	1.037	1.321	162	25	1.103	1.631	162	23	1.153	1.936				
1000	10	228	1	2490.7	0.49	216	1	0.973	1.281	216	1	0.985	1.551	216	1	0.996	1.828				
1000	20	228	1	2097.6	0.83	216	1	0.968	1.328	216	1	0.982	1.642	216	1	1.031	1.997				
1000	40	228	1	1895.1	1.53	228	1	1.033	1.376	216	2	1.085	1.791	216	2	1.139	2.178				
1000	60	228	1	1831.6	2.23	216	2	1.036	1.431	228	2	1.151	1.829	216	3	1.181	2.246				
1000	100	228	1	1794.2	3.64	228	3	1.096	1.447	228	3	1.175	1.861	228	4	1.247	2.279				
1000	200	228	2	1794.2	7.29	228	5	1.093	1.444	228	6	1.175	1.861	216	9	1.196	2.278				
1000	300	228	3	1794.2	10.93	228	8	1.089	1.441	228	9	1.175	1.861	216	13	1.196	2.277				
1000	400	228	4	1794.2	14.58	228	11	1.087	1.439	228	12	1.175	1.861	228	17	1.243	2.276				
1000	500	240	4	1861.2	18.17	228	14	1.048	1.443	228	15	1.133	1.866	228	21	1.198	2.282				

TEXAS WATER DEVELOPMENT BOARD — LOCKWOOD, ANDREWS AND NEWNAM, INC. PROGRAM

COST OF DELIVERING WATER BY PIPELINE - MOST ECONOMICAL DIAMETER

PEAK FACTOR = 1.50 GROWTH RATE = 0.06 INTEREST RATE = 0.040 AMORTIZATION PERIOD = 40 YRS PRESENT WORTH FACTOR = 13.41

FLOW	LENGTH	STATIC HEAD SLOPE = 0				STATIC HEAD SLOPE = 4				STATIC HEAD SLOPE = 8				STATIC HEAD SLOPE = 12			
MGD	MILES	DIA.	NO. PS	C.C. $/MI	W.C.&T/Yr	DIA.	NO. PS	C.C. RATIO	W.C. RATIO	DIA.	NO. PS	C.C. RATIO	W.C. RATIO	DIA.	NO. PS	C.C. RATIO	W.C. RATIO
2	10	16	1	58.6	6.56	16	1	1.035	1.052	16	1	1.071	1.107	16	1	1.106	1.163
2	20	16	1	56.5	12.38	16	1	1.040	1.057	16	1	1.098	1.133	16	1	1.162	1.218
2	40	16	2	56.5	24.77	16	2	1.040	1.057	16	2	1.098	1.133	16	3	1.128	1.201
2	60	16	2	57.0	37.10	16	3	1.032	1.058	16	4	1.077	1.133	16	4	1.126	1.204
2	100	16	4	56.1	61.18	16	5	1.048	1.069	16	6	1.094	1.142	16	7	1.140	1.216
2	200	16	8	56.1	122.36	16	10	1.048	1.069	16	12	1.094	1.142	16	15	1.137	1.215
2	300	16	12	56.1	183.54	16	15	1.048	1.069	16	19	1.091	1.141	16	22	1.137	1.215
2	400	16	16	56.1	244.72	16	21	1.046	1.069	16	25	1.091	1.140	16	29	1.138	1.215
2	500	16	20	56.1	305.90	16	26	1.046	1.069	16	31	1.092	1.141	16	37	1.137	1.215
5	10	24	1	74.3	3.54	24	1	1.030	1.051	21	1	1.071	1.123	21	1	1.107	1.197
5	20	24	1	77.0	6.79	24	1	1.046	1.081	21	2	1.033	1.170	24	1	1.162	1.243
5	40	24	2	77.0	13.58	24	2	1.046	1.081	24	3	1.073	1.158	24	2	1.162	1.243
5	60	24	3	77.0	20.37	24	4	1.038	1.080	24	4	1.080	1.161	21	4	1.105	1.241
5	100	24	4	77.1	33.84	24	6	1.032	1.076	24	8	1.072	1.163	21	7	1.095	1.236
5	200	24	9	76.7	67.50	24	12	1.037	1.079	21	13	1.064	1.168	21	14	1.101	1.240
5	300	24	13	76.6	101.05	24	18	1.039	1.081	21	19	1.068	1.172	21	22	1.098	1.239
5	400	24	17	76.6	134.80	21	22	1.034	1.106	21	26	1.065	1.169	21	29	1.098	1.239
5	500	24	22	76.6	168.54	21	28	1.033	1.104	21	32	1.066	1.170	21	37	1.097	1.237
10	10	30	1	105.1	2.43	27	1	0.958	1.052	27	1	0.987	1.127	30	1	1.052	1.174
10	20	30	1	101.0	4.60	30	1	1.046	1.090	30	1	1.098	1.189	30	2	1.095	1.243
10	40	30	2	101.0	9.20	30	2	1.046	1.090	30	3	1.067	1.162	30	4	1.095	1.243
10	60	30	3	101.0	13.80	30	4	1.031	1.077	30	5	1.063	1.158	30	6	1.095	1.243
10	100	30	5	101.0	23.00	30	7	1.029	1.075	30	9	1.064	1.159	30	10	1.095	1.243
10	200	30	11	100.9	45.96	30	14	1.030	1.076	30	17	1.063	1.158	30	21	1.095	1.243
10	300	30	16	100.8	68.84	30	21	1.032	1.077	30	26	1.064	1.159	30	31	1.096	1.245
10	400	30	21	100.7	91.72	30	28	1.033	1.078	30	35	1.065	1.160	30	41	1.098	1.246
10	500	30	26	100.7	114.70	30	35	1.032	1.078	30	43	1.065	1.160	30	52	1.097	1.245
20	10	39	1	144.3	1.71	39	1	1.013	1.077	39	1	1.027	1.160	39	1	1.045	1.251
20	20	39	1	137.1	3.27	39	1	1.046	1.108	39	2	1.081	1.213	39	2	1.100	1.308
20	40	39	2	137.1	6.53	39	3	1.038	1.101	39	3	1.070	1.203	39	4	1.100	1.308
20	60	39	3	137.1	9.80	39	4	1.033	1.097	39	5	1.066	1.200	39	6	1.100	1.308
20	100	39	5	137.1	16.33	39	7	1.033	1.097	39	8	1.068	1.201	39	10	1.100	1.308
20	200	39	10	137.1	32.67	39	14	1.033	1.097	39	17	1.066	1.200	39	20	1.100	1.308
20	300	39	16	137.0	48.98	39	21	1.033	1.097	39	26	1.066	1.200	39	31	1.100	1.308
20	400	39	21	136.9	65.25	39	27	1.034	1.098	39	34	1.067	1.201	39	41	1.101	1.309
20	500	39	26	136.8	81.53	39	34	1.034	1.098	39	43	1.068	1.201	39	51	1.102	1.310
40	10	48	1	227.8	1.47	48	1	1.012	1.080	48	1	1.027	1.173	48	1	1.052	1.281
40	20	51	1	230.0	2.80	51	1	1.037	1.112	51	1	1.075	1.231	48	2	1.042	1.348
40	40	51	2	230.0	5.59	51	2	1.037	1.112	48	3	1.006	1.225	48	3	1.033	1.341
40	60	51	3	230.0	8.39	51	4	1.035	1.110	48	4	1.004	1.224	51	4	1.094	1.340
40	100	51	5	230.0	13.98	51	6	1.036	1.111	48	7	1.003	1.223	48	8	1.030	1.338
40	200	51	10	230.0	27.95	51	13	1.035	1.110	48	14	1.003	1.223	48	16	1.030	1.338
40	300	51	15	230.0	41.93	51	20	1.035	1.110	51	17	1.065	1.223	48	24	1.030	1.338
40	400	51	20	230.0	55.91	51	26	1.035	1.110	51	23	1.065	1.223	48	32	1.030	1.338
40	500	51	25	230.0	69.89	51	33	1.035	1.110	51	28	1.065	1.223	48	40	1.030	1.338
60	10	60	1	329.2	1.32	57	1	0.955	1.094	57	1	0.965	1.194	60	1	1.031	1.304
60	20	60	1	301.7	2.48	60	1	1.031	1.118	60	1	1.063	1.244	60	1	1.098	1.377
60	40	60	2	301.7	4.95	60	2	1.031	1.118	60	2	1.063	1.244	60	3	1.094	1.374
60	60	60	2	301.5	7.42	60	3	1.031	1.119	60	3	1.064	1.245	60	4	1.089	1.370
60	100	60	4	300.9	12.35	60	5	1.034	1.121	60	6	1.064	1.245	60	7	1.094	1.374
60	200	60	9	300.4	24.67	60	9	1.034	1.121	60	11	1.064	1.245	60	13	1.093	1.374
60	300	60	14	300.2	36.99	60	13	1.034	1.121	60	16	1.065	1.246	60	20	1.094	1.375
60	400	60	18	300.4	49.34	60	17	1.034	1.121	60	22	1.064	1.245	60	26	1.093	1.374
60	500	60	23	300.4	61.66	60	22	1.034	1.121	60	27	1.064	1.245	60	33	1.093	1.374
100	10	72	1	452.7	1.15	72	1	1.006	1.104	72	1	1.013	1.216	72	1	1.020	1.335
100	20	72	1	416.8	2.13	72	1	1.033	1.133	72	1	1.068	1.275	72	1	1.103	1.424
100	40	78	1	449.3	4.25	72	2	0.949	1.135	72	2	0.981	1.278	72	3	1.008	1.422
100	60	78	2	444.5	6.32	72	3	0.960	1.146	72	3	0.992	1.290	72	4	1.013	1.431
100	100	78	3	443.1	10.54	72	5	0.958	1.144	72	6	0.986	1.284	72	7	1.013	1.430
100	200	78	6	443.1	21.08	72	9	0.957	1.143	72	11	0.984	1.283	72	13	1.012	1.430
100	300	78	10	444.5	31.58	72	14	0.959	1.145	72	17	0.986	1.284	72	20	1.013	1.431
100	400	78	13	443.8	42.05	72	18	0.959	1.146	72	22	0.987	1.286	72	27	1.014	1.432
100	500	78	16	443.5	52.53	72	22	0.960	1.147	72	28	0.987	1.286	72	34	1.015	1.433
150	10	90	1	630.3	1.02	84	1	0.938	1.125	84	1	0.944	1.251	84	1	0.952	1.384
150	20	90	1	576.4	1.87	90	1	1.010	1.138	90	1	1.047	1.302	90	1	1.087	1.474
150	40	96	1	595.0	3.67	90	2	0.978	1.161	90	2	1.014	1.328	90	2	1.053	1.504
150	60	90	2	587.0	5.46	90	3	1.045	1.171	90	3	1.084	1.339	90	4	1.121	1.513
150	100	90	3	589.9	9.14	90	5	1.039	1.166	90	5	1.078	1.334	90	6	1.111	1.503
150	200	90	7	588.4	18.24	90	10	1.042	1.168	90	9	1.081	1.336	90	12	1.114	1.506
150	300	90	10	587.0	27.31	90	15	1.045	1.171	90	14	1.083	1.339	90	17	1.115	1.508
150	400	90	13	587.7	36.45	90	20	1.043	1.170	90	19	1.081	1.337	90	23	1.114	1.506
150	500	90	17	587.2	45.53	90	25	1.044	1.170	90	23	1.082	1.338	90	29	1.115	1.508
200	10	102	1	780.1	0.94	96	1	0.947	1.136	96	1	0.954	1.274	96	1	0.962	1.419
200	20	102	1	700.3	1.71	102	1	1.008	1.151	102	1	1.047	1.329	102	1	1.089	1.516
200	40	108	1	708.6	3.30	102	2	0.996	1.190	102	2	1.035	1.374	102	2	1.076	1.567
200	60	102	2	673.7	4.96	102	3	1.048	1.189	102	3	1.089	1.373	102	4	1.131	1.565
200	100	102	3	670.3	8.23	102	4	1.052	1.193	102	5	1.094	1.379	102	6	1.132	1.568
200	200	102	6	670.3	16.46	102	9	1.050	1.191	102	9	1.093	1.378	102	11	1.129	1.565
200	300	102	9	670.3	24.69	102	14	1.049	1.190	102	13	1.093	1.378	102	17	1.130	1.566
200	400	108	9	705.0	32.89	102	19	0.997	1.191	102	18	1.039	1.379	102	22	1.073	1.567
200	500	102	15	670.3	41.15	102	24	1.049	1.190	102	22	1.092	1.378	102	28	1.129	1.566
300	10	120	1	1017.1	0.82	120	1	1.009	1.158	120	1	1.017	1.316	120	1	1.026	1.481
300	20	120	1	891.4	1.48	120	1	1.010	1.175	126	1	1.091	1.376	126	1	1.132	1.584
300	40	126	1	885.4	2.81	120	2	1.023	1.239	126	2	1.106	1.450	126	2	1.148	1.670
300	60	132	1	920.4	4.23	126	2	1.017	1.227	126	3	1.064	1.446	126	3	1.104	1.666
300	100	126	2	867.7	7.05	126	4	1.047	1.221	126	5	1.103	1.447	126	5	1.145	1.666
300	200	126	5	885.4	14.07	126	8	1.050	1.224	120	9	1.061	1.448	120	11	1.102	1.668
300	300	126	7	881.4	21.03	126	12	1.055	1.229	120	13	1.066	1.453	120	16	1.107	1.674
300	400	126	9	879.4	27.98	126	16	1.058	1.231	120	17	1.068	1.456	120	22	1.110	1.677
300	500	126	11	880.2	35.01	126	20	1.056	1.230	120	22	1.067	1.455	120	27	1.108	1.675
500	10	150	1	1484.7	0.70	150	1	0.978	1.192	150	1	0.988	1.380	150	1	0.997	1.575
500	20	150	1	1289.1	1.23	150	1	0.975	1.217	156	1	1.035	1.444	156	1	1.080	1.693
500	40	156	1	1185.4	2.30	156	1	1.066	1.280	156	2	1.122	1.546	156	2	1.171	1.813
500	60	162	1	1200.1	3.38	162	2	1.069	1.291	156	3	1.108	1.574	156	3	1.156	1.847
500	100	156	2	1165.4	5.66	162	3	1.107	1.292	156	4	1.138	1.565	156	5	1.191	1.840
500	200	156	4	1165.4	11.32	156	7	1.074	1.289	156	8	1.138	1.565	156	10	1.191	1.840
500	300	162	5	1200.1	16.91	162	10	1.069	1.291	156	11	1.104	1.570	156	15	1.156	1.847
500	400	162	7	1200.4	22.60	162	13	1.067	1.290	156	15	1.101	1.567	156	19	1.152	1.841
500	500	162	8	1200.6	28.19	162	17	1.069	1.292	156	19	1.104	1.570	156	24	1.154	1.844
1000	10	216	1	2400.6	0.55	216	1	1.012	1.249	216	1	1.024	1.487	216	1	1.036	1.733
1000	20	216	1	2001.5	0.94	216	1	1.014	1.291	216	1	1.029	1.571	216	1	1.081	1.892
1000	40	216	1	1802.0	1.73	228	1	1.088	1.348	216	2	1.143	1.720	216	2	1.200	2.070
1000	60	216	1	1735.4	2.51	216	2	1.093	1.395	216	2	1.166	1.758	216	3	1.246	2.138
1000	100	228	1	1794.2	4.14	216	3	1.050	1.401	216	4	1.134	1.780	216	4	1.202	2.155
1000	200	228	2	1794.2	8.28	216	6	1.050	1.401	216	7	1.129	1.776	216	9	1.196	2.149
1000	300	228	3	1794.2	12.42	216	9	1.050	1.401	216	10	1.128	1.774	216	13	1.196	2.149
1000	400	228	4	1794.2	16.56	228	11	1.087	1.400	216	13	1.127	1.774	216	18	1.196	2.149
1000	500	216	7	1714.5	20.67	228	14	1.138	1.402	216	17	1.181	1.777	216	22	1.250	2.150

TEXAS WATER DEVELOPMENT BOARD — LOCKWOOD, ANDREWS, AND NEWNAM, INC. PROGRAM

COST OF DELIVERING WATER BY PIPELINE - MOST ECONOMICAL DIAMETER

PEAK FACTOR = 1.50 GROWTH RATE = 0.03 INTEREST RATE = 0.040 AMORTIZATION PERIOD = 40YRS PRESENT WORTH FACTOR = 8.92

FLOW	LENGTH	STATIC HEAD SLOPE = 0				STATIC HEAD SLOPE = 4				STATIC HEAD SLOPE = 8				STATIC HEAD SLOPE = 12			
MGD	MILES	DIA.	NO. PS	C.C. $/MI	W.C. $/TG	DIA.	NO. PS	C.C. RATIO	W.C. RATIO	DIA.	NO. PS	C.C. RATIO	W.C. RATIO	DIA.	NO. PS	C.C. RATIO	W.C. RATIO
2	10	16	1	58.6	9.38	16	1	1.035	1.052	16	1	1.071	1.104	16	1	1.106	1.156
2	20	16	1	58.5	17.92	16	1	1.040	1.056	16	1	1.098	1.129	16	1	1.162	1.209
2	40	16	2	58.5	35.85	16	2	1.040	1.056	16	2	1.098	1.129	16	3	1.128	1.184
2	60	16	3	58.5	53.77	16	3	1.040	1.056	16	4	1.086	1.122	16	4	1.135	1.188
2	100	16	4	58.1	88.77	16	5	1.048	1.066	16	6	1.094	1.131	16	7	1.140	1.197
2	200	16	8	58.1	177.54	16	10	1.048	1.066	16	13	1.092	1.131	16	15	1.137	1.196
2	300	16	12	58.1	266.32	16	15	1.048	1.066	16	19	1.091	1.129	16	22	1.137	1.196
2	400	16	16	58.1	355.09	16	21	1.046	1.065	16	25	1.091	1.129	16	30	1.137	1.196
2	500	16	20	58.1	443.86	16	26	1.046	1.064	16	31	1.092	1.130	16	37	1.137	1.195
5	10	21	1	74.3	4.90	21	1	1.030	1.053	21	1	1.071	1.120	21	1	1.107	1.186
5	20	24	1	77.0	9.79	21	2	0.994	1.054	21	2	1.033	1.121	21	2	1.068	1.186
5	40	21	3	73.9	19.42	21	4	1.035	1.063	21	4	1.076	1.130	21	4	1.113	1.197
5	60	21	5	73.8	29.06	21	6	1.039	1.065	21	5	1.082	1.131	21	6	1.117	1.199
5	100	21	8	73.8	48.47	21	10	1.038	1.064	21	9	1.079	1.130	21	7	1.144	1.198
5	200	21	17	73.8	96.82	24	12	1.081	1.077	21	13	1.109	1.137	21	14	1.147	1.200
5	300	21	26	73.5	145.16	24	18	1.082	1.077	21	19	1.112	1.140	21	22	1.144	1.196
5	400	21	35	73.5	193.50	24	24	1.082	1.078	21	26	1.110	1.138	21	29	1.145	1.198
5	500	24	22	76.6	243.35	24	30	1.038	1.071	21	32	1.066	1.133	21	37	1.097	1.189
10	10	27	1	98.1	3.31	27	1	1.027	1.048	27	1	1.058	1.113	27	1	1.086	1.178
10	20	30	1	101.0	6.52	27	2	0.997	1.066	27	2	1.027	1.132	27	2	1.054	1.197
10	40	30	2	101.0	13.04	27	4	0.997	1.066	27	4	1.027	1.132	27	4	1.054	1.197
10	60	30	3	101.0	19.56	27	6	0.997	1.066	27	6	1.027	1.132	27	6	1.054	1.197
10	100	30	5	101.0	32.60	30	7	1.029	1.065	27	9	1.027	1.132	27	10	1.054	1.197
10	200	30	11	100.9	65.13	30	14	1.030	1.066	27	17	1.028	1.133	27	20	1.055	1.199
10	300	30	16	100.8	97.56	30	21	1.032	1.067	27	26	1.029	1.134	27	29	1.057	1.200
10	400	30	21	100.7	129.98	30	28	1.033	1.068	27	34	1.030	1.135	27	39	1.058	1.201
10	500	30	26	100.7	162.54	27	54	0.999	1.068	27	43	1.030	1.135	27	48	1.057	1.200
20	10	36	1	136.7	2.34	36	1	1.014	1.060	36	1	1.042	1.138	39	1	1.103	1.218
20	20	39	1	137.1	4.52	36	2	1.011	1.096	36	2	1.039	1.176	39	2	1.100	1.259
20	40	39	2	137.1	9.04	39	3	1.038	1.089	39	3	1.070	1.173	39	4	1.100	1.259
20	60	39	3	137.1	13.56	39	4	1.033	1.085	39	5	1.066	1.170	39	6	1.100	1.259
20	100	39	5	137.1	22.60	39	7	1.033	1.084	39	8	1.068	1.172	36	9	1.064	1.256
20	200	39	10	137.1	45.20	39	14	1.033	1.084	39	17	1.066	1.170	36	18	1.064	1.256
20	300	39	16	137.0	67.77	39	21	1.033	1.085	39	26	1.066	1.170	36	27	1.064	1.257
20	400	39	21	136.9	90.28	39	27	1.034	1.085	39	34	1.067	1.171	36	35	1.065	1.257
20	500	39	26	136.8	112.79	39	34	1.034	1.086	39	43	1.068	1.172	36	44	1.066	1.258
40	10	45	1	211.3	1.91	45	1	1.025	1.076	45	1	1.049	1.160	45	1	1.070	1.246
40	20	48	1	217.9	3.75	45	2	0.994	1.095	45	2	1.017	1.181	45	2	1.038	1.268
40	40	48	2	217.9	7.51	45	3	0.979	1.082	45	3	1.012	1.176	45	4	1.038	1.268
40	60	48	4	217.9	11.26	45	5	0.984	1.086	45	5	1.010	1.174	45	6	1.038	1.268
40	100	48	6	217.9	18.77	45	8	0.982	1.084	45	9	1.010	1.174	45	10	1.038	1.268
40	200	48	13	217.9	37.54	45	15	0.979	1.083	45	17	1.009	1.173	45	19	1.038	1.268
40	300	48	20	217.9	56.31	45	23	0.980	1.083	45	26	1.008	1.173	45	29	1.038	1.268
40	400	48	27	217.9	75.08	45	30	0.980	1.083	45	35	1.008	1.173	45	39	1.038	1.267
40	500	45	32	204.0	93.84	45	38	1.031	1.082	45	43	1.062	1.173	45	49	1.092	1.267
60	10	54	1	290.3	1.73	54	1	1.012	1.074	54	1	1.035	1.164	54	1	1.056	1.257
60	20	57	1	288.4	3.32	57	1	1.032	1.099	57	1	1.068	1.206	54	2	1.063	1.311
60	40	57	2	288.4	6.64	57	2	1.032	1.099	54	3	1.022	1.196	54	3	1.051	1.300
60	60	57	3	288.4	9.96	54	4	0.991	1.096	54	4	1.023	1.198	54	4	1.051	1.300
60	100	57	5	288.4	16.60	54	6	0.994	1.098	54	7	1.023	1.197	54	7	1.051	1.300
60	200	57	9	288.1	33.17	54	13	0.993	1.097	54	15	1.023	1.198	54	14	1.052	1.301
60	300	57	13	288.0	49.74	54	20	0.993	1.097	54	23	1.023	1.198	54	21	1.052	1.301
60	400	57	17	288.0	66.31	54	26	0.993	1.098	54	31	1.023	1.198	54	27	1.052	1.301
60	500	57	21	287.9	82.88	54	33	0.993	1.097	54	39	1.024	1.198	54	36	1.052	1.302
100	10	66	1	409.8	1.49	66	1	1.007	1.081	66	1	1.024	1.177	66	1	1.041	1.278
100	20	66	1	383.9	2.82	66	1	1.034	1.108	66	1	1.070	1.224	66	1	1.106	1.345
100	40	66	2	383.9	5.65	66	2	1.034	1.108	66	3	1.061	1.217	66	3	1.089	1.332
100	60	66	3	383.9	8.47	66	4	1.033	1.107	66	4	1.061	1.217	66	4	1.086	1.329
100	100	66	5	383.9	14.12	66	6	1.031	1.105	66	6	1.061	1.216	66	7	1.087	1.330
100	200	66	10	383.9	28.24	66	12	1.031	1.105	66	12	1.061	1.216	66	13	1.086	1.329
100	300	66	15	383.8	42.34	66	19	1.031	1.105	66	17	1.061	1.217	66	20	1.087	1.330
100	400	66	21	383.3	56.42	66	25	1.032	1.106	66	23	1.062	1.218	66	26	1.087	1.331
100	500	66	26	383.2	70.51	66	32	1.032	1.106	66	29	1.062	1.218	66	33	1.088	1.331
150	10	78	1	550.3	1.34	78	1	1.008	1.092	78	1	1.022	1.195	78	1	1.042	1.308
150	20	84	1	532.3	2.47	84	1	1.036	1.130	84	1	1.073	1.264	84	1	1.111	1.403
150	40	84	2	532.3	4.94	84	2	1.036	1.130	84	2	1.073	1.264	78	3	1.050	1.397
150	60	84	2	531.4	7.40	84	3	1.037	1.132	84	3	1.075	1.266	84	4	1.103	1.396
150	100	84	4	531.1	12.33	84	5	1.038	1.133	84	6	1.073	1.265	78	7	1.051	1.399
150	200	84	9	530.8	24.64	84	9	1.036	1.131	84	11	1.070	1.262	84	13	1.105	1.398
150	300	84	14	530.7	36.95	84	13	1.037	1.132	84	17	1.071	1.263	84	20	1.104	1.397
150	400	84	19	530.7	49.27	84	18	1.036	1.131	84	22	1.070	1.262	84	27	1.105	1.398
150	500	84	24	530.7	61.58	84	22	1.036	1.131	84	28	1.070	1.262	78	31	1.050	1.398
200	10	90	1	687.7	1.23	90	1	1.008	1.103	90	1	1.017	1.210	90	1	1.036	1.331
200	20	90	1	619.2	2.26	90	1	1.033	1.133	96	1	1.122	1.278	90	1	1.120	1.430
200	40	90	2	619.2	4.52	90	2	1.033	1.133	96	2	1.122	1.278	90	3	1.111	1.422
200	60	96	2	643.7	6.69	90	3	0.994	1.147	96	3	1.080	1.294	90	4	1.067	1.439
200	100	96	4	641.6	11.12	96	4	1.043	1.150	90	6	1.035	1.295	90	6	1.070	1.443
200	200	96	8	641.6	22.24	96	8	1.043	1.150	90	12	1.035	1.295	90	12	1.070	1.443
200	300	96	12	641.6	33.36	96	12	1.043	1.150	90	19	1.034	1.294	90	17	1.070	1.443
200	400	96	17	641.1	44.44	96	16	1.044	1.151	90	25	1.035	1.295	90	23	1.071	1.444
200	500	96	21	641.0	55.55	90	26	0.998	1.151	90	31	1.035	1.295	90	28	1.071	1.444
300	10	108	1	920.0	1.10	108	1	1.009	1.118	108	1	1.019	1.239	108	1	1.031	1.368
300	20	108	1	808.1	1.96	114	1	1.078	1.156	114	1	1.119	1.318	114	1	1.172	1.496
300	40	120	1	854.9	3.85	114	2	1.019	1.176	114	2	1.058	1.342	114	2	1.108	1.522
300	60	114	2	825.4	5.75	114	3	1.055	1.180	114	3	1.095	1.346	108	4	1.104	1.523
300	100	120	3	849.5	9.56	114	4	1.021	1.179	114	5	1.064	1.349	114	6	1.106	1.523
300	200	120	6	849.5	19.13	114	8	1.021	1.179	114	10	1.064	1.349	114	12	1.106	1.523
300	300	120	9	849.5	28.69	114	11	1.021	1.179	114	15	1.064	1.349	114	18	1.106	1.523
300	400	114	15	822.8	38.25	114	15	1.053	1.179	114	20	1.099	1.349	114	24	1.142	1.523
300	500	120	14	849.0	47.80	114	19	1.021	1.179	114	24	1.064	1.349	114	30	1.106	1.523
500	10	138	1	1347.2	0.94	138	1	1.011	1.143	138	1	1.021	1.285	138	1	1.032	1.432
500	20	138	1	1147.7	1.64	144	1	1.051	1.173	138	1	1.069	1.366	144	1	1.149	1.569
500	40	150	1	1130.2	3.09	144	2	1.060	1.244	138	2	1.078	1.448	144	2	1.158	1.663
500	60	144	2	1120.7	4.69	144	2	1.059	1.216	138	3	1.090	1.429	144	3	1.171	1.642
500	100	156	2	1165.4	7.75	144	4	1.025	1.230	138	5	1.053	1.442	138	6	1.102	1.656
500	200	150	5	1130.2	15.45	144	7	1.048	1.233	144	9	1.102	1.444	144	11	1.153	1.659
500	300	150	7	1140.3	23.21	144	10	1.045	1.230	144	13	1.098	1.440	144	16	1.153	1.658
500	400	150	10	1138.2	30.90	144	13	1.047	1.232	144	18	1.102	1.444	144	22	1.153	1.659
500	500	150	12	1138.0	38.61	144	16	1.047	1.232	144	22	1.101	1.443	144	27	1.154	1.660
1000	10	192	1	2217.0	0.76	186	1	0.994	1.182	186	1	1.007	1.359	186	1	1.020	1.542
1000	20	192	1	1818.0	1.27	186	1	0.992	1.217	192	1	1.058	1.452	192	1	1.106	1.699
1000	40	192	1	1631.1	2.32	204	1	1.120	1.295	192	2	1.179	1.596	192	2	1.233	1.867
1000	60	204	1	1677.0	3.43	204	2	1.090	1.312	204	2	1.169	1.605	192	3	1.199	1.891
1000	100	204	2	1666.4	5.69	204	3	1.095	1.318	192	4	1.133	1.607	192	5	1.205	1.900
1000	200	204	4	1666.4	11.39	204	5	1.095	1.318	192	8	1.133	1.607	192	10	1.205	1.900
1000	300	204	6	1666.4	17.08	204	8	1.095	1.318	204	11	1.169	1.607	204	14	1.241	1.900
1000	400	204	8	1666.4	22.77	204	10	1.095	1.318	192	16	1.133	1.607	204	19	1.240	1.900
1000	500	216	7	1714.3	28.43	204	13	1.065	1.320	204	18	1.136	1.608	192	26	1.172	1.902

TEXAS WATER DEVELOPMENT BOARD — LOCKWOOD, ANDREWS AND NEWNAM, INC. PROGRAM

COST OF DELIVERING WATER BY PIPELINE - MOST ECONOMICAL DIAMETER

PEAK FACTOR = 1.75 GROWTH RATE = 0.00 INTEREST RATE = 0.040 AMORTIZATION PERIOD = 40YRS PRESENT WORTH FACTOR = 20.19

FLOW MGD	LENGTH MILES	STATIC HEAD	SLOPE = 0 DIA.	NO. PS	C.C. ($/MI	W.C.C.T/TG	STATIC HEAD SLOPE = 4 DIA.	NO. PS	C.C. RATIO	W.C. RATIO	STATIC HEAD SLOPE = 8 DIA.	NO. PS	C.C. RATIO	W.C. RATIO	STATIC HEAD SLOPE = 12 DIA.	NO. PS	C.C. RATIO	W.C. RATIO
2	10		21	1	67.3	5.06	16	1	0.960	1.032	16	1	0.972	1.068	16	1	1.002	1.125
2	20		21	1	64.1	9.28	21	1	1.023	1.053	21	1	1.055	1.114	18	1	1.097	1.201
2	40		21	1	62.5	17.71	21	1	1.072	1.102	21	2	1.082	1.167	18	2	1.125	1.259
2	60		21	1	63.1	26.61	21	2	1.037	1.084	21	3	1.072	1.165	16	4	1.072	1.256
2	100		21	2	62.2	43.86	21	4	1.046	1.096	21	5	1.087	1.178	18	6	1.119	1.268
2	200		21	4	62.2	87.72	21	7	1.047	1.092	21	11	1.081	1.177	18	12	1.119	1.268
2	300		21	6	62.2	131.58	21	11	1.043	1.090	21	16	1.081	1.175	18	19	1.115	1.268
2	400		21	8	62.2	175.45	21	15	1.044	1.092	21	21	1.083	1.176	18	25	1.116	1.268
2	500		21	10	62.2	219.31	21	18	1.044	1.090	21	27	1.080	1.175	18	31	1.117	1.268
5	10		24	1	85.9	2.75	24	1	0.998	1.035	24	1	1.000	1.086	24	1	1.032	1.168
5	20		24	1	82.3	5.14	24	1	1.034	1.069	24	2	1.043	1.161	24	2	1.077	1.249
5	40		24	2	82.3	10.28	24	2	1.034	1.069	24	3	1.046	1.148	24	3	1.084	1.238
5	60		27	2	86.9	15.29	24	3	0.980	1.078	24	4	0.995	1.156	24	4	1.040	1.241
5	100		27	3	87.0	25.45	24	6	0.971	1.078	24	7	0.992	1.157	24	6	1.051	1.253
5	200		27	6	87.0	50.91	24	11	0.974	1.078	24	13	0.994	1.156	24	13	1.042	1.245
5	300		27	9	87.0	76.36	24	16	0.975	1.078	24	19	0.995	1.156	24	20	1.038	1.242
5	400		27	13	86.8	101.76	24	21	0.978	1.078	24	23	1.009	1.158	24	27	1.039	1.241
5	500		27	16	86.7	127.09	24	26	0.979	1.079	24	29	1.008	1.158	24	34	1.039	1.241
10	10		33	1	120.1	1.90	33	1	0.992	1.055	33	1	0.988	1.125	33	1	1.002	1.194
10	20		33	1	112.9	3.55	33	1	1.023	1.088	33	1	1.054	1.189	33	2	1.065	1.277
10	40		33	2	112.9	7.09	33	2	1.023	1.088	33	3	1.033	1.171	33	4	1.065	1.277
10	60		33	3	112.9	10.64	33	4	1.020	1.085	33	5	1.036	1.174	33	5	1.065	1.277
10	100		33	4	112.4	17.66	33	6	1.018	1.084	33	8	1.038	1.176	33	9	1.067	1.280
10	200		33	9	112.2	35.27	33	12	1.019	1.086	33	15	1.039	1.178	33	19	1.068	1.281
10	300		33	13	112.0	52.80	33	18	1.022	1.088	33	23	1.040	1.179	33	28	1.070	1.283
10	400		33	17	112.0	70.40	33	24	1.022	1.088	33	31	1.040	1.178	33	38	1.070	1.283
10	500		33	21	112.0	88.06	33	30	1.021	1.087	33	39	1.039	1.178	33	47	1.069	1.282
20	10		42	1	176.1	1.46	39	1	0.882	1.063	39	1	0.878	1.148	42	1	0.988	1.256
20	20		42	1	163.1	2.74	42	1	1.024	1.106	39	2	0.949	1.222	42	2	1.067	1.337
20	40		42	2	163.1	5.49	42	2	1.024	1.106	42	3	1.037	1.212	42	4	1.067	1.337
20	60		42	3	163.1	8.23	42	4	1.020	1.102	42	5	1.036	1.211	42	6	1.067	1.337
20	100		42	5	163.1	13.72	42	6	1.019	1.102	42	8	1.035	1.210	42	9	1.067	1.337
20	200		42	9	162.7	27.40	42	13	1.020	1.102	42	16	1.037	1.212	42	19	1.069	1.339
20	300		42	14	162.5	41.05	42	19	1.021	1.104	42	24	1.039	1.214	42	29	1.071	1.341
20	400		42	19	162.4	54.72	42	26	1.021	1.104	42	33	1.039	1.214	42	39	1.071	1.341
20	500		42	24	162.5	68.44	42	32	1.021	1.103	42	41	1.038	1.213	42	49	1.070	1.340
40	10		57	1	307.4	1.25	54	1	0.918	1.081	54	1	0.906	1.175	54	1	0.916	1.295
40	20		57	1	281.3	2.33	57	1	1.001	1.108	57	1	1.019	1.237	57	1	1.056	1.386
40	40		57	1	290.5	4.58	57	2	0.969	1.126	57	2	0.986	1.257	57	3	1.015	1.403
40	60		57	2	275.2	6.85	57	3	1.023	1.128	57	3	1.041	1.259	57	4	1.069	1.403
40	100		57	3	290.1	11.43	57	5	0.971	1.128	57	5	0.988	1.258	57	6	1.013	1.401
40	200		57	7	274.9	22.83	57	10	1.024	1.129	57	10	1.042	1.260	57	12	1.068	1.403
40	300		57	11	274.6	34.22	57	16	1.025	1.130	57	15	1.043	1.261	57	18	1.069	1.404
40	400		57	15	274.7	45.63	57	21	1.025	1.129	57	20	1.043	1.261	57	24	1.069	1.404
40	500		60	14	289.3	57.01	57	27	0.973	1.130	57	24	0.990	1.261	57	30	1.015	1.404
60	10		66	1	404.0	1.13	66	1	0.974	1.089	66	1	0.958	1.194	66	1	0.967	1.324
60	20		66	1	364.9	2.08	66	1	1.000	1.119	66	1	1.016	1.260	66	1	1.055	1.424
60	40		72	1	389.8	4.07	66	2	0.936	1.145	66	2	0.951	1.288	66	3	0.983	1.452
60	60		66	2	356.3	6.12	66	3	1.024	1.141	66	3	1.040	1.283	66	4	1.071	1.443
60	100		66	3	350.6	10.22	66	4	1.022	1.139	66	5	1.039	1.282	66	6	1.067	1.440
60	200		72	5	389.8	20.34	66	8	0.936	1.145	66	10	0.951	1.288	66	12	0.977	1.447
60	300		72	7	389.8	30.51	66	12	0.936	1.145	66	15	0.951	1.288	66	18	0.977	1.447
60	400		72	10	389.8	40.67	66	15	0.936	1.145	66	20	0.951	1.288	66	24	0.977	1.447
60	500		72	12	389.8	50.77	66	19	0.937	1.146	66	25	0.953	1.290	66	30	0.978	1.449
100	10		84	1	599.6	0.98	84	1	0.966	1.105	84	1	0.944	1.222	84	1	0.950	1.369
100	20		84	1	533.0	1.78	84	1	0.984	1.133	84	1	0.999	1.296	84	1	1.033	1.480
100	40		90	1	540.7	3.42	84	2	0.961	1.178	84	2	0.976	1.347	84	3	1.009	1.538
100	60		90	1	547.1	5.14	84	2	0.957	1.174	84	3	0.974	1.344	84	4	1.004	1.532
100	100		90	2	540.2	8.47	84	4	0.967	1.184	84	6	0.986	1.358	84	6	1.014	1.547
100	200		90	4	540.2	16.94	84	9	0.965	1.183	84	12	0.986	1.358	84	11	1.013	1.545
100	300		90	6	540.2	25.42	84	14	0.964	1.182	84	19	0.986	1.358	84	17	1.013	1.546
100	400		90	8	540.2	33.89	84	18	0.965	1.183	84	25	0.986	1.358	84	22	1.013	1.545
100	500		90	10	540.2	42.36	84	23	0.965	1.182	84	32	0.986	1.358	84	27	1.013	1.545
150	10		102	1	817.2	0.87	102	1	0.963	1.122	96	1	0.879	1.255	96	1	0.885	1.419
150	20		102	1	717.4	1.56	102	1	0.982	1.156	102	1	0.989	1.334	102	1	1.023	1.539
150	40		102	1	667.5	2.94	102	2	1.056	1.227	102	2	1.063	1.416	102	2	1.099	1.634
150	60		108	1	703.7	4.40	102	2	0.987	1.217	102	3	1.009	1.420	102	3	1.043	1.638
150	100		108	2	708.5	7.36	102	4	0.977	1.208	102	5	1.005	1.415	102	5	1.038	1.632
150	200		102	5	667.5	14.71	102	8	1.034	1.209	102	11	1.062	1.415	102	10	1.099	1.634
150	300		102	7	664.8	22.00	102	12	1.038	1.213	102	17	1.066	1.419	102	15	1.104	1.639
150	400		108	7	701.5	29.27	102	16	0.984	1.216	102	23	1.010	1.422	102	21	1.046	1.642
150	500		108	9	702.5	36.64	102	20	0.982	1.214	102	29	1.008	1.420	102	26	1.044	1.640
200	10		114	1	967.9	0.80	114	1	0.959	1.133	114	1	0.932	1.278	114	1	0.939	1.457
200	20		114	1	854.9	1.42	114	1	0.980	1.172	120	1	1.031	1.366	114	1	1.021	1.590
200	40		114	1	788.4	2.66	120	1	1.101	1.241	120	2	1.119	1.458	114	2	1.107	1.698
200	60		120	1	821.1	3.93	120	2	1.042	1.245	120	3	1.074	1.478	114	3	1.063	1.721
200	100		120	2	823.7	6.57	114	4	0.992	1.244	120	5	1.070	1.474	114	5	1.059	1.716
200	200		120	4	823.7	13.15	120	7	1.037	1.240	120	10	1.070	1.474	114	10	1.059	1.716
200	300		120	5	821.1	19.67	120	10	1.042	1.245	114	17	1.026	1.478	114	15	1.063	1.721
200	400		120	7	817.4	26.12	120	14	1.045	1.248	120	21	1.078	1.483	114	20	1.068	1.728
200	500		120	9	818.4	32.69	120	17	1.045	1.248	120	26	1.076	1.481	114	25	1.066	1.726
300	10		138	1	1327.2	0.71	138	1	0.955	1.155	138	1	0.924	1.320	138	1	0.932	1.523
300	20		138	1	1127.8	1.23	138	1	0.978	1.203	144	1	1.007	1.417	138	1	1.014	1.679
300	40		138	1	1027.9	2.28	144	1	1.078	1.269	144	2	1.105	1.529	138	2	1.113	1.811
300	60		144	1	1043.2	3.33	144	2	1.051	1.293	144	3	1.089	1.568	138	3	1.097	1.858
300	100		150	1	1115.1	5.59	144	3	0.984	1.286	144	5	1.019	1.559	138	5	1.026	1.847
300	200		144	3	1030.5	11.05	144	6	1.059	1.301	144	10	1.096	1.577	138	10	1.104	1.869
300	300		150	4	1078.8	16.66	144	10	1.016	1.294	144	15	1.053	1.569	138	14	1.060	1.859
300	400		144	6	1030.5	22.11	144	13	1.055	1.298	144	20	1.096	1.577	138	19	1.102	1.867
300	500		150	6	1073.8	27.65	144	16	1.018	1.297	144	24	1.058	1.576	138	24	1.065	1.866
500	10		180	1	1951.3	0.60	174	1	0.924	1.187	174	1	0.890	1.382	174	1	0.898	1.621
500	20		180	1	1618.9	1.02	174	1	0.944	1.251	174	1	0.929	1.503	180	1	1.002	1.815
500	40		180	1	1452.8	1.86	186	1	1.043	1.317	174	2	1.035	1.649	180	2	1.117	1.991
500	60		180	1	1397.2	2.70	174	2	1.029	1.364	180	2	1.106	1.702	180	3	1.161	2.058
500	100		186	1	1415.7	4.44	180	3	1.037	1.374	180	4	1.089	1.724	180	5	1.146	2.087
500	200		186	2	1415.7	8.87	180	6	1.037	1.374	180	9	1.088	1.723	174	9	1.111	2.083
500	300		186	3	1415.7	13.31	180	9	1.037	1.374	180	14	1.087	1.723	180	13	1.142	2.083
500	400		186	5	1371.6	17.72	180	12	1.070	1.376	180	18	1.123	1.725	174	18	1.146	2.086
500	500		186	6	1415.0	22.18	180	15	1.037	1.374	180	23	1.088	1.723	180	22	1.143	2.084
1000	10		252	1	3234.0	0.49	240	1	0.908	1.237	240	1	0.867	1.479	240	1	0.877	1.774
1000	20		252	1	2568.9	0.79	240	1	0.930	1.331	240	1	0.910	1.656	240	1	0.951	2.044
1000	40		252	1	2235.3	1.40	252	1	0.994	1.402	252	1	1.077	1.862	240	2	1.093	2.307
1000	60		252	1	2125.5	2.01	252	1	1.065	1.482	252	2	1.113	1.928	240	3	1.150	2.411
1000	100		252	1	2038.8	3.23	252	2	1.100	1.528	252	3	1.160	1.999	252	4	1.230	2.488
1000	200		252	2	2038.8	6.47	252	5	1.091	1.520	252	6	1.160	1.999	252	8	1.230	2.480
1000	300		264	2	2090.3	9.61	252	7	1.066	1.537	252	9	1.130	2.018	252	12	1.198	2.512
1000	400		264	3	2101.8	12.88	252	10	1.057	1.527	252	12	1.124	2.008	252	16	1.192	2.500
1000	500		252	4	2027.4	16.11	252	13	1.097	1.526	252	15	1.166	2.007	240	21	1.191	2.498

TEXAS WATER DEVELOPMENT BOARD — LOCKWOOD, ANDREWS AND NEWNAM, INC. PROGRAM
COST OF DELIVERING WATER BY PIPELINE - MOST ECONOMICAL DIAMETER
PEAK FACTOR = 1.75 GROWTH RATE = 0.10 INTEREST RATE = 0.040 AMORTIZATION PERIOD = 40YRS PRESENT WORTH FACTOR = 15.78

FLOW MGD	LENGTH MILES	STATIC HEAD SLOPE = 0 DIA.	NO. PS	C.C.Ts/MI	W.C.CT/TG	STATIC HEAD SLOPE = 4 DIA.	NO. PS	C.C.RATIO	W.C.RATIO	STATIC HEAD SLOPE = 8 DIA.	NO. PS	C.C.RATIO	W.C.RATIO	STATIC HEAD SLOPE = 12 DIA.	NO. PS	C.C.RATIO	W.C.RATIO
2	10	16	1	64.0	6.22	16	1	1.009	1.023	16	1	1.021	1.056	16	1	1.053	1.109
2	20	21	1	64.1	11.63	16	1	0.993	1.049	21	1	1.055	1.106	18	1	1.097	1.183
2	40	21	1	62.5	22.36	16	2	1.018	1.091	16	3	1.031	1.146	16	3	1.078	1.218
2	60	21	1	63.1	33.66	21	2	1.037	1.075	16	4	1.027	1.141	16	4	1.072	1.212
2	100	21	2	62.2	55.44	21	4	1.046	1.086	16	7	1.040	1.155	16	7	1.086	1.227
2	200	21	4	62.2	110.87	21	7	1.047	1.084	16	15	1.037	1.155	16	14	1.086	1.227
2	300	21	6	62.2	166.31	21	11	1.043	1.081	16	23	1.035	1.155	16	20	1.087	1.226
2	400	21	8	62.2	221.74	21	15	1.044	1.082	16	30	1.037	1.155	16	27	1.087	1.226
2	500	21	10	62.2	277.18	21	18	1.044	1.082	16	38	1.036	1.155	16	34	1.087	1.226
5	10	24	1	85.9	3.34	24	1	0.998	1.032	24	1	1.000	1.076	24	1	1.032	1.150
5	20	24	1	82.3	6.30	24	1	1.034	1.066	24	2	1.043	1.143	24	2	1.077	1.221
5	40	24	2	82.3	12.60	24	3	1.017	1.063	24	3	1.046	1.133	24	3	1.084	1.215
5	60	24	3	82.3	18.90	24	4	1.022	1.063	24	4	1.050	1.133	24	4	1.098	1.209
5	100	24	6	81.8	31.47	24	7	1.026	1.064	24	7	1.055	1.134	24	8	1.089	1.217
5	200	24	11	81.9	62.88	24	15	1.022	1.064	24	13	1.056	1.135	24	13	1.106	1.214
5	300	24	17	81.8	94.26	24	22	1.024	1.065	24	19	1.058	1.135	24	20	1.104	1.212
5	400	24	23	81.8	125.65	24	30	1.024	1.065	24	23	1.071	1.138	24	27	1.103	1.211
5	500	24	29	81.7	157.03	24	38	1.024	1.066	24	29	1.070	1.137	24	34	1.103	1.210
10	10	30	1	112.4	2.29	30	1	0.990	1.043	30	1	0.992	1.101	33	1	1.071	1.176
10	20	33	1	112.9	4.34	33	1	1.023	1.078	30	2	0.987	1.162	33	2	1.065	1.241
10	40	33	2	112.9	8.68	33	2	1.023	1.078	33	3	1.033	1.148	33	4	1.065	1.241
10	60	33	3	112.9	13.02	33	4	1.020	1.075	33	5	1.036	1.151	33	5	1.065	1.241
10	100	33	4	112.4	21.61	33	6	1.018	1.074	33	8	1.038	1.153	33	9	1.067	1.244
10	200	33	9	112.2	43.15	33	12	1.019	1.075	33	15	1.039	1.155	33	19	1.068	1.245
10	300	33	13	112.0	64.60	33	18	1.022	1.077	33	23	1.040	1.156	33	28	1.070	1.247
10	400	33	17	116.0	86.13	33	24	1.022	1.077	33	31	1.040	1.155	33	38	1.070	1.247
10	500	33	21	112.0	107.74	33	30	1.021	1.077	33	39	1.039	1.155	33	47	1.069	1.246
20	10	39	1	158.2	1.72	39	1	0.982	1.050	39	1	0.978	1.122	39	1	1.006	1.225
20	20	42	1	163.1	3.29	39	1	0.950	1.092	39	2	0.949	1.169	39	2	0.976	1.277
20	40	42	2	163.1	6.59	39	3	0.936	1.080	39	3	0.947	1.168	39	4	0.976	1.277
20	60	42	3	163.1	9.88	39	4	0.935	1.079	39	5	0.947	1.168	39	5	0.973	1.274
20	100	42	5	163.1	16.47	39	6	0.935	1.079	39	7	0.946	1.168	39	8	0.974	1.275
20	200	42	9	162.7	32.88	39	12	0.937	1.081	39	14	0.948	1.170	39	17	0.975	1.277
20	300	42	14	162.5	49.26	39	18	0.938	1.082	39	21	0.950	1.171	39	25	0.976	1.278
20	400	42	19	162.4	65.65	39	24	0.939	1.083	39	28	0.950	1.172	39	33	0.976	1.278
20	500	42	24	162.5	82.12	39	30	0.938	1.082	39	35	0.949	1.171	39	41	0.975	1.277
40	10	54	1	288.8	1.50	54	1	0.978	1.062	51	1	0.904	1.139	54	1	0.975	1.241
40	20	54	1	262.7	2.77	54	1	1.016	1.101	54	1	1.037	1.214	54	2	1.072	1.343
40	40	57	1	276.5	5.53	54	2	0.965	1.101	54	3	0.983	1.213	54	3	1.007	1.334
40	60	57	2	275.2	8.26	54	3	0.970	1.106	54	4	0.985	1.215	54	4	1.009	1.337
40	100	57	3	275.7	13.78	54	5	0.968	1.104	54	6	0.982	1.212	54	7	1.008	1.335
40	200	57	7	274.9	27.50	54	9	0.969	1.106	54	12	0.984	1.215	54	14	1.011	1.338
40	300	57	11	274.6	41.21	54	14	0.971	1.107	54	17	0.984	1.215	54	20	1.011	1.339
40	400	57	15	274.7	54.97	54	18	0.970	1.106	54	23	0.984	1.215	54	27	1.010	1.338
40	500	57	18	274.7	68.71	54	23	0.970	1.106	54	28	0.984	1.215	54	34	1.010	1.338
60	10	66	1	404.0	1.36	60	1	0.870	1.063	60	1	0.853	1.145	60	1	0.871	1.262
60	20	66	1	304.9	2.49	66	1	1.000	1.102	66	1	1.016	1.223	66	1	1.055	1.368
60	40	66	1	356.1	4.89	66	2	1.019	1.120	66	2	1.035	1.243	60	3	0.962	1.382
60	60	66	2	356.3	7.31	66	3	1.024	1.125	66	3	1.040	1.248	66	4	1.071	1.388
60	100	66	3	356.0	12.19	66	4	1.022	1.123	66	5	1.039	1.247	66	6	1.067	1.384
60	200	66	7	356.1	24.35	66	8	1.024	1.125	66	10	1.041	1.249	66	12	1.069	1.386
60	300	66	11	355.9	36.51	66	12	1.025	1.126	66	15	1.042	1.249	66	18	1.070	1.387
60	400	66	15	355.8	48.66	66	15	1.025	1.126	66	20	1.042	1.250	66	24	1.070	1.387
60	500	66	19	355.7	60.82	66	19	1.025	1.126	66	25	1.042	1.250	66	30	1.070	1.387
100	10	78	1	554.8	1.18	78	1	0.963	1.076	78	1	0.939	1.168	78	1	0.945	1.291
100	20	78	1	488.3	2.12	84	1	1.074	1.118	78	1	1.014	1.254	78	1	1.052	1.414
100	40	84	1	500.6	4.11	84	2	1.031	1.155	78	2	0.973	1.295	78	3	1.007	1.458
100	60	84	2	510.9	6.18	84	2	1.025	1.150	78	3	0.970	1.291	78	4	0.996	1.448
100	100	84	3	500.4	10.23	84	4	1.031	1.156	78	5	0.978	1.300	78	6	1.006	1.460
100	200	84	6	500.4	20.46	84	9	1.029	1.154	78	11	0.976	1.299	78	13	1.004	1.458
100	300	84	9	500.4	30.68	84	14	1.029	1.154	78	16	0.975	1.298	78	19	1.003	1.457
100	400	84	12	500.4	40.91	84	18	1.029	1.154	78	21	0.975	1.298	78	26	1.004	1.458
100	500	84	15	500.4	51.14	84	23	1.029	1.154	78	26	0.975	1.298	78	32	1.003	1.457
150	10	96	1	708.9	1.05	96	1	0.961	1.091	96	1	0.934	1.196	96	1	0.941	1.334
150	20	96	1	669.2	1.87	96	1	0.981	1.124	96	1	1.000	1.283	96	1	1.039	1.464
150	40	102	1	667.5	3.55	96	2	0.983	1.182	96	2	1.002	1.349	96	2	1.042	1.540
150	60	96	2	633.9	5.37	96	2	1.031	1.171	96	3	1.052	1.338	96	4	1.091	1.525
150	100	102	2	671.2	8.92	96	4	0.977	1.175	96	5	0.997	1.343	96	6	1.029	1.527
150	200	102	5	667.3	17.75	96	7	0.982	1.181	96	9	1.001	1.348	96	11	1.034	1.533
150	300	102	7	664.8	26.52	96	10	0.986	1.185	96	14	1.006	1.353	96	17	1.037	1.537
150	400	102	9	666.4	35.44	96	14	0.984	1.183	96	18	1.003	1.350	96	23	1.035	1.535
150	500	102	12	663.6	44.25	96	17	0.985	1.184	96	23	1.004	1.351	96	28	1.036	1.536
200	10	108	1	940.2	0.97	108	1	0.957	1.100	108	1	0.928	1.214	108	1	0.936	1.364
200	20	108	1	807.2	1.70	108	1	0.979	1.137	108	1	0.996	1.308	114	1	1.081	1.503
200	40	114	1	788.4	3.19	108	2	1.002	1.214	108	2	1.020	1.397	114	2	1.107	1.605
200	60	120	1	821.1	4.79	114	2	1.000	1.204	108	3	0.979	1.394	114	3	1.063	1.602
200	100	114	2	790.3	7.99	114	4	1.034	1.199	108	5	1.017	1.394	108	6	1.055	1.600
200	200	114	5	788.4	15.94	114	8	1.037	1.201	108	9	1.018	1.395	108	11	1.054	1.600
200	300	114	7	784.0	23.80	114	12	1.042	1.207	108	13	1.024	1.402	108	17	1.061	1.609
200	400	114	9	784.5	31.75	114	16	1.042	1.207	108	18	1.023	1.401	108	22	1.059	1.607
200	500	114	11	785.7	39.73	114	20	1.040	1.205	108	22	1.021	1.399	108	28	1.058	1.605
300	10	132	1	1279.4	0.86	132	1	0.953	1.117	132	1	0.921	1.247	132	1	0.929	1.416
300	20	132	1	1079.8	1.48	132	1	0.977	1.163	132	1	0.982	1.349	132	1	1.020	1.588
300	40	132	1	986.1	2.73	138	1	1.091	1.242	132	2	1.082	1.463	132	2	1.123	1.701
300	60	144	1	1043.2	4.06	138	2	1.016	1.245	132	3	1.016	1.477	132	3	1.055	1.717
300	100	138	2	1007.9	6.75	132	4	1.017	1.252	132	4	1.050	1.479	132	5	1.092	1.722
300	200	144	3	1030.5	13.46	138	7	1.021	1.251	132	8	1.021	1.483	132	10	1.062	1.727
300	300	138	6	1007.9	20.24	138	11	1.050	1.248	132	12	1.050	1.479	132	15	1.092	1.722
300	400	144	8	1030.5	26.91	138	14	1.021	1.251	132	16	1.021	1.483	132	20	1.062	1.727
300	500	138	9	1006.1	33.69	138	18	1.050	1.248	132	20	1.051	1.481	132	25	1.094	1.724
500	10	168	1	1855.4	0.73	168	1	0.946	1.141	168	1	0.910	1.293	168	1	0.919	1.491
500	20	168	1	1562.9	1.24	168	1	0.972	1.200	174	1	0.987	1.410	168	1	1.008	1.674
500	40	168	1	1356.6	2.24	174	1	1.065	1.277	174	2	1.108	1.555	168	2	1.131	1.846
500	60	174	1	1340.9	3.25	174	2	1.066	1.315	174	2	1.113	1.605	168	3	1.138	1.907
500	100	180	1	1415.7	5.43	174	3	1.015	1.311	168	4	1.032	1.601	168	5	1.084	1.903
500	200	174	3	1339.4	10.78	174	6	1.072	1.322	168	7	1.090	1.613	174	9	1.174	1.919
500	300	180	4	1375.0	16.17	174	9	1.045	1.322	168	11	1.062	1.612	168	14	1.113	1.915
500	400	180	5	1371.0	21.52	174	13	1.045	1.323	168	15	1.065	1.616	168	19	1.116	1.920
500	500	180	6	1377.8	27.00	174	16	1.040	1.317	168	18	1.059	1.609	168	24	1.112	1.913
1000	10	240	1	3137.3	0.60	228	1	0.905	1.177	228	1	0.863	1.365	228	1	0.874	1.607
1000	20	240	1	2476.2	0.96	228	1	0.928	1.261	228	1	0.907	1.524	228	1	0.953	1.853
1000	40	240	1	2139.6	1.70	240	1	1.007	1.341	228	2	1.048	1.731	228	2	1.102	2.105
1000	60	240	1	2020.8	2.43	228	2	1.040	1.423	228	2	1.081	1.792	228	3	1.162	2.205
1000	100	252	1	2030.8	3.95	240	2	1.062	1.447	240	3	1.118	1.841	240	4	1.190	2.258
1000	200	252	2	2030.8	7.89	240	5	1.058	1.443	240	6	1.118	1.841	228	9	1.147	2.256
1000	300	252	3	2030.8	11.84	240	8	1.057	1.442	228	10	1.076	1.841	228	13	1.146	2.256
1000	400	252	4	2030.8	15.78	240	11	1.056	1.442	228	13	1.076	1.840	240	17	1.186	2.255
1000	500	252	4	2027.4	19.65	240	14	1.061	1.447	240	16	1.122	1.848	240	21	1.191	2.264

TEXAS WATER DEVELOPMENT BOARD — LOCKWOOD, ANDREWS AND NEWNAM, INC. PROGRAM

COST OF DELIVERING WATER BY PIPELINE - MOST ECONOMICAL DIAMETER

PEAK FACTOR = 1.75 GROWTH RATE = 0.06 INTEREST RATE = 0.040 AMORTIZATION PERIOD = 40YRS PRESENT WORTH FACTOR = 13.41

						STATIC HEAD SLOPE = 0				STATIC HEAD SLOPE = 4				STATIC HEAD SLOPE = 8				STATIC HEAD SLOPE = 12	
MGD	MILES	DIA.NO.PS	C.C.FT/MI	W.C.CT/FT	DIA.NO.PS	C.C.RATIO	W.C.RATIO	DIA.NO.PS	C.C.RATIO	W.C.RATIO	DIA.NO.PS	C.C.RATIO	W.C.RATIO	DIA.NO.PS	C.C.RATIO	W.C.RATIO
2	10	16	1	64.0	7.14	16	1	1.009	1.024	16	1	1.021	1.055	16	1	1.053	1.106
2	20	16	1	81.4	13.42	16	1	1.036	1.049	18	1	1.091	1.109	16	2	1.098	1.177
2	40	21	1	82.5	26.13	16	2	1.018	1.077	16	3	1.031	1.125	16	3	1.078	1.194
2	60	21	1	83.1	39.40	16	4	0.996	1.068	16	4	1.027	1.121	16	4	1.072	1.188
2	100	21	2	82.2	64.84	21	4	1.046	1.080	16	7	1.040	1.134	16	7	1.086	1.203
2	200	21	4	82.2	129.69	21	7	1.047	1.079	16	15	1.037	1.134	16	14	1.086	1.203
2	300	21	6	82.2	194.53	21	11	1.043	1.076	16	23	1.035	1.133	16	20	1.087	1.203
2	400	21	8	82.2	259.38	21	15	1.044	1.077	16	31	1.035	1.133	16	27	1.087	1.203
2	500	21	10	82.2	324.22	21	18	1.044	1.077	16	38	1.036	1.134	16	34	1.087	1.203
5	10	24	1	85.9	3.83	24	1	0.998	1.030	24	1	1.000	1.070	24	1	1.032	1.139
5	20	24	1	82.3	7.25	24	1	1.034	1.065	24	2	1.043	1.131	24	2	1.077	1.205
5	40	24	2	82.3	14.50	24	3	1.017	1.058	24	3	1.046	1.124	24	3	1.084	1.201
5	60	24	3	82.3	21.75	24	4	1.022	1.060	24	5	1.042	1.124	24	4	1.098	1.197
5	100	24	6	81.8	36.18	24	7	1.026	1.061	24	9	1.045	1.126	24	8	1.089	1.204
5	200	24	11	81.9	72.32	24	15	1.022	1.061	24	18	1.044	1.126	24	13	1.106	1.203
5	300	24	17	81.8	108.39	24	22	1.024	1.062	24	28	1.044	1.127	24	20	1.104	1.201
5	400	24	23	81.8	144.47	24	30	1.024	1.062	24	23	1.071	1.131	24	27	1.103	1.199
5	500	24	29	81.7	180.54	24	38	1.024	1.062	24	29	1.070	1.130	24	34	1.103	1.199
10	10	30	1	112.4	2.80	30	1	0.990	1.038	30	1	0.992	1.090	30	1	1.021	1.169
10	20	33	1	112.9	4.99	33	1	1.023	1.072	30	2	0.987	1.135	30	2	1.016	1.218
10	40	33	2	112.9	9.98	33	2	1.023	1.072	33	3	1.033	1.135	30	4	1.016	1.218
10	60	33	3	112.9	14.97	33	4	1.020	1.069	30	6	0.987	1.135	30	7	1.016	1.217
10	100	33	4	112.4	24.84	33	6	1.018	1.067	33	8	1.038	1.140	30	12	1.020	1.223
10	200	33	9	112.2	49.60	33	12	1.019	1.069	30	21	0.992	1.141	33	19	1.068	1.223
10	300	33	13	112.0	74.26	33	18	1.022	1.071	33	23	1.040	1.142	33	28	1.070	1.226
10	400	33	17	112.0	99.01	33	24	1.022	1.071	33	31	1.040	1.142	33	38	1.070	1.226
10	500	33	21	112.0	123.85	33	30	1.021	1.071	33	39	1.039	1.142	33	47	1.069	1.225
20	10	39	1	150.2	1.92	39	1	0.982	1.044	39	1	0.978	1.108	39	1	1.006	1.204
20	20	39	1	150.4	3.69	39	1	1.030	1.087	39	2	1.029	1.157	39	2	1.059	1.257
20	40	39	2	150.4	7.37	39	3	1.015	1.074	39	3	1.027	1.155	39	4	1.059	1.257
20	60	39	3	150.4	11.06	39	4	1.015	1.074	39	5	1.027	1.156	39	5	1.055	1.253
20	100	39	5	150.4	18.43	39	6	1.014	1.073	39	7	1.026	1.155	39	8	1.056	1.254
20	200	39	10	150.4	36.87	39	12	1.014	1.073	39	14	1.026	1.155	39	17	1.055	1.254
20	300	39	15	150.4	55.30	39	18	1.014	1.073	39	21	1.026	1.155	39	25	1.055	1.253
20	400	39	19	150.3	73.73	39	24	1.014	1.073	39	28	1.027	1.155	39	33	1.055	1.253
20	500	39	24	150.3	92.17	39	30	1.014	1.073	39	35	1.026	1.155	39	41	1.055	1.253
40	10	51	1	211.3	1.68	51	1	0.976	1.048	51	1	0.962	1.115	51	1	0.985	1.217
40	20	54	1	206.7	3.12	54	1	1.016	1.093	54	1	1.037	1.197	51	2	1.017	1.311
40	40	54	2	206.7	6.23	54	2	1.016	1.093	51	3	0.980	1.190	51	3	1.006	1.301
40	60	54	2	206.9	9.33	54	3	1.019	1.096	51	4	0.980	1.191	51	5	1.009	1.305
40	100	54	4	206.1	15.56	54	5	1.018	1.095	51	7	0.979	1.190	51	8	1.006	1.302
40	200	54	7	206.9	31.10	54	9	1.018	1.095	51	14	0.980	1.191	51	16	1.007	1.303
40	300	54	10	206.9	46.63	54	14	1.018	1.095	51	20	0.980	1.191	51	24	1.007	1.303
40	400	54	14	206.9	62.19	54	18	1.018	1.095	51	27	0.979	1.190	51	32	1.007	1.303
40	500	54	17	206.9	77.73	54	23	1.018	1.095	51	34	0.979	1.190	51	40	1.007	1.303
60	10	60	1	306.1	1.91	60	1	0.971	1.053	60	1	0.952	1.125	60	1	0.972	1.233
60	20	60	1	326.8	2.79	60	1	1.008	1.090	60	1	1.024	1.197	60	1	1.062	1.326
60	40	60	1	350.1	5.55	60	2	0.925	1.098	60	2	0.940	1.206	60	3	0.962	1.326
60	60	60	2	350.3	8.29	60	3	0.930	1.103	60	4	0.940	1.207	60	4	0.968	1.332
60	100	60	3	350.8	13.82	60	5	0.929	1.102	60	6	0.940	1.207	60	7	0.967	1.330
60	200	60	7	350.1	27.60	60	11	0.929	1.103	60	13	0.940	1.207	60	15	0.968	1.332
60	300	60	11	350.9	41.38	60	16	0.929	1.103	60	19	0.941	1.209	60	23	0.968	1.333
60	400	60	15	350.8	55.16	60	21	0.930	1.104	60	26	0.941	1.208	60	30	0.969	1.333
60	500	60	19	350.7	68.94	60	27	0.929	1.103	60	33	0.941	1.209	60	38	0.969	1.333
100	10	78	1	504.6	1.32	78	1	0.963	1.064	78	1	0.939	1.144	78	1	0.945	1.254
100	20	78	1	488.3	2.38	78	1	1.002	1.108	78	1	1.014	1.231	78	1	1.052	1.379
100	40	84	1	506.6	4.67	78	2	0.961	1.127	78	2	0.973	1.252	78	3	1.007	1.400
100	60	78	2	476.4	7.01	78	3	1.022	1.127	78	3	1.035	1.252	78	4	1.064	1.395
100	100	84	3	506.4	11.63	78	4	0.962	1.129	78	5	0.978	1.257	78	6	1.006	1.401
100	200	84	5	506.4	23.26	78	8	0.962	1.129	78	11	0.976	1.256	78	13	1.004	1.399
100	300	84	7	506.4	34.90	78	13	0.962	1.129	78	16	0.975	1.255	78	19	1.003	1.399
100	400	84	12	506.4	46.53	78	17	0.962	1.129	78	21	0.975	1.255	78	26	1.004	1.399
100	500	84	15	506.4	58.16	78	21	0.962	1.128	78	26	0.975	1.255	78	32	1.003	1.399
150	10	90	1	722.6	1.18	90	1	0.958	1.071	90	1	0.930	1.160	90	1	0.937	1.283
150	20	90	1	622.4	2.10	96	1	1.055	1.115	96	1	1.075	1.259	90	1	1.055	1.423
150	40	96	1	637.3	4.04	96	2	1.029	1.156	96	2	1.049	1.306	90	2	1.029	1.476
150	60	96	2	638.9	6.05	96	2	1.031	1.158	96	3	1.052	1.309	90	4	1.025	1.473
150	100	96	3	638.3	10.07	96	4	1.032	1.159	96	5	1.053	1.310	90	6	1.027	1.476
150	200	96	6	638.3	20.14	96	7	1.032	1.159	90	11	0.992	1.308	90	13	1.024	1.473
150	300	96	9	638.3	30.21	96	10	1.032	1.159	90	16	0.991	1.307	90	19	1.025	1.474
150	400	96	13	638.3	40.23	96	14	1.034	1.161	90	22	0.994	1.310	90	26	1.026	1.475
150	500	96	16	638.3	50.29	96	17	1.034	1.160	90	27	0.993	1.309	90	32	1.027	1.476
200	10	108	1	940.2	1.09	102	1	0.908	1.079	102	1	0.879	1.176	102	1	0.886	1.309
200	20	108	1	807.2	1.92	108	1	0.979	1.121	108	1	0.996	1.275	108	1	1.037	1.455
200	40	114	1	784.4	3.62	108	2	1.002	1.186	108	2	1.020	1.350	108	2	1.062	1.540
200	60	108	2	782.8	5.48	108	2	1.030	1.171	108	3	1.054	1.339	108	3	1.097	1.527
200	100	108	3	758.5	9.07	108	4	1.039	1.180	108	5	1.063	1.348	108	6	1.102	1.534
200	200	114	5	784.4	18.12	108	7	0.996	1.181	108	9	1.018	1.348	108	11	1.054	1.533
200	300	114	7	784.0	27.05	108	10	1.002	1.187	108	13	1.024	1.355	108	17	1.061	1.542
200	400	114	9	784.5	36.09	108	13	1.001	1.186	108	18	1.023	1.354	108	22	1.059	1.540
200	500	114	11	784.7	45.17	108	17	1.000	1.184	108	22	1.021	1.352	108	28	1.058	1.538
300	10	126	1	1234.6	0.97	126	1	0.951	1.095	126	1	0.918	1.204	126	1	0.926	1.354
300	20	126	1	1083.1	1.67	126	1	0.975	1.139	132	1	1.026	1.312	132	1	1.066	1.511
300	40	132	1	980.1	3.09	138	1	1.091	1.231	132	2	1.082	1.423	132	2	1.123	1.639
300	60	138	1	1016.6	4.63	132	2	1.015	1.219	132	3	1.048	1.423	132	3	1.088	1.639
300	100	138	2	1007.9	7.68	132	4	1.017	1.222	132	4	1.050	1.426	132	5	1.092	1.645
300	200	138	4	1007.9	15.37	132	8	1.017	1.222	126	9	1.012	1.426	126	11	1.053	1.643
300	300	138	6	1007.9	23.05	132	12	1.017	1.222	126	13	1.011	1.425	126	17	1.055	1.645
300	400	138	8	1007.9	30.73	132	16	1.017	1.222	126	18	1.012	1.426	126	22	1.053	1.643
300	500	138	9	1008.1	38.36	132	20	1.019	1.224	126	22	1.013	1.427	126	28	1.056	1.647
500	10	162	1	1808.6	0.84	162	1	0.944	1.115	156	1	0.882	1.244	156	1	0.891	1.418
500	20	162	1	1410.0	1.40	162	1	0.971	1.172	168	1	0.994	1.363	162	1	1.011	1.597
500	40	174	1	1309.7	2.53	168	1	1.075	1.257	168	2	1.120	1.509	162	2	1.139	1.769
500	60	174	1	1340.4	3.78	168	2	1.040	1.284	168	3	1.088	1.545	162	3	1.106	1.811
500	100	168	2	1363.3	6.20	168	3	1.062	1.278	162	4	1.075	1.532	162	5	1.127	1.801
500	200	174	3	1337.4	12.27	168	7	1.047	1.291	162	8	1.062	1.549	162	10	1.114	1.822
500	300	180	4	1372.0	18.51	168	10	1.020	1.284	162	12	1.034	1.540	162	15	1.085	1.811
500	400	174	6	1337.4	24.54	168	14	1.047	1.291	162	15	1.061	1.549	162	20	1.114	1.822
500	500	174	8	1344.4	30.77	168	17	1.043	1.287	162	19	1.056	1.543	162	25	1.110	1.816
1000	10	228	1	3041.5	0.68	216	1	0.904	1.146	216	1	0.860	1.304	216	1	0.871	1.517
1000	20	228	1	2378.4	1.10	216	1	0.926	1.226	228	1	0.943	1.455	228	1	0.992	1.752
1000	40	228	1	2043.7	1.92	228	1	1.022	1.313	228	2	1.097	1.661	228	2	1.153	1.999
1000	60	228	1	1933.0	2.74	228	2	1.092	1.388	228	2	1.134	1.721	228	3	1.219	2.098
1000	100	240	1	1906.5	4.50	228	3	1.062	1.403	228	4	1.122	1.758	228	4	1.191	2.129
1000	200	240	2	1906.5	9.00	228	5	1.061	1.402	228	7	1.116	1.752	228	9	1.186	2.125
1000	300	240	3	1906.5	13.49	228	7	1.060	1.401	228	10	1.114	1.750	228	13	1.186	2.124
1000	400	240	4	1906.5	17.99	240	11	1.093	1.401	228	13	1.113	1.750	228	18	1.186	2.125
1000	500	240	6	1906.7	22.47	240	14	1.093	1.402	228	17	1.116	1.753	228	22	1.186	2.125

TEXAS WATER DEVELOPMENT BOARD — LOCKWOOD,ANDREWS,AND NEWNAM,INC. PROGRAM

COST OF DELIVERING WATER BY PIPELINE - MOST ECONOMICAL DIAMETER

PEAK FACTOR = 1.75 GROWTH RATE = 0.03 INTEREST RATE = 0.040 AMORTIZATION PERIOD = 40YRS PRESENT WORTH FACTOR = 8.92

FLOW	LENGTH	STATIC HEAD SLOPE = 0				STATIC HEAD SLOPE = 4				STATIC HEAD SLOPE = 8				STATIC HEAD SLOPE = 12			
MGD	MILES	DIA.	NO. PS	C.C.T$/MI	W.C.CT/TG	DIA.	NO. PS	C.C. RATIO	W.C. RATIO	DIA.	NO. PS	C.C. RATIO	W.C. RATIO	DIA.	NO. PS	C.C. RATIO	W.C. RATIO
2	10	16	1	64.0	10.23	16	1	1.009	1.024	16	1	1.021	1.051	16	1	1.053	1.098
2	20	16	1	81.4	19.45	16	1	1.036	1.049	16	2	1.065	1.106	16	2	1.098	1.156
2	40	21	1	62.5	38.81	16	2	1.018	1.051	16	3	1.031	1.087	16	3	1.078	1.150
2	60	16	3	81.4	58.34	16	4	1.024	1.041	16	4	1.056	1.088	16	5	1.093	1.146
2	100	21	2	62.2	96.43	16	6	1.015	1.052	16	8	1.037	1.096	16	9	1.077	1.155
2	200	21	4	62.2	192.85	16	13	1.011	1.050	16	15	1.037	1.094	16	17	1.078	1.155
2	300	21	6	62.2	289.28	16	20	1.011	1.050	16	23	1.035	1.093	16	26	1.077	1.155
2	400	21	8	62.2	385.71	16	26	1.011	1.050	16	31	1.035	1.093	16	35	1.077	1.154
2	500	21	10	62.2	482.14	16	33	1.010	1.049	16	38	1.036	1.094	16	44	1.076	1.154
5	10	21	1	83.4	5.48	21	1	1.006	1.025	24	1	1.030	1.059	24	1	1.063	1.118
5	20	24	1	82.3	10.46	24	1	1.034	1.060	24	2	1.043	1.108	24	2	1.077	1.171
5	40	24	2	82.3	20.92	24	3	1.017	1.049	24	3	1.046	1.105	24	4	1.077	1.171
5	60	24	3	82.3	31.38	24	4	1.022	1.052	24	5	1.042	1.103	24	4	1.098	1.170
5	100	24	6	81.8	52.09	24	7	1.026	1.055	24	9	1.045	1.106	24	11	1.081	1.175
5	200	24	12	81.8	104.19	24	15	1.023	1.053	24	18	1.045	1.106	21	21	1.072	1.174
5	300	24	17	81.8	156.19	24	23	1.023	1.054	24	28	1.044	1.106	21	32	1.071	1.173
5	400	24	23	81.8	208.13	24	30	1.024	1.054	24	23	1.071	1.117	21	42	1.073	1.175
5	500	24	29	81.7	260.07	24	38	1.024	1.054	24	29	1.070	1.116	24	34	1.103	1.175
10	10	30	1	112.4	3.65	30	1	0.990	1.026	30	1	0.992	1.064	30	1	1.021	1.130
10	20	30	1	109.0	7.11	30	2	1.021	1.055	30	2	1.023	1.094	30	2	1.053	1.161
10	40	30	3	108.6	14.19	30	3	1.013	1.048	30	4	1.024	1.096	30	4	1.055	1.163
10	60	30	4	108.4	21.22	30	5	1.015	1.049	30	6	1.028	1.099	30	7	1.058	1.167
10	100	30	7	108.3	35.33	30	9	1.016	1.051	30	10	1.029	1.100	30	12	1.059	1.168
10	200	30	14	108.3	70.67	30	17	1.015	1.050	30	21	1.028	1.099	30	24	1.059	1.168
10	300	30	21	108.3	106.00	30	26	1.015	1.050	30	31	1.028	1.100	30	36	1.059	1.168
10	400	30	28	108.3	141.34	30	35	1.015	1.049	30	42	1.028	1.099	30	49	1.059	1.168
10	500	30	35	108.3	176.67	30	44	1.015	1.049	30	53	1.028	1.099	30	61	1.059	1.168
20	10	39	1	156.2	2.63	39	1	0.982	1.031	39	1	0.978	1.077	39	1	1.006	1.156
20	20	39	1	150.4	5.03	39	1	1.030	1.078	39	2	1.029	1.129	39	2	1.059	1.212
20	40	39	2	150.4	10.05	39	3	1.015	1.064	39	3	1.027	1.127	39	4	1.059	1.212
20	60	39	3	150.4	15.08	39	4	1.015	1.063	39	5	1.027	1.128	39	5	1.055	1.208
20	100	39	5	150.4	25.13	39	6	1.014	1.063	39	7	1.026	1.127	39	8	1.056	1.210
20	200	39	10	150.4	50.26	39	12	1.014	1.063	39	14	1.026	1.127	39	17	1.055	1.209
20	300	39	15	150.4	75.40	39	18	1.014	1.063	39	21	1.026	1.127	39	25	1.055	1.208
20	400	39	19	150.3	100.52	39	24	1.014	1.063	39	28	1.027	1.127	39	33	1.055	1.208
20	500	39	24	150.3	125.65	39	30	1.014	1.063	39	35	1.026	1.127	39	41	1.055	1.208
40	10	48	1	235.2	2.23	48	1	0.981	1.036	48	1	0.975	1.090	48	1	0.994	1.169
40	20	51	1	231.0	4.25	51	1	1.016	1.074	48	2	0.991	1.144	48	2	1.011	1.228
40	40	51	2	231.0	8.49	48	3	0.974	1.067	48	3	0.982	1.136	48	3	1.008	1.225
40	60	51	3	231.0	12.74	48	4	0.974	1.067	48	5	0.980	1.134	48	5	1.008	1.225
40	100	51	5	231.0	21.23	48	7	0.973	1.066	48	8	0.980	1.135	48	9	1.008	1.225
40	200	51	9	230.1	42.31	48	14	0.977	1.070	48	17	0.983	1.137	48	19	1.012	1.229
40	300	51	14	230.4	63.54	48	22	0.975	1.068	48	25	0.982	1.137	48	29	1.010	1.228
40	400	51	18	230.1	84.62	48	29	0.976	1.069	48	34	0.983	1.137	48	38	1.012	1.229
40	500	51	23	230.3	105.85	48	36	0.976	1.069	48	42	0.982	1.137	48	48	1.011	1.228
60	10	57	1	345.8	2.01	57	1	0.969	1.033	57	1	0.960	1.091	57	1	0.979	1.176
60	20	60	1	328.6	3.73	60	1	1.008	1.076	60	1	1.024	1.162	57	2	1.030	1.268
60	40	60	2	328.0	7.47	60	2	1.008	1.076	57	3	0.989	1.156	57	3	1.015	1.255
60	60	60	2	328.1	11.19	60	3	1.010	1.077	57	4	0.990	1.157	57	4	1.016	1.255
60	100	60	4	328.4	18.56	60	5	1.015	1.082	57	6	0.994	1.163	57	7	1.021	1.261
60	200	60	8	328.4	37.11	60	11	1.014	1.081	57	12	0.994	1.163	57	14	1.021	1.261
60	300	60	13	328.1	55.62	60	16	1.014	1.081	57	18	0.995	1.163	57	21	1.022	1.262
60	400	60	17	328.8	74.10	60	21	1.015	1.083	57	24	0.996	1.164	57	27	1.022	1.263
60	500	60	21	328.9	92.65	60	27	1.014	1.082	57	30	0.996	1.164	57	34	1.022	1.262
100	10	66	1	474.5	1.77	66	1	0.966	1.036	72	1	1.008	1.089	66	1	0.960	1.184
100	20	72	1	456.4	3.19	72	1	1.006	1.084	72	1	1.019	1.180	72	1	1.058	1.300
100	40	72	2	456.4	6.38	72	2	1.006	1.084	72	2	1.019	1.180	72	3	1.043	1.288
100	60	72	2	456.2	9.57	72	3	1.006	1.085	72	4	1.013	1.174	72	4	1.043	1.288
100	100	72	4	454.1	15.88	72	5	1.011	1.089	72	6	1.020	1.181	72	6	1.048	1.293
100	200	72	9	453.0	31.70	72	11	1.011	1.090	72	13	1.021	1.182	72	12	1.051	1.296
100	300	72	13	453.1	47.56	72	17	1.011	1.090	72	20	1.020	1.181	72	18	1.050	1.295
100	400	72	18	453.0	63.40	72	22	1.011	1.090	72	27	1.020	1.181	72	24	1.051	1.296
100	500	72	22	452.9	79.23	72	28	1.011	1.089	72	34	1.021	1.182	72	30	1.051	1.296
150	10	84	1	680.9	1.59	84	1	0.955	1.040	84	1	0.925	1.098	84	1	0.946	1.203
150	20	90	1	622.4	2.81	84	1	0.961	1.097	84	1	0.974	1.203	84	1	1.014	1.338
150	40	90	1	610.5	5.58	84	2	0.971	1.106	84	2	0.983	1.213	84	3	1.013	1.340
150	60	90	2	608.0	8.27	84	3	0.984	1.120	84	4	0.993	1.225	84	4	1.026	1.355
150	100	90	3	607.5	13.77	90	4	1.023	1.118	84	6	0.995	1.227	84	6	1.025	1.355
150	200	90	6	607.5	27.53	90	9	1.022	1.117	84	13	0.994	1.226	84	12	1.025	1.355
150	300	90	9	607.5	41.30	90	13	1.021	1.116	84	20	0.994	1.226	84	18	1.025	1.355
150	400	90	12	607.5	55.07	90	17	1.020	1.115	84	26	0.994	1.226	84	24	1.025	1.355
150	500	90	16	607.3	68.81	90	21	1.020	1.115	84	33	0.994	1.226	84	30	1.026	1.355
200	10	96	1	869.0	1.47	90	1	0.903	1.043	96	1	0.920	1.107	96	1	0.936	1.216
200	20	96	1	727.3	2.57	96	1	0.998	1.099	96	1	1.018	1.220	96	1	1.061	1.366
200	40	108	1	780.0	5.03	96	2	0.955	1.123	96	2	0.974	1.247	96	3	1.009	1.390
200	60	102	2	730.1	7.50	96	3	0.988	1.129	96	3	1.007	1.254	96	4	1.040	1.395
200	100	102	3	733.6	12.48	102	4	1.024	1.130	96	6	1.005	1.252	96	6	1.042	1.397
200	200	102	6	733.6	24.95	102	8	1.024	1.130	96	12	1.005	1.252	96	11	1.042	1.397
200	300	102	9	733.6	37.43	102	12	1.024	1.130	96	18	1.005	1.252	96	17	1.042	1.397
200	400	102	11	733.5	49.90	102	16	1.025	1.130	96	24	1.005	1.252	96	22	1.042	1.397
200	500	102	14	736.6	62.31	102	20	1.026	1.131	96	31	1.006	1.253	96	28	1.043	1.398
300	10	114	1	1144.2	1.32	114	1	0.946	1.052	114	1	0.911	1.122	114	1	0.923	1.238
300	20	114	1	946.8	2.24	120	1	1.030	1.115	120	1	1.040	1.244	120	1	1.092	1.412
300	40	126	1	957.0	4.28	120	2	1.020	1.170	120	2	1.031	1.305	120	2	1.082	1.482
300	60	120	2	940.8	6.47	126	2	1.057	1.155	120	3	1.049	1.295	114	4	1.068	1.469
300	100	126	3	955.2	10.66	120	4	1.012	1.162	120	5	1.033	1.308	120	6	1.078	1.479
300	200	126	6	955.2	21.32	120	8	1.012	1.162	120	10	1.033	1.308	120	12	1.078	1.479
300	300	126	9	955.2	31.99	120	12	1.012	1.162	120	15	1.033	1.308	120	18	1.078	1.479
300	400	126	12	955.2	42.65	120	15	1.010	1.161	120	20	1.033	1.308	120	24	1.078	1.479
300	500	126	15	955.2	53.31	120	19	1.010	1.160	120	25	1.033	1.308	120	30	1.078	1.479
500	10	144	1	1678.3	1.15	144	1	0.939	1.063	144	1	0.899	1.144	144	1	0.909	1.273
500	20	144	1	1343.7	1.89	150	1	1.001	1.122	150	1	1.016	1.277	150	1	1.066	1.467
500	40	156	1	1276.7	3.46	162	1	1.081	1.221	150	2	1.068	1.398	150	2	1.120	1.606
500	60	168	1	1319.6	5.18	150	2	0.998	1.208	150	3	1.035	1.398	150	3	1.085	1.607
500	100	162	2	1296.2	8.60	156	3	1.035	1.211	156	4	1.072	1.402	150	5	1.105	1.612
500	200	162	4	1296.2	17.21	156	6	1.035	1.211	150	9	1.047	1.398	150	11	1.102	1.610
500	300	162	6	1296.2	25.81	156	9	1.035	1.211	150	14	1.048	1.399	150	17	1.101	1.609
500	400	162	9	1293.1	34.34	156	12	1.037	1.214	150	18	1.049	1.401	150	22	1.104	1.613
500	500	162	11	1290.9	42.86	156	15	1.039	1.216	150	23	1.052	1.403	150	28	1.106	1.616
1000	10	204	1	2862.1	0.95	204	1	0.929	1.082	192	1	0.854	1.179	192	1	0.866	1.336
1000	20	204	1	2197.0	1.50	204	1	0.962	1.152	204	1	0.961	1.331	204	1	1.005	1.556
1000	40	204	1	1874.1	2.60	216	1	1.080	1.259	204	2	1.126	1.534	204	2	1.178	1.794
1000	60	216	1	1886.0	3.80	216	2	1.087	1.304	216	2	1.134	1.561	204	3	1.174	1.844
1000	100	210	2	1885.3	6.34	216	3	1.080	1.297	204	4	1.096	1.552	204	4	1.170	1.839
1000	200	228	3	1910.8	12.57	216	5	1.059	1.303	204	8	1.082	1.567	204	8	1.154	1.856
1000	300	228	4	1911.0	18.85	216	8	1.061	1.305	204	12	1.082	1.567	204	12	1.154	1.856
1000	400	228	6	1910.6	25.14	216	10	1.059	1.303	204	16	1.082	1.567	204	16	1.154	1.856
1000	500	228	7	1904.4	31.32	216	12	1.063	1.307	216	18	1.113	1.571	204	20	1.158	1.862

TEXAS WATER DEVELOPMENT BOARD — LOCKWOOD, ANDREWS AND NEWNAM, INC. PROGRAM

COST OF DELIVERING WATER BY PIPELINE - MOST ECONOMICAL DIAMETER

PEAK FACTOR = 2.00 GROWTH RATE = 0.00 INTEREST RATE = 0.040 AMORTIZATION PERIOD = 40 YRS PRESENT WORTH FACTOR = 20.19

FLOW	LENGTH	STATIC HEAD SLOPE = 0				STATIC HEAD SLOPE = 4				STATIC HEAD SLOPE = 8				STATIC HEAD SLOPE = 12			
MGD	MILES	DIA.NO.PS	C.L./MI	W.C.LT/TG		DIA.NO.PS	C.C.RATIO	W.C.RATIO		DIA.NO.PS	C.C.RATIO	W.C.RATIO		DIA.NO.PS	C.C.RATIO	W.C.RATIO	
2	10	21 1	67.9	5.12		21 1	1.015	1.040		21 1	1.032	1.082		21 1	1.062	1.137	
2	20	21 1	66.7	9.40		21 1	1.023	1.050		21 1	1.069	1.122		21 1	1.129	1.209	
2	40	21 1	65.1	17.95		21 2	1.049	1.100		21 2	1.096	1.175		21 3	1.127	1.261	
2	60	21 2	63.6	27.35		21 2	1.055	1.082		21 3	1.087	1.157		21 4	1.127	1.242	
2	100	21 3	63.4	45.30		21 4	1.043	1.079		21 6	1.076	1.159		21 7	1.127	1.249	
2	200	21 5	63.1	89.76		21 8	1.048	1.090		21 12	1.081	1.170		21 15	1.127	1.261	
2	300	21 8	63.2	135.06		21 13	1.042	1.085		21 18	1.079	1.167		21 23	1.124	1.257	
2	400	21 10	63.1	179.52		21 17	1.043	1.087		21 24	1.081	1.170		21 30	1.127	1.261	
2	500	21 13	63.2	224.82		21 21	1.042	1.085		21 30	1.080	1.168		21 38	1.125	1.258	
5	10	27 1	87.3	2.85		24 1	1.001	1.019		24 1	1.018	1.077		24 1	1.052	1.156	
5	20	27 1	87.4	5.36		27 1	1.028	1.066		24 2	0.996	1.149		24 2	1.029	1.232	
5	40	27 2	87.4	10.71		27 2	1.028	1.066		27 3	1.044	1.147		24 4	1.029	1.232	
5	60	27 2	87.6	15.97		27 3	1.024	1.073		24 5	0.994	1.148		24 6	1.025	1.240	
5	100	27 4	88.6	26.40		27 6	1.029	1.081		24 8	1.008	1.156		24 10	1.038	1.250	
5	200	27 8	88.6	52.79		27 11	1.031	1.079		24 16	1.008	1.156		24 19	1.039	1.247	
5	300	27 12	88.6	79.19		27 17	1.029	1.078		24 24	1.008	1.156		24 28	1.039	1.246	
5	400	27 16	88.6	105.59		27 23	1.028	1.078		24 32	1.008	1.156		24 37	1.039	1.246	
5	500	27 20	88.6	131.99		27 29	1.028	1.078		24 40	1.008	1.156		24 46	1.039	1.245	
10	10	33 1	121.2	1.96		33 1	0.995	1.063		33 1	0.993	1.131		33 1	1.015	1.223	
10	20	36 1	122.8	3.75		36 1	1.010	1.078		33 2	0.981	1.181		33 2	1.002	1.276	
10	40	36 2	122.8	7.51		36 2	1.010	1.078		36 3	1.031	1.171		36 3	1.062	1.275	
10	60	36 2	121.2	11.13		36 3	1.023	1.090		36 4	1.043	1.183		36 5	1.071	1.285	
10	100	36 4	121.4	18.57		36 5	1.022	1.089		36 7	1.039	1.179		36 9	1.070	1.284	
10	200	36 7	120.7	36.98		36 11	1.026	1.093		36 14	1.045	1.184		36 17	1.074	1.289	
10	300	36 11	120.9	55.52		36 16	1.023	1.090		36 21	1.043	1.183		36 26	1.072	1.286	
10	400	36 14	120.7	73.95		36 21	1.024	1.091		36 28	1.045	1.184		36 35	1.073	1.288	
10	500	36 18	120.8	92.47		36 26	1.024	1.091		36 35	1.044	1.184		36 43	1.073	1.288	
20	10	42 1	100.3	1.59		42 1	0.988	1.057		42 1	0.982	1.138		42 1	1.008	1.247	
20	20	45 1	104.6	3.02		45 1	1.019	1.097		42 2	0.960	1.202		42 2	0.984	1.317	
20	40	45 2	104.6	6.03		42 3	0.939	1.094		42 3	0.955	1.198		42 3	0.980	1.314	
20	60	45 2	104.4	9.04		42 4	0.940	1.096		42 4	0.955	1.198		42 5	0.982	1.315	
20	100	45 4	103.1	14.98		45 6	1.022	1.100		42 7	0.962	1.205		42 8	0.988	1.322	
20	200	45 8	103.1	29.97		45 12	1.022	1.100		42 13	0.962	1.205		42 16	0.988	1.322	
20	300	45 13	102.7	44.87		45 18	1.024	1.102		42 20	0.964	1.207		42 23	0.989	1.324	
20	400	45 17	102.8	59.80		45 24	1.024	1.102		42 26	0.964	1.208		42 31	0.990	1.325	
20	500	45 21	102.7	74.78		45 30	1.024	1.102		42 33	0.964	1.207		42 38	0.989	1.324	
40	10	60 1	334.6	1.35		57 1	0.928	1.078		57 1	0.918	1.171		57 1	0.928	1.286	
40	20	60 1	304.4	2.51		60 1	1.003	1.104		60 1	1.022	1.231		60 1	1.058	1.375	
40	40	60 1	298.4	4.94		60 2	1.022	1.121		60 2	1.041	1.249		60 3	1.074	1.393	
40	60	60 2	297.6	7.38		60 3	1.026	1.125		60 3	1.046	1.254		60 4	1.075	1.395	
40	100	60 3	298.1	12.32		60 5	1.024	1.124		60 5	1.044	1.252		60 6	1.071	1.391	
40	200	60 7	297.3	24.59		60 10	1.027	1.126		60 10	1.046	1.255		60 12	1.073	1.394	
40	300	60 11	297.1	36.86		60 16	1.028	1.127		60 15	1.047	1.255		60 18	1.074	1.395	
40	400	60 14	297.3	49.18		60 21	1.027	1.126		60 20	1.046	1.255		60 24	1.073	1.394	
40	500	60 18	297.2	61.45		60 27	1.027	1.126		60 24	1.047	1.255		60 30	1.074	1.394	
60	10	72 1	450.6	1.22		66 1	0.886	1.089		66 1	0.873	1.190		66 1	0.883	1.317	
60	20	72 1	414.5	2.25		72 1	0.994	1.113		72 1	1.017	1.256		72 1	1.054	1.414	
60	40	72 1	402.2	4.39		72 2	1.024	1.141		72 2	1.048	1.287		72 3	1.081	1.446	
60	60	72 2	400.4	6.56		72 3	1.029	1.145		72 4	1.053	1.292		72 4	1.084	1.450	
60	100	72 3	399.5	10.91		72 5	1.031	1.147		72 6	1.054	1.294		72 6	1.085	1.451	
60	200	72 6	399.5	21.83		72 9	1.031	1.147		72 13	1.054	1.294		72 11	1.085	1.451	
60	300	72 9	399.5	32.74		72 14	1.030	1.146		72 19	1.054	1.294		72 17	1.084	1.451	
60	400	72 12	399.5	43.66		72 19	1.030	1.146		72 26	1.054	1.294		72 23	1.084	1.451	
60	500	72 16	399.2	54.54		72 24	1.030	1.146		72 33	1.055	1.294		72 28	1.085	1.451	
100	10	90 1	650.1	1.05		84 1	0.905	1.106		84 1	0.886	1.222		84 1	0.892	1.364	
100	20	90 1	580.2	1.91		90 1	0.988	1.133		90 1	1.002	1.292		90 1	1.036	1.471	
100	40	90 1	554.3	3.64		90 2	1.045	1.187		90 2	1.060	1.353		90 2	1.095	1.541	
100	60	90 2	562.2	5.53		90 2	1.024	1.168		90 3	1.045	1.337		90 4	1.080	1.523	
100	100	90 3	557.4	9.15		90 4	1.028	1.173		90 6	1.053	1.346		90 6	1.087	1.532	
100	200	90 5	554.3	18.22		90 9	1.034	1.178		90 12	1.059	1.352		90 11	1.091	1.537	
100	300	90 8	552.8	27.26		90 13	1.035	1.179		90 18	1.062	1.356		90 16	1.094	1.541	
100	400	90 11	553.8	36.41		90 17	1.033	1.178		90 24	1.060	1.353		90 21	1.091	1.538	
100	500	90 13	553.1	45.47		90 22	1.034	1.178		90 30	1.061	1.355		90 27	1.093	1.540	
150	10	102 1	884.7	0.94		102 1	0.916	1.121		102 1	0.895	1.253		102 1	0.901	1.412	
150	20	108 1	770.8	1.68		102 1	0.929	1.153		108 1	0.995	1.331		108 1	1.030	1.532	
150	40	108 1	722.9	3.16		102 2	0.994	1.224		108 2	1.069	1.413		108 2	1.106	1.627	
150	60	114 1	755.6	4.71		108 2	0.996	1.218		108 3	1.023	1.420		108 3	1.058	1.635	
150	100	114 2	761.1	7.90		108 4	0.983	1.205		108 5	1.016	1.412		108 5	1.051	1.625	
150	200	108 5	722.9	15.78		108 8	1.035	1.207		108 11	1.068	1.412		108 10	1.106	1.627	
150	300	114 5	755.8	23.55		108 12	0.990	1.213		108 17	1.021	1.419		108 15	1.058	1.635	
150	400	108 9	718.0	31.38		108 16	1.042	1.213		108 23	1.075	1.420		108 20	1.114	1.636	
150	500	108 11	719.2	39.28		108 20	1.040	1.212		108 28	1.073	1.418		108 25	1.112	1.634	
200	10	120 1	1061.4	0.86		120 1	0.967	1.135		120 1	0.944	1.280		120 1	0.951	1.454	
200	20	120 1	917.5	1.52		120 1	0.985	1.172		126 1	1.035	1.364		120 1	1.030	1.583	
200	40	120 1	865.6	2.84		126 1	1.100	1.240		126 2	1.123	1.457		120 2	1.117	1.692	
200	60	126 1	878.1	4.21		126 2	1.046	1.245		126 3	1.082	1.477		120 3	1.076	1.715	
200	100	126 2	879.9	7.03		120 4	1.000	1.244		126 5	1.080	1.474		120 5	1.074	1.712	
200	200	126 4	879.9	14.05		126 7	1.041	1.240		120 11	1.036	1.474		120 10	1.074	1.712	
200	300	126 5	878.1	21.04		126 10	1.046	1.245		120 17	1.038	1.476		120 15	1.076	1.715	
200	400	126 7	874.0	27.94		126 14	1.048	1.248		126 21	1.086	1.482		120 20	1.081	1.722	
200	500	126 9	874.2	34.93		126 17	1.049	1.249		126 26	1.086	1.481		120 25	1.081	1.721	
300	10	150 1	1460.4	0.75		144 1	0.931	1.159		144 1	0.906	1.324		144 1	0.914	1.522	
300	20	150 1	1244.6	1.31		144 1	0.965	1.205		150 1	0.974	1.416		144 1	0.985	1.674	
300	40	150 1	1130.6	2.43		150 1	1.035	1.270		150 2	1.067	1.529		144 2	1.079	1.808	
300	60	150 1	1100.6	3.55		150 2	1.056	1.295		150 3	1.101	1.571		144 3	1.114	1.858	
300	100	162 1	1178.3	5.95		156 3	1.018	1.290		150 5	1.029	1.562		144 5	1.041	1.847	
300	200	150 3	1101.5	11.84		156 6	1.089	1.297		150 10	1.101	1.570		144 10	1.113	1.857	
300	300	150 4	1103.4	17.69		150 10	1.024	1.299		150 15	1.068	1.577		144 15	1.080	1.864	
300	400	150 5	1103.1	23.58		150 13	1.024	1.299		150 20	1.068	1.577		144 19	1.079	1.864	
300	500	150 6	1097.9	29.52		150 16	1.060	1.298		150 25	1.104	1.575		144 24	1.115	1.861	
500	10	186 1	2057.1	0.64		186 1	0.957	1.193		186 1	0.928	1.388		180 1	0.914	1.622	
500	20	186 1	1699.6	1.09		186 1	0.980	1.255		186 1	0.967	1.504		186 1	1.014	1.810	
500	40	186 1	1519.6	1.96		192 1	1.051	1.319		186 2	1.082	1.653		186 2	1.134	1.988	
500	60	186 1	1459.9	2.87		186 2	1.071	1.368		186 2	1.119	1.703		186 3	1.181	2.056	
500	100	204 1	1550.7	4.74		192 3	1.021	1.376		186 4	1.049	1.722		186 5	1.106	2.079	
500	200	204 2	1550.7	9.47		192 6	1.021	1.376		192 9	1.074	1.722		186 9	1.101	2.075	
500	300	192 4	1484.4	14.18		192 9	1.072	1.378		186 10	1.101	1.725		186 13	1.157	2.079	
500	400	192 5	1476.4	18.84		192 11	1.075	1.382		186 13	1.105	1.731		186 18	1.161	2.086	
500	500	192 6	1474.8	23.50		192 14	1.077	1.384		192 23	1.134	1.735		186 22	1.163	2.089	
1000	10	264 1	3443.9	0.52		252 1	0.921	1.246		252 1	0.886	1.488		252 1	0.897	1.777	
1000	20	264 1	2726.9	0.84		252 1	0.939	1.338		252 1	0.924	1.661		252 1	0.966	2.042	
1000	40	264 1	2387.4	1.49		264 1	0.999	1.409		264 1	1.086	1.866		252 2	1.113	2.310	
1000	60	264 1	2247.5	2.14		264 1	1.070	1.489		264 2	1.126	1.935		252 2	1.172	2.415	
1000	100	264 1	2131.6	3.43		264 2	1.107	1.536		264 3	1.174	2.007		264 4	1.249	2.493	
1000	200	264 2	2131.6	6.86		264 5	1.100	1.530		264 6	1.174	2.007		264 8	1.249	2.493	
1000	300	276 2	2200.1	10.19		264 7	1.075	1.547		264 9	1.145	2.027		264 12	1.218	2.518	
1000	400	276 3	2213.5	13.63		264 10	1.069	1.540		264 12	1.141	2.021		264 16	1.214	2.510	
1000	500	276 4	2226.7	17.08		264 13	1.065	1.535		264 15	1.137	2.015		252 21	1.170	2.503	

TEXAS WATER DEVELOPMENT BOARD — LOCKWOOD,ANDREWS,AND NEWNAM,INC. PROGRAM

COST OF DELIVERING WATER BY PIPELINE - MOST ECONOMICAL DIAMETER

PEAK FACTOR = 2.00 GROWTH RATE = 0.10 INTEREST RATE = 0.040 AMORTIZATION PERIOD = 40YRS PRESENT WORTH FACTOR = 15.78

FLOW MGD	LENGTH MILES	STATIC HEAD SLOPE = 0 DIA.	NO. PS	C.C./AC/MI	W.C./CT/TG	STATIC HEAD SLOPE = 4 DIA.	NO. PS	C.C. RATIO	W.C. RATIO	STATIC HEAD SLOPE = 8 DIA.	NO. PS	C.C. RATIO	W.C. RATIO	STATIC HEAD SLOPE = 12 DIA.	NO. PS	C.C. RATIO	W.C. RATIO
2	10	21	1	87.9	6.34	21	1	1.015	1.039	16	1	1.006	1.077	21	1	1.062	1.130
2	20	21	1	89.7	11.77	21	1	1.023	1.048	21	1	1.069	1.116	21	1	1.129	1.198
2	40	21	1	93.1	22.63	21	2	1.049	1.090	21	2	1.096	1.161	21	3	1.127	1.235
2	60	21	2	96.6	34.40	21	3	1.040	1.076	21	3	1.087	1.145	21	4	1.127	1.221
2	100	21	3	93.4	57.03	21	4	1.043	1.074	21	6	1.076	1.144	21	7	1.127	1.227
2	200	21	5	93.1	113.14	21	8	1.048	1.082	21	12	1.081	1.153	21	15	1.127	1.235
2	300	21	8	93.2	170.17	21	13	1.042	1.077	21	18	1.079	1.150	21	23	1.124	1.231
2	400	21	10	93.1	226.28	21	17	1.043	1.079	21	24	1.081	1.153	21	30	1.127	1.235
2	500	21	13	93.2	283.30	21	21	1.042	1.077	21	30	1.080	1.151	21	38	1.125	1.233
5	10	27	1	87.5	3.46	24	1	1.001	1.022	24	1	1.018	1.074	24	1	1.052	1.147
5	20	27	1	89.4	6.65	24	2	0.980	1.063	24	2	0.996	1.117	24	2	1.029	1.192
5	40	27	2	89.4	13.29	24	3	0.978	1.050	24	4	0.996	1.117	24	4	1.029	1.192
5	60	27	2	89.8	19.88	24	5	0.972	1.055	24	5	0.994	1.116	24	6	1.025	1.196
5	100	27	4	88.6	32.81	24	7	0.988	1.063	24	8	1.008	1.126	24	10	1.038	1.208
5	200	27	8	88.6	65.62	24	14	0.988	1.063	24	16	1.008	1.126	24	19	1.039	1.206
5	300	27	12	88.6	98.43	24	21	0.988	1.063	24	24	1.008	1.126	24	28	1.039	1.205
5	400	27	16	88.6	131.24	24	27	0.989	1.062	24	32	1.008	1.126	24	37	1.039	1.205
5	500	27	20	88.6	164.05	24	34	0.989	1.062	24	40	1.008	1.126	24	46	1.039	1.204
10	10	33	1	121.2	2.38	33	1	0.995	1.052	33	1	0.993	1.109	33	1	1.015	1.188
10	20	33	1	113.5	4.59	36	1	1.074	1.076	33	2	1.043	1.148	33	2	1.066	1.231
10	40	33	2	113.5	9.18	33	3	1.018	1.066	33	3	1.040	1.146	33	4	1.066	1.231
10	60	33	2	121.2	13.73	33	4	0.971	1.072	33	5	0.988	1.147	33	6	1.015	1.235
10	100	33	4	121.4	22.90	33	7	0.968	1.069	33	9	0.984	1.144	33	10	1.014	1.234
10	200	33	7	120.7	45.58	33	15	0.973	1.074	33	18	0.990	1.149	33	21	1.018	1.239
10	300	33	11	120.9	68.45	33	22	0.970	1.072	33	27	0.988	1.148	33	32	1.017	1.237
10	400	33	14	120.7	91.16	33	29	0.972	1.073	33	36	0.990	1.149	33	43	1.018	1.238
10	500	33	18	120.8	114.00	33	36	0.972	1.073	33	45	0.989	1.149	33	54	1.017	1.238
20	10	42	1	100.3	1.89	39	1	0.903	1.049	42	1	0.982	1.117	42	1	1.008	1.214
20	20	42	1	107.9	3.59	42	1	1.026	1.084	42	2	1.043	1.174	42	2	1.069	1.275
20	40	42	2	107.9	7.19	42	3	1.020	1.079	42	3	1.037	1.169	42	3	1.065	1.272
20	60	42	3	107.9	10.78	42	4	1.020	1.079	42	4	1.036	1.169	42	5	1.065	1.272
20	100	42	6	107.8	17.94	42	7	1.021	1.080	42	7	1.038	1.170	42	8	1.066	1.273
20	200	42	12	107.8	35.89	42	15	1.021	1.080	42	13	1.038	1.170	42	16	1.066	1.273
20	300	42	18	107.8	53.83	42	23	1.021	1.080	42	20	1.038	1.170	42	23	1.066	1.273
20	400	42	24	107.8	71.78	42	31	1.021	1.080	42	26	1.038	1.170	42	31	1.066	1.273
20	500	42	31	107.8	89.71	42	39	1.021	1.080	42	33	1.038	1.170	42	38	1.065	1.272
40	10	57	1	314.0	1.62	54	1	0.926	1.058	54	1	0.915	1.133	57	1	0.983	1.236
40	20	57	1	293.7	2.99	57	1	1.017	1.097	57	1	1.039	1.207	57	1	1.074	1.332
40	40	60	1	298.9	5.96	57	2	0.973	1.099	57	2	0.994	1.210	57	3	1.019	1.328
40	60	60	2	297.0	8.90	57	3	0.977	1.103	57	4	0.996	1.213	57	4	1.019	1.330
40	100	60	3	298.1	14.86	57	5	0.975	1.102	57	6	0.992	1.209	57	7	1.018	1.329
40	200	60	7	297.3	29.65	57	9	0.976	1.103	57	11	0.993	1.211	57	13	1.021	1.332
40	300	60	11	297.1	44.45	57	14	0.977	1.104	57	17	0.994	1.211	57	20	1.021	1.332
40	400	60	14	297.3	59.31	57	18	0.976	1.103	57	22	0.993	1.211	57	27	1.020	1.331
40	500	60	18	297.2	74.10	57	22	0.976	1.103	57	28	0.993	1.211	57	34	1.020	1.332
60	10	66	1	413.4	1.46	66	1	0.978	1.066	66	1	0.965	1.149	66	1	0.976	1.257
60	20	66	1	371.1	2.67	66	1	1.017	1.105	66	1	1.040	1.226	66	1	1.076	1.363
60	40	72	1	402.2	5.31	66	2	0.939	1.111	66	2	0.959	1.232	66	3	0.985	1.364
60	60	72	2	400.4	7.93	66	3	0.943	1.115	66	4	0.962	1.236	66	4	0.986	1.365
60	100	72	3	399.5	13.20	66	5	0.945	1.117	66	6	0.961	1.236	66	7	0.988	1.369
60	200	72	6	399.3	26.39	66	9	0.942	1.115	66	11	0.960	1.235	66	14	0.988	1.369
60	300	72	9	399.3	39.59	66	14	0.943	1.116	66	17	0.959	1.234	66	20	0.988	1.368
60	400	72	12	399.3	52.78	66	18	0.942	1.115	66	23	0.960	1.234	66	27	0.987	1.368
60	500	72	16	399.2	65.93	66	23	0.944	1.116	66	28	0.960	1.235	66	34	0.988	1.368
100	10	84	1	513.0	1.26	84	1	0.971	1.079	84	1	0.951	1.172	84	1	0.957	1.291
100	20	84	1	541.1	2.28	84	1	0.999	1.113	84	1	1.014	1.249	84	1	1.055	1.409
100	40	90	1	559.3	4.40	84	2	0.975	1.153	84	2	0.990	1.292	84	3	1.029	1.457
100	60	84	2	562.1	6.67	84	3	1.029	1.141	84	3	1.045	1.280	84	4	1.080	1.438
100	100	90	3	557.4	11.06	84	4	0.967	1.145	84	5	0.985	1.286	84	6	1.013	1.441
100	200	90	5	559.3	22.01	84	8	0.972	1.150	84	10	0.990	1.292	84	12	1.019	1.449
100	300	90	8	559.0	32.93	84	12	0.975	1.153	84	15	0.993	1.296	84	18	1.022	1.452
100	400	90	11	559.8	43.99	84	15	0.973	1.151	84	20	0.991	1.293	84	24	1.020	1.450
100	500	90	13	559.1	54.92	84	19	0.974	1.152	84	25	0.992	1.295	84	30	1.021	1.451
150	10	102	1	630.6	1.13	96	1	0.912	1.092	96	1	0.890	1.195	96	1	0.897	1.329
150	20	102	1	728.7	2.01	102	1	0.986	1.124	102	1	1.006	1.281	102	1	1.046	1.458
150	40	108	1	722.9	3.82	102	2	0.994	1.181	102	2	1.015	1.346	102	2	1.055	1.533
150	60	102	2	692.8	5.77	102	2	1.033	1.170	102	3	1.059	1.336	102	4	1.100	1.521
150	100	102	3	687.0	9.55	102	4	1.040	1.177	102	5	1.067	1.345	102	6	1.104	1.527
150	200	108	5	722.9	19.09	102	9	0.989	1.177	102	9	1.013	1.345	102	11	1.046	1.526
150	300	108	7	719.3	28.50	102	14	0.994	1.182	102	13	1.018	1.351	102	17	1.053	1.533
150	400	108	9	716.0	37.94	102	19	0.995	1.184	102	18	1.020	1.353	102	22	1.054	1.535
150	500	108	11	719.2	47.50	102	24	0.994	1.182	102	22	1.018	1.351	102	28	1.052	1.533
200	10	114	1	1013.7	1.04	114	1	0.965	1.103	114	1	0.941	1.217	114	1	0.949	1.363
200	20	114	1	869.4	1.82	114	1	0.984	1.137	114	1	1.004	1.307	120	1	1.086	1.499
200	40	120	1	843.8	3.41	114	2	1.012	1.215	114	2	1.034	1.397	120	2	1.117	1.602
200	60	120	1	878.1	5.12	120	2	1.007	1.205	114	3	0.995	1.395	120	3	1.076	1.601
200	100	120	2	841.3	8.55	120	4	1.039	1.200	114	5	1.031	1.395	114	6	1.071	1.598
200	200	120	5	843.8	17.06	120	8	1.041	1.202	114	9	1.031	1.395	114	11	1.069	1.597
200	300	120	7	840.8	25.47	120	12	1.047	1.208	114	13	1.036	1.401	114	17	1.076	1.606
200	400	120	9	840.7	33.96	120	16	1.047	1.208	114	18	1.037	1.402	114	22	1.075	1.605
200	500	120	11	842.0	42.50	120	20	1.045	1.206	114	22	1.035	1.400	114	28	1.074	1.603
300	10	138	1	1304.7	0.92	138	1	0.961	1.121	138	1	0.934	1.251	138	1	0.943	1.416
300	20	138	1	1140.4	1.58	138	1	0.982	1.163	144	1	1.024	1.349	138	1	1.031	1.565
300	40	138	1	1041.1	2.92	144	1	1.094	1.241	144	2	1.130	1.464	138	2	1.138	1.698
300	60	150	1	1100.0	4.31	144	2	1.027	1.254	144	3	1.068	1.486	138	3	1.077	1.725
300	100	144	2	1007.1	7.19	144	3	1.063	1.256	138	4	1.064	1.483	138	5	1.111	1.724
300	200	144	4	1007.1	14.38	144	7	1.058	1.252	138	8	1.064	1.483	138	10	1.111	1.724
300	300	150	5	1100.0	21.56	144	11	1.024	1.251	138	12	1.031	1.483	138	15	1.077	1.725
300	400	144	8	1007.1	28.76	144	14	1.058	1.252	138	16	1.064	1.483	138	21	1.110	1.724
300	500	150	8	1097.9	35.85	144	18	1.028	1.255	138	20	1.034	1.487	138	26	1.079	1.728
500	10	180	1	2011.2	0.78	174	1	0.933	1.147	174	1	0.902	1.299	174	1	0.912	1.492
500	20	180	1	1851.6	1.32	174	1	0.951	1.203	180	1	0.969	1.412	174	1	0.991	1.671
500	40	180	1	1471.9	2.39	180	1	1.037	1.279	180	2	1.088	1.559	174	2	1.112	1.846
500	60	180	1	1416.0	3.46	180	2	1.075	1.320	180	2	1.130	1.612	174	3	1.160	1.913
500	100	192	1	1490.2	5.81	186	3	1.036	1.309	180	4	1.085	1.598	174	5	1.093	1.896
500	200	186	3	1447.9	11.49	186	6	1.072	1.323	180	7	1.099	1.613	180	9	1.156	1.915
500	300	186	4	1444.9	17.21	186	9	1.074	1.326	180	11	1.102	1.617	180	14	1.158	1.918
500	400	192	5	1470.4	22.96	186	12	1.050	1.325	180	14	1.077	1.615	174	19	1.105	1.917
500	500	186	7	1446.7	28.61	186	15	1.077	1.329	180	17	1.105	1.620	180	23	1.161	1.922
1000	10	252	1	3547.5	0.64	240	1	0.919	1.187	240	1	0.883	1.375	240	1	0.894	1.612
1000	20	252	1	2630.5	1.03	240	1	0.948	1.268	240	1	0.922	1.530	240	1	0.969	1.854
1000	40	252	1	2270.9	1.80	252	1	1.013	1.347	252	1	1.096	1.735	240	2	1.123	2.110
1000	60	252	1	2151.1	2.58	264	1	1.118	1.430	240	2	1.097	1.799	240	2	1.184	2.211
1000	100	264	1	2151.6	4.18	252	2	1.071	1.457	252	3	1.134	1.852	252	4	1.211	2.268
1000	200	264	2	2151.6	8.36	252	5	1.069	1.454	252	6	1.134	1.852	240	9	1.173	2.267
1000	300	264	3	2151.6	12.54	252	8	1.068	1.454	252	9	1.134	1.852	240	13	1.171	2.266
1000	400	264	4	2151.6	16.72	252	11	1.067	1.453	240	13	1.096	1.852	252	17	1.209	2.265
1000	500	264	4	2149.3	20.87	252	14	1.069	1.455	252	16	1.138	1.855	252	21	1.209	2.268

TEXAS WATER DEVELOPMENT BOARD LOCKWOOD,ANDREWS,AND NEWNAM,INC. PROGRAM
COST OF DELIVERING WATER BY PIPELINE - MOST ECONOMICAL DIAMETER
PEAK FACTOR = 2.00 GROWTH RATE = 0.06 INTEREST RATE = 0.040 AMORTIZATION PERIOD = 40YRS PRESENT WORTH FACTOR = 13.41

FLOW MGD	LENGTH MILES	STATIC HEAD SLOPE = 0 DIA.NO.PS	C.C./M	C.C.RATIO	W.C.RATIO	STATIC HEAD SLOPE = 4 DIA.NO.PS	C.C.RATIO	W.C.RATIO	STATIC HEAD SLOPE = 8 DIA.NO.PS	C.C.RATIO	W.C.RATIO	STATIC HEAD SLOPE = 12 DIA.NO.PS	C.C.RATIO	W.C.RATIO
2	10	21 1	67.9	7.34	16 1	0.991	1.035	16 1	1.006	1.067	16 1	1.041	1.120	
2	20	21 1	64.7	13.70	21 1	1.023	1.046	21 1	1.069	1.112	21 1	1.129	1.191	
2	40	21 1	63.1	26.43	21 2	1.049	1.085	21 2	1.096	1.153	21 3	1.127	1.221	
2	60	21 2	63.6	40.13	21 3	1.040	1.071	21 4	1.077	1.138	21 4	1.127	1.209	
2	100	21 3	63.4	66.56	21 4	1.043	1.070	21 6	1.076	1.135	21 7	1.127	1.214	
2	200	21 5	63.1	132.15	21 9	1.045	1.078	21 12	1.081	1.144	21 15	1.127	1.221	
2	300	21 8	63.2	198.72	21 13	1.042	1.073	21 18	1.079	1.141	21 23	1.124	1.217	
2	400	21 10	63.1	264.31	21 17	1.043	1.074	21 24	1.081	1.144	21 31	1.126	1.220	
2	500	21 13	63.2	330.87	21 21	1.042	1.073	21 30	1.080	1.142	21 38	1.125	1.218	
5	10	24 1	67.3	3.95	24 1	1.001	1.023	24 1	1.018	1.072	24 1	1.052	1.140	
5	20	27 1	65.4	7.70	24 2	0.980	1.049	24 2	0.996	1.100	24 2	1.029	1.170	
5	40	24 3	65.1	15.28	24 3	1.027	1.047	24 4	1.046	1.108	24 4	1.081	1.179	
5	60	24 4	65.4	22.93	24 5	1.022	1.048	24 5	1.046	1.105	24 6	1.078	1.179	
5	100	27 4	66.6	38.04	24 7	0.988	1.051	24 8	1.008	1.109	24 10	1.038	1.184	
5	200	27 8	66.6	76.08	24 14	0.988	1.051	24 16	1.008	1.109	24 19	1.039	1.182	
5	300	27 12	66.6	114.13	24 21	0.988	1.051	24 24	1.008	1.109	24 28	1.039	1.182	
5	400	27 16	66.6	152.17	24 27	0.989	1.051	24 32	1.008	1.109	24 37	1.039	1.181	
5	500	27 20	66.6	190.21	24 34	0.989	1.051	24 40	1.008	1.109	24 46	1.039	1.181	
10	10	33 1	121.2	2.72	33 1	0.995	1.046	33 1	0.993	1.095	33 1	1.015	1.168	
10	20	33 1	115.5	5.24	33 1	1.029	1.072	33 2	1.043	1.138	33 2	1.066	1.213	
10	40	33 2	115.5	10.48	33 3	1.018	1.062	33 3	1.040	1.135	33 4	1.066	1.213	
10	60	33 3	115.5	15.72	33 4	1.020	1.064	33 5	1.037	1.133	33 6	1.066	1.213	
10	100	33 6	115.4	26.19	33 7	1.018	1.063	33 9	1.035	1.130	33 10	1.066	1.213	
10	200	33 11	115.6	52.19	33 15	1.022	1.067	33 18	1.039	1.135	33 21	1.069	1.217	
10	300	33 17	115.6	78.29	33 22	1.020	1.065	33 27	1.039	1.135	33 32	1.069	1.217	
10	400	33 22	115.6	104.38	33 29	1.021	1.065	33 36	1.039	1.135	33 43	1.069	1.217	
10	500	33 28	114.9	130.38	33 36	1.022	1.066	33 45	1.040	1.136	33 54	1.070	1.218	
20	10	39 1	103.3	2.10	39 1	0.996	1.043	39 1	1.002	1.112	39 1	1.027	1.200	
20	20	42 1	107.9	4.05	42 1	1.026	1.080	39 2	0.965	1.153	39 2	0.988	1.243	
20	40	42 2	107.9	8.09	39 3	0.967	1.071	39 4	0.965	1.153	39 4	0.988	1.243	
20	60	42 3	107.9	12.14	39 5	0.951	1.075	39 5	0.959	1.148	39 6	0.988	1.243	
20	100	42 5	107.8	20.21	39 7	0.950	1.074	39 9	0.962	1.151	39 10	0.989	1.245	
20	200	42 12	107.8	40.42	39 15	0.949	1.073	39 17	0.960	1.149	39 19	0.988	1.244	
20	300	42 18	107.8	60.63	39 22	0.948	1.072	39 25	0.961	1.150	39 29	0.988	1.244	
20	400	42 24	107.8	80.84	39 29	0.948	1.072	39 34	0.960	1.149	39 38	0.988	1.244	
20	500	42 31	107.8	101.04	39 37	0.948	1.073	39 42	0.960	1.149	39 48	0.987	1.243	
40	10	54 1	240.2	1.81	54 1	0.982	1.048	54 1	0.970	1.114	54 1	0.993	1.212	
40	20	57 1	203.7	3.37	57 1	1.017	1.090	54 1	0.995	1.190	54 2	1.029	1.305	
40	40	57 2	203.7	6.74	57 2	1.017	1.090	54 3	0.990	1.186	54 3	1.013	1.291	
40	60	57 2	204.2	10.07	57 3	1.023	1.095	54 4	0.990	1.187	54 4	1.022	1.300	
40	100	57 4	204.3	16.79	54 6	0.977	1.094	54 7	0.991	1.187	54 8	1.018	1.297	
40	200	57 7	204.3	33.57	54 11	0.975	1.092	54 13	0.990	1.187	54 15	1.019	1.297	
40	300	57 10	204.2	50.34	54 16	0.976	1.093	54 20	0.990	1.187	54 23	1.018	1.297	
40	400	57 13	204.2	67.11	54 22	0.975	1.092	54 27	0.991	1.187	54 31	1.018	1.297	
40	500	57 17	204.3	83.90	54 27	0.975	1.092	54 33	0.990	1.187	54 39	1.018	1.297	
60	10	66 1	413.4	1.64	60 1	0.882	1.055	66 1	0.965	1.131	66 1	0.976	1.228	
60	20	66 1	371.1	2.99	66 1	1.017	1.099	66 1	1.040	1.210	66 1	1.076	1.337	
60	40	66 2	371.1	5.98	66 2	1.017	1.099	66 2	1.040	1.210	66 3	1.068	1.330	
60	60	66 2	368.0	8.93	66 3	1.024	1.105	66 4	1.045	1.216	66 4	1.070	1.334	
60	100	66 4	367.0	14.91	66 5	1.021	1.102	66 6	1.039	1.210	66 7	1.068	1.331	
60	200	66 7	366.9	29.77	66 9	1.021	1.102	66 11	1.040	1.211	66 14	1.071	1.334	
60	300	66 10	366.6	44.63	66 14	1.022	1.103	66 17	1.040	1.211	66 20	1.070	1.334	
60	400	66 14	366.9	59.55	66 18	1.021	1.102	66 23	1.039	1.211	66 27	1.069	1.333	
60	500	66 17	366.7	74.41	66 23	1.022	1.103	66 28	1.040	1.211	66 34	1.069	1.333	
100	10	78 1	567.5	1.43	78 1	0.969	1.059	78 1	0.947	1.138	78 1	0.961	1.250	
100	20	84 1	541.1	2.57	84 1	0.999	1.103	84 1	1.014	1.225	84 1	1.055	1.373	
100	40	90 1	554.3	5.02	84 2	0.975	1.127	84 2	0.990	1.252	78 3	0.961	1.398	
100	60	84 2	523.1	7.51	84 3	1.029	1.132	84 3	1.045	1.257	78 4	1.014	1.402	
100	100	84 3	523.6	12.52	84 4	1.025	1.129	84 5	1.044	1.256	84 6	1.075	1.397	
100	200	84 7	524.9	25.02	84 8	1.027	1.130	84 10	1.048	1.258	84 12	1.076	1.399	
100	300	84 11	524.5	37.51	84 12	1.027	1.130	84 15	1.046	1.258	84 18	1.077	1.400	
100	400	84 15	524.5	50.01	84 15	1.027	1.130	84 20	1.046	1.258	84 24	1.077	1.400	
100	500	84 19	524.4	62.51	84 19	1.027	1.130	84 25	1.047	1.259	84 30	1.077	1.400	
150	10	96 1	769.6	1.27	96 1	0.966	1.074	96 1	0.943	1.164	96 1	0.950	1.283	
150	20	96 1	661.7	2.25	102 1	1.054	1.120	96 1	1.020	1.256	96 1	1.063	1.420	
150	40	102 1	691.8	4.34	102 2	1.036	1.162	96 2	1.005	1.303	96 2	1.048	1.473	
150	60	102 2	692.8	6.52	102 2	1.033	1.157	96 3	1.003	1.302	96 4	1.040	1.466	
150	100	102 3	687.6	10.79	96 4	0.988	1.162	96 5	1.011	1.310	96 6	1.046	1.474	
150	200	102 6	687.6	21.58	96 8	0.988	1.162	96 10	1.011	1.310	96 12	1.046	1.474	
150	300	102 9	687.6	32.38	96 12	0.988	1.162	96 16	1.010	1.310	96 19	1.045	1.473	
150	400	102 12	687.6	43.17	96 16	0.988	1.162	96 21	1.010	1.309	96 25	1.044	1.473	
150	500	102 15	687.6	53.96	96 20	0.988	1.162	96 26	1.009	1.309	96 31	1.045	1.473	
200	10	108 1	96.4	1.18	108 1	0.963	1.082	108 1	0.938	1.179	108 1	0.946	1.308	
200	20	120 1	823.6	2.06	114 1	1.039	1.122	108 1	1.014	1.276	114 1	1.105	1.453	
200	40	120 1	845.0	3.88	114 2	1.012	1.189	108 2	0.988	1.352	114 2	1.076	1.539	
200	60	120 1	870.1	5.88	114 2	0.967	1.172	108 3	0.951	1.340	114 3	1.036	1.525	
200	100	114 3	812.0	9.70	114 4	1.045	1.182	108 5	1.028	1.352	108 6	1.068	1.535	
200	200	114 6	812.0	19.41	114 7	1.045	1.182	114 9	1.073	1.350	114 11	1.112	1.533	
200	300	120 7	844.8	28.97	114 10	1.010	1.188	114 13	1.036	1.356	114 17	1.076	1.542	
200	400	120 9	840.7	38.62	114 13	1.010	1.188	114 18	1.037	1.357	114 22	1.075	1.541	
200	500	120 11	842.0	48.34	114 16	1.009	1.187	114 22	1.035	1.355	114 28	1.074	1.539	
300	10	132 1	1318.2	1.04	132 1	0.960	1.099	132 1	0.932	1.209	132 1	0.941	1.355	
300	20	132 1	1102.5	1.79	132 1	0.981	1.139	138 1	1.034	1.312	138 1	1.075	1.508	
300	40	138 1	1041.1	3.29	144 1	1.094	1.231	138 2	1.095	1.427	138 2	1.138	1.640	
300	60	138 1	1100.6	4.94	138 2	0.999	1.223	138 3	1.036	1.427	138 3	1.077	1.640	
300	100	144 2	1087.1	8.17	138 4	1.029	1.230	138 4	1.064	1.432	138 5	1.111	1.651	
300	200	144 4	1087.1	16.35	138 8	1.029	1.230	138 8	1.064	1.432	132 11	1.075	1.650	
300	300	144 6	1087.1	24.52	138 12	1.029	1.230	138 12	1.064	1.432	138 15	1.111	1.651	
300	400	144 8	1087.1	32.70	138 16	1.029	1.230	138 16	1.064	1.432	132 22	1.075	1.650	
300	500	144 10	1087.1	40.87	138 20	1.029	1.230	138 20	1.064	1.432	138 26	1.110	1.650	
500	10	168 1	191.7	0.89	168 1	0.954	1.120	168 1	0.922	1.250	168 1	0.932	1.420	
500	20	168 1	1530.1	1.49	168 1	0.978	1.173	174 1	1.006	1.365	168 1	1.025	1.596	
500	40	168 1	1370.4	2.70	174 1	1.082	1.258	174 2	1.137	1.513	168 2	1.159	1.770	
500	60	180 1	1412.0	3.92	180 2	1.075	1.294	180 2	1.130	1.559	168 3	1.131	1.825	
500	100	174 2	1366.7	6.59	180 3	1.096	1.285	168 4	1.093	1.540	168 5	1.150	1.809	
500	200	180 3	1447.9	13.12	180 6	1.051	1.292	168 8	1.048	1.548	168 10	1.103	1.818	
500	300	180 5	1412.0	19.61	180 10	1.075	1.294	174 11	1.099	1.551	174 14	1.158	1.825	
500	400	180 6	1447.9	26.24	180 13	1.049	1.290	174 15	1.073	1.546	174 19	1.128	1.817	
500	500	180 7	1440.7	32.66	180 17	1.055	1.296	174 18	1.078	1.553	174 24	1.133	1.824	
1000	10	240 1	3233.1	0.73	228 1	0.917	1.155	228 1	0.880	1.314	228 1	0.892	1.522	
1000	20	240 1	2538.0	1.17	228 1	0.936	1.231	240 1	0.956	1.461	240 1	1.005	1.753	
1000	40	240 1	2170.3	2.04	240 1	1.027	1.318	240 1	1.109	1.667	240 2	1.171	2.005	
1000	60	240 1	2030.7	2.92	240 2	1.101	1.396	240 2	1.147	1.728	240 2	1.239	2.105	
1000	100	252 1	2087.6	4.78	240 3	1.073	1.412	240 3	1.138	1.767	240 4	1.212	2.136	
1000	200	252 2	2087.6	9.55	240 5	1.070	1.409	240 7	1.133	1.762	240 9	1.209	2.133	
1000	300	252 3	2087.6	14.33	240 7	1.069	1.409	240 10	1.130	1.760	240 13	1.207	2.132	
1000	400	252 4	2087.6	19.10	240 9	1.069	1.408	240 13	1.129	1.759	240 17	1.208	2.133	
1000	500	252 6	2089.0	23.84	240 11	1.071	1.410	240 16	1.133	1.763	240 22	1.209	2.134	

TEXAS WATER DEVELOPMENT BOARD — LOCKWOOD, ANDREWS AND NEWNAM, INC. PROGRAM

COST OF DELIVERING WATER BY PIPELINE - MOST ECONOMICAL DIAMETER

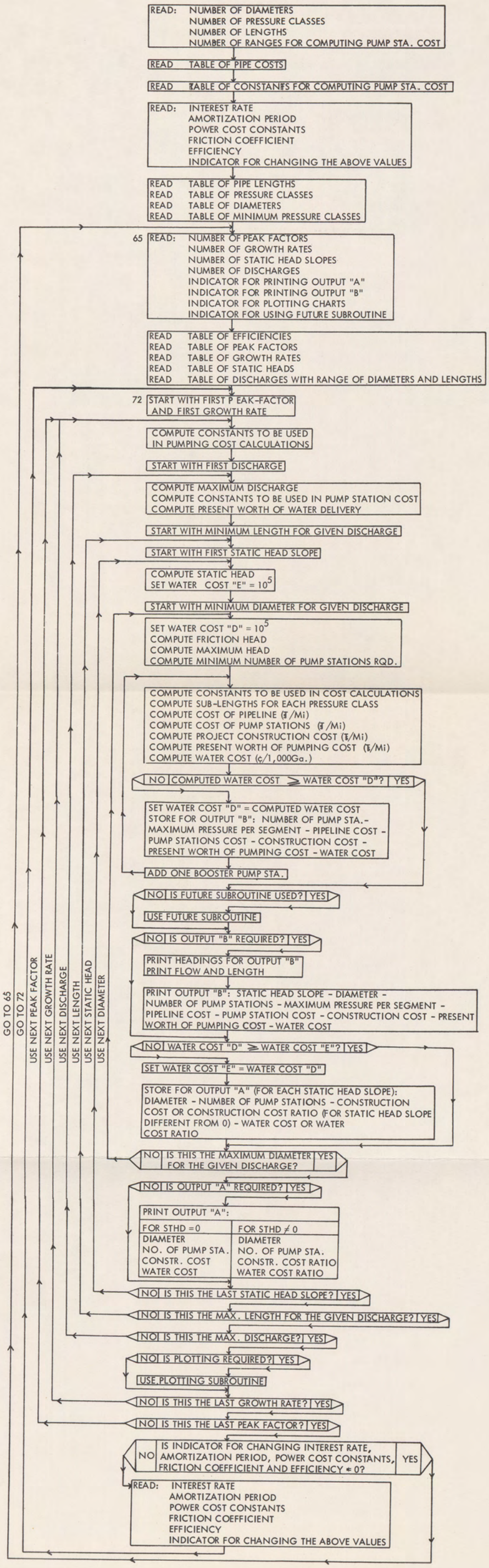
PEAK FACTOR = 2.00 GROWTH RATE = 0.03 INTEREST RATE = 0.040 AMORTIZATION PERIOD = 40 YRS PRESENT WORTH FACTOR = 8.92

FLOW MGD	LENGTH MILES	STATIC HEAD SLOPE = 0 DIA.	NO. PS	C.C./1000/MI	W.C. FT/TO	STATIC HEAD SLOPE = 4 DIA.	NO. PS	C.C. RATIO	W.C. RATIO	STATIC HEAD SLOPE = 8 DIA.	NO. PS	C.C. RATIO	W.C. RATIO	STATIC HEAD SLOPE = 12 DIA.	NO. PS	C.C. RATIO	W.C. RATIO
2	10	16	1	66.5	10.65	16	1	1.012	1.023	16	1	1.027	1.051	16	1	1.063	1.100
2	20	21	1	64.7	20.20	21	1	1.023	1.042	21	1	1.069	1.103	16	2	1.092	1.161
2	40	21	1	63.1	39.20	21	2	1.049	1.074	21	2	1.096	1.136	21	3	1.127	1.192
2	60	21	2	63.6	59.41	21	3	1.040	1.063	21	4	1.077	1.121	16	5	1.115	1.184
2	100	21	3	63.4	98.61	21	4	1.043	1.063	21	6	1.076	1.118	21	8	1.122	1.187
2	200	21	5	63.1	196.02	21	9	1.045	1.068	21	12	1.081	1.125	21	15	1.127	1.192
2	300	21	8	63.2	294.03	21	13	1.042	1.064	21	18	1.079	1.123	21	23	1.124	1.189
2	400	21	10	63.1	392.05	21	17	1.043	1.065	21	24	1.081	1.125	21	31	1.126	1.192
2	500	21	13	63.2	490.66	21	21	1.042	1.064	21	30	1.080	1.124	21	38	1.125	1.190
5	10	24	1	87.5	5.62	24	1	1.001	1.024	24	1	1.018	1.065	24	1	1.052	1.125
5	20	24	1	86.1	11.05	24	2	1.017	1.041	24	2	1.034	1.084	24	2	1.069	1.145
5	40	24	3	85.4	21.83	24	3	1.027	1.049	24	4	1.046	1.098	24	4	1.081	1.159
5	60	24	4	85.4	32.80	24	5	1.022	1.046	24	5	1.046	1.096	24	5	1.082	1.156
5	100	24	7	85.3	54.63	24	9	1.022	1.047	24	8	1.048	1.096	24	9	1.080	1.153
5	200	24	13	85.1	109.15	24	18	1.023	1.048	24	16	1.050	1.097	24	18	1.082	1.155
5	300	24	23	85.1	163.71	24	28	1.023	1.048	24	24	1.050	1.097	24	27	1.082	1.155
5	400	24	30	85.1	218.30	24	37	1.023	1.048	24	32	1.050	1.097	24	36	1.082	1.155
5	500	24	38	85.1	272.82	24	46	1.023	1.048	24	40	1.050	1.097	24	45	1.082	1.155
10	10	30	1	114.2	3.79	30	1	1.004	1.035	30	1	1.016	1.082	30	1	1.040	1.142
10	20	33	1	115.5	7.44	30	2	0.993	1.056	30	2	1.005	1.104	30	2	1.029	1.165
10	40	33	2	115.5	14.88	33	3	1.018	1.053	30	4	1.005	1.104	30	4	1.029	1.165
10	60	33	3	115.5	22.32	30	5	0.992	1.054	30	6	1.005	1.104	30	6	1.029	1.165
10	100	33	6	115.4	37.20	33	7	1.018	1.053	30	9	1.004	1.103	30	10	1.029	1.165
10	200	33	11	115.0	74.10	33	15	1.022	1.057	30	17	1.008	1.107	30	20	1.033	1.170
10	300	33	17	115.0	111.14	33	22	1.020	1.056	30	26	1.008	1.107	30	29	1.032	1.169
10	400	33	22	115.0	148.19	33	29	1.021	1.056	30	35	1.008	1.107	30	39	1.033	1.169
10	500	33	28	114.9	185.09	33	36	1.022	1.057	30	43	1.009	1.108	30	49	1.034	1.170
20	10	39	1	163.5	2.79	39	1	0.996	1.034	39	1	1.002	1.094	39	1	1.027	1.167
20	20	39	1	160.8	5.51	39	2	1.012	1.054	39	2	1.019	1.110	39	2	1.044	1.184
20	40	39	3	159.7	10.95	39	3	1.007	1.050	39	4	1.026	1.117	39	4	1.051	1.191
20	60	39	4	159.0	16.35	39	5	1.016	1.058	39	5	1.025	1.116	39	6	1.056	1.196
20	100	39	6	158.8	27.22	39	7	1.015	1.057	39	9	1.028	1.119	39	10	1.057	1.198
20	200	39	12	158.6	54.44	39	15	1.013	1.056	39	17	1.026	1.117	39	19	1.055	1.196
20	300	39	19	158.7	81.62	39	22	1.013	1.055	39	25	1.027	1.118	39	29	1.056	1.197
20	400	39	25	158.6	108.78	39	29	1.014	1.056	39	34	1.027	1.118	39	38	1.056	1.197
20	500	39	31	158.6	135.94	39	37	1.014	1.056	39	42	1.027	1.118	39	48	1.056	1.197
40	10	51	1	279.8	2.42	51	1	0.984	1.036	51	1	0.983	1.091	51	1	1.002	1.168
40	20	54	1	273.4	4.60	51	1	0.987	1.071	51	2	1.000	1.148	51	2	1.026	1.229
40	40	54	2	273.4	9.20	51	3	0.983	1.068	51	3	0.991	1.135	51	3	1.019	1.223
40	60	54	3	273.4	13.80	51	4	0.979	1.064	51	5	0.992	1.135	51	5	1.019	1.223
40	100	54	4	273.3	22.98	51	7	0.979	1.064	51	8	0.991	1.135	51	7	1.019	1.223
40	200	54	9	272.5	45.85	51	14	0.982	1.067	51	16	0.994	1.138	51	14	1.022	1.226
40	300	54	13	272.1	68.69	51	21	0.983	1.068	51	24	0.995	1.139	51	21	1.023	1.228
40	400	54	17	272.4	91.86	51	28	0.982	1.067	51	32	0.994	1.138	51	28	1.023	1.227
40	500	54	22	272.3	114.54	51	35	0.983	1.068	51	41	0.995	1.139	51	35	1.023	1.227
60	10	60	1	373.4	2.17	60	1	0.976	1.035	60	1	0.971	1.094	60	1	0.989	1.177
60	20	60	1	344.2	4.04	60	1	1.012	1.071	60	1	1.034	1.159	60	1	1.070	1.261
60	40	60	2	344.2	8.07	60	2	1.012	1.071	60	3	1.027	1.153	60	3	1.054	1.248
60	60	60	3	344.2	12.11	60	3	1.012	1.071	60	4	1.026	1.151	60	4	1.052	1.246
60	100	60	5	344.2	20.18	60	5	1.012	1.071	60	6	1.024	1.150	60	7	1.052	1.246
60	200	60	9	344.0	40.34	60	10	1.013	1.072	60	12	1.025	1.151	60	14	1.053	1.247
60	300	60	13	343.9	60.50	60	15	1.013	1.072	60	18	1.025	1.151	60	20	1.053	1.247
60	400	60	17	343.8	80.65	60	20	1.013	1.072	60	24	1.026	1.151	60	27	1.053	1.246
60	500	60	21	343.8	100.81	60	25	1.014	1.073	60	30	1.026	1.151	60	34	1.053	1.247
100	10	72	1	526.8	1.89	72	1	0.970	1.038	72	1	0.957	1.100	72	1	0.973	1.189
100	20	78	1	504.0	3.45	78	1	1.007	1.084	78	1	1.030	1.186	78	1	1.069	1.304
100	40	78	2	504.0	6.90	78	2	1.007	1.084	72	3	0.976	1.182	72	3	1.000	1.287
100	60	78	2	501.7	10.30	78	3	1.012	1.089	72	4	0.978	1.185	72	4	1.004	1.292
100	100	78	4	498.8	17.08	78	5	1.018	1.094	72	6	0.982	1.190	72	7	1.008	1.297
100	200	78	8	498.8	34.16	78	10	1.018	1.094	72	12	0.982	1.190	72	14	1.008	1.297
100	300	78	12	498.8	51.23	78	15	1.018	1.094	72	19	0.982	1.190	72	21	1.008	1.297
100	400	78	15	498.1	68.23	78	20	1.019	1.096	72	25	0.983	1.191	72	28	1.009	1.298
100	500	78	19	497.7	85.23	78	25	1.020	1.097	72	31	0.984	1.192	72	35	1.010	1.299
150	10	90	1	744.6	1.71	84	1	0.915	1.043	90	1	0.939	1.105	90	1	0.957	1.205
150	20	90	1	640.1	3.02	90	1	1.007	1.094	90	1	1.028	1.205	90	1	1.070	1.337
150	40	90	1	670.1	6.01	90	2	0.974	1.100	90	2	0.994	1.212	90	3	1.027	1.337
150	60	90	2	666.9	8.93	90	3	0.984	1.111	90	3	1.005	1.224	90	4	1.036	1.349
150	100	90	3	662.1	14.87	90	5	0.985	1.112	90	6	1.003	1.222	90	6	1.037	1.350
150	200	90	6	662.1	29.73	90	10	0.985	1.112	90	12	1.003	1.222	90	12	1.037	1.350
150	300	90	9	662.1	44.60	90	15	0.985	1.112	90	19	1.002	1.221	90	17	1.037	1.350
150	400	90	12	662.1	59.46	90	20	0.985	1.112	90	25	1.002	1.221	90	23	1.037	1.350
150	500	90	15	662.1	74.33	90	25	0.985	1.112	90	31	1.002	1.221	90	28	1.037	1.350
200	10	102	1	963.1	1.59	96	1	0.916	1.045	102	1	0.935	1.115	102	1	0.949	1.219
200	20	102	1	766.9	2.75	102	1	1.008	1.105	102	1	1.031	1.227	102	1	1.075	1.370
200	40	114	1	817.5	5.39	102	2	0.970	1.128	102	2	0.992	1.253	102	3	1.033	1.397
200	60	108	2	793.2	8.05	102	3	1.000	1.134	102	3	1.023	1.258	102	4	1.058	1.398
200	100	108	3	792.2	13.41	108	4	1.031	1.134	102	6	1.020	1.256	102	7	1.060	1.400
200	200	108	6	792.2	26.81	108	8	1.031	1.134	102	12	1.020	1.256	102	14	1.060	1.400
200	300	108	8	791.7	40.20	102	14	1.000	1.134	102	18	1.020	1.256	102	21	1.060	1.400
200	400	108	11	791.5	53.58	102	19	0.999	1.133	102	24	1.020	1.257	102	28	1.061	1.401
200	500	108	14	791.6	66.99	102	24	0.999	1.133	102	30	1.020	1.257	102	35	1.060	1.401
300	10	120	1	1230.4	1.42	120	1	0.957	1.058	120	1	0.926	1.130	120	1	0.939	1.243
300	20	120	1	1018.5	2.40	126	1	1.034	1.118	126	1	1.049	1.248	126	1	1.102	1.414
300	40	130	1	1041.1	4.57	126	2	1.012	1.177	126	2	1.026	1.313	126	2	1.078	1.488
300	60	132	2	1030.6	6.91	132	2	1.035	1.159	126	3	1.037	1.303	126	3	1.089	1.476
300	100	132	3	1021.0	11.41	126	4	1.020	1.166	126	5	1.047	1.314	126	6	1.094	1.484
300	200	132	6	1021.0	22.82	126	8	1.020	1.166	126	10	1.047	1.314	126	12	1.094	1.484
300	300	132	9	1021.0	34.23	126	12	1.020	1.166	126	15	1.047	1.314	126	18	1.094	1.484
300	400	132	12	1021.0	45.64	126	15	1.018	1.165	126	20	1.047	1.314	126	24	1.094	1.484
300	500	138	14	1069.8	57.01	126	19	0.999	1.165	126	25	1.028	1.315	126	30	1.074	1.485
500	10	150	1	1707.6	1.23	150	1	0.950	1.070	150	1	0.916	1.153	150	1	0.927	1.280
500	20	150	1	1426.1	2.02	156	1	1.011	1.127	156	1	1.028	1.281	156	1	1.080	1.469
500	40	168	1	1370.4	3.68	174	1	1.082	1.226	156	2	1.065	1.408	156	2	1.119	1.615
500	60	180	1	1412.0	5.51	162	2	1.015	1.218	156	3	1.040	1.411	156	3	1.093	1.618
500	100	174	2	1388.7	9.14	162	3	1.032	1.222	162	4	1.074	1.415	156	5	1.111	1.626
500	200	174	4	1388.7	18.28	162	6	1.032	1.222	156	9	1.053	1.414	156	11	1.110	1.625
500	300	174	6	1388.7	27.42	162	9	1.032	1.222	162	13	1.071	1.412	162	16	1.128	1.624
500	400	174	8	1388.7	36.56	162	13	1.031	1.221	162	17	1.069	1.411	162	21	1.128	1.624
500	500	174	10	1388.7	45.71	162	16	1.031	1.220	162	21	1.070	1.411	162	27	1.128	1.623
1000	10	210	1	3074.9	1.02	204	1	0.916	1.091	204	1	0.876	1.192	204	1	0.889	1.345
1000	20	216	1	2355.9	1.60	216	1	0.971	1.159	216	1	0.973	1.339	216	1	1.018	1.559
1000	40	216	1	1990.4	2.76	228	1	1.087	1.269	216	2	1.149	1.553	216	2	1.201	1.809
1000	60	228	1	1999.6	4.03	228	2	1.098	1.315	228	2	1.150	1.574	216	3	1.199	1.858
1000	100	252	1	2087.6	6.75	216	3	1.021	1.304	216	4	1.072	1.562	216	4	1.145	1.846
1000	200	240	3	2032.7	13.37	228	5	1.067	1.310	216	8	1.101	1.578	216	8	1.176	1.865
1000	300	240	4	2032.4	20.03	228	7	1.071	1.314	216	12	1.103	1.580	216	12	1.178	1.867
1000	400	240	6	2032.7	26.73	228	10	1.067	1.310	216	16	1.101	1.578	216	16	1.176	1.865
1000	500	240	7	2029.4	33.27	228	12	1.071	1.315	228	18	1.132	1.585	216	20	1.182	1.873

PART II

BLOCK DIAGRAM FOR COMPUTER PROGRAM

BLOCK DIAGRAM FOR COMPUTER PROGRAM



PART III

COST ESTIMATING PROCEDURE
(FOR PUMP STATION OPERATION AND MAINTENANCE COSTS)
Supplied by U.S. Bureau of Reclamation

COST ESTIMATING PROCEDURE
(FOR PUMP STATION OPERATION AND MAINTENANCE COSTS)
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General

The study of 174 pumping plants ranging in size from 5 to 15,000 horsepower indicates that annual operation and maintenance costs can best be estimated by considering operation costs and maintenance costs separately. The procedures presented in this report are for estimating direct O&M costs for the pumps, motors, accessory electric equipment, miscellaneous equipment, and the plant structure for plants up through 15,000 horsepower. Wherever reference is made to horsepower, total plant horsepower is meant and not the horsepower of individual pumps. Estimates for plants larger than 15,000 horsepower should be made by using Figure 3 in Part 153 of Reclamation Instructions as a guide [Fig. 6 of this Appendix]. This table is based on powerplant operating experience. Costs for the intake channel, and discharge line, and administrative and general expense are not covered by these procedures and should be estimated separately, as appropriate, under existing instructions. Also, costs of replacement of major items are to be estimated separately in accordance with existing instructions.

Operation Costs

Operation Costs Defined

Direct operation costs included in these procedures are those costs incurred at the pumping plant for such items as: Starting and stopping pumping units, opening and closing valves, observing and recording motor and pump performances; noting water levels and general operating conditions, routine cleaning, lubricating machinery, servicing plant service facilities, and checking control equipment. They also include transportation, supplies, a nominal amount of trashrack cleaning, and direct supervision expenses associated with the performance of these functions. In those cases where trashrack cleaning is expected to be a major expense, the cleaning should be estimated separately and added to the cost. The cost of electric power for operation of pump motors and auxiliaries should be estimated separately because power rates vary so much from project to project. Operation costs for intake channel, discharge line, substation, powerline, housing, and for administrative and general expense are not covered by these procedures and should be estimated separately, as appropriate, under existing instructions.

Classification of Plants

The primary factor in the cost of operation of pumping plants, exclusive of energy costs, is the degree of attendance. For this reason it is necessary that the cost estimating procedures include the classification of plants according to attendance requirements. Three classifications have been established as follows:

a. Unattended plants.--This includes plants automatically controlled, relift plants in laterals or distribution systems operated by ditchriders, plants remotely controlled, and other plants which receive only periodic attendance of short duration. Attendance of plants in this group is less than 2.5 man-hours per day during the operating season. For the plants analyzed, the average attendance was about 0.5 man-hour per day.

b. Semiattended plants.--This includes plants of relatively high system importance to which a pumping plant operator is assigned but continuous attendance is not required. It also includes plants which are part of a group of plants being operated by a single operator. The attendance is from 2.5 up to 16 man-hours per day during the operating season. For the plants analyzed, the average attendance was about 7 man-hours per day.

c. Attended plants.--This includes those plants of high system importance which require extended or continuous attendance because of frequent changes in discharge or for other reasons. The attendance is 16 or more man-hours during the operating season. For the plants analyzed, the average attendance was 21 man-hours per day.

By methods of multiple correlation, the influence of the following factors on operation costs was investigated for each of the classifications:

1. Plant size as represented by (a) horsepower; (b) size index; or (c) plant discharge and total design head.

2. Length of operating season.

3. Number of plants being operated.

4. Seasonal plant factor.

It has been found that the factors which have the most influence on operation costs, secondary to the effect of attendance, are plant size, as represented by plant discharge and total design head, and length of the operating season. Inclusion of the seasonal plant factor and the number of plants being operated does not appear to significantly improve the correlations.

Nomographs, Figures 1, 2, and 3, for estimating operation costs for the three plant classifications are included at the end of this chapter. These nomographs relate the annual operation cost to total plant discharge, total design head, length of operating season, hourly wage rates for the plant operator, and price level. When a plant pumps to more than one elevation, the average of the heads weighted by the unit discharge at each of the design heads should be used. Note that design head rather than static head should be used in making estimates.

Maintenance Costs Defined

Direct maintenance costs included in these procedures are those costs incurred in preventive and corrective maintenance of the pumping plant equipment and structures. They include such items as: Periodic inspection and test of equipment, the dismantling of pumps for inspection, the repair or replacement of parts, the cleaning and repair of motors, and the repair of auxiliary and control equipment. They also include service contracts covering both labor and materials, equipment rental, transportation, materials and supplies, and direct supervision expense. Replacement of the major items such as pump impellers, stator windings, rotor windings, thrust bearings, station service transformers, and motor control cubicles are either included as a part of maintenance or are estimated separately as provision for replacement, depending on the size of plant. This is done in accordance with existing replacement procedures. Maintenance costs for intake channel, discharge line, substation, powerline, housing, and for administrative and general expense are not covered by these procedures and should be estimated separately, as appropriate, under existing instructions.

Classification of Plants

In the development and use of procedures for estimating maintenance costs, pumping plants are classified according to the following size groups:

a. Pumping plants 5 to 149 horsepower.

b. Pumping plants 150 to 6,999 horsepower.

c. Pumping plants 7,000 to 15,000 horsepower.

For maintenance costs, multiple correlation methods also were used to investigate the importance of the following factors:

1. Plant size as represented by (a) horsepower, (b) size index, or (c) plant discharge and total design head.

2. Equivalent hours of operation.

3. Plant age.

4. Type of pump (for plants 150 hp and larger).

5. Condition of water pumped (for plants 150 hp and larger).

Maintenance costs for the size group 5 to 149 horsepower have been found to be affected by plant size to the extent that the other factors do not appear to significantly improve correlations for estimating purposes. For the size groups 150 to 6,999 horsepower, and 7,000 to 15,000 horsepower, the optimum correlations include the effect of equivalent hours of operation (in terms of annual water pumped) in addition to plant size. In developing correlations,

plant age was included. However, for estimating purposes, an age of 17 years, which represented average maintenance cost, was selected and substituted in the equation, thereby eliminating the age factor.

Nomographs, Figures 4 and 5, for estimating maintenance costs for the three size classifications are included at the end of this chapter. In Figure 4, for pumping plants 5 to 149 horsepower, maintenance cost is related to total plant discharge, total design head, mechanic's hourly wage rate, and price level. In Figure 5, for pumping plants 150 to 15,000 horsepower, maintenance cost is related to these same factors and also the annual water pumped. When a plant pumps to more than one elevation, the average of the heads weighted by the unit discharge at each of the design heads should be used.

Hydraulic-Driven Pumping Plants

In the absence of better information, the nomographs for the electric-driven pumping plants may also be used for estimating O&M costs for hydraulic-driven pumping plants.

Reconnaissance and Feasibility Estimates

With the increasing use of pumping plants in plans for potential projects, there has been an increased need for improved O&M estimating procedures and guidelines for this type of project function and feature. Previous guidelines for reconnaissance estimates wherein costs were related only to plant size have been found to be too general to provide sufficiently representative estimates for many pumping situations. In feasibility-type estimates, where it has been necessary in the past to itemize personnel, equipment, and material requirements, there has been need for more criteria with which to estimate number of man-hours, equipment hours, and material quantities for the various pumping plant O&M conditions.

The nomographs developed in this report may be used for either reconnaissance or feasibility-type estimates and provide improved estimating procedures for both types of estimates. For reconnaissance estimates, the results, without adjustment, can be added to other O&M costs estimated separately for other functions or features to obtain the total project O&M cost. However, when used for feasibility estimates, which require the itemization of O&M personnel, the labor part of the pumping plant O&M estimate must be reduced by the amount of wages of the itemized personnel assigned to operation and maintenance of the pumping plant. The horsepower designations give the limits of the supporting data.

Example

Plant Description and Conditions

1. An electric-driven pumping plant (1,500 installed horsepower) pumps from a canal into a lateral. Operation requires the attention of one pump operator who also attends two other pumping plants during an 8-hour day.

2. Q Total plant discharge is 100 cubic feet per second.

3. h Total design head is 100 feet.

4. G Annual water pumped is 20,000 acre-feet.

5. T Length of the operating season is 20 weeks.

6. Wo Pump operator's hourly wage rate is $2.

7. Wm Pump mechanic's hourly wage rate is $3.

8. I Ratio of current price level to 1962 price level is 1.00.

Operation Costs

The classification of the plant is based on the degree of attendance. Assuming the pump operator were to divide his time equally between the three plants, the average daily attendance at each plant for the operating season would be 2.7 man-hours. Therefore, the plant would be classed as a semiattended plant because the attendance falls between 2.5 and 16 man-hours. Considering this, the cost of operation is estimated by use of Figure 2.

Referring to Figure 2, connect Q (total plant discharge) of 100 cubic feet per second to h (total design head) of 100 feet and locate point of intersection on Turn 1. Next, connect point on Turn 1 with T (length of operating season) of 20 weeks and locate point of intersection on Turn 2. From point on Turn 2, connect to Wo (operator's hourly wage rate) of $2 and read C_1 (labor cost) as $2,400. From same point on Turn 2, connect to I (price level ratio) of 1.00 and read C_2 (other costs) as $410. The total operation cost is $2,400 plus $410 or $2,810.

Maintenance Costs

Maintenance costs for a 1,500-horsepower pumping plant would be estimated from Figure 5.

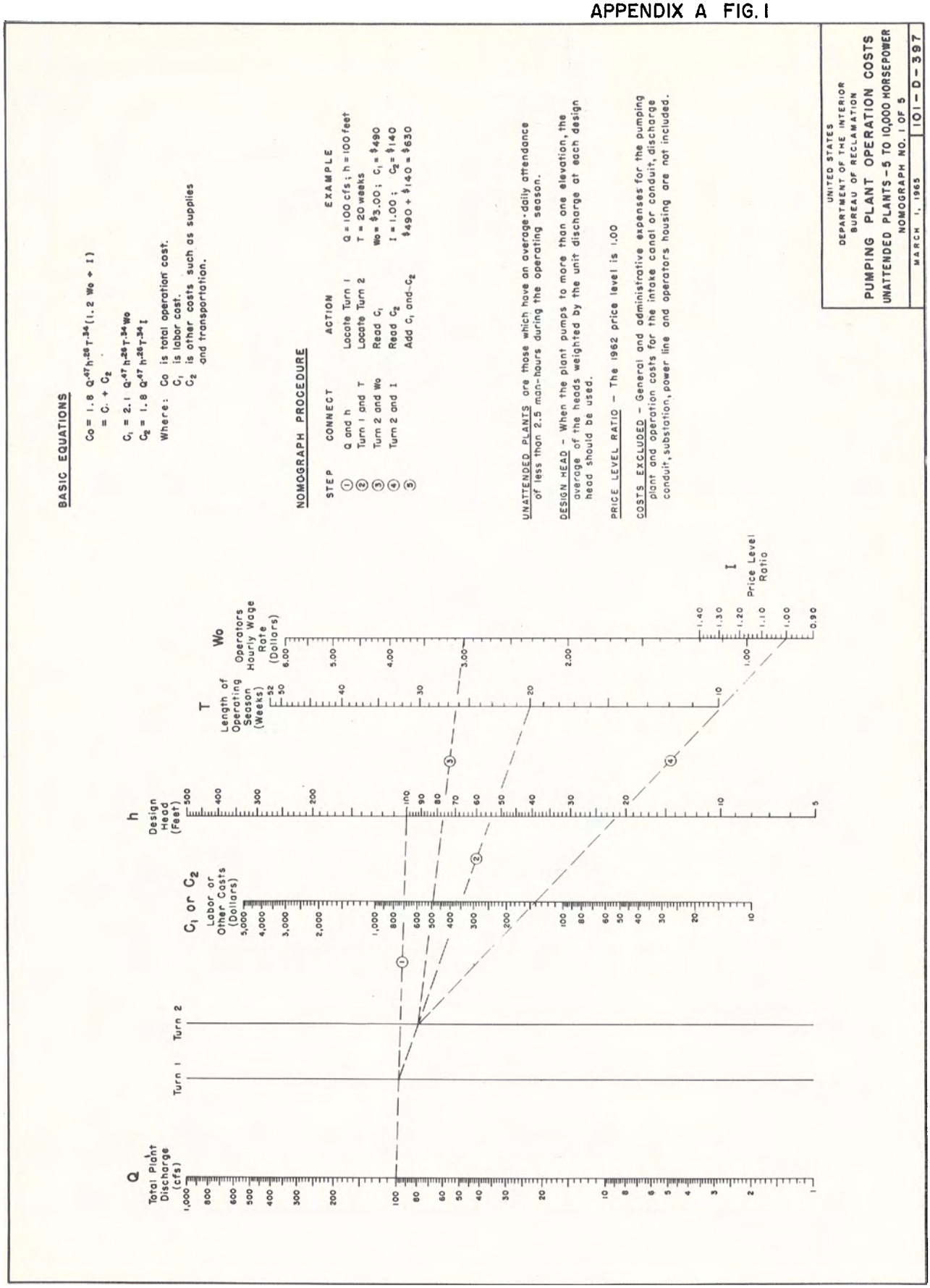
Referring to Figure 5, connect Q (total plant discharge) of 100 cubic feet per second to h (total design head) of 100 feet and locate point of intersection on Turn 1. Next, connect point on Turn 1 with G (annual water pumped) of 20,000 acre-feet and locate point of intersection on Turn 2. From point on Turn 2, connect to Wm (mechanic's hourly wage rate) of $3 and read C_1 (labor cost) for plants 150 to 6,999 horsepower as $2,220. From same point on Turn 2, connect to I (price level ratio) of 1.00 and read C_2 (other cost) for plants 150 to 6,999 horsepower as $1,550. The total maintenance cost is $2,220 plus $1,550 or $3,770.

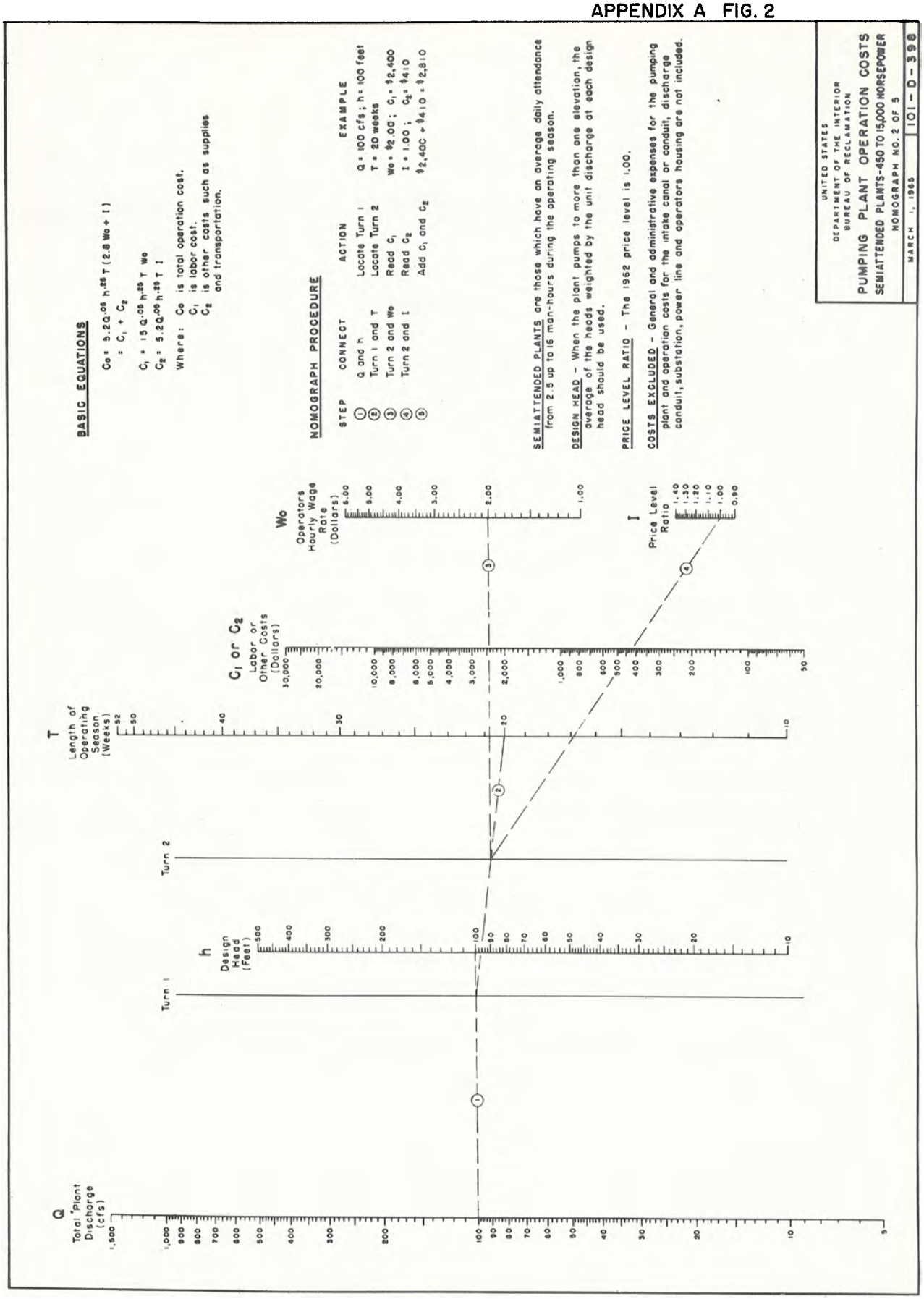
Total O&M Costs

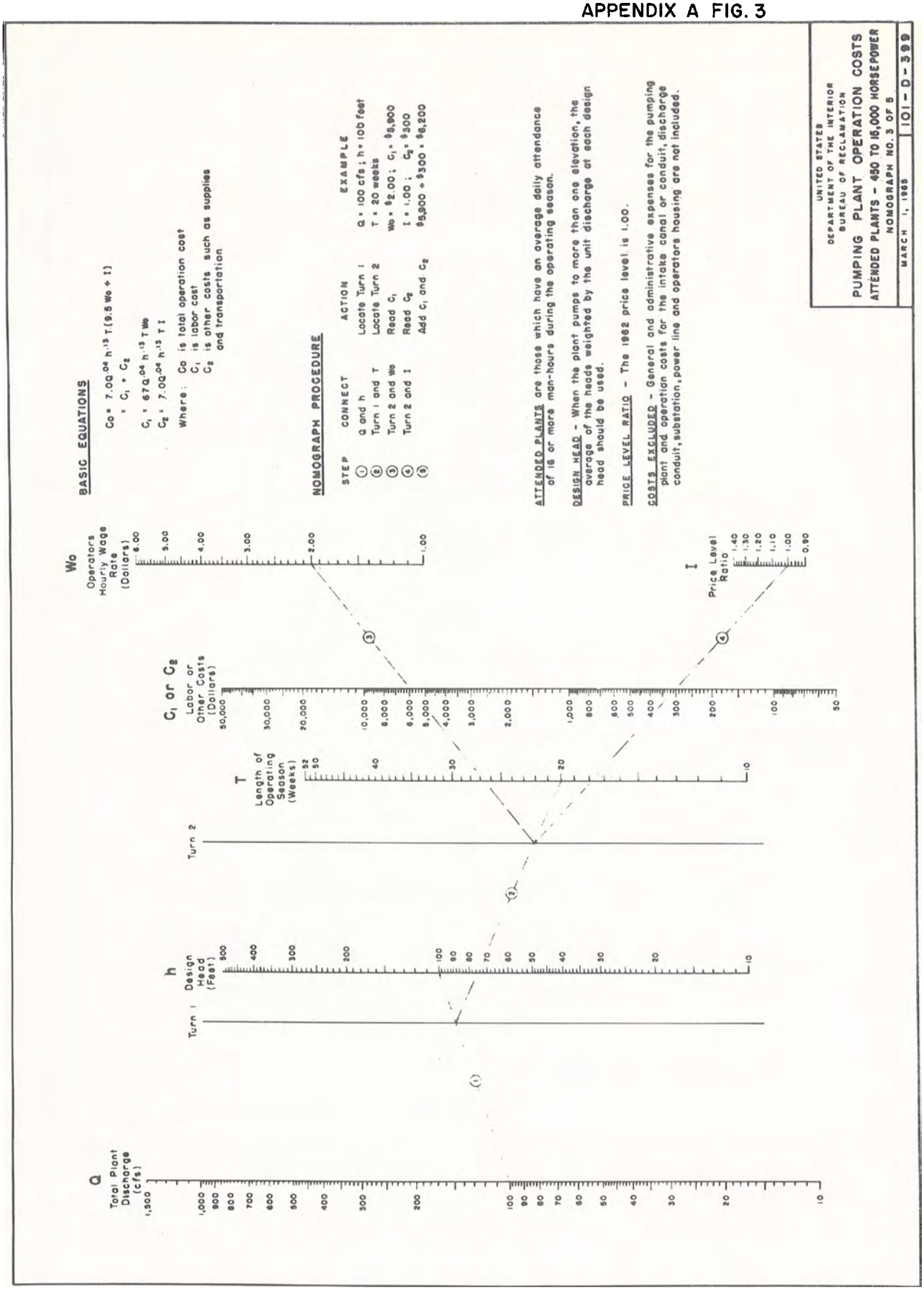
The total estimated annual O&M cost would be as follows:

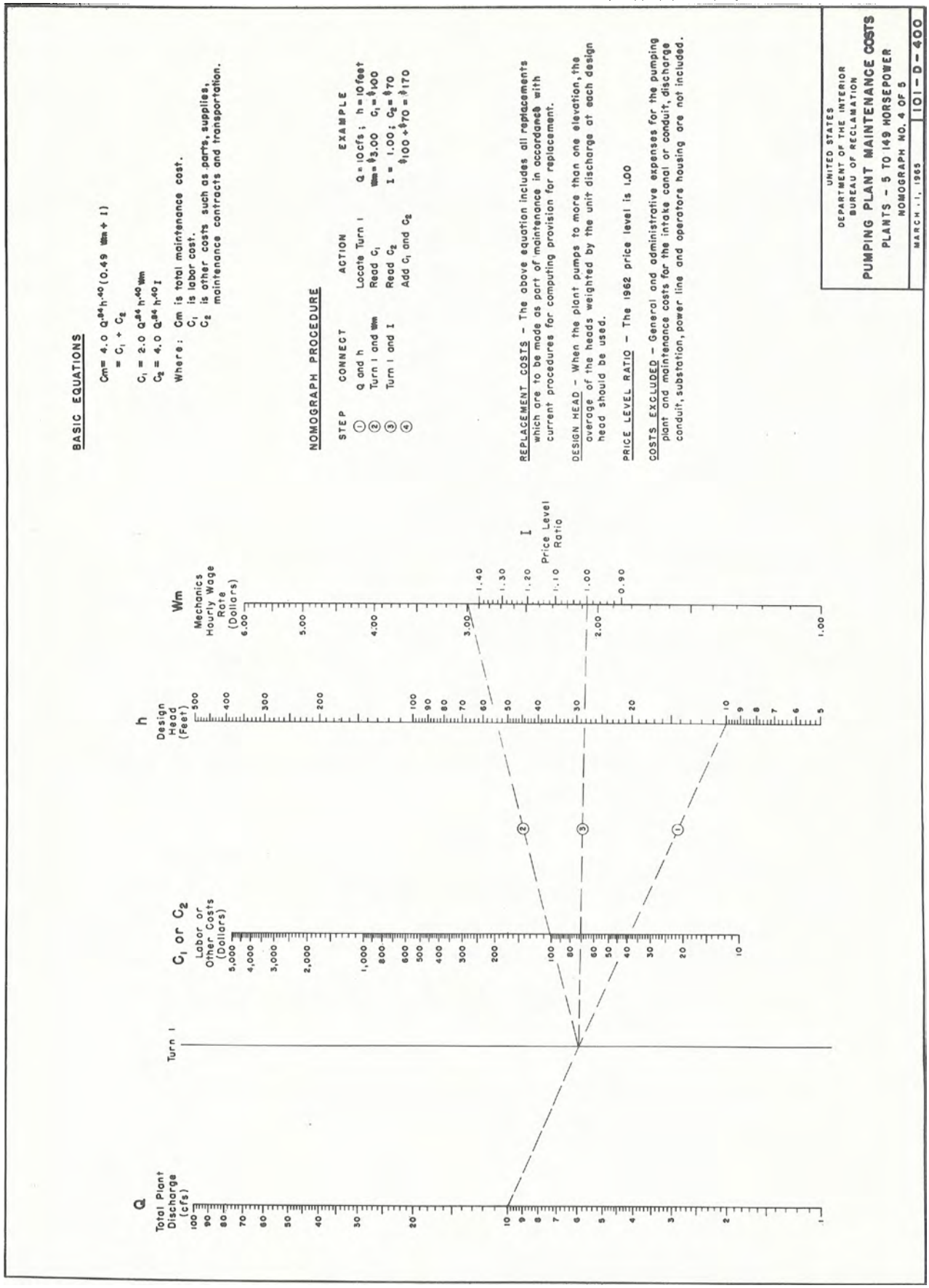
Operation cost	$2,810
Maintenance cost	3,770
Annual O&M cost	$6,580

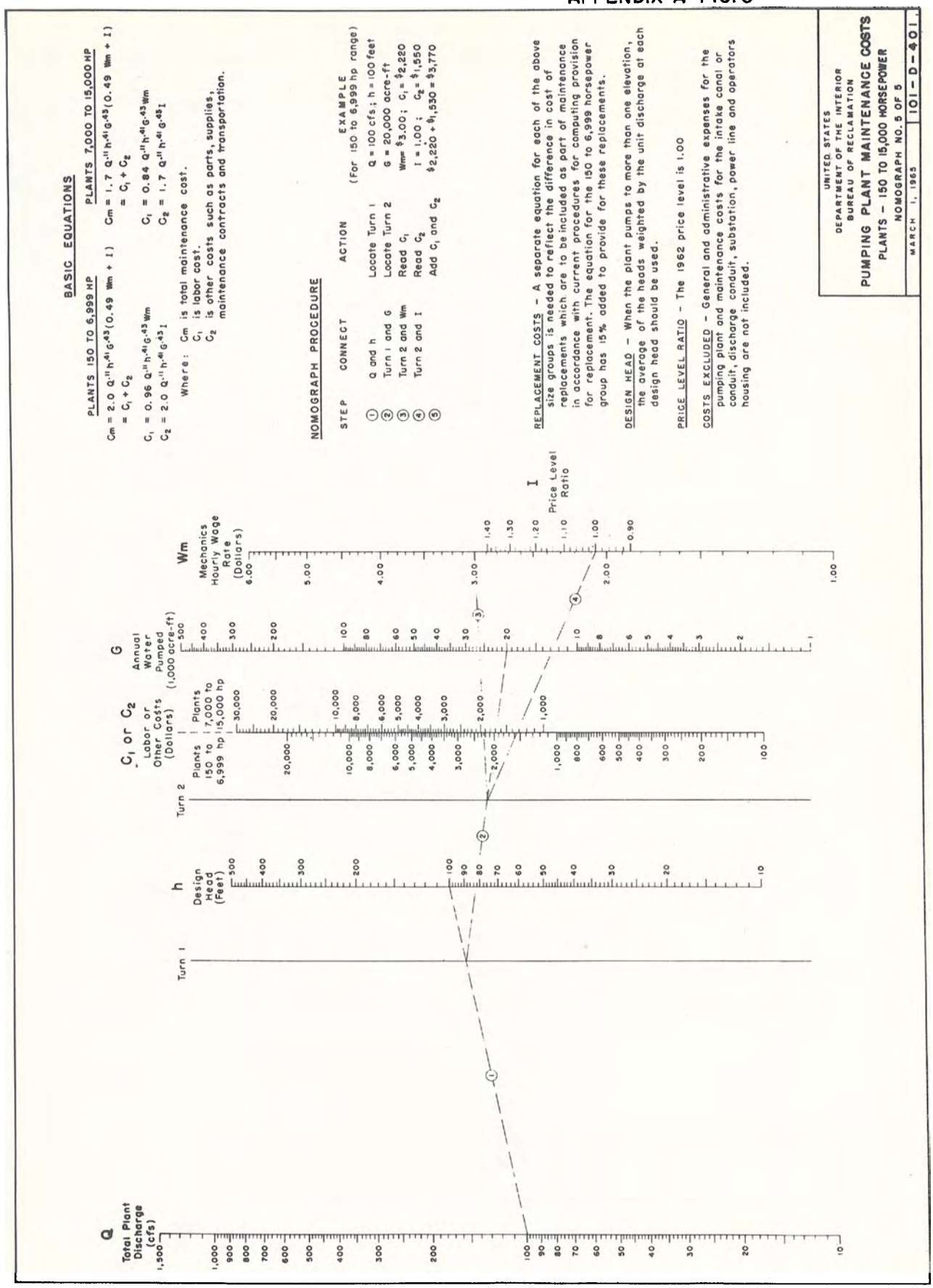
Administrative and general expense, and the O&M cost of intake channels, discharge lines, housing, power service facilities, and unusual trashrack cleaning would be estimated separately, as appropriate, in accordance with existing instructions not included in this report.


BASIC EQUATIONS
Co = 1.8 Q^.47 h^.26 T^.34 (1.2 Wo + I)
= C1 + C2
C1 = 2.1 Q^.47 h^.26 T^.34 Wo
C2 = 1.8 Q^.47 h^.26 T^.34 I
Where: Co is total operation cost.
C1 is labor cost.
C2 is other costs such as supplies and transportation.
NOMOGRAPH PROCEDURE
STEP CONNECT ACTION EXAMPLE
① Q and h Locate Turn 1 Q = 100 cfs ; h = 100 feet
② Turn 1 and T Locate Turn 2 T = 20 weeks
③ Turn 2 and Wo Read C1 Wo = $3.00 ; C1 = $490
④ Turn 2 and I Read C2 I = 1.00 ; C2 = $140
⑤ Add C1 and C2 $490 + $140 = $630
UNATTENDED PLANTS are those which have an average-daily attendance of less than 2.5 man-hours during the operating season.
DESIGN HEAD - When the plant pumps to more than one elevation, the average of the heads weighted by the unit discharge at each design head should be used.
PRICE LEVEL RATIO - The 1962 price level is 1.00
COSTS EXCLUDED - General and administrative expenses for the pumping plant and operation costs for the intake canal or conduit, discharge conduit, substation, power line and operators housing are not included.
Q
Total Plant Discharge (cfs)
Turn 1
Turn 2
C1 or C2
Labor or Other Costs (Dollars)
h
Design Head (Feet)
T
Length of Operating Season (Weeks)
Wo
Operators Hourly Wage Rate (Dollars)
I
Price Level Ratio
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
PUMPING PLANT OPERATION COSTS
UNATTENDED PLANTS - 5 TO 10,000 HORSEPOWER
NOMOGRAPH NO. 1 OF 5
MARCH 1, 1965
101-D-397


BASIC EQUATIONS
Co = 5.2Q^.05 h^.25 T (2.8 Wo + I)
= C1 + C2
C1 = 15 Q^.05 h^.25 T Wo
C2 = 5.2Q^.05 h^.25 T I
Where: Co is total operation cost.
C1 is labor cost.
C2 is other costs such as supplies and transportation.
NOMOGRAPH PROCEDURE
STEP CONNECT ACTION EXAMPLE
1 Q and h Locate Turn 1 Q = 100 cfs; h = 100 feet
2 Turn 1 and T Locate Turn 2 T = 20 weeks
3 Turn 2 and Wo Read C1 Wo = $2.00; C1 = $2,400
4 Turn 2 and I Read C2 I = 1.00; C2 = $410
5 Add C1 and C2 $2,400 + $410 = $2,810
SEMIATTENDED PLANTS are those which have an average daily attendance from 2.5 up to 16 man-hours during the operating season.
DESIGN HEAD - When the plant pumps to more than one elevation, the average of the heads weighted by the unit discharge at each design head should be used.
PRICE LEVEL RATIO - The 1962 price level is 1.00.
COSTS EXCLUDED - General and administrative expenses for the pumping plant and operation costs for the intake canal or conduit, discharge conduit, substation, power line and operators housing are not included.
Q Total Plant Discharge (cfs)
h Design Head (Feet)
Turn 1
Turn 2
T Length of Operating Season (Weeks)
C1 or C2 Labor or Other Costs (Dollars)
Wo Operators Hourly Wage Rate (Dollars)
I Price Level Ratio
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
PUMPING PLANT OPERATION COSTS
SEMIATTENDED PLANTS-450 TO 15,000 HORSEPOWER
NOMOGRAPH NO. 2 OF 5
MARCH 1, 1965
101-D-398


UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
PUMPING PLANT OPERATION COSTS
ATTENDED PLANTS - 450 TO 16,000 HORSEPOWER
NOMOGRAPH NO. 3 OF 5
MARCH 1, 1965
101-D-399
BASIC EQUATIONS
Co = 7.00 Q^.04 h^.13 T(9.5 Wo + I)
= C1 + C2
C1 = 67Q^.04 h^.13 T Wo
C2 = 7.00 Q^.04 h^.13 T I
Where: Co is total operation cost
C1 is labor cost
C2 is other costs such as supplies and transportation
NOMOGRAPH PROCEDURE
STEP CONNECT ACTION EXAMPLE
1 Q and h Locate Turn 1 Q = 100 cfs; h = 105 feet
2 Turn 1 and T Locate Turn 2 T = 20 weeks
3 Turn 2 and Wo Read C1 Wo = $2.00; C1 = $5,900
4 Turn 2 and I Read C2 I = 1.00; C2 = $300
5 Add C1 and C2 $5,900 + $300 = $6,200
ATTENDED PLANTS are those which have an average daily attendance of 16 or more man-hours during the operating season.
DESIGN HEAD - When the plant pumps to more than one elevation, the average of the heads weighted by the unit discharge at each design head should be used.
PRICE LEVEL RATIO - The 1962 price level is 1.00.
COSTS EXCLUDED - General and administrative expenses for the pumping plant and operation costs for the intake canal or conduit, discharge conduit, substation, power line and operators housing are not included.
Q
Total Plant Discharge (cfs)
h
Design Head (Feet)
Turn 1
Turn 2
T
Length of Operating Season (Weeks)
C1 or C2
Labor or Other Costs (Dollars)
Wo
Operators Hourly Wage Rate (Dollars)
I
Price Level Ratio


BASIC EQUATIONS
Cm = 4.0 Q^.84 h^.40 (0.49 Wm + I)
= C1 + C2
C1 = 2.0 Q^.84 h^.40 Wm
C2 = 4.0 Q^.84 h^.40 I
Where: Cm is total maintenance cost.
C1 is labor cost.
C2 is other costs such as parts, supplies, maintenance contracts and transportation.
NOMOGRAPH PROCEDURE
STEP CONNECT ACTION EXAMPLE
① Q and h Locate Turn I Q = 10 cfs ; h = 10 feet
② Turn I and Wm Read C1 Wm = $3.00 C1 = $100
③ Turn I and I Read C2 I = 1.00 ; C2 = $70
④ Add C1 and C2 $100 + $70 = $170
REPLACEMENT COSTS – The above equation includes all replacements which are to be made as part of maintenance in accordance with current procedures for computing provision for replacement.
DESIGN HEAD – When the plant pumps to more than one elevation, the average of the heads weighted by the unit discharge at each design head should be used.
PRICE LEVEL RATIO – The 1962 price level is 1.00
COSTS EXCLUDED – General and administrative expenses for the pumping plant and maintenance costs for the intake canal or conduit, discharge conduit, substation, power line and operators housing are not included.
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
PUMPING PLANT MAINTENANCE COSTS
PLANTS – 5 TO 149 HORSEPOWER
NOMOGRAPH NO. 4 OF 5
MARCH 1, 1965
101-D-400
Q
Total Plant Discharge (cfs)
Turn I
C1 or C2
Labor or Other Costs (Dollars)
h
Design Head (Feet)
Wm
Mechanics Hourly Wage Rate (Dollars)
I
Price Level Ratio


BASIC EQUATIONS
PLANTS 150 TO 6,999 HP
Cm = 2.0 Q^.11 h^.41 G^.43 (0.49 Wm + 1) = C1 + C2
C1 = 0.96 Q^.11 h^.41 G^.43 Wm
C2 = 2.0 Q^.11 h^.41 G^.43 I
PLANTS 7,000 TO 15,000 HP
Cm = 1.7 Q^.11 h^.41 G^.43 (0.49 Wm + 1) = C1 + C2
C1 = 0.84 Q^.11 h^.41 G^.43 Wm
C2 = 1.7 Q^.11 h^.41 G^.43 I
Where: Cm is total maintenance cost.
C1 is labor cost.
C2 is other costs such as parts, supplies, maintenance contracts and transportation.
NOMOGRAPH PROCEDURE
STEP CONNECT ACTION
① Q and h Locate Turn 1
② Turn 1 and G Locate Turn 2
③ Turn 2 and Wm Read C1
④ Turn 2 and I Read C2
⑤ Add C1 and C2
EXAMPLE (For 150 to 6,999 hp range)
Q = 100 cfs; h = 100 feet
G = 20,000 acre-ft
Wm= $3.00; C1 = $2,220
I = 1.00; C2 = $1,550
$2,220 + $1,530 = $3,770
REPLACEMENT COSTS - A separate equation for each of the above size groups is needed to reflect the difference in cost of replacements which are to be included as part of maintenance in accordance with current procedures for computing provision for replacement. The equation for the 150 to 6,999 horsepower group has 15% added to provide for these replacements.
DESIGN HEAD - When the plant pumps to more than one elevation, the average of the heads weighted by the unit discharge at each design head should be used.
PRICE LEVEL RATIO - The 1962 price level is 1.00
COSTS EXCLUDED - General and administrative expenses for the pumping plant and maintenance costs for the intake canal or conduit, discharge conduit, substation, power line and operators housing are not included.
Q Total Plant Discharge (cfs)
Turn 1
h Design Head (Feet)
Turn 2
C1 or C2 Labor or Other Costs (Dollars)
Plants 150 to 6,999 hp
Plants 7,000 to 15,000 hp
G Annual Water Pumped (1,000 acre-ft)
Wm Mechanics Hourly Wage Rate (Dollars)
I Price Level Ratio
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
PUMPING PLANT MAINTENANCE COSTS
PLANTS - 150 TO 15,000 HORSEPOWER
NOMOGRAPH NO. 5 OF 5
MARCH 1, 1965
101-D-401

Use Figures 1-5 | Use for Pumping Plants of 15,000 HP or greater (see note below)

BUREAU OF RECLAMATION PROJECTS
ANNUAL POWERPLANT O&M EXPENSE
(For Reconnaissance Estimating Only, Based on Average 1955 Price Level)

Capacity - kw	2,000	4,000	6,000	8,000	10,000	15,000	20,000	30,000	40,000	60,000	80,000	100,000	150,000	200,000	250,000	300,000	400,000	500,000
Manual Operation (a)																		
Operation	--	23,200	25,500	28,100	31,600	34,900	39,400	42,000	45,600	50,600	54,400	59,600	76,000	93,000	109,000	126,000	162,000	202,000
Maintenance	--	12,800	14,500	15,900	17,400	20,100	22,800	26,000	28,400	31,400	33,800	36,400	44,000	52,000	81,000	69,000	88,000	108,000
Total O&M (a)	--	36,000	40,000	44,000	49,000	55,000	62,000	68,000	74,000	82,000	88,000	96,000	120,000	145,000	170,000	195,000	250,000	310,000
Semi-Automatic Semi-Attended Operation (a) (b)																		
Operation	9,200	11,200	13,500	16,000	19,600	22,900	27,400	30,000	33,600	38,600								
Maintenance	11,800	12,600	14,500	15,900	17,400	20,100	22,800	26,000	28,400	31,400								
Total O&M (a)	21,000	24,000	28,000	32,000	37,000	43,000	50,000	56,000	62,000	70,000								
Remote Control Unattended Operation (a)																		
Operation	500	750	900	1,200	1,600	2,000	2,500											
Maintenance	12,500	13,500	15,250	17,100	18,800	21,400	24,000	27,500										
Total O&M (a)	13,000	14,000	16,000	18,000	20,000	23,000	26,000	30,000										

(a) The above estimates exclude reservoir, dams, and waterway expense and administrative and general expense. Reservoir, dams, and waterway expense depends upon type and purpose of reservoir and/or waterway in the project plan and the portion to be charged to power. See Figure 2 for estimating dam and reservoir O&M expense. For multipurpose reservoirs, add portion to be charged to power to above normal O&M expense. For canals and waterways, add full amount. Estimated O&M expense of power and multipurpose canals and waterways should be handled similarly. For administrative and general expense an allowance of 15 percent should be made of the total plant production - transmission expenses.

(b) Also to be used for remotely controlled plants requiring small plant force to provide "on call" service and part time attendance.

Notes: For plants of intermediate capacity between those indicated above estimates may be obtained by interpolation.

For estimating Pumping Plant annual expense convert the horsepower rating into kilowatts (Factor - .746) and adjust this table for the individual case.