ARIZONA CANAL DIVERSION CHANNEL STUDY

BILTMORE PROPERTIES AND VICINITY

Sverdrup & Parcel

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PHASE I REPORT

ARIZONA CANAL DIVERSION CHANNEL STUDY

BILTMORE PROPERTIES AND VICINITY

PREPARED FOR
MARICOPA COUNTY FLOOD CONTROL DISTRICT
PHOENIX, ARIZONA

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FEBRUARY 1978

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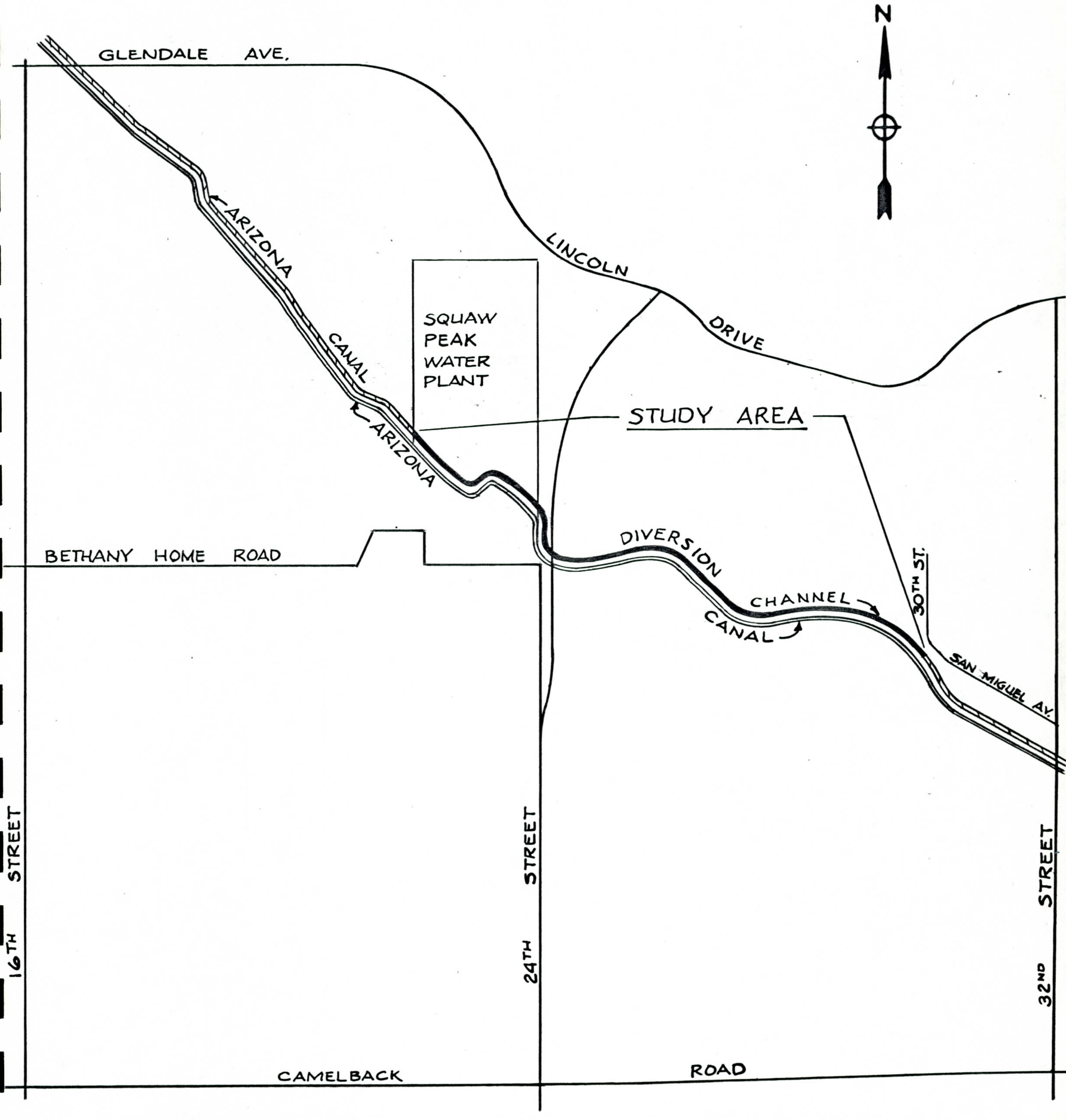
Arizona U. S. A.

BY

SVERDRUP & PARCEL AND ASSOCIATES, Inc.
CONSULTING ENGINEERS
TEMPE, ARIZONA



VICINITY MAP

FOREWORD

This report is submitted in fulfillment of Phase I of the contract for engineering and surveying services, number FCD-77-23, between Maricopa County Flood Control District and Sverdrup & Parcel and Associates, Inc.

The report compiles the structural designs and costs of providing a covered channel for the Arizona Canal Diversion Channel in the vicinity of Arizona Biltmore Estates, Phoenix, Arizona.

SVERDRUP & PARCEL

SHEET NO. 1 OF

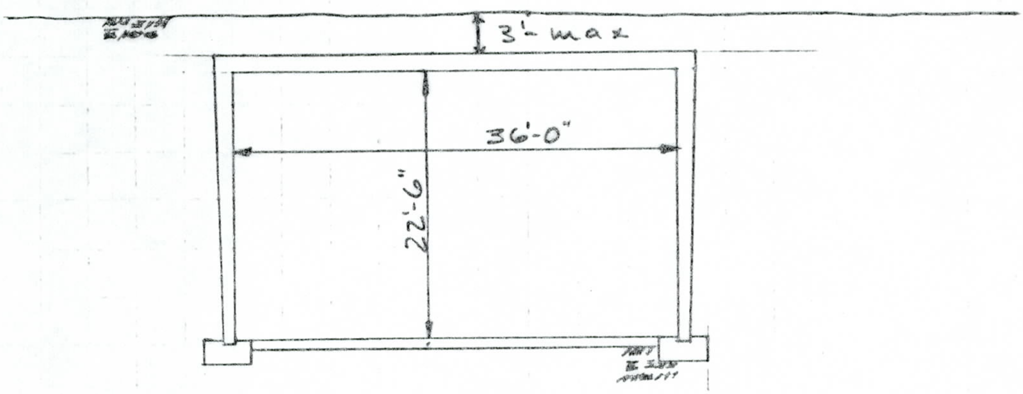
JOB 5672 M.C.F.C.D.

DATE

COMPUTATIONS FOR Covered C.I.P. #2

BY CJB CHKD

1. Typical Section



2. Assumptions

a) $f'_c = 3000$ psi for deck & walls

$f'_c = 3000$ psi for footing block

b) $f'_y = 60{,}000$ psi

c) 3' Earth cover max

d) Drained backfill @ 118 lb/ft^3

e) Eq. Fluid Pressure = 51 lb/ft^3

f) Allow. Soil Pressure = 10 K/ft^2

g) Hinged at footing

h) Neglect impact

18

3. Frame Design

Min slab $t = \frac{S+10}{30} = \frac{36+10}{30} = 1.53'$

Use t = 20"

Leg tapers from 20" to 10"

Distribute wheel loads over "E" width of slab

$E = 4 + 0.06S = 4 + 0.06 \times 36 = 6.2$ ft

Slab span = 36'

Leg span = 22'-6" = 22.5'

Compute Dist. Factors

$$K_{slab} = \frac{4EI}{L} = \frac{4 \times 1/12 \times 12 \times 20^3 \times E}{36 \times 12} = 74E$$

Leg-Large End PCA, Paper # ST 41

$$\frac{\text{min } d}{\text{max } d} = \frac{10}{20} = .5$$

$$K_{L.le.} = \frac{19.9 E I_s}{L} = \frac{19.9 \times 1/12 \times 12 \times 10^3 \times E}{22.5 \times 12} = 73.7E$$

$C_{L.le.} = .29$

$C_{L.se} = .85$

$$K^R_{L.le.} = 73.7E(1 - .29 \times .85) = 55.5E$$

$$D.F._s = \frac{74\cancel{E}}{(55.5+74)\cancel{E}} = 0.57, \quad DF_L = 0.43$$

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JOB 5672 M.C.F.C.D SHEET NO. 3 OF

DATE 12/77

COMPUTATIONS FOR Covered C.I.P. #2 BY CJB CHKD

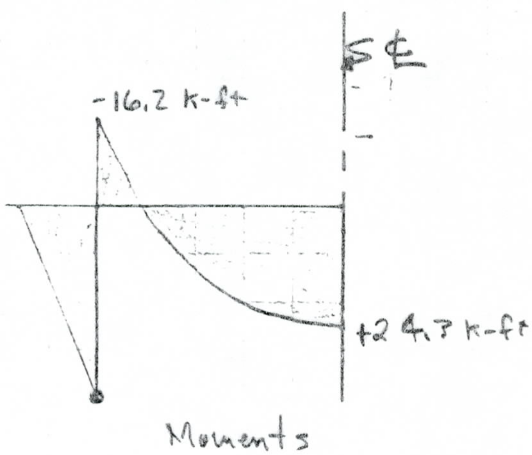
3 Frame Design

Dead Load

Simple Span Moment $= \frac{1}{8} \times \frac{20}{12} \times .15 \times 36^2 = 40.5$ k-ft

FEM $= \frac{w l^2}{12} = \frac{20}{12} \times .15 \times 36^2 \times \frac{1}{12} = 27$ k-ft

.43	.57
	-27.0
+11.6	+15.4
	- 7.7
+3.3	+ 4.4
	-2.2
+1.0	+1.2
	-0.6
0.3	+3
+16.2	-16.2

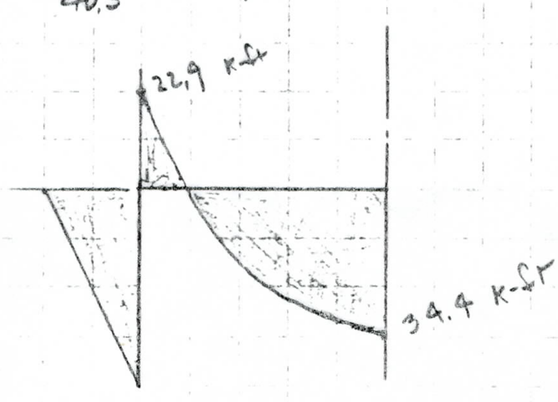


Earth Load - Vertical

Simple Span Moment $= \frac{1}{8} \times 3 \times .118 \times 36^2 = 57.3$ k-ft

M @ heel $= 16.2 \times \frac{57.3}{40.5} = 22.9$ k-ft

M @ midspan $= 24.3 \times \frac{57.3}{40.5} = 34.4$ k-ft



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JOB 5672 M.C.F.C.D.

COMPUTATIONS FOR Covered C.I.P #2

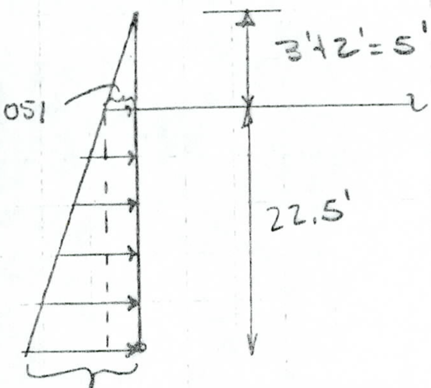
SHEET NO. 4 OF

DATE 12/77

BY CJB CHKD

3 Frame Design

Earth Load - Lateral



Simple Beam Moment $= \frac{wl^2}{8} + Wl \times 0.1283$

$= \frac{0.2 \times 22.5^2}{8} + \frac{1}{2} \times 22.5 \times 1.2 \times 22.5$

$= 51.6$ k-ft

$\frac{I_{min}}{I_{max}} = \frac{10^3}{20^3} = 0.125$

FEM $= 0.165\, W h^2 + 0.167\, W_1 h^2$ See Calif Bridge Design Practice Fig 15-7

$= 0.165 \times .6 \times 22.5^2 + .167 \times .2 \times 22.5^2$

$= 67$ k-ft

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JOB 5672 M.C.F.G.D. SHEET NO. 5 OF

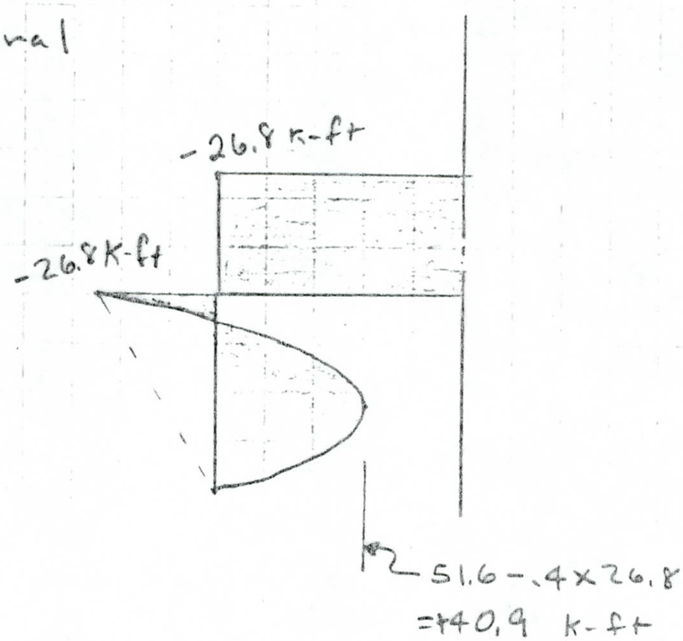
COMPUTATIONS FOR Covered C.I.P. #2 DATE

BY CJB CHKD

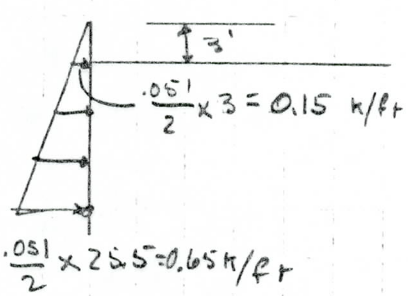
3. Frame Design

Earth Load - Lateral

.43	.57
+67.0	
-28.8	-38.2
	+19.1
-8.2	-10.9
	+5.4
-2.3	-3.1
	+1.6
-0.7	-0.9
	+0.4
-0.2	-0.2
+26.8	-26.8



Earth Load - ½ Lateral (Resisting (+) slab moments)



Simple Span $M = \frac{.15 \times 22.5^2}{8} + \frac{1}{2}\, 22.5 \times .65 \times 22.5 \times .12$

$= 30.6$ k-ft

$M_{@\,slab} = \frac{30.6}{51.6} \times 26.8 = 15.9$ k-ft

$d =$

$.375 \times .85 \times 18.5 = 5.90$

$C = .9 \times .85 \times 3000 \times 5.9 \times 12 = 162$ ←

$d - \frac{a}{2} = 18.5 - \frac{5.9}{2} = 15.5$

~~125~~

$C = \frac{125 \times 12}{15.5}$

24.3
− 13.2
21.6
34.4

669

$d^2 = \frac{66.9}{.193 \times 10} = 18.6$

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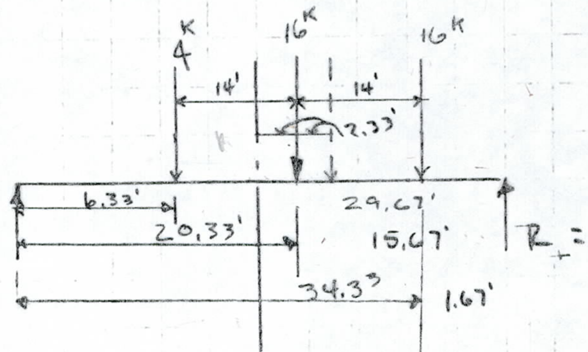
JOB 5672 M.C.F.C.D. SHEET NO. 6 OF

DATE 12/77

COMPUTATIONS FOR Covered C.I.P #2 BY CJB CHKD

3. Frame Design

Live Load HS20-44



$$FEM_L = \frac{Pa^2b}{L^2E} = \left(\frac{4 \times 29.67^2 \times 6.33}{36^2} + \frac{16 \times 15.67^2 \times 20.33}{36^2} + \frac{16 \times 1.67^2 \times 34.33}{36^2}\right) \div 6.$$

$= 12.9$ k-ft

$$FEM_R = \frac{Pab^2}{L^2E} = \left(4 \times 29.67 \times 6.33^2 + 16 \times 15.67 \times 20.33^2 + 16 \times 1.67 \times 34.33^2\right) \div 36^2$$

$= 17.4$ k-ft

.43	.57		.57	.43
	-12.9		+17.4	
+5.5	+7.4		-9.9	-7.5
	-5.0		+3.7	
+2.2	+2.8		-2.1	-1.6
	-1.0		+1.4	
+.4	+.6		-0.8	-0.6
	-0.4		+0.3	
+0.2	+0.2		-0.2	-0.1
+8.3	-8.3		+9.8	-9.8

Simple Span $M = \frac{378.9}{2 \times 6.2} = 30.6$ k-ft

SVERDRUP & PARCEL

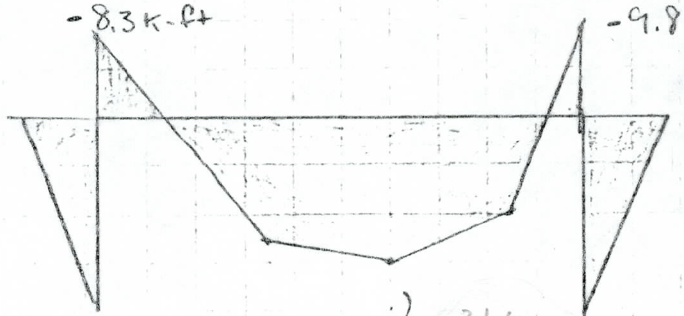
JOB 5672 M.C.F.C.D. SHEET NO. 7 OF

DATE

COMPUTATIONS FOR Covered C.I.P. #2 BY CJB CHKD

3 Frame Design

Live Load HS20-44



31.6

$30.6 - \frac{8.3+9.8}{2} = +21.55$ k-ft

Design Mu's

+Mu @ midspan slab =

13.4

$1.3 \times (24.3 - 15.9 + \frac{5}{3} \times 21.6 + 34.4) = 102.3$ k-ft

-Mu @ heel =

$1.3 \times (16.2 + \frac{5}{3} \times 9.8 + 22.9 + 1.3 \times 26.8) = 117.4$ k-ft

+ Mu @ midspan leg =

$1.3 \times (-.4 \times 16.2 - .4 \times 22.7 + 1.3 \times 40.9) = 48.8$ k-ft

3. Frame Design

Reinf @ midspan slab

$$k_u = \frac{M_u\,12000}{b d^2} = \frac{102.3 \times 12000}{12 \times (20-1.5-.5)^2} = 316$$

$\rho = 0.0063$, $A_s = 12 \times 18 \times .0063 = 1.36\ in^2/ft$

→ Use #7 @ 5" $A_{s\,prov} = \frac{.6}{(\frac{5}{12})} = 1.44\ in^2/ft$

Reinf @ heel

$$k_u = \frac{117.4 \times 12000}{12 \times (20-2-.5)^2} = 383$$

$\rho = 0.0078$, $A_s = 17.5 \times 12 \times .0078 = 1.64\ in^2/ft$

→ Use #8 @ 5" $A_{s\,prov} = \frac{.79}{\frac{5}{12}} = 1.89\ in^2/ft$

Reinf @ mid span leg

$h = \frac{10}{22.5} \times .4 \times 22.5 + 10 = 14$, $d = 18-1.5-.5 = 16$

$k_u = \frac{49.8 \times 12000}{12 \times 16^2} = 190$, $\rho = .0037$

$A_s = 12 \times 16 \times .0037 = 0.71\ in/ft$

→ Use #7 @ 10"

3. Frame Design

Distribution Reinf

$\% = \frac{100}{\sqrt{S}} = \frac{100}{\sqrt{36}} = 17\%$

$A_s = 0.17 \times 1.36 = 0.23 \text{ in}^2/\text{ft}$

→ Use #4 @ 12"

4. Footing Block

DL slab $= \frac{20}{12} \times (36 + \frac{40}{12}) \times .15 = 9.8$ k

DL legs $= (\frac{10}{12} + \frac{20}{12}) \times 22.5 \times .15 = 8.4$ k

E.L. $= 3 \times (36 + \frac{40}{12}) \times 0.118 = 13.9$ k

32.1 k

$R = 32.1 \div 2 = 16$ k, neglect Live Load

Allowable Soil Pressure $= 10^k$

$A = 16/10 = 1.6 \text{ ft}^2/\text{ft}$

Use width = 4', h = 18"

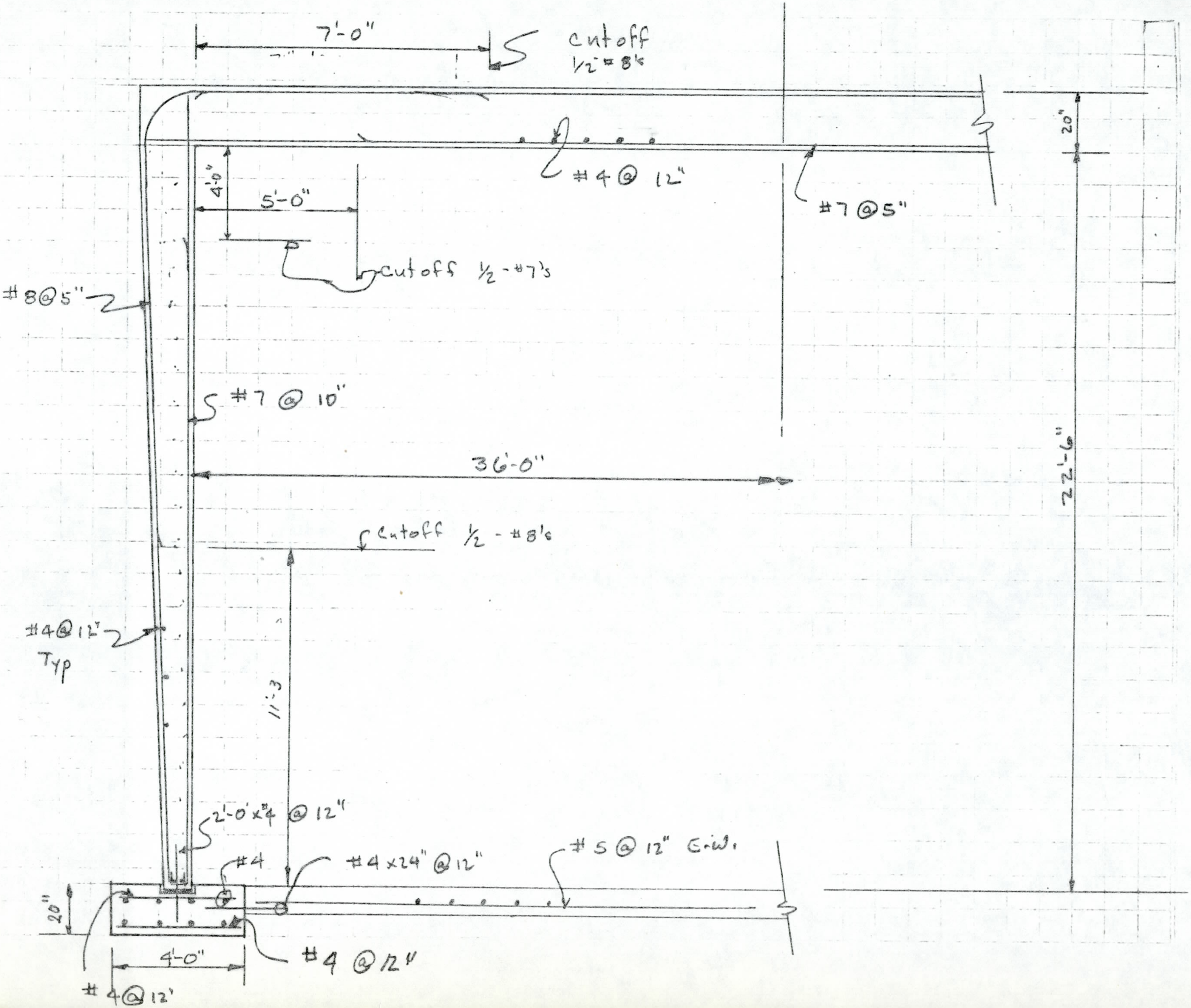
$R_u = 1.3 \times 16 = 21$ k

$M_u = \frac{21}{4} \times (4 - \frac{10}{12})^2 \div 8 = 6.6$ k-ft/ft

$K_u = \frac{M_u\, 12000}{b\, d^2} = \frac{6.6 \times 12000}{12 \times (18-3-.5)^2} = 31$ (6.6 written over struck-out 64.2)

$\rho_{req} = 0.0006 \times 1.33$, $A_s = .0006 \times 1.33 \times 12 \times 14.5 = 0.14 \text{ in}^2/\text{ft}$

Use #4 @ 12"



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JOB 5672 M.C.F.C.D.

COMPUTATIONS FOR Covered C.I.P.

SHEET NO. 10 OF

DATE 12/77

BY CJB CHKD

SUMMARY

This report is the first in a series of two. It presents the results of an engineering and economic study on providing a covered channel over the Arizona Canal Diversion Channel, an open rectangular concrete flood control channel proposed by the Corps of Engineers in the vicinity of the Arizona Biltmore Estates, Phoenix, Arizona. The second report will study various alignments through the study area in an attempt to minimize total project cost.

This report finds that at least two structural systems are possible solutions. A concrete rigid frame, Type V, built by the tilt up method. Cost is $760.00 per linear foot. The second is a long span metal plate arch, Type VII, whose cost is $770.00 per linear foot. These costs compare with $650.00 per linear foot for the open channel proposed by the Corps of Engineers, Type I. Costs quoted are for the structures alone and do not include any incidental costs.

PHASE I REPORT

ARIZONA CANAL DIVERSION CHANNEL STUDY

BILTMORE PROPERTIES AND VICINITY

PREPARED FOR
MARICOPA COUNTY FLOOD CONTROL DISTRICT
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CONSULTING ENGINEERS
TEMPE, ARIZONA

INTRODUCTION

The Arizona Canal Diversion Channel is a flood control project planned jointly by the Los Angeles District Corps of Engineers and the Maricopa County Flood Control District. The purpose of the channel is to provide protection to Phoenix, Glendale and Peoria from storm water runoff from the north. The Channel parallels the north side of the Arizona Canal and flows west from 40th Street to its outlet at Skunk Creek, a distance of approximately 15 miles.

The area of focus begins at canal spillway No. 4, approximately 30th Street, and proceeds through the Arizona Biltmore Estates property, crosses 24th Street and ends at a point just west of the City of Phoenix water treatment plant.

The channel design proposed for this area is a rectangular reinforced concrete lined channel with the approximate dimensions of 36 ft. wide by 22.5 ft. deep. Approximate average flow rate through the area is 8,600 cfs for the standard project flood.

At present there exists a grant of easement from Arizona Biltmore Estates, Inc. in favor of the City of Phoenix. The easement is for the construction of the channel and was made in consideration for the City's rezoning certain Biltmore property. The grant provides for conveying fee title of the easement area to the Maricopa County Flood Control District when and if the channel is constructed.

In addition the grant requires that the engineering and economic feasibility of using a covered channel through the area be investigated. If it is determined that the additional cost of covering the channel is less than 25% of the uncovered cost a covered channel must be used. If the cost is more than 25%, Arizona Biltmore Estates may still require the covered channel by participating in costs that exceed the 25% level.

The Maricopa County Flood Control District retained Sverdrup & Parcel to prepare the study which will be produced in two parts. Phase I presents various covered channel designs and their costs and compares them with the uncovered channel cost. This report is Phase I. Phase II will present three different alignments and the total covered and uncovered costs for each alignment.

METHODOLOGY

Several structural systems were considered and the most promising were selected for preliminary design. The designs were carried only far enough to make an accurate quantity take-off for cost estimating. The first design was for an uncovered "Corps type" open channel. The remaining designs were for covered channels.

The basic assumption made was that all non-structure costs are the same for each type considered. This applied to excavation, sub-drainage systems, etc. The only exceptions were backfill which was assumed to be 3 ft. for all covered structures except Type VII for which backfill was assumed to be 4 ft. and fencing required for open channel.

Design criteria were as follows:

A. Open Channels

1. Equipment surcharge = 2 ft. earth
2. Equivalent fluid pressure = 31 lb/ft^3
3. Unit weight soil = 115 lb/ft^3
4. Allowable soil pressure = 8,000 lb/ft^2

B. Covered Channels

1. Backfill depth = 3 ft. (4' Type VIII)
2. Unit soil weight = 118 lb/ft^3
3. Equivalent fluid pressure = 51 lb/ft^2
4. Loading = HS 20-44
5. Allowable soil pressure = 10,000 lb/ft^2

Assumptions as to soil values were made prior to soils tests after conversation with engineers familiar with the area. Recommended values in soils report were in some instances at slight variance with those assumed. No adjustment was made in the designs for this, the effect being insignificant.

Costs were obtained from the latest estimating guides and from material suppliers. Costs quoted represent structure costs only and represent the total cost for that portion of work including labor, material and contractor overhead and profit. Costs such as excavation and landscaping are not included since they are considered equal for all types.

The open channel proposed by the Corps of Engineers was assumed to require a minimum of 70 ft. of right-of-way. The minimum right-of-way required by all covered channels is assumed to be 40 ft. plus construction easements.

SOIL CONDITIONS

The results of a field investigation indicate the soils are of rock-like hardness and densely cemented. Thus it is anticipated that excavation will be very difficult, however, vertical cut slopes should be possible and this will decrease excavation volume somewhat. Attesting to the dense nature of the soils is the fact that no ground water was encountered during test boring in spite of the close proximity to the Arizona Canal. A complete copy of the soils report is included in the Appendix.

STRUCTURAL SYSTEMS

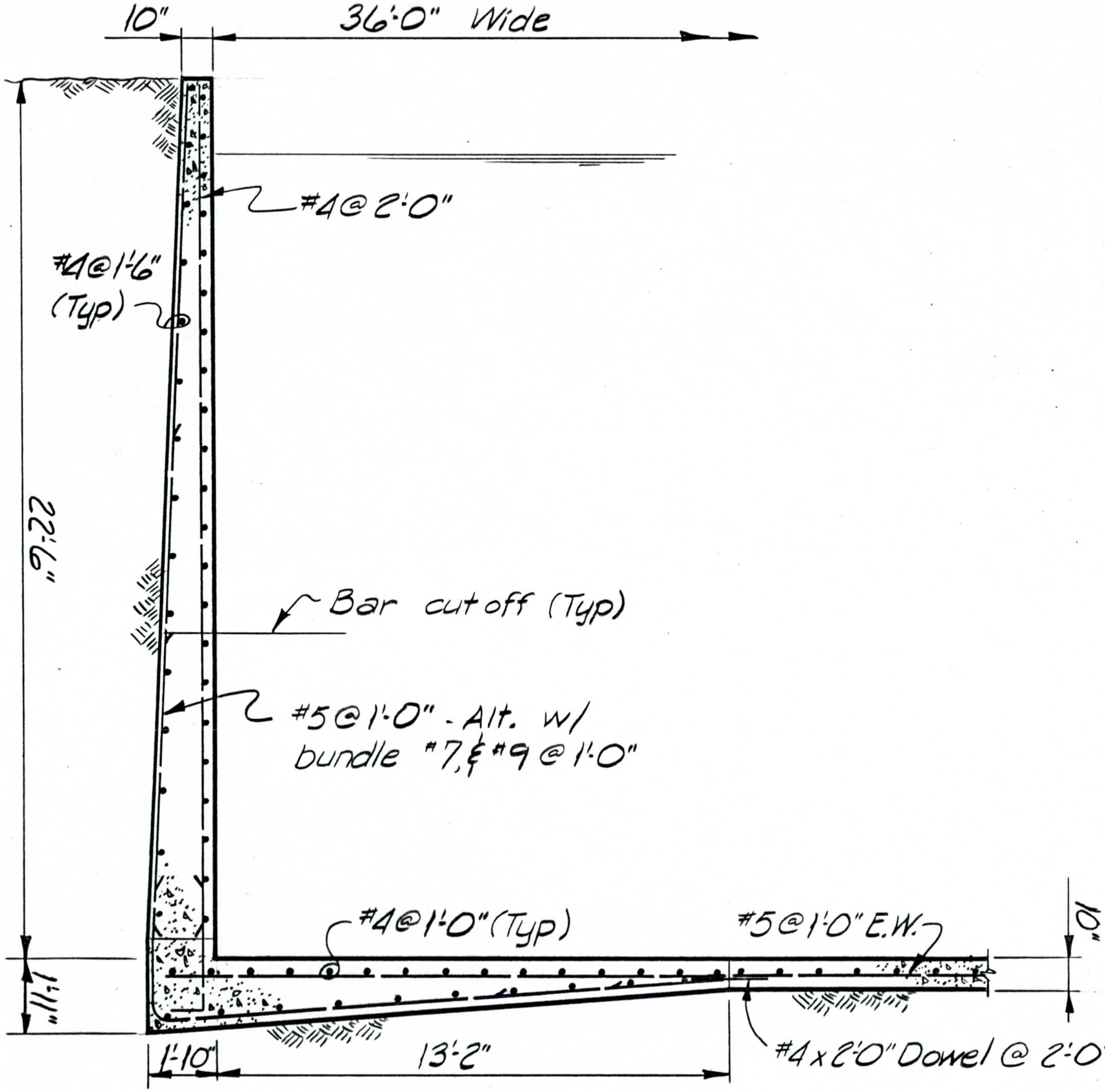
Following is presented a compilation of structural systems selected for detailed study. Their major features and estimated cost per foot of channel are enumerated.

All channel sections considered are rectangular or nearly so. A trapezoidal section was not studied in detail for the following reasons:

1. To carry the same volume of water as a rectangular section the top width of any trapezoidal channel would have to be greater, thus increasing the costs to the District as follows:
   a. right-of-way cost would be greater if an uncovered section is built
   b. super structure cost would be greater if a covered section is built.
2. The Corps of Engineers has, after studying the project, determined that a rectangular channel is the more economical section given the high cost of right-of-way along the project.

A double barrel box was not seriously considered because:

1. The cost savings to be realized in the deck was more than offset by the cost of a middle wall.
2. The tilt-up method of construction could not easily be used.
3. Hydraulic performance of a multiple barrel conduit is inferior to a single barrel conduit.



TYPE I STRUCTURE

Type I Structure

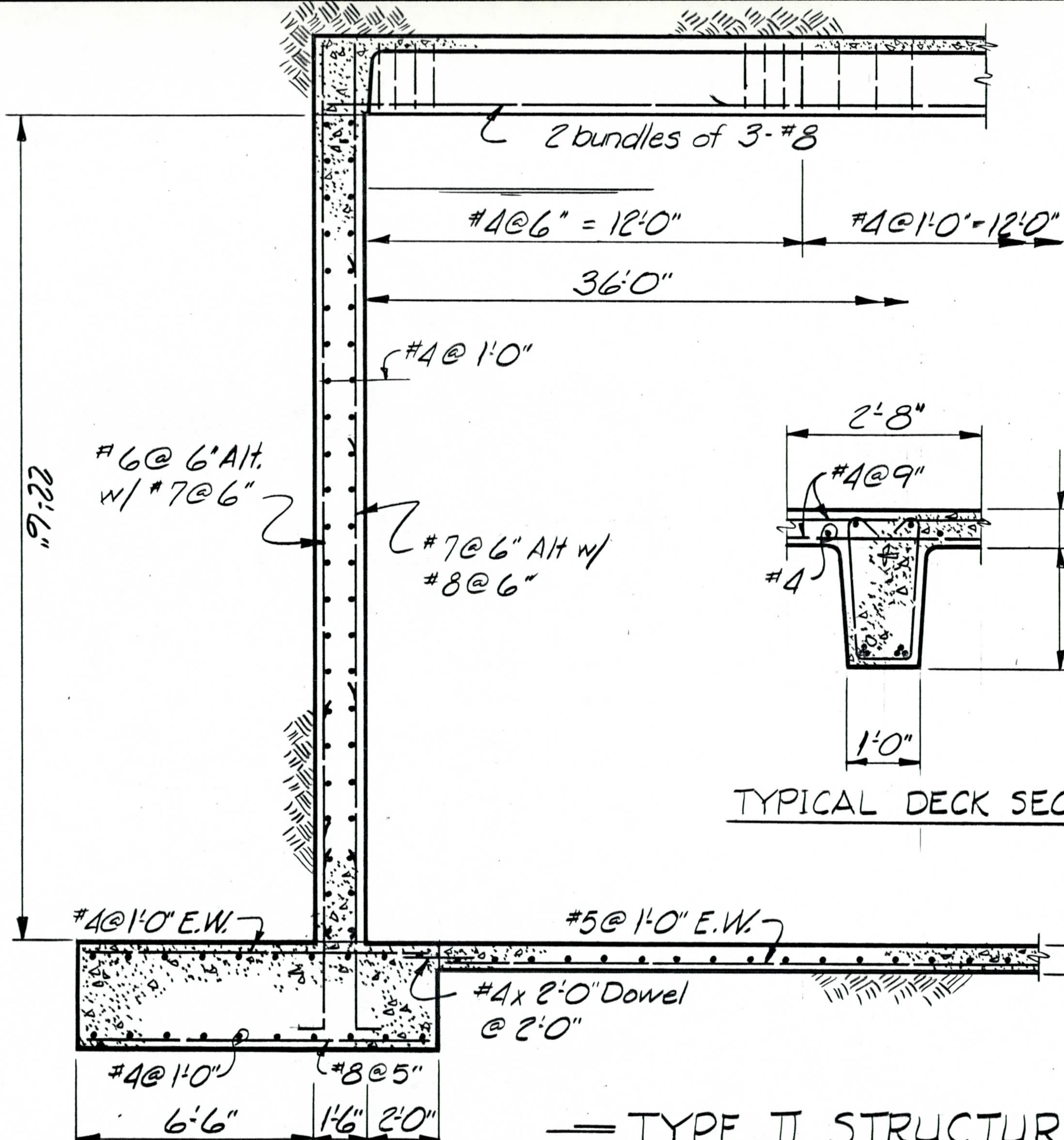
Type I structure is designed as a cantilever retaining wall. In an effort to obtain an accurate basis for cost comparison Type I was designed utilizing the same structure proportions and design stresses as the Corps of Engineers would use.

Construction system was assumed to be conventional cast-in-place concrete. It is realized that the Corps has been experimenting with pre-cast tilt-up elements for channel construction but since this new procedure has not yet been adopted as a standard construction procedure, it was used not for cost estimating Type I. Cost for Type I is estimated at $630/ft. This cost might be reduced as much as 30% if the pre-cast and tilt-up method was used.

Design stresses were:

f'_c = 3000 psi all concrete

fy = 40,000 psi all bars



TYPICAL DECK SECTION

— TYPE II STRUCTURE —

Type II Structure

Type II structure uses a simple span deck supported by continuous vertical walls. The wall to footing connection is considered fixed. Since the foundation material is essentially rock, this assumption seems reasonable.

The construction is all cast-in-place with conventional reinforcing. The deck is formed using standard one-way joist forms. Cost is estimated at $1250/ft.

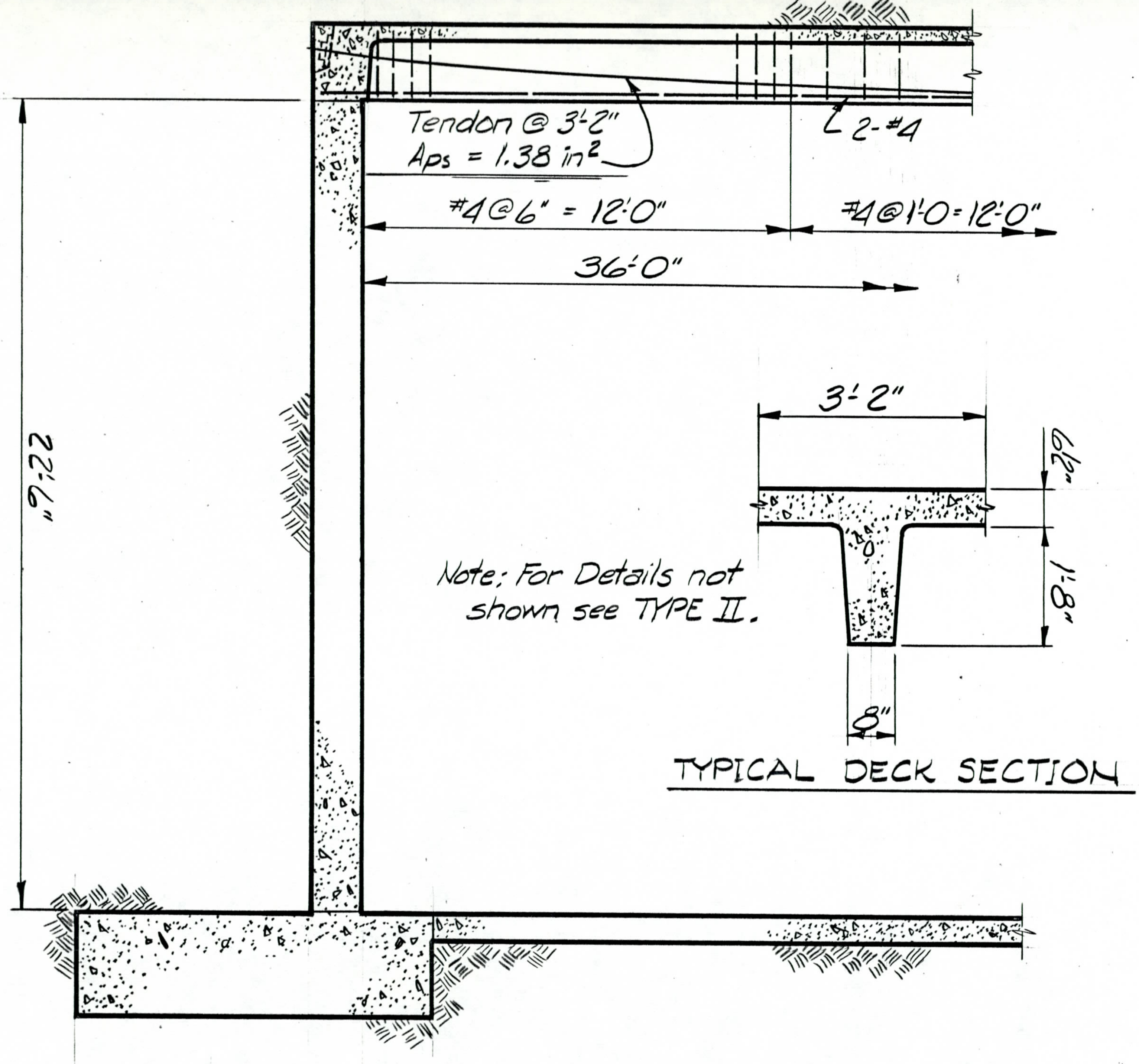
Design stresses were:

f'_c = 4000 psi deck and walls

f'_c = 3000 psi footings and invert

f_y = 40,000 psi #6 and smaller

f_y = 60,000 psi #7 and larger



TYPE III STRUCTURE

Type III Structure

Type III is essentially the same as Type II except post-tensioning is utilized in the deck section. Also, as a result, a slightly lighter deck is possible. However, at $1250 per linear foot the cost is identical to Type II.

Design stresses were:

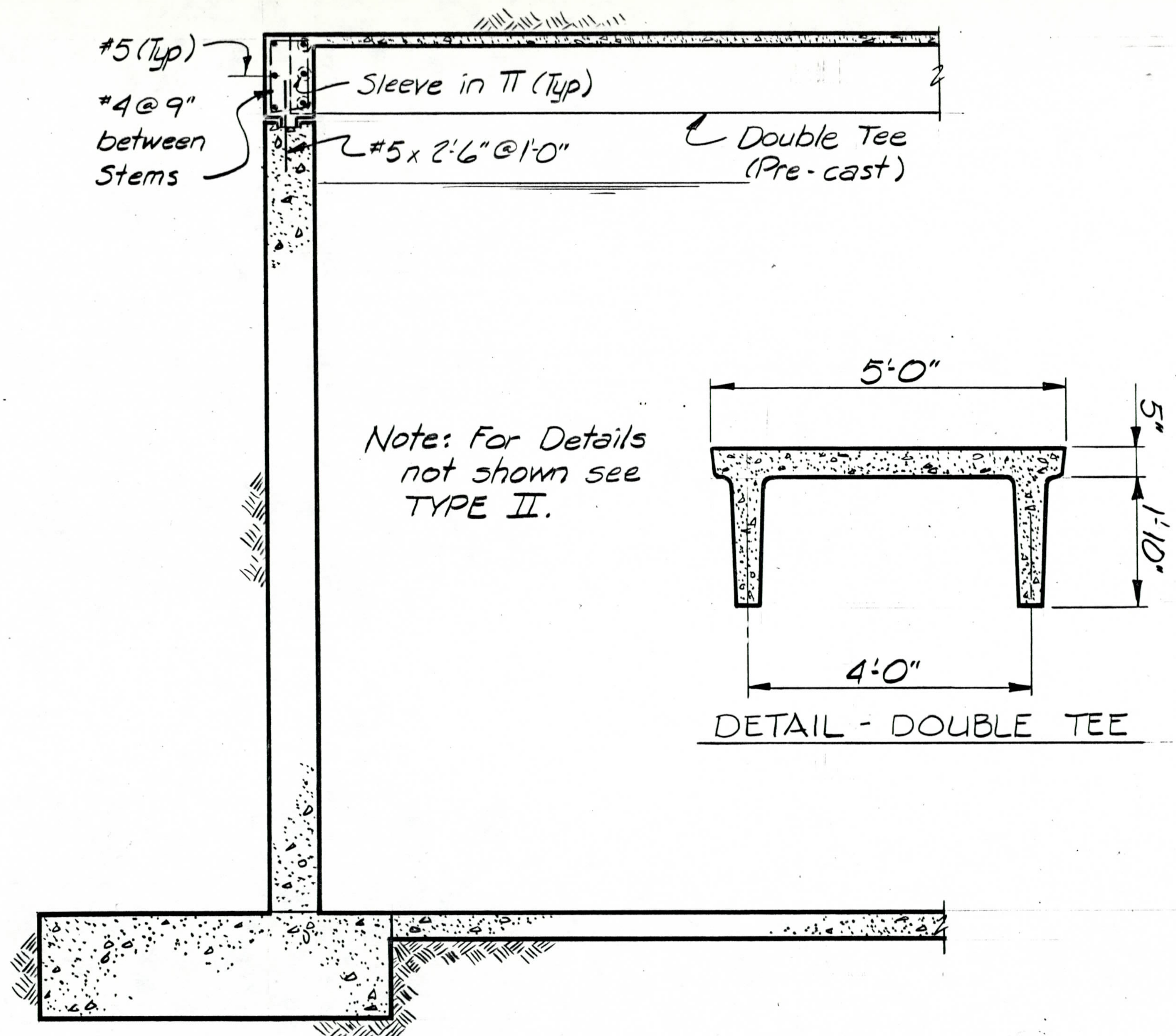
f'_c = 5,000 psi deck

f'_c = 4,000 psi walls

f'_c = 3,000 psi footings and invert

f_y = 60,000 psi all bars

f_{ps} = 270,000 psi post-tensioning tendons



— TYPE IV STRUCTURE —

Type IV Structure

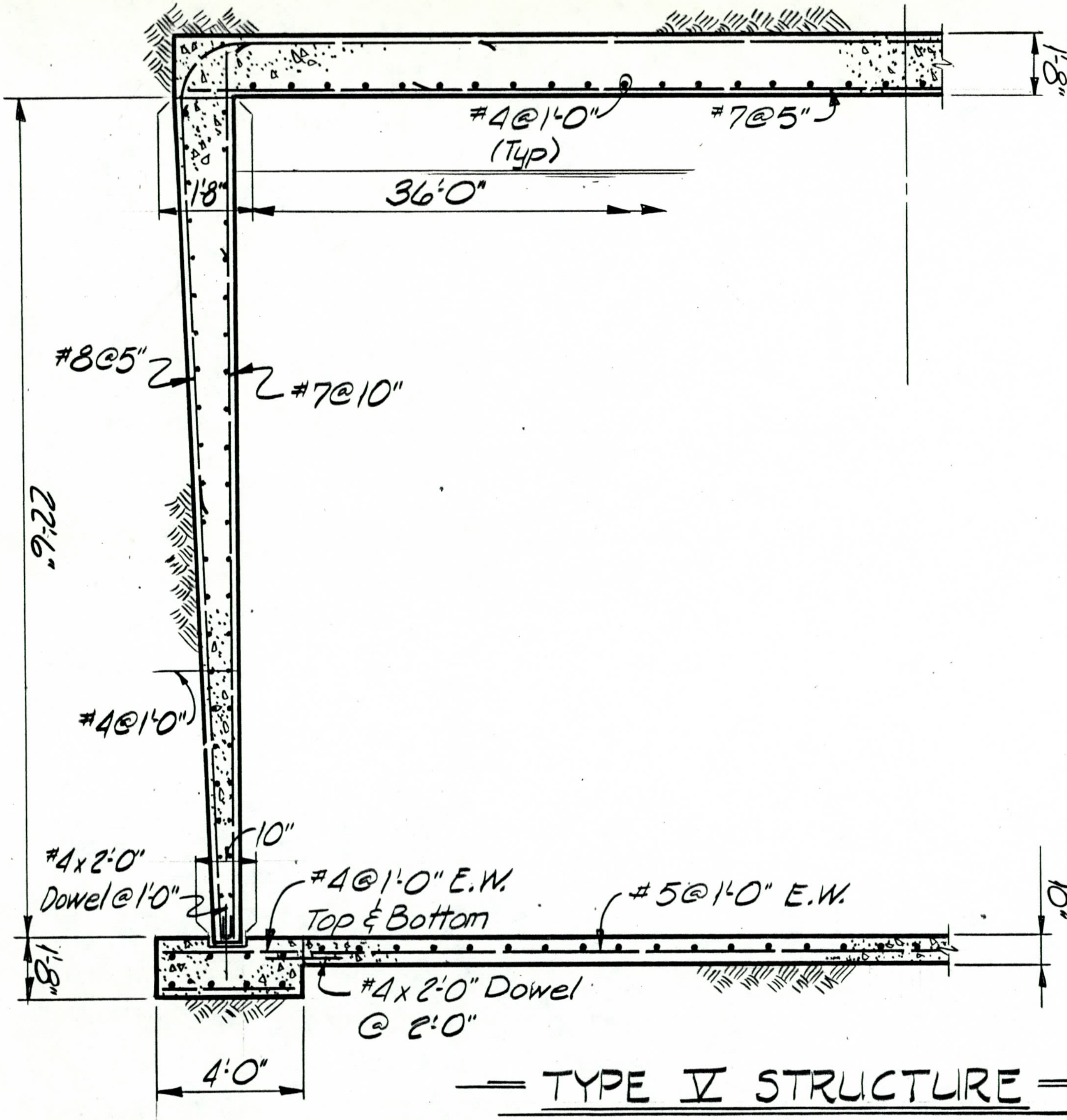
Type IV structure is also similar to Type II with the deck being composed of precast double tee's. The double tees are nominal 24" units modified as shown. They would be cast at a plant and trucked to the site. Cost is estimated to be $1,000 per linear foot.

Design stresses were:

f'_c = 4,000 psi walls

f'_c = 3,000 psi footings and invert

f_y = 60,000 psi all bars



— TYPE V STRUCTURE —

Type V Structure

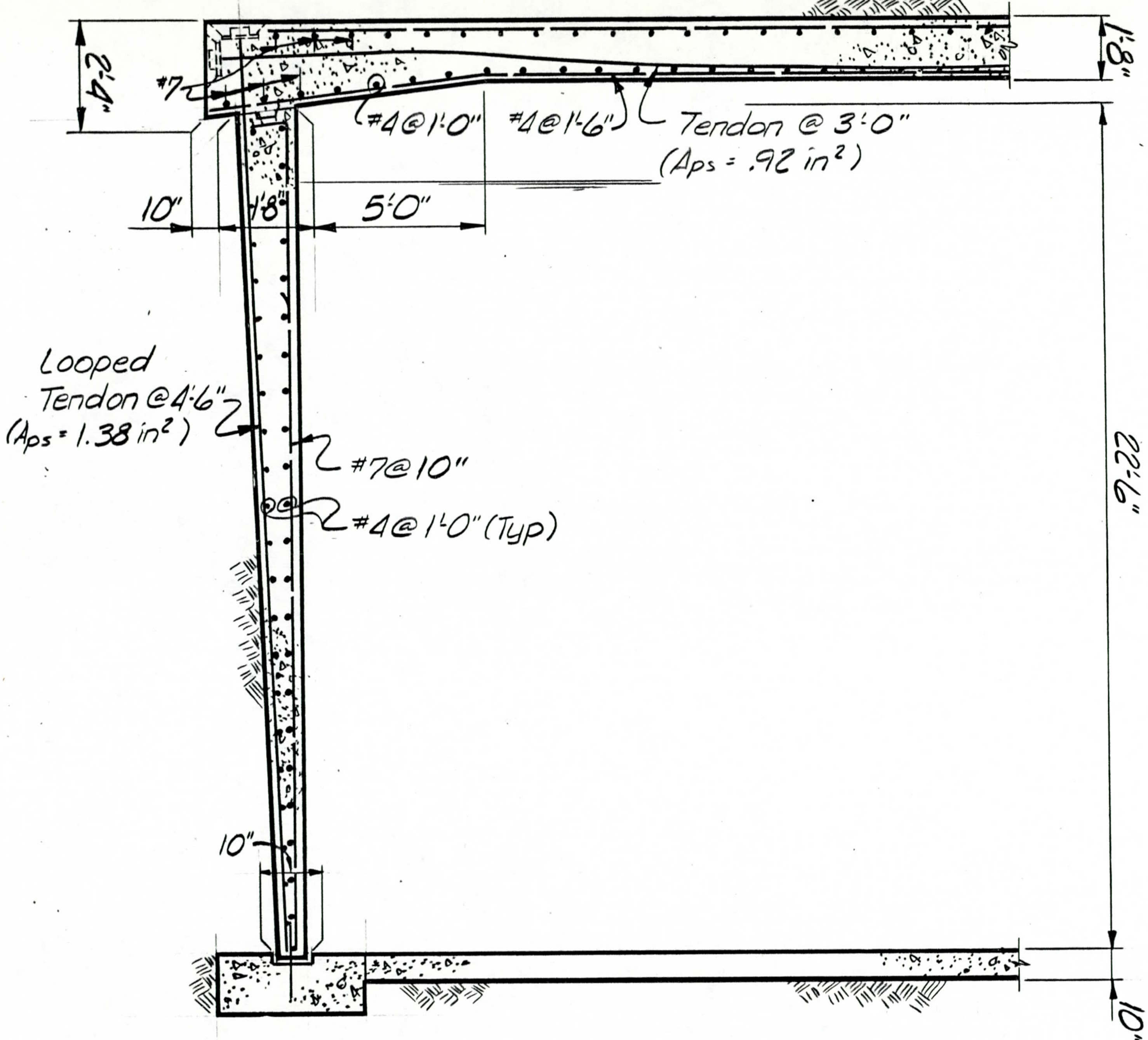
Type V structure acts as a rigid frame with legs pinned at the footing. This permits much smaller footings. The walls are tapered and the deck is solid.

The construction method assumed is that the invert and footing blocks are cast first. Footing blocks are to be spaced on 20 ft. centers. Next the walls are cast on the invert slab. Wall panels 20 ft. in length resulting in a panel weighing about 42 Tons are utilized. After attaining strength, the edge forms are stripped, the panels erected, aligned, and braced on the footing blocks; then the balance of the footings may be poured and the deck cast-in-place in the conventional manner. The cost is estimated at $760 per linear foot. This is a considerable savings over the cost for Types II, III, and IV but is attainable only if the tilt-up method of construction is used.

Design stresses are:

f'_c = 3,000 psi deck, walls, footings, invert

f_y = 60,000 psi all bars



TYPE VI STRUCTURE

Type VI Structure

Type VI structure is the same as Type V except the deck is also cast on the invert slab. The deck is post-tensioned after obtaining strength. The forms are stripped and the deck erected on the walls. The walls and deck are then post-tensioned together. Deck panels may have to be shorter in length than wall panels to keep weight down. Cost is estimated at $750 per linear foot.

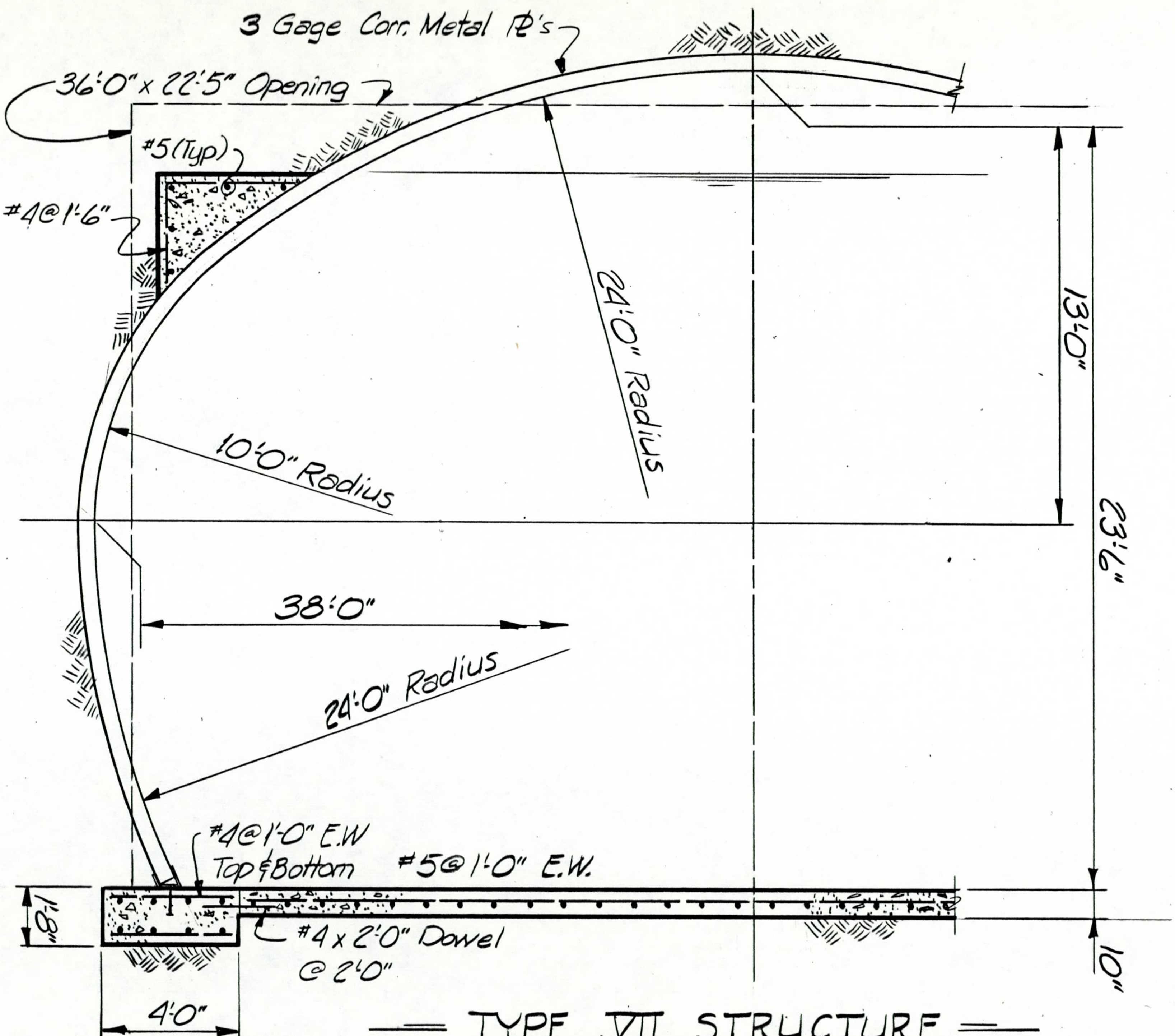
Design stresses were:

f'_c = 5,000 psi deck and walls

f'_c = 3,000 psi footings and inverts

f_y = 60,000 psi all bars

f_{ps} = 270,000 psi post-tensioning tendons



TYPE VII STRUCTURE

Type VII Structure

Type VII structure is a long span metal plate arch. Thrust beams are required along each side to insure arch action. A minimum of 4 ft. of cover is also required for proper performance. Cost of Type VII structure is estimated at $770 per linear foot.

As can be seen from the sketch it is not clear whether the 2 ft. Corps free board requirement is met. Hydraulic performance would have to be evaluated using backwater methods. If the water way opening is inadequate, the next size structure may be used at a cost increase of about 7%.

Type VII is considerably different from the preceding types but the Corps of Engineers has used this type of structure previously. Also any degree of corrosion resistance may be specified.

CONCLUSIONS

The results of this study indicate that the base cost of the Type I or "Corps of Engineers" structure, is $650 per foot. The incremental costs of providing a covered channel ranges from $100 to $120 per ft. or 15% to 18% for Types V through VII.

Structure Types II through IV are clearly uneconomical and should not be considered further.

Structure Type V cost is $760 per ft. The tilt-up method of construction assumed for this study is similar to an experimental method the Corps has had good experience with on the Cucamonga Creek Channel in California. The conventionally reinforced rigid frame is a well proven structural system extensively used in underground applications. For these reasons it is felt that Type V is likely to be acceptable to the Corps.

Structure Type VI cost is $750 per ft.; however, as this is not a clear advantage, Type V is preferred on basis of simplicity.

Structure Type VII cost is $770 per ft., clearly within economic range. Long span metal arch has been used by the Corps at Shenango River Lake, Pennsylvania. Since the water way opening is not rectangular, hydraulic performance would have to be evaluated to verify the equivalent size. The only feature of Type VII that could cause problems during final design is that 4 ft. of cover is required over the arch.

Right-of-way required by all covered channels is approximately 30 ft. less than that required by the Type I structure.

APPENDIX I

SOILS REPORT

THOMAS-HARTIG & ASSOCIATES, INC.
SOIL & FOUNDATION ENGINEERS

Sverdrup & Parcel & Associates, Inc.
1650 W. Alameda Drive
Tempe, Arizona

6 January 1978

Attention: Chris Baker

Project: Arizona Canal Diversion Channel Study
Biltmore Properties
Phoenix, Arizona

Project No. 78-027

In accordance with your authorization soil and foundation engineering services have been provided along the route of the proposed Diversion Channel. The purpose of these services is to determine subsoil conditions, active soil pressure, soil unit weight, allowable bearing pressure, excavation conditions and suggested cut slopes. It is understood that the proposed covered channel will be concrete, it will be approximately 3/4 mile in length, and its base will be approximately 23 feet below the existing grade.

Test borings were drilled at the six locations as specified by you. Boring locations are shown on the attached site plan. As disclosed by the test borings, and as illustrated on the attached boring logs, shallow granular deposits 1 to 6 feet thick were found to overly highly cemented silty sand and rock fragments(breccia). These highly cemented materials are of rock-like hardness. Only two of the borings could be extended to the planned 23 foot depth. The other borings were described as refusing the auger drilling between depths of 10 to 17 feet. Shist bedrock is known to underly the breccia in this area, and the possibility exists that it could be encountered within the zone of proposed excavation.

Due to the very dense, granular, cemented, rock-like nature of the subsoils, undisturbed sampling for direct shear testing was neither appropriate nor possible. Based on the results of the penetration testing and soil profiles, the following recommendations are presented.

TOM W. THOMAS, P.E. • HARRY E. HARTIG, P.E.
1210 W. ALAMEDA STREET, SUITE 127 • TEMPE, AZ. 85282 • (602) 894-2159

Friction Angle: 40 degrees

Unit Weight: 130 pcf

Active Soil Pressure: 28 psf/ft

Allowable Bearing Pressure: If foundations are required below the base of the channel for support of structural elements, these footings need be founded only at minimum construction depths. An allowable bearing pressure of 8000 psf is recommended for bearing on the highly cemented sand, gravel and rock fragments (breccia).

Excavation-Cut Slopes: It is anticipated that excavation into the breccia will be very difficult. Large dozers with ripping teeth may be effective in some areas, however in other areas jackhammering or blasting may be required. Some slight sloughing or ravelling could be expected if weakly cemented zones were encountered in the breccia, however it is our opinion that temporary cut slopes will stand vertical in this material.

If there are any questions please do not hesitate to contact us.

Respectfully submitted,

THOMAS-HARTIG & ASSOCIATES, INC.

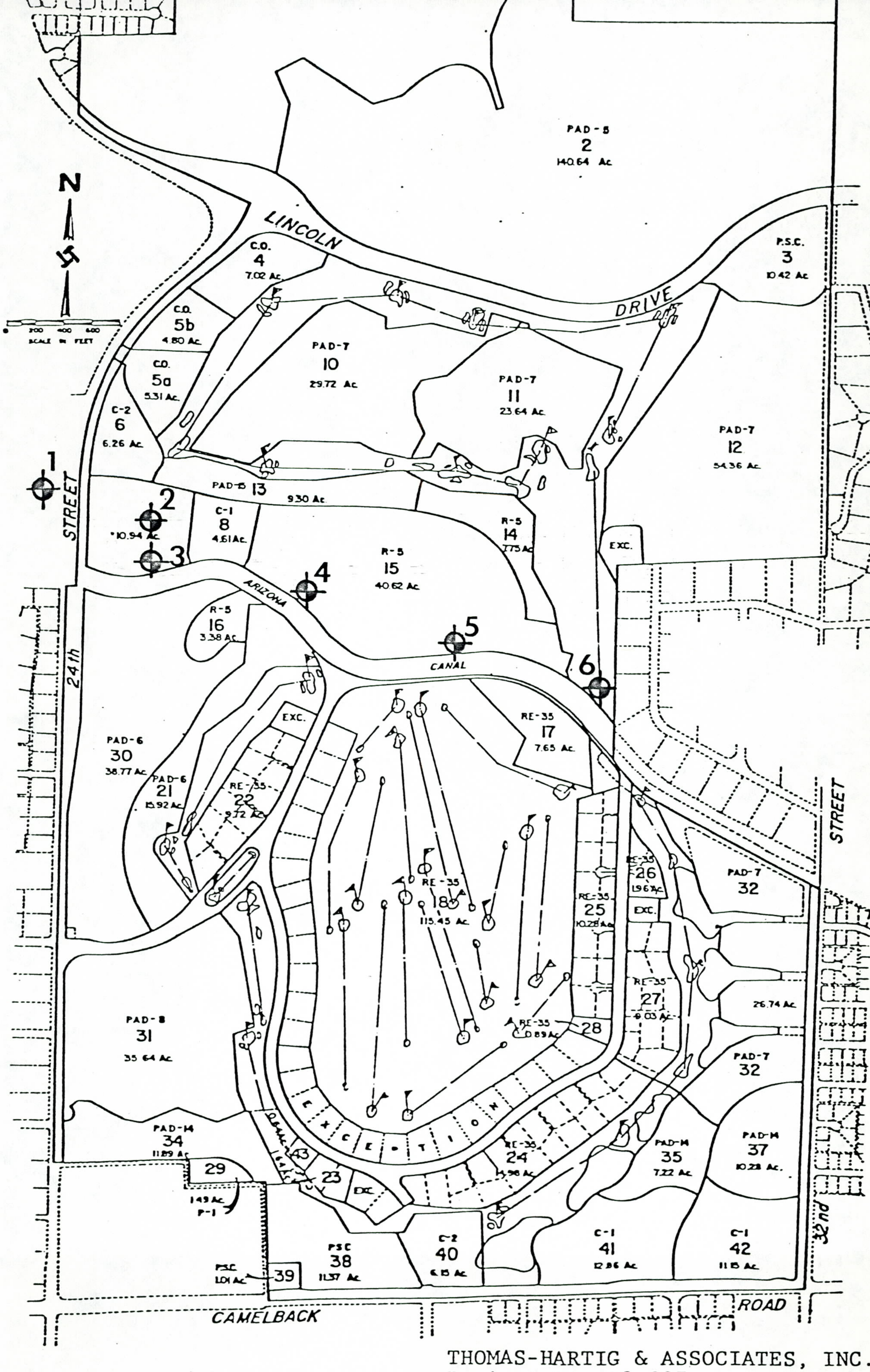
By: [signature] Reviewed by: [signature]
Harry E. Hartig, P.E. Tom W. Thomas, P.E.

Registered Professional Engineer (Civil) Certificate No. 7641 Harry E. Hartig Date Signed 1/6/78 Arizona, U.S.A.

Registered Professional Engineer Certificate No. 5979 Tom W. Thomas Date Signed 1/6/78 Arizona, U.S.A.

/bls

Copies to: Addressee (3)



THOMAS-HARTIG & ASSOCIATES, INC.
Project No. 78-027

LEGEND

SOIL CLASSIFICATION ASTM: D2487

COARSE-GRAINED SOIL

MORE THAN 50% LARGER THAN 200 SIEVE SIZE

Symbol	Letter	DESCRIPTION	MAJOR DIVISIONS
	GW	WELL-GRADED GRAVELS OR GRAVEL-SAND MIXTURES, LESS THAN 5% - 200 FINES	GRAVELS More than half of coarse fraction is larger than No. 4 sieve size.
	GP	POORLY-GRADED GRAVELS OR GRAVEL-SAND MIXTURES, LESS THAN 5% - 200 FINES	
	GM	SILTY GRAVELS, GRAVEL-SAND-SILT MIXTURES, MORE THAN 12% - 200 FINES	
	GC	CLAYEY GRAVELS, GRAVEL-SAND-CLAY MIXTURES, MORE THAN 12% - 200 FINES	
	SW	WELL-GRADED SANDS OR GRAVELLY SANDS, LESS THAN 5% - 200 FINES	SANDS More than half of coarse fraction is smaller than No. 4 sieve size.
	SP	POORLY-GRADED SANDS OR GRAVELLY SANDS, LESS THAN 5% - 200 FINES	
	SM	SILTY SANDS, SAND-SILT MIXTURES MORE THAN 12% - 200 FINES	
	SC	CLAYEY SANDS, SAND-CLAY MIXTURES MORE THAN 12% - 200 FINES	

FINE-GRAINED SOIL

MORE THAN 50% SMALLER THAN 200 SIEVE SIZE

Symbol	Letter	DESCRIPTION	MAJOR DIVISIONS
	ML	INORGANIC SILTS AND VERY FINE SANDS, ROCK FLOUR, SILTY OR CLAYEY FINE SANDS OR CLAYEY SILTS WITH SLIGHT PLASTICITY	SILTS AND CLAYS Liquid limit less than 50
	CL	INORGANIC CLAYS OF LOW TO MEDIUM PLASTICITY, GRAVELLY CLAYS, SANDY CLAYS, SILTY CLAYS, LEAN CLAYS	
	OL	ORGANIC SILTS AND ORGANIC SILT-CLAYS OF LOW PLASTICITY	
	MH	INORGANIC SILTS, MICACEOUS OR DIATOMACEOUS FINE SANDY OR SILTY SOILS, ELASTIC SILTS	SILTS AND CLAYS Liquid limit greater than 50
	CH	INORGANIC CLAYS OF HIGH PLASTICITY, FAT CLAYS	
	OH	ORGANIC CLAYS OF MEDIUM TO HIGH PLASTICITY, ORGANIC SILTS	
	PT	PEAT AND OTHER HIGHLY ORGANIC SOILS	

log denotes visual approximation unless accompanied by mechanical analysis and Atterberg limits.

GRAIN SIZES

U.S. STANDARD SERIES SIEVE — CLEAR SQUARE SIEVE OPENINGS

	200	50	16	4	3/4"	3"	6"
SILTS & CLAYS DISTINGUISHED ON BASIS OF PLASTICITY	SAND			GRAVEL		COBBLES	BOULDERS
	FINE	MEDIUM	COARSE	FINE	COARSE		

MOISTURE CONDITION (INCREASING MOISTURE ——→)

DRY — SLIGHTLY DAMP — DAMP (PL) — MOIST — VERY MOIST — WET (SATURATED) (LL)

DEFINITIONS

Penetration Resistance — Blows per foot using 'A' rod and 140 lb. hammer with 30 inch free fall unless otherwise noted.

N Standard Penetration Resistance (ASTM:D1586), 2.0 inch O.D. split barrel sampler.

C Continuous Penetration Resistance, 2.0 inch O.D. Bull Nose.

R Penetration Resistance, 2.42 inch I.D. Ring Sampler

Sample Type

R - Ring T - Shelby Tube S - Standard Split Barrel B - Block
G - Grab C - Cutting V - Vertical Face Cut

CONSISTENCY			RELATIVE DENSITY	
CLAYS & SILTS	BLOWS/FOOT*	STRENGTH ‡	SANDS & GRAVELS	BLOWS/FOOT*
VERY SOFT	0-2	0-¼	VERY LOOSE	0-4
SOFT	2-4	¼-½	LOOSE	4-10
FIRM	4-8	½-1	MEDIUM DENSE	10-30
STIFF	8-16	1-2	DENSE	30-50
VERY STIFF	16-32	2-4	VERY DENSE	OVER 50
HARD	OVER 32	OVER 4		

* Number of blows of 140 pound hammer falling 30 inches to drive a 2 inch O.D. (1-3/8 inch I.D.) split spoon (ASTM D-1586).
‡ Unconfined compressive strength in tons/sq ft. Read from a pocket penetrometer.

SOIL BORING LOG

NO. 1 ELEV: SIZE OF HOLE: 4" FIELD ENGR: JT DATE: 1/5/78

DEPTH FT	PENETRATION RESISTANCE BLOWS/FT C	N	SAMPLE TYPE	DRY DENSITY PCF	MOISTURE CONTENT	DESCRIPTION	SOIL CLASSIFICATION	GRADATION WELL	MED	POOR	GRAIN SHAPE ANGULAR	SUBANGULAR	ROUNDED	SUBROUNDED	RELATIVE DENSITY LOW	MEDIUM	HIGH	PLASTICITY NONE	LOW	MEDIUM	HIGH	CONSISTENCY SOFT	FIRM	STIFF	VERY STIFF	HARD	CEMENTATION NONE	WEAK	MEDIUM	STRONG
1	55			high	sli	Sand, Gravel & Rock	GP			X	X						X	X	X								X			
2	25/1"				damp	Fragments, grey-brown																								
3																														
4																														
5																														
6																														
7				high	sli	Breccia, highly	Rock-like condition																							
8					damp	cemented silty sand																								
9						and rock fragments,																								
10						light brown																								
1																														
2																														
3																														
4																														
5																														
6						Auger refusal at 13'																								
7						No ground water																								
8																														
9																														
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PROJECT NO. 78-027

SOIL BORING LOG

NO. 2 ELEV: SIZE OF HOLE: 4" FIELD ENGR: JT DATE: 1/5/78

DEPTH FT	PENETRATION RESISTANCE BLOWS/FT C	PENETRATION RESISTANCE BLOWS/FT N	SAMPLE TYPE	DRY DENSITY PCF	MOISTURE CONTENT	DESCRIPTION	SOIL CLASSIFICATION	GRADATION WELL	GRADATION MED	GRADATION POOR	GRAIN SHAPE ANGULAR	GRAIN SHAPE SUBANGULAR	GRAIN SHAPE ROUNDED	GRAIN SHAPE SUBROUNDED	RELATIVE DENSITY LOW	RELATIVE DENSITY MEDIUM	RELATIVE DENSITY HIGH	PLASTICITY NONE	PLASTICITY LOW	PLASTICITY MEDIUM	PLASTICITY HIGH	CONSISTENCY SOFT	CONSISTENCY FIRM	CONSISTENCY STIFF	CONSISTENCY VERY STIFF	CONSISTENCY HARD	CEMENTATION NONE	CEMENTATION WEAK	CEMENTATION MEDIUM	CEMENTATION STRONG
1	68			high	sli	Sand, Gravel & Rock	GP			X	X						X	X	X								X			
2	25/0"				damp	Fragments, grey-brown																								
3						Breccia, highly cemented		Rock-like condition																						
4						silty sand and rock																								
5						fragments, light brown																								
6	25/0"																													
7																														
8																														
9																														
10	30/½"																													
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3																														
4						Auger refusal at 12'																								
5						No ground water																								
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PROJECT NO. 78-027

SOIL BORING LOG

NO. 3 ELEV: SIZE OF HOLE: 4" FIELD ENGR: JT DATE: 1/5/78

Depth FT	Penetration Resistance Blows/FT C	Penetration Resistance Blows/FT N	Sample Type	Dry Density PCF	Moisture Content	Description	Soil Classification	Gradation Well	Gradation Med	Gradation Poor	Grain Shape Angular	Grain Shape Subangular	Grain Shape Rounded	Grain Shape Subrounded	Relative Density Low	Relative Density Medium	Relative Density High	Plasticity None	Plasticity Low	Plasticity Medium	Plasticity High	Consistency Soft	Consistency Firm	Consistency Stiff	Consistency Very Stiff	Consistency Hard	Cementation None	Cementation Weak	Cementation Medium	Cementation Strong
1	100/10"			high	sli	Sand, Gravel & Rock	GP			X	X						X	X	X								X			
2					damp	Fragments, grey-brown																								
3				high	sli	Breccia, highly cemented		Rock-like condition																						
4					damp	silty sand and rock																								
5						fragments, light brown																								
6																														
7																														
8																														
9																														
10	25/1"																													
1																														
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3																														
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8																														
9						Auger refusal at 17'																								
20						No ground water																								
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PROJECT NO. 78-027

SOIL BORING LOG

NO. 4 ELEV: SIZE OF HOLE: 4" FIELD ENGR: JT DATE: 1/5/78

DEPTH FT	PENETRATION RESISTANCE BLOWS/FT		SAMPLE TYPE	DRY DENSITY PCF	MOISTURE CONTENT	DESCRIPTION	SOIL CLASSIFICATION	GRADATION			GRAIN SHAPE				RELATIVE DENSITY			PLASTICITY				CONSISTENCY					CEMENTATION			
	C	N						WELL	MED	POOR	ANGULAR	SUBANGULAR	ROUNDED	SUBROUNDED	LOW	MEDIUM	HIGH	NONE	LOW	MEDIUM	HIGH	SOFT	FIRM	STIFF	VERY STIFF	HARD	NONE	WEAK	MEDIUM	STRONG
1	100/6"			high	sli	Sand, Gravel & Rock	GP			X	X						X	X	X								X			
2					damp	Fragments, grey-brown																								
3				high	sli	Breccia, highly cemented	Rock-like condition																							
4					damp	silty sand and rock																								
5						fragments, light brown																								
6																														
7																														
8																														
9	50/0"																													
10																														
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3																														
4																														
5						Stopped augering at 23'																								
6						No ground water																								
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SOIL BORING LOG

NO. 5 ELEV: SIZE OF HOLE: 4" FIELD ENGR: JT DATE: 1/5/78

DEPTH FT	PENETRATION RESISTANCE BLOWS/FT. C	PENETRATION RESISTANCE BLOWS/FT. N	SAMPLE TYPE	DRY DENSITY PCF	MOISTURE CONTENT	DESCRIPTION	SOIL CLASSIFICATION	GRADATION: WELL	GRADATION: MED	GRADATION: POOR	GRAIN SHAPE: ANGULAR	GRAIN SHAPE: SUBANGULAR	GRAIN SHAPE: ROUNDED	GRAIN SHAPE: SUBROUNDED	RELATIVE DENSITY: LOW	RELATIVE DENSITY: MEDIUM	RELATIVE DENSITY: HIGH	PLASTICITY: NONE	PLASTICITY: LOW	PLASTICITY: MEDIUM	PLASTICITY: HIGH	CONSISTENCY: SOFT	CONSISTENCY: FIRM	CONSISTENCY: STIFF	CONSISTENCY: VERY STIFF	CONSISTENCY: HARD	CEMENTATION: NONE	CEMENTATION: WEAK	CEMENTATION: MEDIUM	CEMENTATION: STRONG
1	92			high	sli	Sand, Gravel & Rock	GP			X	X						X	X	X								X			
2	58				damp	Fragments, grey-brown																								
3	46																													
4	100/8'																													
5				high	sli	Breccia, highly cemented		Rock-like condition																						
6					damp	silty sand and rock																								
7						fragments, light brown																								
8																														
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10	50/0'																													
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8						cementation decreasing																								
9					damp	below 17 feet																								
20																														
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5						Stopped augering at 23'																								
6						No ground water																								
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SOIL BORING LOG

NO. 6 ELEV: SIZE OF HOLE: 4" FIELD ENGR: JT DATE: 1/5/78

DEPTH FT	PENETRATION RESISTANCE BLOWS/FT. C	N	SAMPLE TYPE	DRY DENSITY PCF	MOISTURE CONTENT	DESCRIPTION	SOIL CLASSIFICATION	GRADATION WELL	MED	POOR	GRAIN SHAPE ANGULAR	SUBANGULAR	ROUNDED	SUBROUNDED	RELATIVE DENSITY LOW	MEDIUM	HIGH	PLASTICITY NONE	LOW	MEDIUM	HIGH	CONSISTENCY SOFT	FIRM	STIFF	VERY STIFF	HARD	CEMENTATION NONE	WEAK	MEDIUM	STRONG
1	26			high	sli	Sand, Gravel & Rock	GP			X	X						X	X	X								X			
2	50/2"				damp	Fragments, grey-brown																								
3																														
4						Breccia, highly cemented					Rock-like condition																			
5						silty sand and rock																								
6				high	sli	fragments, light brown																								
7					damp																									
8																														
9																														
10	25/0"																													
1																														
2																														
3						Auger refusal at 10'																								
4						No ground water																								
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APPENDIX II

SUMMARY OF QUANTITIES & COSTS

SUMMARY OF QUANTITIES & COSTS

ITEM	QUANTITY PER FT.	UNIT COST	TOTAL COST PER FT.
Type I Structure			
3,000 psi Concrete	4.05 CY	$115/CY	$ 466*
Reinf., Grade 40	463 lb.	.35/lb	162
Fencing			20
			$ 650**
Type II Structure			
3,000 psi Concrete	3.21 CY	$ 55/CY	$ 176
4,000 psi Concrete	4.45 CY	140/CY	623
Reinf., Grade 60	1182 lb	.37/lb	437
Additional Backfill	5 CY	2/CY	10
			$1,250
Type III Structure			
3,000 psi Concrete	3.21 CY	$ 55/CY	$ 176
4,000 psi Concrete	2.50 CY	141/CY	352
5,000 psi	1.57	167/CY	262
Reinf., Grade 60	992 lb	.38/lb	377
Post-tensioning, Grade, 270	60 lb	1.20	72
Added Backfill	5/CY	2/CY	10
			$1,250
Type IV Structure			
3,000 psi Concrete	3.21 CY	$ 55/CY	$ 176
4,000 psi Concrete	2.72 CY	140/CY	381
Reinf. Grade 60	827 lb	.33/lb	274
Precast Deck	37.5 $ft.^2$	4.30/S.F.	161
Added Backfill	5 CY	2/CY	10
			$1,000
Type V Structure			
3,000 psi Concrete	6 CY	$ 70/CY	$ 420
Reinf. Grade 60	950 lb	.35/lb	330
Additional Rack	5 CY	2/CY	10
			$ 760

* Extensions rounded to nearest whole dollar

** Totals rounded to nearest 10 dollars

ITEM	QUANTITY PER FT.	UNIT COST	TOTAL COST PER FT.
Type VI Structure			
3,000 psi Concrete	1.5 CY	$ 60/CY	$ 90
5,000 psi Concrete	4.84 CY	80/CY	387
Reinf. Grade 60	381 lb	.38/lb	145
Post-tensioning, Grade 270	96 lb	1.20/lb	114
Additional Backfill	5 CY	2/CY	10
			$ 750
Type VII Structure			
3,000 psi Concrete	2.21 CY	$ 70/CY	$ 155
Reinf., Grade 50	107 lb	.41/lb	44
3 Ga. Meta Arch Plates			550
Additional Backfill	9 CY/ft	2/ft	18
			$ 770