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SURFACE WATER RUNOFF CONTROL
INVESTIGATION AND ALTERNATIVES STUDY
FOR COTTER CANON CITY MILL SITE

1.0 INTRODUCTION AND DESIGN CRITERIA

A surface water runoff control investigation and alternatives study was conducted by Wahler Associates for the Cotter Canon City mill site in accordance with Item 3(3)d/9-18-80 in Cotter's December 19, 1980 submittal to the Department. Specifically, this investigation includes an assessment of the topics outlined below for the purpose of addressing what measures are conceptually desirable to divert naturally occuring runoff around the mill site, and to significantly reduce the water in the SCS resevoir that has heretofore been pumped back to the mill site.

i) Channel relocation/flow diversion;

ii) temporary storage of runoff in impoundments and conveyance of stored uncontaminated runoff to natural channels away from the Cotter property and;

iii) combination of i) and ii) above.

This engineering report presents results of adequacy checks on existing surface water runoff control facilities and proposed systems for additional runoff control at the Canon City mill site. At the outset of this engineering study, Cotter provided the following information to Wahler Associates for review work and additional engineering design:

- Topographic map of the mill site and vicinity;

- Survey information, including cross sections and profiles of the existing diversion trench and elevation-capacity curve for the existing diversion catch dam. The original design bases for these structures are discussed in the Supplement to Design Report-Cotter Uranium-Vanadium Tailings Impoundment (W. A. Wahler & Associates and Mountain States Mineral Enterprises, Inc., January, 1979).

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2.0 DESIGN PROCEDURES

2.1 SOIL CONSERVATION SERVICE (SCS) GRAPHICAL PROCEDURE FOR PEAK DISCHARGE DETERMINATION

The Soil Conservation Service (SCS) graphical procedure for peak discharge determination is commonly used as an approximation of the detailed hydrograph analysis, SCS-TR-20 "Computer Program for Project Formulation--Hydrology," (U. S. Department of Agriculture, Soil Conservation Service, 1975). The method considers watershed runoff time of concentration, a 24-hour design storm rainfall amount, associated rainfall losses, and total peak discharge. Site-specific information is required.

2.1.1 Watershed Delineation

The local topography surrounding the Cotter mill site is shown on Figure 1. Designated watershed areas, including ephemeral streams in the watersheds, are also indicated. The watershed drainage areas are presented in Table 1.

2.1.2 WATERSHED RUNOFF TIME OF CONCENTRATION*

Watershed runoff times of concentration were computed using the following equation (U. S. Department of Agriculture, Soil Conservation Service, 1972):

$$t_c = \left[\frac{11.9L^3}{H}\right]^{0.385}$$

*Watershed runoff time of concentration is defined as the time required for a particle of water to travel from the most hydraulically distant point of the watershed to the design point.

where:

t_c = runoff time of concentration, in hours;

L = length of longest watercourse in watershed, in miles; and

H = elevation difference between watershed divide and design point, in feet.

L and H were measured from Figure 1.

2.1.3 Design Storm Rainfall Depth

The 100-year rainfall for a duration of 24 hours was estimated from the NOAA Atlas 2, Volume III-Colorado (U. S. Department of Commerce, 1973) to be 3.8 inches.

2.1.4 Rainfall Excess

A rainfall excess value (i.e., runoff amount) was determined based on the design storm rainfall depth and appropriate SCS runoff curve number. A runoff curve number represents the relative value of the watershed hydrologic soil-cover complex as a direct runoff producer. A greater amount of direct runoff is expected from a storm for a watershed with a higher runoff curve number than from one with a lower number. Based on the soils and land-use information available for the Cotter mill site, a runoff curve number of 85 was estimated for the watershed areas shown on Figure 1. This curve number is commonly considered for local thunderstorm conditions. The rainfall excess value for the design storm amount is estimated at 2.28 inches.

2.1.5 Peak Flood Discharge Determination

Peak discharges for the watershed areas (Figure 1) were estimated using the unit discharge values shown on Figure 2 and the relationship:

$$q_p = q_p' AQ$$

where:

q_p' = peak discharge in cubic feet per second per square mile per inch of runoff ($ft^3/sec/mi^2/in$), obtained by using Figure 2 (a curve relating watershed runoff time of concentration, t_c, to the peak discharge, q_p');

A = watershed area, in square miles;

Q = runoff volume, in inches; and

q_p = peak discharge from watershed, in cfs.

Since all streams at the Cotter mill site are characteristically ephemeral, base flow (or ground water discharge) was considered negligible as compared to maximum surface runoff rates. The computed peak flows and associated total runoff volumes for each watershed area are summarized in Table 1.

2.2 OPEN CHANNEL DESIGN PROCEDURE

The Manning equation for steady, uniform flow conditions was utilized to design and evaluate the adequacy of various open channel configurations. The equation used is commonly expressed as (Henderson, F. M., 1966):

$$Q = \frac{1.486}{n} AR^{2/3} S^{1/2}$$

where:

A = cross-sectional area of flow, in square feet;

R = hydraulic radius (defined as the area of flow divided by the wetted perimeter of flow), in feet;

S = slope of the energy gradient in the direction of flow, in feet per foot (ft/ft);

n = hydraulic roughness coefficient, dimensionless; and

Q = discharge, in cfs.

Based on published data on roughness characteristics of natural channels (Barnes, Harry H., Jr., 1967), excavated channels in earth (Haan, C. T., and Barfield, B. J., 1978), and related field experience, the hydraulic roughness coefficient, n, for earth channels at the Cotter mill site is estimated as 0.025.

2.3 PUMP SYSTEM ALTERNATIVES DESIGN PROCEDURE

Pump system alternatives were designed using the following procedure and equations:

1) Given a flow quantity, Q, in gallons per minute (gpm), a standard pipe size was selected so that flow velocities would range from four to six feet per second.

2) For new steel pipe in the range of design flow velocities and for the range in Reynolds Number* considered, the friction factor, f (dimensionless), was estimated at 0.015.

3) The pipe head loss, due to friction, h_ℓ , was computed using the Darcy-Weisbach equation (Olson, Reuben M., 1966):

$$h_\ell = f \frac{L}{D} \frac{v^2}{2g}$$

*The Reynolds Number is the inertia force divided by the viscous force, commonly expressed in terms of viscosity of fluid and hydraulic diameter (for pipe flow, the hydraulic diameter equals the pipe diameter).

where:

L = pipe length, in feet;

D = pipe diameter, in feet;

V = average pipe flow velocity, in feet per second;

g = 32.2 feet per second squared; and

f = friction factor (dimensionless).

3) Pumping head, h_p, was computed using the Bernoulli Equation (Olson, Reuben M., 1966), which can be simplified to:

$$h_p = (Z_2 - Z_1) + h_\ell$$

where:

Z_1 = pump elevation, in feet;

Z_2 = greatest pipe elevation, in feet; and

h_ℓ is as defined above.

4) The required pump horsepower was computed from the relationship (Olson, Reuben M., 1966):

$$HP = \frac{Q \gamma_w h_p}{e(550)}$$

where:

γ_w = specific weight of water, equal to 62.4 pounds per cubic foot;

e = pump efficiency, assumed to be 0.70; and other terms are as previously defined.

3.0 CAPACITY OF EXISTING RUNOFF CONTROL FACILITIES

3.1 DIVERSION TRENCH

Cotter provided Wahler Associates with survey information on the existing diversion trench, including a channel profile (Figure 3) and two cross sections (Figure 4). The alignment of the existing trench is shown on Figure 1. The channel capacities at cross sections F-F' and G-G' (Figure 4) were estimated using the Manning equation to be about 3080 and 2150 cfs, respectively. The estimated design discharge for Watershed Area 6 (Table 1) is 172 cfs; therefore, the capacity of the existing diversion trench is more than adequate to convey the 100-year design flood.

3.2 DIVERSION CATCH DAM

Cotter also provided Wahler Associates with survey information on the storage capacity versus elevation relationship for the existing diversion catch dam. This relationship is shown on Figure 5. This dam has the capacity to store the estimated 100-year flood runoff volume from Watershed Areas 6 and 7 which totals 36.9 acre-feet (Table 1). Storage capacity behind the existing dam with the spillway invert elevation at 5630 feet (mean sea level datum*) is 60 acre-feet. Accordingly, the existing diversion catch dam and reservoir is more than adequate to store the anticipated 100-year flood runoff from the contributing drainage area.

4.0 ALTERNATIVE RUNOFF CONTROL FACILITIES

During a 100-year storm event, over 270 acre-feet of uncontrolled surface runoff could potentially cross the Cotter mill site and drain to the existing SCS reservoir. Also, about 18 acre-feet of additional storm runoff could enter the main and secondary tailings impoundments without the runoff control facilities discussed herein. As designed, the proposed runoff control facilities could divert or store most of the presently uncontrolled surface runoff from the watersheds upstream from the Cotter mill site. These facilities could also:

- Extend the useful life of the existing main and secondary tailings impoundments; and

*All elevations referenced herein are to mean sea level datum.

- o Reduce the amount of contaminated water storage required on site.

It is noteworthy that a reported daily storm rainfall amount of over four inches (i.e., in excess of the 100-year storm) occurred on April 24, 1980 (Colorado Climate Center, January 6, 1981). Consequently, the large amount of rainfall runoff associated with this storm accounted for a large portion of the pump back water volume measured since that time. The volume of pump back water reported for the period March 6, 1980 through September 30, 1980 is 481 acre-feet (Cotter Corporation, October, 1980). The relative amounts of surface runoff and local ground water discharge to the SCS reservoir, however, are unknown.

4.1 WEST FORK SAND CREEK DIVERSION TRENCH

The West Fork of Sand Creek can be intercepted before entering the Cotter property and diverted to an adjacent drainage (refer to Figure 1). For the conceptual design, a trapezoidal diversion channel configuration has been considered. The channel would be about 3300 feet long and cross a portion of the Shadow Hills Golf Course to below the golf course buildings. The point of diversion would begin at about elevation 5615 feet. The end of the channel would have a bottom elevation at about 5550 feet. Once runoff is conveyed past the golf course buildings, it could be subject to controlled discharge to the natural drainage. The channel slope would be at 0.02 ft/ft. Also, it would have a 2-foot bottom width, 2:1 side slopes, and depth of five feet. The typical channel cross section is shown on Figure 6. The estimated channel flow capacity is 2930 cfs. This exceeds the combined peak runoff rate of 2350 cfs noted in Table 1 for Watershed Areas 1, 2, 3, and 4. Approximately 18,300 cubic yards of excavation would be required to construct this channel. Also, culverts would be required at road crossings.

Constraints to this diversion scheme include questions of water rights, non-land ownership, and regulatory review (i.e., Colorado State Engineer Office) regarding channel diversion and routing of runoff to an adjacent drainage.

4.2 WEST DIVERSION TRENCH EXTENSION

The existing diversion trench can be extended over 2900 feet in the direction as shown on Figure 1, in order to intercept runoff from Watershed Area 5. The inlet elevation of the channel would be approximately at 5690 feet. This channel would grade into the bed elevation of the inlet end of the existing trench at approximately elevation 5675 feet. The conceptual design of the trench extension with a trapezoidal channel configuration and slope at 0.005 ft/ft, 4-foot bottom width, 2:1 side slopes, and 3-foot depth, is shown on Figure 7. The estimated channel flow capacity is 181 cfs which is greater than the estimated peak runoff rate of 146 cfs from Watershed Area 5 noted in Table 1. Approximately 3220 cubic yards of excavation would be required to construct this channel. The estimated discharge capacity of the existing diversion trench at cross section G-G' is 2150 cfs, which is still more than adequate to handle the estimated combined design peak discharg of 318 cfs from Watershed Areas 5 and 6.

Construction of the west diversion trench extension could potentially increase the amount of runoff behind the diversion catch dam from 36.9 to 45.8 acre-feet for a 100-year storm. This volume, however, would still be less than the total available storage capacity of 60 acre-feet behind the dam below the invert of the emergency spillway.

4.3 EAST DIVERSION TRENCH

An east diversion trench can be constructed as shown on Figure 1 to intercept runoff from Watershed Area 5' and convey it to either an adjacent drainage or to below the SCS dam (Figure 1).

For an east diversion trench scheme to the adjacent drainage, the trench would end near the east abutment of the main tailings impoundment. For its conceptual design, a 5500-foot long trapezoidal channel is considered. The channel inlet would begin at about elevation 5668 feet and the outlet end would be at about elevation 5630 feet at the section line. It would slope at about 0.0025 ft/ft for most of its length, have a 4-foot bottom width with 2:1 side slopes, and have depths of two and three feet at the head and outlet ends, respectively (Figure 8). The estimated maximum channel flow capacity is about 128 cfs which would exceed the estimated 100-year peak rate of discharge of 85 cfs from Watershed Area 5' (Table 1). Approximately 4700 cubic yards of excavation would be required to construct this channel.

For the conceptual design, a 10,700-foot long trapezoidal channel is considered to below the SCS dam. The channel inlet would begin at about elevation 5668 feet and the outlet end would be at about elevation 5500 feet. It would slope at about 0.0025 ft/ft above the main tailings impoundment and be approximately 0.027 ft/ft from about the east abutment of the main impoundment to below the SCS dam, have a 4-foot bottom width with 2:1 side slopes, and have depths of two and three feet at the head and outlet ends, respectively. Channel construction would be similar to that shown on Figure 8. The estimated maximum channel flow capacity near the outlet end is about 420 cfs which would exceed the estimated 100-year peak rate of discharge of 85 cfs from Watershed Area 5' (Table 1) routed to below the SCS dam and combined with other local inflow. The estimated peak discharge at the outlet end would total about 150 cfs. Approximately 10,500 cubic yards of excavation would be required to construct this channel.

On the basis of excavated soil volume only, the east diversion trench alternative to the adjacent drainage is favored over the diversion trench to below the SCS dam. However, both alternatives could present water rights issues.

4.4 DIVERSION CATCH DAM PUMP FACILITIES

In addition to evaporative and infiltration losses, at least a portion of runoff stored behind the diversion catch dam associated with a 100-year storm or other significant precipitation event should be evacuated in a short time span in order to provide for adequate surcharge capacity should a similar storm occur within a few days after the first one. Construction of a low-level outlet works or an underdrain to evacuate the runoff in storage does not appear feasible at this time for engineering, environmental, and/or related regulatory considerations. However, pump arrangements can be utilized to serve any of the above options. For illustrative purposes, three pump arrangements and runoff evacuation periods from one to ten days to convey uncontaminated runoff away from the mill site were evaluated. The total volume of runoff estimated for the 100-year design storm event only is considered, however. Runoff from lesser storms or average annual runoff is not addressed. Results of analyses for the three alternatives are presented in the following paragraph and in Tables 2A, 2B, and 2C.

For Alternative A, runoff water would be pumped through about 9100 feet of pipeline to a discharge point below the SCS dam. For Alternative B, water would be pumped through about 2000 feet of pipeline to a discharge point in an adjacent watershed (Figure 1). For Alternative C, water would be pumped into the head end of an east diversion trench which is conceptually designed to convey 100-year peak discharges to either below the SCS dam or to an adjacent drainage. Runoff evacuation periods, pump requirements, and pipe sizes are summarized in Tables 2A, 2B, and 2C. It should be noted that large pumps would not be necessary to purchase if they could be rented as needed.

4.5 DIVERSION CATCH DAM RAISE

The existing diversion catch dam can be raised either within the next year and thus provide for additional design storage capacity in the main tailings impoundment, or coincident with the final raise for the main impoundment in order to provide for adequate future upstream runoff control. The final raise for the main tailings impoundment will be constructed to elevation 5655 feet (W. A. Wahler & Associates and Mountain States Mineral Enterprises, Inc., 1978).

For the conceptual design, the crest length of the raised embankment for the diversion catch dam would be about 1100 feet, the crest elevation would be at about 5670 feet, and the maximum embankment height would be about 70 feet. Side slopes would be 2:1. Available storage capacity behind the dam as estimated from Figure 5 would be greater than 160 acre-feet.

An emergency spillway for the raised dam, with spillway crest elevation at 5668 feet, would be designed to discharge into the east diversion trench. Approximately 135,000 cubic yards of earth fill would be required to raise the existing diversion catch dam to elevation 5670 feet.

A pumping scheme could be utilized to evacuate storm water runoff from behind the raised diversion catch dam into the east diversion trench. Also, a portion of the existing diversion trench would have to be relocated to be able to convey flood runoff above the main tailings impoundment to the diversion catch dam.

4.6 WEST FORK SAND CREEK UPPER STORAGE DAM

As shown on Figure 1, a storage dam is depicted in the location where, conceptually, it can be constructed across the ephemeral stream in Watershed Area 1. This dam, coupled with the West Fork Sand Creek upper diversion trenches (Section 4.7), could serve to collect most of the runoff from the upper portion of the Sand Creek drainage. For the conceptual design, the crest length of the earth dam would be about 700 feet, the crest elevation would be at 5755 feet, and the maximum embankment height would be 55 feet. Side slopes would be 2:1. Storage capacity behind this structure as shown on Figure 9 would be approximately 290 acre-feet. Approximately 55,000 cubic yards of earth fill would be required to construct the dam. A low-level outlet works and emergency spillway system would be included. Constraints to the construction of this facility, however, are questions about land ownership, land access, and water rights.

4.7 WEST FORK SAND CREEK UPPER DIVERSION TRENCHES

Diversion trenches could be constructed as shown on Figure 1 to intercept runoff from Watershed Areas 2 and 3 and convey it to the West Fork Sand Creek Upper Storage Dam. A trapezoidal channel configuration 900 feet long is considered for the conceptual design from point A to point B (Figure 1). The channel bed elevation along this reach would start at about 5760 feet and end at about 5755 feet. As shown on Figure 10, the channel would slope at 0.005 ft/ft, have a 10-foot bottom width, 2:1 side slopes, and be four feet deep. The estimated channel flow capacity is 570 cfs which is greater than the estimated 100-year design peak discharge of 400 cfs from Watershed Area 3 (Table 1). Approximately 2400 cubic yards of excavation would be required to construct this channel segment.

Another trapezoidal channel, also 900 feet long, is considered from point B to point C (Figure 1). The channel bed elevation along this reach would begin at about 5755 feet and end at about 5750 feet. As shown on Figure 10, this channel would slope at 0.005 ft/ft, have a 15-foot bottom width with 2:1 side slopes, and be six feet deep. The estimated channel flow capacity is 1680 cfs which is greater than the estimated combined 100-year design peak discharge of 1240 cfs from Watershed Areas 2 and 3 (Table 1). Approximately 5400 cubic yards of excavation would be required to construct this channel segment.

4.8 LOWER MILL SITE INTERCEPTOR TRENCH AND STORAGE FACILITY

An interceptor trench can be constructed along the northern boundary of the Cotter property to intercept surface runoff from the mill site. Water in the trench can be collected at a storage facility located as shown on Figure 1 and then pumped into the main tailings impoundment for permanent storage. This would serve to reduce the distance of pumping some contaminated runoff water from the SCS reservoir to the main tailings impoundment and complement the larger and deeper interceptor trenches already in use at the mill site. The contributing drainage area above the trench and storage facility is approximately 0.12 square mile and if one inch of runoff is assumed for the conceptual design, then the storage facility should be sized for 6.4 acre-feet of capacity.

For the conceptual design, a 4300-foot rectangular interceptor trench five feet wide and five feet deep is sufficient to collect surface and shallow subsurface flow. About 3980 cubic yards of excavation would be required to construct this trench. The low dam for the storage facility would have a 700-foot crest length, a 10-foot maximum height, and 2:1 side slopes. It would require approximately 1800 cubic yards of earth fill to construct. No additional pumps would be required since Cotter could move existing pumps from the SCS dam for use at this facility.

5.0 ENGINEERING COST ESTIMATE

Estimated capital costs for earthwork and equipment related to surface water runoff control for the Cotter mill site are summarized in the following tables and figures. Table 3 presents a summary of the estimated earthwork costs for all feasible runoff control facilities. Fifty cents ($0.50) per cubic yard is the estimated excavation cost for the diversion trenches and $2.00 per cubic yard is the estimated placement cost for earth fill material. These costs are based on 1980 dollars. Tables 4A, 4B, and 4C present summaries of the estimated installed pipe costs and pump costs for pumping Alternatives A, B, and C, respectively. These costs are also based on 1980 dollars. The total estimated costs for these alternatives are also presented graphically on Figure 11.

6.0 RECOMMENDATIONS

The following alternatives related to surface water runoff control for the Cotter mill site are presented in order of probable capital cost effectiveness, however, without consideration to land acquisition costs or to water rights issues, if applicable. Also, the results of surface water monitoring for quality above the Cotter property should be adequately assessed (i.e., after one year of data collection) prior to implementation of a runoff control alternative(s) not on site.

Surface water runoff can be effectively controlled for the Cotter mill site for the design storm criteria established herein. The proposed runoff control facilities could:

1) Extend the useful lives of the existing main and secondary tailings impoundments; and

2) Reduce the amount of contaminated water storage required on site.

6.1 CONSTRUCT THE WEST FORK SAND CREEK DIVERSION TRENCH

The total estimated cost for constructing this diversion trench is $ 9150. This trench would divert most of the runoff from the Sand Creek drainage away from the Cotter mill site and SCS reservoir. Land aquisition would be necessary. Also, there is a potential conflict with existing water rights since surface waters would be diverted to an adjacent drainage (Figure 1).

6.2 CONSTRUCT THE WEST DIVERSION TRENCH EXTENSION

The total estimated construction cost for this diversion trench is $1610. This trench would divert a considerable amount of runoff away from the secondary tailings impoundment. No significant problems are anticipated with this trench scheme, since it would be located on site.

6.3 CONSTRUCT THE EAST DIVERSION TRENCH

The total estimated construction cost for an east diversion trench to below the SCS dam is $5250. There is a potential water rights conflict associated with this scheme; however, no other major problems are anticipated. If water could be diverted to the adjacent drainage (Figure 1), the total estimated construction cost is $2350. Other than a potential water rights issue, no other major problems with this trench scheme are anticipated.

6.4 PUMP WATER TO THE EAST DIVERSION TRENCH

Consider use of Alternative C, as discussed previously, and pump storm water runoff from behind the existing diversion catch dam to the east diversion trench. Alternative C is far more economical than pumping water from behind the dam by pipeline either to below the SCS dam or to the adjacent drainage (Figure 1). The total estimated pipe cost for this scheme is less than $15,000. Furthermore, it would not be necessary to purchase large pumps if they could be rented as needed. Other than a potential water rights issue, no major problems are anticipated for this alternative.

6.5 CONSTRUCT THE INTERCEPTOR TRENCH AND STORAGE FACILITY ON SITE

The total estimated construction cost for the interceptor trench and storage facility is $5590. Pumps currently in operation for the SCS pump back system could be relocated for temporary use at the storage facility.

6.6 RAISE THE DIVERSION CATCH DAM

The total estimated construction cost for the diversion catch dam raise is $270,000. This construction is proposed to be done within the next year or to be coupled with the final embankment raise for the main tailings impoundment.

6.7 CONSTRUCT THE WEST FORK SAND CREEK UPPER STORAGE DAM AND UPPER DIVERSION TRENCHES

The total estimated construction cost for this project is $113,900, excluding low-level outlet works or emergency spillway system.

Construction of this facility could potentially either decrease the size of or else eliminate the need for the West Fork Sand Creek diversion trench.

7.0 CONCLUSIONS

Cotter Corporation has numerous alternatives available which could potentially control most surface water runoff above the Cotter mill site. Additional engineering design studies will be necessary for some of the alternatives, depending upon the results of further investigations by Cotter regarding land ownership and water rights issues. Each alternative was presented in the context of its ability to divert a specific portion of runoff separate from the other alternatives. However please note that combinations of these alternatives are capable of diverting almost all of the naturally occuring runoff, and Cotter acknowledges the merits of using the appropriate combination of alternatives if the legal issues can be adequately addressed and a technical approach that is acceptable to both the Department and Cotter is identified.

TABLE 1

SURFACE WATER DISCHARGE AND RUNOFF SUMMARY

FOR 100-YEAR DESIGN STORM

Watershed Area[1] Designation	Drainage Area (acres)	Drainage Area (mi^2)	Runoff Time of Concentration, t_c (hr)	Peak Discharge (cfs)	Storm Runoff Volume (acre-feet)
1	475	0.742	0.40	981	90.3
2	429	0.670	0.44	840	81.5
3	166	0.260	0.30	400	31.5
(1+2+3)	1070	1.672	(0.40)[2]	(2210)	(203.3)
4	50.3	0.079	--	140[3]	9.6
(1+2+3+4)	1120.3	1.750	--	(2350)[3]	(212.9)
5	46.8	0.073	0.15	146	8.9
(5')[4]	56.3	0.088	0.67	85	(10.7)
6	51.0	0.080	0.12	172	9.7
7	143	0.223	0.19	421	27.2

[1] Refer to Figure 1 for watershed location.

[2] Weighted.

[3] Determined based on simple routing of combined peak discharge fro Watershed Areas (1+2+3) through Watershed Area 4.

[4] Watershed Area above east diversion trench to adjacent drainage (Figure 1).

TABLE 2 A

PUMP REQUIREMENTS FOR ALTERNATIVE A—PUMPING TO BELOW SCS DAM[1]

Runoff Evacuation Period (days)	Pipe Size[2] (inches)	Pump Head (feet)	Pump Horsepower	Flow Rate (gpm)
1	32	125	560	12,420
2	24	121	270	6210
3	18	138	205	4140
4	16	138	154	3100
5	16	126	112	2480
6	12	174	130	2070
7	12	153	97	1780
8	12	143	81	1550
9	12	134	67	1380
10	10	166	75	1240

[1]Refer to Figure 1 for conceptual layout.

[2]Required pipe length would be about 9100 feet.

TABLE 2 B

PUMP REQUIREMENTS FOR ALTERNATIVE B—
PUMPING TO ADJACENT DRAINAGE[1]

Runoff Evacuation Period (days)	Pipe Size[2] (inches)	Pump Head (feet)	Pump Horsepower	Flow Rate (gpm)
1	32	86	384	12,420
2	24	85	190	6210
3	18	88	131	4140
4	16	88	98	3100
5	16	86	76	2480
6	12	96	72	2070
7	12	92	58	1780
8	12	89	50	1550
9	12	87	44	1380
10	10	95	43	1240

[1]Refer to Figure 1 for conceptual layout.

[2]Required pipe length would be about 2000 feet.

TABLE 2 C

PUMP REQUIREMENTS FOR ALTERNATIVE C— PUMPING TO EAST DIVERSION TRENCH[1]

Runoff Evacuation Period (days)	Pipe Size[2] (inches)	Pump Head (feet)	Pump Horsepower	Flow Rate (gpm)
1	32	51	233	12,420
2	24	51	116	6210
3	18	51	78	4140
4	16	51	58	3150
5	16	51	47	2480
6	12	52	39	2070
7	12	51	33	1780
8	12	51	29	1550
9	12	51	26	1380
10	10	52	23	1240

[1] Refer to Figure 1 for conceptual layout.

[2] Required pipe length would be about 200 feet.

<u>TABLE 3</u>

ESTIMATED EARTHWORK COST SUMMARY

Structure*	Earthwork Volume (cubic yards)	Total Cost (dollars)
West Fork Sand Creek Diversion Trench	18,300	9150
West Diversion Trench Extension	3220	1610
East Diversion Trench		
i) to below SCS dam	10,500	5250
ii) to adjacent drainage (Figure 1)	4700	2350
Diversion Catch Dam Raise	135,000	270,000
West Fork Sand Creek Upper Storage Dam	55,000	110,000
West Fork Sand Creek Upper Diversion Trenches	7800	3900
Interceptor Trench On Site	3980	1990
Storage Facility On Site	1800	3600

*Refer to Figure 1 for structure location and conceptual layout.

TABLE 4 A

PUMP COSTS FOR ALTERNATIVE A—
PUMPING TO BELOW SCS DAM

Runoff Evacuation Period (days)	Installed Pipe Cost (dollars/foot)	Pipe Cost for 9100 feet (dollars)	Pump Cost (dollars)	Total Cost (dollars)
1	75	683,000	50,000	733,000
2	59	537,000	45,000	582,000
3	45	410,000	40,000	450,000
4	36	328,000	30,000	358,000
5	36	328,000	25,000	353,000
6	30	273,000	30,000	303,000
7	30	273,000	25,000	298,000
8	30	273,000	20,000	293,000
9	30	273,000	20,000	293,000
10	27	246,000	20,000	266,000

TABLE 4 B

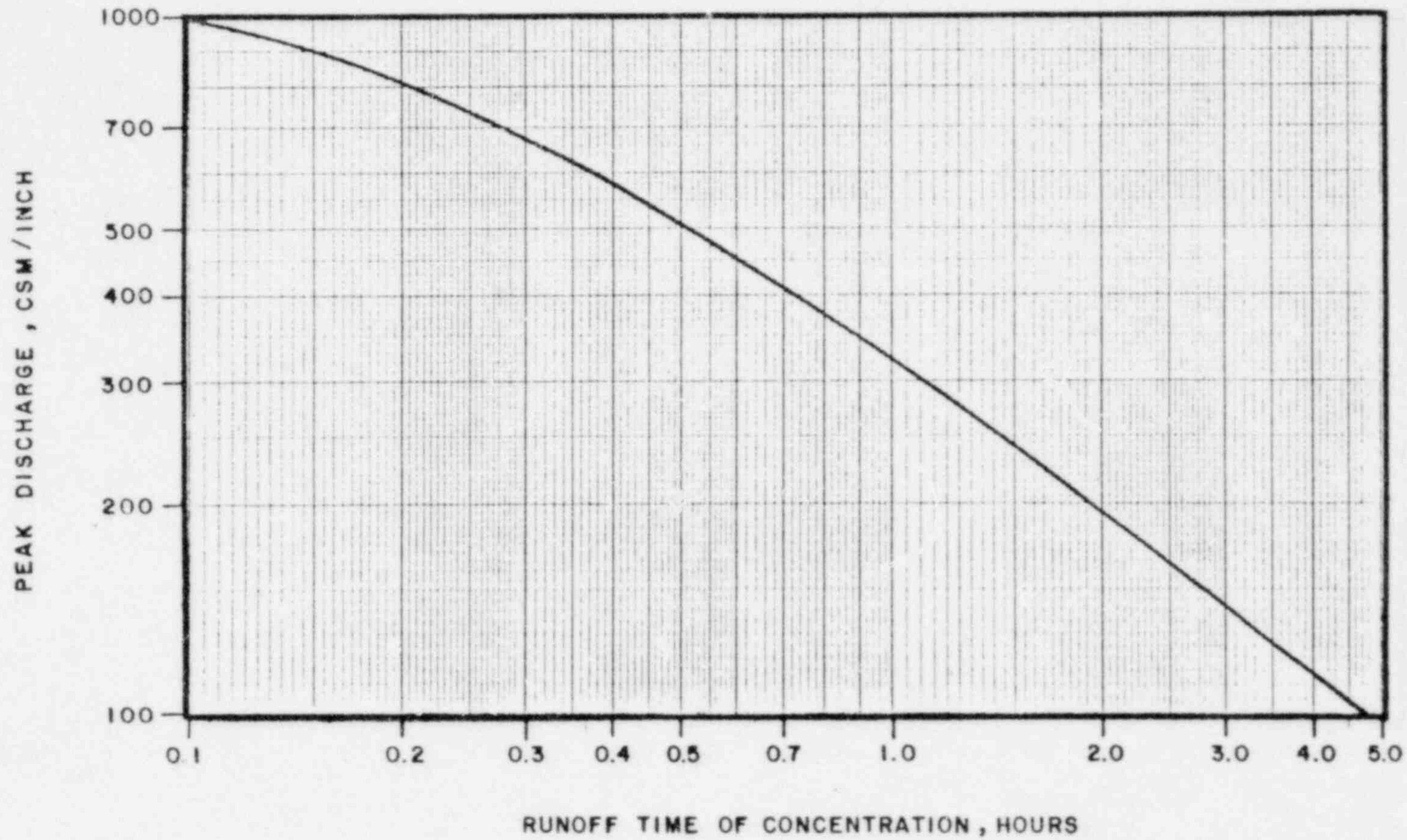
PUMP COSTS FOR ALTERNATIVE B—
PUMPING TO ADJACENT DRAINAGE

Runoff Evacuation Period (days)	Installed Pipe Cost (dollars/foot)	Pipe Cost for 2000 feet (dollars)	Pump Cost (dollars)	Total Cost (dollars)
1	75	150,000	50,000	200,000
2	59	118,000	40,000	158,000
3	45	90,000	30,000	120,000
4	36	72,000	20,000	92,000
5	36	72,000	20,000	92,000
6	30	60,000	20,000	80,000
7	30	60,000	20,000	80,000
8	30	60,000	20,000	80,000
9	30	60,000	20,000	80,000
10	27	54,000	20,000	74,000

TABLE 4C

PUMP COSTS FOR ALTERNATIVE C—
PUMPING TO EAST DIVERSION TRENCH

Runoff Evacuation Period (days)	Installed Pipe Cost (dollars/foot)	Pipe Cost for 200 Feet (dollars)	Pump Cost (dollars)	Total Cost (dollars)
1	75	15,000	40,000	55,000
2	59	12,000	35,000	47,000
3	45	9,000	30,000	39,000
4	36	7,000	25,000	33,000
5	36	7,000	20,000	27,000
6	30	6,000	15,000	21,000
7	30	6,000	15,000	21,000
8	30	6,000	15,000	21,000
9	30	6,000	15,000	21,000
10	27	6,000	15,000	21,000



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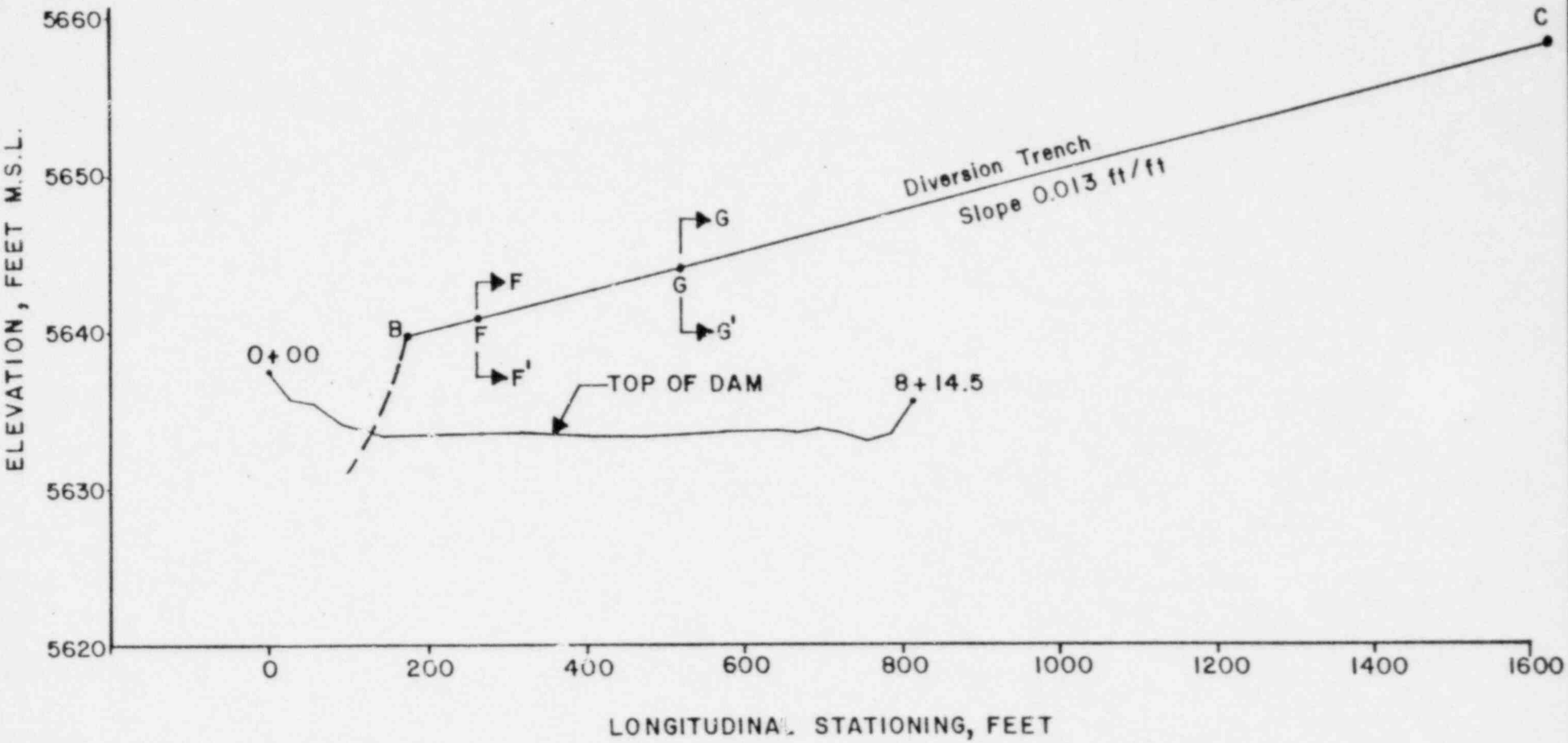
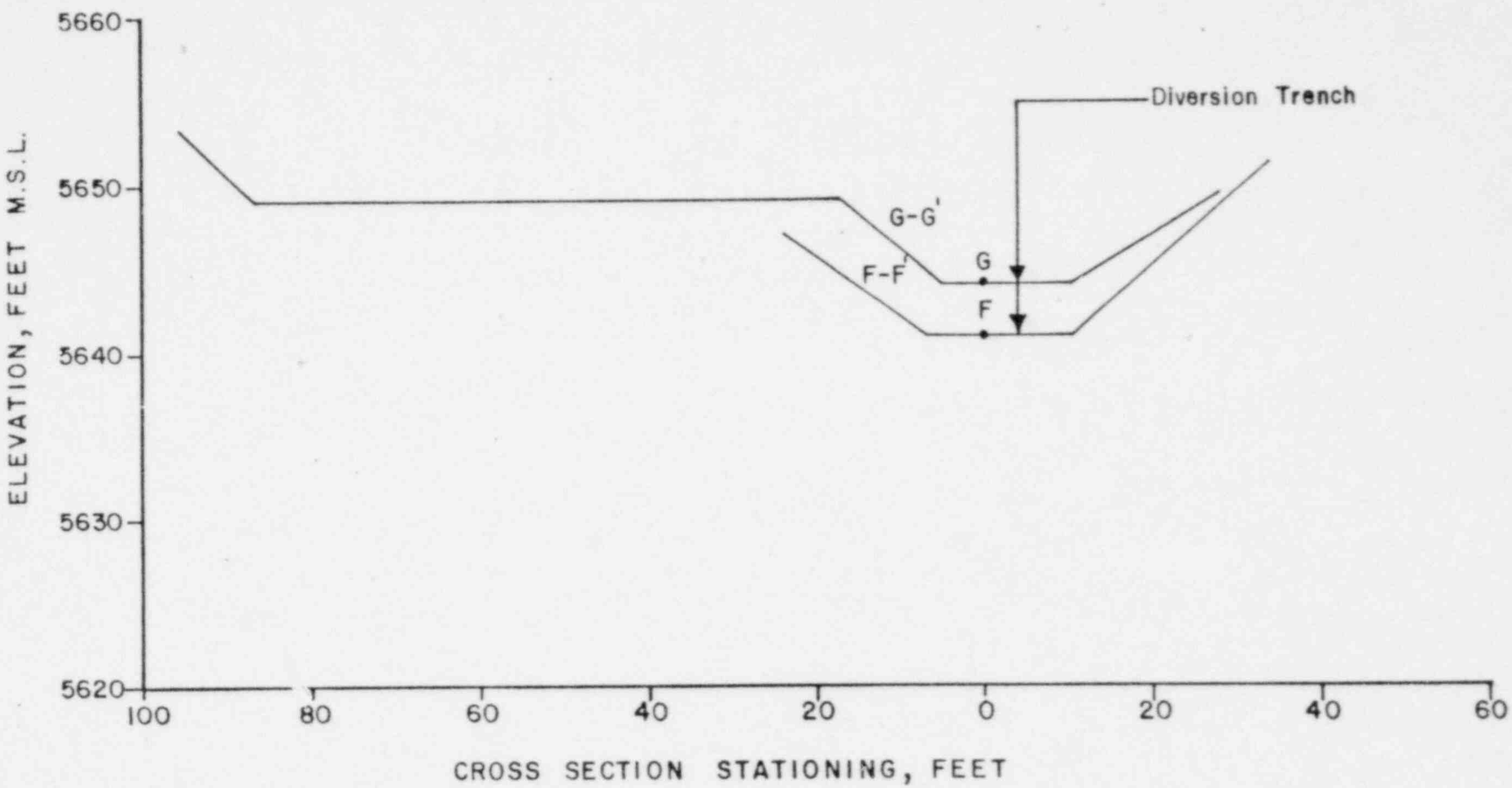
PEAK DISCHARGE IN CUBIC FEET PER SECOND PER SQUARE MILE (CSM) PER INCH OF RUNOFF VERSUS RUNOFF TIME OF CONCENTRATION FOR 24-HOUR STORM

FIGURE: 2

PROJECT: COT 102 B 108

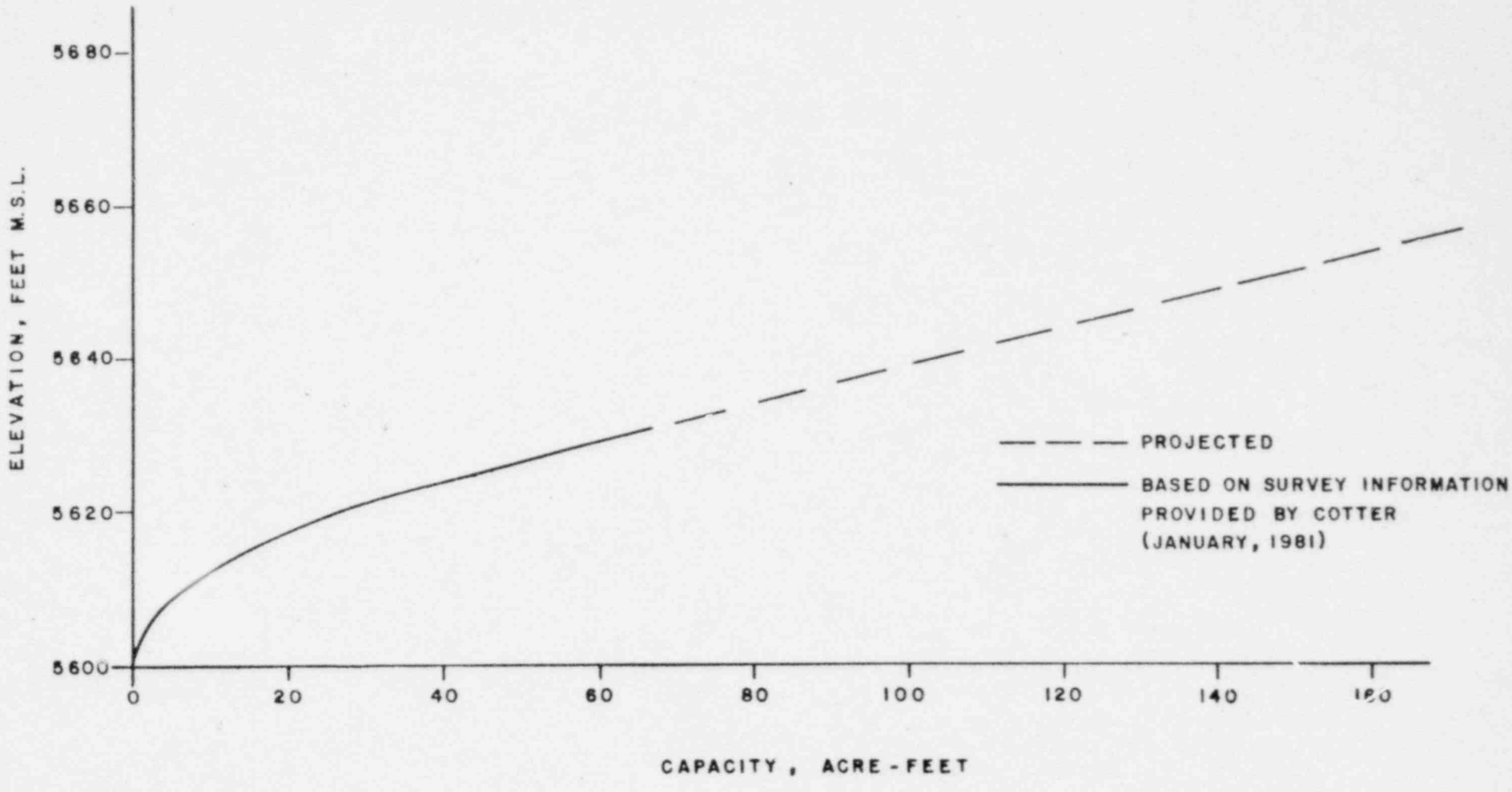


Wahler Associates	LONGITUDINAL PROFILE-EXISTING DIVERSION TRENCH	FIGURE: 3
		PROJECT: COT 102 B 108



NOTE: REFER TO FIGURE 3 FOR LOCATIONS OF CROSS SECTIONS.

Wahler Associates	TYPICAL CROSS SECTIONS – EXISTING DIVERSION TRENCH	FIGURE: 4
		PROJECT: COT 102 B 108



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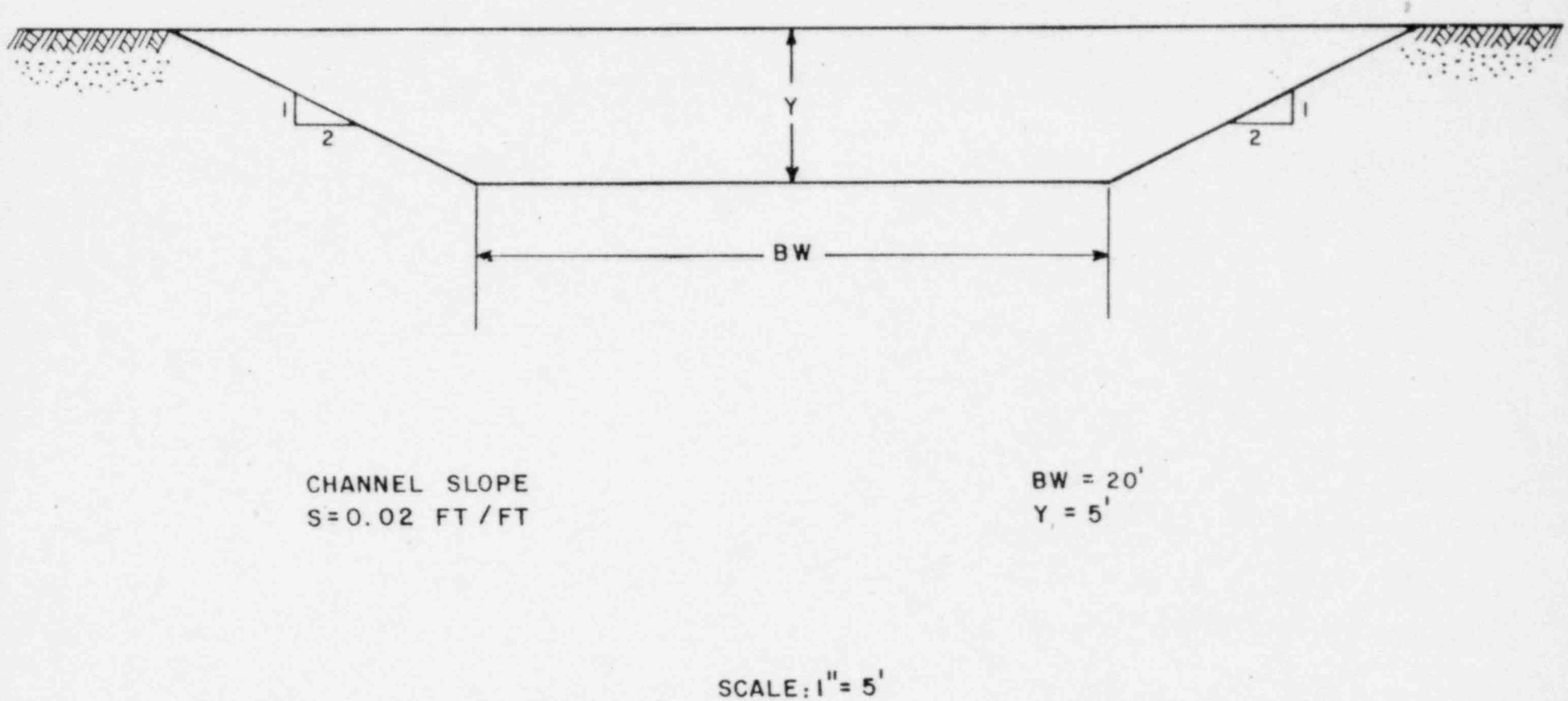
CAPACITY VERSUS ELEVATION RELATIONSHIP FOR DIVERSION CATCH DAM

FIGURE: 5

PROJECT: COT 102B108



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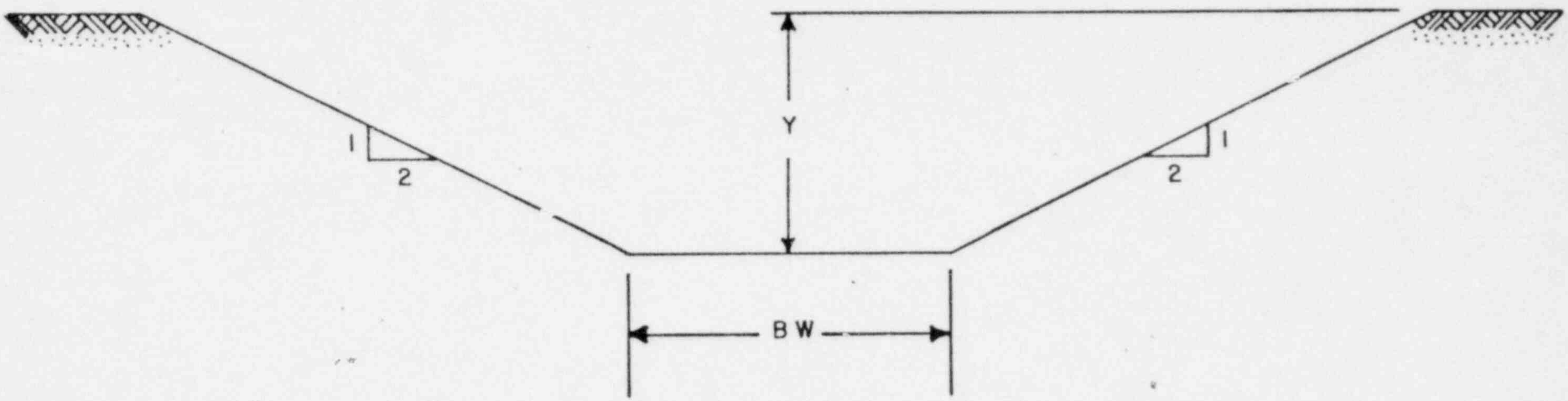
TYPICAL CROSS SECTION — WEST FORK SAND CREEK DIVERSION TRENCH

FIGURE: 6

PROJECT: COT 102 B 108

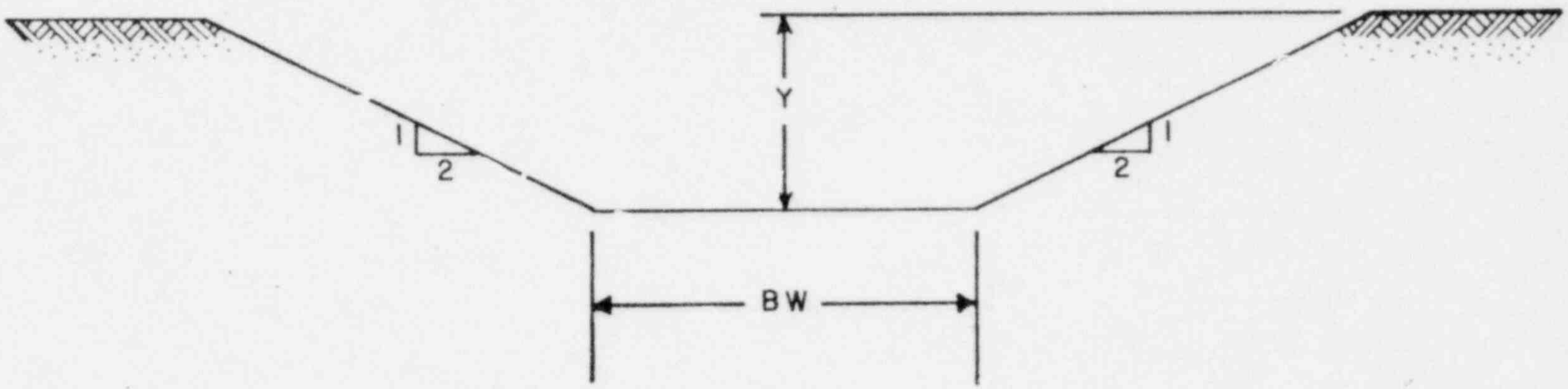


CHANNEL SLOPE
S=0.005 FT/FT

BW = 4'
Y = 3'

SCALE: 1" = 2'

Wahler Associates	TYPICAL CROSS SECTION — WEST DIVERSION TRENCH EXTENSION	FIGURE: 7 PROJECT: COT 102 B 108

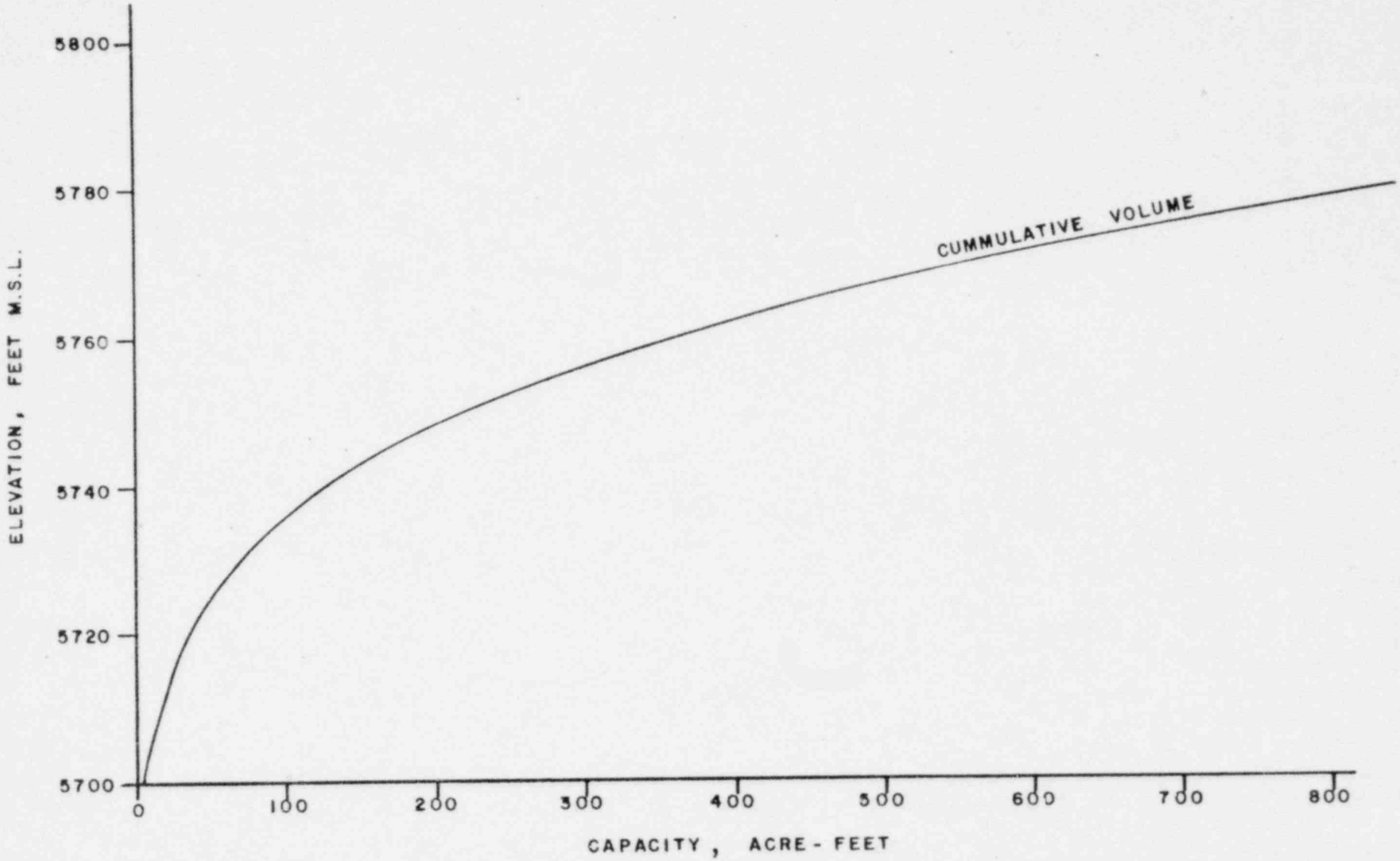


CHANNEL SLOPE
S=0.0025 FT/FT

BW = 4'
Y = 2' AT HEAD END, INCREASING LINEARLY TO 3' AT OUTLET END

SCALE: 1" = 2'

Wahler Associates	TYPICAL CROSS SECTION — EAST DIVERSION TRENCH TO ADJACENT DRAINAGE	FIGURE: 8
		PROJECT: COT 102 B108



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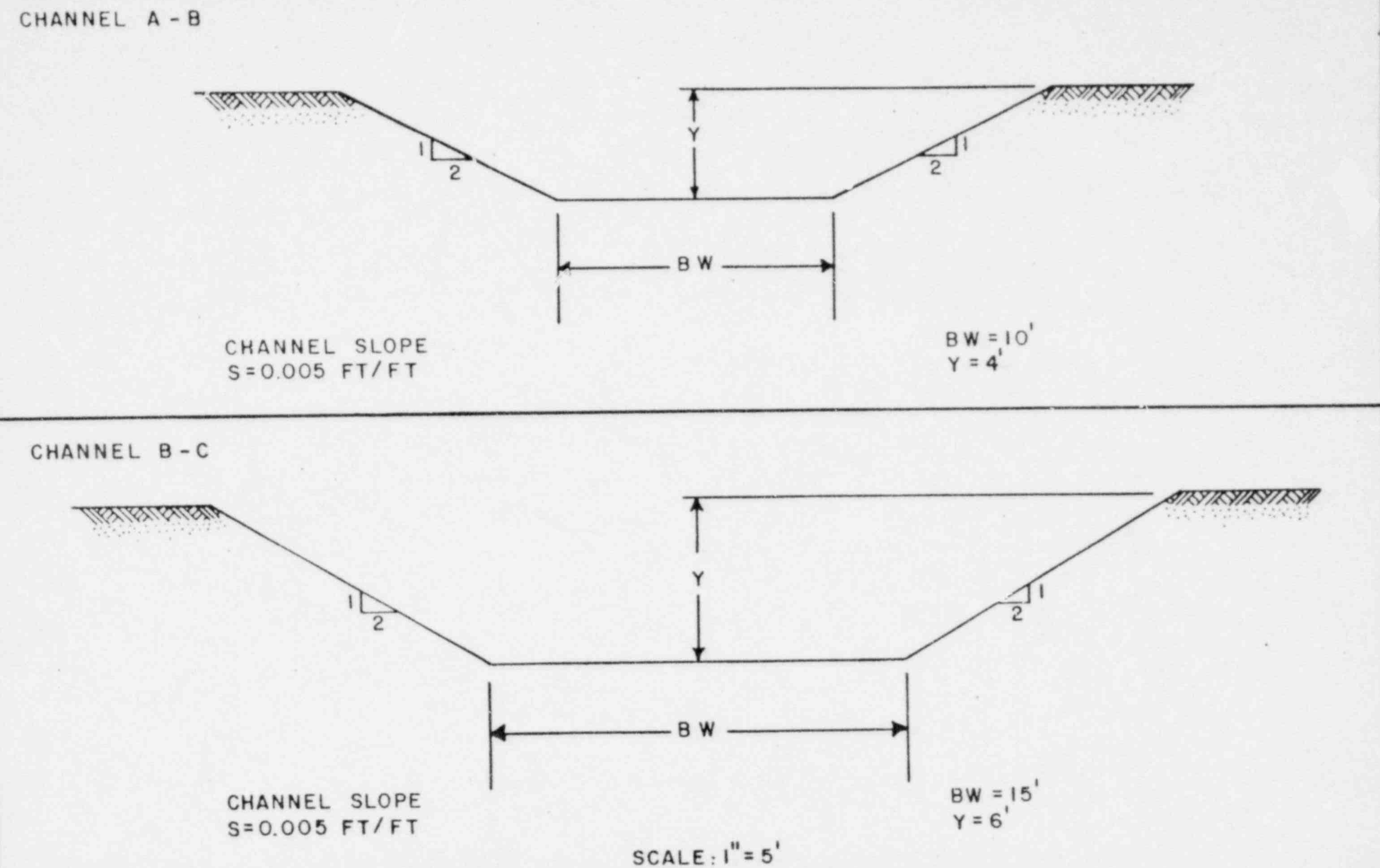
CAPCITY VERSUS ELEVATION RELATIONSHIP
FOR WEST FORK SAND CREEK UPPER STORAGE DAM AND RESERVOIR

FIGURE: 9

PROJECT: COT 102 B 108

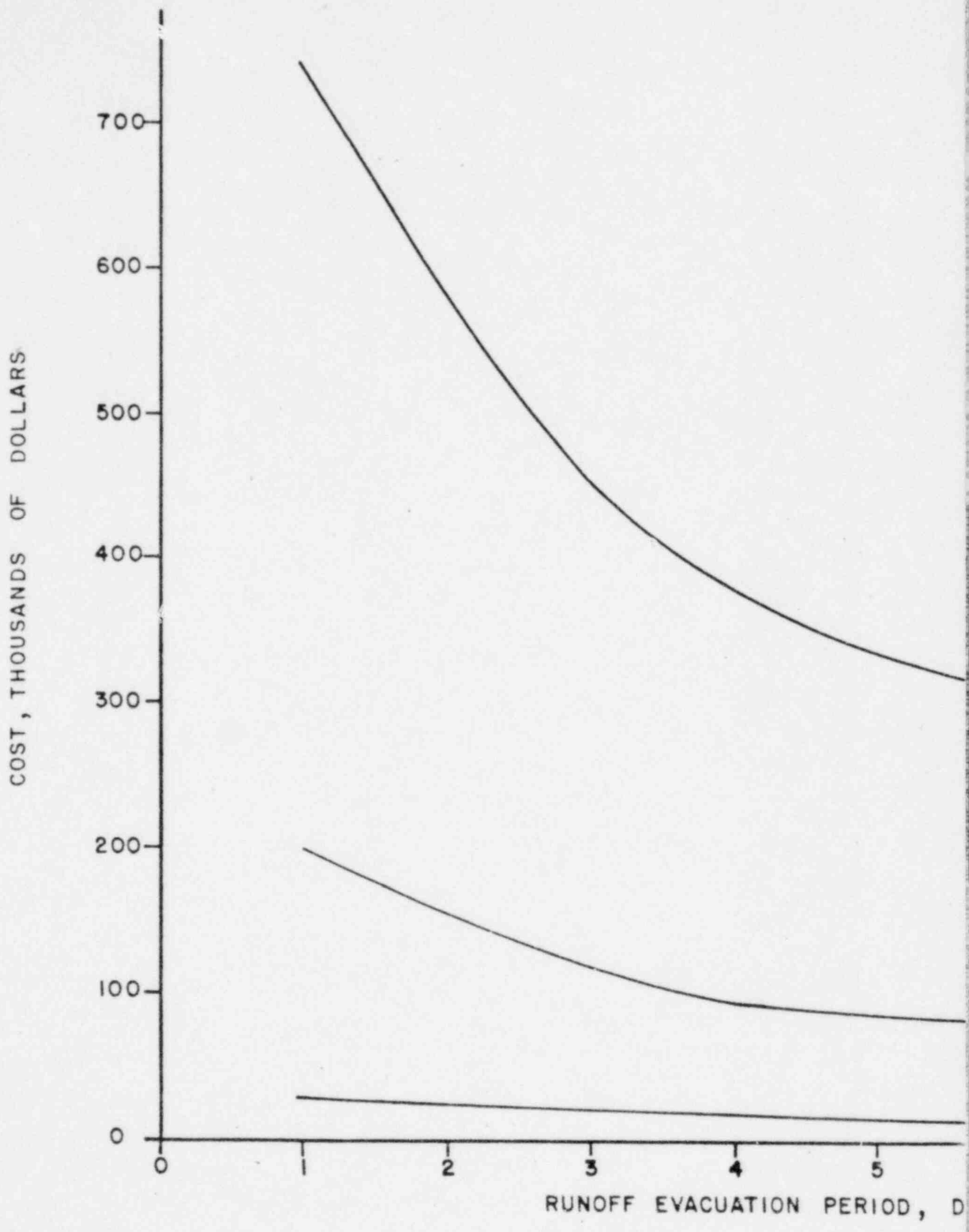


Wahler Associates

TYPICAL CROSS SECTIONS — WEST FORK SAND CREEK UPPER DIVERSION TRENCHES

FIGURE: 10

PROJECT: COT 102 B 108



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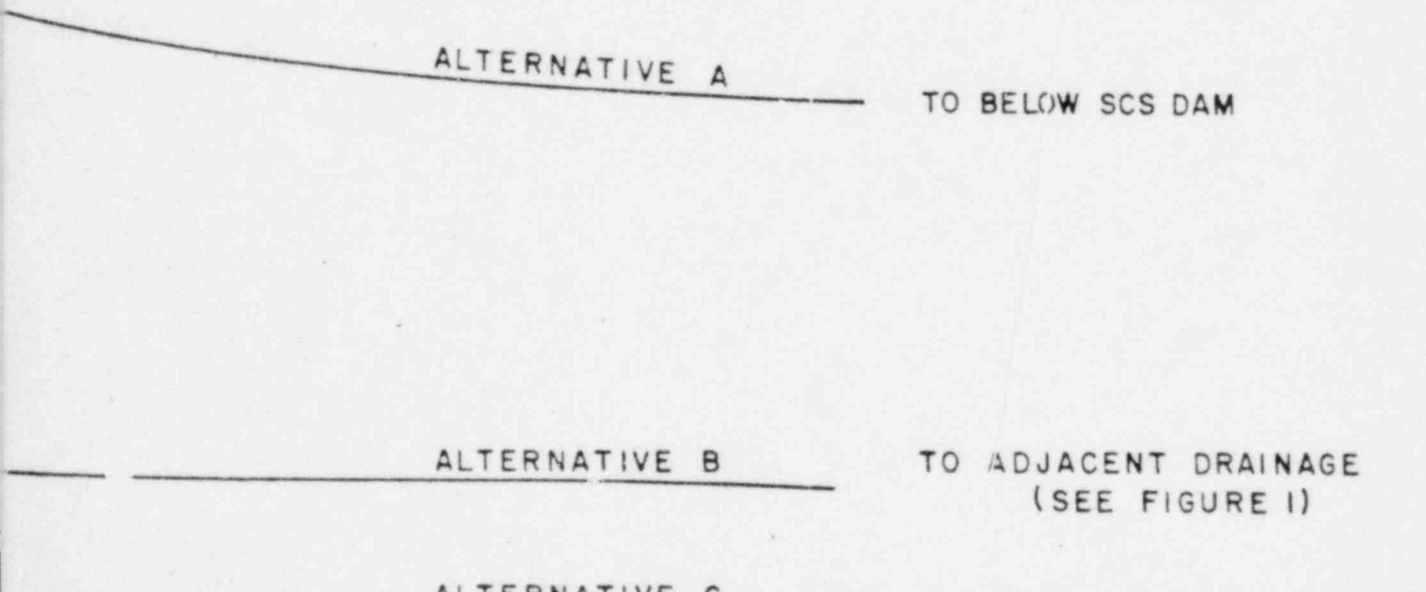

APPROXIMATE TOTAL COST CURVES
DIVERSION CATCH DAM PUMPING ALTERNATIVES

FIGURE : 11

PROJECT: COT 102 B 108

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