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TUNNELING COST ANALYSIS,

Louis A. Spittel James C. Willyard RMC Incorporated 7315 Wisconsin Avenue Bethesda, Maryland, 20014



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FOREWORD

This report was prepared for the Office of High Speed Ground Transportation Contract FR-00040. Its purpose is to review tunneling costs in various areas of the United States and under varying environmental constraints.

Lately, the tunneling industry has been able to increase productivity to an extent sufficient to offset the escalation of labor costs, but not enough to significantly lower the total cost of tunneling. Those advances which have been achieved are primarily in the form of improvements to existing equipment. The mechanical tunneling machine, although promising in certain applications, does not exhibit the rate of technological advance necessary to achieve the desired total cost reductions.

The Office of High Speed Ground Transportation has provided funds for many research projects to accelerate the rate of technological growth. It is anticipated that this report will provide a means to evaluate the impact of this research on tunneling costs.

The research for this report was carried on from June 1970 to March 1971 under the guidance of Mr. William N. Lucke of the Office of High Speed Ground Transportation. In addition, the authors gratefully acknowledge the cooperation received from the following individuals:

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13. **

INTRODUCTION

This report provides the Office of High Speed Ground Transportation with a review and analysis of tunnel construction costs. The data for all cost analyses in the report were obtained from historical records of tunnel owners, contractors, and equipment and material manufacturers throughout the United States.

As for the report proper, Chapter 2 discusses the kinds of data sought, how the sources were determined, and data problems. Chapter 3 covers the analysis of the data, including the format used in recording costs. Once the cost elements were analyzed to eliminate unbalancing¹ and to accurately relate to performance considerations, it then became possible to develop the basic cost estimating relationships (CERs). (Note: Some of the cost data are of a proprietary nature and therefore have not been printed in this report.)

During the course of collecting the required data, there were numerous opportunities to review the cost impact of different design and construction policies within the tunneling industry. In Chapter 4, some of these differences are presented so that future tunnel planners can consider them as possible ways to reduce costs.

Finally, Chapter 5 outlines some areas for further research that should materially aid in the reduction of tunneling costs.

1. Unbalancing--an adjustment in unit bid pricing that results in their not reflecting a true cost for performing a certain task.

DATA COLLECTION

Data collection--determining owners and sponsoring contractors--was a major effort in this study. However, the Gardner Denver Company greatly aided this task by furnishing a list of tunnel projects for which they had supplied materials and equipment. Other tunnel projects were identified from lists furnished to us by Hercules, Inc. The remaining projects were identified through a literature search at RMC.

Our original study plan called for obtaining the following data for each project:

- (1) From the owner
 - (a) tunnel cross-section details and profiles,
 - (b) tunnel specifications,
 - (c) geologic reports,
 - (d) bid tabulations,
 - (e) final cost adjustments, and
 - (f) production data.
- (2) From the contractor
 - (a) complete bid breakdown
 - labor, material, and equipment allocation for excavation, supports, lining, and indirect costs;
 - (b) crew sizes (each shift)
 - excavation crew,
 - supporting crew,

- Ifning crew,
- labor crew not in tunnel,
- shifts per day, and
- paid hours per shift;
- (c) production data
 - planned time estimate for excavation,
 - actual time required for excavation,
 - planned time estimate for lining, and
 - actual time required for lining.
- (3) From the machine manufacturer
 - (a) machine capital cost,
 - (b) machine operating cost,
 - (c) machine advance rates,
 - maximum per day,
 - average per day,
 - availability, and
 - utilization.
- (4) From local trade associations
 - (a) tunnel labor costs and agreements for the last five years.

Obviously; if one has all of the data defined above for each specific project, the analysis is simple. However, all of these data were not available for each project. For example, some tunnel owners did not have tunnel cross-section details and profiles; in such cases, these data were obtained from the consulting engineers who had designed the tunnel. Geologic exploration and reports were uneven at best--they ranged from very good to none at all. And although production data do exist, in most cases obtaining them was not feasible because they are in the possession of the project engineer responsible for the project. Since he is often now on another project, tracking him down would have been entirely too

time consuming. In a few instances, the owner agency did have centralized production records that were made available.

In sum, the available owner data included dimensional details and low bidder data for all tunnels as well as final costs and geology information for many.

Collecting contractor cost breakdown data was gratifying because, except for one contractor, they were accommodating and asked only that their privacy be respected. However, due to the quantity and diversity of geographic location, time would not permit a visit to the sponsoring contractor for each tunnel project. Consequently, those tunnel contractors visited were of national reputation who had each been responsible for constructing several recent tunnels. Another advantage of obtaining data from these large firms was that they employed a more standardized format for estimating, making our analysis easier. This seems to have been a valid expediency because it has been possible, using these cost breakdowns, to develop logical cost breakdowns on projects for which the contractor has never been contacted.

Contractor cost data were not available on projects that have not been completed or projects for which claims are now pending. Obtaining reliable crew size and production data was not easy because comprehensive reports of tunneling progress are not generally available; it seems that these data were often the sole property of the project manager for each specific project, who was somewhat elusive. The contractor time and material cost breakdown information was a great help, but due to its proprietary nature has been used solely for analysis and may not be reported as raw data in this report.

Obtaining reliable data on mechanical excavator investment and operating costs is difficult for a variety of reasons. But the primary reason is apparently that few mechanically excavated hard rock tunnel projects have been completedly successful for all concerned. Consequently, accurate cost figures, whether good or bad, concerning specific projects could effect the competitive position of machine manufacturers. Also, some machines are placed on projects experimentally, before the manufacturer or contractor is contractually obligated. Under such circumstances,

the contractor's costs might be different from that of the manufacturer. It has also been reported that some contractors have contracted privately with local firms to make cutter bits rather than obtaining all of them from the manufacturer. No doubt, as the hard rock mole surmounts more and more of its obstacles, there will be no need for subsidization, and reliable data will become available. This is not an attempt to be critical of the manufacturer, in fact he and the contractor deserve credit for continuing to develop and experiment. However, it will become more and more difficult for the increased productivity to continue to offset the rise in the cost of labor unless the mechanical hard rock tunneler does become more reliable. This appears to be a particular problem in some of the Northeast Corridor cities where the overall cost of tunneling is higher than elsewhere. Contractors working in these areas appear to have difficulty in being the sole decision-maker in determining the underground crew size, particularly on projects using the mechanical excavator, primarily because of local work rules.

In that reliable rock tunneling machine costs are so sketchy and even nonexistent for very hard rocks and large diameter tunnels, it was not possible to generate cost estimating relationships from only historical data. Therefore, a metalurgical engineer who has done research for and designed rock tunneling outter bits for three of the large manufacturers was visited. He agreed to develop a series of representative costs reflecting variations in tunnel diameter and rock strength. Naturally, when these CERs are used, it is important to keep in mind that the effect of other cost variables on mechanical tunneling--such as mixed faces, large water inflows, and steep grades--could not be included. It is necessary to also point out that rock strength, as measured by unconfined compressive strength, is not the sole criterion for determining machine performance. For example, it has been demonstrated more than once that result brittleness is an important factor although this rock characteristic has not meet reliably modeled.

Very hard rocks containing large percentages of quartz seem quite brittle and relatively easy to penetrate. After developing the CERs from the supplied estimates, the available historical data were plotted and found to show reasonable correlation.

The labor cost data from trade associations--e.g., The Association of General Contractors and The Association of Underground Contractors--are completely reliable because they originated from actual union contacts. Of course, these work agreements set the amount of wages per hour and the cost of fringe benefits but have no bearing on the actual money paid for the hours worked. This is to say that, depending on the distance from shaft to heading, the contractor might pay for eleven hours to get eight hours work, per shift, at the heading.

Generally, the quality of the data is good, giving a high confidence level to the cost predictions for tunneling. The one exception is possibly in the operating costs for boring machines.

COST ANALYSIS

Cost data for this study were obtained from two major sources. The first being contractor data in which costs are expressed in terms of the three basic tunneling tasks (excavation, support, and lining) and the three basic resource elements (labor, materials, and equipment). Additionally, two other costs were provided by the contractor: indirect (broken into labor, equipment, and materials) and other costs (not pertinent to tunnel driving). Contractors who cooperated in the study plan and provided data were assured that their data would be treated as proprietary. Consequently, individual data points based on contractor data will not be identified. The second source of cost data was tunnel "owners" who furnished bid tabulation data and final cost adjustment data. Most of this data is public information and no proprietary conditions are known to exist. In one instance, owner data were proprietary because the owner was not a public agency and costs were unavailable.

The first step in the cost analysis procedure was to develop a standard format for recording the cost data. This format standardization is important in that it allows system costs to be organized into meaningful cost elements which aid in subsequent cost analysis. The requirements for the format are:

- raw data must be easily placed in the format;
- meaningful homogeneous cost elements expressing costs in terms of tasks (e.g., excavation, support, and lining and/or resources (labor, materials, equipment, overhead, etc.) must be determined;

- the cost elements must be sufficiently detailed and as uniform as possible in cost magnitude; and
 - cost elements should be capable of being related to physical performance and program characteristics.

These guidelines were followed in selecting the format used for Appendix A.

Raw data, which were transcribed from bid tabulations, varied considerably in the bidding detail. In some cases, the bidding procedure required furnishing unit costs for more than 20 cost elements pertaining to tunnel construction. Other project documents required only a cost per linear foot for a finished tunnel or a lump sum for the finished tunnel.

The greatest problem of data analysis was that of separating the costs of cement and reinforcing steel used for the tunnel itself, from those costs for construction of nearby facilities and accesses. Previous experience in designing surface facilities led to an assumption of 1.5 barrels of cement and 150 pounds of reinforcing steel per cubic yard of concrete for average conditions. Upon further investigation of several projects where the bidding detail permitted, it was found that reinforcing steel varied from 145 lbs/cu yd to 165 lbs/cu yd which justified our assumption.

Other minor adjustments were made, where appropriate, on a project-byproject basis. These adjustments were few and are footnoted on the specific project sheet in Appendix A.

DATA ANALYSIS

Experience has shown that more reliable cost estimating relationships can be developed at higher levels of cost detail rather than at lower levels. In most cases, extremely detailed cost data reflect significant variations that cannot be adequately explained by physical, performance, and project characteristics. On the other hand, analysis of data at too aggregate a level may produce misleading results by not introducing the proper system characteristics.

The levels of detail selected for this study are presented in Figure 3-1. Cost data for the first three levels were tabulated in Table 3-1. At the fourth level, the data began to reflect significant variation. In addition, many of the cost elements reflected cost values that were insignificant compared to costs of other elements and total project costs. For these reasons, the following discussion is limited to the first three levels.

Preliminary analysis indicated that the most meaningful cost estimating relationships could be developed at the second level of cost detail. Multiple regression analysis was used in relating costs per foot for the three major tasks to physical, performance, and project characteristics.

The physical characteristics used in this study were tunnel size, length of the tunnel, and tunnel geology. Unlined diameters and finished diameters were obtained for all observations in the tunnel sample for which costs were available. These two diameters were used to calculate cubic yard requirements for the excavation and lining tasks. Cubic-yard-per-linear-foot parameters were more convenient for two reasons:

- tunnel projects were usually bid by cubic yards of excavation and cubic yards of concrete (lining) and
- non-linearities present in cost functions related to diameter were reduced by incorporating the area expression.

A second important physical characteristic was a measure of the degree of fracture of the material through which the tunnel is driven. A measure of this degree of fracture--RQD--was not generally provided by tunnel owners or contractors because of problems in definition. Methodology developed by Harza¹ was expressed in terms of pounds of steel sets per linear foot of tunnel versus tunnel diameter with respect to constant RQD levels. Figure 3-2 presents this relation-ship with data points from the study sample. Table 3-1 shows the RQD range of the sample tunnels. No RQD values are shown for soft ground tunnels.

^{1.} Harza Engineering Company, <u>A Computer Program for Estimating Costs</u> of <u>Hard Rock Tunneling (COHART)</u>, (May 1970), p. 30.





Table 3-1 T COST AND QUANTITY DATA POB SAMPLE TUNNELS Å

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Note: Data was not available for items left blank.

Note: Data was not evaluate mor Henra Let Danak. a. Included in excavation. b. Included In Sector 1. b. Includes Integ. c. Includes Henra. d. Includes Henra. e. Includes Henra. f. Includes Henra. f. Includes Silver. f. Costs and quantities of resilversing steal. f. Costs and quantities of resilversing steal and connect uppear high. These theme were expressed in terms of total project requirements and outd ant be allocated to tunasi.

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Table 3-1 (continued

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				Suppo	rt Quantiti	es per CYE			Primary	Sepports			Quantitie	per Cubic Y	ard of Lining		Costs pe	r Cubic Yard o	of Lining]	
CYE per LF alculated	Yards Lining (CYL)	per L Ho- portar	F CYL Per LF Colculated	Steal Sets ([b)	Timber (MBM)	Rock Bolts	Excavation	Steel Seta	Timber	Rock Bolie	Other	Total	Coment (BBL)	Relatorcing Steel (lbs)	Conorste Operations (cf)	Concrete	Cemen	Reinforcing Reinforcing	Other Concrete Operations	Total		
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Project performance, as measured by advance rates, was unavailable for most of the sample projects. Advance rates were found--in this effort as in previous studies--to be a function of tunnel bore, geology, and whether the boring is accomplished by machine or by conventional drilling and blasting methods. Machine advance rates were generally higher for the projects in the sample for which data were obtained. Furthermore, these machine rates also appeared to be a function of the level of technology at the time the machine was produced. For example, the same machine was used in the Water Hollow Tunnel as was used in the earlier Azotea Project. The advance rates for the two tunnels were approximately the same (Water Hollow advanced at 300 LF per week compared to 340 LF for the Azotea). However, the River Mountain Tunnel, which was bid in the same time period as the Water Hollow, used an up-to-date machine which averaged 510 LF per week:

Preliminary regression analysis resulted in high coefficients of variation (indicating considerable variation between actual values and estimates of the regression equation) and low coefficients of correlation. The coefficients of variation that resulted from the preliminary analysis ranged from 40 to 60 percent.

Closer inspection indicated that the variation was not as great as the statistical measures reflected. In many cases, an overestimate in one task would be offset by a corresponding underestimate in one or both of the other tasks for a particular tunnel project. This effect was caused by the bid "unbalancing" described in the previous chapter.

Regression analysis was first performed on the lining task. Several of the sample tunnel projects reflected the effects of bid "unbalancing" in this task. Low costs in this element were offset by high costs in either the support or excavation tasks. When this effort was determined to exist in a sample project, the project was dropped from the sample. This procedure allowed the cost estimating relationship to be developed with a minimal amount of distortion caused by unbalancing.

Costs per linear foot were related to cubic yard of concrete requirements per linear foot of tunnel using the calculated values. An allowance of 15 percent overbreak was used for hand-mined tunnels (15 percent of the excavated volume).

A fixed cost was indicated by the residual values of the equation. The reciprocal of tunnel length was introduced as a parameter that would measure the magnitude of this fixed element. The resulting value (\$245,400) compared favorably with costs of the concrete plant and the lining forms. This equation is presented in Table 3-2.

Regression analysis was next performed on the support task. Only three observations (San Fernando, Hells Canyon, and Lawrence Avenue) were excluded from the sample. These three observations were excluded because no quantities associated with supports were available.

The most cost significant item in the support category was steel sets. Tunnel projects for the Metropolitan Water District of Southern California (MWDSC) were bid by direction (\$.18 per pound) for all amounts of steel sets in excess of the specified bid quantity. In addition, bid quantities for the specified quantities were somewhat less than \$.18 per pound. Since most other tunnel projects reflected unit prices considerably in excess of this amount, it was assumed that unit prices for MWDSC tunnels included only the material cost. For this reason, a "stratification" variable was entered to allow labor and material elements to be shown separately.

Support costs were related to quantities of steel sets (lbs), rockbolts (l.f.), and timber (MBM). All these variables were expressed in terms of linear feet of tunnel. Rockbolts and timber requirements were relatively insignificant for the sample data. Regression analysis could not provide suitable coefficients (i.e., coefficients were of the wrong sign and/or magnitude and were found to be statistically insignificant). For this reason, averages derived from Appendix A (\$2.00/1.f. rockbolt and \$300/ MBM timber) were used as coefficients for these terms.

Support costs were correlated with quantities of steel sets using the stratification variable. The resulting equation indicated \$.1785/LB for material cost and \$.1465/LB for labor. This relationship was entered in Table 3-2.

TUNNEL COST ESTIMATING RELATIONSHIPS

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Total Tunnel Equations by Major Task (Lovel 2, Figure 3-1) Equations for Total Dunnel (Level), Figure 3-1) \$/LF = 194.375 + 5.272 CYE Excavation Conventional (hand) 11QD>75% Option 1: Use if support quustities are available. Conventional (hand) RQD>75 \$/LF = 190.15 + 5.27 CYE + .325 SS LF + 2.00 HD + 300.00 T + 215, 100 + 35, 41 LF \$/LF = 351. 498 + 12. 565 CYE Conventional mandi ROD<769 \$/LF = 73.762 + 10.007 CYE Machine Conventional (hand) HQD<75. $LF = 347.27 + 12.66 \frac{CYE}{LF} + .325 \frac{RE}{LF} + 2.00 \frac{RB}{LF} + 330.00 \frac{T}{LF} + \frac{245,400}{LF} + 33.64 \frac{CYL}{LF}$ Coefficient of Correlation = $\frac{1}{2}$ LF = 69.54 + 10.67 $\frac{CYE}{LF}$ + .325 $\frac{89}{LV}$ + 2.00 $\frac{BB}{LV}$ + 300 $\frac{T}{LV}$ + $\frac{245,400}{LV}$ + 38.64 $\frac{CYL}{LV}$ Machino Standard Error - 49.60 Coefficient of Variation = .133 Quantity Available \$/LF . 323 1.F . 2.00 1.F + 300.00 1.F Supports Option 2: Use if support quantities are not available. Conventional (hand) IKQD>75 \$/LF = 190.18 + [5.272 + .37 (100 - RQD%)] CYE + 245,400 + 39.64 CYE Standard Error = 41.41 3-12 Coefficient of Variation = . 338 Conventional (hand) RQD<75 \$/LF - 347.27 + [12.565 + .27 (100 - RQIVb)] (YE) + 245,400 + 36.64 (YL) Quantity not Available \$/LF = . 27 (100 - RQD2) x CYE \$/LF = 69.54 + [10.667 + . 27 (100 - RQD%)] CYE + 245,400 + 38.64 CYL Machine $LF = -4.224 + \frac{245.490}{LF} + 36.644 \frac{CYL}{LF}$ Lining **Option 3: Planning Model** Coefficient of Correlation Standard Error - 42.29 Conventional (hand) RQD>75 $\frac{11}{1F} = 190.16 + [14.00 + .395 (109 - RQD7)] \frac{CYE}{1F} + \frac{245,400}{1F}$ Coefficient of Variation Conventional (hand) RQD<75 \$/LF = 69.54 + [21.31 + .395 (200 - RQDT)] CYE + 245,400 $\frac{1}{2}$ (LF = 69.54 + [19.42 + .395 (100 - RQD%)] $\frac{CYE}{LF}$ + $\frac{245,400}{LF}$ Maching Key LF = Linear Feet of Tunnel CYE = **Cubic Yards Excavation** Steel Sets (pounds) Rock Bolts (linear feet of rock bolt) - Timber (MBM - Thousand Board Feet) CYL = Cubic yards lining (concrete)

Table 3–2

Fourteen sample observations reflected no support costs or quantities (support costs were included in the excavation task). In addition, three observations, as stated previously, reflected support costs but no quantities. For this reason, cost estimating relationships were derived for support costs as a function of tunnel size (cubic yards excavation per linear foot of tunnel) and geology--measured by RQD. This relationship is shown in Table 3-2 and can be used as a tool in estimating tunnels that reflect no support quantities or in planning purposes.

Excavation costs (including material handling) reflected variation caused by

- (1) "unbalancing" with respect to lining task costs and
- (2) differences in allocating labor costs between the excavation and support tasks.

For this reason, excavation costs used in the regression analyses were obtained by subtracting support and lining estimates from total tunnel costs. The support costs used in this calculation were those derived by multiplying the support quantities by the unit prices derived in the support regressions. Other tunnel projects, for which quantities were not available, used estimated support costs per cubic yard of excavation with respect to geology.

Regression analysis indicated that excavation costs were related to tunnel size (cubic yards of excavation per linear foot) and geology. The resulting equation is shown in Table 3-2.

Table 3-3 presents the actual costs for the sample tunnel projects and those provided by the regression equations. Variance measures (residual values and percent differences) between these costs computed in Table 3-3 indicated the three equations did well in estimating total tunnel costs. More variance--caused by bid "unbalancing"--was indicated between the actual and estimated costs for the three major tasks.

Equations for the three major tasks were aggregated to provide equations to estimate total tunnel costs. Three equations are provided to estimate these totals in Table 3-2. The first of these is recommended when support quantities are available.

Table 3-8

COMPARISON OF ACTUAL COSTS AND EQUATION ESTIMATES FOR THE SAMPLE PROJECTS

		Actual	Inte	,		Estimated	i Data.	والأطب القيها البادلي ب		Portont
No.	Excavation	Support	Lining	Total	Excavation	• Supports	Lining	Total	Residual ^C	Difference ^d
1	248.20	16.58	61, 89	326.67	244.07	11.71	50.78	306.56	20.11	-6.16
	101 76	87 10	0.04 98.98	300.00	252.00	20.00	16.29	325,61	-16,93	5.48
Å Å	447 20	80.79	30.30 AQ: AQ	204.24	210.35	30,95	20.48	275.80	8.44	-2.97
	997 80	40.99	70.90	240 42	220.02	33.74	53.18	316.32	18.14	-5.42
	440 31	112 07	146 69	717 08	- 058 00 /	21.30	93.13	416.81	-16.39	22.44
	807 00	188 13	200.00	1050 95	860.41	430.04	232.92	723.74	-5.78	0.81
	494 60	100.11	256 04	700.91	004.41	250, 31	203.11	1112.03	-52.78	4.98
	912 55	104.14	08.04	403 68	241.40	· 400.10	2/3.03	780.65	9.50	-1.21
10	801 08.	1146 88	50.04	0406 57	407.00	234.30	175.57	618.07	-14.42	2.39
11	700 34	926 60.	201 44	1200 75	500.97	409.90	020.10	2375.93	04.09	-2.09
12	1186 10	202 44	302. 11	1705 45	018 30	323.00	321.40 601 20	1314.03	24.09	-1.80
15	505 70	088 49	94 11	A100.40	481 83	014 21	122.30	1829.09	-04.24	3.04
14	632 71	197 14	810 49	1520.40	4691.01	119.01	177.29	1499.00	-7.04	0,94
18	190-99:	19 89	63.00	242 04	119.01	430.00	403.08	1428.99	110.41	18 02
14	150 93	7.61	RA 82	102 97	110.01	80 10	07,43	203.72	38.32	-10,83
17	149.9J	1 14	64 68.	153.31	112.60	90.18	91.10 57 53	209.11	-15,74	0.14
19			01.00	104.13	011 00	100.01		171.80	-17,73	11.50
10			· ·	970 48	061.69	422.21	100 21	407.40	- (03.01 -	25.42
20	182.98	2.64	61.00	246 63	010 48	14 06	152.31	510.00	239.34	00.07
21	894.19	90.10	127:50	741 72	252.00	127 50	33.90	253.07	184 50	14.95
1 22	490 89	188 13	780 94	1466 97	479 05	121.00	140.43	906,24	-104.32	22.13
23	871 69	205 81	985 73	1047 23	478.14	151 49	134.13	1400.99	1.00	-0.13
26		200002.	2001.0	247 30	124:04	191.40 97 9h	90.01	1111.00	-08.35	0.00
27	• •			240.00	124.54	27.00	110.60	433.01	10 20	-1.39
28	:			275 00	162.93	25 47	124 94	212.30	-12.30	4.13
. 29	· · · ·			230 00	124 58	27 14	134.24 01 94	022. 34 029 EA		10.93
30				1063 60	A17 74	107 10	31.01	203.04	-23,92	10.23
31			-	261 60	142.62	21 19	208.20	013.04	230.30	-23.30
32			1	101 10	124.56	07 14 ·	100.03	410.0 1	-9.34	49.12
33				190 74	194 66	27.14	109.91	203 41	101.51	42.13
34	396 RG	2.82	87.00	205 50	290.91	21.17	100.71	322, 41	-131.01	09.03
35	259.00		48.04	304 04	192.10	34.31	69.20	330.83	04.10 A1 91	-10.37
36	269,00		64.98	324 96	161.76	20.04	74 97	444.13	10.05	-20, 74
40	336.80		75.08	411 89.	174.35	44 90	70.07	213.91	110 67	-15.09
54	1177.31	56.44	593.87	1827.64	311.45	111.13	495.86	918.44	909.20	-49.75
<u> </u>										
l	•			Average	Standard	Coefficient	Percentare			
]	,		· //	Cost	Error	of Variation	Error			
	Lir To	nited Sample Ial Cample	L .	800 . 9 7 649 . 3 7	43. 12 172. 0 9	5,38 26,50	8.23 24.60	î.	. ,	

Consists of observations used in developing the relationships. These are Numbers 1-17, 20, 22, 23. Lining costs were adjusted by multiplying project unit prices times values of 1.8 bbls cement per cubic 8.

b.

yard lining and 20 lbs. Rebar por cubic yard lining for all projects reflecting values in excess of these two limits. Actual Cost minus Estimated Cost.

c.

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d. Estimated Cost divided by Actual Cost minus 100%.

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If these quantities are not available, the second equation can be applied using an estimate for the value of RQD. The third equation is useful in planning exercises where only the tunnel bore and geology are required for input to obtain the tunnel estimate. For this latter equation, lining thicknesses were normalized for the ranges of RQD.

Graphs are also provided as a tool for estimating costs of future tunnel projects. These graphs provide cost as a function of unlined diameter and RQD to eliminate the need for calculating cubic yard per linear foot requirements. Total cost as a function of unlined diameter and RQD is shown in Figure 3-3.

As mentioned previously, contractors often distorted costs of the three major tasks--excavation, supports, and lining--by "unbalancing" their bids. For this reason, both actual costs and equation estimates were plotted against unlined tunnel diameter with respect to RQD. Figures 3-4 through 3-9 present the graphical relationships of the three major tasks as a function of unlined diameter and RQD.

Cost factors were obtained for the cost elements at level 3--Figure 3-1. These factors were derived by calculating average values from Table 3-1 for all cost elements except excavation and concrete. The factor for obtaining estimates of the excavation task is identical to the equation shown in Table 3-2, except that it is arranged to provide estimates expressed in terms of cost per cubic yard of excavation. The concrete cost factor was obtained by rearranging the lining cost equation in Table 3-2 to be expressed in terms of cost per cubic yard of concrete and subtracting the cost per cubic yard of concrete averages for cement, reinforcing steel, and other concrete operation costs. These cost factors are presented in Table 3-4.





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Excavation ^a	\$/CYE =	5.272 + 190.15 (LF/CYE)
	\$/CYE =	12.565 + 347.27 (LF/CYE)
	\$/CYE =	10.667 + 69.54 (LF/CYE)
Supports		• • • •
Steel Sets	\$/LB =	\$.325
Rock Bolts	\$/1.f. =	\$2.00
Timber	\$/MBM=	\$300
Lining ^a		
Concrete	\$/CYL =	23.52 + 245.400/CYL
Cement ^b	\$/CYL =	8.08
Reinforcing Steel ^b	\$/CYL =	1.60
Other Concrete Operations	\$/CYL =	5.44

COST FACTORS FOR LEVEL 3 (FIGURE 3-1) ESTIMATES

Table 3-4

Key: LF = Linear Feet of Tunnel CYE = Cubic Yards Excavation CYL = Cubic Yards Lining (concrete)

- .a. Negative lining constant (-4.224) in Table 3-2 was set to zero. Excavation constants reflect this amount subtracted.
- b. Cement and reinforcing steel costs were adjusted by multiplying project unit prices times values of 1.8 bbls cement per cubic yard lining and 20 lbs reinforcing steel per cubic yard lining for all projects reflecting values in excess of these two limits.
MACHINE TUNNELING COSTS

The purpose of presenting machine tunneling costs is to provide some insight into the trade-off economics for consideration between machine and conventional "drill and shoot" excavation. The costs presented are intended to be exclusive of those associated with material removal.

The cost of purchasing a machine is somewhat like acquiring an automobile in that advertised prices do not always include desirable and sometimes essential equipment. For example, a laser guidance system is generally not included because there is more than one type, and price, available. They vary from a simple target indicating type, which still requires an operator to manually guide the machine, to the much more sophisticated types, which are coupled automatically to the machine steering mechanism. A dust removal system is also optional because some geologic conditions do not require its use. Some more essential items not always included are the material loading system or the cutter head and cutter set. It was found in one or two instances that a fully equipped machine from one manufacturer will cost 60 to 80 percent more than a "stripped" machine, of the same size, from another manufacturer. Some of this difference, quite possibly, could also be caused by variations in manufacturing costs.

Some price reductions have been achieved by modifying or overhauling used machines; it is apparent that standardization of tunnel sizes could make this practice more common. Foreign-made machines appear to be lower priced than some machines manufactured in the United States, but shipping charges might offset these savings.

True operating costs are also difficult to obtain due to private negotiations between manufacturer and contractor. At this time, some subsidization takes place on certain projects. For example, a manufacturer may, as an inducement, offer to bore some amount of tunnel footage free in order to back up a promised advance rate or cutter cost. Or a manufacturer may, as inducement, guarantee the cutter cost, which means that he may lose money. The final true cutter cost

records have not been made available. One manufacturer could not supply cutter costs because he reported that some contractors, on machine projects, had their cutter bits made locally. The price of one manufacturer's machine includes the cost for maintaining a factory representative at the job site for the duration of excavation.

An additional problem in projecting rock machine cost data to 40-foot diameter tunnels is that, based on historical data, the advance or boring rate in such a tunnel is almost zero. This is primarily due to the lagging cutter bit research, which shows that as diameter increases, boring rates decrease. There is no theoretical reason why boring rate could not be relatively constant with diameter. Greater research efforts should prove this; therefore, lacking historical data on the 40-foot tunnels, projected costs were based upon projected technology also.

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The various rule-of-thumb cost estimating relationships supplied by manufacturers for predicting machine investment cost appeared to have little agreement between them. It seems that each rule of thumb is valid only for those machines-operating in their design environment--that have actually been built. They are of no use for larger tunnel diameters and variations in geology. The CERs are intended to give a more realistic view of tunnel machine cost for a greater environmental variation.

Figure 3-10 shows rock tunneling machine investment costs and Figure 3-11 shows the soft ground tunneling machine investment costs. The cost estimating relationships were constructed using some actual costs, where available, and projections based on extrapolations of manufacturing specifications for torque, thrust, and weight for known existing and successful machines. The costs shown are intended to include equipment required for production tunnel boring. The rather widely heard criterion of \$1,000 per horsepower for the cost of a tunneling machine appears to be broadly acceptable, with reservations. First, this price does not seem to include costs for a set of cutter bits, a dust control system, a



Figure 3-10: ROCK TUNNEL MACHINE COSTS





laser guidance system, or a material loading system. Second, it appears that a lag in cutter bit bearing development has allowed smaller horsepower requirements for larger diameters than economical boring rates would dictate. If thrust and RPM of cutter bit bearings could be increased, cutter head RPM would not have to be reduced on large diameter machines. This, in turn, would require greater horsepower, at greater cost, for large machines, but should greatly improve boring rates.

Figure 3-12, which shows machine advance rates for various rock strengths, was constructed primarily from industry estimates. There is no variation in diameter shown because, as discussed previously, if historical data are extrapolated to large diameters we get unrealistic advance rates. The boring rate shown reflects present technology in existing machine diameters and the assumption has been made that when larger machines are built technological advances will permit a relatively constant boring rate. Several points from historical records have been shown; they seem to substantiate the findings. The large diameter machines did have very slow boring rates, but they were relatively old machines. The most recent machines' rates follow the estimates very closely. It should also be noted that of the few recent medium-sized machines, an improved technology is apparent. Accelerated cutter bit research should close the gap in diameter constraints.

Figure 3-13, which shows rock cutter costs, is also based primarily on industry estimates due to a lack of reliable data. The reason for showing two cost estimating relationships for 15,000 psi rock is due to the change from steel cutters to tungsten carbide cutters. It was estimated that this would take place at approximately 15,000 psi. The small amount of reliable data that was available has been shown and agrees well with the estimates.

Figure 3-14, which shows the direct labor cost, assumes the crew size to be determined solely by the manufacturer or the contractor. The crew size could be relatively constant with diameter variations, which limits the cost per linear foot



Figure 3-12: MACHINE ADVANCE BORING RATE









primarily to variations in boring rate. The discontinuity, shown on the graph, is occasioned by a reported slight increase in boring rate when carbide cutters are installed at 15,000 psi of rock strength. There were no reliable historical data available for calibration of Figure 3-14.

The cost of machine maintenance, repairs, and power is shown in Figure 3-15. This CER is based on an assumption of machine amortization over five miles of tunnel.



Figure 3-15: MECHANICAL ROCK EXCAVATOR MAINTENANCE COST

TUNNELING COST REDUCTION

Tunneling contractors have done much to keep the tunneling cost from escalating at as rapid a rate as experienced by other segments of the construction industry. There is little doubt that effort will be continued, but indications are that the job of holding down costs will be getting more and more difficult. Consequently, during the data gathering phase of this study the views of contractors, owners, and engineers were sought regarding possible procedures or techniques for maintaining or improving the costs of tunneling.

STANDARDIZATION

Reducing the amount of hand labor in tunneling in favor of increased machine production will obviously result in cost reduction; however, the increased machinery cost must be reckoned with. To derive the greatest benefit from his machines, the contractor must strive for the most intensive use of this equipment. Consequently, he must evaluate all equipment purchases in view of "use intensity" and idle time between tunneling jobs. Some "owners" who, for example, needed a 10-foot diameter tunnel were quite happy to accept a 12-foot or 13-foot tunnel for the same costs, or less--just because the contractor had some equipment, e.g., a sliding floor or jumbo, which would not work in a 10-foot tunnel. Tunneling machines are being designed for each tunnel project and only rarely, if ever, are they not written-off on the job for which they were originally purchased. Clearly, costs would be lower if the machines could be written-off over several tunnels. Still another example

is the forming for concrete lining the tunnel, which must be constructured individually for each project.

Tunnel sizes and shapes should be standardized into perhaps six or eight sizes and one shape--instead of circular, horseshoe, basket handle, modified horseshoe, modified basket handle, etc. The payoff here is threefold: first, the equipment can be produced in greater quantity at lower cost; second, the contractor can anticipate greater usage with a corresponding lower write-off cost; and third, greater anticipated use will justify greater expenditures, by equipment manufacturers, to improve and develop new equipment.

However, standardization of the inside tunnel diameter and shape without some universal criteria for lining thicknesses would be only a small improvement. Usually, the final design thickness is usually some function of the tunnel diameter, i.e., 1 inch per diameter foot, or 3/4 inch per diameter foot, etc. Likewise, design concrete strengths generally tend to be 2500 psi or 3000 psi. There is no attempt to criticize any of these rule-of-thumb criteria--but it does seem reasonable that if 3000 psi concrete and 1 inch per diameter foot could become a lining standard, extraordinary conditions requiring a strong lining than this might be satisfied by increasing the concrete strength, i.e., use 4000 psi or 5000 psi concrete instead of 3000 psi. This will not only save money from a lining standardization standpoint but is a relatively inexpensive way to obtain a stronger lining.

CONTRACT AWARDING

Some cost reductions can be achieved by simply changing the criteria by which tunnel contracts are awarded. Instead of awarding contracts to the apparent low bidder, they should be awarded to the contractor offering the lowest anticipated final cost, to the owner, who additionally must pay interest on the utility bond. We are referring to the added expense, to the owner, of an unbalanced contract bid. For example, let's look at a hypothetical but reasonable situation:

Assume

(1) tunnel diameter = 24 feet (I.D.)

(2) tunnel length = 6 miles

The bid quantities could be:

	Bid Quantity
mobilization	lump sum
excavation	722,000 c.y.
structural steel supports	5,000 tons
concrete lining	192,000 c.y.

Assume that the low bid is submitted as follows:

· · ·	Quantity	Unit Price	Total
mobilization	· · · ·	lump sum	2,500,000~
excavation	722,000 c.y.	\$ 36/c.y.	25,992,000
structural steel supports	5,000 tons	\$600/ton	3,000,000
concrete lining	192,000 c.y.	\$ 15/c.y.	2,880,000
		Total	94 979 000

And the second low bid is:

	Quantity	Unit Price	Total
mobilization	• ,	lump sum	500,000
excavation	722,000 c.y.	\$ 30/c.y.	21,660,000
structural steel supports	5,000 tons	\$600/ton	3,000,000
concrete lining	192,000 c.y.	\$ 50/c.y.	9,600,000
·		Total	34 760 000

The low bidder is apparently low by \$388,000, but the owner is wrong if he thinks that the taxpayers have saved this money.

Looking at a reasonable construction schedule:

Date of contract award	January 1, 1971
assuming 30 ft/day (average)	March 1, 1975
Date of lining completion assuming 3200 ft/month	December 1975

Now assuming an interest rate of 6 percent/year on the construction bonds, and a uniform tunnel advance rate:

• • •		Approximate Time	Approximate
Low Bidder		For Interest	Interest
mobilization	2,500,000	5 Years	\$ 900,400
excavation	25,992,000	2 Years	1,665,600
supporting	3,000,000	2 Years	191,280
lining	2,880,000	5 Months	72,000

Total Interest (disregarding other work) \$2,892,280

	:)	Approximate Time	Approximate
Second Bid	der	For Interest	Interest
mobilizatio	on 500,000	5 Years	\$ 80,020
excavation	21,660,000	2 Years	1,380,000
supporting	3,000,000	2 Years	191,280
lining	9,600,000	5 Months	241,920
	Fotal Interest (disr	egarding other work)	\$1, 893, 220
.]	Difference		\$ 936,070

Net additional cost to taxpayer by awarding the contract to an unbalanced low bid.

\$936,	070
388,	000
\$548,	070

This situation could be avoided by making a similar analysis of tunnel bids and awarding the contract to the bidder submitting the "low anticipated final cost," instead of low bidder. Many bids are unbalanced simply to obtain greater than normal payments early in the construction phase. This is not always the case, however.

Sometimes unbalancing is virtually forced upon a contractor to avoid losing the job. Using the previous hypothetical bid quantities, suppose that the engineer made a 25 percent error when computing the amount of concrete lining.

concrete lining 1.25 (192,000 c.y.) = 240,000 c.y.

When the estimator checks this quantity, using the lining thickness, tunnel length, and estimated over-break concrete, he will detect the error. The estimator has found the concrete error, and now he prepares an estimate of his cost to line the tunnel. His cost has little to do with the advertised concrete quantity but is based on the fixed cost of plant, equipment, and forms, the cost per day for labor and overhead, and the number of weeks required to line the tunnel. In other words the lining cost is first determined as a lump sum and then by simple division is converted to a price per cubic yard. Again, from the previous example,

cost to line tunnel \$9,600,000

If this price is spread over the incorrect concrete quantity of 240,000 cubic yards, the unit bid price becomes:

$$\frac{9,600,000}{240,000} = $40/c.y.$$

However, the estimator knows that only 192,000 cubic yards of concrete will be used, bringing a return of only:

 $40 \times 192,000 = 7,680,000, \text{ or } 9,600,000 - 7,680,000 = 1,920,000$

less than anticipated. If he uses the proper \$50/cu yd and the engineer's incorrect quantity, he bids:

50 per c.y. x 240,000 c.y. = \$12,000,000

which may lose the job. Knowing he is faced with a quantity reduction, the estimator must drastically reduce his unit price bid to minimize the total dollar loss for the item:

 $15/c.y. \times 240,000 c.y. = 33,600,000$

now he must put

\$9,600,000 - \$3,600,000 = \$6,000,000

back into his bid. Along with the

 $(240,000 - 192,000) \times \$15 = \$720,000$

The logical way to offset this is to increase the unit price bid for some item which could overrun, like steel supports. The mechanics of accomplishing this are straightforward. Normal profit per ton of steel supports:

say \$30

increase the profit 5 times or bid:

 $(5 \times 30) + (800 - 30) = 720/ton$

applied to the bid quantity we have:

$$3720 \times 5,000 \text{ tons} = 33,600,000$$

This in effect has replaced \$600,000 of the \$6,000,000 leaving \$5,400,000 yet to be replaced. The \$5,400,000 can now be placed into the excavation:

 $\frac{5,400,000+25,992,000}{722,000} = 43.48/\text{c.y.}$

Now the only deficit is the \$720,000 which will be made up by overrunning the steel supports. The excess profit in steel supports is \$120 per ton, which means that the steel supports must be overrun by:

 $\frac{720,000}{120}$ = 6,000 tons or 120 percent

This is a conservative overrun based on some of our data. Where we encountered this type of unbalance, we also found errors in the construction quantities. Apparently, there is insufficient care of precautions taken in computing bid quantities.

SPECIFICATIONS

Construction specifications are intended to convey those ideas and requirements that are not appropriate for display in drawings but are necessary for the proper and efficient functioning of the facility to which they relate. Unfortunately, they appear to be sometimes written by people who are unfamiliar with the technology

or are unsure of when the point of proper and efficient functioning is reached. Some specification, as written, appear to result in more costly construction than necessary. For example, the requirement for cleaning of tunnel inverts to bare rock before lining appears to be unwarranted, considering the additional costs involved. Also, some specifications allow the lining form to go out of round, within certain limits, so long as the tunnel area is not reduced. It is difficult to imagine how a form for lining can go out of round without reducing the area. This clause could be quite costly if rigidly enforced, allowing no tolerances.

One anonymous "owner agency" realized that one of the large cost items in tunneling is the contingency factor, and set out to reduce it. They made a thorough study of the cost-driving factors associated with changes in geology and then wrote their specifications in such a manner that the contractor is compensated for changed conditions without the added expense of claims. For example, their study of bids showed no significant excavation cost increase for installing supports 6' on centers or greater. The study also showed what the excavation cost increase amounted to as support spacing decreased. Thus, their contracts are now bid with a support cost escalation factor in the specification:

unit price/lin. ft. of tunnel = $\binom{0.75 + 1.5}{S}P$

where S = average spacing center to center of sets (in feet), and P = bid unit price/ lin. ft. of tunnel based on sets at 6 foot center-to-center. This owner has set up similar methods for reimbursing the contractor for excessive water flows, running ground, and squeezing ground. Also included in their specification is an incentive plan for sharing any cost reductions with the contractor.

Another area of potential savings is in the specified tunnel safety requirement. The frequency of tunneling cave-ins or serious accidents today seems much less compared with years ago. It therefore seems reasonable that a state government spending large amounts on tunneling could carry blanket tunnel accident insurance cheaper than could each contractor. This could also result in additional savings

through reductions in steel supports in tunnels. It has been reported to us that if state governments assumed the responsibility for tunnel safety, they would not be forced to allow structural steel overruns dictated by the ultra-conservative design formulas used by supppliers who must guarantee safety.

GEOLOGIC REPORTING

The amount of geologic information furnished to tunneling contractors runs the gamut from absolutely nothing to an excellent survey and report. The best geologic reports for bidding contractors that we encountered were those prepared by the Metropolitan Water District of Los Angeles. The reason for regarding these particular reports highly is not that the MWD does more boring or testing than some other "owners," but they do much more to interpret the borings and t_{\pm} test data in meaningful language to a tunneling contractor. For example, some "owners" furnish sonic velocity reports on the rock to be encountered even though to actually use such data a contractor must be an experienced tunneler in that specific rock type, in the same part of the country. It is highly unlikely that any tunneling contractor could accurately interpret sonic velocity data in all rocks; in all parts of the United States. Consequently, the local tunneling contractor has an advantage over the out-of-state contractor, which can lead to reduced competition and higher costs. This is a characteristic of tunneling not found in general contracting, where there is usually a sufficient quantity of local talent on hand to maintain competition. The interpretation of geologic data could, however, be performed by the owner or the engineer, who is almost always local to the geographic area.

At the other extreme is the owner who furnishes nothing in the way of geologic data other than U. S. Geological Survey Maps. The expressed philosophy is that geologic exploration does not result in enough tunnel cost savings to pay for the exploration. Needless to say, this interesting view has never been thoroughly researched. Such a comparison, although beyond the scope of this study, could no doubt be made using the data gathered here. If the belief is substantiated, time as well as money could be saved.

Some tunneling projects were encountered for which a plot of the boring data indicated that the boring fell far short of reaching the tunnel grade elevation. This could greatly influence contingency factors as well as changed condition claims.

The testing of rock samples for unconfined compressive strength appears generally to be a coming practice even though it is historically lacking. Discussions with tunnel owners and engineers indicate that compressive testing is performed only when the use of mechanical boring machines is anticipated. Another drillability factor generally believed to indicate the advisability of attempting to mechanically bore rock is brittleness. Unfortunately, no evidence that brittleness has been related to the unconfined compressive strength was found. In practically every instance where unconfined compressive tests were conducted by boring machine manufacturers and agents of the owner, the owner's test samples were always inferior to those tested by the manufacturer.

The design of cutter bits and cutter bearings for full-face boring is an area where U. S. Government-sponsored research could accelerate the state of the art. There is evidence that tunnel machine manufacturers do not have the necessary resources for an adequate effort and have been concentrating all available resources for improving machine reliability.

At the outset of this study, the Office of High-Speed Ground Transportation desired to relate tunnel support requirements to "Rock Quality Designation" (RQD), but very few people were encountered who had even heard of the term. In the one project where the RQD was determined from borings, its value appears to be misleading. Although the determination of an RQD from a boring is straightforward, relating the RQD to a type and frequency of support is quite another thing. A factor that is necessary but lacking from the procedure for determining RQD is the effect of variations in the orientation of the rock stratigraphy to the tunnel axis. Although this might take the form of a simple sine or cosine function, it does seem needed.

RECOMMENDATIONS FOR FUTURE RESEARCH

There is a need for research into the economics of shared financing and shared use of large tunnels. It would seem that the communications, power, petroleum, natural gas, postal, and sanitary waste disposal industries all have a need for inter-urban underground passageways. Tunnel structures, having such long anticipated lives, might attract significant financial construction aid from such interested use sharers. Large tunnels also offer safety and low maintenance to the various power and pipeline industries.

Our report also suggests research into the costs of tunneling with and without exploratory borings. In addition to determining whether or not exploratory borings are economically justified, research should be conducted to determine that if borings are justified, what amount of investment is justified.

Finally, an area of technological improvement which time did not permit a study to be included in this report is large diameter rock shaft boring. Most of the known data in this specialized field is with the Uranium Mining Industry. The greatest cost in large diameter mechanical shaft boring, in rock, is the high equipment investment, but this probably would be reduced by standardization and more intensive utilization. The technique involved appears to be similar to down hole reaming except that packers are used for torque control instead of the drill shaft.

A-1

APPENDIX A

APPENDIX A KEY

· · · ·			
LF	=	linear feet	
HS	=	horseshoe	
BH	= .	basket handle	•
LS	=	lump sum	
lf	=	linear feet of pilot hole, rock bo	lt, or grout hole
cy	=	cubic yards	
CYE	=	cubic yards excavation	· · ·
CYL	Ξ	cubic yards lining (concrete)	
lb	-	pounds	·
MBM	. 2	thousands of board feet	
SY	_=	square yards	· ·
BBL	=	barrels	
cf	=	cubic feet	
ea	=	each	
PAMO] =	pneumatically applied mortar co	at

Approximate Date: 1966

Name:	Loon Lake		
Location:	North California (Eldorado County)		
Owner:	Sacramento Municipal Utility District		
Contractor:	Walsh Construction Company		
Machine Manufacturer:	None		
Shape:	BH		
Length:	21,500 LF		
Bore:	18' x 18'		
Inside Diameter:	16'4" x 16'4"		
Calculated Volumes:			
Excavation:	9.43 CY/LF		
Excavation:	199,500 CY		
"Lining:	1.94 CY/LF^{a}		
Lining:	41,700 CY ^b		
Matorial ·	Dredominately granite diorite and gr		

Predominately granite, diorite and grano-diorite medium to coarse grained. hard and equiangular. Joints range from 1 to 4 ft on center.

		Quantity		Unit Price		
	Quantity	per	Enginconic	Average of	Low	Dollars
	quantity	LF	Engineer s	of Three	LUW Dia	Low
		of Tunnel	Estimate	Lowest Bids	BIG	Bid
Mahillantina	TO			1 509 000	1 990 000	1 990 000
Mobilization			1	1,592,000	1,230,000	1,230,000
Clear, Grub	го					1 880 000
Subtotal			• •			1,230,000
Drill Pilot Holes	1,000 lf	.05		15.83	11	11,000
Tunnel Excavation	21,500 lf			249.67	190	4,085,000
Tunnel Enlargement		· · ·				
Subtotal			· ·	1	· ·	4,096,000
			1	0.07		07 500
Steel Sets	650,000 15	30.23		.207	. 15	97,500
ROCK BOITS	300,000 If	13.95		3.05	2.43	730,000
Timber	2,200 H		1 ·	111.67	13.00	28,600
Rock Bolt Shapes						
Chain Link Fabric	15,000 sy		· · ·	3.67	3.00	45,000
Liner Plate		· · ·	{ .			
Other Wire Mesh				29,333	40,000	40,000
subtotal				•		941,000
	(21, 500 lf ^C			35.67	49.00	1.053.500
Concrete	2,200 lf ^d			127.00	121.00	266,200
Cement	1 40.000 BBI	1.86	· · ·	4.90	4,70	188,000
Reinforcing Steel	1.500.000 lb	69.77	• • • •	. 197	.18	270,000
Subtotal						1.777.700
Drill Grout Holes	3,000 lf	i sa se	}	4.50	4.00	12,000
Grout Pipe						
Grout Connection	200 ea		·	21.67	20.00	4,000
Grout Operation	3,000 cf	.14	, ,	6.50	7.00	21,000
PAMC	10,000 cf	. 47		8.00	9.00	90,000
Other		1 · · · ·				
Subtotal			·, ·			127,000
Other Tunnel						0
Tunnel Total		1				8 171 800
						0.111,000
Other Project		1 .		and the second second	· *	2,200,610
Total Project			1 ··· ·	a de set a		10,372,410
1			· · ·	· · ·	1 Carlos]
	к	1			1	1
			ł		1	
						l
-				•		

Invert . 56; Arch 1.38. a.

15,100 cy requirement. Invert Concrete. b.

Ċ.

d. Arch & Walls.

Name:	Loon Lake
Location:	N. California (Eldorado County)
Owner:	Sacramento Municipal Utility Dist.
Contractor:	Walsh Construction Company
Machine Manufacturer:	None
Shape:	BH
Length:	21152 LF
Bore:	18' x 18'
Inside Diameter:	16'4" x 16'4"
Calculated Volumes:	
Excavation:	9,43
Excavation:	199, 500
Lining:	$1.94 \text{ CY/LF}^{\text{c}}$
Lining:	41,700 CY d
Material:	Predominately granite, diorite and

Predominately granite, diorite and grano-diorite medium to coarse grained. hard and equiangular. Joints range from 1 to 4 ft on center.

	Quantity	Quantity per LF of Tunnel	Unit Price	Final Cost
Mobilization Clear, Grub Subtotal	LS LS	· .	1,230,000	1,230,000 1,230,000
Drill Pilot Holes Tunnel Excavation Tunnel Enlargement	100 lf 21, 152 lf	.005	11.00 190.00	1,100 4,018,880
Subtotal Steel Sets Rock Bolts	107, 374 lbs 106, 493 lf	5.08 5.03	. 15	<u>4,019,980</u> 16,106 291,685
Timber Rock Bolt Shapes Chain Link Fabric	440 lf 10,003 sy		13.00 3.00	6,344 30,009
Liner Plate Other (wire mesh) Subtotal				<u> </u>
Concrete	$\left\{\begin{array}{c} 21, 134.5 \text{ If} \\ 837 \text{ If} \end{array}\right.$		49.00 121.00	1,035,590 101,277
Cement Reinforcing Steel Subtotal	38,618 BBl 1,101,672 lb	1.83 52.08	4.70 .18	181,505 <u>198,301</u> <u>1,516,673</u>
Drill Grout Holes Grout Pipe Grout Connections Grout Operation				
PA MC Other Subtotal	2,062 cf	. 10	9.00	18,558
Other Tunnel Tunnel Total				<u>0</u> 7,135,828
Other Project Total Project				$\frac{2,529,414}{9,665,242}$

a. Invert

b. Walls & Arch

c. .56 Invert

1.38 Arch

d. 13,000 cy Requirement

A-4.

Name: White Rock Location: North California (Eldorado County) Sacramento Municipal Utility District Owner: Walsh Construction Company Contractor: Machine Manufacturer: None Shape: HS Length: 25,760 LF Bore: 24' x 24' Inside Diameter: 21'8" x 21'8" **Calculated Volumes:** Excavation: 16.75 CY/LF 432, 400 CY (nearest hundred) Excavation: 3.23 CY/LF^{a} Lining: 83,200 CY (nearest hundred)^b Lining: Material:

Predominately granite and granite gneiss, hard and blocky to massive. Estimated compressive strength 30,000 psi and estimated RQD = 90 to 95 percent. Unit Price Quantity Total per Average of Dollars Quantity Engineer's Low LF of Three Low Estimate Bid of Tunnel Lowest Bids Bid 1,547,000 1,547,000 Mobilization LS 1,519,167 Clear, Grub 97,000 97,000 LS . 74,333 Subtotal 1,644,000 1,500 lf 12,000 . 06 9.50 **Drill Pilot Holes** 8 4,900,000 24,500 lf 216.33 200 **Tunnel Excavation** 1,260 lf 283.33 290 365,400 Tunnel Enlargement 5,277,400 Subtotal Steel Sets 5,000,000 lb 194.10 .174 . 20 1,000,000 **Rock Bolts** 5,000 lf 3.50 3.00 15,000 .19 Timber 11,000 lf 19 20.00 220,000 **Rock Bolt Shapes**

Chain Link Fabric					~	
Liner Plate			· .			
Other Wire Fabric		•				2,000
Subtotal					÷	1,237,000
	(10,000 lf ^a			20:50	18.00	180,000
Concrete	$\{15,000 \text{ lf}^{a}\}$	•		13.50	10.00	· 150,000
	9,000 lf ^b			90.33	83.00	747,000
Cement	70,000 BBI	2.72		4.40	4.50	315,000
Reinforcing Steel	990,000 lb	34.94		. 123	. 13	117,000
Subtotal		1				1,509,000
Drill Grout Holes	4,000 lf			5.37	4.70	18, 800
Grout Pipe						. · · ·
Grout Connection	300 ea		1	18.00	· 13.00	3,900
Grout Operation	4,000 cf	. 16		4.75	4.50	18,000
РАМС	1,500 cf	.06	-	5.00	8.00	12,000
Other					1	
Subtotal	н. К.,		· ·			52,900
Other Tunnel				· .		0
Tunnel Total						9,720,100
Other Project						2,749,040
Total Project				· .		12,469,140
			1	1 .	4	, , , , , , , , , , , , , , , , , , , ,

a. 2.58 Wall & Arch; .65 Invert.

b. 39,500 cy requirement.

c. Invert.

d. Arch.

Approximate Date: 1964

Name:	White Rock	Approximate Da
Location:	N. California (Eldorado County)	,
Owner:	Sacramento Municipal Utility Dist.	
Contractor:	Walsh Construction Company	
Machine Manufacturer:	None	
Shape:	HS	
Length:	25,800 LF	
Bore:	24' x 24'	<u>'</u>
Inside Diameter:	21'8" x 21'8"	
Calculated Volumes:		
Excavation:	16.75 CY/LF	,
Excavation:	432, 400 CY	
Lining:	3.23 ^C CY/LF	
Lining:	83,300 °CY	
Material	Predominately granite and granite gnelss.	hard and blocky to

massive. - 5u g Estimated compressive strength 30,000 psi and estimated RQD = 90 to 95 percent.

	Quantity	Quantity per LF of Tunnel	Unit Price	Final Cost
Mobilization Clear, Grub Subtotal	LS LS		1,547,000 97,000	1,547,000 47,000 1,644,000
Drill Pilot Holes	(4.000.000
Tunnel Excavation	24,998 cy 802 cy		200.00	4,999,600 232,664
Tunnel Enlargement Subtotal	· · · · · · · · · · · · · · · · · · ·			5,232,264
Steel Sets	417,581 lbs	16.19	. 20	83,516
Rock Bolts Timber Rock Bolt Shapes Chain Link Fabric	276,431 lf 911.5 lf	10.70	3.00 20.00	829,311 18,230
Liner Plate Other (wire fabric) Subtotal			• •	<u> </u>
Concrete	$\begin{cases} 804 \text{ lf } a \\ 809 \text{ lf } b \end{cases}$	i	18.00	14,472 67,147
Cement	44,022 BBl	1.71	4.50	198,099
Reinforcing Steel Subtotal	995,018 lb	38.57	. 13	$\frac{129,352}{409,070}$
Drill Grout Holes Grout Pipe	2,630 lf	х. Х.	4.70	12,361
Grout Connections	82 ea.		13.00	1,066
PAMC	2,005 cf 1.704 cf	.08	4.50	9,023 13,632
Other Subtotal			.	36,082
Other Tunnel Tunnel Total			,	0 8,264,072
Other Project Total Project				2,192,632 10,456,704
ţ,				

a. Invert

b. Arch & Walls

c. 2.58 Arch & Walls .65 Invert

d. 2,600 cy Requirement

Name:	Lowman Ridge
Location:	N. California (Yuba County)
Owner:	Yuba County Water Agency
Contractor:	Perini Company
Machine Manufacturer:	None
Shape:	HS
Leigth:	19,410 LF
Bore:	12'6" x 12'6"
Inside Diameter:	9'8'' x 9'8''
Calculated Volumes:	
Excavation:	4.55 CY/LF
Excavation:	88,300 CY (nearest hundred)
Lining:	1.83 CY/LF
Lining:	35.500 ^a CY (nearest hundred
Material:	Very hard amphibolite appro

Approximate Date: 1966

arest hundred)

Very hard amphibolite approximately 15 percent lined.

¥

	Quantity	Quantity per LF of Tunnel	Unit Price	Final Cost
Mobilization Clear, Grub Subtotal	LS LS			<u>33,000</u> 33,000
Drill Pilot Holes Tunnel Excavation Tunnel Eniargement Subtotal	19,410 lf ^b		190.00	3,687,900 3,687,900
Steel Sets Rock Bolts	1,850,000 lbs	95.31	.60	1,110,000
Timber Rock Bolt Shapes Chain Link Fabric Liner Plate Other Expansion Bolts			•	
Subtotal				1,110,000
Cement Reinforcing Steel Subtotal			•	<u>652,500</u> ^c
Drill Grout Holes Grout Pipe Grout Connection Grout Operation PAMC	8,400 lf 1,900 lb 40 ea 5,000 cf	. 26	2.92 1.25 17.00 1.20	24,500 2,375 680 6,000
Other Subtotal				33,555
Other Tunnel Tunnel Totai				$\frac{1}{5,516,955}$
Other Project Total Project				$\frac{\underline{934,085}}{\underline{6,451,040}}$

a. Lined tunnel 5,300 cy (2,900 LF).

b. \$41.88/cy.

652,500 was shown and represented toal lining cost for 2,900 LF (225/LF). c.

A-7

Name:	Camptonville
Location:	N. California (Yuba County
Owner:	Yuba County Water Agency
Contractor:	Perini Company
Machine Manufacturer:	None
Shape:	HS
Length:	6,107 LF
Bore:	14'6" x 14'6"
Inside Diameter:	12'8" x 12'8"
Calculated Volumes:	
Excavation:	6.12 CY/LF
Excavation:	37,400 CY (nearest hundred
Lining:	1.45 CY/LF
Lining:	8,900 ^a CY (nearest hundred
Material:	Predominately very hard an

ater Agency rest hundred)

rest hundred) very hard amphibolite, massive requiring 18 to 20 percent lining. Reported powder factor = 3.0.

	Quantity	Quantity per LF of Tunnel	Unit Price	Final Cost
Mobilization Clear, Grub Subtotal	LS LS		14,000	<u>14,000</u> <u>14,000</u>
Drill Pilot Holes Tunnel Excavation Tunnel Enlargement Subtotal	6, 107 lf		225.00	$1,374,075^{b}$ $\overline{1.374,075}$
Steel Sets Rock Bolts Timber Rock Bolt Shapes Chain Link Fabric Liner Plate Other Expansion Bolts Subtotal	675,000	110.53	. 55	371,250 <u>371,250</u>
Concrete Cement Reinforcing Steel Subtotal				<u></u> 261,250 ^C
Drill Grout Holes Grout Pipe Grout Connection Grout Operation PAMC Other Subtotal	4,700 lf 1,100 lb 40 ea 4,000 cf	.65	3.24 1.50 11.50 1.20	15,220 1,650 460 4,800
Other Tunnel Tunnel Total				2,042,705
Other Project Total Project				720,665 2,763,370
·			· ·	

Cubic yards for 950 LF = 1,380 cy. a.

b. Cost/cy = \$36.84.

c. Cost of 261, 250 represents cost of lining 950 LF (\$275/LF).

and the second production of the

Name:	Colgate (Section I)	Approximate Date:
Location:	N. California (Yuba County)	•
Owner:	Yuba County Water Agency	•
Contractor:	Perini Yuba Associates	
Machine Manufacturer:	None	
Shape:	HS	
Length:	21,678 LF	
Bore:	26' x 26'	
Inside Diameter:	21' x 21'	
Calculated Volumes:		
Excavation:	19.67 CY/LF	
Excavation:	426, 400 CY (nearest hundred)	
Lining:	6.84 CY/LF	
Lining:	148,300 CY (nearest hundred)	
Material:	Predominately very hard amphibolitic rock, tunnel lined, reported powder factor 3.1.	11 to 12 percent of

	tunnet inneu, reporte	d powder lactor	J. F.	
	Quantity	Quantity per LF of Tunnel	Unit Price	Final Cost
Mobilization Clear, Grub Subtotal	LS LS			
Drill Pilot Holes Funnel Excavation Funnel Enlargement	21,678 lf		230	4,985,940
Subtotal Steel Sets Rock Bolts				
Fimber Rock Bolt Shapes Chain Link Fabric Liner Plate			· · ·	
Other Expansion Bolts Subtotal	3 900 lf		300	1 170 000
Cement Reinforcing Steel Subtotal			300	<u>1,170,000</u>
Drill Grout Holes Grout Pipe Grout Connection				
Grout Operation PAMC Other Subtotal				
Other Tunnel Tunnel Total		· .		
Other Project Total Project		· · ·		

. A-9

Name: Location: Owner: Contractor: Machine Manufacturer: Shape: Length: Bore: Inside Diameter: Calculated Volumes: Excavation: Excavation: Lining: Lining: Material: Colgate (Section II) N. California (Yuba County) Yuba County Water Agency Perini Yuba Associates None HS 1,946 19' x 19' 15' x 15' 10.51 CY/LF 20,500 CY (nearest hundred)

20,500 CY (nearest hundred 3.95 CY/LF 7,700 CY (nearest hundred)

Predominately very hard amphibolitic rock, 11 to 12 percent of tunnel lined, reported powder factor 3.1.

	Quantity	Quantity per LF of Tunnel	Unit Price	Final Cost
Mobilization Clear, Grub Subtotal	LS LS			
Drill Pilot Holes Tunnel Excavation Tunnel Enlargement Subtotal	1,946 lf		200.00	389,200 389,200
Steel Sets Rock Bolts Timber Rock Bolt Shapes Chain Link Fabric Liner Plate Other Expansion Bolts Subtotal				
Concrete Cement Reinforcing Steel Subtotal	10,000 cy 17,400 BBi ^a		23.00 5.80	230,000 100,920 = 330,920 ;
Drill Grout Holes Grout Pipe Grout Connection Grout Operation PAMC Other Subtotal				A.
Other Tunnel Tunnel Total				
Other Project	1	I .	1	•

a. Assume 1.5 BBI/CY for other structure.

Name:ColgatLocation:N. CaOwner:Yuba dContractor:PerintMachine Manufacturer:NoneShape:HSLength:23,624Bore:Inside Diameter:Calculated Volumes:Excavation:Excavation:18.92Excavation:446,90

Colgate (Total) N. California (Yuba County) Yuba County Water Agency Perini Yuba Associates None HS 23,624 LF

Imcs: 18.92 CY/LF 446,900 CY (nearest hundred) 6.60 CY/LF

Lining: Material:

Lining:

156,000 CY (nearest hundred) Predominately very hard amphibolitic rock, 11 to 12 percent of tunnel lined, reported powder factor 3.1.

	Quantity	Quantity per LF of Tunnel	Unit Price	Final Cost
Mobilization Clear, Grub Subtotal	LS		6,400	<u> </u>
Drill Pilot Holes Tunnel Excavation Tunnel Enlargement Subtotal	23,624 LF		227.53	5,375,140 5,375,140
Steel Sets Rock Boits Timber	2,000,000 lbs	84.86	.50	1,000,000
Rock Bolt Shapes Chain Link Fabric Liner Plate Other				-
Subtotal Concrete				1,000,000
Cement Reinforcing Steel Subtotal			· · · · · · · · · · · · · · · · · · ·	1,500,920
Drill Grout Holes Grout Pipe Grout Connections Grout Operation	20,000 lf 65,000 lb 1,430 ea 12,000 cf	. 51	2.55 .90 10.00 3.00	51,000 58,500 14,300 36,000
Other Subtotal				159,800
Other Tunnel Tunnel Total				$\frac{3,462,500}{11,504,760}$
Other Project Total Project				<u>8,548,365</u> 20,053,125

Name:	Glendora (Section 1)	Approximate Date: 196				
Location:	Southern California (Glendora County)					
Owner:	Metropolitan Water District of Southern Cal	ifornia				
Contractor:	Shea Company					
Machine Manufacturer:	None	. `				
Shape:	Circular					
Length:	26189 LF Tunnel: 24589 Adit: 1600					
Bore:	18'6'' 17'4''					
Inside Diameter:	15'6" 14'					
Calculated Volumes:						
Excavation:	11.16 CY/LF					
Excavation:	292, 300 CY (nearest hundred)					
Lining:	4.24 CY/LF					
Lining:	111,000 CY (nearest hundred)					
Material:	Granite (medium hard, medium blocky)					

		Quantity	Unit Price		Total	
	Overtite.	per	Engineenia	Average of	*	Dollars
	Quantity	LF	Engineer's	of Three	Low	Low
· · · ·	· · ·	of Tunnel	Estimate	Lowest Bids	BID	Bid
Mobilization	1.8			•		
Clear Grub	IS			197 000	75 000	. 75.000
cicul, crub				121,000	,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,	
Subtotal		· · ·				75 000
	. ·					10,000
Drill Pilot Holes	4.500 lf	.17		5.00	3.00	13,500
Tunnel Excavation	290,000 cy	11.07		36.57	37.70	10,933,000
Tunnel Enlargement	1,500 cy	, 057		68.33	60.00	90,000
Subtotal	-				·* 1	11,036,500
Steel Sets	4,800,000 lb	183.28		. 16	.10	480,000
Rock Bolts	40, 000 lf ^a	1.53		2.50	2.50	100,000
Timber	1,000 MBM	. 038	•	400	100	- 100,000
Rock Bolt Shapes						
Chain Link Fabric	4,444 sy			6.30	3.60	16,000
Liner Plate	120, 900 lb	4.58		. 29	.13	15,600
Other Expansion Bolts						
Subtotal						711,600
Generate	107 000	4.00				
Concrete	107,000 CY	4.09		31.22	22.00	2,354,000
Reinfording Stool	160,000 BBI	7.00		4.03	3.60	666,000
Subtotel	1, 500, 000 10	57.28		.10	.15	225,000
Subtotat						3,245,000
Drill Grout Holes	4, 200 1f			3.87	2 50	10 500
Grout Pine	5,000 lb			1.23		3 500
Grout Connection	1.200 ea.			23.33	10.00	12,000
Grout Operation	105,300 cf	4.02	ļ .	3.72	3.00	315,900
	<i>i</i> 1,000	.42	1	7.67	5.00	55,000
PAMC	6,500 ^{CI}	. 25	1	5.00	4.00	26,000
Other	•					
Subtotal	· · ·			,	· ·	422 900
			1	· ·		
Other Tunnel			4			107
Tunnel Total	· · ·	1				401,020
	•	4	, v	· ·		15,892,020
Other Project			ł			359,410
Total Project]			16,251,430
			1	1 .	1 .	

a. Converted to linear feet by using 2.5 lbs/lf

Name:	Glendora (Section 2)	Approximate Date:	1965
Location:	Southern California (Glendora County)		
Owner:	Metropolitan Water District of Southern Califor	nia	
Contractor:	Shea Co.		
Machine Manufacturer:	None		
Shape:	Circular		
Length:	7,914 LF		
Bore:	18'6"	·	
Inside Dlameter:	15'6''		
Calculated Volumes:			
Excavation:	11.26 CY/LF		
Excavation:	91,200 CY (nearest hundred)	,	•
Lining:	4.27 CY/LF		
Lining:	33.800 CY		
Material:	Granite (medium hard, medium blocky)		

		Quantity	Unit Price			Total
		per		Average of	_	Dollars
	Quantity	LF	Engineer's	of Three	Low	Low
		of Tunnei	Estimate	Lowest Bids	Bid	Bid
	· · ·					
Mobilization	LS			· ·		
Clear. Grub	LS			52 667	58 000	58,000
Subtotal		•		02,001	00,000	58,000
	· .	·			•	
Drill Pilot Holes	1,500 lf	. 19		5,00	3.00	4, 500
Tunnel Excavation	91,000 cy	11.50		39.23	37.70	3,430,700
Tunnel Enlargement	500 cy	. 06		85.00	60.00	30,000
Subtotal	, i i i i i i i i i i i i i i i i i i i					3,465,200
;						-,,
Steel Sets	2,200,000 lb	277.99		. 162	.10	220,000
Rock Bolts	12,000 lf	1.52		2.19	2.50	30,000
Timber	400 MBM	. 051	,	400.00	100.00	40.000
Rock Bolt Shapes				· · ·		
' Chain Link Fabric	1,333 sy		•••	6.30	3.60	· 4,800
Liner Plate	340,000 lb	42.96	· ·	.38	.13	44,200
Subtotal				. •		339,000
			· ·			
Concrete	33,000 cy	4.17		31.22	22.00	726,000
Cement	57,000 BBl	7.20		4.03	3.60	205,200
Reinforcing Steel	800,000 lb	101.09	· ·	.162	. 165	132,000
Subtotal			•	· .	1	1,063,200
Drill Grout Holes	1,300 lf			3,17	2.50	3,250
Grout Pipe	2,000 lb		· · ·	1.40	.70	1,400
Grout Connection	400 ea.			23.33	10.00	`4,000
Grout Operation	32,400 cf	4.09		3.72	3.00	97,200
PAMC	4,000 cf	.51		7.67	5.00	20,000
Othin	(3,000	.38		5.00	4.00	12,000
Other		÷.				
Subtotal				· · .		137,850
Other Turnel (dreen)				· .		405 400
Turnel Total		e				487,600
						5,550,850
Other Project			· ·			207 050
Total Project			1			5 757 000
						0,101,000
· · ·	•			,		
· · ·			1		<u> </u>	

a. Converted to linear feet by using 2.5 lbs/lf

A-13

Name:	Glendora (Tot	al)	•	Approximate Date:	1965
Location:	S. California	(Glendora Cou	unty)	•	
Owner:	Metropolitan V	Water Dist. of	S. California		
Contractor:	Shea Co.			,	
Machine Manufacturer:	None				
Shape:	Circular	Tunnel	Adit		
Length:	34,103 LF	32,503	1,600		
Bore:		18'6"	17'4"		
Inside Diameter:		15'6"	14'		
Calculated Volumes:					
Excavation:	11.25 CY/LF				
Excavation:	383,500 CY (nearest hundre	ed)		
Lining:	4.25 CY/LF			•	
Lining:	144,800 CY (nearest hundre	ed)		
Material:	Granite (medi	um hard, med	lium blocky)		
			·. ·	s.	
			•		

المحادثين المستريب والبريد والمحادث والمحادث		.	Quantity	Unit Price			Total d
			per	Eveningenla	Average of	T and	Dollars
ĺ	Quantity		LF	Engineer's	of Three	LOW	Low
			of Tunnel	Estimate	Lowest Bids	Bia	Bid
Mobilization	LS						
Clear, Grub	L.S.	÷ 1	÷ .		179,667	133,000	133,000
Subtotal					10,001	100,000	133,000
Subboun							
Drill Pilot Holes	6,000 lf	f	.18		5.00	3.00	18,000
Tunnel Excavation	381,000 cy	у	11.17		37.21	37.70	14,363,700
Tunnel Enlargement	2,000 cy	у	. 059		72.50	60.00	<u> 120,000</u>
Subtotal	·				•		<u>14,501,700</u>
Steel Sets	7.000.000 11	b İ	205, 26		. 16	. 10	700.000
Rock Bolts	52,000 lf	f ^a	1.52	• *	2.19	2, 50	130,000
Timber	1.400 N	ивм	.041		400.00	100.00	140.000
Rock Bolt Shapes			••				- •
Chain Link Fabric	5.777 s	v			6.30	3,60	20,800
Liner Plate	460.000 lt	b	13.49		.36	.13	59,800
Other Expansion Bolts		-				-	
Subtotal							1,050,600
Concrete	140,000 c	y	4.11		31.22	22,00	3,080,000
Cement	242,000 E	BBL	7.10		4.03	3.60	871,200
Reinforcing Steel	2,300,000 0	b	67.44		.161	. 155	357,000
Subtotal							4,308,200
Drill Grout Holes	5,500 1	f			3.70	2.50	13,750
Grout Pipe	7,000-ll	b ·		{	1.28	.70	4,900
Grout Connection	1,600 e	ea.			23.33	10.00	16,000
Grout Operation	137,700 c	f	4.04		3.72	3.00	413,100
DANC	<pre></pre>		. 44		7.67	5.00	75,000
FAMC	⁶ 4,500 و	1	.28		5.00	4.00	38,000
Other	· ·						
Subtotal	1		ł			ł	560,750
Other Tunnel (liner)	1.955.000 1	hs				l ·	888, 620
Tunnel Total	1,000,000						21,442,870
Other Project							566, 460
Total Project]	ļ			22,009,330
	· ·	•					
1			ſ	· ·	1	1	Į.
1			1				
	1		}			-	
1	1		(f	1	1	1 '

Converted to linear feet using 2.5 lbs/LF. а.

Approximate Date: 1965

Name:	Glendora (Section I) Approxim	nate Date:	196			
Location:	S. California (Glendora County)					
Owner:	Metropolitan Water District of Southern California					
Contractor:	Shea Co.					
Machine Manufacturer:	None					
Shape:	Circular					
Length:	26,189 LF; 24,589; 1,600					
Bore:	18'6'' 17'4''					
Inside Diameter:	15'6" 14'					
Calculated Volumes:			•			
Excavation:	11.16 CY/LF					
Excavation:	292,300 CY (nearest hundred)					
Lining:	4.24 CY/LF					
Lining:	111,000 CY (nearest hundred)					
Material:	Granite (Medium, Hard, Medium Blocky)					

		Quantity	Quantity per LF of Tunnel	Unit Price	Final Cost
	Mobilization Clear, Grub Subtotal	LS LS	€°.<	58,000	75,000
	Drill Pilot Holes Tunnel Excavation Tunnel Enlargement Subtotal	302,107 cy 370 cy	11.53 .01	37.70 60.00	11,389,434
	Steel Sets Rock Bolts	{ 4,800,000 lbs 15,080,000 lbs	759.10	.10 .18	480,000 2,717,280
	Timber Rock Bolt Shapes Chain Link Fabric Liner Plate Other Subtotal	911.1 MBM	.035	100.00	91,110 <u>3,288,390</u>
	Concrete Cement Reinforcing Steel Subtotal	113,997 cy 197,517 BBL 936,047 lb	4.35 7.54 35.74	22.00 3.60 .15	$2,507,934 \\711,061 \\140,407 \\3,359,402$
	Drill Grout Holes Grout Pipe Grout Connections Grout Operation PAMC Other	$\begin{array}{c} 3,595 \text{ lf} \\ 7,294 \text{ lf} \\ 4,760 \text{ lb} \\ 2,097 \text{ ea} \\ 193,644 \text{ cf} \\ \left\{\begin{array}{c} 45 \text{ cf} \\ 82,572 \text{ cf} \end{array}\right.$	7.39 2.15	$\begin{array}{c} 3.00 \\ 2.50 \\ .70 \\ 10.00 \\ 3.00 \\ 5.00 \\ 4.00 \end{array}$	$10,785 \\ 18,235 \\ 3,332 \\ 20,970 \\ 580,932 \\ 225 \\ 330,288$
the same and the	Subtotal Other Tunnel Tunnel Total				$\frac{964,767}{384,407}$ 19,483,600
	Other Project Total Project				<u>330,498</u> 19,814,098
J	4 · · · ·		1	I	F

Name: Glendora (Section II) Approximate Date: 1965 Location: Southern California (Glendora County) Owner: Metropolitan Water District of Southern California Contractor: Shea Co. Machine Manufacturer: None Circular Shape: Length: 7,914 Bore: 18'6" Inside Diameter: 15 Calculated Volumes: Excavation: 11.26 CY/LF Excavation: 91,200 CY (nearest hundred) Lining: 4.27 CY/LF Lining: 33,800 CY (nearest hundred) Material: Granite (Medium Hard, Medium Blocky

	Quantity	Quantity per LF of Tunnel	Unit Price	Final Cost
Mobilization Clear, Grub Subtotal	LS LS		58,000	58,000 <u>58,000</u>
Drill Pilot Holes Tunnel Excavation Tunnel Enlargement Subtotal	92,071 cy	11.63	37.70	3,471,077 <u>3,471,077</u>
Steel Sets	{ 2,200,000 lbs 1,584,000 lbs	478.14	.10 .16	220,000 285,120
Rock Bolts Timber Rock Bolt Shapes Chain Link Fabric Liner Plate Other	285.4 MBM	. 036	100.00	28,540
Subtotal				533,660
Concrete Cement Reinforcing Steel Subtotal	35, 091 cy 60, 790 BBL 434, 806 lb	4.43 7.68 54.94	22.00 3.60 .165	772,002 218,844 $-71,742$ 1,062,588
Drill Grout Holes Grout Pipe Grout Connections Grout Operation	3,085 lf 1,762 lf 589 lb 492 ea 62,424 cf	7.89	3.00 2.50 .70 10.00 3.00	9,255 4,405 412 4,920 187.272
PAMC Other Subtotal	{ 1,265 cf 11,780 cf	.16 1.49	5.00 4.00	6,325 47,120
Other Tunnel Tunnel Total				<u>472,038</u> 5,857,072
Other Project Total Project				<u>195, 158</u> <u>6, 052, 230</u>
Name:	Glendora (Total)	Approximate Date:	1965	
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Location:	Southern California (Glendora County)	••		
Owner:	Metropolitan Water District of Southern California	ornia		
Contractor:	Shea Co.			
Machine Manufacturer:	None	•		
Shape:	Circular			
Length:	34,103 LF; Tunnel32,503 LF; Adid1,600	LF		
Bore:	Tunnel18'6"; Adid17'4"			
Inside Diameter:	Tunnel15'6"; Adid14'			
Calculated Volumes:				
Excavation:	11.25 CY/LF			
Excavation:	383,500 CY			
Lining:	4.25 CY/LF			
Lining	144 800 CV			

Lining: Material:

Granite (Medium Hard, Medium Blocky)

		/		
, , ,	Quantity	Quantity per LF of Tunnel	Unit Price	Final Cost
Mobilization Clear, Grub Subtotal	LS LS		133,000	133,000
Drill Pilot Holes Tunnel Excavation Tunnel Enlargement Subtotal	394,178 cy 370 cy	11.56 .01	37.70 60.00	14,860,511 22,200 14,882,711
Steel Sets Rock Bolts	{ 7,000,000 lbs { 16,664,000 lbs	693.90	.10 .18	700,000 3,002,400
Timber Rock Bolt Shapes Chain Link Fabric Liner Plate Other Subtotal	1, 196.5 MBM	. 035	100.00	119,650 <u>3,822,050</u>
Concrete Cement Reinforcing Steel Subtotal	\ 149,088 cy 258,307 BBL 1,370,853 lb	4.37 7.57 40.20	22.00 3.60 .155	3,279,936 929,905 <u>212,149</u> <u>4,421,990</u>
Drill Grout Holes Grout Pipe Grout Connections Grout Operation PAMC Subtotal Other Tunnel Tunnel Total Other Project Total Project	<pre>{ 6,680 lf 9,056 lf 5,349 lb 2,589 ea 256,068 cf { 2,310 cf 94,352 cf</pre>	10.34	$3.00 \\ 2.50 \\ .70 \\ 10.00 \\ 3.00 \\ 5.00 \\ 4.00$	$\begin{array}{r} 20,040\\ 22,640\\ 3,744\\ 25,890\\ 768,204\\ 6,550\\ \hline 377,408\\ \hline 1,224,476\\ \hline 856,445\\ 25,340,672\\ \hline 525,656\\ \hline 25,866,328 \end{array}$
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A-17

No mo	Delhan Inlat		1000
Name:	Baiboa milet	Approximate Date:	1966
Location:	S. California (Newhall County)	,	
Owner:	Metropolitan Water Dist. of S. California		
Contractor:	Dixon, Arundel, MacDonald & Kruse, Kiewit		
Machine Manufacturer:	None	,	
Shape:	Circular		
Length:	500 LF		
Bore:	18'4''		
Inside Diameter:	14'		
Calculated Volumes:			
Excavation:	9.78 CY/LF •		
Excavation:	48,900 CY (nearest hundred)		
Lining:	4.08 CY/LF	· ·	
Lining:	20,400 CY		
Material:	Predominately thinly to thickly interbedded and	intertongued gray,	tan an
	light brown sandstone, some mudstone and sha conglomerate. Sandstone compressive strengt	e and some pebble t 1.000-3.000 psi.	o boul

urest hund	red)		-	
thinly to thickly interbedded and intertongued gray, tan and distone, some mudstone and shale and some pebble to boulder Sandstone compressive strength 1,000-3,000 nsi.				
Quantity		Unit Price		Total
per LF of Tunnel	Engineer's Estimate	Average of of Three Lowest Bids	Low Bid	Dollars Low Bid
		· · · · · · · · · · · · · · · · · · ·		

	Quantity	per LF of Tunnel	Engineer's Estimate	Average of of Three Lowest Bids	Low Bid	Dollars Low Bid
Mobilization Clear, Grub	LS LS			18,889	25,000	25,000
Subtotal	the states of					25,000
Drill Pilot Holes			<i>.</i>		••	
Tunnel Excavation	50,000 cy	10.00		60.05	45.00	2,250,000
Tunnel Enlargement	300 cy	.06		86.67	100.00	30,000
Other (Rock Refill)				10,000	15,000	15,000
Subtotal		•	-			2,295,000
Steel Sets	1,500,000 lb	300,00		. 117	. 13	195,000
Rock Bolts	3,200.lf	. 64		2,25	1.50	4,800
Timber	500/MBM	.10		250.00	550.00	275,000
Rock Bolt Shapes	•					
Chain Link Fabric	(356 sv			3,60	5.40	1,920
Them Diete				3.70	3.00	1,200
Other Fundation Police	72,000 IB	14.40	}	. 238	. 25	18,000
Subtotal						495,920
Concrete	19,600 cy	3.92		40.33	35.00	686,000
Cement	32,800 BB1	6.56		4.50	4.00	131,200
Reinforcing Steel	2, 385, 000 lb	477.00		. 153	. 18	429,300
Subtotal			ļ			1,246,500
Drill Grout Holes	850 lf			3.67	2.00	1,700
Grout Pipe	300 lb			1,53	2.00	600
Grout Connection	350 ea.			16.33	10.00	3,500
Grout Operation	19,980°.cf	4.00		3.52	3.70	74,000
PAMC	600∗cf.	.12		4.33	4.00	2,400
Other	. ,				·	
Subtotal		1	}		•	82,200
Other Tunnel	•					296,850
Tunnel Total	•					4, 441, 700
Other Project	·'					27.400
Total Project						4, 468, 870
1	£	1			} .	ŀ
1			1	1	1	1

Name:	Newhall		
Location:	S. California (Newhall County)	Approximate Date:	1966
Owner:	Metropolitan Water Dist. of S. California	÷ -	
Contractor:	Dixon, Arundel, MacDonald & Kruse, Kiewit		
Machine Manufacturer:	Calweld		
Shape:	Circular		
Length:	18,290 LF		
Bore:	25'7"		
Inside Diameter:	20'6"	•	
Calculated Volumes:			
Excavation:	1918 CY/LF		
Excavation:	350, 800 CY (nearest hundred)		
Lining:	6.95 CY/LF		
Lining:	127, 100 CY (nearest hundred)	_	_

Material:

127,100 CY (nearest hundred) Predominately thinly to thickly interbedded and intertongued gray, tan and light brown sandstone, some mudstone and shale and some pebble to boulder conglomerate. Sandstone compressive strength 1,000-3,000 psi.

the second se		Quantity	Unit Price			Total
	Quantity	per	Engineenia	Average of	T orm	Dollars
	Quantity	LF	Eligilieer s	of Three		Low
· · · · ·		of Tunnel	Estimate	Lowest Bids	Bid	Bid
Mobilization	TQ				}]
Mobilization		· · ·		300 000	300 000	300.000
Clear, Grub	LS			141,667	75,000	75,000
Subtotal					10,000	375,000
Drill Dilot Holes					÷	
Tunnel Exception	335 000 ov	18 32		16 92	25 60	11 996 000
Tunnel Enlargement	3,000 cy	16.02		88 33	120 00 -	360,000
Other (Bock Refill)	3,000 Cy	• 10		46 667	60 000	60,000
Subtotal				10,007	00,000	12,346,000
						1210101000
Steel Sets	17,000,000 15	929.47	•	.115	.13	2,210,000
ROCK BOILS	8,000 lf	.44	÷.	2.25	1.50	12,000
Deels Delt Shance	3,000 MBM	. 16		250.00	550.00	1,650,000
Rock Bolt Snapes	(000			0.00		1 200
Chain Link Fabric	8000 SY	~	:	3.60	5.40	19,000
Liner Diste	800 000 lb.	49 74	• •	3.07	3.00	200,000
Other Expansion Bolts	800,000 10	40.14		. 230	.25	200,000
Subtotal						4.094.800
Concrete	100,000 cy a	5.47		38.33	35.00	3,500,000
Cement	173,900 BBI	9.51		4.50	4.00	695,600
Reinforcing Steel	9,889,000 Ib~	540.67		.16	.18	1,780,020
Subtotal				· · · ·	ł	5,975,620
Drill Grout Holes	3,600 lf			3.50	2.50	9,000
Grout Pipe	3,000 lb			1.37	1.50	4,500
Grout Connection	1,500 ea.			18.00	15.00	22,500
Grout Operation	162,000 cf	8.86		3.27	3.70	600,000
PAMC	9,000 cf	. 49		4.33	4.00	36,000
Other						
Subtotal	· · ·					672,000
Other Tunnel		·				863,700
Tunnel Total				· ·		24,327,120
Other Project	a .			ł .		1 977 640
Total Droient			.]	26 304 760
					1	20,004,700
					ŀ	
		ļ]	1

a. Assume 1.5 BBls/cy for Surface Structures (7,400 cy).

b. Assume 150 lbs/cy for Surface Structures.

Name: Location: Owner: Contractor: Machine Manufacturer: Shape: Length: Bore: Inside Diameter: Calculated Volumes: Excavation: Excavation: Lining: Lining:

Material:

Balboa-Newhall S. California (Newhall County) Metropolitan Water Dist. of S. California Dixon, Arundel, MacDonald & Kruse, Kiewit Calweld in Newhall Circular 23, 290 LF

17.16 CY/LF 399,700 CY (nearest hundred) 6.33 CY/LF 147,500 CY (nearest hundred) Predominately thinly to thickly brown sandstone, some mudsto

147,500 CY (nearest hundred) Predominately thinly to thickly interbedded and intertongued gray, tan and light brown sandstone, some mudstone and shale and some pebble to boulder conglomerate. Sandstone compressive strength 1,000-3,000 psi.

•	1 . 1	Quantity		Unit Price		
·		per	· · · · ·	Average of		Dollars
	Quantity	ĹF	Engineer's	of Three	Low	Low
-	(of Tunnol	Estimate	Towest Bide	Bid	Did Did
	┝ ────	OI Tunner	┟╼╶╌╍╌╸┥	LUWESI DIUS	<u> </u>	<u> </u>
Mobilization	LS				ł .	
			{ . }	318,888	325,000	325,000
Clear, Grub	LS	l l		141.667	75.000	75,000
Subtotal						400,000
Drill Pilot Holes		Ι.				1
Tunnel Excavation	385,000 cv	16.53		48, 63	36.82	14.176.000
Tunnal Enlargement	3 300 cv	.14		88 15	178.18	390,000
Abon (Doak Doffil)	0,000.09	•••	i ·}	00.10	110.10	75 000
Other (Nock Renn)						10,000
Subtotal	· ·	. ·	÷ .		۲ 	14,"641,000
Steel Sets	18.500,000 lb	794.33		. 115	.13	2,405,000
Rock Bolts	11,200 lf ^a	. 48	1 · 1	2.25	1.50	16.800
Timber	3:500 MBM	. 15	1 1	250 00	550.00	1.925.000
Deals Dalt Shanag	0,000 11011	• 10	} }			1,000,000
Rock Don Shapes	· (1 04E)	× .	}	9 60	- 40	6 790
Chain Link Fabric	1,245 sy		1 · ·	3.00	5.40	0,720
	(6,400			3.67	3.00	19,200
Liner Plate	872,000 lb	37.44		. 238	. 25	218,000
Other Expansion Bolts		ł	Į į		{	4,590,720
Subtotal	Į į				{	
Conorete	119 600 ov	5 14		38 66	35.00	4.186.000
Coment	206 700 DDI b	0.14	· · .	4.50	4 00	976 900
Cement	200, 100 DDL C	507.01		4.00	4.00	040,000
Reinforcing Steel	12,274,000 10	527.01		. 10	• 18 ·	2,209,320
Subtotal	. "	(1	7,222,120
Drill Grout Holes	4.450 lf	ĺ		3.53	2.40	10,700
Grout Pipe	3.300 lb	Į .		1.38	1.55	5,100
Grout Connection	1,850 68.	(²)		17.68	14.05	26,000
Grout Operation	181 980 of	7 82		3 43	3.70	674,000
DAMO			Į I	4.99	4.00	29 400
PANC	3,000 CI	41		4,00	4. 00	30, 400
Other			1		[· .	754 000
Subtotal]	· · ·	754,200
Other Tunnel	1	i .				1,160,550
Tunnel Total		1.]	1	28,768,590
		ŀ	})	100,100,000
Other Project					1	2,005,040
Total Project					}	30,773,630
					}	
		1		·		
	· · ·				· · ·	

a. Converted to linear feet by assuming 2.5 lbs/lf.

b. Cement for Structure (7,400 cy) was assumed to be 1.5 BBl/cy.

c. Rebar for Structures was assumed to be 150 lbs/cy.

Naine:	Balboa Inlet Approximate Date: 1966
Location:	Southern California (Newhall County)
Owner:	Metropolitan Water District of Southern California
Contractor:	Dixon, Arundel, MacDonald & Kruse, Kiewit
Machine Manufacturer:	None
Shape:	Round .
Length:	5,000 LF
Bore:	18'4''
Inside Diameter:	14'
Calculated Volumes:	
Excavation:	9.78 CY/LF
Excavation:	48,900 CY
Lining:	4.08 CY/LF
Lining:	20,400 CY
Material:	Predominately thinly to thickly interbedded and intertongued gray, tan and light brown sandstone, some mudstone and shale and some pebble to
·	boulder conglomerate. Sandstone compressive strength 1,000-3,000 psi.

	Quantity	Quantity per LF of Tunnel	Unit Price	Final Cost
Mobilization Clear, Grub Subtotal	LS		25,000	25,000 25,000
Drill Pilot Holes Tunnel Excavation Tunnel Enlargement Other (Rock Refill) Subtotal	49,313 cy	9.86	45.00	2,219,085 <u>16,470</u> <u>2,235,555</u>
Steel Sets Book Bolts	1,458,000 lbs	291.60	.13	189,540
Timber Rock Bolt Shapes Chain Link Fabric	502 MBM	.10	550.00	. 276,100
Liner Plate Other Subtotal	56, 800 lb	11.36	.25	14, 195
Concrete Cement Reinforcing Steel Subtotal	19,506 cy 32,800 BBL 2,219,842 lb	3.90 6.56 443.97	35.00 4.00 .18	682, 810 107, 872 <u>399, 572</u> 1, 190, 254
Drill Grout Holes Grout Pipe Grout Connections . Grout Operation PAMC	996 lf 441 lb 307 ea 42,511.5 cf	8.50	2.00 2.00 10.00 3.70	1,992 882 3,070 157,450
Other Subtotal				163,394
Other Tunnel Total Tunnel				$\frac{292,016}{4,386,054}$
Other Project Total Project			· ·	$\frac{24,896}{4,410,950}$

Name:	Newhall	Approximate Date:	1966
Location:	Southern California (Newhall County)		
Owner:	Metropolitan Water District of Southern Califo	rnia	
Contractor:	Dixon, Arundel, MacDonald & Kruse, Kiewit	· · ·	
Machine Manufacturer:	Calweld		
Shape:	Circular		
Length:	18,290		
Bore:	25'7''		
Inside Diameter:	20'6"	к.	
Calculated Volumes:			
Excavation:	19.18 CY/LF		
Excavation:	350,800 CY (nearest hundred)		
Lining:	6.95 CY/LF		
Lining:	127,100 CY (nearest hundred)		

Material:

Predominately thinly to thickly interbedded and intertongued gray, tan and light brown sandstone, some mudstone and shale and some pebble to boulder conglomerate. Sandstone compressive strength 1,000-3.000 psi.

	Quantity	Quantity per LF of Tunnel	Unit Price	Final Cost
Mobilization Clear, Grub Subtotal	LS LS		300,000 75,000	300,000 <u>75,000</u> <u>375,000</u>
Drill Pilot Holes Tunnel Excavation Tunnel Enlargement Subtotal	323,075 lf	17.66	35.60	$\frac{11,501,475}{11,501,475}$
Steel Sets Rock Bolts	16,566,000 lbs	905.74	. 13	2, 153, 567
Timber Rock Bolt Shapes	3,000 MBM	.16	550.00	1,650,000
Chain Link Fabric	2,371 SY	<u></u> -	3.00	7,113
Liner Plate	176,000 I b	9.62	.25	44,000
Subtotal		· · ·		3,854,680
Concrete	98,796 cy	5,40	35.00	3,457,860
Cement	156,323 BBL	8.55	4.00	625,292
Reinforcing Steel Subtotal	6,695,213 lb	366.06	.18	1,205,138 5,288,290
Drill Grout Holes	2,251 lf		2,50	5 628
Grout Pipe	3,412 lb		1.50	5, 118
Grout Connections	1,052 ea		15.00	15,780
Grout Operation	172,800 cf	9.99	3.70	640,000
PAMC Other	• 16,980 cf	.93	4.00	67,920
Subtotal		1	,	734,446
Other Tunnel				0
Tunnel Total				21,753,891
Other Project Total Project				$\frac{1,083,845}{22,837,736}$

A-22

1

Name:	Balboa-Newhall
Location:	Southern Califor
Owner:	Metropolitan Wa
Contractor:	Dixon, Arundel,
Machine Manufacturer:	Calweld in Newh
Shape:	Circular
Length:	23,290 LF
Bore:	
Inside Diameter:	
Calculated Volumes:	
Excavation:	17.16 CY/LF
Excavation:	399,700 CY (nea

Southern California (Newhall County) Metropolitan Water District of Southern California Dixon, Arundel, MacDonald & Kruse Kiewit Calweld in Newhall Circular 23,290 LF 17.16 CY/LF 399,700 CY (nearest hundred)

6.33 CY/LF

Lining: Lining: Material:

147,500 CY (nearest hundred) Predominately thinly to thickly interbedded and intertongued gray, tan and light brown sandstone, some mudstone and shale and some pebble to boulder conglomerate. Sandstone compressive strength 1,000-3,000 psi.

e,	Quantity	Quantity per LF of Tunnel	Unit Price	Final Cost
Mobilization Clear, Grub Subtotal	LS LS		325,000	325,000
Drill Pilot Holes Tunnel Excavation Tunnel Enlargement Other (Rock Refill)	372,388 cy	15.99	36.84	13,720,560 <u>16,470</u>
Subtotal Steel Sets Back Balta	18,024,000 lbs	773.89	.13	$\frac{13,737,030}{2,343,107}$
Timber Rock Bolt Shapes	3,502 MBM	.15	550.00	1,926,100
Chain Link Fabric Liner Plate Other Subtotal	2,371 sy 232,800 lb	10.00	3.00 .25	7,113 58,195
Concrete Cement Reinforcing Steel Subtotal	118,302 cy 189,123 BBL 8,915,055 lb	5.08 8.12 382.78	35.00 4.00 .18	$\begin{array}{r} 4,334,515\\ 4,140,670\\ 733,164\\ \underline{1,604,710}\\ \underline{-6,478,544}\end{array}$
Drill Grout Holes Grout Pipe Grout Connections Grout Operation PAMC Other Subtotal	3,247 lf 3,853 lb 1,359 ea 225,311.5 cf 16,980 cf	9.67 .73	$2.35 \\ 1.56 \\ 13.87 \\ 3.70 \\ 4.00$	7,620 6,000 18,850 797,450 67,920
Other Tunnel Tunnel Total	· · ·			$\frac{292,016}{26,139,945}$
Other Project Total Project		· · ·		1,108,741 27,248,686
		•		

Name: Saugus, Placerita, Newhall Siphon Approximate Date: 1966 Location: S. California (Los Angeles County) Owner: Metropolitan Water Dist. of S. California Contractor: Delaware Corp. Machine Manufacturer: MEMCO Shape: Circular Length: 9582 LF Bore: 25'8" Inside Diameter: 20'6" Calculated Volumes: Excavation: 19.18 CY/LF Excavation: 183,800 CY (nearest hundred) Lining: 6.95 CY/LF Lining: 66,600 CY (nearest hundred) Material: Saugus formation, brown and tan sandstone conglomerate, greenish-gray sandstone and reddish-brown siltstone. Mainly non-marine origin.

	• •	Quantity	Unit Price			Total 🗖
	Quantita	per		Average of	.	Dollars
	Quantity	LF	Engineer's	of Three	Low	Low
	1	of Tunnel	Estimate	Lowest Bids	Bid	Bid
1						
Mobilization	LS	·.		300,000	300,000	300,000
Clear, Grub	LS	1	. · · ·	35,333	100,000	100,000
Subtotal	·			•		400,000
				·		
Drill Pilot Holes						0.015:000
Tunnel Excavation	145,000 cy	15.13		21.67	27.00	3,915,000
Tunnel Enlargement	• .			· ·]	
Subtotal						3,915,000
Steel Sets	6, 800, 000 lb	709.66		. 165	. 125	8504000
Book Bolta	0,000,000	100100				,
Timber	1.e		-		1	
Deels Delt Sherros					l .	
Rock Boit Snapes	15 000	,		70	60	. 97 000
Chain Link Fabrie	40,000 Sy	140.07		1.14	.00	21,000
Liner Plate	1,140,000 10	118.97		.184	.08	91,200
Other Expansion Bolts).		
Subtotal			}	1		968,200
Conc rete	46,000 cy	4.80	}	37.50	32.50	1,495,000
Cement	68,800 BBI ⁸	7.18	· ·	4.62	5.00	344,000
Reinforcing Steel	386, 500 lb	46.34	ł	.145	.13	50,245
Subtotal		· · ·			1	1,889,245
Dutill Grout Walse	0 540 16			0.00	= 00	10 700
Drill Grout Holes	2,540 11		· ·	3.83	5.00	12,100
Grout Pipe	2,100 15			1.03	1.00	2,100
Grout Connection	830 ea.		ļ·	10.00	12.00	9,960
Grout Operation	18,900 cf	1.97	ł	2.90	2.41	45,500
PAMC	67,000 cf	6,99	1 × 1	2,52	4.00	268,000
Other			· ·			
Subtotal	•		, ,	·		338,260
Other Tunnel				1	1	7 520 240
]	15 020,045
						10,000,010
Other Project				·	1	2,059,375
Total Project		· ·	ļ	•		17,090,320
,	. :	ł	l .	• • • •		
		l			· ·	
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	L	j	1		ł	
	•			· ·		1
	,	1	1	1	1 .	1

A-24

a. Assume 1.5 BBI/cy for Surface Structures and cast-in-place pipe (18470 cy).

b. Assume 150 lbs/cy for Surface Structures and cast-in-place pipe.

Name:	Castaic #1. #2		Approximate I	Date: 1966	
Location:	S. California (Los Angeles County)		•		
Owner:	Metropolitan Water Dist. of S. Califor	rnia	· .		
Contractor:	Delaware Corp.			-	
Machine Manufacturer:	MEMCO				
Shape:	Circular			•	
Length:	18,503 LF		÷	,	
Bore:	25'8"				
Inside Diameter:	20'6''				
Calculated Volumes:					
Excavation:	19.8 CY/LF	4			
Excavation:	354, 900 CY (nearest hundred)		• •	•	
Lining:	6.95 CY/LF				
Lining:	128, 600 CY (nearest hundred)				
Material:	Castaic and Saugus formation tan and h clay stone, marine and non-marine or	brown sa igin.	andstone, tan s	iltstone and	

·····	1. • • • 4 .	Quantity	Unit Price			Total ;
	Quantity	per LF of Tunnel	Engineer's Estimate	Average of of Three	Low Bid	Dollars Low Pid
Mobilization Clear, Grub Subtotal	LS LS	or runner		300,000 56,333	300,000 160,000	300,000 160,000 460,000 460,000 460,000
Drill Pilot Holes Tunnel Excavation Tunnel Enlargement Subtotal	341,000 cy	18 . 43		18.50	21.00	7,161,000
Steel Sets Rock Bolts Timber	16,200,000 lb	875.58	-	. 165	.125	2,025,000
Rock Bolt Shapes Chain Link Fabric Liner Plate Other Expansion Bolts Subtotal	121,000 sy			.72	. 60	72,600
Concrete Cement Reinforcing Steel Subtotal	106,700 cy 160,350 BB1 11,035,000 Ib	5.77 8.67 596.39	~	29.83 4.62 .145	27.50 5.00 .13	2,934,250 801,750 1,434,550 5,170,550
Drill Grout Holes Grout Pipe Grout Connection Grout Operation PAMC Other Subtotal	3,500 lf 4,500 lb 1,320 ea. 45,900 cf 182,000 cf	2.48 9.84		3.83 1.03 9.00 2.90 2.52	$5.00 \\ 1.00 \\ 12.00 \\ 2.41 \\ 4.00$	17,500 4,500 15,840 110,500 728,000 876,340
Other Tunnel Tunnel Total	н 					<u>1,336,310</u> 17,101,800
Other Project Total Project						$\frac{470,400}{17,572,200}$

a. Assume 15 BBL/CY in Surface Structures (1, 100 CY)

b. Assume 150 lbs/cy in Surface Structures

A-25

Castaic #1, #2, Saugus, Placerita, Newhall Siphon (Total) S. California (Los Angeles County) Metropolitan Water Dist. of S. Cal. Delaware Corp. MEMCO Circular 28,085 LF 25'8'' 20'6'' 19.18 CY/LF 538,700 CY (nearest hundred)

6.95 CY/LF

195, 200 CY (nearest hundred)

See previous sheets.

Approximate Date: 1966

Name: Location: Owner: Contractor: Machine Manufacturer: Shape: Length: Bore: Inside Diameter: Calculated Volumes: Excavation: Excavation: Lining: Lining: Material:

		Quantity		Unit Price	·	Total p
	Quantity	per LF of Tunnel	Engineer's Estimate	Average of of Three Lowest Bids	Low Bld	Dollars Low Bid
Mobilization Clear, Grub Subtotal	LS LS			600,000 91,667	600,000 260,000	600,000
Drill Pilot Holes Tunnel Excavation Tunnel Enlargement Subtotal	486,000 cy	17.34				11,076,000 11,076,000
Steel Sets Rock Bolts Timber Rock Bolt Shapes	23,000,000 lb	818.94		. 165	. 125	2;875,000
Chain Link Fabric Liner Plate Other Expansion Bolts Subtotal	166,000 sy 1,140,000 lb	40.59		.72 .184	. 60 . 08	99,600 91,200 <u>3,065,800</u>
Concrete Cement Reinforcing Steel Subtotal	152,700 cy 229,150 BBl 11,421,500 lb	5.44 8.16 406.68		4.62 .145	5.00 .13	4,429,250 1,145,750 <u>1,484,795</u> 7,059,795
Drill Grout Holes Grout Pipe Grout Connection Grout Operation PAMC Other	6,040 lf 6,600 lb 2,150 ea. 64,800 cf 249,000 cf	2.31 8.87		3.83 1.03 9.39 2.90 2.52	5.00 1.00 12.00 2.41 4.00	30,200 6,600 25,800 156,000 996,000
Subtotal Other Tunnel Tunnel Total						<u>1,214,600</u> 8,856,550 32,132,745
Other Project Total Project			· .			2,529,775 <u>34,662,520</u>
•			а —			

A-26

a. Assume 1.5 BBI/cy for Structures and Cast-in-place pipe (19570 cy).

Name:	San Fernando Apr	roximate Date:	1969
Location:	S. California (Los Angeles County)		
Owner:	Metropolitan Water Dist. of S. Cal.		
Contractor:	Lockheed Shipbuilding and Construction Co.		
Machine Manufacturer:	Robbins		
Shape:	Circular		
Length:	28,825 LF		
Bore:	21'10"		
Inside Dlameter:	18'		
Calculated Volumes:			
Excavation:	13.87 CY/LF		
Excavation:	399,800 CY (nearest hundred)		
Lining:	4.44 CY/LF		
Lining:	128,000 CY (nearest hundred)		
Material:	Approximately 50 percent old alluvium, soft to firm,	dry to wet,	

Approximately 50 percent old alluvium, soft to firm, dry to wet, and 50 percent dry to set sandstone and conglomerate.

•		Quantity		Unit Price		Total
	Quantity	per LF of Tunnel	Engineer's Estimate	Average of of Three Lowest Bids	Low Bid	Dollars Low Bid
Mobilization Clear, Grub Subtotal	LS LS		·	500,000	500,000	500,000 500,000
Drill Pilot Holes	•			+		
Tunnel Excavation	11,430 lf 17,395 lf			328.00 367.00	260.00 320.00	2,971,800 5,566,400
Tunnel Enlargement Subtotal	· · ·	3				8,538,400
Steel Sets	{ 11,430 lf 17,395 lf			143.00 180.00	170.00 210.00	1,943,100 3,652,950
Rock Bolts Timber Rock Bolt Shapes Chain Link Fabric Liner Plate Other Expansion Bolts Subtotal						5,596,050
Concrete Cement	28,825 lf	70 95		77,00	70.00	2,017,750
Subtotal	2,100,000 10	12.00	- ⁻	. 133	.14	294,000
Drill Grout Holes Grout Pipe Grout Connection Grout Operation PAMC Other	3,600 lf 4,500 lb 1,400 ea. 189,000 cf	6.56		2.67 2.67 13.33 1.60	4.00 1.00 10.00 2.22	14,400 4,500 14,000 420,000
Subtotal				÷		452,900
Other Tunnel Tunnel Total						$\frac{236,000}{17,634,900}$
Other Project Total Project	• .					1,711,900 19,346,800
	•				•	-

A · 27

Name: Castaic Dam Diversion Location: S. California (Los Angeles County) Owner: Metro. Water District Contractor: Klewit Co. Machine Manufacturer: None Circular Shape: 3,598 LF 1,950 LF 1,648 LF Length: 33'6" 23'10" Bore: 25' 19' Inside Diameter: Calculated Volumes: Excavation: 25.27 CY/LF 90,900 CY (nearest hundred) Excavation: 10.60 CY/LF Lining: 38,100 CY (nearest hundred) Lining: Material:

Approximate Date: 1964

Interbedded shales, siltstones and sandstone layers of fractions of inch to 8 feet thick, sandstone weakly cemented and subject to sliding.

		Quantity		Unit Price	<u></u>	Total
	Orrentline	per	Dl- conta	Average of	*	Dollars
	Quantity	LF	Engineers	of Three	LOW	Low
		of Tunnel	Estimate	Lowest Bids	Bid	Bid
Mabilization	10		1 415 000	400 000	50.000	E0 000
Close Cash			1,415,000	466,667	50,000	50,000
Clear, Grub		•	10,000	5,833	5,500	. 5, 500
Subtotal	· · · · ·			· · ·		55,500
Drill Pilot Holes	1 000 14	97	19 60	10 67	19.00	12 000
Tunnel Exception	94'100 or	26 16	12.00	12.07	12.00	9 271 220
Tunnel Enlargement	94,100 Cy	20,10	10,50	20.40	25.20	2,0/1,020
Subtotol						0.000.000
Subtotal						2,383,320
Steel Sets	3,210,000 lb	892.16	. 25	. 25	. 35	1,123,500
Rock Bolts				·		
Timber	470 MBM	.13	400.00	283.00	300.00	141,000
Rock Bolt Shapes		!				
Chain Link Fabric				· · ·		
Liner Plate		Į				
Other Expansion Bolts			·			
Subtotal					1	1.264.500
			•	2		
Concrete	36,215 cy	10.07	37.00	38.00	42.00	1,521,030
Cement	47,400 BBI	13.17	5.00	4.50	4.50	213,300
Reinforcing Steel	594,500 lb ^D	165.23	. 15	.143	. 15	<u> </u>
Subtotal						1,823,505
	(7 000 lf		4 15	4 43	4 80	33,600
Drill Growt Holes	360 lf	1	2.95	4 59	4.00	1,530
	1 080 15		4.75	4.00	4.20	4,860
Grout Pipe	11,000 lb	· ·	1 00	4.07	4.50	6 720
Grout Connection	1,200 10		1.00	10 99	19.00	13 200
Grout Operation	1,100 ea.		25.00	10.33	12.00	24 000
DA MC	4,000 CL	1.11	3.00	3.30	8.00	34,000
PAMC			1			
Subtatal	· · ·					
Subtotal	· · ·	1				93,910
Other Tunnel]			1 · ·	0
Tunnel Total		.			· · ·	5,620,735
Other Ducks					1	2 960 205
Other Project						8 580 940
I otal Project		· ·				0,000,010
		· ·		1	1	

a. Assume 1.5 BBl/cy for surface structures.

b. Assume 150 lbs/cy for surface structures.

Name:	Castalc Dam Diversion			A
Location:	S. California (Los Angeles County)			
Owner:	Metro. Wa	ter Distric	t'	
Contractor:	Kiewit Co.			
Machine Manufacturer:	None			•
Shape:	Circular			
Length:	3,598 LF	1,950 LF	1,648 LF	
Bore:		33'6"	23'10''	
Inside Diameter:		25'	19'	
Calculated Volumes:			1	
Excavation:	25, 27 CY/	'LF		
Excavation:	90,900 CY	(nearest h	undred)	
Lining:	10.60 CY/	′LF		
Lining:	38, 100 CY (nearest hundred)			
Material:	Interbedded shales, siltstones and sandstone			

Interbedded shales, siltstones and sandstone layers of fractions of inch to 8 feet thick, sandstone weakly cemented and subject to sliding.

	Quantity	Quantity per LF of Tunnel	Unit Price	Final Cost
Mobilization Clear, Grub Subtotai	LS LS		50,000 5,500	50,000 <u>5,500</u> <u>55,500</u>
Drill Pilot Holes Tunnel Excavation Tunnel Enlargement Subtotal	1,000 lf 96,115 cy	.28 26.71	12.00 25.20	$ \begin{array}{r} 12,000 \\ 2,422,098 \\ \hline \hline 2,434,098 \end{array} $
Steel Sets Rock Bolts	11, 167 , 649 lbs	3,103.85	. 35	3,908,677
Timber Rock Bolt Shapes Chain Link Fabric Liner Plate	726 MBM	. 20	300.00	217,809
Subtotal		, ·		4,126,486
Concrete Cement Reinforcing Steel Subtotal	37,906 cy 65,571 BBI 594,500 lb	10.54 18.22 165.23	42.00 4.50 .15	$1,592,047 \\ 295,071 \\ \underline{89,175} \\ \underline{1,976,293}$
Drill Grout Holes Grout Pipe	<pre>{ 7,000 lf 360 lf 1,080 lf 11,200 lb</pre>		4.80 4.25 4.50 .60	$33,600 \\ 1,530 \\ 4,860 \\ 6,720$
Grout Connection Grout Operation PAMC Other Subtotal	1, 100 ea 4,000 cf NA	1, 11	12.00 8.50 NA	13,200 34,000 44,519
Other Tunnel Tunnel Total			• •	<u>0</u> 8,730,806
Other Project Total Project				2,960,205 11,691,011

a. Assume 1.5 BBl/cy for surface structures.

b. Assume 150 lbs/cy for surface structures.

4

5 a g

NA = Not Available.

Name	Carley V. Porter Approximate Date: 1965
Location:	S. California (Kern County)
Owner:	California Dept. of Water Resources
Contractor:	Dravo, Atkinson, Groves
Machine Manufacturer:	None
Shape:	Circular
Length:	25,080 LF
Bore:	24'4''
Inside Diameter:	20'
Calculated Volumes:	
Excavation:	17.23 CY/LF
Excavation:	432, 100 CY (nearest hundred)
Lining:	5.59 CY/LF
Lining: Material:	140, 200 CY (nearest hundred) Highly fractured to crushed igenous and metamorphic rocks of the Garlock Fault deeply weathered to altered granite and soft moderately indurated claystones

d.

and gravelly mudstones.

		Quantity		Unit Price		Total
	Quantity	per LF of Tunnel	Engineer's Estimate	Average of of Three Lowest Bids	Low Bid	Dollars Low Bid
Mobilization Clear, Grub Subtotal	LS LS			1,000,000 126,667	1,000,000 20,000	1,000,000 20,000 1,020,000
Drill Pilot Holes Tunnel Excavation Tunnel Enlargement Subtotal	500 lf 435, 000 cy	.02 17.34	25.00 48.00	35.00 49.17	30.00 38.00	15,000 16,530,000 16,545,000
Steel Sets	24,800,000 lb	988.84 1156.30	. 41	16.33	. 25	7,250,000
Rock Bolts Timber Rock Bolt Shapes Chain Link Fabric Liner Plate Other Expansion Bolts Subtotal	4,000 MBM	.16	500.00	357.00	300.00	1, 200, 000 8, 450, 000
Concrete Cement Reinforcing Steel Other Pozzolan Subtotal	127,000 cy 140,000 BBl 1,740,000 lb	5.06 5.51 69.38	46.00 5.00 .25	56.33 5.00 .17	45.00 5.00 .15	5,715,000 700,000 261,000 126,000 6,802,000
Drill Grout Holes Grout Pipe Grout Connection Grout Operation PAMC Other Subtotal						
Other Tunnel Tunnel Total						32,817,000
Other Project Total Project		, ,				<u>971,800</u> 33,788,800

a. Option on two sizes of Steel Sets.

Name:	Carley V. Porter	App	roximat	e Date:	1900
Location:	S. California (Kern County)				
Owner:	California Department of Wate	r Resources			
Contractor:	Dravo, Atkinson, Groves				
Machine Manufacturer:	None				
Shape:	Circular				
Length:	25,080				
Bore:	24'4''				
Inside Diameter:	20'			-	
Calculated Volumes:					
Excavation:	17.23 CY/LF				
Excavation:	432, 100 CY (nearest hundred)				
Lining:	5.59 CY/LF				
Lining:	140,200 (nearest hundred)				
Material:	Highly fractured to crushed ige	enous and metam	norphic	rocks o	f the
	Garlock Fault, deeply weather	ed to altered gra	inite an	d soft m	oderately
	indurated claystones and grave	lly mudstones.			
· · · · · · · · · · · · · · · · · · ·		<u> </u>			

	Quantity	Quantity Quantity LF of Tunnel		Final Cost	
Mobilization Clear, Grub Subtotal	LS LS		1,000,000 20,000	1,000,000 20,000 1,020,000	
Drill Pilot Holes Tunnel Excavation Tunnel Enlargement Subtotal	500 lf 435,000 cy	.02 17.34	30.00 38.00	$ 15,000 \\ 16,530,000 \\ \overline{16,545,000} $	
Steel Sets Bock Bolts	29,000,000 lbs	1,156.30	. 25	7,250,000	
Timber Rock Bolt Shapes Chain Link Fabric	4,000 MBM	.16	300.00	1,200,000	
Liner Plate Other Expansion Bolts Subtotal				8,450,000	
Concrete Cement Reinforcing Steel Other (Pozzolan) Subtotal	141,061 cy 165,085 BBI 1,740,000 lb	5.62 6.58 69.36	45.00 5.00 .17	6,347,765825,428261,000126,0007,560,193	
Drill Grout Holes Grout Pipe Grout Connection Grout Operation PAMC Other Subtotal					
Other Tunnel Tunnel Total				$\frac{782,297}{34,357,490}$	
Other Project Total Project				$\frac{971,800}{35,329,290}$	

Approximate Date: 1966

Name: Location: Owner: • Contractor: Machine Manufacturer: Shape: Length: Bore: Inside Diameter: **Calculated Volumes:** Excavation: Excavation: Lining: Lining: Material:

Angeles S. California (Los Angeles County) California Department of Water Resources Shea, Kaiser, Lockheed, Healy None Circular 37,774 LF 35'6" 30' 36.67 CY/LF 1,385,200 CY (nearest hundred) 10.48 CY/LF 395,900 CY (nearest hundred) Interbedded sandstone, siltstone, and shale. Compressive strength

4,000 to 7,000 psi.

		Quantity			Total 1	
	Ouantitu	per	Engineenia	Average of	T our	Dollars
	Quantity	LF	Engineers	of Three	LOW	Low
·		of Tunnel	Estimate	Lowest Bids	BIG	Bid
Mobilization	LS	7	5,000,000	3,000,000	3,000,000	3,000,000
Clear, Grub	LS		34,700	739,633	2,000,000	2,000,000
Subtotal						5,000,000
Drill Pilot Holes	10.000 lf	f . 26	13.65	7.67	3.00	30,000
Tunnel Excavation	1.396,000 c	v 36.96	17.00	23.61	27.95	39.018.200
Tunnel Enlargement	-,					00,000,000
Subtotal	*			-		39.048,200
a [a						
Steel Sets	35,842,000 10	948.85	.25	.23	.25	8,960,500
Rock Bolts	511,000 11	13.53	3.00	1.18	1.75	894,250
Timber	7,000 M	(BM . 19	325.00	142.00	150.00	1,050,000
Rock Bolt Shapes						
Chain Link Fabric	71,000 8	У	4.65	3.03	2.00	142,000
Liner Plate	• .			<i>4</i>	.	1
Other Expansion Bolts		× .		-	[·	
SUDIOUAL				4		11,046,750
Concrete	406,000 c	y 10.75	28.00	30.33	15.00	6,090,000
Cement	565,000 B	BI	4.75	4.48	4.50	2, 542, 500
Reinforcing Steel	640,000 lt	b 16.94	.26	.218	. 25	160,000
Subtotal	· .		ľ			8,792,500
	120.000 lf		4.35	3.67	4.00	480,000
	70.000		4.35	3.83	3.00	210,000
Drill Grout Holes .	60,000		4.35	4.57	3.20	192,000
	20,000		3.75	2.40	3.20	64,000
Cont Dies		L	1.05	1.00		
Grout Pipe			1.30	UU.1	1.00	280,000
Grout Connection	35,000 8		27,00	13.00	12.00	420,000
Grout Operation	39,000 0	Z.20	3.40	- 5, 17	5.00	467,500
PAMU Other (Crout Sand)	039,000 8	π	.00	.00	1.00	639,000 47 500
Other (Grout Sand)						47,500
Subtotat				· ·		2,800,000
Other Tunnel		· [1	1		10,800,620
Tunnel Total					· ·	77,488,070
Other Project	4.* -	·	1	· .		17 551 580
Total Project	· · ·					95 039 650
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Name:	San Bernardino	Approximate
Location:	S. California (San Bernardino County)	
Owner:	California Department of Water Resources	
Contractor:	Shea Co.	•
Machine Manufacturer:	None	
Shape:	Circular	
Length:	20,123 LF	
Bore:	16'6"	•
Inside Diameter:	12'9"	
Calculated Volumes:		
Excavation:	7.92 CY/LF	
Excavation:	159, 400 CY (nearest hundred)	
Lining:	3.19 CY/LF	
Lining:	64,200 CY (nearest hundred)	
Material:	Granitic and gnelssic basement rock including	; so me marble.

	Quantity	Quantity per LF of Tunnel	Unit Price	Final Cost
Mobilization	LS J LS		582, 536 867, 885	582,536 867,885
Subtotal	l ls		462,305	462,305 1 912 726
Drill Pilot Holes Tunnel Excavation Tunnel Enlargement	2,000 lf 160,182 cy	.099 7.96	20.00 51.35	40,000 8,225,338
Steel Sets Rock Bolts Timber	11,890,540 lbs 27 lf 1,500 MBM	591.11 .001 .075	.38 1.50 400.00	4,518,405 405 600,000
Rock Bolt Shapes Chain Link Fabric Liner Plate	314,778 sy		. 72	25,040
Subtotal			•	5,143,850
Concrete Cement Reinforcing Steel Subtotal	49,360 cy 94,458 BBI 310,000 lb	2.45 4.96 15.41	15.00 4.00 .15	740,400377,83246,5001,164,732
Drill Grout Holes Grout Pipe Grout Connection	{ 2,000 lf { 16,200 lf 30,000 lb 740 ea (14,000 ef	0.10	20.00 12.00 1.00 30.00	40,000 194,400 30,000 22,200
Grout Operation PAMC Other { Grout Sand Fabric	44,000 cf 40,000 cf 2,700 cf	2.19 1.99 .13	2.50 2.50 5.56	100,000 100,000 15,000 50,000 460
Subtotal Other Tunnel Tunnel Total				$\frac{562,060}{252,000}$
Other Project Total Project				<u>6,638,930</u> 23,939,636

a.

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Assume 1.5 BBI/cy for surface structure (10,650 cy). Assume small reinforcing steel in Tunnel Surge Chamber and Surge Chamber (6,800 cy) b. has 150 lbs/cy.

Name: Location: Owner: Contractor: Machine Manufacturer: Shape: Length: Bore: Inside Dlameter: Calculated Volumes: Excavation: Excavation: Lining: Lining: Material:

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San Bernardino S. California (San Bernardino County) California Department of Water Resources Shea Co. None Circular 20, 123 LF 16'6'' 12'9'' 7. 92 CY/LF 159, 400 CY (nearest hundred) 3. 19 CY/LF 64, 200 CY (nearest hundred)

Granitic and gneissic basement rock including some marble.

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· ·	· .	Quantity			Total	
	Quantity	per	Engineeria	Average of	Tom	Dollars
	Quantity .	LF	Engineer's	of Three		Low
	•	of Tunnel	Estimate	Lowest Bids	Біц	Bid
Mobilization	LS		1,000,000	860,845	582,536	582,536
Cloan Crub	∫ LS		194,500	896,295	867,885	867,885
Clear, Grub	LS		40,200	244, 102	462,305	462,305
Subtotal				:		1,912,726
Drill Pilot Holtes	2,000 lf	. 099	22.00	26,33	20.00	40,000
Tunnel Excavation	166,000 cy	8.25	30.00	46.45	51.35	8,524,100
Tunnel Enlargement						
Subtotal	· · ·					8,564,100
Steel Sets	2,620,000 lb	130.20	.30	.44	. 38	9 95,600
Rock Bolts	104,000 lf	5,17	2.85	3.17	1.50	156,000
Timber	1,500 MBM	.075	485.00	367.00	400.00	600 ,000
Rock Bolt Shapes	· · · · ·				1	·
Chain Link Fabric	34,778 sy	á.	3.60	3.99	. 72	25,040
Liner Plate	-					
Other Expansion Bolts				• • .		
Subtotal				-		1,776,640
Concrete	71,000 cy	3.53	43.50	39 .67	• 15.00	1,065,000
Cement	97,000 BBI	4.82	4.00	4.43	4.00	388,000
Reinforcing Steel	310,000 lb ^d	15.41	.18	177	. 15	46,500
Subtotal	•		· · ·			1,499,500
· .	(2,000 lf		22.00	26.33	20.00	40,000
	12,000 lf		4.50	9.33	12.00	144,000
Drill Grout Holes	900 lf	1	6.00	10.33	12.00	10,800
	3,300 lf		7.00	11.33	12.00	39,600
Grout Pipe	30,000 lb		1.35	1.07	1.00	30,000
Grout Connection	740 ea		25.00	48.00	30.00	22,200
Grout Operation	{ 44,000 cf	2.19	4.40	7.17	2.50	110,000
dious operation	40,000 cf	1.99	4.40	12.17	2.50	100,000
PAMC	2,700 cf	ł	1.63	2.41	5.56	15,000
Other Grout Sand)	50,000
Fabric				-		460
Subtotal						562,060
Other Tunnel					·	252,000
Tunnel Total	· ·				1	14,567,025
Other Project		· .			· · .	6,638,930
Total Project	· ·		· · · · · · · · · · · · · · · · · · ·		1	21,205,956

a. Assume 1.5 BBL/CY for Surface Structures (10,650 CY).

b. Assume Small Rebar in Tunnel Dollar Surge Chamber and Surge Chamber (6,800 CY) has 150 lbs/cy.

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Name:	Tehachapi #1, #2, #3
Location:	S. California (Kern County)
Owner:	California Department of Water Resources
Contractor:	Granite, Gates and Fox, Bell
Machine Manufacturer:	None
Shape:	Circular
Length:	16,052 LF
Bore:	28'10"
Inside Diameter:	23'6"
Calculated Volumes:	- · · ·
Excavation:	24.19 CY/LF
Excavation:	388, 300 CY (nearest hundred)
Lining:	8.12 CY/LF
Lining:	130,300 CY (nearest hundred)
Material:	Moderately blocky and seamy schists.

Unit Price Quantity Total Average of per Dollars Engineer's Quantity Low LF of Three Low Estimate Bid of Tunnel Lowest Bids Bid Mobilization 3,000,000 2,500,000 \mathbf{LS} 3,000,000 3,000,000 109,000 209,333 253,000 253,000 Clear, Grub LŚ 138,000 783,333 300,000 300,000 Subtotal 3,553,000 Drill Pilot Holes Tunnel Excavation 405,000 cy 25,23 20.50 24.75 24.249,821,250 Tunnel Enlargement Subtotal 9,821,250 Steel Sets 19,700,000 lb 1,227,26 .23 . 18 . 15 2,955,000 **Rock Bolts** 59.000 lf 326 2.25 2.87 3.50 206,500 . 11 Timber 1,800 MBM 380.00 317.00 400.00 720.000 **Rock Bolt Shapes** Chain Link Fabric 2.70 8.25 35,899 sy 9.00 123,000 Liner Plate Other (Welded Wire Fabric) 7,700 Subtotal 4,012,200 Concrete 148,000 cy 9.22 36.00 35.67 40.00 5,920,000 Cement 196,000 BBI 12.21 5.00 4.75 5.00 980,000 **Reinforcing Steel** 2,140,000 lb 133.32 .16 . 16 299,600 .14 Subtotal 7,201,600 Drill Grout Holes 35,000 lf 3.13 4.70 5.50 192,500 25,400 lb **Grout Pipe** 1.25 1.17 1,00 25,400 **Grout Connection** 2,300 ea 21.00 18.67 11.00 25,300 Grout Operation 20,000 cf 1.25 5.25 3.25 4.42 65,000 PAMC Other Subtotal 308,200 **Other Tunnel Tunnel** Total 24,896,250 Other Project 4,498,398 **Total Project** 29,394,648

Name:TehadLocation:SouthOwner:CalifoContractor:GrandMachine Manufacturer:NoneShape:CircuLength:16,05Bore:28'10Inside Diameter:23'6''Calculated Volumes:Excavation:Excavation:388,3Lining:8.12 0Lining:130,3Material:Moder

Tehachapi #1, #2, #3 Southern California (Kern County) California Department of Water Resources Granite, Gates & Fox, Bell None Circular 16,052 LF 28'10" 23'6" 24.19 CY/LF 388,300 CY (nearest hundred) 8.12 CY/LF 130,300 CY (nearest hundred) Moderately blocky and seamy schists.

	Quantity	Quantity per LF	Unit Price	Final Cost
		of Tunnel		· · · · · · · · · · · · · · · · · · ·
Mobilization	LS	•	3,000,000	3,000,000
Clear, Grub	LS	· · ·	253,000	253,000
Subtotal			(300,000	3,553,000
Drill Pilot Holes				
Tunnel Excavation	404,704 cy	25.21	24.25	9,814,080
Tunnel Enlargement		· ·	· · .	·
Subtota1				9,814,080
Steel Sets	11,920,693 lbs	742.63	.15	1,788,104
Rock Bolts	26,550 lf	1.65	3.50	92,925
Timber	2,748.7 MBM	.17	400.00	1,099,475
Rock Bolt Shapes]		
Chain Link Fabric	1,742 sy		1	15,676
Other Francion Bolts				7 700
Subtotal				3,003,880
Concrete	146,879 Cy	9.15	40.00	5,875,159
Reinforcing Steel	2 140,000 lb	133.32	14	299 600
Subtotal	2,140,000 15	100.04	• 17	7,307,570
Drill Grout Holes	35,000 lf	•	5.50	192,500
Grout Pipe	25,400 lb	1	1.00	25,400
Grout Connections	2,300 ea		11.00	25,300
Grout Operation	20,000 cf	1.25	3.25	65,000
PAMC	, NA		NA	723,805
Subtotal			24 - A.	1,032,005
Other Tunnel				0
Tunnel Total		1		24,710,535
Other Project	· .	}		4, 498, 398
Total Project		1	-	29,208,933
	}			
	·			l.
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Name:WaterLocation:UtahOwner:BureaContractor:BoyleMachine Manufacturer:RobbiShape:CircuLength:21,583Bore:12'8"Inside Diameter:10'4"Calculated Volumes:Excavation:Excavation:100,80Lining:1.56 CLining:33,700Material:Sands

Water Hollow Utah (Duchesne County) Bureau of Reclamation Boyles Brothers, Gibbons & Reed Robbins Circular 21,582 LF 12'8'' 10'4'' 4.67 CY/LF 100,800 CY (nearest hundred) 1.56 CY/LF

33,700 CY (nearest hundred) Sandstone, Siltstone

•		Quantity	Unit Price			Total
•	Quantity	per	Engineenis	Average of	Tow	Dollars
	Quantity	LF	Engineer s	Three Low-	Did	Low
		of Tunnel	Estimate	est Bids	BIU	Bid
Mobilization	LS					
Clear. Grub	LS LS					
Drill Pilot Holes	4,300 If	.20	2.00	1.62	1.62	6,966
Tunnel Excavation	96,400 cy	4.47	36.00	34.84	31.12	2,999,968
Tunnel Enlargement						0.000.004
Subtotat						3,006,934
Steel Sets	600,000 lb	27.80	.30	.30	.30	180,000
Rock Bolts	90,000 lf	4.17	2.00	2.00	2.00	180,000
Timber						
Rock Bolt Shapes	150,000 lb		.40	.40	.40	60,000
Chain Link Fabric	500 sy		4.75	4.75	4.75	2,375
Liner Plate						
Other Expansion Bolts		ан. С				1,000
Subtotal						423,375
Concrete	30,000 cy	1.39	54.00	45.10	45.30	1,359,000
A	(40,700 BB1	1.89	6.30	5.89	6.37	259,259
Cement	5,700 ^a	.26	7.30	7.54	11.31	64,467
Reinforcing Steel	22,000 lb	1.02	.19	.24	.26	5,720
Subtotal						1,688,446
Drill Crout Holes					•	
Grout Pine					•	
Grout Connection						·
Grout Operation						
PAMC	35,000 cf	1.62	3.00	3 00	3 00	105 000
Other			0.00	0.00	0.00	100,000
Subtotal						105,000
				•		
Other Tunnel	с. <u>т. х. у</u>					0
Tunnel Total						5,223,755
Other Project				÷		371.073
Total Project						5,594,828
		•				
		*				
s	<u>.</u>		Í			

a. Cement for PAMC

A-37

Name:	Azotea A
Location:	Colorado, Nex Mexico (Santa Fe County)
Owner:	Bureau of Reclamation
Contractor:	Gibbons & Reed, Boyles Brothers, Dugan Graham
Machine Manufacturer:	Robbins
Shape:	Circular
Length:	66,959 LF
Bore:	12'6"
Inside Diameter:	10'11"
Calculated Volumes:	· ·
. Excavation:	4.55 CY/LF
Excavation:	304,700 CY (nearest hundred)
Lining:	1.08 CY/LF
Lining:	72, 100 CY (nearest hundred)
Material:	Sandstone, Shale

		Quantity	Ţ		Total	
	0	per	Dealersouth	Average of	Tom	Dollars
	Quantity	LF	Engineer's	Three Low-	TOM	Low
-		of Tunnel	Estimate	est Bids	. BIO	Bid
Mahiliantian				· · · · · · · · · · · · · · · · · · ·		
Modilization	13					
Clear, Grub	т <u>о</u>			•		
Drill Pilot Holes	33,400 lf	. 50	4.00	1.50	1.00	33,400
Tunnel Excavation	340,000 cy	5.08	29.50	25.10	23.60	8,024,000
Tunnel Enlargement	1,700 cy	. 03	70.00	55.87	23.60	40,120
Subtotal				* 1 [*]	i	8,097,520
Steel Sets	7 500 000 lb	112 01	25	098	045	337, 500
Book Bolta	100.000 15	1 49	2.00	2.47	1.00	100,000
Timber	2.400 MBM	036	275.00	81.67	30.00	72,000
Rock Bolt Shanes	1,200 MILIN			001	00100	,
Chain Link Fabric	· · .				ļ	
Liner Plate				-	· · .	
Other Expansion Bolts					{	
Subtotal			•		r -	509,500
Concrete	107,500 cy	1.61	30.00	31.00	27.00	2,902,500
Cement	189,900 BBI ⁸	2.84	6.00	5.23	6.00	1, 139, 400
Reinforcing Steel	79,000 lb ^b	1,18	.17	· .15	. 15	11,850
Subtotal						4,058,750
Drill Grout Holes	300 lf		5.00	4.67	6.00	1,800
Grout Pipe	300 lb		1.00	2.61	1.00	300
Grout Connection	}					
Grout Operation	2,000 cf	.030	5.00	5.67	5.00	10,000
PAMC	100,000 cf	1.49	1.75	2.87	2.75	275,000
Other		f -	{	1 .		
Subtotal			1			287,100
Other Turnel			· ·			0
Tunnel Total				[{	12 947 870
Tumier Totat	· .			ł	<i>.</i>	12,011,010
Other Project					1	843,130
Total Project]					13,791,000
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1	4	1	1		Į	1

a. Derived from total requirement by assuming 1.5 BBl cement per CY for structures.

b. Derived from total requirement using .733 lbs/cy (concrete) based on the River Mountain. This compares favorably with the \$.106/cy concrete estimated for River Mountain.

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River Mountain
Nevada (Henderson)
Bureau of Reclamation
Utah Mining
Jarva
Circular
19,970 LF
12'
10'
4.19 CY/LF
83,700 CY (nearest hundred)
1.28 CY/LF
25,600 CY (nearest hundred)
Rhyolite, Rhyodacite, Conglomerate

		Quantity		Unit Price		Total
• • • • •	Quantity	per LF	Engineer's	Average of of Three	Low	Dollars Low
		of Tunnel	LStillate	Lowest Bids		Bid
Mobilization ^a	LS		1,500	3,700	100	100
Clear, Grub Subtotal	LS					100
Drill Pilot Holes	4,000 lf	. 20	2.25	2.33	2.50	- 10,000
Tunnel Excavation	85,700 cy	4.29	40.00	36.17	21.25	1.821,125
Subtotal	-					1,831,125
Steel Sets	510,000 lb	25.54	. 30	.30	. 30	153,000
Rock Bolts Timber	54,000 lf	2.70	2.00	2.00	2.00	108,000
Rock Bolt Shapes	82,000 lb		. 40	. 40	.40	32,800
Chain Link Fabric	500 sy		4.75	4.75	4.75	2,375
Liner Plate	· ·					1 000
Subtotal					-	297,175
Concrete	28,200 cy	1.41	51.00	53.68	42.75	1,205,550
Cement	37,500 BBI	1.88	5.75	5.33	5.00	187.500
Duinforming Staal	1 6,700°	.34	6.50	5.83	5.50	36,850
Subtotal	13, 00 <u>0</u> 10	.00	.19	.20	. 22	$\frac{2,992}{1,432,892}$
Drill Grout Holes	880 lf	ľ	3.50	3.33	1.00	880
Grout Pipe	1,000 lb	· ·	1.10	1.33	1.00	1,000
Grout Connection	88 ea		18.00	31.00	30.00	2,640
PAMC	880 CI	.044	3.50	3.83	1.75	1,540
Other Subtotal					÷	6,060
Other Tunnel Tunnel Total						$\frac{0}{3,567,352}$
Other Project Total Project	•					$\frac{379,267}{3,946,619}$
					e.	
• •						

Grout Mobilization. Grout Cement. a.

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Name:	River Mountain	
Location:	Nevada (Henderson)	
Owner:	Bureau of Reclamation	
Contractor:	Utah Mining	
Machine Manufacturer:	Jarva	
Shape:	Circular	
Length:	19,970 LF	
Bore:	12'	
Inside Diameter:	· 10' ·	
Calculated Volumes:		
Excavation:	4.19 CY/LF	
Excavation:	83,700 CY	
Lining:	1.28 CY/LF	
Lining:	25,600 CY	
Material:	Rhyolite, Rhyodacite,	Conglomerate

	Quantity	Quantity per LF of Tunnel	Unit Price	Final Cost
Mobilization Clear, Grub Subtotal	LS LS			
Drill Pilot Holes Tunnel Excavation Tunnel Enlargement Subtotal	4,000 82,542 cy	.20 4.13	2.50 21.25	10,000 1,754,018 <u>1,764,018</u>
Steel Sets Rock Bolts Timber	4,055 lbs 5,820 lf	. 20 . 29	. 30 2. 00	1,216 11,640
Rock Bolt Shapes Chain Link Fabric Liner Plate Other Expansion Bolts Subtotal	22, 424 lbs		.40	8,970 <u>1,000</u> 22, <u>826</u>
Concrete . Cement	{ 25,047 cy 41,698 222 BBl	1.25 2.10	42.75 5.00 5.50	1,070,759 208,490 1 226
Reinforcing Steel Subtotal	13, 600 lb	. 681	. 22	$\frac{2,992}{1,283,467}$
Drill Grout Holes	{ 270 870 lf		7.50	2,025 870
Grout Connections Grout Operation PAMC Other	87 ea. 880 cf	. 044	30.00 1.75	2, 610 1, 540
Subtotal Other Tunnel Tunnel Total			•	<u>8,045</u> <u>0</u> 3,078,356
Other Project Total Project				379,267 3,457,623
	1	1	j - + ,	1

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Name:
Location:
Owner:
Contractor:
Machine Manufacturer:
Shape:
Length:
Bore:
Inside Diameter:
Calculated Volumes:
Excavation:
Excavation:
Lining:
Lining:
Material:
Material:

Navajo #1 New Mexico (Farmington) Bureau of Reclamation Fenix and Scisson Hughes Circular 10,040 20'7'' 18' 12,32 CY/LF 123,700 CY (nearest hundred) 2.89 CY/LF 29,000 CY (nearest hundred) Sandstone, Shale

		Quantity	Ī	Unit Price		Total
	Quantity	per	Engineeris	Average of	Low	Dollars
	Quantity	LF	Engineer s	Three Low-	Did Did	Low
		of Tunnel	Estimate	est Bids(d)	Blu	Bid ·
Mobilization	LS					
Clear, Grub	LS					
	. –					
Drill Pilot Holes	5,000lf	. 50				ć
Tunnel Excavation	130,500 cy	12.90				*:
Tunnel Enlargement	700 cy	. 02				
Subtotal						
Steel Sets	3,150,000 lb	313.75		· ·		
Rock Bolts	26 , 300 lf	2.62				
Timber	_530MBM	. 05				
Rock Bolt Shapes				· .		
Chain Link Fabric						
Liner Plate						
Subtotal						
Concrete	00.050.00	0.00				
Comont	30,350 Cy	3.02	e	7 1 0	F 05	070 000
Beinforcing Steel	26 650 lb	2.45	0.00	0.12 195	5.25	378,000
Subtotal	20,00010	4.00	.10	. 135	.14	3,198
DUNJOUL					•	
Drill Grout Holes						
Grout Pipe						
Grout Connection						
Grout Operation						
PAMC						
Other						
Subtotal						
a .						
Other Tunnel	,					
Tunnel Total				÷*		3,639,178
Othen Duck+	۱ ۱					
Uner Project						1,763,816
Total Project						5,402,994
		l				

a. Tunnel bid by linear foot (\$324.50/LF or \$3,257,980

b. Assume 1.5BBI/CY for surface structures (11,000 cy)

c. Assume .733lbs/CY (Water Hollow)

d. Two low bidders (third bid another option)

A-41

Approximate Date: 1965

Name: Location: Owner: Contractor: Machine Manufacturer: Shape: Length: Bore: Inside Diameter: Calculated Volumes: Excavation: Excavation: Lining: Lining: Material: Navajo #2 New Mexico (Farmington) Bureau of Reclamation Shea, Kaiser, Macco None Horseshoe 25,720 LF 20'1" X 20'1" 17'6" X 17'6" 11.73CY/LF 301,700CY (nearest hundred) 2.82CY/LF 72,500CY (nearest hundred) Sandstone

الله 17 والدانية اليوسية بين البيراني العربي اليوني ب		Quantity	Ţ	Jnit Price		Total
		per	Dania	Average of	Tow	Dollars
	Quantity	LF	Engineer's	Three Low-		Low
· · ·		of Tunnel	Estimate	est Bids	שום	Bid (a)
Mobilization	LS					•
Clear, Grub	LS					
•				.•		
			·	ĺ	l. •	
Drill Pilot Holes	12,900 lf	.50			·	· · ·
Tunnel Excavation	328,400 cy	12.77		· ·	۱ I	
Tunnel Enlargement	1,700 cy	. 07			{	
Subtotal	j i		-			
				l i	ł i	
Steel Sets	4,290,0001b	166.80			()	
Rock Bolts	61,730 lf	2.40				
Timber	520MBM	.02	} 1		· ·	
Rock Bolt Shapes			ł · .		Į	
Chain Link Fabric	j . *		1			
Liner Plate		· ·	· ·	· · ·	l '	
Other Expansion Bolts		1	}	5	(· · ·)	
Subtotal			1		· · ·	
Company	b an ann b					
Concrete	83,880 CY	3,26	5 50		r 00	740 770
	149,750 BBI	5.82	5.50	4.90	5.00	748,750
Subtotel	40,10010	1.19	10	. 101	. 20	9,220
Juniorat		1	1.	}		<u>~</u>
Drill Grout Holes	585 L	ł	4.00	7.33	15.00	8,775
Grout Pipe	400 lb	·	1.00	2.00	2.00	800
Grout Connection) .	ļ	J		•	
Grout Operation	2,000 cf	08	5.00	5.33	8.00	16,000
PAMC	ľ	ł	1	}]	
Other		1	· ·			
Subtotal	li v		{	1	1	95,575
	· ·	1	1	1	.	4J#0(0
Other Tunnel	÷ *	1	· ·	· ·	{	
Tunnel Total	1.	1	}		ľ	6,956,345
	}			1		
Uther Project	t · .	1	}	} · · · ·	i	1,684,066
Total Project	1			ł	}	8,640,411
	1	í	1	.		

A-42

a. Tunnel bid by linear foot (\$240/LF) or \$6,172,800

b. Assume 1.5BBls/CY in surface structures

c. Assume \$.110/CY (Azotea, Navajo #1, Divide)

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750

Name:
Location:
Owner:
Contractor:
Machine Manufacturer:
Shape:
Length:
Bore:
Inside Diameter:
Calculated Volumes:
Excavation:
Excavation:
Lining:
Lining:

Material:

Divide (Total) App Colorado (Glenwood Springs County) Bureau of Reclamation Winston Brothers, Foley, Hurley, Frasier-Davis None

59,361 LF

CY/LF CY (nearest hundred) CY/LF CY (nearest hundred) Highly Fractured Granite

		Quantity	Ţ	Unit Price		Total
•	Quantity	per	Engineeric	Average of	Low	Dollars
·*	Quantity	LF	Engineers	Three Low-	Did	Low
		of Tunnel	Estimate	est Bids	Biu	Bid
			· · ·			
Mobilization	. LS		<i>i.</i>			
Clear, Grub	LS					
	_					
Drill Pilot Holes	10,000 lf ^a	.17	2.00	1.25	1.00	,10,000
Tunnel Excavation	206 ,000 cy	3.47	41.13	52.65	52.65	10,845,000
Tunnel Enlargement	200 cy ^a	.003	55.00	32.5	25.00	5,000
Subtotal		· ·				10,860,000
Steel Sets	2,400,000 lb	40.43	. 25	. 168	.055	132,000
Rock Bolts	54,000 lf	.91	2.00	1.62	.50	27,000
Timber						
Rock Bolt Shapes						
Chain Link Fabric						· .
Liner Plate	, *			· .	•	:
Other Expansion Bolts	· ·					
Subtotal			· (•		159,000
Concrete	54,985 cy	. 93	52.82	56.69	55.87	3,072,275
Cement	115,000 BBl	1.94	6.00	6.75	° 5.00	575,000
Reinforcing Steel	43,000lb	72	. 16	. 175	.14	6,020
Subtotal		r				3,653,295
Drill Grout Holes	750 lf		5.00	3.25	1.50	1,125
Grout Pipe	2.000 lb		1.00	1.00	1.00	2,000
Grout Connection	500 ea.		20.00	14.00	8.00	4,000
Grout Operation	20,000 cf	. 34	4.00	4.50	2.00	40,000
PAMC	}.	· ·				
Other			A			
Subtotal						47,125
Other Tunnel						
Tunnel Total						14,719,420
			•	•	•	
Other Project	· ·					2,836,747
Total Project						17,556,167
•			· .			
· · · ·						
۰ <u>،</u> ۱				•		
	i i i					l l

a. Not allocated to individual tunnels

A-43

Name: Location: **Owner**: Contractor: None Machine Manufacturer: BH Shape: 2000 LF Length: 34' x 26' Bore: 32' x 24' Inside Diameter: Calculated Volumes: Excavation: Excavation: Lining: Lining: Material:

Glenwood SpringsApprColorado (Glenwood Springs County)Colorado Highway DepartmentColorado ConstructorsNoneBH2000 LF34' x 26'32' x 24'28.15 CY/LF56,300 CY (nearest hundred)3.77 CY/LF7,500 CY (nearest hundred)Blocky and seamy porphoritic, coarse and grained granite.

-	·. ·	Quantity		Unit Price		Total
	Quartity	per	Engineer's	Average of	Low ^a	Dollars
<i>x</i>		LF	Estimate	of Three	Bid	Low
		of Tunnel		Lowest Bids		Bid
Mobilization	LS					
Clear, Grub	LS		·			
Drill Plint Holes						
Tunnel Excavation	59,900 cy	29.95	17.50			1,048,250
Tunnel Enlargement					· · ·	·
Subtotal		•				<u>1,048,250</u>
Charles Carter	COO 000 11	940 00		· ·	1	149 600
Bleer Bers	17,000 lf	8.50	1.80			30,600
Timber	1,000 1					
Rock Bolt Shapes			· .			
Chain Link Fabric	*				1	. .
Liner Plate	• . ,		} .			
Subtotal			{ ·		<u>.</u>	180,200
Concrete	s son avb	A 05	30.00	l· · .	1	255 000
Cement	0,000 C I	4.20	30.00		· ·	200,000
Reinforcing Steel	•		}	• .	•	
Subtotal	<u>^.</u>					255,000
Drill Grout Holes	•					· ·
Grout Pipe	4 a.	1) · · .	
Grout Connection		· .			. ·	
Grout Operation	· · ·	· ·				
PAMC *						
Subtotal	** *	}	}			
Other Tunnel	· · ·					
Tunnel Total				-		1,483,450
Other Project						90 460
Total Project	•		{			$\frac{30,400}{1,573,910}$
			1	• • •		
· · ·		·				
, ·			· ·			
9	•	.	1			1

A- 44

a. Low bidder estimate not available, used engineer's estimate.

b. Includes cement, reinforcing steel, and grout.

Name:	Hells Canyon	Approximate Date:	1900
Location:	Idaho (Cambridge County)		
Owner:	Idaho Power Commission		
Contractor:		•	
Machine Manufacturer:			
Shape:			
Length:	1,694 LF		
Bore:	43'		
Inside Diameter:	40'		
Calculated Volumes:			·
Excavation:	53.81 CY/LF		
Excavation:	91,200 CY (nearest hundred)		
Lining:	7.25 CY/LF		
Lining:	12,300 CY (nearest hundred)		
Material:	Metamorphic volcanics, basalt flows, ash agle	omerate, boulders.	

Quantityper LFEngineer's EstimateAverage of of Three Low BidDolla Low BidMobilizationLSClear, GrubLSDrill Pilot Holes Tunnel Engreent SubtotalLSDrill Pilot Holes Tunnel Excavation Tunnel Engreent SubtotalSaltSteel Sets Rock Bolts Timber Rock Bolts SubtotalSaltConcrete Comment SubtotalSaltConcrete Concrete Concrete Grout Operation SubtotalSaltConcrete Concrete Grout Pipe Grout Connection Grout OperationSaltOther Expansion Bolts SubtotalSaltSubtotalSaltConcrete Concrete Grout OperationSaltCoher Expansion Bolts SubtotalSaltConcrete Concretion SubtotalSaltConcrete Concretion SubtotalSaltConcrete Concretion SubtotalSaltCoher Tunnel Tunnel TotalSaltCoher Pipect Tunnel TotalSaltCoher Project Tunnel TotalSaltCoher ProjectSaltSubtotalSaltCoher ProjectSaltSubtotalSaltCoher ProjectSaltSubtotalSaltCoher ProjectSaltSubtotalSaltSubtotalSaltSubtotalSaltSubtotalSaltSubtotalSaltSubtotalSaltSubtotalSaltSubtotalSaltSubtotalSa		•	Quantity		Unit Price		Total •
Mobilization Clear, Grub LS Drill Pilot Holes Tunnel Excavation Tunnel Excavation Tunnel Excavation Subtotal 831, 331, 333, 333, 333, 333, 333, 3318, Concrete Chan Link Fabric Liner Plate Chan Link Fabric Liner Plate 318, 318, 318, Concrete Cement Reinforcing Steel Subtotal 318, 318, 318, 318, 318, 318, 318, Concrete Concrete Cement Reinforcing Steel Subtotal 318, 318, 318, 318, 318, 318, 318, 318,		Quantity	per LF of Tunnel	Engineer's Estimate	Average of of Three Lowest Bids	Low Bid	Dollars Low Bid
Drill Pilot Holes Tunnel Excavation Tunnel Enlargement Subtotal Steel Sets Rock Bolts Timber Rock Bolts Timber Rock Bolts Subtotal Chain Link Fabric Liner Pitte Other Expansion Bolts Subtotal Concrete Cement Reinforcing Steel Subtotal Drill Grout Holes Grout Pipe Grout Connection Grout Operation PAMC Other Subtotal Other Tunnel Tunnel Total Other Project Total Project. Subtotal Drill Pipe Grout Connection Grout Operation PAMC Concrete Cancel Subtotal Subtotal Subtotal Subtotal Concrete Grout Operation PAMC Cother Subtotal Cother Tunnel Tunnel Total Cother Project Cother Project Cother Project Cother Subtotal Cother Project Cother Project Cother Project Cother Subtotal Cother Project Cother Project C	Mobilization Clear, Grub	LS LS					
Steel Sets Steel Sets Rock Bolts Timber Rock Bolt Shapes Chain Link Fabric Liner Plate Other Expansion Bolts Other Expansion Bolts 318, Concrete Cement Reinforcing Steel 318, Subtotal 318, Concrete 20, Grout Holes 20, Grout Operation 10, PAMC 10, Other Subtotal 30, Other Tunnel 30, Other Project 7, Total Project 7,	Drill Pilot Holes Tunnel Excavation Tunnel Enlargement Subtotal					- 	831, 442
Chain Link Fabric Liner Plate Other Expansion Bolts Subtotal Concrete Cement Reinforcing Steel Subtotal Drill Grout Holes Grout Pipe Grout Operation PAMC Other Tunnel Tunnel Total Other Project Total Project	Steel Sets Rock Bolts Timber Rock Bolt Shapes						
Concrete Cement Reinforcing Steel J. 304, Subtotal J. 304, Drill Grout Holes 20, Grout Pipe 10, Grout Operation 10, PAMC 30, Other Subtotal Other Tunnel 2,484, Other Project 7, Total Project 2,492,	Chain Link Fabric Liner Piate Other Expansion Bolts Subtotal						318,661
Drill Grout Holes Grout Pipe Grout Connection Grout Operation PAMC Other Subtotal Other Tunnel Tunnel Total Other Project Total Project	Concrete Cement Reinforcing Steel Subtotal						<u>1,304,586</u>
Grout Operation PAMC Other Subtotal Other Tunnel Tunnel Total Other Project Total Project 2,484, 2,484,	Drill Grout Holes Grout Pipe Grout Connection		- -				20,056
Other Tunnel Tunnel Total Other Project Total Project	Grout Operation PAMC Other Subtotal						10,208
Other Project $\overline{2,492}$ Total Project $\overline{2,492}$	Other Tunnel Tunnel Total		· · · ·				2,484,953
	Other Project Total Project					•	$\frac{7,860}{2,492,813}$
						,	

A-45

Aanc:	Flathead
Location:	Montana (Flathead County)
Owner:	Corps of Engineers
Contractor:	Dravo
Machine Manufacturer:	None
Shape:	BH
Length:	35,960 LF
Bore:	21' x 29'3"
Inside Diameter:	18' x 25'3''
Calculated Volumes:	
Excavation:	21.00 CY/LF
Excavation:	755, 200 CY (nearest hundred)
Lining:	5.45 CY/LF
Lining:	196,000 CY (nearest hundred)
Material:	Predominately argillite moder

. -

Predominately argillite moderately hard to hard, bedded 1 to 6 inches and quartzitic argillite, hard bedded 2 inches to 2 feet, some metasandstone.

	•	Quantity		
	0	per	Unit	Final
;	Quantity	LF	Price	Cost
		of Tunnel		
Mobilization	79		3,037,700	3,037,700
MODITIZATION			44,000	44,000
Clear, Grub	- IS -			
Subtotal	•			3,081,700
Delli Dilet Meles	4,043	. 11	12.00	48,516
Drift Pilot Holes	58,972	1.64	3.30	194,608
Tunnel Excavation	783, 317	21.78	22.50	17,232,966
Tunnel Enlargement				
Subtotal				17,476,090
	1 4,000,000 m	000 01	. 49	1,960,000
Steel Sets	9,582,294	377.71	. 25	2,418,073
Rock Bolts	516, 464 lf	14.36	3.00	1,549,392
Timber	(ŧ.	(· ,	· · ·
Rock Bolt Shapes	162, 843 lbs	1	. 40	65,137
Chain Link Fabric	95,542 sy		3.00	286,626
Liner Plate	74,788 sf	x	15.00	1,121,820
Other Expansion Bolts				
Subtotal				_7,401,048
Concrete	191,258	E 90	33.00	6,311,525
Coment	365,125 cy	10.17	5.50	2,008,190
Cement	463 BB	10.11	8.00	3,704
Reinforcing Steel	6,780,317 lb	188.55	. 20	1,356,063
Other Fluidifier				822
Subtotal				9,680,304
Drill Grout Holes	1,128 lf	<u> </u>	2.50	2,820
Grout Pipe				
Grout Connections		· ·	ļ ⁻	
Grout Operation	6,029 cf	. 17	7.00	42,203
PAMC		1		1
Other	· ·		} .	45 099
Subtotal				40,023
Other Tunnel		1 ·	1	<u> </u>
Tunnel Total	· · · ·	· ·		37,684,165
Other Project			· · · ·	7,711,164
Total Project		ļ		45, 395, 329
1 · · ·	- N			

A-46

1.

Name: Location: Owner: Contractor: Machine Manufacturer: Shape: Length: Bore: Inside Diameter: Calculated Volumes: Excavation: Excavation: Lining:

Lining: Material: Broken Bow Oklahoma (Broken Bow County) Corps of Engineers Al Johnson Company

Circular 3000 FT. 29 FT.

Generally metamorphized shale and argillite. ONLY PROPRIETARY CONTRACTOR DATA

<u> </u>	· · · ·	Quantity		Unit Price		Total
· · ·	Quantity	.per LF of Tunnel	Engineer's Estimate	Average of of Three Lowest Bids	Low Bid	Dollars Low Bid
				•		
: ¹ *	•					•
			· · ·			
· · · ·				. * .		
· · ·						
				•		· · ·
				· · ·		
				· ·		• • • •
		, Y				-
• • • • •				· · ·		

Name: Location: Owner: Contractor: Machine Manufacturer: Shape: Length: Bore: Inside Diameter: Calculated Volumes: Excavation: Excavation: Lining: Lining:

Material:

. .

Dworshak Diversion Idaho Corps of Engineers Peter Kiewit and Sons Company None Circular 1950 FT. 43 FT.

Approximate Date: 1965

Highly fractured granite gnelss.

ONLY PROPRIETARY CONTRACTOR DATA

	•	Quantity		Unit Price	Total	
	Quantity	per LF of Tunncl	Engineer's Estimate	Average of of Thrce Lowest Bids	Low Bid	Dollars Low Bid
	·					
	· .		· ·			
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Name:	4781-20 (Sect. 1)	ippioninae bac. 190
Location:	Minneapolis, Minn.	
Owner:	City of Minneapolis	
Contractor:	Al Johnson Co.	
Machine Manufacturer:	1	
Shape:	Circular	
Length:	2,822 LF	
Bore:	11'	х.
Inside Diameter:	9'	
Calculated Volumes:		
Excavation:	3.52 CY/LF	
Excavation:	10,000 CY (nearest hundred)	
Lining:	1.16 CY/LF	
Lining:	3,000 CY	
Material:	St. Peter sandstone, medium to fine graine quartzose sandstone. Massive appearing w straining. Some silty and shaly zones.	d rounded to subrounded ell sorted with some iron

	Quantity	Quantity per LF of Tunnel	Unit Price	Final Cost
Mobilization Clear, Grub Subtotal				
Drill Pilot Holes Tunnel Excavation Tunnel Enlargement Subtotal				
Steel Sets Rock Bolts Timber Rock Polt Shapes Chain Link Fabric Liner Plate Other Expansion Bolts Subtotal				
Concrete Cement Reinforcing Steel Subtotal				
Drill Grout Holes Grout Pipe Grout Connections Grout Operation PAMC Other Subtotal				
Other Tunnel Tunnel Total				592, 584
Other Project Total Project				

a. Tunnel bid by linear foot (\$210/LF).

A- 49

Name:	2781-26 (Sect. II)	Approximate Date:	1963
Location:	Minneapolis, Minn.		
Owner:	City of Minneapolis		
Contractor:	Al Johnson Co.		
Machine Manufacturer:			
Shape:	Circular		
Length:	1,155 LF		
Bore:	14'		
Inside Diameter:	12'		
Calculated Volumes:			
Excavation:	5.70 CY/LF		
Excavation:	6,600 CY (nearest hundred0		
Lining:	1.51 CY/LF		
Lining:	1,700 CY (nearest hundred)		
Material:	St. Peter sandstone, medium to fine gra quartzose sandstone. Massive appearin straining. Some silty and shaly zones.	ained rounded to sub g well sorted with s	rounded ome iron

1

	Quantity	Quantity per	Unit	Final
		LF of Tunnel	Price	Cost
Mobilization Clear, Grub Subtotal				
Drill Pilot Holes Tunnel Excavation Tunnel Enlargement Subtotal				
Steel Sets Rock Bolts Timber Rock Bolt Shapes Chain Link Fabric				
Liner Plate Other Expansion Bolts Subtotal				
Concrete Cement Reinforcing Steel Subtotal				
Drill Grout Holes Grout Pipe Grout Connections Grout Operation PAMC Other Subtotal				
Other Tunnel Tunnel Total ² Other Project				300, 323
Total Project				

a. Tunnel bid by linear fcot (260/LF).

A- 50

Name:	2781-26 (Sect. III) Approximate Date: 1963
Location:	Minneapolis, Minn.
Owner:	City of Minneapolis
Contractor:	Al Johnson Co.
Machine Manufacturer:	
Shape:	Circular
Length:	4,688 LF
Bore:	16'
Inside Diameter:	14'
Calculated Volumes:	
Excavation:	7.45 CY/LF
Excavation:	34,900 CY (nearest hundred)
Lining:	1.75 CY/LF
Lining:	8,200 CY (nearest hundred)
Material:	St. Peter sandstone, medium to fine grained rounded to subrounded quartzose sandstone. Massive appearing well sorted with some iron straining. Some silty and shaly zones.

	Quantity	Quantity per LF of Tunnel	Unit Price	Final Cost
Mobilization Clear, Grub Subtotal Drill Pilot Holes Tunnel Excavation Tunnel Enlargement Subtotal				
Steel Sets Rock Bolts Timber Rock Bolt Shapes Chain Link Fabric Liner Plate Other Expansion Bolts Subtotal				
Concrete Cement Reinforcing Steel Subtotal				
Drill Grout Holes Grout Pipe Grout Connections Grout Operation PAMC Other Subtotal				
Other Tunnel Tunnel Total ^a				1,289,261
Total Project				

Name:	2781-26 (Total) Approximate Date: 1903	
Location:	Minneapolis, Minn.	
Owner:	City of Minneapolis	
Contractor:	Al Johnson Co.	
Machine Manufacturer:		
Shape:	Circular	
Length:	8,824 LF	
Bore:	Vorteur	
Inside Diameter: 🖌 👘	various	
Calculated Volumes:		
Excavation:	5.84 CY/LF	
Excavation:	51, 500 CY (nearest hundred)	
Lining:	1.46 CY/LF	
Lining:	12,900 CY (nearest hundred)	
Material:	St. Peter sandstone, medium to fine grained rounded to subrounded quartzose sandstone. Massive appearing well sorted with some iro	'n

straining. Some silty and shaly zones.

Quantity Unit Final per Quantity : -LF. Price Cost of Tunnel Mobilization Clear, Grub Subtotal **Drill Pilot Holes** Tunnel Excavation Tunnel Enlargement Subtotal Steel Sets Rock Bolts Timber Rock Bolt Shapes Chain Link Fabric Liner Plate Other Expansion Bolts Subtotal Concrete Cement **Reinforcing Steel** Subtotal Drill Grout Holes Grout Pipe Grout Connections Grout Operation PAMC Other Subtotal Other Tunnel Tunnel Total 2, 182, 168 406, 538 Other Project 2,588,706 Total Project

a. Tunnel Cost \$251.81/LF (Weighted Ave.)

A-52
Name: Location: Owner: Contractor: Machine Manufacturer: Shape: Length: Bore: Inside Diameter: Calculated Volumes: Excavation: Excavation: Lining: Lining:

Material:

City of Minneapolis Al Johnson Co. Circular 4,346 LF 14'

Minneapolis, Minn.

2782-50

12' 5.70 CY/LF 24,800 CY (nearest hundred) 1.51 CY/LF 6,600 CY (nearest hundred)

St. Peter sandstone, medium to fine grained rounded to subrounded quartzose sandstone. Massive appearing well sorted with some iron straining. Some silty and shaly zones.

	Quantity	Quantity per LF of Tunnel	Unit Price	Final Cost
Mobilization Clear, Grub Subtotal				
Drill Pilot Holes Tunnel Excavation Tunnel Enlargement Subtotal				
Steel Sets Rock Bolts Timber Rock Bolt Shapes Chain Link Fabric Liner Plate Other Expansion Bolts Subtotal				- - - -
Concrete Cement Reinforcing Steel Subtotal				
Drill Grout Holes Grout Pipe Grout Connections Grout Operation PAMC Other Subtotal				
Other Tunnel Tunnel Total ² Other Project				1,130,020 5,852
Total Project				<u>1,135,872</u>

a. Tunnel bid by linear foot (\$260/LF)

A-53

Name: Location: Owner: Contractor: Machine Manufacturer: Shape: Length: Bore: Inside Diameter: Calculated Volumes: Excavation: Excavation: Lining: Lining: Material:

Minneapolis, Minn. City of Minneapolis Al Johnson Co. Circular 3,465 LF 16' 14' 7.45 CY/LF 25,800 CY (nearest hundred) 1.75 CY/LF 6,100 CY (nearest hundred)

2783-06

St. Peter sandstone, medium to fine grained rounded to subrounded quartzose sandstone. Massive appearing well sorted with some iron straining. Some silty and shaly zones.

A- 54

	Quantity	Quantity per LF of Tunnel	Unit Price	Final Cost
Mobilization Clear, Grub Subtotal				
Drill Pilot Holes Tunnel Excavation Tunnel Enlargement Subtotal				9
Steel Sets Rock Bolts Timber Rock Bolt Shapes Chain Link Fabric Liner Plate Other Expansion Bolts Subtotal				
Concrete Cement Reinforcing Steel Subtotal				
Drill Grout Holes Grout Pipe Grout Connections Grout Operation PAMC Other Subtotal				
Other Tunnel Tunnel Total ^a				952, 831
Other Project Total Project				<u>148,878</u> <u>1,101,709</u>

a. Tunnel bid by linear foot (\$275/LF).

Name	2782-17 Approximate Date: 19
Location:	Minneapolis, Minnesota
Owner:	City of Minneapolis
Contractor:	Foley Bros., Hurley, Winston Bros.
Machine Manufacturer:	
Shape:	Circular
Length:	6,509 LF
Bore:	14'
Inside Diameter:	12'
Calculated Volumes:	
Excavation:	5.70 CY/LF
Excavation:	37,100 CY (nearest hundred)
Lining:	1.57 CY/LF
Lining:	9,800 CY (nearest hundred)
Material:	St. Peter sandstone, medium to fine grained rounded to subrounded quartzose sandstone. Massive appearing well sorted with some iron

straining. Some silty and shaly zones.					
	Quantity	Quantity per LF of Tunnel	Unit Price	Final Cost	
Mobilization Clear, Grub Subtotal	LS LS				
Drill Pilot Holes Tunnel Excavation Tunnel Enlargement Subtotal					
Steel Sets Rock Bolts Timber Rock Bolt Shapes Chain Link Fabric Liner Plate Other Expansion Bolts Subtotal					
Concretc Cement Reinforcing Steel Subtotal					
Drill Grout Holes Grout Pipe Grout Connections Grout Operation PAMC Other Subtotal					
Other Tunnel Tunnel Total ^a				1,497,116	
Otner Project Total Project				<u>315,946</u> <u>1,813,062</u>	

Tunnel bid by linear foot (\$230/LF) a.

A-55

Name:	2782-71	Approximate Date:	19
Location:	Minneapolis, Minnesota	,	
Owner:	City of Minneapolis	•	
Contractor:	Winston Bros., Hurley, Foley Bros.		
Machine Manufacturer:	· ·	· · · ·	
Shapo:	Circular	· .	
Length:	1,593 LF		
Bore:	14'		
Inside Diameter:	12'		
Calculated Volumes:	· ·		
Excavation:	5.70 CY/LF	· ·	
Excavation:	9,100 CY (nearest hundred)		
Lining:	1.51 CY/LF		
Lining:	2,400 CY (nearest hundred)	· .	
Material	St. Deter conditions medium to fine and	uned rounded to subr	OUT

ounded um to rine gr quartzose sandstone. Massive appearing well sorted with some iron straining. Some silty and shaly zones.

	Quantity	Quantity per LF of Tunnel	Unit Price	Final Cost
Mobilization Clear, Grub Subtotal	LS LS	- - -		
Drill Pilot Holes Tunnel Excavation Tunnel Enlargement Subtotal	-			
Steel Sets Rock Bolts Timber Rock Bolt Shapes Chain Link Fabric Liner Plate Other Expansion Bolts Subtotal				
Concrete Cement Reinforcing Steel Subtotal				
Drill Grout Holes Grout Pipe Grout Connections Grout Operation PAMC Other Subtotal				
Other Tunnel Tunnel Total ^{a, b}				1,694,325
Other Project Total Project				<u>38,084</u> 1,732,409
	1	· · · ·		1

a. Tunnel bid by linear foot averaging \$920.81/LF for three 12' ID sections.
b. Total includes \$227,470 grout.

4. 4. 5. 5.

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Name:	2783-19 Approximate Date: 1966	
Location:	Minneapolis, Minn.	
Owner:	City of Minneapolis	
Contractor:	Delaware Corp, American Structures	
Machine Manufacturer:	Delaware V. M.	
Shape:	Circular	
Longth:	6587 LF	
Bore:	15'	
Inside Diameter:	13'	
Calculated Volumes:	· · ·	
Excavation:	6.55 CY/LF	
Excavation:	43, 100 CY (nearest hundred)	
Lining:	1.63 CY/LF	
Lining:	10,700 CY (nearest hundred)	
Material:	St. Peter sandstone, medium to fine grained rounded to subround quartzose sandstone. Massive appearing well sorted with some i	ed .ron

QuantityQuantityUnitFinalQuantityperUnitFinalLFPriceCostof TunnelImage: CostImage: CostMobilizationSubtotalImage: Cost	
Mobilization Clear, Grub Subtotal	
	¢
Drill Pilot Holes Tunnel Excavation Tunnel Enlargement Subtotal	
Steel Sets Rock Bolts Timber Rock Bolt Shapes Chain Link Fabric Liner Plate Other Expansion Bolts Subtotal	
Concrete Cement Reinforcing Steel Subtotal	
Drill Grout Holes Grout Pipe Grout Connections Grout Operation PAMC Other Subtotal	
Other Tunnel Tunnel Total ^a Other Project ^b Total Project <u>591,</u> <u>2,313,</u>	553 027 580

a. Bid by linear foot (\$261.50/LF).

b. Other project items are \$272,954. Four small and/or short-tunnels are included in this amount (\$318,073).

Name;	6282-23	Approximate Date: 1961
Location:	Minneapolis. Minnesota	
Owner:	City of Minneapolis	
Contractor:	Winston Bros., Hurley, Foley Bros.	
Machine Manufacturer:		· .
Shape:	Elliptical	
Length:	4,400 LF	
Bore:	14'	
Inside Diameter:	12'	
Calculated Volumes:	•	
Excavation:	5.70 CY/LF	. ,
Excavation:	25,100 CY (nearest hundred)	
Lining:	1.51 CY/LF	
Lining:	6.600 CY (nearest hundred)	
Material:	St. Peter sandstone, medium to fine gra quartzose sandstone. Massive appearin straining. Some silty and shalv zones.	lined rounded to subrounded g well sorted with some iron

	Quantity	Quantity per LF of Tunnel	Unit Price	Final Cost
Mob ilization Clear, Grub Subtotal	LS LS	• •		
Drill Pilot Holes Tunnel Excavation Tunnel Enlargment Subtotal	•			
Steel Sets Rock Bolts Timber Rock Bolt Shapes Chain Link Fabric Liner Plate Other Expansion Bolts Subtotal				
Concrete Cement Reinforcing Steel Subtotal				
Drill Grout Holes Grout Pipe Grout Connections Grout Operation PAMC Other Subtotal				
Other Tunnel Tunnel Total ^{a, b} Other Project Total Project		· · · · · · · · · · · · · · · · · · ·		840,850 <u>521,300</u> <u>1,362,150</u>

Tunnel bid by linear foot \$189/LF. Total includes grout \$9,250. a.

b.

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Name:	6282-41 Approximate Date: 1961
Location:	Minneapolis, Minnesota
Owner:	City of Minneapolis
Contractor:	Foley Bros., Hurley, Winston Bros.
Machine Manufacturer:	
Shape:	Circular
Lengil:	2303
Bore:	14'
Inside Diameter:	12'
Calculated Volumes:	
Excavation:	5.70 CY/LF
Excavation:	13,100 CY (nearest hundred)
Lining:	1.51 CY/LF
Lining:	3,500 CY (nearest hundred)
Material:	St. Peter sandstone, medium to fine grained rounded to subrounded
	quartzose sandstone. Massive appearing well sorted with some iron

straining. Some silty and shaly zones.				
	Quantity	Quantity per LF of Tunnel	Unit Price	Final Cost
Mobilization Clear, Grub Subtotal				
Drill Pilot Holes Tunnel Excavation Tunnel Enlargement Subtotal				
Steel Sets Rock Bolts Timber Rock Bolt Shapes Chain Link Fabric Liner Plate Other Expansion Bolts Subtotal				
Concrete Cement Reinforcing Steel Subtotal				
Drill Grout Holes Grout Pipe Grout Connections Grout Operation PAMC Other Subtotal				
Other Tunnel Tunnel Total ^{a, b}				439,267
Other Project Total Project				<u>13,900</u> <u>453,167</u>

Approximate Date: 1967 Name: Lawrence Avenue (Section I) Location: Chicago, Illinois City of Chicago, Department of Public Works Owner: Contractor: McHugh, Healy, Kenny Lawrence Machine Manufacturer: Shape: Circular 16.638 LF Length: 13'4" Bore: 12' Inside Dlameter: Calculated Volumes: 5.17 CY/LF Excavation: 86,000 CY (nearest hundred) Excavation: .98 CY/LF Lining: 16,300 CY (nearest hundred) Lining: Material: Pink and gray dolomitic limestone, compressive strength 10,000 to 17,000 psi.

	· · · · · · · · · · · · · · · · · · ·	Quantity	Unit Price			Total
	Quantity	per LF of Tunnel	Engineer's Estimate	Average of of Three Lowest Bids	Low Bid	Dollars Low Bid
Mobilization Clear, Grub		·				ł
Drill Pilot Holes Tunnel Excavation Tunnel Enlargement Subtotal						4,658,640 ^a
Steel Sets Rock Bolts Timber Rock Bolt Shapes						
Chain Link Fabric Liner Plate Other Expansion Bolts Subtotal	•					
Concrete Cement Reinforcing Steel Subtotal	 				· · ·	998,280 ^b
Drill Grout Holes Grout Pipe Grout Connection Grout Operation PAMC Other						
Subtotal Other Tunnel Tunnel Total						5,656,920
Other Project Total Project	• .					· · ·

a. Does not include supports (\$280/LF). Supports bid for total contract.

b. Includes grout (\$60/LF).

Name:	Lawrence Avenue (Section II)	Annovimate Date: 1967
Location:	Chicago, Illinois	Approximate Date: 1301
Owner:	City of Chicago, Department of Public Works	
Contractor:	McHugh, Healy, Kenny	
Machine Manufacturer:	Lawrence	
Shape:	Circular	· .
Length:	9,126	
Bore:	18'4"	
Inside Diameter:	17'	
Calculated Volumes:	" •	
Excavation:	9.78 CY/LF	
Excavation:	89,300 CY (nearest hundred)	
Lining:	1.35 CY/LF	
Lining:	12,300 CY (neared hundred)	•
Material:	Pink and gray dolomitic limestone, compressi	ve strength 10,000 to 17,000 psi.

		Quantity	Unit Price			Total
	Quantity	per LF of Tunnel	Engineer's Estimate	Average of of Three Lowest Bids	Low Bid	Dollars Low Bid
Mobilization Clear, Grub Subtotai						
Drill Pilot Holes Tunnel Excavation Tunnel Enlargement Subtotal						$\frac{1}{3,732,534}^{a}$
Steel Sets Rock Bolts Timber Rock Bolt Shapes Chain Link Fabric Liner Plate Other Expansion Bolts Subtotal						
Concrete Cement Reinforcing Steel Subtotal						<u></u>
Drill Grout Holes Grout Pipe Grout Connection Grout Operation PAMC Other Subtotal	•					
Other Tunnel Total Tunnel				- -		4,462,614
Other Project Total Project						

.

a. Does not include supports. Supports were bid for total contract (\$409/LF).
b. Includes grout (\$80/LF).

b.

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Namer	Lawrence Avenue (Total)	Approximate Date: 1967
Location:	Chicago, Illinois	
Owner:	City of Chicago, Department of Public Works	· ·
Contractor:	McHugh, Healy, Kenny	:
Machine Manufacturer:	Lawrence	
Shape:	Circular	·
Length:	25,764 LF	
Bore:		
Inside Diameter:		
Calculated Volumes:		
Excavation:	6.80 CY/LF	
Excavation:	175,300 CY (nearest hundred)	: · · · · · · · · · · · · · · · · · · ·
Lining:	1.11 CY/LF	
Lining:	28,600 CY (nearest hundred)	•
Material:	Pink and gray dolomitic limestone, compressiv	e strength 10,000 to 17,000 psi

Quantity Unit Price Total Dollars Average of per Engineer's Low Quantity LF of Three Low Estimate Bid Bid of Tunnel Lowest Bids Mobilization LS Clear, Grub LS Drill Pilot Holes **Tunnel Excavation** Tunnel Enlargement Subtotal 8,391,174 Steel Sets Rock Bolts Timber Rock Bolt Shapes Chain Link Fabric Liner Plate Other Expansion Bolts Subtotal 72,560 Concrete Cement **Reinforcing Steel** Subtotal 728,360 Drill Grout Holes Grout Pipe **Grout** Connection Grout Operation PAMC Other Subtotal Other Tunnel **Tunnel** Total 10, 192, 094 Other Project 600,000 Total Project 10,792,094

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Name:	Lawndale Avenue (13-A)	Approximate Date: 1966
Location:	Chicago, Illinois	
Owner:	City of Chicago, Department of Public Works	
Contractor:	Healy & Kenny	
Machine Manufacturer:	Robbins	
Shape:	Circular	
Length:	17,634 LF	
Bore:	13'10"	
Inside Diameter:	12'	
Calculated Volumes:		``
Excavation:	5.57 CY/LF	
Excavation:	98,200 CY (nearest hundred)	
Lining:	1.38 CY/LF	e
Lining:	24,300 CY (nearest hundred)	
Material:	Dolomitic limestoneapproximately 15,000 p	sicompetent tunnel unlined.

		Quantity	Unit Price			Total :
	Quantity	per LF of Tunnel	Engineer's Estimate	Average of of Three Lowest Bids	Low Bid	Dollars Low Bid
Mobilization Clear, Grub	LS LS		•			
Drill Pilot Holes Tunnel Excavation Tunnel Enlargement Subtotal						4,567,206 ^a
Steel Sets Rock Bolts Timber Rock Bolt Shapes Chain Link Fabric Liner Plate Other Expansion Bolts Subtotal						
Concrete Cement Reinforcing Steel Subtotal						793,530 ^b
Drill Grout Holes Grout Pipe Grout Connection Grout Operation PAMC Other Subtotal						
Other T unnel Tu nnel Total						5,360,736
Other Project Total Project			2 10			850,000 6,210,736

Includes support (\$259/LF). a.

Includes grout; this item was subsequently removed from the contract (\$45/LF). b.

Shaft. c.

A-63

Crawford Avenue (18-E) Namë: Chicago, Illinois Location: City of Chicago, Department of Public Works Owner: S&M Contractor: Machine Manufacturer: Jarva Shape: Circular Length: 18,320 LF 16'10" Bore: Inside Diameter: 15' Calcutated Volumes: Excavation: 8.25 CY/LF Excavation: 151,100 CY (nearest hundred) 1.70 CY/LF Lining: 31,100 CY (nearest hundred) Lining:

Material:

Dolomitic limestone, competent, compressive strength approximately 15,000 psi.

		Quantity	Unit Price			Total	
	Quantity	per LF of Tunnel	Engineer's Estimate	Average of of Three Lowest Bids	Low Bid	Dollars Low Bid	
Mobilization Clear, Grub	LS LS						
Drill Pilot Holes Tunnel Excavation Tunnel Enlargement Subtotal				• • •		<u>4,763,200</u> a	
Steel Sets Rock Bolts Timber Rock Bolt Shapes Chain Link Fabric Liner Plate Other Expansion Bolts Subtotal							
Concrete Cement Reinforcing Steel Subtotal				,		1,190,475 ^b	
Drill Grout Holes Grout Pipe Grout Connection Grout Operation PAMC Other Subtotal							
Other Tunnel Tunnel Total						5,953,675	
Other Project Total Project						$\frac{1,000,000}{6,953,675}^{c}$	

a. Includes support (\$260/LF).

b. Includes grout; however, this item was subsequently removed from the contract (\$65/LF).

A- 64

c. Shaft.

Name:	Northwest Interceptor	Ar Ar
Location:	Chicago	
Owner:	City of Chicago	
Contractor:	Kenny	
Machine Manufacturer	:	
Shape:	Circular	•
Length:	5580 LF	
Bore:	14' - 4''	
Inside Diameter:	11 ⁺ - 0 ⁺⁺	
Calculated Volumes:	·	
Excavation:	33,300 CY	
Excavation:		
Lining:	13,720 CY	
Lining:	•	•
Material:	Hard gray silty clay	

· · · · · · · · · · · · · · · · · · ·		Quantity	Unit Price			Total
	Quantity	per LF of Tunnel	Engineer's Estimate	Average of of Three Lowest Bids	Low Bid	Dollars Low Bid
Total Tunnel	5580 lf		•••		\$220.00/lf	1,227,600
Other Project			z,			1,645,000
Total Project	•				. •	2,872,600
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Name:	Leamington Avenue	Approximate Date: 1968
Location:	Chicago	
Owner:	City of Chicago	· .
Contractor:	Pontarelli and O'Brien	
Machine Manufacturer:		
Shape:	Circular	•
Length:	4695 LF	
Bore:	14' - 4"	. •
Inside Diameter:	12'- 0"	
Calculated Volumes: Excavation: Excavation:	28,000 CY	
Lining: Lining:	8,400 CY	
Material:	Hard silty clay with trace	s of sand and pebbles
	Quantity.	Unit Price Total

	ĺ	Quantity.		Unit Price	····	Total	
·	Quantity	per LF of Tunnel	Engineer's Estimate	Average of of Three Lowest Bids	Low Bid	Dollars Low Bid	. *
Total Tunnel	4695 lf				\$285.00/lf	1,338,075	1 1 1
Other Project						1,582,023	·
Total Project						2,920,098	
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Normal Avenue Name: Chicago Location: City of Chicago Owner: Healy and Kenny Contractor: Machine Manufacturer: Circular Shape: 12,125 LF Length: 15' - 6" Bore: 13' - 0" Inside Diameter: Calculated Volumes: 84,700 CY Excavation: Excavation: 25, 200 CY Lining: Lining:

Material:

Approximate Date: 1968

Silty clay with traces of sand and find gravel

		Quantity		Total		
	Quantity	per LF of Tunnel	Engineer's Estimate	Engineer's Average of Estimate Lowest Bids		Dollars Low Bid
Total Tunnel	12,125 lf				\$324.00/lf	3,928,500
Other Project			•			341, 415
Total Project		•				4,269,915
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Name:	Port Huron
Location:	Port Huron, Michigan
Owner:	City of Detroit
Contractor:	Greenfield Construction Co.
Machine Manufacturer:	Lawrence
Shape:	Circular
Length:	31,960 LF
Bore:	18'
Inside Diameter:	16'
Calculated Volumes:	
Excavation:	9.43 CY/LF
Excavation:	301,400 CY (nearest hundred)
Lining:	1.98 CY/LF
Lining:	63,300 CY (nearest hundred)
Material	Antrim shale fairly intact of

tact, compressive strength 6,000 to 12,000 psi.

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		Quantity		Unit Price		Totai Dollars Low Bid	
	Quantity	per LF of Tunnel	Engineer's Estimate	Average of of Three Lowest Bids	Low Bid		
Mobilization Clear, Grub Subtotal	ls Ls			• • •	· ·	350,000	
Drill Pilot Holes Tunnel Excavation Tunnel Enlargement Subtotal		¢				<u>10,414,000</u> a	
Steel Sets Rock Bolts Timber Rock Bolt Shapes Chain Link Fabric Liner Plate Other Expansion Bolts Subtotal							
Concrete Cement Reinforcing Steel Subtotal						2,400,000 ^b	
Drill Grout Holes Grout Pipe Grout Connection Grout Operation PAMC Other Subtotal				• • • •			
Other Tunnel Tunnel Total					•	13, 164, 000	
Other Project Total Project						618,000 ^C 13,782,000	
			•				
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a. Includes supports.

b. Includes grout.

c. Shaft.

Name:	Corridor Interceptro PCI-5
Location:	Detroit
Owner:	City of Detroit
Contractor:	Corridor Constructors
Machine Manufacturer:	
Shape:	Circular
Length:	14,630 LF
Borc:	15' ⇔ 5"
Inside Diameter:	12' - 9''
Calculated Volumes: Excavation:	101,400 CY
Excavation: Lining:	31,900 CY
Lining:	·
Material:	Silty clay with traces of sand and gravel

· · · ·	and the second second	Quantity		Unit Price		Total
	Quantity	per	Engineer's	Average of	Low	Dollars
· · · · ·		of Tunnel	Estimate	Lowest Bids	Bid	Bid
Excavation and						
Primary Lining				• •	\$402.00/lf	5,881,260
Concrete Lining					137.00/lf	2,004,310
Total Tunnel			· · · ·		539.00/lf	7,885,570
Other Project						533,430
Total Project						8,419,000
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Corridor Interceptor PCI-6 Approximate Date: 1970 Name: Detroit Location: City of Detroit Owner: Corridor Constructors Contractor: Machine Manufacturer: Circular Shape: 13,033 LF Length: 15' - 5" Bore: 12" - 9" Inside Diameter: Calculated Volumes: 90,000 CY Excavation: Excavation: 28,400 CY Lining: Lining: Material: Silty clay with trace of sand and gravel and methane gas .

		Quantity		Unit Price	* -	Total
· · · · · · · · · · · · · · · · · · ·	Quantity	per LF of Tunnel	Engineer's Estimate	Average of of Three Lowest Bids	Low Bid	Dollars Low Bid
Excavation and Primary Lining	13,033 lf				\$493.00/1f	6,425,269
Concrete Lining	13,033 lf				137.00/lf	1,785,52
Total Tunnel				•	630.00/lf	8,210,79
Other Project						554,21
Total Project						8,765,00
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Name:	Corridor Interceptor PCE-7 Approximate Date:
Location:	Detroit
Owner:	City of Detroit
Contractor:	Michigan Sewer Construction Company
Machine Manufacturer:	
Shape:	Circular
Length:	13,633
Bore:	15' → 5''
Inside Diameter:	12' - 9"
Calculated Volumes:	·
Excavation:	94, 400 CY
Excavation:	
Lining:	29, 700 CY
Lining:	•
Matorial	Silty clay with traces of sand and gravel and methane gas

1970

		1	Quantity		Unit Price		Total
• •	, ' 	Quantity	per LF of Tunnel	Engineer's Estimate	Average of of Three Lowest Bids	Low Bid	Dollars Low Bid
Mobilization	• • • •			•			180,000
Dewatering	•						420,288
Tunnel		а. С				\$587. 00/1f	8,002, <u>571</u>
Total Tunnel							8,602,859
Other Project	· ·						<u>374,906</u>
Total Project							8,977,765
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Name:	Bedford-Cadieux Relief Sewer	Approximate Date: 1967
Location:	Detroit	-Frankis Bub. 1001
Owner:	City of Detroit	
Contractor:	Greenfield and Mancini Construction. I	nc.
Machine Manufacturer:		· · · · ·
Shape:	Circular	•
Length:	10,791 LF	
Bore:	14' - 4''	
Inside Diameter:	11' - 0''	,
Calculated Volumes:		
Excavation:	64, 500 CY	
Excavation:		
Lining	17.850 CY	• ,
Lining:	•	
Matorial.	Soft plastic clay with trace of sand and	gravel

1				Quantity		Unit Price		Total	
			Quantity	per LF of Tunnel	Engineer's Estimate	Average of of Three Lowest Bids	Low Bid	Dollars Low Bid	
Total	Tunnel					•	\$164.00/lf	1,769,724	
Other	Project		14					1,725,276	, -
Tota	l Project	•	· · .					3,495,000	
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Name:	North Interceptor
Location:	Detroit
Owner:	City of Detroit
Contractor:	Corridor Constructors
Machine Manufacturer:	
Shape:	Circular
Longth:	5,713 LF
Bore:	20' - 10''
Inside Diameter:	17' - 6"
Calculated Volumes:	•
Excavation:	72, 200 CY
Excavation:	· · ·
Lining:	21,200 CY
Lining:	•
Material:	Gray silty clay
·.	

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		•	Quantity	l	Unit Price		Total
		Quantity	per LF of Tunnel	Engineer's Estimate	Average of of Three Lowest Bids	Low Bid	Dollars Low Bid
	· ·						
Excavation and Primary Lining						\$425.00/1f	2,428,025
Concrete Lining	· .· ·					197.00/1f	1,121,521
Total Tunnel		,		, , , , , , , , , , , , , , , , , , ,			3,549,546
Other Project	•	, ·	.		•		335,454
Total Project		р			د		3,885,000
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Name:	Wyoming Relief Sewer
Location:	Detroit
Owner:	City of Detroit
Contractor:	
Machine Manufacturer:	
Shape:	Circular
Length:	12'~ 6,049 LF 10'~4,445 LF
Bore:	14' - 8" & 12' - 0"
Inside Diameter:	
Calculated Volumes:	· ·
Excavation:	· 12'~ 37,800 CY
Excavation:	10'~ 18,600 CY
Lining:	12'~ 12,500 CY
Lining	10'~ 5,690 CY
Material:	Plastic gray sandy clay

Quantity Unit Price per Average of Quantity Engineer's Low LF of Three Estimate Bid of Tunnel Lowest Bids . \$180.00/lf 6,049 lf 154.00/lf 4,445 lf

Total Tunnels

Tunnel 12'

Tunnel 10'

Tr (. . .

Other Project

Total Project

A-74

Approximate Date: 1968

Total

Dollars

Low

Bid

1,088,820

684,530

1,773,350

973,724

2,747,074

Blenheim-Gilboa Name: New York (Blenheim County) Location: New York Power Authority 'Owner: Perini Company Contractor: Machine Manufacturer: Circular Shape: 15'~4@ 1,928 LF 32'~ 910 LF Length: 15' - 0" & 32' - 0" Bore: 12' - 0" & 28' - 0" Inside Diameter: **Calculated Volumes:** 32' ~ 27,100 CY Excavation: 15' ~ 50, 500 CY Excavation: 32'~ 7,000 CY Lining: 15'~ 21,000 CY Lining: Interbedded sandstone and shale Material:

Unit Price Quantity Total per Average of Dollars Engineer's Quantity Low LF of Three Low Estimate Bid of Tunnei Lowest Bids Bid 15' Tunnel Excavation 50, 500 cy 6.6 cy \$200.00/lf 1,542,000 35.00/cy 735,000 Concrete Lining (No Forms) 2,277,000 Total 32' Tunnel 700.00/lf 637,000 27,100 cy 29.7 cy Excavation **Concrete** Lining 55.00/cy 385,000 (Including Forms) Subtotal 1,022,000 **Total Tunnels** 3,299,000 63,507,010 Other Project **Total Project** 66,806,010

Approximate Date: 1969

Name: Location: Owner: Contractor: Machine Manufacturer: Shape: Length: Bore: Inside Diameter: Calculated Volumes: Excavation: Excavation: Lining: Lining: Materiai:

5.0-

Richmond Tunnel New York (New York County) N.Y.C. Board of Water Supply Perini Company

Circular

NO DETAILED DATA AVAILABLE

Pegmatite schist with feldspar and garnet, compressive strength approximately 30,000 psi.

Approximate Date: 1954

		Quantity	Unit Price			Total
	Quantity	per LF of Tunnel	Engineer's Estimate	Average of of Three Lowest Bids	Low Bid	Dollars Low Bid
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Name:	Tunnel Number 3-520	•	Approximate	Jaic. 1	, u
Location:	New York (New York County)		·		
Owner:	N.Y.C. Board of Water Supply				
Contractor:	Walsh Construction Company				
Machine Manufacturer:	None				
Shape:	Circular	• •			
Length:	17,611 LF				
Bore:	26' - 10"	· .			
Inside Diameter:	24'- 0"				
Calculated Volumes:					
Excavation:	370,000 CY				
Excavation:					
Lining:	73,900 CY				
Lining:				· · ·	
Material:	Manhattan Schist, intact, compres	sive strength ap	proximately 30,0	000 psi	•

		Quantity	·	Unit Price	<u></u>	Total
	Quantity	per LF of Tunnel	Engineer's Estimate	Average of of Three Lowest Bids	Low Bid	Dollars Low Bid
Total Tunnel	370,000 cy	21 cy			\$1916/lf	33,700,000
Other Project					-	37,300,000
Total Project					-	71,000,000
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Tunnel Number 3-521 Name: New York Location: N.Y.C. Board of Water Supply Owner: Walsh Construction Company Contractor: None Machine Manufacturer: Circular Shape: 31,370 LF Length: 26' - 10" Bore: 24' - 0" Inside Diameter: Calculated Volumes: 656,000 CY Excavation: Excavation: 131,700 CY Lining: Lining: Materiai:

Approximate Date: 1969

Manhattan Schist, intact, compressive strength approximately 30,000 psi.

	· · · · · · · · · · · · · · · · · · ·	Quantity		Unit Price		Total
	Quantity	per LF of Tunnel	Engineer's Estimaté	Average of of Three Lowest Bids	Low Bid	Dollars Low Bid
Cotal Tunnel	656,000 cy	21 cy			\$1370.00/lf	43,000,000
Other Project						27,500,000
Total Project		{	•			70,500,000
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A -78

Name:	Tunnel Number 3-522	Approximate Date: 1969
Location:	New York (New York County)	
Owner:	N.Y.C. Board of Water Supply	
Contractor:	Walsh Construction Company	
Machine Manufacturer:	None	
Shape:	Circular	
Length:	23,151 LF	
Bore:	22' - 10''	•
Inside Diameter:	20' - 0''	
Calculated Volumes:		
• Excavation:	351,000 CY	۲
Excavation:		
Lining:	82,000 CY	
Lining:	· · · ·	
Material:	Manhattan Schist, intact, compressive st	rength approximately 30,000 psi.

		Quantity		Unit Price		Total
	Quantity	per LF of Tunnel	Engineer's Estimate	Average of of Three Lowest Bids	Low Bid	Dollars Low Bid
Total Tunnel	351,000 cy	15 cy			\$1586.00/ 1f	36,700,000
Other Project			н. П			44,300,000
Total Project						<u>81,000,000</u>
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Name:	West Side Sewer
Location:	New York (New York County)
Owner:	N.Y.C. Sewer Department
Contractor:	Poirer and McLean Company
Machine Manufacturer:	None
Shape:	H. S.
Length:	4,212 LF
Bore:	21' - 0''
Inside Diameter:	$16' - 0 \times 16' - 0''$
Calculated Volumes: Excavation: Excavation: Lining: Lining:	2,468 LF soft ground, 1,744 LF rock
Material:	Soft ground and granite

Soft ground and granite

•	·	Quantity		Unit Price		Total
	Quantity	per LF	Engineer's Estimate	Average of of Three	Low	Dollars Low
Soft Ground Portion		of Tunnel		Lowest Bids	Dia	Bid
(12 psi air)	2,468 lf	*	,		· ·	
Bond					30/lf	74,000
Plant			• •		1840/lf	4,540,000
Cast Iron					500/lf	1,234,000
Excavation					3€55/lf	9,030,000
Concrete					390/lf	963,000
Clean-Up			•		75/lf	185,000
Total	•				6490/1f	16,726,000
Rock Portion	1. 1. 1.					
Bond	1,744 lf				20/lf	,34, 900
Excavation					2370/lf	4 , 1 40, 000
Concrete					260/lf	454,000
Clean Up					<u>50/lf</u>	87,200
Total		•			2700/lf	4,716,100
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A-80

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Name:	63rd Street Subway	Approx
Location:	New York (New York County)	
Owner:	Metropolitan Transit Authority	
Contractor:	Peter Kiemit, Sons Co.	
Machine Manufacturer:	· ·	
Shape:	- 4 Cell Box	
Length:	3140 LF	:
Bore:		
Inside Diameter:	•	
Calculated Volumes:		
Excavation:	· · ·	
Excavation:		
Lining:		
Lining:	•	
Material:	Partially in Granite and Part Sunken Tube	

		Quantity		Unit Price		Total
· · · ·	Quantity	per LF of Tunnel	Engineer's Estimate	Average of of Three Lowest Bids	Low Bid	Dollars Low Bid
Rock Excavation Subtotal	95,000 c.y.				100/c.y.	9,500,000 9,500,000
Steel Supports	425 tons 462 tons				1000/ton 750/ton	425,000 346,500
Rock Bolts	125,000 lbs. 125,000 lbs.				1.60/lb. 1.40/lb.	200,000 175,000
Timber Supports Subtotal	425 MBFM				600/MBFN	1 255,000 1,401,500
Concrete Subtotal	46,800 c.y.				180/c.y.	7,424,000 7,424,000
Grout Connections Grout Other (Cement) Subtotal	820 ea. 1,000 bbls. 1,500 bbls.				90/ea 150/bbl. 70/bbl.	73,800 150,000 <u>105,000</u> 328,800
Rock Tunnel Total			· · ·			18,654,300
Other Project Total Project						50,826,620 69,480,920
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A-81

Route 101-13 Location: New York, New York New York City Transit Authority Contractor: Cayoga, Johnson, Drake & Piper Machine Manufacturer: None Box (Approx.) 3097 LF (2 tubes of 3097 LF) 32' x 18' (total) Inside Diameter: 14'6" x 14'3" (2 tubes) Calculated Volumes: **Exeavation:** 21.33 CY/LF Excavation: 66,100 CY Lining: 7.69 CY/LF Lining: 24,700 CY Material: Granite and injection gneiss.

Name:

Owner:

Shape:

Length: Bore:

Approximate Date: 1966

بمرحدته وحصريب والمتكافيين والمحتي معتور بواكا فنباك	and the second			
	Quantity	Quantity per LF of Tunnel	Unit Price	Final Cost
Mobilization Clear, Grub	LS LS			
Drill Pilot Holes Tunnel Excavation Tunnel Enlargement Subtotal	68,795 cy	22. 21	53.00	3, 646, 117 <u>3, 646, 117</u>
Steel Sets Bock Bolts	970,306 lbs	313.31	.15	145, 546
Timber Book Bolt Shapes	97.5 MBM	.031	300.00	29,251
Chain Link Fabric Liner Plate Other				174 797
Concrete	23,201 cy	7.49	72.00	1,670,493
Cement Reinforcing Steel Subtotal	117, 274 lb	37.87	.35	$\frac{41,046}{1,711,539}$
Drill Grout Holes Grout Pipe Grout Connections				
Grout Operation PAMC	8,057 BB1	x	16.00	128,907
Subtotal			·.	128,907
Other Tunnel Tunnel Total				0 5,661,360
Other Project Total Project				2,384,680 8,046,040
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Name:	Tuscarora	Approximate Date:	1965
Location:	Pennsylvania (Harrisburg County)		
Owner:	Pennsylvania Turnpike Authority	•	
Contractor:	Peter Kiewit, Son Company		
Machine Manufacturer:			
Shape:	B. H.		,
Length:			
Bore:			
Inside Diameter:			
Calculated Volumes:			
Excavation:		·	
Excavation:	н. 1		
Lining:			
Lining:			
Material:	Predominately shale and sandstone with good tu	inneling characteristics.	, some

very hard quartzite. ONLY PROPRIETARY CONTRACTOR DATA

		Quantity	Unit Price			Total	
	Quantity	per LF of Tunnel	Engineer's Estimate	Average of of Three Lowest Bids	Low Bid	Dollars Low Bid	
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Name:	Dorchester
Location:	Massachusetts (Dorchester County)
Owner:	Metropolitan District Comm.
Contractor:	S. J. Groves Co.
Machine Manufacturer:	Lawrence Mfg. Co.
Shape:	Circular
Length:	32,880 LF
Bore:	12'-2''
Inside Diameter:	10'-0''
Calculated Volumes:	· · · ·
Excavation:	141,700 CY
Excavation:	
Lining:	45,800 CY
Lining:	•
Material:	Conglomerate and Argillite

Quantity Unit Price Total Average of Dollars per Engincer's Quantity Low of Three \mathbf{LF} Low Estimate Bid of Tunnel Lowest Bids Bid <u>8,220,</u>000 32, 880 lf Tunnel Excavation 332/LF 250.00/LF Subtotal 8,220,000 3,300,000 lbs .23/lb .30/lb 9901000 Steel Support 990,000 Subtotal 160/LF 33,468 lf 122/LF 5,354,880 Concrete Lining ----4.46/bbl 5.00/bbl 650,000 Cement 130,000 bbls 6,004,880 Subtotal **Drilling Grout Holes** 50,000 lf 3.70/LF 4.00/LF 200,000 **Grout** Pipe 14,000 lf 2.40/LF 2.00/LF 28,000 52,9000 10.00/cy **Grout Connection** 5,200 ea 22.00/ea 1,400,000 Grouting 14,000 cy 83/cy 100/cy Other 21/cy 30/cy 18,000 (Grout Sand) 600 cy Other 66/LF 135/LF 337,500 (Grout Crete) 2,500 lf Subtotal 2,035,500 **Tunnel Total** 17,250,380 1,850,005 Other Project 19,100,385 Total Project

A-84

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Name: 🔅	Contract M0011
Location:	San Francisco
Owner:	Bay Area Rapid Transit District
Contractor:	Peter Kiemit, Sons, Co.
Machine Manufacturer:	Calweid
Shape:	Circular
Length:	7000 LF
Bore:	18'-8"
Inside Diameter:	16'-0"
Calculated Volumes:	
Excavation:	
Excavation:	
Lining:	
Lining:	

Material:

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Dense Sandy materials with some bay mud. Bay mud is soft silty clay with varying amounts of organic material.

	. .	Quantity	Unit Price			Total	
	Quantity	per LF of Tunnel	Engineer's Estimate	Average of of Three Lowest Bids	Low Bid	Dollars Low Bid	
Mob ilization Tunnel				:	35/LF 1086/LF	250,000 7,600,000	
Other Tunnel Liner Plate (Material Only)					330/LF	2,300,000	
Tunnel Total			9 ¹			10,150,000	
Other Project Total Project					- -	5,349,000 15,499,000	
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Name: Location: Owner: Contractor: Machine Manufacturer: Shape: Circular Length: 4874 LF 18'-8" Bore: Inside Dlameter: 16' Calculated Volumes: Excavation: Excavation: Lining: Lining: Material:

Contract K0061 San Francisco Bay Area Rapid Transit District

Approximate Daté: 1968

Fine Sand and Clay

Quantity Unit Price Total per Average of Dollars Quantity Engineer's Low LF of Three Low Estimate Bid of Tunnel Lowest Bids Bid Mobilization 400,000 (75/LF Excavation, Supporting & 1310/LF 69400,000 Lining Invert Concrete 130/LF 1650,000 Other Tunnel Liner Plate 380/LF 1, 860, 000 (Material Only) Tunnel Total 5,310,000

Name: Contract K0016 Approximate Date: 1968 San Francisco Location: Bay Area Rapid Transit District Owner: Oakland Wye Contractors Contractor: Machine Manufacturer: Circular Shape: Length: 3260 LF 18'-8" Bore: 16'-0" Inside Diameter: Calculated Volumes: Excavation: Excavation: Lining: Lining: Silty Sand Material:

		Quantity	Unit Price			Total
	Quantity	per LF of Tunnel	Engineer's Estimate	Average of of Three Lowest Bids	Low Bid	Dollars Low Bid
Mobilization					100/LF	330,000
Supporting & Lining			·		1200/lf	3,940,000
Other Tunnel Liner Plate			-		330/LF	<u>1,080,000</u>
Tunnel Total						<u>5,350,000</u>
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Contract M0031 Name: Approximate Date: 1968 Location: San Francisco Bay Area Rapid Transit District Owner: Morrison-Knudsen, Perini, Brown & Root Contractor: Machine Manufacturer: Circular Shape: Length: 9030 LF Bore: 18'-8" Inside Diameter: 16'-0" Calculated Volumes: Excavation: . Excavation: Lining: Lining:

Silty and Sandy Clay

Material:

Quantity Unit Price Total per Average of Dollars Quantity Engineer's Low LF of Three Low Estimate Bid of Tunnel Lowest Bids Bid Mobilization 55/LF 500,000 Excavation Supporting & 971/LF 8,770,000 Lining Invert Concrete 60/LF 550,000 Other Tunnel Liner Plate 336/LF 2,980,000 (Material Only) Tunnel Total 12,800,000 Other Project 2,438,000 Total Project. 15,238,000 ≥ 1 · .83 A-88
Contract B0031 Approximate Da	te: 1968
San Francisco	
Bay Area Rapid Transit District	
Perini Company and Brown & Root Co.	
Circular	
2800 LF	
19'-6''	
17'-0"	
	•
•	
Recent Bay Clays with obstructions and back-filled zone under	bay.
	Contract B0031 Approximate Da San Francisco Bay Area Rapid Transit District Perini Company and Brown & Root Co. Circular 2800 LF 19'-6'' 17'-0'' Recent Bay Clays with obstructions and back-filled zone under

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Unit Price Quantity Total per Average of Dollars Engineer's Quantity Low LF of Three row. Estimate Bid of Tunnel Lowest Bids Bid . 360/LF Mobilization 1,000,000 Excavation, 9,950,000 Supporting & 3550/LF Concreting Invert Concrete 70/LF 200,000 Other Tunnel Liner Plate 500/LF 1,400,000 (Material Only) Tunnel Total 12,550,000 3,243,000 15,793,000 Other Project **Total Project** 

A-89

Name: Location: Owner: Contractor: Machine Manufacturer: Shape: ۰. Length: Bore: Inside Diameter: Calculated Volumes: Excavation: . Excavation: Lining: Lining: Material:

Contract K0014 San Francisco Bay Area Rapid Transit District Oakland Wye Contractors

Circular 4170 LF 18'-8" & 19' - 8" 16'-0" & 17'-0"

## Approximate Date: 1968

Fine Sand and Clay

|                         | Quantity Unit Price          |                        |                        |                                                                                                                | •          | Total                 |
|-------------------------|------------------------------|------------------------|------------------------|----------------------------------------------------------------------------------------------------------------|------------|-----------------------|
|                         | Quantily                     | per<br>LF<br>of Tunnel | Engineer's<br>Estimate | Average of<br>of Three<br>Lowest Bids                                                                          | Low<br>Bid | Dollars<br>Low<br>Bid |
|                         |                              |                        |                        | ÷1                                                                                                             |            | ļ                     |
| Mobilization            |                              |                        |                        | · ·                                                                                                            | 120/LF     | 500,000               |
| Excavation,             |                              | )                      |                        |                                                                                                                | :          | <u>}</u>              |
| Supporting &            |                              |                        | -                      | · · · · ·                                                                                                      | 1206/LF    | 5,100,000             |
| Concreting              |                              |                        |                        |                                                                                                                |            |                       |
| Other Tunnel            |                              | 1 · *                  |                        |                                                                                                                |            |                       |
| Liner Plate             |                              |                        |                        | <i></i>                                                                                                        | 330/LF     | 1,400,000             |
| (Material Only)         |                              |                        |                        |                                                                                                                |            |                       |
| <b>Married 1 Market</b> |                              | a second               |                        |                                                                                                                |            |                       |
| I undel Total           |                              | 1. '                   | ·. /                   |                                                                                                                |            | 7,000,000             |
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Name: Contract M0042 Approximate Date: 1968 San Francisco Location: Bay Area Rapid Transit District Owner: Contractor: Machine Manufacturer: Calweld Circular Shape: 3560 LF Length: Bore: 18'-8" 16'-0" Inside Diameter: Calculated Volumes: . Excavation: Lining: Lining: Fine Sand, Meta Sandstone and Fractured Shale Material:

Quantity. **Unit Price** Total per Average of Dollars Quantity Engineer's Low LF of Three Low Estimate Bid • 1 of Tunnel Lowest Bids Bid 35/LF 120,000 Mobilization Excavation, 680/LF 2,450,000 Supporting & Concreting 66/LF 230,000 Invert Concrete Other Tunnel Liner Plate 330/LF 1,200,000 (Material Only) Tunnel Total 4,000,000 ; 2,137,000 Other Project 6,137,000 Total Project

## Approximate Date: 1968

Name: Contract C0041 Location: San Francisco Bay Area Rapid Transit District Owner: Shea, Kaiser and Macco Contractor: Machine Manufacturer: Shape: Circular 32,400 LF Length: 20' - 8" Bore: 17' - 4" Inside Diameter: Calculated Volumes: Excavation: Excavation: Lining: Lining: Material:

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Mixed rock strata, part of Franciscan formation.

|                                |          | Quantity               | Unit Price             |                                       |            | Total                 |  |
|--------------------------------|----------|------------------------|------------------------|---------------------------------------|------------|-----------------------|--|
|                                | Quantity | per<br>LF<br>of Tunnel | Engineer's<br>Estimate | Average of<br>of Three<br>Lowest Bids | Low<br>Bid | Dollars<br>Low<br>Bid |  |
| Mobilization                   |          |                        |                        |                                       | 20/lf      | 6,50,000              |  |
| Excavation &<br>Primary Lining |          |                        |                        |                                       | 640/lf     | 20,750,000            |  |
| Total Tunnel                   |          |                        |                        |                                       |            | 9<br>21,400,000       |  |
| Other Project                  |          |                        |                        |                                       |            | 10,253,000            |  |
| Total Project                  |          |                        |                        |                                       |            | 31,653,000            |  |
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| Name:                 | Contract S0022                         |
|-----------------------|----------------------------------------|
| Location:             | San Francisco                          |
| Owner:                | Bay Area Rapid Transit District        |
| Contractor:           | Morrison-Knudsen, Perini, Brown & Root |
| Machine Manufacturer: | Mining Equipment Manufacturing Co.     |
| Shape:                | Circular                               |
| Length:               | 10,230 LF                              |
| Bore:                 | 18'-6''                                |
| Inside Diameter:      | 16'-0''                                |
| Calculated Volumes:   |                                        |
| Excavation;           |                                        |
| Excavation:           |                                        |
| Lining:               | •                                      |
| Lining:               | •                                      |
| Material:             | Dense Sand and Clay                    |

|                                                |          | Quantity Unit Price    |                        |                                       |                         |                         |
|------------------------------------------------|----------|------------------------|------------------------|---------------------------------------|-------------------------|-------------------------|
|                                                | Quantity | per<br>LF<br>of Tunnel | Engineer's<br>Estimate | Average of<br>of Threc<br>Lowest Bids | Low<br>Bid <sup>†</sup> | Dollars<br>Low<br>Bíd   |
| Mobilization<br>Exception                      |          |                        |                        |                                       | 100/LF                  | 1,030,000               |
| Supporting &<br>Concreting                     |          |                        |                        |                                       | 1365/LF                 | 13,970,000<br>620,000   |
| Invert Concrete                                |          |                        |                        |                                       | 007 111                 |                         |
| Other Tunnel<br>Liner Plate<br>(Material Only) |          |                        |                        |                                       | 330/LF                  | 3,380,000               |
| Tunnel Total                                   |          |                        |                        |                                       |                         | • <b>19,000,</b> 000    |
| Other Project<br>Total Project                 |          |                        |                        |                                       |                         | 2,794,000<br>21,794,000 |
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Approximate Date: 1968

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Contract 80011 Name: Approximate Date: 1968 Location: San Francisco Bay Area Rapid Transit District Owner: Contractor: Machine Manufacturer: Circular Shape: 6272 LF Length: 18'-8" Bore: 16'-0" Inside Diameter: Calculated Volumes: . Excavation: Excavation: Lining: Lining: Very Dense Sands with occasional clay lenses. Material: , *\** 

| Quantity Per<br>LF Engineer's<br>of Turnet Average of<br>Othree<br>Lowes Bids Low<br>Bid   Mobilisation<br>Excavation,<br>Supporting 4<br>Lining 90/LF 500,000   Data 90/LF 500,000   Invert Concrete 60/LF 330/LF   Other Project<br>Total Project 330/LF 24070,000                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                 | Quantity Unit Price |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                        | Total                  |              |                |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------|---------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------|------------------------|--------------|----------------|
| Mobilization<br>Excavation,<br>Supporting &<br>Liting<br>Invert Concrete     B0/LF     500,000       Other Tunnel<br>Liner Plate<br>(Material Only)     1205/LF     7,555,000       Other Tunnel<br>Liner Plate<br>(Material Only)     330/LF     21070,000       Other Project<br>Total Project     10,500,000     1/731,000       12/231,000     12/231,000     12/231,000                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | · .             | Quantity            | per<br>LF                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | Engineer's<br>Estimate | Average of<br>of Three | Low .<br>Bid | Dollars<br>Low |
| Mobilization<br>Excavation,<br>Supporting &<br>Lining<br>Invert Concrete   500/LF   500,000     Other Tunnel<br>Liner Plate<br>(Material Only)   330/LF   24070,000     Other Project<br>Total Project   10,500,000   11/731,000     12/2331,000   12/2331,000                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | ·               |                     | orrannel                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | <u> </u>               | Lowest Blas            |              | RIG            |
| Excavation,<br>Supporting &<br>Liting<br>Invert Concrete<br>Other Tunnel<br>Liner Plate<br>(Material Only)<br>Tunnel Total<br>Other Project<br>Total Project<br>A - 94                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | Mobilization    | 4                   |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | •                      |                        | 80/LF        | .500.000       |
| Supporting &   1205/LF   7,555,000     Ining   60/LF   375,000     Other Tunnel   10,500,000   10,500,000     Other Project   10,500,000   12,231,000     Other Project   10,200,000   12,231,000     Other Project   10,500,000   10,300     Other Project   10,500,000 </td <td>Excavation,</td> <td></td> <td></td> <td></td> <td></td> <td>007 222</td> <td></td> | Excavation,     |                     |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                        |                        | 007 222      |                |
| Lining<br>Invert Concrete<br>Other Tunnel<br>Liner Plate<br>(Material Only)<br>Tunnel Total<br>Other Project<br>Total Project<br>10,500,000<br>12,231,000<br>12,231,000                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | Supporting &    |                     | ļ                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 1                      | <b>j</b>               | 1205/LF      | 7,555,000      |
| Invert Concrete   60/LF   375,000     Other Tunnel   Liner Plate   330/LF   24070,000     (Material Only)   10,500,000   10,500,000   12,221,000     Other Project   12,221,000   12,221,000   12,221,000                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | Lining          |                     |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                        |                        |              |                |
| Other Tunnel   Jiner Plate   330/LF   24070,000     Tunnel Total   10,500,000   11/731,000   12/231,000     Other Project   11/731,000   12/231,000     Total Project   12/231,000   12/231,000                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | Invert Concrete |                     |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                        |                        | 60/LF        | 375,000        |
| Liner Project   330/LF   24070,000     Tunnel Total   10,500,000   1/731,000     Other Project   1/22,231,000     Total Project   1/22,231,000     12/231,000   1/22,231,000     12/231,000   1/22,231,000                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | Other Turnel    |                     | · .                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                        |                        |              |                |
| (Material Only)<br>Tunnel Total<br>Other Project<br>Total Project<br>A - 94                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | Liner Plate     |                     |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                        |                        | 330/T.F      | 2.070 000      |
| Tunnel Total   10; 500,000     11; 731,000   12; 231,000     12; 231,000   12; 231,000     13; 231,000   12; 231,000     14; 731,000   12; 231,000     15; 500,000   12; 231,000     16; 500,000   12; 231,000     17; 731,000   12; 231,000     12; 231,000   12; 231,000     12; 231,000   12; 231,000     12; 231,000   12; 231,000     13; 231,000   12; 231,000     14; 731,000   12; 231,000     15; 231,000   12; 231,000     16; 500,000   12; 231,000     17; 731,000   12; 231,000     18; 231,000   12; 231,000     19; 10; 10; 10; 10; 10; 10; 10; 10; 10; 10                                                                                                                                                                                                                                                                                                                                                                                                                                     | (Material Only) |                     |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                        | · · · ·                | 0007 111     | 21010,000      |
| Tunnel Total<br>Other Project<br>Total Project                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | •••             |                     | l i v                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                        |                        |              |                |
| Other Project<br>Total Project                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | Tunnel Total    |                     |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                        |                        |              | 10,500,000     |
| Cher Project<br>Total Project                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                 |                     |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                        |                        |              |                |
| A-94                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Other Project   | · ·                 |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                        |                        |              | 1,731,000      |
| Α-94                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | TOTEL PLOJOCI   |                     |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                        |                        | · · ·        | 12,231,000     |
| Α-94                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                 |                     |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                        | · · · ·                | · ·          | -<br>-         |
| Α-94                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                 |                     |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                        |                        |              |                |
| Α-94                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                 |                     |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                        |                        | •            | •              |
| Α-94                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | · ·             |                     |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                        |                        | "            |                |
| A-94                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | ,               |                     |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                        |                        |              |                |
| A-94                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                 |                     | · · · · ·                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                        |                        |              |                |
| A-94                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | · · ·           |                     |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                        |                        |              |                |
| A-94                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | <i>к</i>        | ··· ·               | 1996 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 19 |                        |                        | , d          |                |
| A-94                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | *               |                     |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                        |                        |              |                |
| A-94                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                 | 1. 1                | 10                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                        |                        | , .          |                |
| A-94                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                 |                     |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                        |                        |              |                |
| A-94                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | -               |                     |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                        |                        |              |                |
| A-94                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | · · · ·         |                     |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                        |                        | · ·          |                |
| A-94                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                 |                     |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 1                      |                        | -            | ,              |
| A-94                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | •               |                     |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | · .                    |                        |              |                |
| A-94                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                 | ,                   |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                        |                        |              |                |
| A-94                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | • •             | · · ·               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                        |                        |              |                |
| A-94                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                 |                     |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                        | ·                      | · .          |                |
| A-94                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                 |                     |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | ł                      |                        |              |                |
| A-94                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                 |                     | · ·                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                        |                        |              |                |
| A-94                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                 | <b>.</b>            | <u>.</u>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | <u> </u>               | <u> </u>               | <u> </u>     |                |
| A-94                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | •               |                     | · .                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                        |                        | •            |                |
| A-94                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | •               | s,                  | •                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                        | 4                      | • • •        |                |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                 | •                   |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 1-94                   |                        | •            | • •            |

| Name:                 | Contract M00  | 11         |          | • • | Approximate Dat | <b>e:</b> 1968 |
|-----------------------|---------------|------------|----------|-----|-----------------|----------------|
| Location:             | San Francisco | ,<br>,     |          |     | · · ·           |                |
| Owner:                | Bay Area Rap  | ld Transit | District |     |                 |                |
| Contractor:           |               | •          |          | . ` |                 |                |
| Machine Manufacturer: | Jarva         |            |          | •   |                 | · ·            |
| Shape:                | Circular      | · · ·      |          |     |                 |                |
| Length:               | 6,875 LF      | -          |          |     |                 |                |
| Bore:                 | 18' - 8"      |            | •        | •   | · · · · · · ·   |                |
| Inside Diameter:      | 16' - 0"      |            |          | •   |                 | , ·            |
| Calculated Volumes:   | •             |            |          |     | ж.<br>19        |                |
| Excavation:           | •             | ·          | 8        | · . |                 |                |
| Excavation:           |               | 1          |          | •   |                 | P.             |
| Lining:               |               |            |          |     |                 |                |
| Lining:               | •             |            |          |     |                 | ;              |
| Material              | Meta sandston | e and gree | istone   |     |                 |                |

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|                                |          | Quantity Unit Price    |                                                                         |                                       | · · · · · · · · · · · · · · · · · · · | Total                 |  |
|--------------------------------|----------|------------------------|-------------------------------------------------------------------------|---------------------------------------|---------------------------------------|-----------------------|--|
| · · · ·                        | Quantity | per<br>LF<br>of Tunnel | Engineer's<br>Estimate                                                  | Average of<br>of Three<br>Lowest Bids | Low<br>Bid                            | Dollars<br>Low<br>Bid |  |
| Mobilization                   |          |                        |                                                                         |                                       | 45/lf                                 | 309,000               |  |
| Excavation &<br>Primary Lining |          |                        | ч<br>-<br>-<br>-<br>-<br>-<br>-<br>-<br>-<br>-<br>-<br>-<br>-<br>-<br>- |                                       | 790/lf                                | 5,431,000             |  |
| Total Tunnel                   |          |                        |                                                                         |                                       |                                       | 5,740,000             |  |
| Other Project                  |          | -                      |                                                                         |                                       | · . · ·                               | <u>3,441,000</u>      |  |
| Total Project                  |          |                        | , , , , , , , , , , , , , , , , , , , ,                                 |                                       | ,                                     | <u>9,181,000</u>      |  |
| · · ·                          |          | · · ·                  |                                                                         |                                       |                                       |                       |  |
| · · · ·                        |          |                        | :<br>                                                                   |                                       |                                       |                       |  |
| · , ·                          | · · ·    |                        |                                                                         |                                       |                                       |                       |  |
|                                |          |                        |                                                                         |                                       | · · · ·                               |                       |  |
|                                |          |                        |                                                                         |                                       | •                                     |                       |  |
| •<br>• •                       |          |                        |                                                                         |                                       |                                       |                       |  |
|                                |          |                        |                                                                         |                                       |                                       |                       |  |
|                                |          | :                      |                                                                         |                                       |                                       |                       |  |
| ,                              |          |                        |                                                                         |                                       |                                       |                       |  |
| <br>                           |          | · · · · ·              |                                                                         |                                       |                                       |                       |  |
| , · · ·                        |          |                        |                                                                         |                                       |                                       |                       |  |

10.74

## Approximate Date: 1968

Name: Location: Owner: Contractor: Machine Manufacturer: Shape: Length: Bore: Inside Diameter: Calculated Volumes: Excavation: Excavation: Lining: Lining: Material:

Contract 80021 San Francisco Bay Area Rapid Transit District Delaware V. M. Mining Equipment Manufacturing Co. Circular 7580 LF 18'-8'' 16'-0''

## Dense Sands with clay and peat areas.

|                                                |          | Quantity               |                        | Unit Price                            |            | Total                          |
|------------------------------------------------|----------|------------------------|------------------------|---------------------------------------|------------|--------------------------------|
|                                                | Quantity | per<br>LF<br>of Tunnel | Engineer's<br>Estimate | Average of<br>of Three<br>Lowest Bids | Low<br>Bid | , Dollars<br>Low<br>Bid        |
|                                                |          | or runnel              |                        | Lowest Dius                           |            | <u> </u>                       |
| Mobilization                                   |          |                        | • • •                  |                                       | 65/LF      | 500,000                        |
| Excavation,<br>Supporting &                    |          |                        |                        |                                       | 1080/LF    | 8,200,000                      |
| Invert Concrete                                |          |                        |                        |                                       | 50/LF      | 400,000                        |
| Other Tunnel<br>Liner Plate<br>(Material Only) |          |                        |                        |                                       | 330/LF     | 2,500,000                      |
| Tunnel Total                                   |          |                        | i                      |                                       |            | 11,600,000                     |
| Other Project.<br>Total Project                |          |                        |                        |                                       |            | $\frac{2,143,000}{13,743,000}$ |
| •                                              |          |                        |                        |                                       |            |                                |
|                                                |          |                        |                        |                                       |            |                                |
|                                                |          |                        |                        |                                       |            |                                |
|                                                |          |                        |                        |                                       |            |                                |
|                                                |          |                        |                        |                                       |            | · · ·                          |
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| Name:                      | Pitt-McCloud Approximate Date: 1965                                                                                |
|----------------------------|--------------------------------------------------------------------------------------------------------------------|
| Location:                  | Carlorna (McCroud County)                                                                                          |
| Owner:                     | Pacific Gas and Electric Company                                                                                   |
| Contractor:                | Peter Kiewit and Sons Company                                                                                      |
| Machine Manufacturer:      |                                                                                                                    |
| Shape:                     | •                                                                                                                  |
| Length:                    |                                                                                                                    |
| Bore:                      |                                                                                                                    |
| Inside Diameter:           |                                                                                                                    |
| <b>Calculated Volumes:</b> |                                                                                                                    |
| Excavation:                |                                                                                                                    |
| Excavation:                |                                                                                                                    |
| Lining:                    |                                                                                                                    |
| Lining:                    |                                                                                                                    |
| Material:                  | Generally alternate beds of hard metamorphosed breccia and fine grained red                                        |
| of alteration.             | metasedimentary rock resembling mudstone, shale or slate depending upon degree<br>ONLY PROPRIETARY CONTRACTOR DATA |

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|        |       | Quantity Unit Price |           |                        |                        |            | Total                                 |  |
|--------|-------|---------------------|-----------|------------------------|------------------------|------------|---------------------------------------|--|
| •<br>• |       | Quantity            | per<br>LF | Engineer's<br>Estimate | Average of<br>of Three | Low<br>Bid | Dollars<br>Low                        |  |
|        |       |                     | of runner |                        | Lowest Bids            |            | Did                                   |  |
|        |       |                     |           |                        |                        |            |                                       |  |
|        |       |                     | •         |                        |                        |            |                                       |  |
|        |       |                     |           |                        |                        |            |                                       |  |
|        |       |                     |           |                        |                        |            |                                       |  |
|        |       |                     |           |                        |                        | · · · ·    |                                       |  |
|        |       |                     |           |                        |                        |            |                                       |  |
|        |       | • •                 |           |                        |                        |            | · .                                   |  |
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