MINING AND RECLAMATION PLAN

BLACK MESA AND KAYENTA MINES

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ATTACHMENT C

Permanent Program Permit Diversion

Reed Valley Diversion Channel

Revised 07/01/97

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Reed Valley Diversion Channel

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I. Introduction

The proposed plan for coal mining at the Kayenta Mine includes the construction of the J-19 haul road, the J-19 haul road/Reed Valley Wash crossing, and Reed Valley diversion in 1993. This construction will occur in portions of the Reed Valley Wash's watershed. The boundaries of the watershed contributing runoff to the proposed haul road crossing and diversion channel area is indicated on Drawing 85400 (Sheets M-9, N-9, and N-10). Proposed mining and reclamation operations in the J-19 mine area will extend south of the stream buffer zone boundary; however, construction and reclamation activities in the haul road crossing and diversion area will disturb an approximate 1300-foot wide area (see Drawing 85360) along the existing Reed Valley Wash. The plans for the J-19 haul road and the Reed Valley Diversion are shown on Drawing 85400 and 85440. Drawing 85440, Sheet 3 of 3, shows the plan view of the J-19 haul road crossing and the horizontal alignment of the Reed Valley diversion. The profile of the proposed diversion is shown on Figure 1. The proposed diversion horizontal alignment will straighten this section of Reed Valley Wash and move the centerline of the wash approximately 250 feet north of the existing alignment. This will allow Peabody to maximize coal recovery in this area, allow additional working area to open the J-19 box cut pit, facilitate the J-19 Haul Road crossing of the Reed Valley Wash and facilitate final reclamation grading next to the J-19 Haul Road crossing. In the first several cuts, the J-19 haul road will ramp into the bottom of the pit in the mining disturbance area. Once the J-19 pit advances sufficiently south and the initial pits are backfilled, the J-19 haul road will become the primary ramp and haul road for hauling coal to the truck dump from this mine area.

The proposed diversion including the temporary haul road crossing will be a permanent diversion approximately 1,000 feet long and will include approximately 274 feet of upstream channel, 295 feet of concrete headwalls and 108-inch diameter corrugated metal culvert pipe, and 431 feet of downstream channel. When the haul road and crossing is no longer required for operation, the haul road and crossing will be reclaimed in accordance with the Transportation section in Chapter 6. The channel alignment under the culvert will be riprapped to blend into the upstream and downstream channel (see Appendices C and D).

During construction and during the life-of-mining, sedimentation control will be provided

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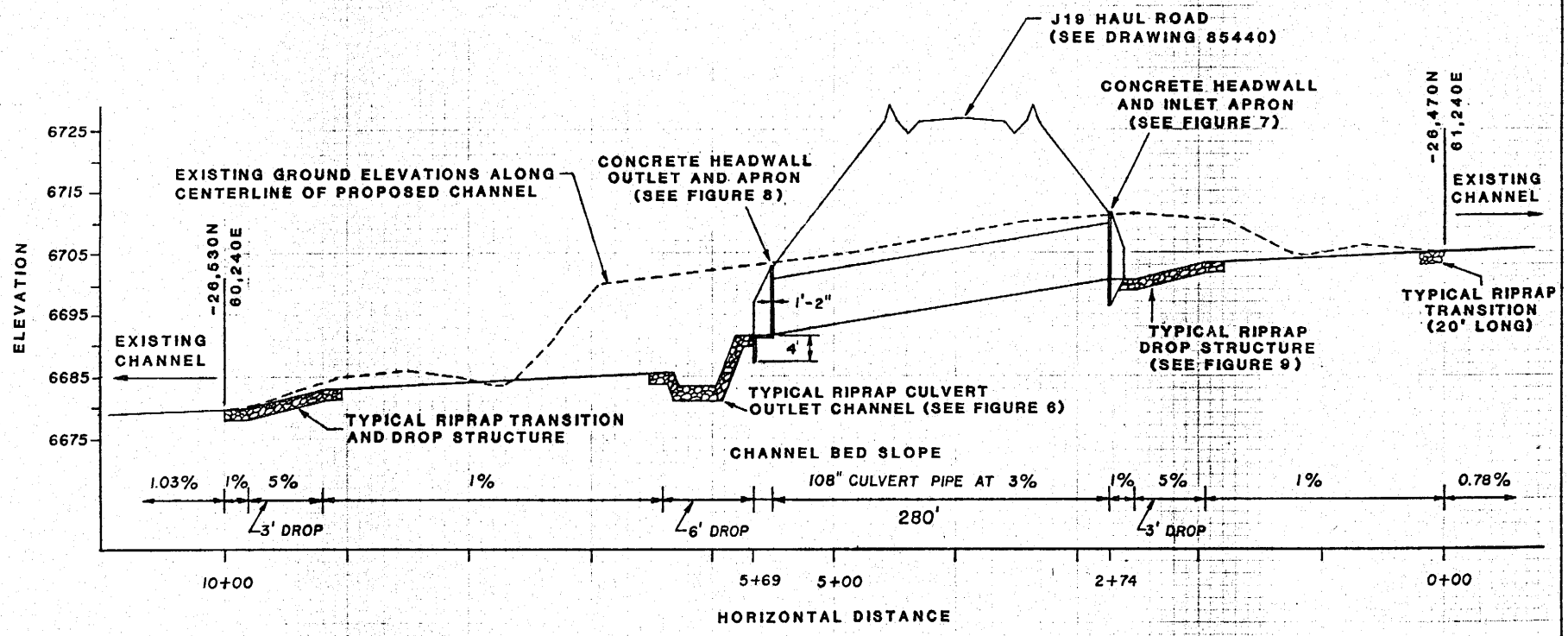

NOTE:
SEE FIGURE 2 FOR TYPICAL RIPRAPPED AND VEGETATED CHANNEL CROSS-SECTION.

PROFILE OF PROPOSED REED VALLEY DIVERSION CHANNEL

FIGURE 1

PROFILE OF PROPOSED REED VALLEY DIVERSION CHANNEL
KAYENTA MINE

PEABODY COAL CO., 1300 SOUTH YALE, FLAGSTAFF, AZ 86001

DESIGNED BY: P.C.C.	SCALE: NOT TO SCALE
DRAWN BY: G.Y.	PHOTO DATE: N/A
CHECKED BY: J.G.S.	DRAWING DATE: 4/15/92
REVISIONS	

downstream by the existing J16-L, Reed Valley Dam. Thus, the contribution of additional sediment to surface stream outside the permit area as a result of constructing the proposed diversion will be minimized. The proposed channel design includes two alternative typical cross-sections, a vegetated section and a riprap section, which are 30-foot wide with 3:1 or flatter side slopes (see Figure 2). Where the channel is not protected from erosion by riprap, the disturbed areas will be revegetated in accordance with the approved reclamation plan. The steeper slopes and transition areas upstream and downstream will be protected with riprap (see Figure 1 for locations). Peabody Coal Company will operate a maintenance and repairs program for this diversion and a surface water monitoring program along the downstream receiving stream. Through these programs, Peabody will be able to locate any problems in the channel pertaining to excess erosion, scours, sedimentation and riprap protection, and undertake appropriate measures to repair and rectify such problems. Peabody plans to continue mining operations in the area until 2011 when mine reclamation is likely to be completed. Thereafter, there will be a ten-year bonding period. It is anticipated that this will provide sufficient time for the channel to stabilize, develop natural armor and vegetation cover, and to perform adequate repairs to vulnerable channel reaches, if necessary.

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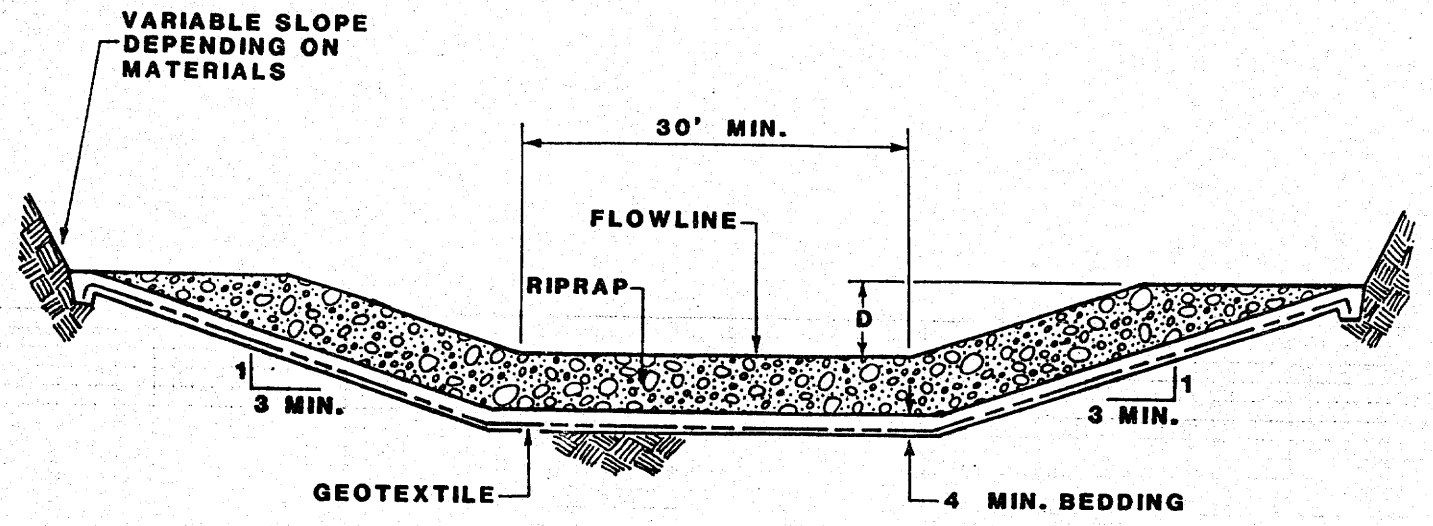
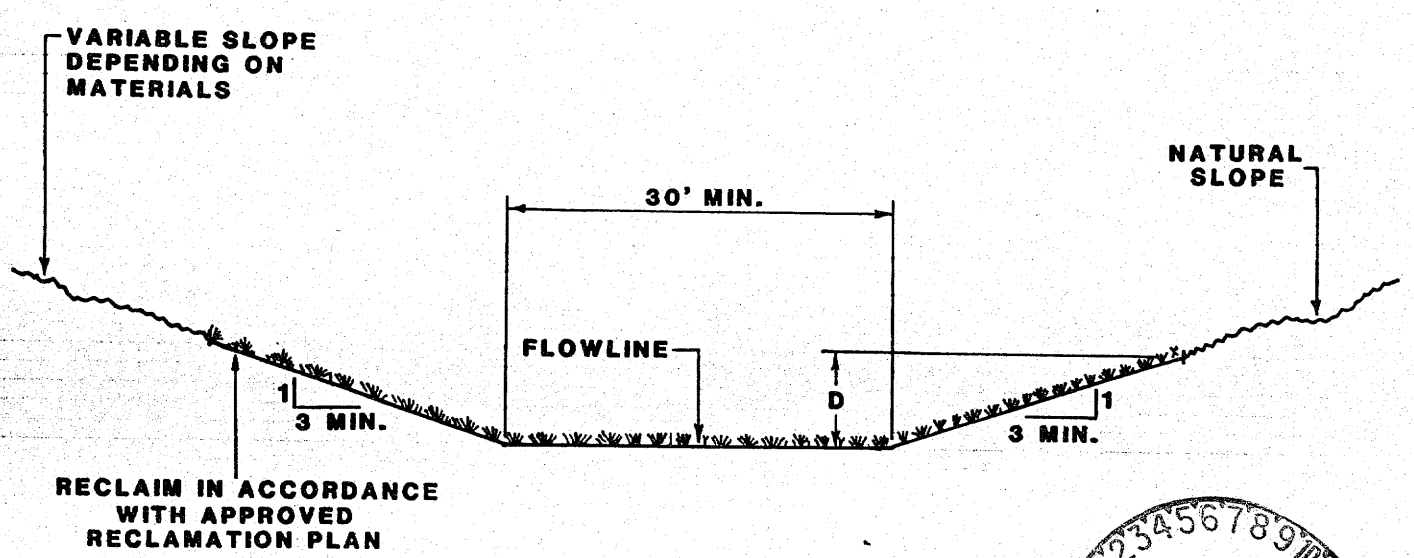
II. Hydrologic Analysis

The total drainage area within the Reed Valley Wash watershed at the diversion is approximately 2,340 acres. This assumes the J-19 pit or permanent impoundment, J19-RA will intercept the runoff from the J19-RA watershed. The existing channel bottom is generally above the local water table and the channel conveys runoff only after the occurrence of precipitation in portions of the contributing subwatersheds. Therefore, from a hydrologic standpoint, the existing channel may be classified as an ephemeral channel. However, the total drainage area of the channel contains more than one square mile, the channel has to be designed as a permanent diversion for an intermittent or perennial channel to be in conformance with existing regulations of the Office of Surface Mining (OSM). The hydrologic design standard for permanent diversions of perennial and intermittent streams is the peak runoff of a 100-year, 6-hour precipitation event (30 CFR 816.43(b)(3) and 701.5).

As stated above, the hydrologic design standard for the Reed Valley channel diversion is the 100-year, 6-hour precipitation event. The cumulative depths of 100-year precipitation for various durations are shown in Table 1 (NOAA, 1973). The proposed channel crossings



RIPRAP SECTION
(SUPER CRITICAL FLOW)



VEGETATED SECTION
(SUBCRITICAL FLOW)

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REED VALLEY DIVERSION CHANNEL
TYPICAL CROSS-SECTIONS

FIGURE 2

will, however, be designed to pass the peak flow resulting from a 10-year, 6-hour precipitation event with a headwater to culvert pipe diameter (HW/D) ratio of less than 1.0 subject to the condition that there is no potential for overtopping the roadway during the 100-year, 6-hour precipitation event (30 CFR 816.151C, 1986). The cumulative depths of 10-year precipitation for various durations are also shown in Table 1 (NOAA, 1973).

TABLE 1

Time Distributions of 100-Year and 10-Year, 6-Hour

Precipitation at Kayenta Mine Site

Duration	Depth of Cumulative Precipitation (In.)	
	100-Year	10-Year
5 minutes	0.56	0.35
10 minutes	0.86	0.54
15 minutes	1.09	0.68
30 minutes	1.52	0.95
1 hour	1.92	1.20
2 hours	2.10	1.34
3 hours	2.25	1.43
6 hours	2.40	1.60

The hydrologic analysis was completed using the SEDCAD+ computer program. The following parameters were used in the hydrologic analysis (see Appendices A and B):

1.	Water Course Length, L	3.72 miles
2.	Elevation Difference, H	592 feet
3.	Time of Concentration, Tc	1.013 hr
4.	Rainfall Depth, 10-year, 6-hour storm	1.60 in
	100-year, 6-hour storm	2.40 in
5.	Drainage Area	2340.47 ac
6.	SCS Weighted Curve Number	78

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TABLE 2

Weighted SCS Curve Number

Cover Type	Hydro Cond.	Soil Type	CN	Area (Acres)	CN*Area
Reclaimed	fair	C	81	1050.42	85084.02
Disturbed	--				
Road	--	C	87	11.90	1035.30
P-J	35	B	65	21.08	1370.20
		C	78	933.05	72777.90
S-G	30	B	60	123.90	7434.00
		C	73	200.12	14608.76
				2340.47	182,310.18

$$\text{Weighted CN} = \frac{182,310.18}{2340.47} = 77.89 = \underline{78}$$

The following peak discharges were utilized in the channel design (see Appendices A and B):

Q_{10} = 271.1 cfs

Q_{100} = 795.6 cfs

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III. Hydraulic Analysis

Historical measured flow velocities in different channels within the mine area during severe storms in 1983 and 1984 are shown in Table 3. It may be noted that the measured velocities are approximately the same or significantly greater than (ranging from 6.2 to 16.8 ft/sec) as the estimated design values for the proposed channel. The main reasons the existing channels can withstand such high velocities without excessive degradation, erosion, and scour include the following:

1. The storm runoff in the area is heavily silt laden. This fact is corroborated by actual measurements of total suspended solids concentrations in streamflows in the area (see Table 4).
2. The bed and banks of the existing channels are generally protected by well-established vegetation.
3. Portions of the existing channel beds have hydraulic controls in the form of rock outcrops.

TABLE 3

Measured Channel Velocities at Different Locations in the Area

Site No.	Approximate Location	Stream	Date	Discharge (cfs)	Velocity (fps)	Method of Measurement
37	Upstream of confluence with Dugout Wash	Reed Valley	07/16/84	500	11.3	Slope-area
			07/27/84	105	8.6	Surface floats
			09/01/84	240	10.1	Surface floats
35	4 miles northeast of Reed Valley Site	Moenkopi Wash	07/23/84	380	7.2	Surface floats
25	8 miles southwest of Reed Valley Site	Coal Mine Wash	07/23/84	415	6.5	Surface floats
26	7 miles southwest of Reed Valley Site	Moenkopi Wash	07/23/84	240	8.7	Surface floats
50	8 miles northwest of Reed Valley Site	Upper Yellow Water Canyon	08/10/83	220	7.7	Current meter
			09/30/83	89	6.7	Current meter
78	4.5 miles southeast of Reed Valley Site	Upper Dinnebito Wash	09/30/83	557	7.2	Current meter
85	7 miles southwest of Reed Valley Site	Yucca Flat Wash	07/23/84	570	7.7	Surface floats
			08/14/84	3,900	16.8	Surface floats
155	7 miles southwest of Reed Valley Site	Red Peak Valley	08/05/84	343	8.6	Surface floats
15	8 miles northwest of Reed Valley Site	Lower Yellow Water Canyon	08/09/83	141	6.2	Current meter

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The proposed channel will have similar or better hydraulic, vegetative, and geologic environment and so is expected to withstand the anticipated velocities with similar sediment transport characteristics. It may be noted that the heavy suspended sediment loads shown in Table 4 can be transported without deposition only if the corresponding flow velocities are relatively high. A channel designed with lower flow velocities during flood events may prove to be an aggrading channel requiring regular maintenance.

TABLE 4

Observed Total Suspended Solids Concentrations in Streamflows

Site No.	Stream	Date	Discharge (cfs)	Simultaneous Total Suspended Solids Concentration (mg/l)
35	Moenkopi Wash	09/20/85	79	101,525
16	Upper Coal Mine Wash 6 miles northwest of Reed Valley Site	07/29/85	120	380,896
50	Upper Yellow Water Canyon	07/18/85	230	1,056,254
37	Reed Valley Wash	08/24/86	81	127,572
37	Reed Valley Wash	07/23/86	44	94,360
25	Coal Mine Wash at the confluence with Moenkopi Wash	08/22/86	116	131,912

Following is a summary of hydraulic design parameters:

	Q_{10}	Q_{100}
Design Discharge (cfs)	271.1	795.6
Channel Width (ft)	30	30
Side Slopes (H:V)	3:1	3:1
Vegetated Channel (n)	0.03	0.03
Riprap Channel (n)	Sedcad+	Sedcad+
Critical Slope (%)	1.3	1.0

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Appendices C and D contain the hydraulic calculations for the 10-year, 6-hour and 100-year, 6-hour storm event, respectively.

IV. Hydraulic Control Structure Design

A. Tributary Inlets and Riprap Protection. To ensure that the course of the existing channel is permanently diverted, the existing channel will be backfilled during construction of the J-19 ramp and riprap protection will be provided at the upstream and downstream ends of the diverted reaches, tributary outfalls, and channel crossings. The design of a typical tributary inlet is shown in Figure 3. Approximate locations are shown on Figure 1 and Drawing 85440, Sheet 3 of 3, and details of riprap placement are shown in Figure 4. The length of the riprap protection indicated is based on information available on the 1-inch = 100-foot topographic maps of the area. Based on field conditions, these lengths may require some changes during construction.

The stones used for riprap would be angular pieces of locally available rock with a unit weight of 140 lbs/cft or more. The gradation of different sizes of riprap will generally conform to the specifications shown in Table 5. The riprap will be placed over a four-inch thick bedding of granular material. The gradations of the granular material are also indicated in Table 5.

The particle sizes of the granular material are based on the criteria in the SEDCAD+ computer program for riprap channels assuming the following:

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Q	=	795.6 cfs
Max Slope	=	5%
Z	=	3:1
Bottom Width	=	30 ft
Freeboard	=	1 ft

Two representative particle size distributions of the base material are shown in Figure 5.

As an alternative to the bedding of granular material, the riprap may be underlain by a mat of geotextile fabric spread over the existing base material of the banks and dikes. Several manufacturers have developed satisfactory types of geotextile fabrics for erosion control applications. The criteria for the selection of appropriate geotextile fabrics which can be used as substitutes for the granular bedding below rock riprap are given in Table 6. The aforementioned specifications will be used to select appropriate fabrics with due regard to the properties of the base material of the banks or dikes, e.g.,

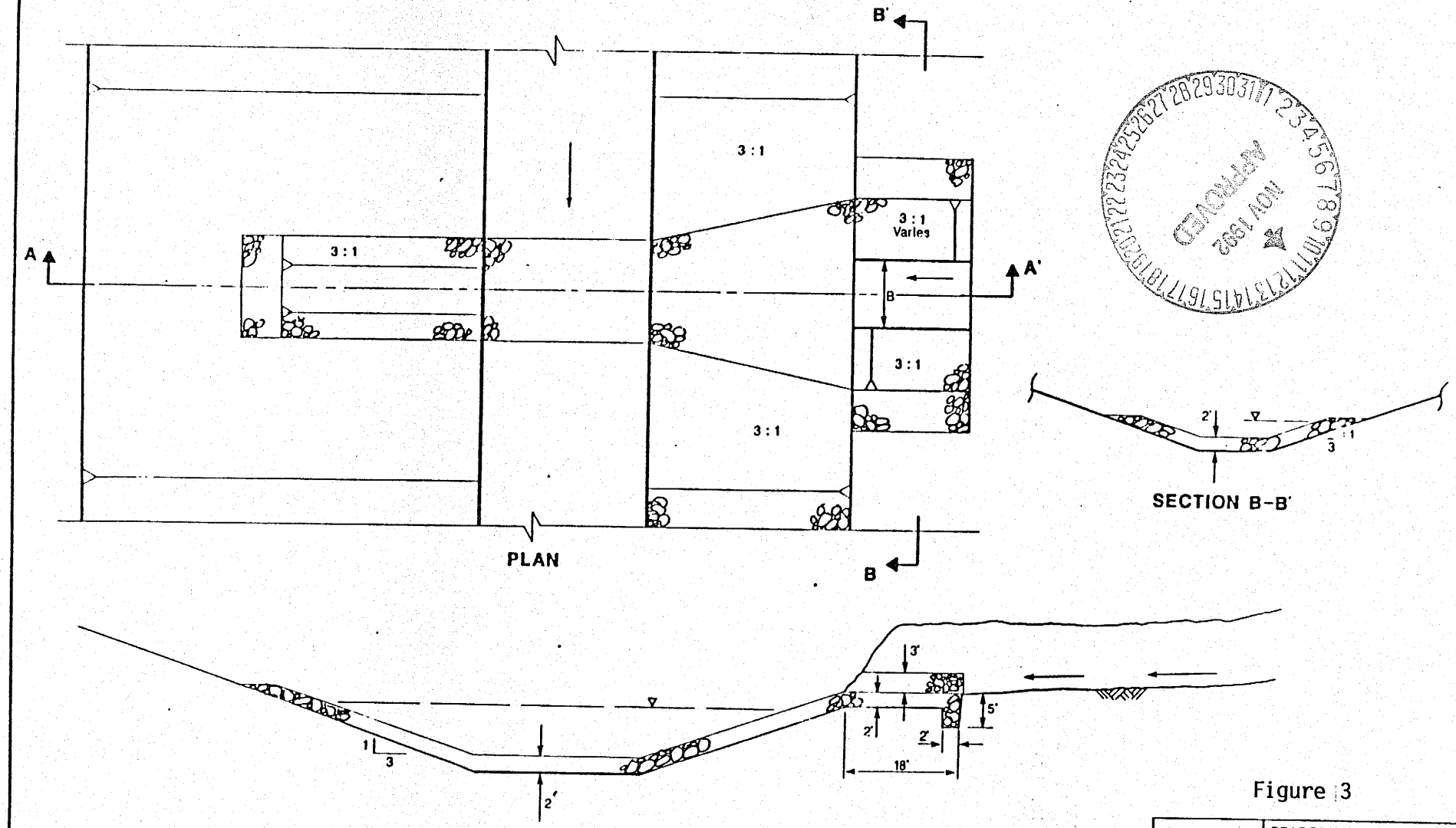
B'
A
A'
3 : 1
3 : 1
3 : 1
Varies
B
3 : 1
3 : 1
PLAN
B
2'
1
3
SECTION B-B'
3'
5'
2'
2'
18'
1
3
2'
SECTION A-A'
Not to Scale
Dames & Moore
PEABODY COAL COMPANY
Black Mesa - Kayenta Mine
TYPICAL
TRIBUTARY INLET
DESIGNED BY AP
DRAWN BY DJH
CHECKED BY AP
APPROVED BY AP
DATE 11/10/87
DRAWING NO
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Figure 3

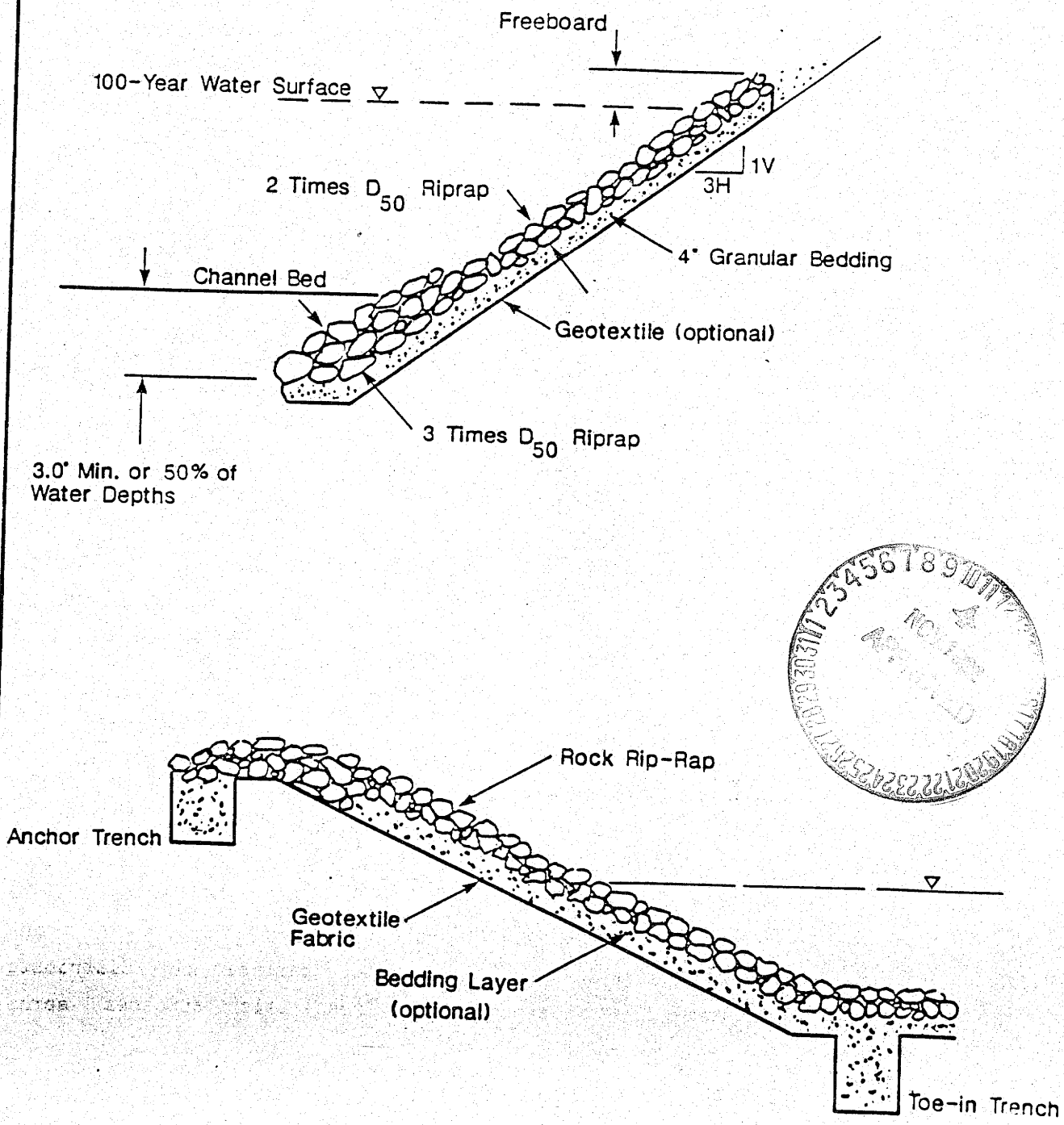
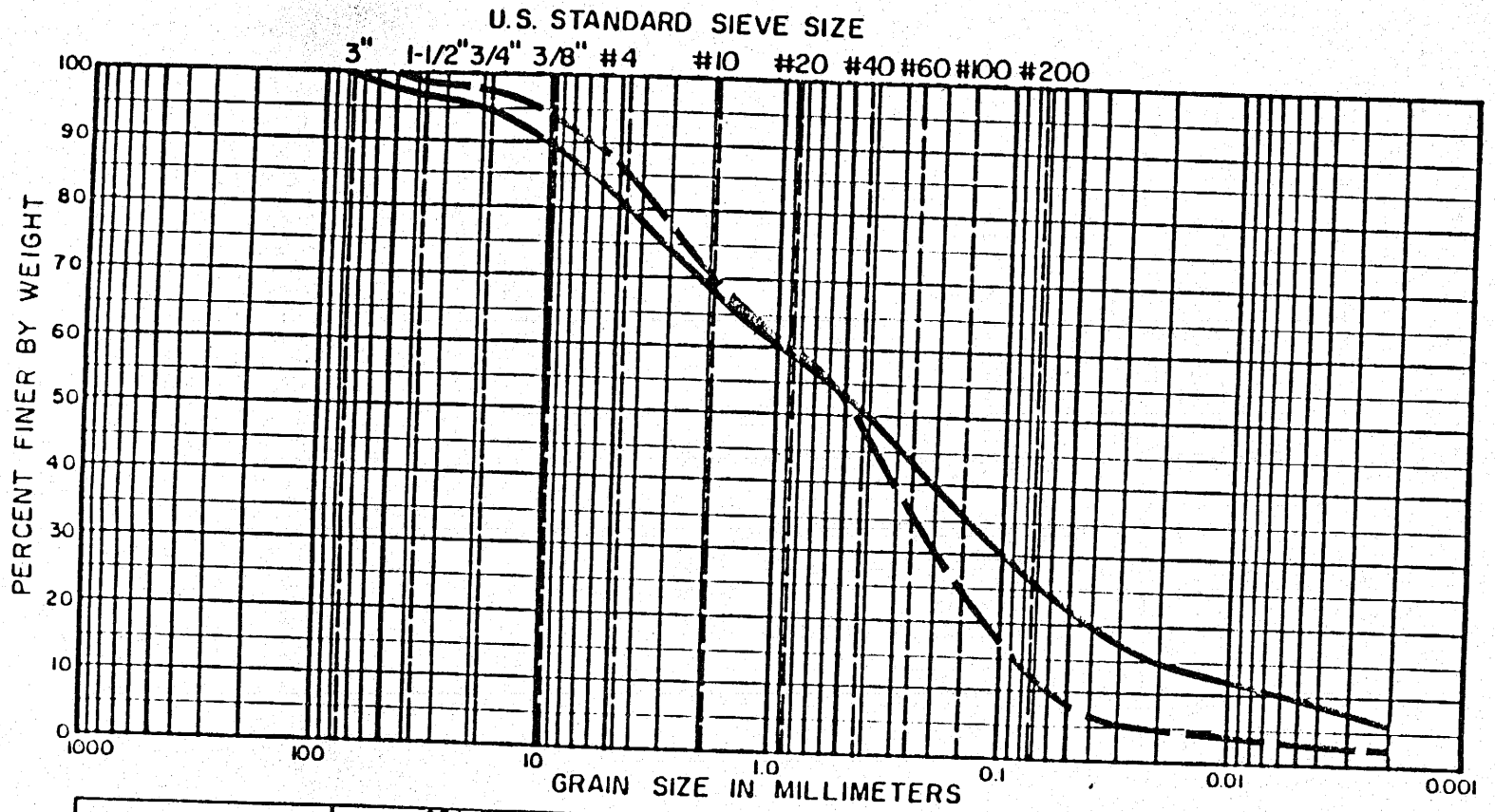


Figure 4

Typical Riprap Details

Dames & Moore

Figure 5



COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

LOCATION	DEPTH	CLASSIFICATION	
REED VALLEY	SURFACE	SILTY SAND WITH SOME GRAVEL	SM
REED VALLEY	SURFACE	SILTY SAND	SM

Gradation Curves for Base Material of Proposed Reed Valley Channel Bed and Banks

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particle size distribution, cohesiveness, permeability, erodibility, installation stresses, abrasion potential, and chemical composition.

TABLE 5

Specifications for Riprap Sizes

	Riprap Channel & Drop Structures	Culvert Outlet Channel
Riprap		
D_{100}	= 12 inches (at least 30 percent by weight of all stones must be this size or larger)	D_{100} = 22.5 inches
D_{50}	= 9 inches	D_{50} = 18 inches
D_{10}	= 3 inches	D_{10} = 6 inches
Thickness	= 2 to 3 ft. or as specified on the drawings	Thickness = 3 feet
Granular Material		
D_{50}	= 0.5 inch	D_{50} = 0.5 inch
D_{15}	= 0.0335 inch	D_{15} = 0.0335 inch
Thickness	= 4 inches	Thickness - 4 inches

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To install the geotextile fabric, the bank or dike slope will be graded to provide a smooth and level graded surface. The fabric will be laid loosely avoiding any folds or wrinkles. Adjacent rolls of fabric will be overlapped by a minimum of 18 inches. The overlaps will be seamed or pinned using steel security pins. Placement of stones above the fabric will start at the base of the required blanket area moving up the slope. As far as possible, the stones will be placed from the center outward. Stones weighing more than 100 pounds will not be allowed to roll downslope. The height of drop of stones will be limited to three feet or less. The fabric will be toed in at the top and bottom of the bank or dike, or the riprap will be extended several feet beyond the fabric, both at the toe and crest of the slope. A typical method of placement for geotextile fabric is illustrated in Figure 4.

TABLE 6

Specifications for Geotextile Fabric

1. The permeability of the selected geotextile fabric should be larger than that of the base soil.
2. The selected geotextile mat may be made by woven or unwoven fabrics. For woven fabrics, the percent open area should be more than four. For nonwoven fabric, the porosity of the geotextile mat should be more than 30 percent.

3. If the protected base soil contains particle sizes ranging from U.S. No. 200 sieve to 1 inch, the selection of the geotextile fabric may be based on the U.S. No. 4 sieve.
4. The grab strength (ASTM D-1682), puncture strength (ASTM D-751-68), and burst strength of the selected geotextile fabric should not be less than 90 pounds, 40 pounds, and 145 lbs/sq. in., respectively.

B. Culvert and Drop Structures. A new culvert, #P0266 will be provided at the J-19 haul road crossing with the proposed diversion channel. This culvert will consist of one 108-inch diameter corrugated metal pipe extending from approximately Station 2+80 to 5+60 laid at a slope of 3 percent. It will be provided with concrete headwalls both on the upstream and downstream ends. To minimize the potential for scour, 2-foot thick riprap with D_{50} = 1.0 foot will be provided in a length of about 20 feet on the upstream side of the upper headwall. On the downstream side, the outflow from the culvert pipes will be conveyed through a concrete apron and a riprap outlet channel, see Appendix D. A typical plan for the culvert outlet channel is shown on Figure 6. Figures 7 and 8 show the typical concrete headwall and aprons for the 108-inch diameter culvert. This culvert is designed to pass the peak flow of 271.1 cfs from a 10-year, 6-hour storm event with a HW/D ratio of 0.7 (see Chapter 6, Attachment Q). Also, this design ensures that more than 3 feet of freeboard is available between the top of the road and the maximum water surface elevation resulting from the peak flow from a 100-year, 6-hour storm (30 CFR 816.151C).

As stated previously, two 3-foot drop structures will be provided at the upstream entrance to the J-19 haul road culvert and the downstream transition end of the channel. The conceptual plan of a typical riprap drop structure is shown in Figure 9. The design of this drop structure is based on the hydraulic criteria described in the Surface Water Hydrology and Sedimentology Manual (OSM, 1982b), see Appendix D. This design utilizes a 3H:1V sloping riprap surface to negotiate a drop of 3 feet and create a hydraulic jump within the boundaries of the sloping and horizontal riprap aprons to dissipate energy. The riprap size is estimated using the method given in Surface Mining Water Diversion Design Manual (OSM, 1982a). If, during construction, competent bedrock is encountered at the locations of the proposed culvert or drop structures, then the riprap indicated in Figures 6 and 9 will be eliminated or modified suitably.

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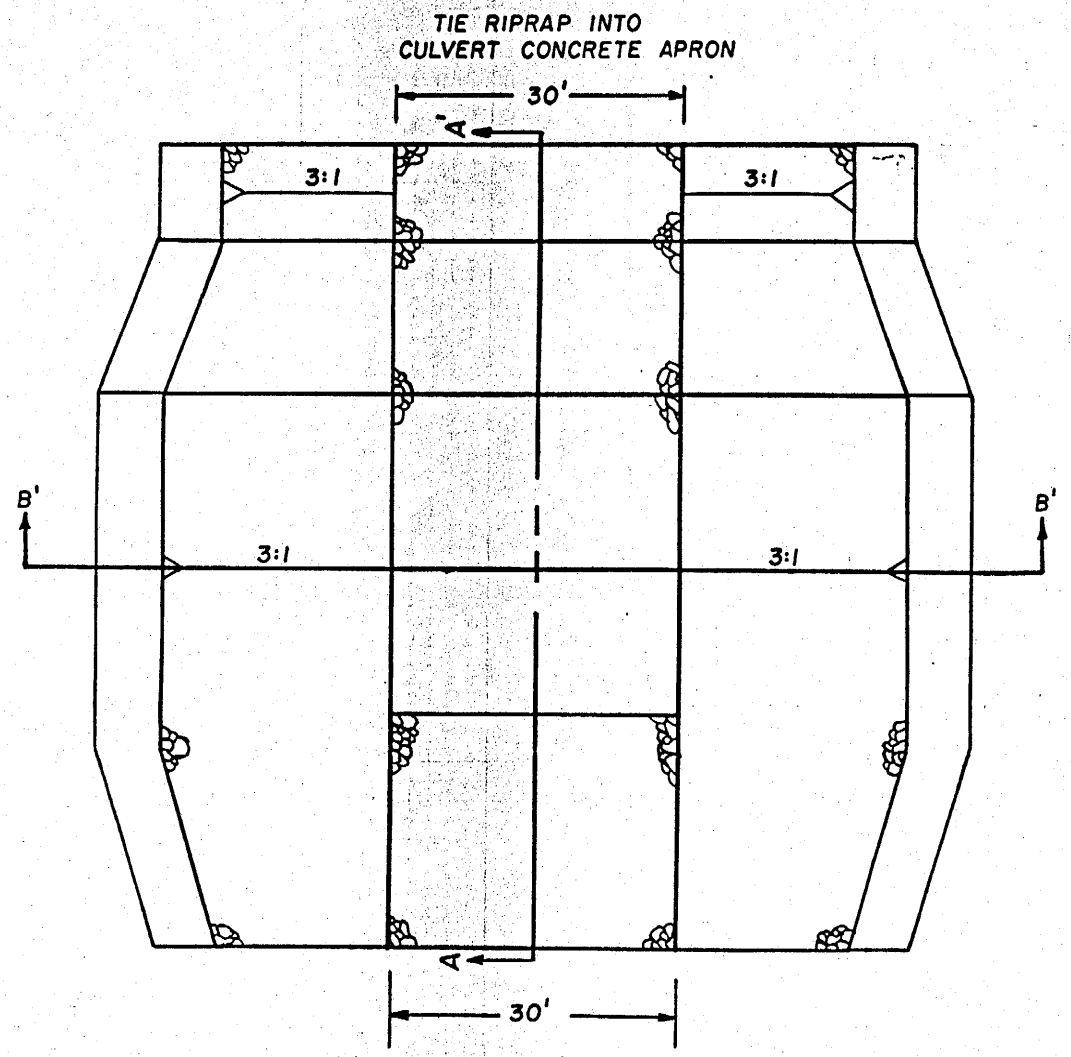
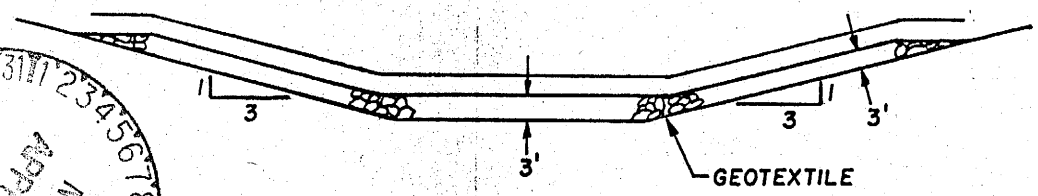
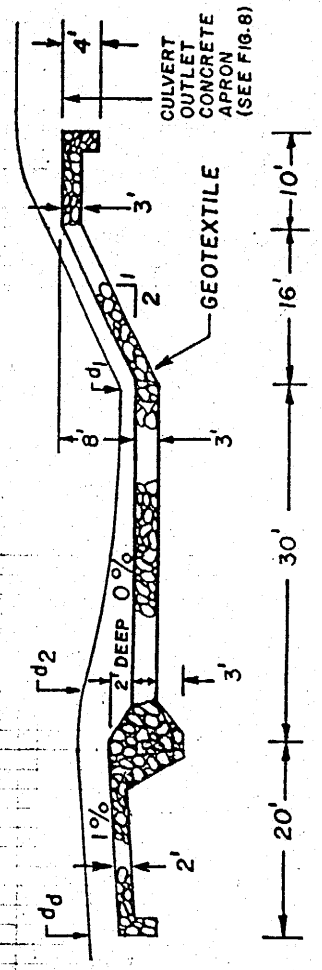
V. Channel Reclamation and Monitoring

A. Introduction. The proposed mining operations in the J-19 coal resource area will encompass subwatersheds on the south side of the existing Reed Valley Wash stream channel. Proposed mining and reclamation operations may extend within 500 feet of the existing





SECTION B-B'



SECTION A-A'

FIGURE 6
TYPICAL RIPRAP CULVERT OUTLET CHANNEL

KAYENTA MINE

PEABODY COAL CO., 1300 SOUTH YALE, FLAGSTAFF, AZ 86001

DESIGNED BY: P.C.C.	SCALE: NOT TO SCALE
DRAWN BY: G.Y.	PHOTO DATE: N/A
CHECKED BY: J.G.S.	DRAWING DATE: 4/15/92
REVISIONS	

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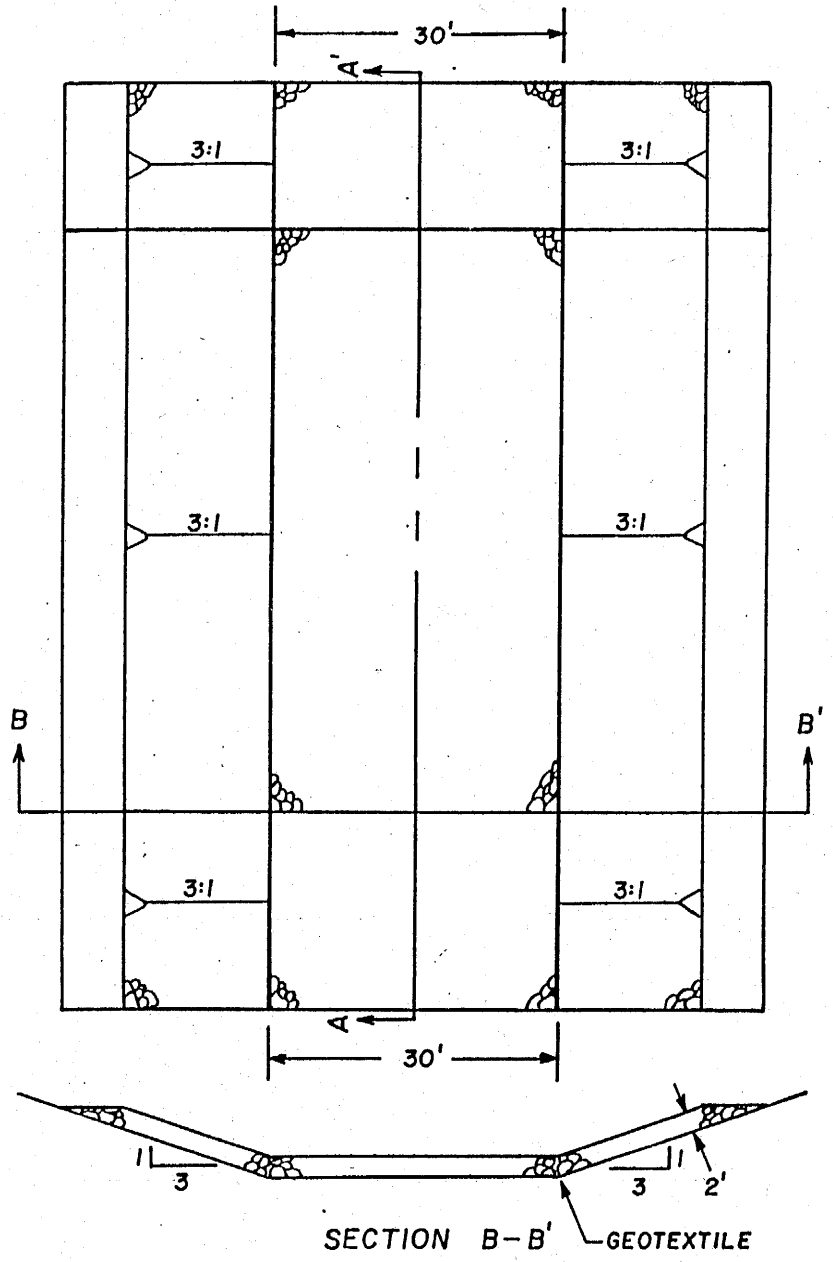

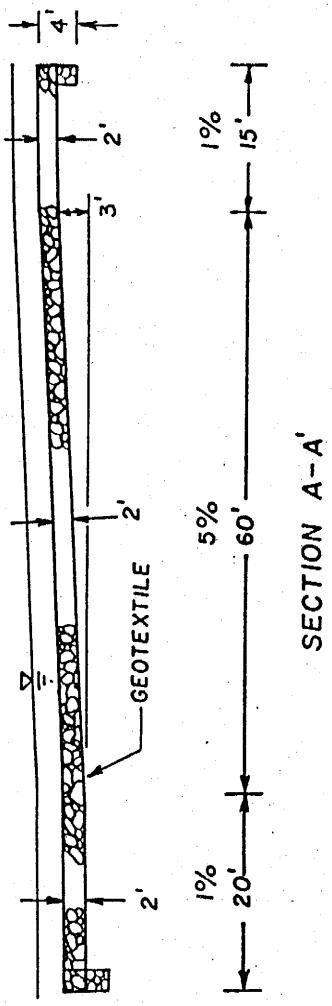

FIGURE 9

TYPICAL RIPRAP DROP STRUCTURE

KAYENTA MINE

PEABODY COAL CO., 1300 SOUTH YALE, FLAGSTAFF, AZ 86001

DESIGNED BY: P.C.C.	SCALE: NOT TO SCALE
DRAWN BY: G.Y.	PHOTO DATE: N/A
CHECKED BY: J.G.S.	DRAWING DATE: 4/15/92
REVISIONS	

stream buffer zones in certain reaches. Peabody proposes to construct a permanent diversion in a portion of the wash upstream and downstream of the J-19 haul road crossing in order to maintain uninterrupted drainage around the mining areas and to facilitate the J-19 haul road corssing of Reed Valley Wash. The location of the diversion is shown on Drawing 85400 (Sheet No. M-9). The design report for the proposed Reed Valley diversion channel is contained in Volume 2, Chapter 6, Attachment C. The diversion is proposed for construction in early 1993.

The information contained herein outlines the soil reconstruction and revegetation plans for affected areas during and after construction of the diversion. As proposed, the diversion will be a permanent structure. Therefore, the reclamation activities described here are designed to be permanent in nature with provisions for maintenance in accordance with activities outlined in the design report, and Chapters 22 and 23 entitled Minesoil Reconstruction and Revegetation Plan, respectively.

B. Soil Reconstruction. The proposed diversion disturbance area, including J-19 ramp area, will be approximately 1,300 feet in length and up to 200 feet in width, or about 6.0 acres in total area. These dimensions include a 150-foot buffer on each end and construction traffic areas located parallel to the alignment. Peabody proposes to redistribute suitable plant growth media over the entire affected area except that portion of the channel which is designed to carry the peak runoff from a 100-year, 6-hour precipitation event and those other portions of the channel which consist of competent material (e.g., rock). This portion of the channel is considered the active channel bed where flow frequency and volume is such that topsoiling is not practical. By not topsoiling the active channel bed, material that would otherwise wash down the conveyance channel to the J16-L sediment control structure will be conserved. The mean width of the active channel and side slopes will be approximately 50 feet plus the 300 feet of ramp area contains the 2.5 acres within the affected area that constitute the active channel which will not receive topsoil. The result is approximately 3.5 acres of topsoil liability area.

The Minesoil Reconstruction Plan (Chapter 22) requires that a minimum of four feet of suitable plant growth material, which includes twelve inches of topsoil, exists on disturbed lands prior to conducting revegetation activities. Approximately 3.5 acre-feet of topsoil material will be required to reclaim the affected area, assuming that construction activities will result in a final graded alignment that has a suitable base from the surface to a depth of 3 feet. Approximately 14 acre-feet of suitable plant

growth material will be required for reclamation if construction activities expose unsuitable noncompetent materials over the entire liability area. The criteria in Table 17, Page 46, Chapter 22 will be used to assess the suitability of materials exposed as a result of construction activities.

Topsoil material availability for the Reed Valley diversion channel, as originally proposed in the 1985 Permit Application Package, was accounted for in the topsoil and supplemental plant growth material planning summary for the J-19 coal resource area (Table 14, Page 34, Chapter 22). Approximately 2,322.6 acre-feet of material is available in mining year block 1991-1995, the majority of which is alluvial material associated with the wash and its side tributaries (Drawing 85305A, Sheet 7, Volume 19). Fifteen percent of this material, or 348.3 acre-feet, is projected to be required for reclamation in the first five years of mining at J-19. The remaining 1,974.3 acre-feet will be available to cover unsuitable graded spoil material or unsuitable, noncompetent materials uncovered during construction of the diversion, on an as-needed basis. The material originally accounted for to reclaim the area affected by construction of the diversion, and the excess material from the J-19 mining area that can be used on an as-needed basis indicates that sufficient plant growth media is available to meet all reclamation requirements.

The proposed channel will be excavated in bed, bank, and terrace materials similar to those of the existing channel. The information regarding the chemical and physical suitability for plant growth on the channel bank materials was collected during the course of conducting the baseline soil investigations. Soil pedon sample sites 13-14 DSS and 13-15 DS (Drawing 85305A, Sheet 7, Volume 9, and Appendix A, Volume 11) are located within or immediately adjacent to the area affected by the diversion. These pits were sampled to depths exceeding twelve feet.

Peabody's soil scientist will sample the final graded surface in accordance with the procedures outlined in Chapter 22. Peabody plans to direct haul all materials needed for minesoil reconstruction. Surface stabilization, erosion control, and soil amendment application procedures will follow those outlined in Chapter 22 and the diversion design report.

C. Revegetation and Maintenance Plan. The following Revegetation and Maintenance Plan was developed in consideration of the specific site and environmental characteristics in the area of the Reed Valley diversion channel. Other primary considerations were the

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long-term erosional stability of the 100-year flood plain, establishment of vegetation within the active channel where possible, and benefits to wildlife in terms of food and cover habitat. Because of the desire to maintain good hydrologic cover for erosion control and structural diversity for wildlife, livestock grazing was not considered as a primary use after permanent revegetation. Grazing is not to be restricted, but the selection of largely unpalatable species should limit this to only incidental use. Chapter 23 "Revegetation Plan" is to be consulted during any review or implementation of the following Revegetation Plan. This plan is based on Chapter 23 and except for specifics as detailed in the following, it is consistent with that chapter.

Approximately six acres will be affected by construction and reclamation activities associated with the Reed Valley diversion channel. This area includes a maximum distance of up to 100 feet either side of the channel centerline and grading disturbance above and below the constructed diversion to properly tie into the undisturbed portions of the Reed Valley drainage. In certain reaches of the diversion where excavation will be into competent bedrock materials, these areas will not be revegetated and should be inherently resistant to erosion. All other reclaimed areas within the affected area of the Reed Valley diversion channel will be topsoiled or have suitable plant growth medium applied and will be permanently revegetated. Any areas in the 100-year food plain channel with suitable plant growth medium are also included.

Upon completion of all final grading and redistribution of suitable topsoil materials, ripping and seedbed preparation activities will commence in the areas above the 100-year, 6-hour active channel area. Areas to be revegetated will be deep ripped to reduce compaction and improve infiltration and enhance rooting depths. All topsoiled areas will be contour disked as the final seedbed preparation prior to seeding.

The following seed mix (Table 7) has been developed with these objectives in mind:

1. Maximize hydrologic cover and erosional stability;
2. Provide for vegetative structural diversity and an adequate level of species diversity;
3. Provide for food and cover habitat benefits to wildlife;
4. Provide for species that are generally unpalatable to livestock after stand establishment and maturity to prevent overgrazing and to minimize erosion.

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TABLE 7

Permanent Diversion Seed Mix

Species		Drilled Rate	PLS Seeds/ft^2
Scientific Name[1]	Common Name	PLS lbs/ac[2]	at Broadcast Rate
Agropyron cristatum(I)	Crested wheatgrass	1.00	6.9
Agropyron elongatum(I)	Tall wheatgrass	3.00	7.2
Agropyron sibericum(I)	Siberian wheatgrass	2.00	6.8
Agropyron smithii(N)	Western wheatgrass	2.00	7.0
Agropyron trichophorum(I)	Pubescent wheatgrass	2.00	4.4
Elymus cinereus(N)	Basin wildrye	2.00	7.2
Sporobolus airoides(N)	Alkali sacaton	0.25	16.0
Sanquisorba minor(I)	Small burnet	3.00	3.6
Sphaeralcea ambigua(N)	Desert globemallow	1.00	9.6
Chrysothamnus nauseosus(N)	Rubber rabbitbrush[3]	0.50	4.5
Sarcobatus vermiculatus(N)	Greasewood	1.00	6.4
Tamarix pentandra(I)	Saltcedar tamarisk[4]	.10	--
	Total:	17.85	79.6
		PLS lbs/ac	PLS seeds/ft^2

[1] N = Native; I = Introduced

[2] Broadcast seeding rate is double the drilled rate

[3] Because of fluffy nature of seed, special handling or separate broadcast seeding may be required

[4] Limited or non-existent seed availability may limit the use of this species to cuttings, seedlings, or transplants.

The following varieties are recommended:

Common Name	Variety or Source
Crested wheatgrass	Ephraim
Tall wheatgrass	Jose
Siberian wheatgrass	P-27
Western wheatgrass	Arriba
Pubescent wheatgrass	Luna
Basin wildrye	Magnar

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Common Name	Variety or Source
Alkali sacaton	Salado
Small burnet	Delar
Desert globemallow	Regional
Rubber rabbitbrush	Regional
Greasewood	Regional
Saltcedar tamarisk	Regional

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Because a number of species in the seed mix outlined in Table 7 are benefited by fall planting or require an "over-wintering" period for best results, the fall planting season (September through December) is the preferred planting period. If a significant period is to occur prior to the fall seeding season (where regrading and topsoil replacement have been completed), a cover crop of barley will be applied at the rates specified in Chapter 23. The stand of annual grain will be mowed prior to development of viable seed if it appears that seed maturity will occur.

As noted, saltcedar tamarisk may not be available as seed or as commercial seedlings. This species will be exclusively planted as cuttings or transplants from native stands in the area if no commercial availability exists. Planting will generally be done during those periods of highest expected precipitation, but dormant season plantings may be made as well.

Seeding will be accomplished using broadcast seeders or drill seeding equipment. The broadcast seeder is attached to a farm tractor with a harrow pulled behind the tractor to lightly cover the seed. Broadcast seeding will be used for areas where site or equipment limitations would restrict drill seeding or where the seeding of certain species would be better facilitated by broadcast seeding. Drill seeding using Truax and Laird Rangeland drills will be the preferred method of seeding. Wherever practicable, all seeding operations will be performed on the contour.

Mulching will be conducted on all slopes which are 5:1 or steeper. Wheat straw will be applied at a rate of 1.5 tons per acre using Reinco Model 80-C or Mulchmaster drum type mulchers. The mulch will be anchored by crimping or through the use of various commercially available tackifying agents.

Fertilization will be carried out based on the results of soil tests performed on regraded

and retopsoiled areas. If testing indicates phosphorus deficiencies, this nutrient will be applied at the required rates after topsoiling, but prior to disking and seeding. Nitrogen is applied at the specified rates one to three growing seasons after seeding as a top dressing. This is done to discourage excessive early weed growth and maximize benefits to desirable perennial vegetation.

The revegetated areas will be included in Peabody's Maintenance and Management program as detailed in Chapter 23. The reclaimed areas will be monitored for success and effectiveness of revegetation based on the objectives outlined earlier and the various regulatory requirements. Maintenance and management includes: 1) reseeding, planting, or interseeding; 2) fertilization; 3) weed control where necessary; 4) monitoring for rills and gullies and repair when necessary; and 5) fencing.

The Revegetation and Maintenance Plan presented in this section, along with Chapter 23, will provide for establishment of a permanent and effective vegetative cover sufficient in diversity for the postmine land uses. As stated earlier, the approximate six revegetated acres associated with reclamation of this permanent diversion will primarily benefit wildlife. This is consistent with the overall reclamation objective of enhancing wildlife habitat where possible on lands affected by mining on the Black Mesa leasehold.

Revegetation success standards for ground cover, production, and shrub density as presented in Chapter 23 will be applied to the revegetated areas associated with reclamation of the Reed Valley diversion channel. The procedures to be used for determination of revegetation success during the required ten-year liability period are also presented in Chapter 23.

D. Monitoring Plan. Any necessary design changes that vary significantly from design features included in this report will be submitted to OSMRE as a technical revision for approval before construction commences. A qualified registered professional engineer or other qualified personnel under the professional engineer's supervision will inspect the diversion regularly during construction and upon completion of construction. Minor alignment changes and as-built site condition will be included in the as-built certified drawings prepared under the supervision of a registered professional engineer.

After construction, Peabody would expect some aggradation and degradation of the active channel area until the vegetation has been established and the low flow channel meandering

establishes itself. If the meandering creates excessive erosion beyond the limits of the high flow channel, Peabody will repair and maintain this portion of the channel with riprap or other nonerodible material in accordance with standard engineering practice.

Peabody has numerous personnel including engineers, technicians, environmental scientists, operations, and reclamation personnel that work within the permit area on a scheduled basis who will be observing the condition of the diversion on a periodic basis. In addition, Peabody will include the new diversion with the hydrological monitoring already being undertaken in the undisturbed portions of the Reed Valley Wash. The hydrological monitoring and reporting will be consistent with the reporting procedures in the Annual Hydrology Report and the procedures described in the Hydrologic Monitoring Program found in Chapter 16, Volume 11 of the Black Mesa PAP.

VI. References

Chow, V.T., 1959, Open-Channel Hydraulics, McGraw-Hill Book Company, New York.

Code of Federal Regulations, 30 CFR, Article 816.43, Diversions; 701.5; and 816.151C, July 1, 1986.

Dames & Moore, Report on the Hydraulic Design of Reed Valley Channel Diversion, November 10, 1987.

Lee, L.T. and T.L. Essex, 1983, Urban Headwater Flooding Damage Potential, Journal of Hydraulic Engineering, ASCE, Vol. 109, No. 9, April, 1983, Pages 519-535.

National Oceanic and Atmospheric Administration (NOAA), 1973, Precipitation Frequency Atlas of the Western United States, Vol. III, Arizona, NOAA Atlas-2, 1973, Silver Springs, Maryland.

Office of Surface Mining (OSM), 1982a, Surface Mining Water Diversion Design Manual, U.S. Department of the Interior, OSM/TR-82/2.

Office of Surface Mining (OSM), 1982b, Surface Water Hydrology and Sedimentology Manual, U.S. Department of the Interior.

U.S. Bureau of Reclamation (USBR), 1977, Design of Small Dams, Denver, Colorado.

U.S. Department of Transportation (USDOT), April, 1970, Hydraulic Engineering Circular (HEC) No. 11, Use of Riprap for Bank Protection.

University of Kentucky, College of Agriculture/Civil Software Design. SEDCAD+ User's Manual by Schwab and Warner. 1988 and 1992.

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APPENDIX A

SEDCAD+ Computer Runs

(10-Year, 6-Hour Event)

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CIVIL SOFTWARE DESIGN

SEDCAD+ Version 3

REED VALLEY DIVERSION & J-19 HAUL ROAD CMP, 10-YR.,6-HR.STORM

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by

Name: JGS

Company Name: Peabody Coal Company
File Name: E:\SEDCAD3\K-MINE\RVDIV10

Date: 05-15-1992

Civil Software Design -- SEDCAD+ Version 3.1
Copyright (C) 1987-1992. Pamela J. Schwab. All rights reserved.

Company Name: Peabody Coal Company
Filename: E:\SEDCAD3\K-MINE\RVDIV10 User: JGS
Date: 05-15-1992 Time: 12:02:22
REED VALLEY DIVERSION & J-19 HAUL ROAD CMP, 10-YR.,6-HR.STORM
Storm: 1.60 inches, 10 year- 6 hour, SCS Type II
Hydrograph Convolution Interval: 0.1 hr

SUBWATERSHED/STRUCTURE INPUT/OUTPUT TABLE

-Hydrology-

JBS	SWS	Area (ac)	CN	UHS	Tc (hrs)	K (hrs)	X	Base-Flow (cfs)	Runoff Volume (ac-ft)	Peak Discharge (cfs)
111	1	2340.47	78	M	1.010	0.000	0.000	0.0	54.27	271.12
		Type: Null		Label: RV DIV.& J-19 H.RD.						
111	Structure	2340.47							54.27	
111	Total IN/OUT	2340.47							54.27	271.12

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APPENDIX B

SEDCAD+ Computer Runs

(100-Year, 6-Hour Event)

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CIVIL SOFTWARE DESIGN

SEDCAD+ Version 3

REED VALLEY DIVERSION & J-19 HAUL ROAD CMP,100-YR.,6-HR. STORM

NOV 1992
APPROVED

by

Name: JGS

Company Name: Peabody Coal Company
File Name: E:\SEDCAD3\K-MINE\RVDIV100

Date: 05-15-1992

Civil Software Design -- SEDCAD+ Version 3.1
Copyright (C) 1987-1992. Pamela J. Schwab. All rights reserved.

Company Name: Peabody Coal Company
Filename: E:\SEDCAD3\K-MINE\RVDIV100 User: JGS
Date: 05-15-1992 Time: 12:02:25
REED VALLEY DIVERSION & J-19 HAUL ROAD CMP,100-YR.,6-HR. STORM
Storm: 2.40 inches, 100 year- 6 hour, SCS Type II
Hydrograph Convolution Interval: 0.1 hr

SUBWATERSHED/STRUCTURE INPUT/OUTPUT TABLE

-Hydrology-

JBS	SWS	Area (ac)	CN	UHS	Tc (hrs)	K (hrs)	X	Base-Flow (cfs)	Runoff Volume (ac-ft)	Peak Discharge (cfs)
111	1	2340.47	78	M	1.010	0.000	0.000	0.0	141.18	795.59
		Type: Null		Label: RV DIV. & J-19 H.RD.						
111	Structure	2340.47							141.18	
111	Total IN/OUT	2340.47							141.18	795.59

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APPENDIX C

Hydraulic Calculations

(10-Year, 6-Hour Event)

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TRAPEZOIDAL CHANNEL ANALYSIS
CRITICAL DEPTH COMPUTATION

May 11, 1992
REED VALLEY DIVERSION

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PROGRAM INPUT DATA:

DESCRIPTION	VALUE
Flow Rate (cubic feet per second)	271.1
Manning's Roughness Coefficient (n-value)	0.0300
Channel Side Slope - Left Side (horizontal/vertical)	3.00
Channel Side Slope - Right Side (horizontal/vertical)	3.00
Channel Bottom Width (feet)	30.0

PROGRAM RESULTS:

DESCRIPTION	VALUE
Critical Depth (feet)	1.30
Critical Slope (feet per foot)	0.0126
Flow Velocity (feet per second)	6.13
Froude Number	1.000
Velocity Head (feet)	0.58
Energy Head (feet)	1.89
Cross-Sectional Area of Flow (square feet)	44.20
Top Width of Flow (feet)	37.82

TRAPEZOIDAL CHANNEL ANALYSIS COMPUTER PROGRAM, Version 1.3 (c) 1986
Dodson & Associates, Inc., 7015 W. Tidwell, #107, Houston, TX 77092
(713) 895-8322. A manual with equations & flow chart is available.

SEDCAD+ RIPRAP CHANNEL DESIGN

REED VALLEY DIVERSION

INPUT VALUES:

Shape	TRAPEZOIDAL	
Discharge	271.10 cfs	
Slope	1.00 %	
Sideslopes (L and R)	3.00:1	3.00:1
Bottom Width	30.00 feet	
Freeboard	1 ft	

RESULTS:

Mild Slope Design

Depth	1.59 ft
with Freeboard	2.59 ft
Top Width	39.54 ft
with Freeboard	45.54 ft
Velocity	4.91 fps
Cross Sectional Area	55.27 sq ft
Hydraulic Radius	1.38 ft
Manning's n	0.038
Froude Number	0.73
Dmax	1.500 ft (18.00 in)
D50	0.750 ft (9.00 in)
D10	0.250 ft (3.00 in)

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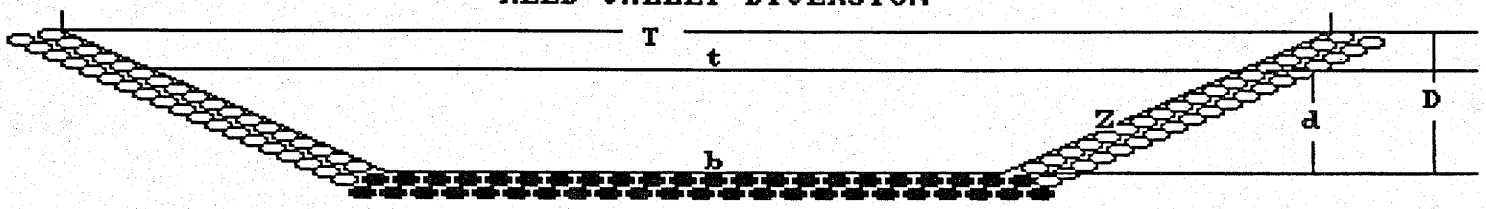
SEDCAD+ CHANNEL DESIGN
REED VALLEY DIVERSION



Riprap - Mild Slope Design

					w/ Freeboard
Discharge	= 271.10 cfs		Depth (d)	= 1.59	(D = 2.59
Bottom (b)	= 30.00 ft		Top width (t)	= 39.54	(T = 45.54
Side slopes (Z)	= 3.0:1(L) 3.0:1(R)		Velocity	= 4.91 fps	
Bed Slope	= 1.00 %		Hydraulic Radius	= 1.38 ft	
Manning's n	= 0.038		Froude number	= 0.73	

Dmax = 1.50 ft (18.00 in)
D50 = 0.75 ft (9.00 in)
D10 = 0.25 ft (3.00 in)

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SEDCAD+ NONERODIBLE CHANNEL DESIGN

REED VALLEY DIVERSION

INPUT VALUES:

Shape	TRAPEZOIDAL	
Discharge	271.10 cfs	
Slope	1.00 %	
Sideslopes	3.00:1 (L)	3.00:1 (R)
Bottom Width	30.00 ft	
Manning's n	0.030	
Material	OTHER	
Freeboard	1 ft	

RESULTS:

Depth	1.39 ft
with Freeboard	2.39 ft
Top Width	38.36 ft
with Freeboard	44.36 ft
Velocity	5.69 fps
Cross Sectional Area	47.62 sq ft
Hydraulic Radius	1.23 ft
Froude Number	0.90

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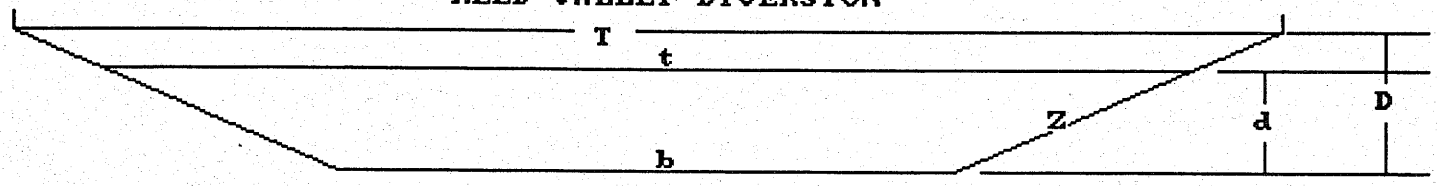
SEDCAD+ CHANNEL DESIGN
REED VALLEY DIVERSION



MATERIAL: OTHER

Discharge	= 271.10 cfs		Depth (d)	= 1.39	w/ Freeboard (D = 2.39
Bottom (b)	= 30.00 ft		Top width (t)	= 38.36	(T = 44.36
Side slopes (Z)	= 3.0:1(L)	3.0:1(R)	Velocity	= 5.69 fps	
Bed Slope	= 1.00 %		Hydraulic Radius	= 1.23 ft	
Manning's n	= 0.030		Froude number	= 0.90	

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SEDCAD+ RIPRAP CHANNEL DESIGN

REED VALLEY DIVERSION

INPUT VALUES:

Shape	TRAPEZOIDAL	
Discharge	271.10 cfs	
Slope	5.00 %	
Sideslopes (L and R)	3.00:1	3.00:1
Bottom Width	30.00 feet	
Freeboard	1 ft	

RESULTS:

Steep Slope Design - PADER Method

Depth	1.15 ft	
with Freeboard	2.15 ft	
Top Width	36.88 ft	
with Freeboard	42.88 ft	
Velocity	7.07 fps	
Cross Sectional Area	38.32 sq ft	
Hydraulic Radius	1.03 ft	
Manning's n	0.048	
Froude Number	1.22	
Dmax	0.625 ft	(7.50 in)
D50	0.500 ft	(6.00 in)
D10	0.167 ft	(2.00 in)

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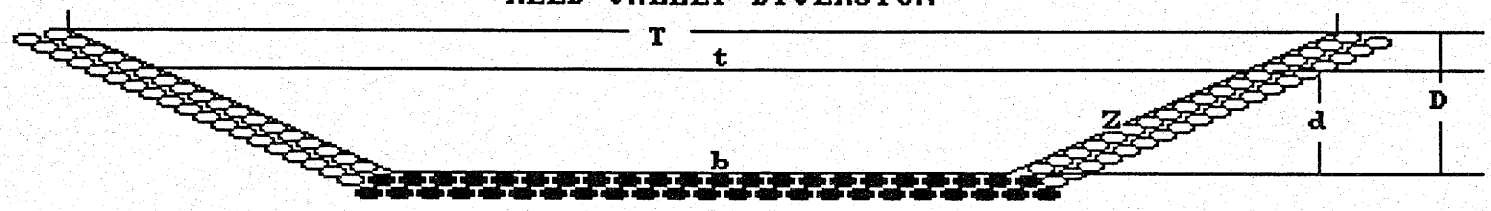
SEDCAD+ CHANNEL DESIGN
REED VALLEY DIVERSION



Riprap - Steep Slope Design - PADER Method

						w/ Freeboard	
Discharge	= 271.10 cfs		Depth (d)	=	1.15	(D =	2.15
Bottom (b)	= 30.00 ft		Top width (t)	=	36.88	(T =	42.88
Side slopes (Z)	= 3.0:1(L)	3.0:1(R)	Velocity	=	7.07 fps		
Bed Slope	= 5.00 %		Hydraulic Radius	=	1.03 ft		
Manning's n	= 0.048		Froude number	=	1.22		

Dmax = 0.63 ft (7.50 in)
D50 = 0.50 ft (6.00 in)
D10 = 0.17 ft (2.00 in)

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SEDCAD+ RIPRAP CHANNEL DESIGN

REED VALLEY DIVERSION

INPUT VALUES:

Shape	TRAPEZOIDAL	
Discharge	271.10 cfs	
Slope	50.00 %	
Sideslopes (L and R)	3.00:1	3.00:1
Bottom Width	30.00 feet	
Freeboard	1.0 ft	

RESULTS:

Steep Slope Design - PADER Method

Depth	0.73 ft
with Freeboard	1.73 ft
Top Width	34.36 ft
with Freeboard	40.36 ft
Velocity	11.59 fps
Cross Sectional Area	23.39 sq ft
Hydraulic Radius	0.68 ft
Manning's n	0.070
Froude Number	2.48
Dmax	1.250 ft (15.00 in)
D50	1.000 ft (12.00 in)
D10	0.333 ft (4.00 in)

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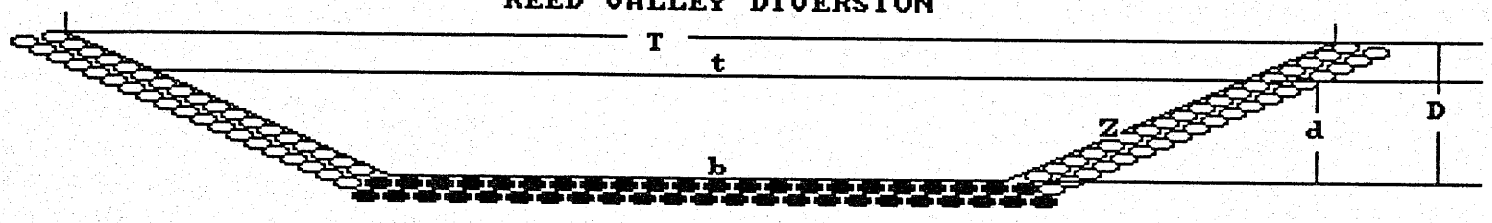
SEDCAD+ CHANNEL DESIGN
REED VALLEY DIVERSION



Riprap - Steep Slope Design - PADER Method

Discharge	≡ 271.10 cfs		Depth (d)	≡ 0.73	w/ Freeboard (D = 1.73
Bottom (b)	≡ 30.00 ft		Top width (t)	≡ 34.36	(T = 40.36
Side slopes (Z)	≡ 3.0:1(L)	3.0:1(R)	Velocity	≡ 11.59 fps	
Bed Slope	≡ 50.00 %		Hydraulic Radius	≡ 0.68 ft	
Manning's n	≡ 0.070		Froude number	≡ 2.48	

Dmax = 1.25 ft (15.00 in)
D50 = 1.00 ft (12.00 in)
D10 = 0.33 ft (4.00 in)

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SEDCAD+ RIPRAP CHANNEL DESIGN

RECLAIMED #P0266

INPUT VALUES:

Shape	TRAPEZOIDAL	
Discharge	271.10 cfs	
Slope	3.00 %	
Sideslopes (L and R)	3.00:1	3.00:1
Bottom Width	30.00 feet	
Freeboard	1 ft	

RESULTS:

Steep Slope Design - PADER Method

Depth	1.23 ft
with Freeboard	2.23 ft
Top Width	37.38 ft
with Freeboard	43.38 ft
Velocity	6.54 fps
Cross Sectional Area	41.47 sq ft
Hydraulic Radius	1.10 ft
Manning's n	0.042
Froude Number	1.09
Dmax	0.625 ft (7.50 in)
D50	0.500 ft (6.00 in)
D10	0.167 ft (2.00 in)

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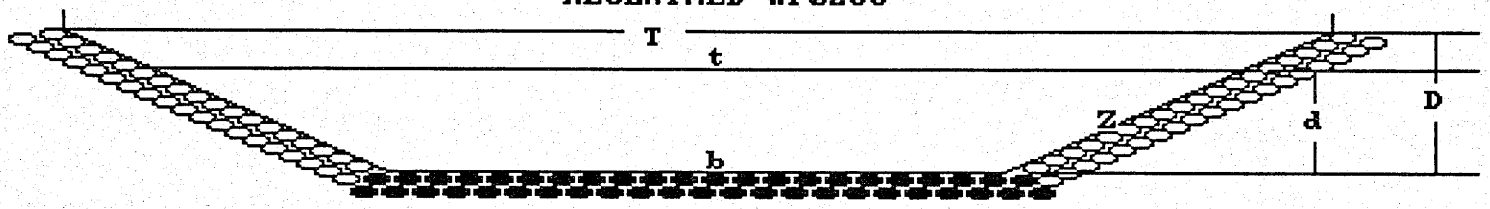
SEDCAD+ CHANNEL DESIGN
RECLAIMED #P0266



Riprap - Steep Slope Design - PADER Method

							w/ Freeboard
Discharge	=	271.10 cfs	Depth (d)	=	1.23	(D =	2.23
Bottom (b)	=	30.00 ft	Top width (t)	=	37.38	(T =	43.38
Side slopes (Z)	=	3.0:1(L) 3.0:1(R)	Velocity	=	6.54 fps		
Bed Slope	=	3.00 %	Hydraulic Radius	=	1.10 ft		
Manning's n	=	0.042	Froude number	=	1.09		

Dmax = 0.63 ft (7.50 in)
D50 = 0.50 ft (6.00 in)
D10 = 0.17 ft (2.00 in)

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APPENDIX D

Hydraulic Calculations

(100-Year, 6-Hour Event)

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TRAPEZOIDAL CHANNEL ANALYSIS
CRITICAL DEPTH COMPUTATION

May 11, 1992
REED VALLEY DIVERSION

==========

PROGRAM INPUT DATA:

DESCRIPTION	VALUE
Flow Rate (cubic feet per second)	795.6
Manning's Roughness Coefficient (n-value)	0.0300
Channel Side Slope - Left Side (horizontal/vertical)	3.00
Channel Side Slope - Right Side (horizontal/vertical)	3.00
Channel Bottom Width (feet)	30.0

==========

PROGRAM RESULTS:

DESCRIPTION	VALUE
Critical Depth (feet)	2.55
Critical Slope (feet per foot)	0.0105
Flow Velocity (feet per second)	8.27
Froude Number	1.000
Velocity Head (feet)	1.06
Energy Head (feet)	3.62
Cross-Sectional Area of Flow (square feet)	96.23
Top Width of Flow (feet)	45.33

==========

TRAPEZOIDAL CHANNEL ANALYSIS COMPUTER PROGRAM, Version 1.3 (c) 1986 Dodson & Associates, Inc., 7015 W. Tidwell, #107, Houston, TX 77092 (713) 895-8322. A manual with equations & flow chart is available.

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SEDCAD+ RIPRAP CHANNEL DESIGN

REED VALLEY DIVERSION

INPUT VALUES:

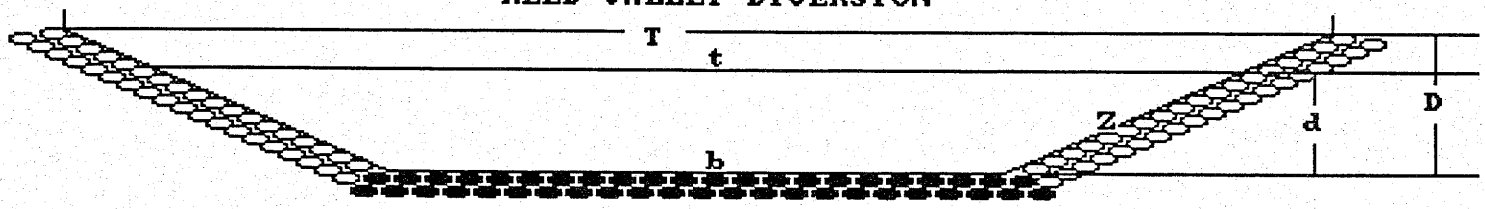
Shape	TRAPEZOIDAL	
Discharge	795.60 cfs	
Slope	1.00 %	
Sideslopes (L and R)	3.00:1	3.00:1
Bottom Width	30.00 feet	
Freeboard	1 ft	

RESULTS:

Mild Slope Design

Depth	2.93 ft
with Freeboard	3.93 ft
Top Width	47.61 ft
with Freeboard	53.61 ft
Velocity	6.99 fps
Cross Sectional Area	113.89 sq ft
Hydraulic Radius	2.35 ft
Manning's n	0.038
Froude Number	0.80
Dmax	1.500 ft (18.00 in)
D50	0.750 ft (9.00 in)
D10	0.250 ft (3.00 in)

SEDCAD+ CHANNEL DESIGN
REED VALLEY DIVERSION



Riprap - Mild Slope Design

Discharge	= 795.60 cfs	Depth (d)	= 2.93	w/ Freeboard (D =	3.93
Bottom (b)	= 30.00 ft	Top width (t)	= 47.61	(T =	53.61
Side slopes (Z)	= 3.0:1(L) 3.0:1(R)	Velocity	= 6.99 fps		
Bed Slope	= 1.00 %	Hydraulic Radius	= 2.35 ft		
Manning's n	= 0.038	Froude number	= 0.80		

Dmax = 1.50 ft (18.00 in)
D50 = 0.75 ft (9.00 in)
D10 = 0.25 ft (3.00 in)

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SEDCAD+ NONERODIBLE CHANNEL DESIGN

REED VALLEY DIVERSION

INPUT VALUES:

Shape	TRAPEZOIDAL	
Discharge	795.60 cfs	
Slope	1.00 %	
Sideslopes	3.00:1 (L)	3.00:1 (R)
Bottom Width	30.00 ft	
Manning's n	0.030	
Material	OTHER	
Freeboard	1 ft	

RESULTS:

Depth	2.58 ft
with Freeboard	3.58 ft
Top Width	45.50 ft
with Freeboard	51.50 ft
Velocity	8.16 fps
Cross Sectional Area	97.53 sq ft
Hydraulic Radius	2.10 ft
Froude Number	0.98

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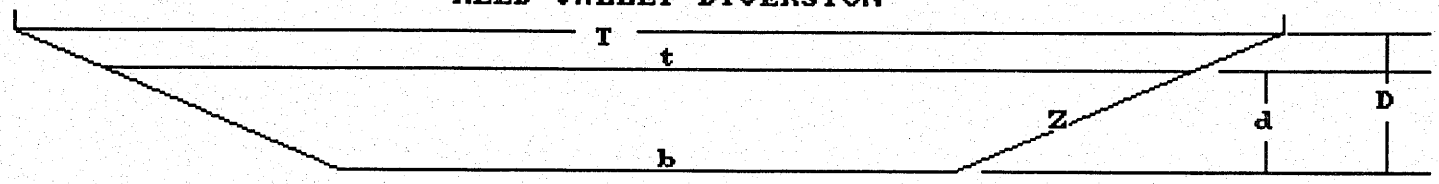
SEDCAD+ CHANNEL DESIGN
REED VALLEY DIVERSION



MATERIAL: OTHER

Discharge	= 795.60 cfs		Depth (d)	= 2.58	w/ Freeboard (D = 3.58
Bottom (b)	= 30.00 ft		Top width (t)	= 45.50	(T = 51.50
Side slopes (Z)	= 3.0:1(L)	3.0:1(R)	Velocity	= 8.16 fps	
Bed Slope	= 1.00 %		Hydraulic Radius	= 2.10 ft	
Manning's n	= 0.030		Froude number	= 0.98	

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SEDCAD+ RIPRAP CHANNEL DESIGN

REED VALLEY DIVERSION

INPUT VALUES:

Shape	TRAPEZOIDAL	
Discharge	795.60 cfs	
Slope	5.00 %	
Sideslopes (L and R)	3.00:1	3.00:1
Bottom Width	30.00 feet	
Freeboard	1.0 ft	

RESULTS:

Steep Slope Design - PADER Method

Depth	2.16 ft
with Freeboard	3.16 ft
Top Width	42.97 ft
with Freeboard	48.97 ft
Velocity	10.08 fps
Cross Sectional Area	78.89 sq ft
Hydraulic Radius	1.81 ft
Manning's n	0.049
Froude Number	1.31
Dmax	0.938 ft (11.25 in)
D50	0.750 ft (9.00 in)
D10	0.250 ft (3.00 in)

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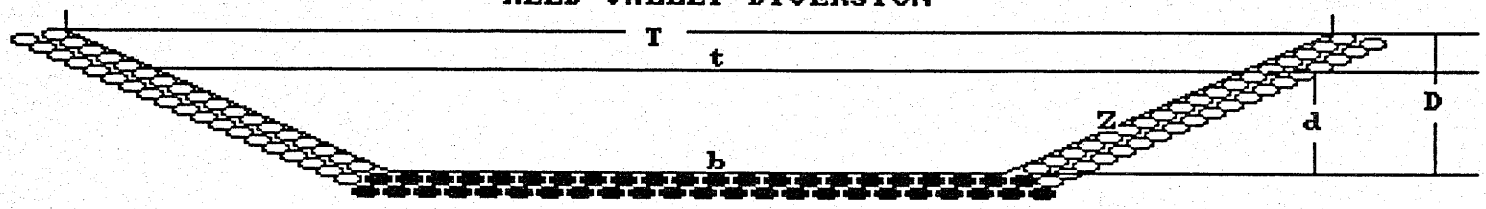
SEDCAD+ CHANNEL DESIGN
REED VALLEY DIVERSION



Riprap - Steep Slope Design - PADER Method

					w/ Freeboard
Discharge	= 795.60 cfs	Depth (d)	= 2.16	(D =	3.16
Bottom (b)	= 30.00 ft	Top width (t)	= 42.97	(T =	48.97
Side slopes (Z)	= 3.0:1(L) 3.0:1(R)	Velocity	= 10.08 fps		
Bed Slope	= 5.00 %	Hydraulic Radius	= 1.81 ft		
Manning's n	= 0.049	Froude number	= 1.31		

Dmax = 0.94 ft (11.25 in)
D50 = 0.75 ft (9.00 in)
D10 = 0.25 ft (3.00 in)

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SEDCAD+ RIPRAP CHANNEL DESIGN

REED VALLEY DIVERSION

INPUT VALUES:

Shape	TRAPEZOIDAL	
Discharge	795.60 cfs	
Slope	50.00 %	
Sideslopes (L and R)	3.00:1	3.00:1
Bottom Width	30.00 feet	
Freeboard	1.0 ft	

RESULTS:

Steep Slope Design - PADER Method

Depth	1.46 ft
with Freeboard	2.46 ft
Top Width	38.74 ft
with Freeboard	44.74 ft
Velocity	15.90 fps
Cross Sectional Area	50.05 sq ft
Hydraulic Radius	1.28 ft
Manning's n	0.078
Froude Number	2.46
Dmax	1.875 ft (22.50 in)
D50	1.500 ft (18.00 in)
D10	0.500 ft (6.00 in)

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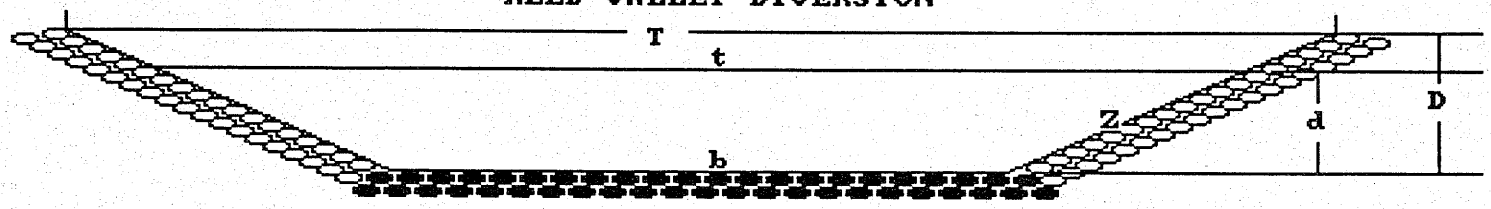
SEDCAD+ CHANNEL DESIGN
REED VALLEY DIVERSION



Riprap - Steep Slope Design - PADER Method

Discharge	=	795.60 cfs	Depth (d)	=	1.46	(D =	w/ Freeboard 2.46
Bottom (b)	=	30.00 ft	Top width (t)	=	38.74	(T =	44.74
Side slopes (Z)	=	3.0:1(L) 3.0:1(R)	Velocity	=	15.90 fps		
Bed Slope	=	50.00 %	Hydraulic Radius	=	1.28 ft		
Manning's n	=	0.078	Froude number	=	2.46		

Dmax = 1.88 ft (22.50 in)
D50 = 1.50 ft (18.00 in)
D10 = 0.50 ft (6.00 in)

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SEDCAD+ RIPRAP CHANNEL DESIGN

RECLAIMED #P0266

INPUT VALUES:

Shape	TRAPEZOIDAL	
Discharge	795.60 cfs	
Slope	3.00 %	
Sideslopes (L and R)	3.00:1	3.00:1
Bottom Width	30.00 feet	
Freeboard	1 ft	

RESULTS:

Steep Slope Design - PADER Method

Depth	2.35 ft
with Freeboard	3.35 ft
Top Width	44.11 ft
with Freeboard	50.11 ft
Velocity	9.13 fps
Cross Sectional Area	87.14 sq ft
Hydraulic Radius	1.94 ft
Manning's n	0.044
Froude Number	1.14
Dmax	0.938 ft (11.25 in)
D50	0.750 ft (9.00 in)
D10	0.250 ft (3.00 in)

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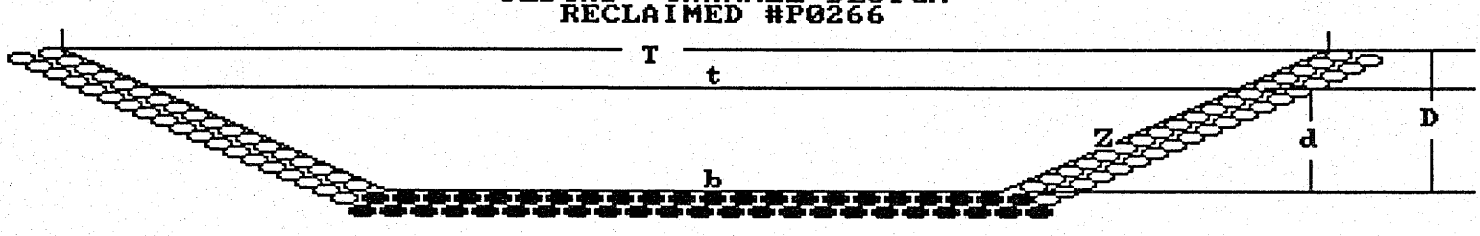
SEDCAD+ CHANNEL DESIGN
RECLAIMED #P0266



Riprap - Steep Slope Design - PADER Method

						w/ Freeboard	
Discharge	= 795.60 cfs		Depth (d)	=	2.35	(D =	3.35
Bottom (b)	= 30.00 ft		Top width (t)	=	44.11	(T =	50.11
Side slopes (Z)	= 3.0:1(L)	3.0:1(R)	Velocity	=	9.13 fps		
Bed Slope	= 3.00 %		Hydraulic Radius	=	1.94 ft		
Manning's n	= 0.044		Froude number	=	1.14		

Dmax = 0.94 ft (11.25 in)
D50 = 0.75 ft (9.00 in)
D10 = 0.25 ft (3.00 in)

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Culvert: Outlet Channel

Riprap Drop Structure

Design Calculations

Date: (see Chapter 6, Attachment C, Figure 6)

Q_{100} = 795.6 cfs

b = 30 feet

Z = 3:1

d_c = 2.55′

Drop Height = 8′

Channel Slope = 50%

Downstream d_d = 2.93 ft.

Downstream Channel Slope = 1%

Downstream Channel Velocity = 6.99 fps

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Solution:

- Use a trapezoidal section drop. The cross-section is the same as the channel cross-section.
- Use a 50% slope at the drop. Assume no head loss through the sloped drop.

Determined by d_1:

$$H = d_2 + \frac{V2^2}{2g} = 2.93' + \frac{(6.99)^2}{2(32.2)} = 3.69'$$

Head available at toe of slope:

8′ + 3.69′ = 11.69′

Let d_1 be at the toe of slope:

b = 30′ $\qquad$ d_1 = 1.46′

s = 50% $\qquad$ V_1 = 15.9 fps

n = 0.078 (Sedcad+ Calc.) $\qquad$ F_1 = 2.46

Determine d_2:

$$\frac{d_2}{d_1} = 0.5\left(\sqrt{1 + 8F_1^2} - 1\right)$$

$$= 0.5\left(\sqrt{1 + 8(2.46)^2} - 1\right) = 3.01'$$

$$d_2 = 3.01\,(d_1) = 3.01\,(1.46)$$

$$= 4.39'$$

Determine the jump length from Figure 7 (Length of jump in terms of d_2 (Basin I)

$$\frac{L}{d_2} = 4.85$$

$$L = 4.85\ (d_2) = 4.85\ (4.39) = 21.3 \text{ ft.}$$

Use 30 ft.

The basin should be set at

$d_2 - d_d$ = depth below downstream channel

4.39′ - 2.93′ = 1.46′ use 2′

below the downstream channel bed.

Upstream and downstream length of structure

$Lu = 2H = 2\ (3.69') = 7.4'$ Use 10′

$Ld = 2d_2 = 2\ (4.85') = 9.7'$ Use 20′

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Riprap Size (Sedcad+ Calc.):

D_{max} = 22.5 in.

D_{50} = 18 in.

D_{10} = 6 in.

Thickness 2 (D_{50}) = 3 ft. thick

Let cutoff riprap wall upstream and downstream be the same size.

d_{cw} = Cutoff Wall Depth

$$d_{cw} = 1/2(d_2) = 1/2\ (4.39') = 2.2' \text{ Use } 3'$$

Ref: Surface Water Hydrology and Sedimentology Manual, by J.F. Sato, Simons, LI and Shepherd, March 1981

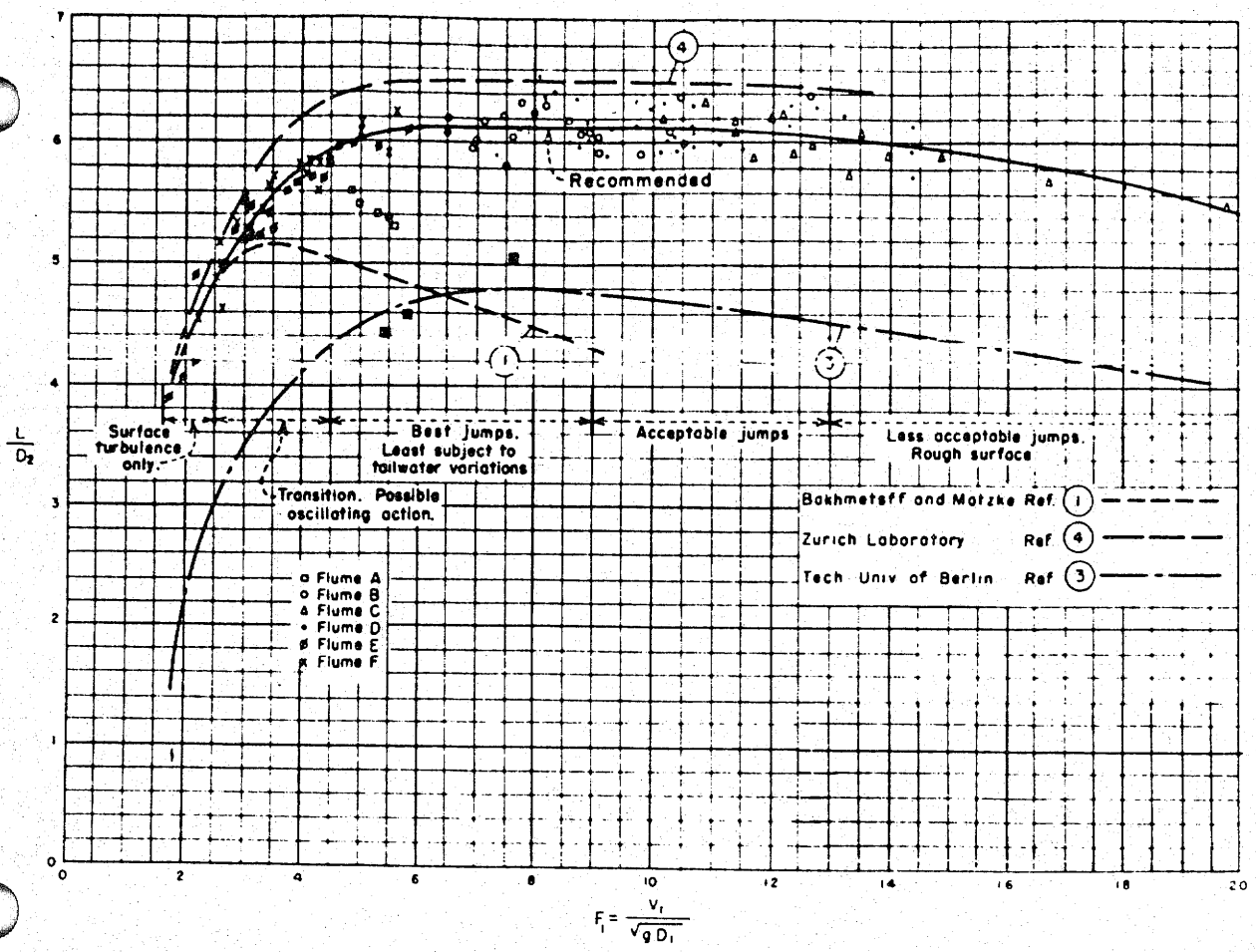

FIGURE 7.—*Length of jump in terms of D_2 (Basin I).*

Reference:

U.S. Bureau of Reclamation, Hydraulic Design of Stilling Basins and Energy Dissipators, 1983.

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Riprap Drop Structure

Design Calculations

Data: (See Chapter 6, Attachment C, Figure 9)

Q_{100} = 795.6 cfs

b = 30′

z = 3:1

Drop Height = 3′

Channel Slope = 5%

Downstream d = 2.93′

Downstream Channel Slope = 1%

Solution:

Length of Structure:

$L = L_u + L_s + L_d$

L_u = 5 x Downstream d

= 5 x 2.93 = 14.6 <u>Use 15′</u>

L_s = H/S = 3′/0.05 = <u>60′</u>

$L_d = L_u$ Use L_d = 20′

L = 15′ + 60′ + 20′ = 95′

Riprap sizing for Q_{100} = 795.6 cfs:

D_{max} = 12"

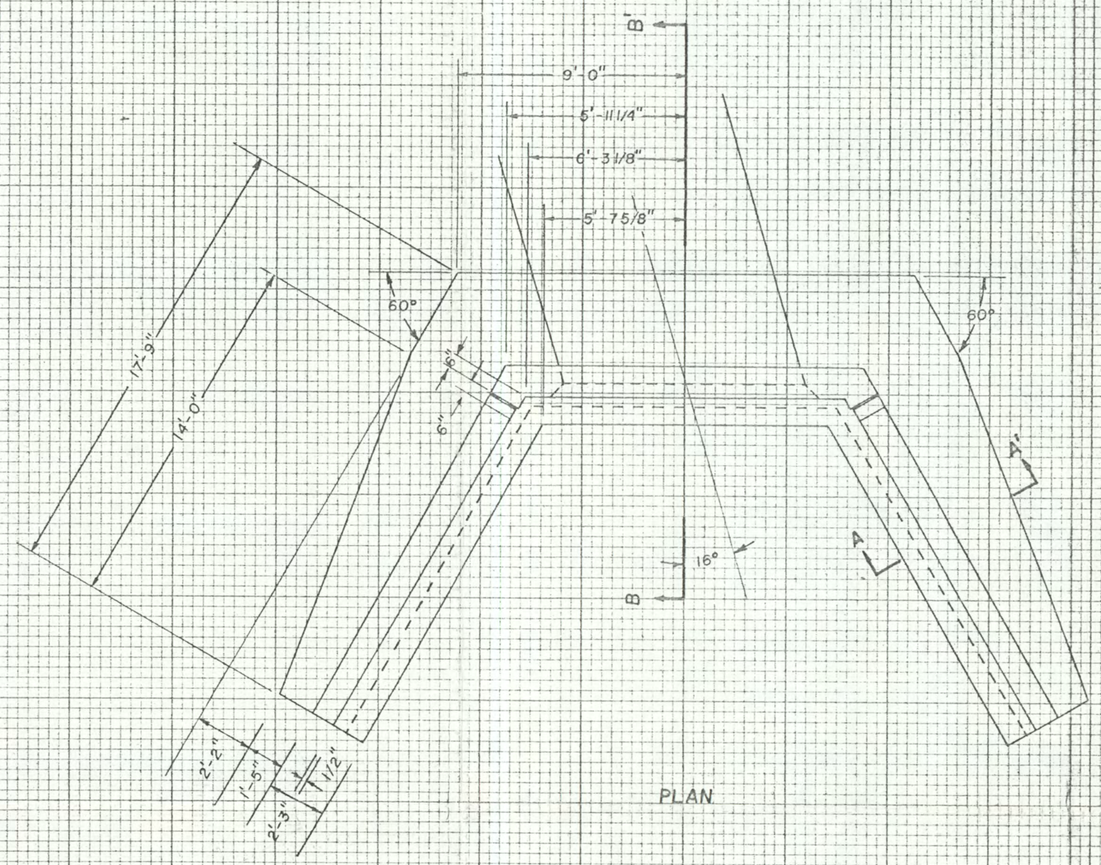
D_{50} = 9"

D_{10} = 3"

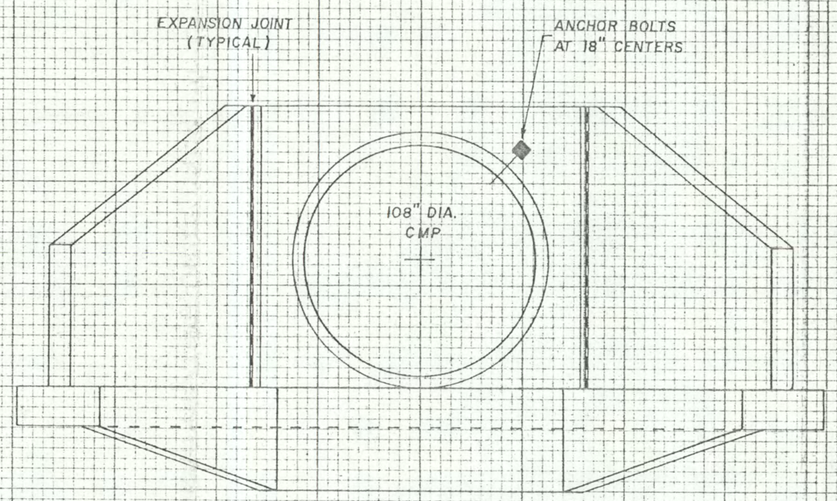
Riprap thickness = Z (D_{50}) = 2(0.75) = 1.5′ <u>Use 2′</u>

APPROVED NOV 1992

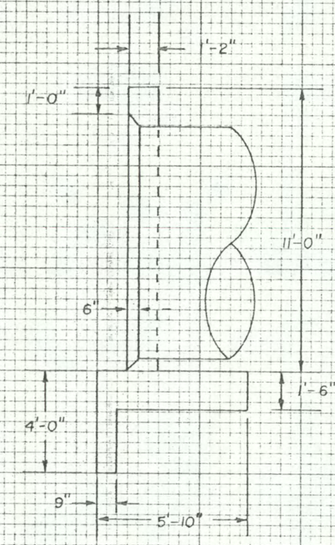
Reference: Surface Mining Water Diversion Design Manual, Simons, Li & Associates, September, 1982.



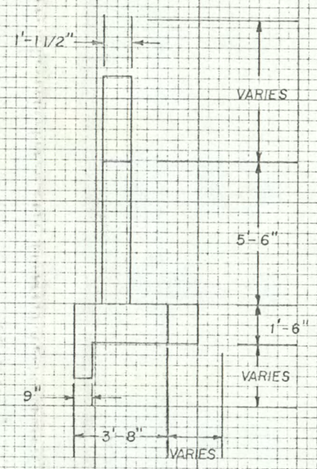
PLAN



ELEVATION



SECTION B-B'



SECTION A-A'

NOTES:

1. SEE ARIZONA DEPARTMENT OF TRANSPORTATION'S STANDARD DRAWINGS, STANDARD NO. PH-1 TO PH-23 FOR DETAILS.
2. FIELD VERIFY PIPE AND WING WALL SKEW DURING CONSTRUCTION.
3. FOLLOW A.D.O.T. STANDARD DRAWINGS AND REBAR PLACEMENT DURING CONSTRUCTION.

APPROVED NOV 17 1994

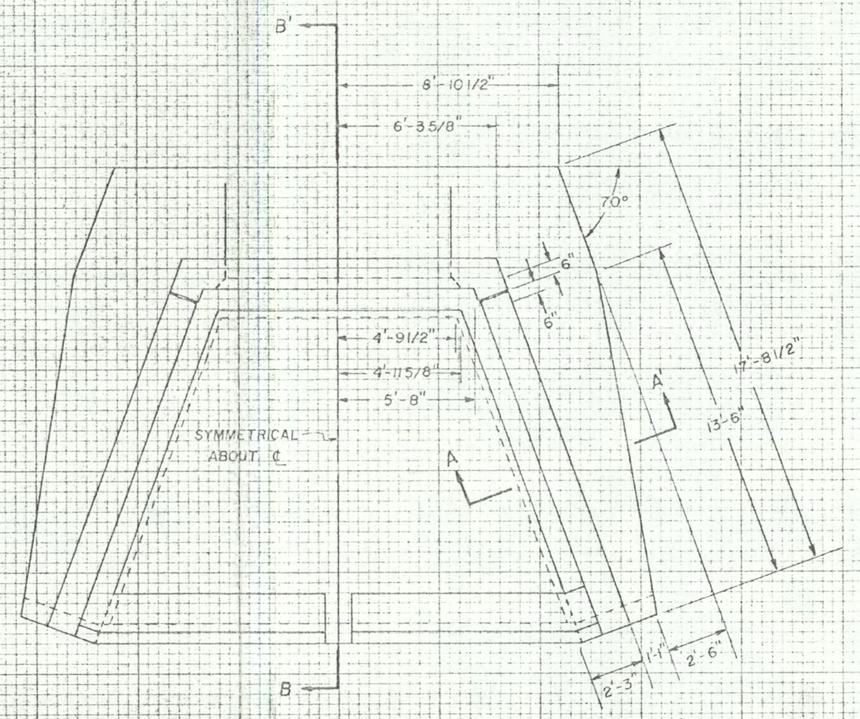
FIGURE 7

J-19 HAUL ROAD/REED VALLEY CROSS
108" CMP HEADWALL AT INLET
KAYENTA MINE

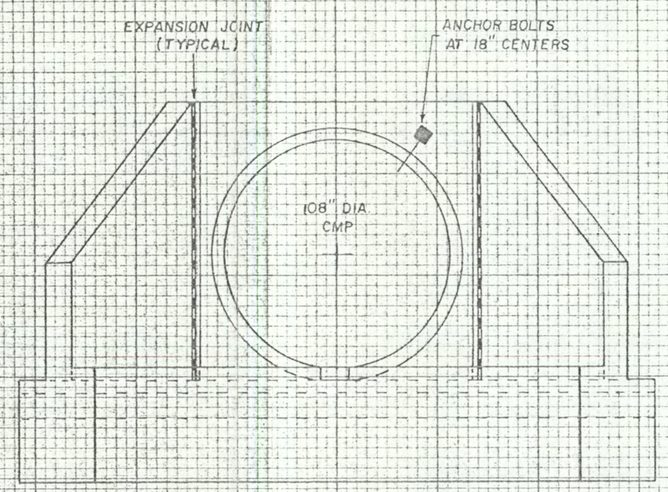
PEABODY COAL CO. 1800 SOUTH YALE, FLAGSTAFF, A

DESIGNED BY:	A.D.O.T.	SCALE:	NOT TO SCALE
DRAWN BY:	G.Y.	PHOTO DATE:	N/A
CHECKED BY:	J.G.S.	DRAWING DATE:	4/15/

REVISIONS



PLAN



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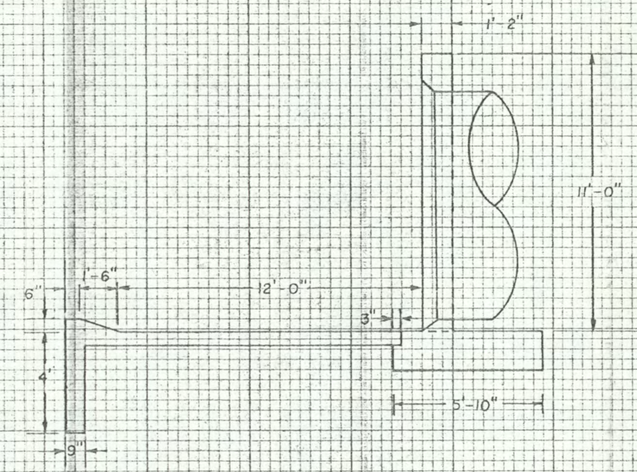
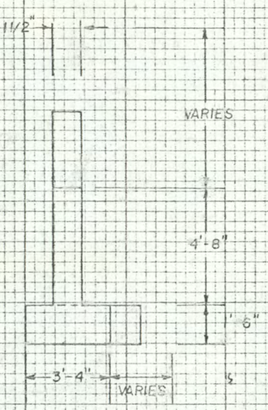


SECTION B-B'



SECTION A-A'

NOTES:

1. SEE ARIZONA DEPARTMENT OF TRANSPORTATION'S STANDARD DRAWINGS, STANDARD NO. PH-1 TO PH-23 FOR DETAILS.
2. FIELD VERIFY PIPE AND WING WALL SKEW DURING CONSTRUCTION.
3. FOLLOW A.D.O.T. STANDARD DRAWINGS AND REBAR PLACEMENT DURING CONSTRUCTION.

FIGURE 8

J-19 HAUL ROAD/REED VALLEY CROSSIN
108" CMP HEADWALL & APRON AT OUTL
KAYENTA MINE

PEABODY COAL CO., 1500 SOUTH YALE, FLAGSTAFF, AZ 8

DESIGNED BY:	A.D.O.T.	SCALE:	NOT TO SCALE
DRAWN BY:	G.Y.	PHOTO DATE:	N/A
CHECKED BY:	J.C.S.	DRAWING DATE:	4/15/92

REVISIONS

NOV, 1992 APPROVED

ATTACHMENT D

"General Report"

Geotechnic, Hydrologic and Hydraulic Evaluation

of Sedimentation Structures

GENERAL REPORT

Geotechnic, Hydrologic and Hydraulic Evaluation of Sedimentation Structures

Kayenta and Black Mesa Mines

Navajo County, Arizona

for

PEABODY COAL COMPANY

Dames & Moore
10139-011-22

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1.0 INTRODUCTION

Inspections, field investigations, laboratory testing and engineering analyses have recently been performed by Dames & Moore to evaluate compliance of sedimentation structures at Peabody Coal Company's Kayenta and Black Mesa Coal Mines in Navajo County, Arizona, with the performance standards for sedimentation structures set forth in the Office of Surface Mining (OSM) Indian land regulations, 30 CFR, Chapter VII, Parts 780 and 816. This General Report presents a summary of assumptions, data and methodologies that were used in our evaluations and is intended to serve as a companion document to the individual inspection reports that have been prepared for each of the sedimentation structures.

The locations of the sedimentation structures are shown on Drawing No. 85405.

2.0 GEOLOGY OF THE KAYENTA-BLACK MESA COAL MINES AREA

2.1 GENERAL

In the area surrounding the Kayenta-Black Mesa Coal Mines, several formations of the late Cretaceous Mancos Shale and Mesa Verde Group crop out (Figure 2-1). From the oldest, the Mancos Shale, the Toreva Formation, the Wepo Formation and the Yale Point Sandstone are exposed at the surface. Quaternary alluvium is found in the washes throughout the area. These outcrops are described below.

As shown on Figure 2-1, there are several folds in the area and the strata dip gently throughout most of Black Mesa Basin. No major faults have been mapped in the area.

2.2 MANCOS SHALE

The Mancos Shale (Km) is a marine shale that crops out in areas highly eroded by washes in the central portions of the basin and around the margins of the basin (Figure 2-1). The Mancos is composed of silt, clay, and very fine-grained sand. It varies in color from light to dark gray and is yellowish gray in areas where it has a high sand content. Thinly-bedded, fine-grained sandstones occur in several zones. Beds of bentonitic clay up to 3 feet thick occur in several horizons. All of the sediments in the Mancos of the Black Mesa area are well sorted, weakly cemented, and have flat, very thin bedding. The formation generally weathers to a fairly gentle slope (Page and Repenning, 1958; Cooley and others, 1969).

2.3 MESA VERDE GROUP

2.3.1 Toreva Formation

The Toreva Formation (Kt) overlies and intertongues with the Mancos Shale. This formation crops out in areas highly eroded by washes in the central portion of the basin and around the periphery of the basin (Figure 2-1). The Toreva has been subdivided into three members: a lower sandstone member, a middle carbonaceous member, and an upper sandstone member (Page and Repenning, 1958).

The lower sandstone member is light brown to pale yellowish gray, fine to medium-grained quartz sandstone with mica as an accessory mineral. Several mudstone units occur in the lower part of the section. Also, fine-grained sandstones are evident. The upper part of the lower sandstone member is fine- to medium-grained with no mudstones present. These sandstones are composed of several sets of crossbeds. The lower sandstone member of the Toreva forms vertical, blocky cliffs.

The middle carbonaceous member of the Toreva consists of an alternation of flat and thinly-bedded carbonaceous mudstone, varicolored siltstones with coal, and thick lenses of yellowish gray fine- to coarse-grained poorly sorted, cross-bedded quartz sandstone.

The upper member is a yellowish gray to grayish orange-pink cross-bedded sandstone composed of fine to very coarse-grained, poorly sorted quartz sand. Toward the north this upper sandstone member includes an

additional unit of coal, carbonaceous shale, and sandstone and is capped by medium- to fine-grained sandstone.

2.3.2 Wepo Formation

The Wepo Formation (Kw) is the predominant outcrop in the northern part of the basin and throughout the mine area (Figure 2-1). This formation is in gradational contact with and overlies the Toreva Formation. The Wepo Formation is a thick series of layered siltstone, mudstone, sandstone and coal. The siltstone and mudstone units vary in color from dark olive-gray to light olive-brown to medium light gray. The bedding is generally flat, laminated to very thin; cross bedding is occasionally apparent in some sandy horizons but it is often masked by the shaley weathering of these units. The siltstone-mudstone unit is mostly carbonaceous with some sandstone lenses and sandy zones.

The sandstone portion of the Wepo Formation is cross-bedded and usually has a yellowish-gray color. The sandstones vary from weakly cemented, very argillaceous units which weather to slopes, to strongly cemented, cliff-forming units. Some of the thicker sandstone units are partly conglomeritic. Iron-rich concretions, mud pellets, silty lenses, and carbonized plant remains are also common.

Siltstone units are common within the major sandstone units of the Wepo Formation. Coal beds occur within these siltstone layers. Also typical of the formation in this portion are hard baked shales which are the

result from the burned coal. These baked layers vary from yellowish red to terracotta to dark reddish brown in color. Locally these layers are termed scoria.

2.3.3 Yale Point Sandstone

The Yale Point Sandstone (Ky) overlies and intertongues with the Wepo Formation. It crops out in the northeastern portion and around most of the margin of Black Mesa Basin (Figure 2-1) forming spectacular vertical cliffs. No younger consolidated sediments overlie the Yale Point Sandstone, so its upper limit is the surface of recent erosion.

This sandstone is yellowish gray and weathers to a grayish orange. It is composed of coarse- to medium-grained subrounded to subangular clear quartz. The formation has lenticular bedding and is cross-bedded. There are occasional silty units which weather to the ledges and minor slopes on the cliff face. In areas where the Yale Point Sandstone intertongues with the Wepo Formation, the outcrop has much more of a ledge appearance instead of the cliff-forming pattern. This is due to the increase in fine-grained layers. Minor amounts of coal are also present in these intertongued, ledge and slope-forming units.

2.4 QUATERNARY AND RECENT DEPOSITS

The Quaternary and recent unconsolidated materials were derived from the weathering of the surface formation. A veneer of residual soil mantles all but the steepest slopes and cliffs. These soils, transported as

slope wash, increase in thickness on the lower portions of the slopes and contribute to the alluvium in the washes.

On the slopes, residual soils reflect the character of the parent bedrock. Shales and mudstones have weathered to clayey and silty soils of low to medium plasticity. Soils derived from sandstone consist of silty fine sands, generally with no plasticity. More resistant bedrock fragments are included in the soils as gravel- to cobble-size material.

The alluvial soils are predominantly very fine to coarse sands (SP, GP) with varying amounts of gravel, derived from the weathering of the surface formation and transport as alluvium in the washes. The alluvial soils are generally susceptible to collapse.

2.5 SEISMICITY

2.5.1 Historic Activity

Historic seismic activity in Arizona has been moderate in some areas to virtually nonexistent in others. Of the recorded epicenters within Arizona, very few have had a magnitude greater than 5.0 on the Richter scale. The strongest events have occurred in north-central and northwestern Arizona, in a northwest-trending zone, and in the southwest part of the state. Historic seismic activity in northeastern Arizona and the Four Corners area has been quite limited. Earthquakes of note in the area include one with a Richter magnitude of 5.75 which occurred in 1959 near

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slope wash, increase in thickness on the lower portions of the slopes and contribute to the alluvium in the washes.

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The alluvial soils are predominantly silty and clayey sands with interbeds of platy gravel. The alluvial soils have low density and are susceptible to collapse.

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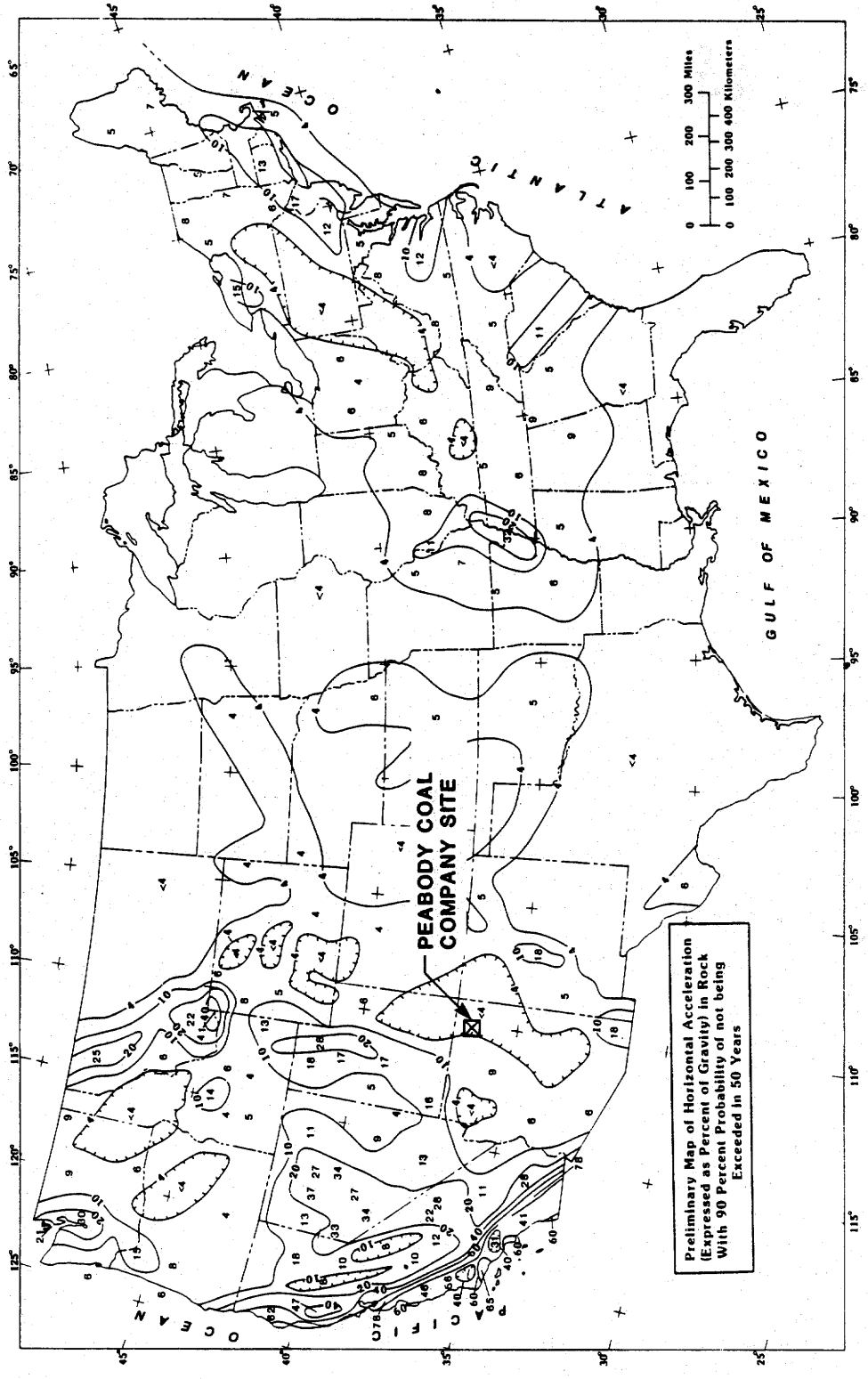
Fredonia, Arizona approximately 130 miles to the west of Kayenta and two minor earthquakes 20 to 30 miles southwest of Kayenta. No recent faults are known to occur within the site area (Dubois, 1979; Sumner, 1976).

2.5.2 Earthquake Probability

Studies by Algermissen and others (1982) indicate that the central part of Colorado Plateau has significantly less earthquake activity than at the margins. For the site area, Algermissen and others (1982) have estimated a horizontal acceleration of less than 0.04g in rock with a 90 percent probability of not being exceeded in 50 years (Figure 2-2). A horizontal acceleration of 0.04g is therefore considered appropriate for use in evaluating the stability of the sedimentation structures under earthquake loading conditions.



ALGERMISSEN AND PERKINS SEISMICITY

REFERENCE: ALGERMISSEN AND OTHERS (1962)

BY Dames & Moore

Figure 2-2

3.0 GEOTECHNICS

3.1 GENERAL

Field inspection of the sedimentation structures was conducted by a senior geotechnical engineer whose training and experience qualified him to recognize specific signs of structural instability and other hazardous conditions by visual observation. A general data sheet and visual inspection checklist was developed specifically for this evaluation and used by the engineer for each structure inspected.

One hundred and fourteen structures were inspected by Dames & Moore's engineers during this evaluation and eight structures were selected for detailed field explorations. These eight structures were selected to include the complete range of embankment material types and foundation material types represented by the 114 structures that were inspected. The remaining existing ponds consists of ponds to be reclaimed, MSHA-size structures, ponds incised which do not have embankments or ponds which already have been approved under the 30 CFR's which were designed and inspected by other engineers and which can be found in other portions of Chapter 6 (see Table 4B). The 114 structures inspected by Dames & Moore are well distributed around the permit area and are representative of the soils conditions and site conditions encountered during sedimentation pond construction. The explorations on the eight structures consisted of drilling borings into and through the embankments and recovering representative samples of the soil and rock encountered for testing (see Table 3-3). Details of the selection, explorations, and laboratory testing are described in subsequent

sections of this report.

Stability analyses were then conducted to evaluate the factors of safety against slope failure of the sedimentation structures. Physical characteristics and strength parameters used in the stability analyses were derived from laboratory test data, a review of data from other reports for structures at the mine site and published literature. Stability analyses were performed using the STABL2 computer program.

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3.2 INSPECTION PROCEDURES

The procedures for a typical embankment inspection began with locating available topographic plans, design files, construction records and previous inspection reports pertinent to the structure. These records were reviewed for consistency, i.e., whether elevations on the topographic maps agreed with actual design and construction grades, and whether design slopes and grades concurred with similar values in the construction records and subsequent inspection reports. Any discrepancies disclosed at this stage were discussed with Peabody Coal Company staff and surveys were initiated, if necessary, to determine the existing site topography. The details of design and construction of the structure were entered on the checklist, and copies of applicable plans were made for field checking.

With the checklist and copies of the drawings as reference, the geotechnical engineer measured the crest width, crest length, height and slope angles of the embankment to verify as-built parameters. Measurements were made with a 100-foot tape, a 6-foot folding rule and a hand-held clinometer. Additional information was sketched or noted on the drawings, including existing riprap protection, location of channels, instrumentation, observation wells, pipes and evidence of distress (including cracks, slumps and seepage).

After direct measurements were completed and entered on the checklist, the inspection continued with recording of the visual features and conditions of the structure. This portion of the inspection was subjective,

relying on the experience and judgment of the geotechnical engineer to quantify the features and conditions without making direct measurements. The checklist served as a prompt with specific headings for features and conditions that were either present or absent. Such experience-based assessments were made of erosion, riprap size, percent coverage of vegetation, seepage rates, and characteristics of foundation and embankment materials.

3.3 MATERIAL CLASSIFICATIONS

The materials that constitute the embankment fills were classified into the following three main soil groups:

1) Residual sandstone soils (SM, SP, GP) consisting of mottled tan to reddish brown silty fine to medium sands with varying amounts of sandstone fragments.

2) Residual shale soils (SM, ML, GM) consisting of mottled light to dark brown fine sandy silts and silts with some clay and with fragments of shale.

3) Alluvial soils (SP, GP) consisting of brown very fine to coarse sands with some silt, clay and gravel.

The soil and rock materials that constitute the embankment foundations vary from bedrock to residual or alluvial soils derived from the parent bedrock. These materials were classified into the following groups:

1) Sandstone, tan to reddish brown; usually highly weathered and fractured.

2) Shale, light brown to brown to gray; usually highly weathered and flaking.

3) Residual sandstone soils.

4) Residual shale soils.

5) Alluvium, brown very fine to coarse sand with varying amounts of gravel in lenticular bands.

3.4 EMBANKMENT CATEGORIES

OSM, in agreement Peabody Coal Company, is allowing sedimentation structures to be grouped into appropriate categories to expedite the geotechnical evaluation of the structures (OSM, 1985a). We concur that this approach is sound since the majority of the structures are similar in size, design and construction.

The criteria for grouping of the sedimentation structures into categories included is based on the type of soil or rock material in the embankments and the foundations of these structures. These criteria were selected because the engineering properties of the embankment and foundation materials are the principal factors contributing to the stability of the structures. Table 3-1 lists the categories that were selected to represent the sedimentation structures.

It was noted that a number of embankments consist of a mixture of residual sandstone, residual shale and alluvial soils. For purposes of categorization, the embankment soil type was classified in accordance to the material which predominated in the embankment. A few of the structures inspected did not fall into the categories listed above. Of these, two are small concrete walls that act as dams and spillways combined, and three are internal impoundments that are made of mine spoil and control sediment runoff into a temporary landfill. These few special cases have been evaluated individually.

Table 3-1

CATEGORIES OF STRUCTURES BASED ON
EMBANKMENT AND FOUNDATION MATERIALS

Category	Embankment Soil Type	Foundation Type
A-1	Residual Sandstone Soil (SM)	Residual Sandstone Soil (SM)
A-2	Residual Sandstone Soil (SM)	Residual Shale Soil (ML)
A-3	Residual Sandstone Soil (SM)	Alluvial Soil (SP) originally listed as ML 20 ft OSHRE
A-4	Residual Sandstone Soil (SM)	Shale Bedrock
A-5	Residual Sandstone Soil (SM)	Sandstone Bedrock
B-1	Residual Shale Soil (ML)	Residual Shale Soil (ML)
B-2	Residual Shale Soil (ML)	Residual Sandstone Soil (SM)
B-3	Residual Shale Soil (ML)	Alluvial Soil (SP)
B-4	Residual Shale Soil (ML)	Shale Bedrock
B-5	Residual Shale Soil (ML)	Sandstone Bedrock
C-1	Alluvial Soil (SP)	Alluvial Soil (SP)

In addition to grouping the structures based on the engineering properties of the embankment and foundation materials, structures were also categorized according to topographic setting as shown in Table 3-2.

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Table 3-1

CATEGORIES OF STRUCTURES BASED ON EMBANKMENT AND FOUNDATION MATERIALS

Category	Embankment Soil Type	Foundation Type
A-1	Residual Sandstone Soil (SM)	Residual Sandstone Soil (SM)
A-2	Residual Sandstone Soil (SM)	Residual Shale Soil (ML)
A-3	Residual Sandstone Soil (SM)	Alluvial Soil (ML)
A-4	Residual Sandstone Soil (SM)	Shale Bedrock
A-5	Residual Sandstone Soil (SM)	Sandstone Bedrock
B-1	Residual Shale Soil (ML)	Residual Shale Soil (ML)
B-2	Residual Shale Soil (ML)	Residual Sandstone Soil (SM)
B-3	Residual Shale Soil (ML)	Alluvial Soil (SP)
B-4	Residual Shale Soil (ML)	Shale Bedrock
B-5	Residual Shale Soil (ML)	Sandstone Bedrock
C-1	Alluvial Soil (SP)	Alluvial Soil (SP)

In addition to grouping the structures based on the engineering properties of the embankment and foundation materials, structures were also categorized according to topographic setting as shown in Table 3-2.

Table 3-2

CATEGORIES OF STRUCTURES BASED ON TOPOGRAPHIC SETTING

Structure Type	Description
Cross-Valley	A single embankment that completely crosses a valley or drainage channel.
Side-hill	An embankment that lies along the side of a hill or valley, consisting of a main embankment with small sections that tie back into the hill at both ends.
Roadway	An embankment, similar to either a side-hill or cross-valley in setting, where the crest also serves as a roadway.
In-wash	An embankment that is located entirely in a wash or drainage channel and makes up at least three sides of the structure.
Incised	A sedimentation structure that has no embankment, i.e. a totally below-grade structure with the excavated material used as fill in a nearby embankment or a depression in a reclaimed area.

This topographic categorization has only a minor impact on the stability of the structure; however, some design considerations influence the overall performance of the structure. For example, the slopes of the in-wash embankments need to be riprapped on the flow side of the wash, and roadway embankments are usually wider at the crest than normal and have CMP spillways rather than open channels.

3.5 FIELD EXPLORATIONS

As mentioned previously, field explorations were conducted to investigate the embankment and foundation materials of eight sedimentation structures. The eight structures were selected to include all of the

embankment material and foundation material types included on the project. Further, because of their size, setting or perceived deficiencies based on the field inspection, these eight structures were considered to be representative of the least stable of the 114 structures that were inspected. The selected embankments are listed in Table 3-3.

Table 3-3

SEDIMENTATION STRUCTURES SELECTED FOR FIELD EXPLORATION

Sedimentation Structure	Category	Embankment Material	Foundation Material
J3-E	A-1	R. Sandstone Soils	R. Sandstone Soils
J7-I	A-5	R. Sandstone Soils	Sandstone
J16-J	A-1	R. Sandstone Soils	R. Sandstone Soils
J28-C	B-1	R. Shale Soils	R. Shale Soils
N1-AC	B-1	R. Shale Soils	R. Shale Soils
N1-O	C-1	Alluvial Soils	Alluvium
N10-D	B-3	R. Shale Soils	Alluvium
N14-O	B-3	R. Shale Soils	Alluvium

The field explorations consisted of drilling borings at selected locations on the embankments of the sedimentation structures. A total of 21 borings, ranging in depth from 17 to 47 feet, were drilled with a Mobile B-61 drill rig using 6.25-inch-diameter hollow stem augers. The drill rig was operated by the Jim Winnek Drilling Company. The drilling program was directed by a Dames & Moore geotechnical engineer who logged the borings as they were drilled and assisted in obtaining samples of the soils encountered.

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Subsurface materials encountered in the 21 borings included soils classified, according to the Unified Soil Classification system, as GP, SP, SM, SC, ML and CL. The cohesionless materials were generally medium dense to dense. Recovered materials showing some cohesion generally fell into one of two groups; one was a dense to very dense soil. The other was a soft to medium dense soil; however, this soil type usually contained gravel sized fragments of sandstone or shale stone.

Borings were sampled at 5-foot vertical intervals. Samples were recovered using a 2.42 inch inside diameter drive sampler of the type shown on Figure 3-1. The sampler was driven with a 140-pound hammer falling 30 inches per blow. The number of blows to drive the sampler each 6-inch interval was recorded and provided an indication of the relative density of the materials sampled. In addition to the drive samples, the cuttings from the augers were inspected and random samples of cuttings were also recovered. All samples were returned to the Dames & Moore laboratory for additional classification and testing.

This type of soil sampling device was chosen for two reasons: first, we have successfully recovered samples with this sampler on other projects with similar and worse soils conditions. Secondly, with the interbedded granular materials, a core retaining device is necessary to keep the soil sample in the sampler during recovery. As shown in Figure 3-1, the modified Sprague & Henwood sampler can be filled with a thin-wall tube; however, this sampling method is primarily for soft, cohesive soils. Due to the dense, granular and non-uniform nature of the encountered soils, pushing a thin-wall or "Shelby" tube sampler was not considered feasible.

12/01/86

The sampler shown in Figure 3-1 is similar to the Dames & Moore sampler. The difference is that the Dames & Moore sampler has a 3.25-inch outside diameter; whereas the Modified Sprague & Henwood's outside diameter is 3.0 inches. The internal components of the two samplers are interchangeable. This sampler is a sophisticated piece of sampling equipment which has been refined by 30 years of use and improvements. This sampler has been used to obtain relatively undisturbed samples on numerous water and tailings dams throughout North America, and our experience has provided a high level of confidence in the representative nature of the samples obtained with this equipment. The sampler's relatively large diameter provides a sample with a lesser percentage of disturbed material than with smaller samplers. An evaluation of the sample disturbance for the Modified Sprague & Henwood sampler, solely on the basis of inside to outside diameter ratio, is deceptive because of the sharp-edged and gently-tapered cutting bit used on the sampler.

Typically the effects of sample disturbance are minimized for all laboratory strength testing by re-consolidating the test samples under confining pressures which simulate the in situ pressures in the embankment prior to testing. Sample disturbance is a problem which is common, in varying degrees, to all sampling equipment and procedures. The procedure described above minimizes disturbance effects.

The sampler shown in Figure 3-1 has been used to investigate the soil conditions in literally hundreds of dams in North America over the past 30 years. The recovered soil samples were then tested to develop shear strength values for use in the dam design. Final dam designs have then been

subject to approval by county, state and Federal agencies including U.S. Soil Conservation Service, U.S. Department of Energy, U.S. Environmental Protection Agency and U.S. Nuclear Regulatory Commission. For the Sebastian Martin-Black Mesa flood control dam project in New Mexico, conducted for the U.S. Soil Conservation Service, we were requested to drill and sample the foundation soil using the Modified Sprague & Henwood sampler, a 6-inch diameter Pitcher sampler, and a 3-foot diameter bucket auger. The borings for each of the three sampling methods were drilled in adjacent locations and comparisons were made of the recovered samples. Results of this project re-affirmed our confidence in the quality of recovered sample using the Modified Sprague & Henwood drive sampler.

The locations of the borings are shown on Figures 3-2A through 3-2H, and the Log of Borings are presented on Figures 3-3A through 3-3U. The materials are identified on the basis of the Unified Soil Classification System presented on Figure 3-4A. The Key to Log of Borings is presented on Figure 3-4B.

3.6 LABORATORY TESTING

Selected samples of the soils encountered were tested in our laboratory to aid in identification and classification and to determine the engineering properties. Testing was completed to evaluate moisture content, dry density, grain size distribution, soil plasticity, specific gravity, consolidation and shear strength. The laboratory testing data are presented on Figures 3-5A through 3-5D, 3-7A and 3-7B, 3-10 and on the Log of Borings, Figures 3-3A through 3-3U.

12/01/82

3.6.1 Moisture Content and Dry Density

The moisture content and dry density of recovered samples were determined as an aid to classification of the soils and estimation of engineering properties. The moisture content was determined in accordance with ASTM D 2216 test procedures. The results of the moisture content and density determinations are presented on the Logs of Borings, Figures 3-3A through U.

3.6.2 Grain Size Distribution

The particle size distribution of representative samples was determined by passing a specimen of soil through a nested set of standard sieves. The test was completed in accordance with ASTM D 422 procedures. The test results are presented on Figures 3-5A through D.

3.6.3 Atterberg Limits

As an aid to classifying the soils, the liquid and plastic limits of representative samples were determined in accordance with ASTM D 4318 procedures. The results of the plastic and liquid limit determinations are presented on the Logs of Borings, Figures 3-3A through U.

3.6.4 Specific Gravity

The specific gravity of selected soil samples was determined to provide information for the engineering analyses. The specific gravity was determined in accordance with ASTM C 854 procedures. Results of specific gravity testing are presented on Table 3-4.

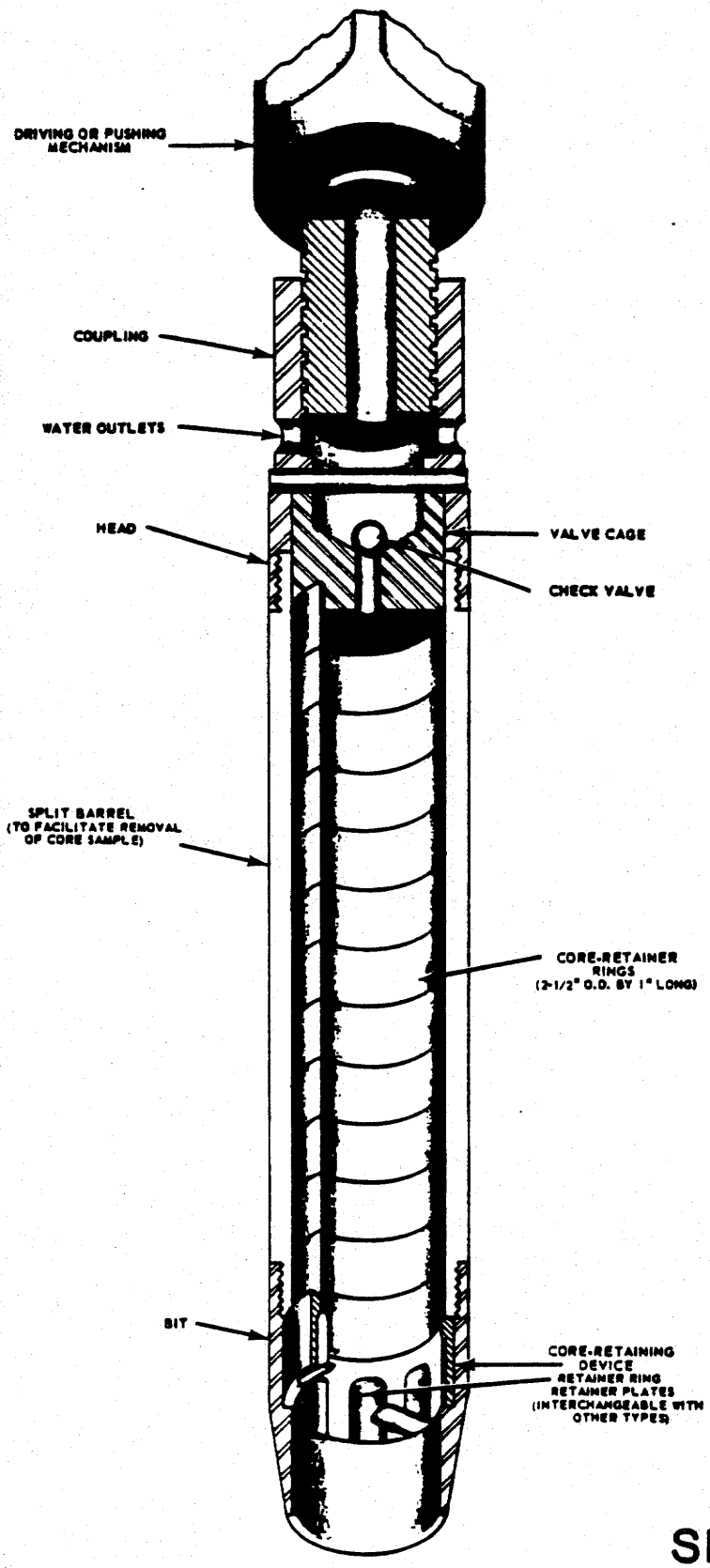
Table 3-4

RESULTS OF SPECIFIC GRAVITY TESTING

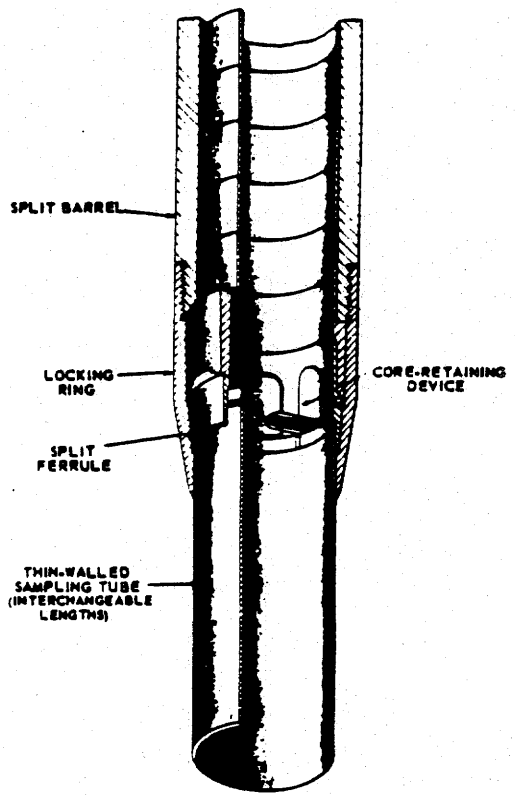
Sedimentation Structure	Sample Depth (ft)	Soil Type	Specific Gravity
J3-E1	8	SM-ML	2.58
J7-I2	8	SM	2.59
N1-O1	5.5	ML	2.54
N10-C	Surface	SP	2.64
N10-D1	23	SP	2.62
N10-E	Surface	SP	2.56

3.6.5 Direct Shear Tests

Direct shear tests were performed to evaluate the shear strength of representative samples of alluvial soils. Samples were loaded vertically (normal to the ends of the sample) and the shearing force was applied horizontally in the form of a constant rate of deflection. The test results are presented on Figures 3-3A through U, and the method of completing the tests is described on Figure 3-6.

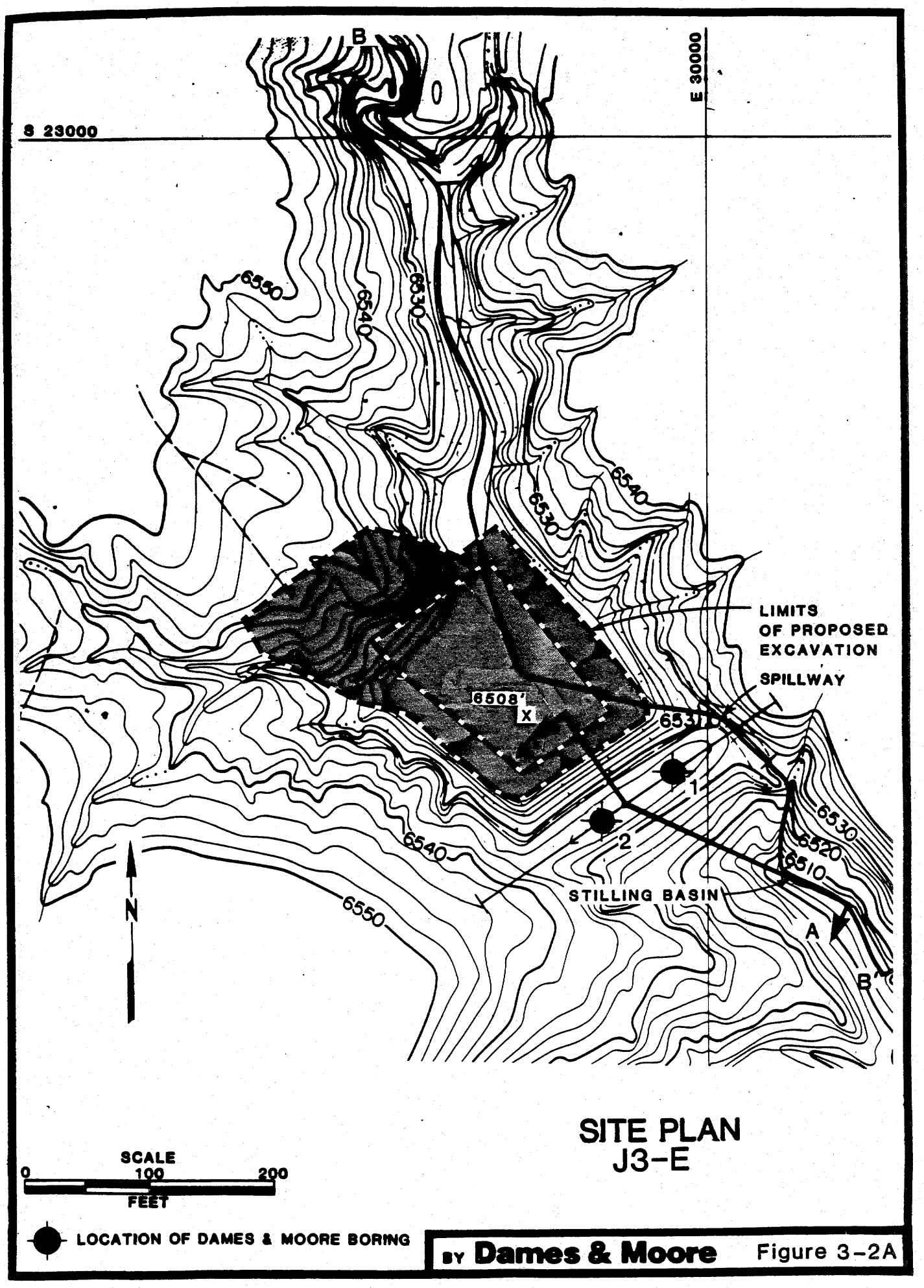


ALTERNATE ATTACHMENTS



MODIFIED SPRAGUE & HENWOOD SAMPLER

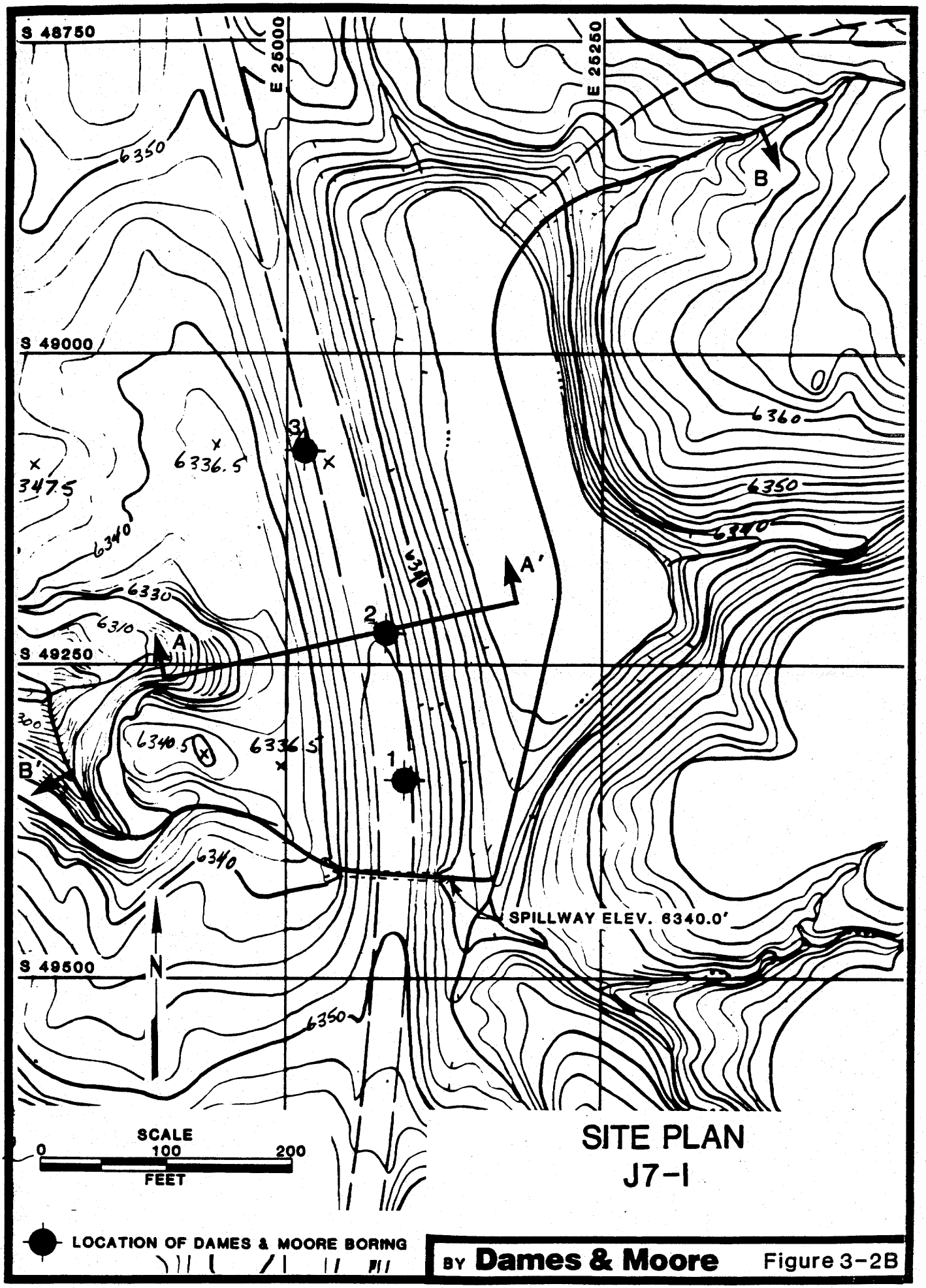
BY Dames & Moore Figure 3-1



SITE PLAN
J3-E

BY Dames & Moore

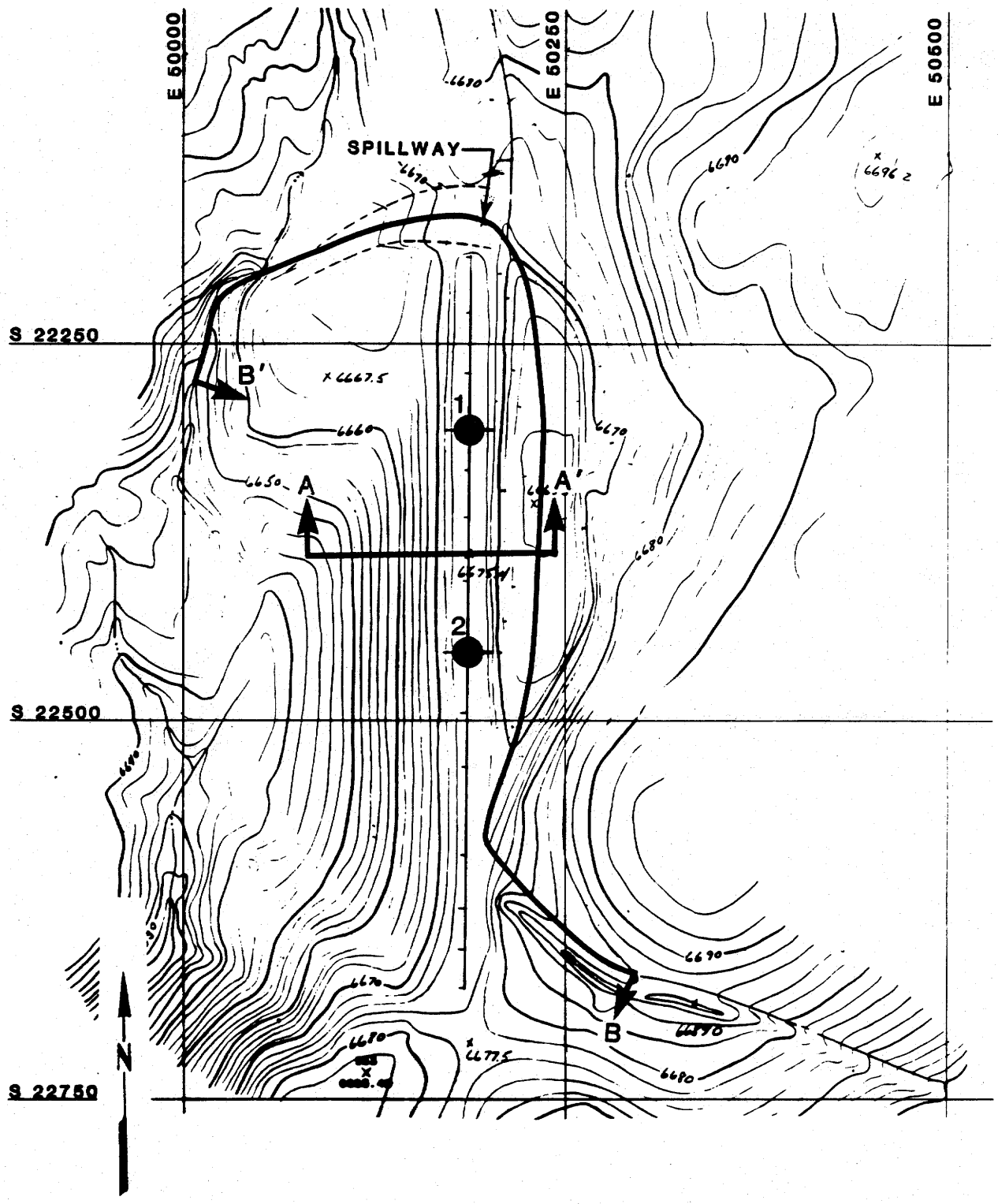
Figure 3-2A



SITE PLAN
J7-I

BY **Dames & Moore**

Figure 3-2B



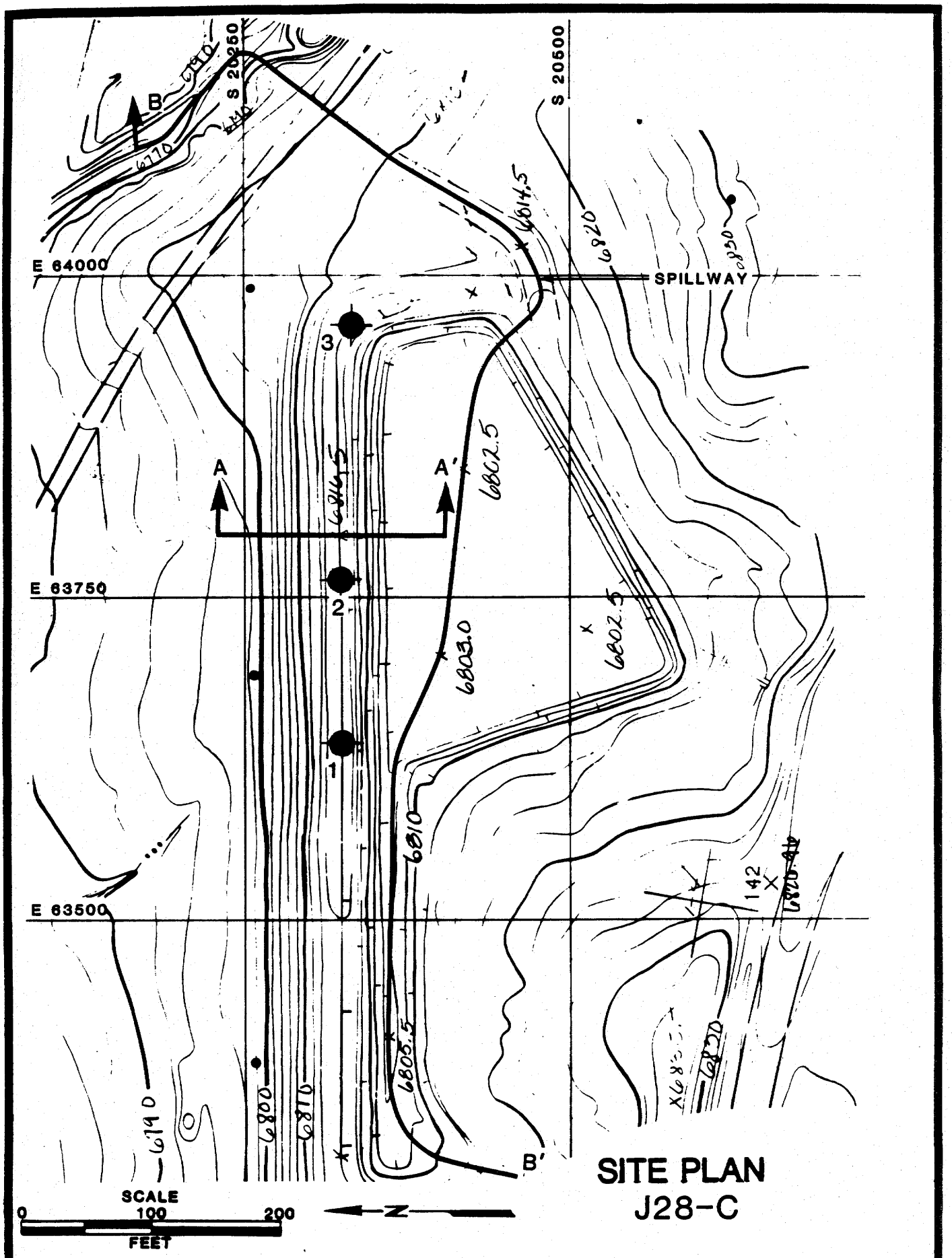
SITE PLAN
J16-J

SCALE
0 100 200
FEET

LOCATION OF DAMES & MOORE BORING

BY **Dames & Moore**

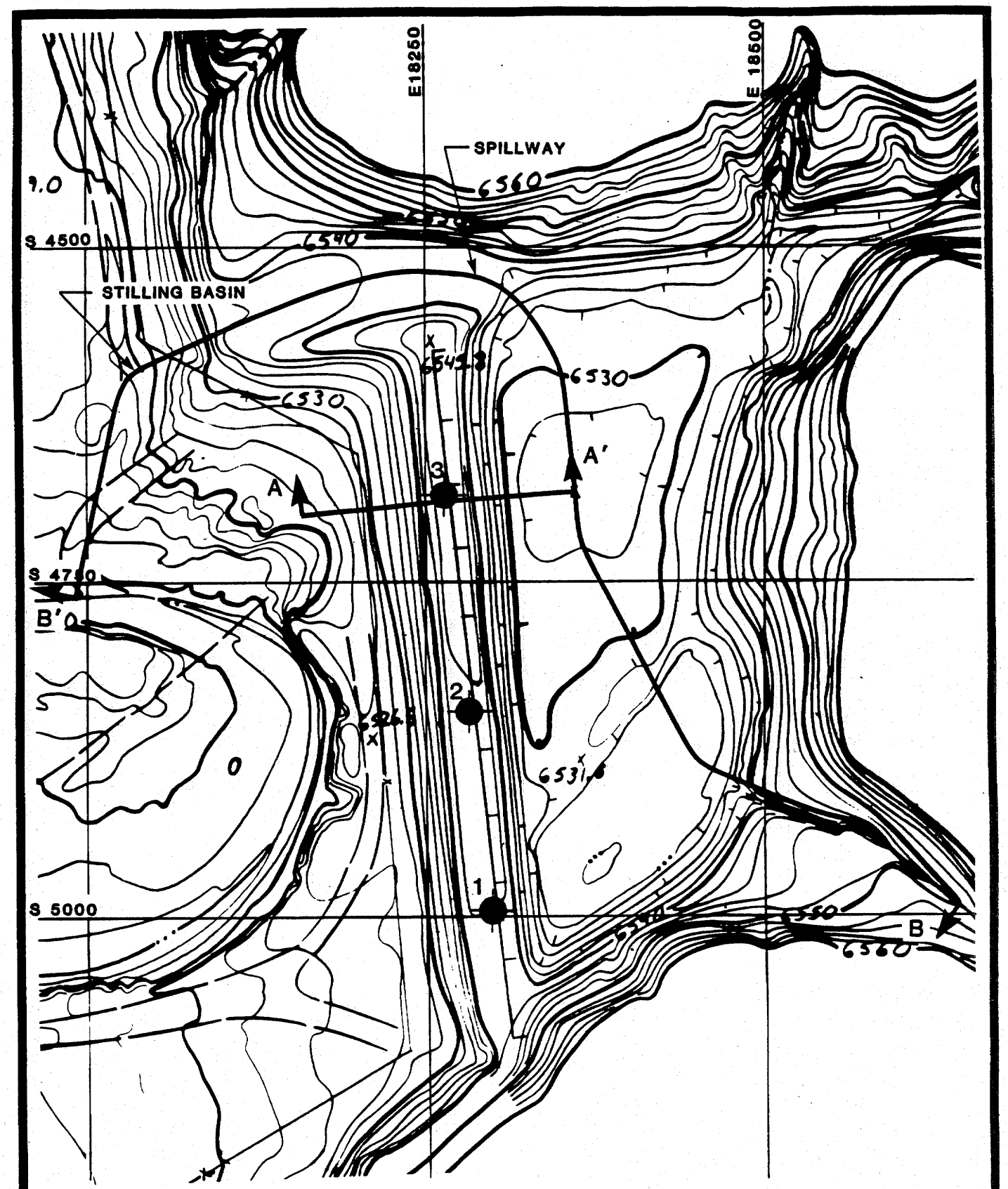
Figure 3-2C



SITE PLAN
J28-C

BY Dames & Moore

Figure 3-2D

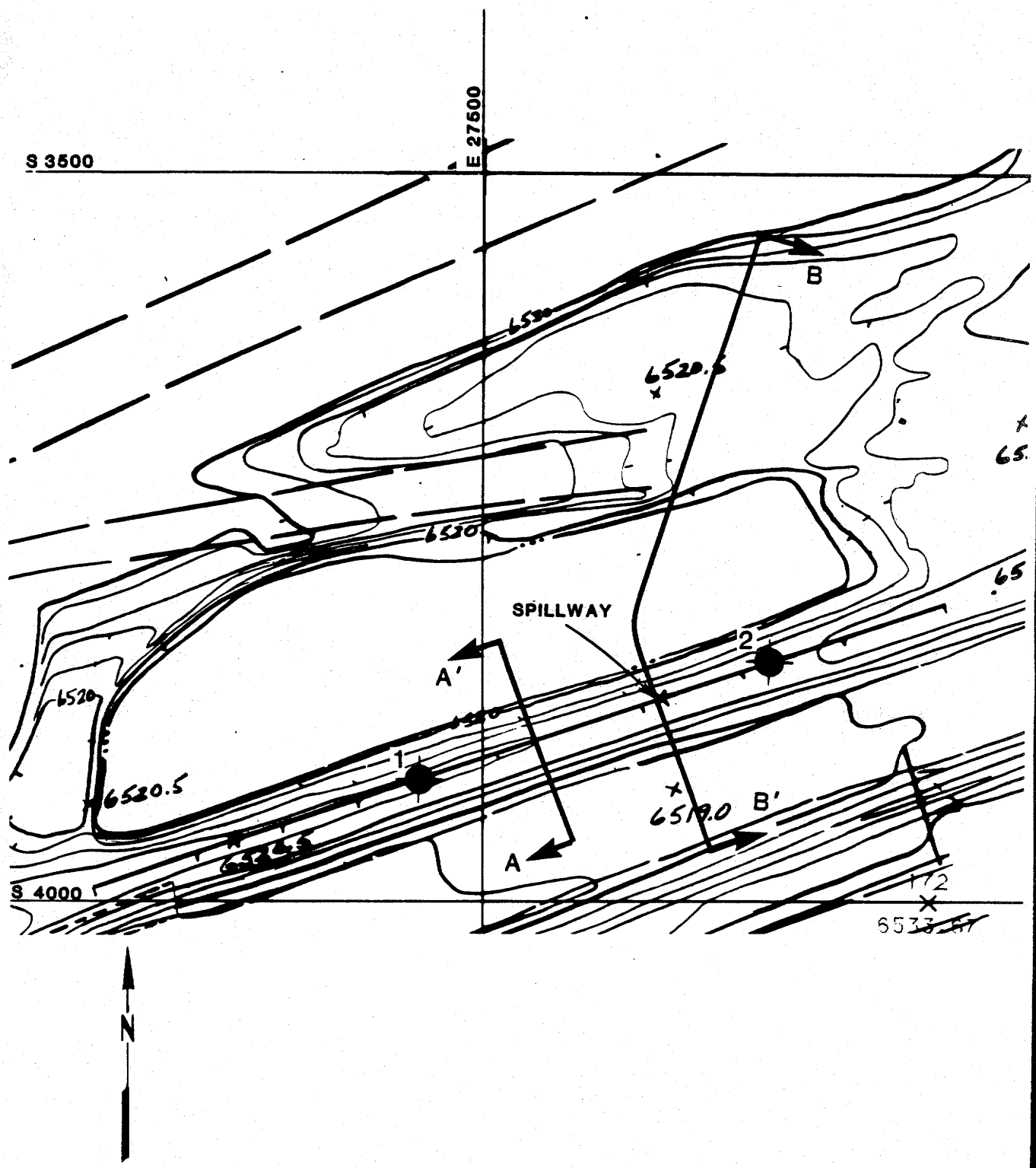


SITE PLAN
N1-AC

SCALE
0 100 200
FEET

LOCATION OF DAMES & MOORE BORING

BY **Dames & Moore** Figure 3-2E



SITE PLAN
N1-O

SCALE
0 100 200
FEET

LOCATION OF DAMES & MOORE BORING

BY **Dames & Moore** Figure 3-2F

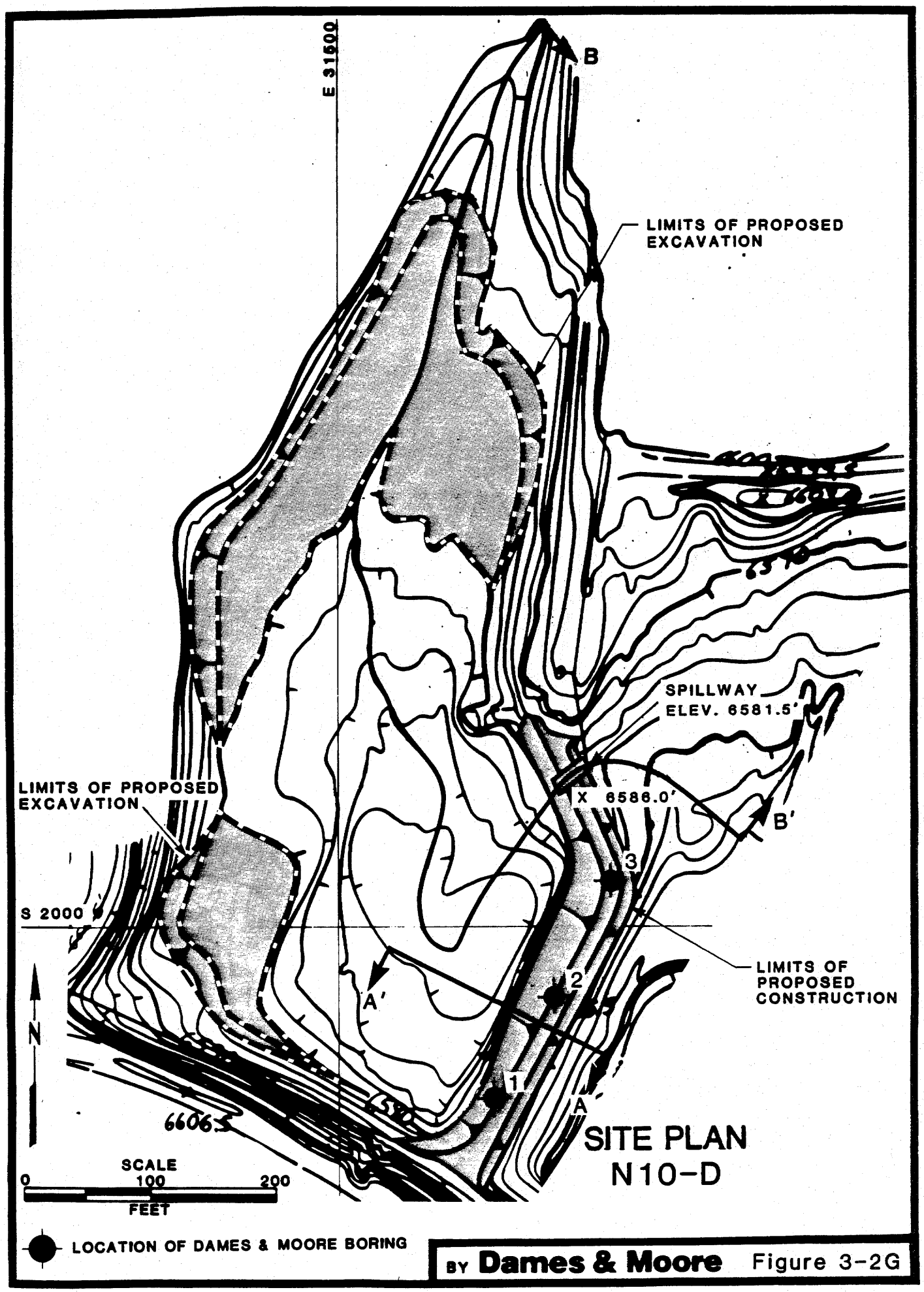
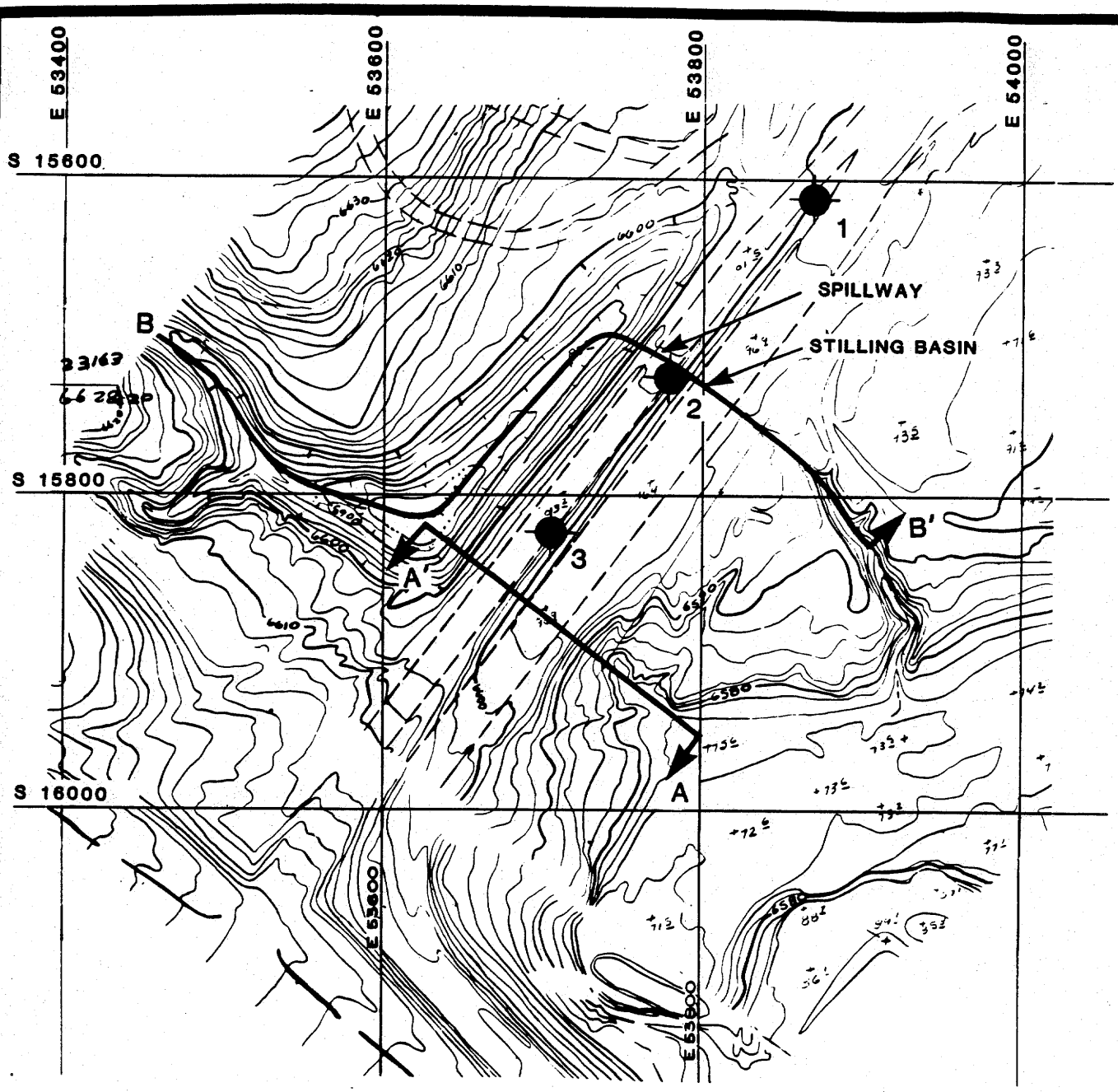

E 31600
B
LIMITS OF PROPOSED EXCAVATION
SPILLWAY ELEV. 6581.5'
X 6586.0'
B'
LIMITS OF PROPOSED EXCAVATION
S 2000
3
2
1
A'
A
LIMITS OF PROPOSED CONSTRUCTION
N
6606
SCALE
0
100
200
FEET
SITE PLAN
N10-D
LOCATION OF DAMES & MOORE BORING
BY Dames & Moore

Figure 3-2G



SCALE
0 100 200
FEET

LOCATION OF DAMES & MOORE BORING

SITE PLAN

N14-0

BY **Dames & Moore** Figure 3-2H

BORING J3-E1

SURFACE ELEVATION: 6538.3 FEET
PCC COORDINATES
S 23517
E 29987

LABORATORY TEST DATA

	TESTS REPORTED ELSEWHERE	ATTERBERG LIMITS: LIQUID LIMIT (%)	ATTERBERG LIMITS: PLASTICITY INDEX (%)	STRENGTH TEST DATA: TYPE OF TEST	STRENGTH TEST DATA: NORMAL OR CONFINING PRESSURE (PSF)	STRENGTH TEST DATA: SHEAR STRENGTH (PSF)	STRENGTH TEST DATA: DEVIATOR STRESS (PSF)	MOISTURE CONTENT (%)	DRY DENSITY (PCF)
0–5								10.4	115.3
5–10	G								
10–15	MA	22.9	7.3					13.6	115.8
15–20				—					
20–25									
25–30									
30–35									
35–40									
40–45									
45–50									
50–55									
55–60									
60–65									
65–70									
70–75									
75–80									

BLOWS/FT.	SAMPLES
75	■
52	■
21	■
80	■
21	■

SYMBOLS	DESCRIPTION
SM–ML	MOTTLED BROWN AND GRAY SILTY FINE SAND, CLAYEY AND SANDY SILT WITH FRAGMENTS OF SANDSTONE (DENSE)
	MEDIUM DENSE
SC	CLAYEY FINE SAND WITH FRAGMENTS OF SANDSTONE
	LOOSE
SP	SANDSTONE BOULDER (DENSE)
	BROWN FINE SAND WITH GRAVEL AND FRAGMENTS OF SANDSTONE
COAL	

FILL

BORING TERMINATED AT 27.5 FEET ON 9-30-85.
NO GROUNDWATER ENCOUNTERED.

LOG OF BORING

BY **Dames & Moore**

Figure 3-3A

BORING J3-E2

SURFACE ELEVATION: 6535.9 FEET
PCC COORDINATES
S 23548
E 29918

LABORATORY TEST DATA

	TESTS REPORTED ELSEWHERE	ATTERBERG LIMITS: LIQUID LIMIT (%)	ATTERBERG LIMITS: PLASTICITY INDEX (%)	STRENGTH TEST DATA: TYPE OF TEST	STRENGTH TEST DATA: NORMAL OR CONFINING PRESSURE (PSF)	STRENGTH TEST DATA: SHEAR STRENGTH (PSF)	STRENGTH TEST DATA: DEVIATOR STRESS (PSF)	MOISTURE CONTENT (%)	DRY DENSITY (PCF)	BLOWS/FT. SAMPLES
0										
5										70
10								11.6	118.5	92
15								11.8	114.7	53
20								17.3	111.9	50/4"
25										
30										
35										
40										
45										
50										
55										
60										
65										
70										
75										
80										

SYMBOLS	DESCRIPTION
SM-ML	MOTTLED BROWN AND GRAY SILTY FINE SAND, CLAYEY AND SANDY SILT WITH FRAGMENTS OF SANDSTONE (DENSE)
	DENSE
	MEDIUM DENSE
SM	BROWN SILTY FINE SAND WITH FRAGMENTS OF SANDSTONE (DENSE)
SHALE	

FILL

BORING TERMINATED AT 22.5 FEET ON 9/30/85.
NO GROUNDWATER ENCOUNTERED.

LOG OF BORING

BY **Dames & Moore**

Figure 3-3B

BORING J7-11

SURFACE ELEVATION: 6348.4 FEET
PCC COORDINATES
S 49344
E 25096

	LABORATORY TEST DATA									BLOWS/FT. SAMPLES
	TESTS REPORTED ELSEWHERE	ATTERBERG LIMITS		STRENGTH TEST DATA				MOISTURE CONTENT (%)	DRY DENSITY (PCF)	
		LIQUID LIMIT (%)	PLASTICITY INDEX (%)	TYPE OF TEST	NORMAL OR CONFINING PRESSURE (PSF)	SHEAR STRENGTH (PSF)	DEVIATOR STRESS (PSF)			
0										
5										54/ 6"
10										75/ 8"
15										50/ 2"
20										
25										
30										
35										
40										
45										
50										
55										
60										
65										
70										
75										
80										

SYMBOLS	DESCRIPTION
SM	MOTTLED GRAY AND BROWN SILTY FINE SAND WITH SANDSTONE FRAGMENTS (VERY DENSE)
SHALE	MOTTLED OLIVE BROWN WEATHERED SHALE (VERY DENSE)
COAL	
SS	LIGHT GRAY SANDSTONE (VERY DENSE)

FILL

BORING TERMINATED AT 17.5 FEET ON 9/25/85.
NO GROUNDWATER ENCOUNTERED.

LOG OF BORING

BY **Dames & Moore**

Figure 3-3C

BORING J7-12

SURFACE ELEVATION: 8347.3 FEET
PCC COORDINATES
S 49228
E 25080

LABORATORY TEST DATA

	TESTS REPORTED ELSEWHERE	ATTERBERG LIMITS: LIQUID LIMIT (%)	ATTERBERG LIMITS: PLASTICITY INDEX (%)	STRENGTH TEST DATA: TYPE OF TEST	STRENGTH TEST DATA: NORMAL OR CONFINING PRESSURE (PSF)	STRENGTH TEST DATA: SHEAR STRENGTH (PSF)	STRENGTH TEST DATA: DEVIATOR STRESS (PSF)	MOISTURE CONTENT (%)	DRY DENSITY (PCF)	BLOWS/FT.	SAMPLES
0											
		26.3	9.4					14.1	113.3	80	
5											
	G							12.1	97.9	49	
10											
								17.5	111.1	52	
15											
20											
25											
30											
35											
40											
45											
50											
55											
60											
65											
70											
75											
80											

SYMBOLS	DESCRIPTION
ML	MOTTLED DARK BROWN SANDY SILT WITH FRAGMENTS OF SANDSTONE, TRACE CLAY (MEDIUM DENSE)
SM	BROWN SILTY SAND WITH FRAGMENTS OF SANDSTONE (MEDIUM DENSE)
SS	LIGHT GRAY SANDSTONE (VERY DENSE)

BORING TERMINATED AT 17.6 FEET ON 9/25/85.
NO GROUNDWATER ENCOUNTERED.

LOG OF BORING

BY **Dames & Moore**

Figure 3-3D

BORING J7-13

SURFACE ELEVATION: 6348.7 FEET
PCC COORDINATES
S 49078
E 25014

LABORATORY TEST DATA

	TESTS REPORTED ELSEWHERE	ATTERBERG LIMITS		STRENGTH TEST DATA				MOISTURE CONTENT (%)	DRY DENSITY (PCF)
		LIQUID LIMIT (%)	PLASTICITY INDEX (%)	TYPE OF TEST	NORMAL OR CONFINING PRESSURE (PSF)	SHEAR STRENGTH (PSF)	DEVIATOR STRESS (PSF)		
0									
5									
10									
15								12.5	103.7
20									
25									
30									
35									
40									
45									
50									
55									
60									
65									
70									
75									
80									

BLOWS/FT. SAMPLES	SYMBOLS	DESCRIPTION
50/5"	SM	DARK BROWN SILTY FINE TO COARSE SAND WITH FRAGMENTS OF BLACK SANDSTONE, TRACE CLAY (VERY DENSE)
103/9"		COLOR CHANGES TO MOTTLED BROWN (VERY DENSE)
50/5"		VERY DENSE
50/1"	SS	LIGHT GRAY SANDSTONE

FILL

BORING TERMINATED AT 17.2 FEET ON 9/25/85.
NO GROUNDWATER ENCOUNTERED.

LOG OF BORING

BY **Dames & Moore**

Figure 3-3E

BORING J16-J1

SURFACE ELEVATION: 6675.9 FEET
PCC COORDINATES
S 22309
E 50189

LABORATORY TEST DATA

	TESTS REPORTED ELSEWHERE	ATTERBERG LIMITS: LIQUID LIMIT (%)	ATTERBERG LIMITS: PLASTICITY INDEX (%)	STRENGTH TEST DATA: TYPE OF TEST	STRENGTH TEST DATA: NORMAL OR CONFINING PRESSURE (PSF)	STRENGTH TEST DATA: SHEAR STRENGTH (PSF)	STRENGTH TEST DATA: DEVIATOR STRESS (PSF)	MOISTURE CONTENT (%)	DRY DENSITY (PCF)
0									
5								10.7	122.2
10								7.1	102.2
15									
20									
25									
30									
35									
40									
45									
50									
55									
60									
65									
70									
75									
80									

BLOWS/FT. SAMPLES

83/11"

62

95/11"

SYMBOLS	DESCRIPTION
SM	MOTTLED GRAY AND OLIVE BROWN SILTY FINE SAND (DENSE)
	BROWN SILTY FINE SAND (MEDIUM DENSE)
ML	BROWN FINE SANDY SILT WITH TRACE OF CLAY AND SHALE FRAGMENTS
SHALE	BROWN SHALE (DENSE)
COAL	

FILL

BORING TERMINATED AT 17.5 FEET ON 9/27/85.
NO GROUNDWATER ENCOUNTERED.

LOG OF BORING

BY **Dames & Moore**

Figure 3-3F

BORING J16-J2

SURFACE ELEVATION: 6681.9 FEET
PCC COORDINATES
S 22458
E 50181

LABORATORY TEST DATA

	TESTS REPORTED ELSEWHERE	ATTERBERG LIMITS: LIQUID LIMIT (%)	ATTERBERG LIMITS: PLASTICITY INDEX (%)	STRENGTH TEST DATA: TYPE OF TEST	STRENGTH TEST DATA: NORMAL OR CONFINING PRESSURE (PSF)	STRENGTH TEST DATA: SHEAR STRENGTH (PSF)	STRENGTH TEST DATA: DEVIATOR STRESS (PSF)	MOISTURE CONTENT (%)	DRY DENSITY (PCF)	BLOWS/FT.	SAMPLES
0											
5								11.7	117.1	65	■
10		29.1	3.3					11.4	104.5	77/6"	■
										98	■
15								21.9	94.3	50	■
20											
25											
30											
35											
40											
45											
50											
55											
60											
65											
70											
75											
80											

SYMBOLS	DESCRIPTION
SM	BROWN SILTY FINE SAND (DENSE)
ML	BROWN FINE SANDY SILT
SM	MOTTLED BLACK, BROWN SILTY SAND WITH FRAGMENTS OF SHALE (DENSE)
SHALE	GRAY SHALE
COAL	COAL (MEDIUM DENSE)

FILL

BORING TERMINATED AT 18.0 FEET ON 9/27/85.
NO GROUNDWATER ENCOUNTERED.

LOG OF BORING

BY **Dames & Moore**

Figure 3-3G

BORING J28-C1

SURFACE ELEVATION:6816.0 FEET
PCC COORDINATES
S 20321
E 63636

LABORATORY TEST DATA

	TESTS REPORTED ELSEWHERE	ATTERBERG LIMITS: LIQUID LIMIT (%)	ATTERBERG LIMITS: PLASTICITY INDEX (%)	STRENGTH TEST DATA: TYPE OF TEST	STRENGTH TEST DATA: NORMAL OR CONFINING PRESSURE (PSF)	STRENGTH TEST DATA: SHEAR STRENGTH (PSF)	STRENGTH TEST DATA: DEVIATOR STRESS (PSF)	MOISTURE CONTENT (%)	DRY DENSITY (PCF)
0									
5		27.1	9.4					7.9	99.5
10									
15	MA			TXCUPP				15.2	110.7
20									
25								132.9	34.7
30									
35									
40									
45									
50									
55									
60									
65									
70									
75									
80									

BLOWS/FT.	SAMPLES	SYMBOLS	DESCRIPTION
64		ML	MOTTLED TAN AND BROWN FINE SANDY SILT WITH TRACE OF CLAY (MEDIUM DENSE)
29			MEDIUM DENSE
31			MEDIUM DENSE
27			MEDIUM DENSE
72		COAL, ML, SHALE	GRAY CLAYEY SILT (DENSE) MOTTLED BROWN SHALE

FILL

BORING TERMINATED AT 24.0' ON 9/18/85.
NO GROUNDWATER ENCOUNTERED.

LOG OF BORING

BY **Dames & Moore**

Figure 3-3H

BORING J28-C2

SURFACE ELEVATION: 8815.0 FEET
PCC COORDINATES
S 20323
E 63763

LABORATORY TEST DATA

Depth	TESTS REPORTED ELSEWHERE	ATTERBERG LIMITS: LIQUID LIMIT (%)	ATTERBERG LIMITS: PLASTICITY INDEX (%)	STRENGTH TEST DATA: TYPE OF TEST	STRENGTH TEST DATA: NORMAL OR CONFINING PRESSURE (PSF)	STRENGTH TEST DATA: SHEAR STRENGTH (PSF)	STRENGTH TEST DATA: DEVIATOR STRESS (PSF)	MOISTURE CONTENT (%)	DRY DENSITY (PCF)	BLOWS/FT. SAMPLES
0										
5										44
10				TXCUPP				16.5	108.4	25
15				DS-UU	1500	1520		16.7	193.0	55
20		27.4	10.9	TXCUPP				18.2	107.4	28
25		36.3	16.1					16.3	112.2	129
30										
35										
40										
45										
50										
55										
60										
65										
70										
75										
80										

SYMBOLS	DESCRIPTION
ML	LIGHT BROWN FINE SANDY SILT WITH TRACE OF CLAY (MEDIUM DENSE)
	COLOR CHANGES TO MOTTLED BROWN (MEDIUM DENSE)
CL	DARK BROWN SILTY CLAY (MEDIUM DENSE)
	MEDIUM DENSE
	COLOR CHANGES TO MOTTLED OLIVE BROWN
SHALE	BROWN SHALE FRAGMENTS, BLACK COAL AND GRAY SHALE (VERY DENSE)

BORING TERMINATED AT 27.5 FEET ON 9/19/85.
NO GROUNDWATER ENCOUNTERED.

LOG OF BORING

BY **Dames & Moore**

Figure 3-31

BORING J28-C3

SURFACE ELEVATION: 6816.0 FEET
PCC COORDINATES
S 20332
E 63962

LABORATORY TEST DATA

Depth	TESTS REPORTED ELSEWHERE	ATTERBERG LIMITS: LIQUID LIMIT (%)	ATTERBERG LIMITS: PLASTICITY INDEX (%)	STRENGTH TEST DATA: TYPE OF TEST	STRENGTH TEST DATA: NORMAL OR CONFINING PRESSURE (PSF)	STRENGTH TEST DATA: SHEAR STRENGTH (PSF)	STRENGTH TEST DATA: DEVIATOR STRESS (PSF)	MOISTURE CONTENT (%)	DRY DENSITY (PCF)	BLOWS/FT.	SAMPLES
0											
5								8.1	107.9	63	■
10				DS-UU	1000	2920		14.9	117.4	62	■
15		30.5	13.3					16.4	102.1	11	■
20								10.9	117.7	100/5"	■
25											
30											
35											
40											
45											
50											
55											
60											
65											
70											
75											
80											

SYMBOLS	DESCRIPTION
ML	MOTTLED OLIVE BROWN FINE SANDY SILT WITH SOME CLAY (DENSE)
	COLOR CHANGES TO DARK BROWN (DENSE)
SC	LIGHT BROWN CLAYEY FINE SAND (LOOSE)
SM	MOTTLED BROWN FINE SAND WITH TRACE OF CLAY (VERY DENSE)
SS	BROWN SANDSTONE

FILL

BORING TERMINATED AT 22.5 FEET ON 9/19/85.
NO GROUNDWATER ENCOUNTERED.

LOG OF BORING

BY **Dames & Moore**

Figure 3-3J

BORING N1-AC1

SURFACE ELEVATION:6541.5 FEET
PCC COORDINATES
S 4994
E 15298

LABORATORY TEST DATA

	TESTS REPORTED ELSEWHERE	ATTERBERG LIMITS: LIQUID LIMIT (%)	ATTERBERG LIMITS: PLASTICITY INDEX (%)	STRENGTH TEST DATA: TYPE OF TEST	STRENGTH TEST DATA: NORMAL OR CONFINING PRESSURE (PSF)	STRENGTH TEST DATA: SHEAR STRENGTH (PSF)	STRENGTH TEST DATA: DEVIATOR STRESS (PSF)	MOISTURE CONTENT (%)	DRY DENSITY (PCF)	BLOWS/FT.	SAMPLES
0											
5								9.3	118.3	54	
10		26.5	5.4							61	
15								6.1	97.4	15	
20										40	
25		24.0	7.7					10.6	97.7	37	
30											
35											
40											
45											
50											
55											
60											
65											
70											
75											
80											

SYMBOLS	DESCRIPTION
SM	MOTTLED BROWN SILTY FINE SAND WITH FRAGMENTS OF SANDSTONE (MEDIUM DENSE)
	GRADES WITH SOME CLAY (DENSE)
	GRADES WITH LESS CLAY (LOOSE)
	GRADES WITH SOME CLAY AND WHITE STREAKS (MEDIUM DENSE)

FILL

BORING TERMINATED AT 26.5 FEET ON 9/24/85.
NO GROUNDWATER ENCOUNTERED.

LOG OF BORING

BY **Dames & Moore**

Figure 3-3K

BORING N1-AC2

SURFACE ELEVATION: 6543.3 FEET
PCC COORDINATES
S 4849
E 15281

LABORATORY TEST DATA

TESTS REPORTED ELSEWHERE	ATTERBERG LIMITS: LIQUID LIMIT (%)	ATTERBERG LIMITS: PLASTICITY INDEX (%)	STRENGTH TEST DATA: TYPE OF TEST	STRENGTH TEST DATA: NORMAL OR CONFINING PRESSURE (PSF)	STRENGTH TEST DATA: SHEAR STRENGTH (PSF)	STRENGTH TEST DATA: DEVIATOR STRESS (PSF)	MOISTURE CONTENT (%)	DRY DENSITY (PCF)
	24.1	7.6					10.0	124.7
							10.8	120.6
	27.8	9.7					7.7	93.0
							7.2	102.0

BLOWS/FT. SAMPLES	SYMBOLS	DESCRIPTION
104/10"	SM	MOTTLED BROWN SILTY FINE SAND WITH FRAGMENTS OF SANDSTONE (VERY DENSE)
83		DENSE
76		WITH SOME CLAY (DENSE)
43	SP	BROWN VERY FINE TO FINE SAND (MEDIUM DENSE)
54	SM	BROWN SILTY FINE SAND WITH SOME CLAY (MEDIUM DENSE)
60		MEDIUM DENSE

FILL

BORING TERMINATED AT 30.5 FEET ON 9/24/85.
NO GROUNDWATER ENCOUNTERED.

0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80

LOG OF BORING

BY **Dames & Moore**

Figure 3-3L

BORING N1-AC3

SURFACE ELEVATION: 8544.5 FEET
PCC COORDINATES
S 4888
E 18288

LABORATORY TEST DATA

	TESTS REPORTED ELSEWHERE	ATTERBERG LIMITS: LIQUID LIMIT (%)	ATTERBERG LIMITS: PLASTICITY INDEX (%)	STRENGTH TEST DATA: TYPE OF TEST	STRENGTH TEST DATA: NORMAL OR CONFINING PRESSURE (PSF)	STRENGTH TEST DATA: SHEAR STRENGTH (PSF)	STRENGTH TEST DATA: DEVIATOR STRESS (PSF)	MOISTURE CONTENT (%)	DRY DENSITY (PCF)
0									
								10.2	123.8
5									
10									
								16.7	115.8
15									
20									
	MA	23.6	5.3					13.6	119.5
25									
30									
35									
40									
45									
50									
55									
60									
65									
70									
75									
80									

BLOWS/FT. SAMPLES

81
79
82
70
66
39

SYMBOLS	DESCRIPTION
ML-CL	MOTTLED BROWN SILTY FINE SAND WITH FRAGMENTS OF SANDSTONE AND SOME CLAY (DENSE)
	GRADES WITH LESS CLAY (DENSE)
	DENSE
	GRADES TO INCLUDE FINE SANDY SILT POCKETS (DENSE)
ML	DARK BROWN FINE SANDY SILT (DENSE)
	DENSE
SP	VERY FINE TO FINE SAND WITH FRAGMENTS OF SANDSTONE

FILL

BORING TERMINATED AT 29.0 FEET ON 9/24/85.
NO GROUNDWATER ENCOUNTERED.

LOG OF BORING

BY **Dames & Moore**

Figure 3-3M

BORING N1-01

SURFACE ELEVATION: 8528.1 FEET
PCC COORDINATES
S 3918
E 27459

LABORATORY TEST DATA

	TESTS REPORTED ELSEWHERE	ATTERBERG LIMITS: LIQUID LIMIT (%)	ATTERBERG LIMITS: PLASTICITY INDEX (%)	STRENGTH TEST DATA: TYPE OF TEST	STRENGTH TEST DATA: NORMAL OR CONFINING PRESSURE (PSF)	STRENGTH TEST DATA: SHEAR STRENGTH (PSF)	STRENGTH TEST DATA: DEVIATOR STRESS (PSF)	MOISTURE CONTENT (%)	DRY DENSITY (PCF)	BLOWS/FT. SAMPLES
0										
5	G							11.5	116.4	92/ 11"
10								8.0	104.0	89
15										23
20										
25								20.2	108.1	75/ 9"
30										
35										
40										
45										
50										
55										
60										
65										
70										
75										
80										

SYMBOLS	DESCRIPTION
ML	MOTTLED OLIVE BROWN FINE SANDY SILT WITH FRAGMENTS OF SHALE (VERY DENSE)
	FILL
SP	BROWN FINE TO COARSE SAND WITH GRAVEL (DENSE)
	BROWN FINE TO COARSE SAND WITH GRAVEL (LOOSE)
	GRADING LESS GRAVEL
ML	BLACK GRAY SILT
SHALE	DARK GRAY SHALE (DENSE)

BORING TERMINATED AT 25.5 FEET ON 9/27/85.
GROUNDWATER ENCOUNTERED AT 15.0 FEET ON 9/27/85.

LOG OF BORING

BY **Dames & Moore**

Figure 3-3N

BORING N1-02

SURFACE ELEVATION: 6526.0 FEET
PCC COORDINATES
S 3839
E 27896

LABORATORY TEST DATA

TESTS REPORTED ELSEWHERE	ATTERBERG LIMITS: LIQUID LIMIT (%)	ATTERBERG LIMITS: PLASTICITY INDEX (%)	STRENGTH TEST DATA: TYPE OF TEST	STRENGTH TEST DATA: NORMAL OR CONFINING PRESSURE (PSF)	STRENGTH TEST DATA: SHEAR STRENGTH (PSF)	STRENGTH TEST DATA: DEVIATOR STRESS (PSF)	MOISTURE CONTENT (%)	DRY DENSITY (PCF)	BLOWS/FT.	SAMPLES
							7.6	116.9	72	
							12.9	113.1	46	
							4.8	100.5	30	
							19.7	105.9	30	
									72	
									50/1"	

0, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80

SYMBOLS	DESCRIPTION
ML	MOTTLED OLIVE BROWN FINE SANDY SILT WITH FRAGMENTS OF SHALE (DENSE)
	DENSE
SP	BROWN FINE SAND WITH TRACES OF COAL (MEDIUM DENSE)
SM-SP	BROWN SILTY FINE SAND AND FINE TO COARSE SAND WITH GRAVEL (MEDIUM DENSE)
	(DENSE)
	GRADING LESS GRAVEL
ML	DARK GRAY SILT
COAL	VERY DENSE

FILL

BORING TERMINATED AT 36.1 FEET ON 9/27/85.
GROUNDWATER ENCOUNTERED AT 17.0 FEET ON 9/27/85.

LOG OF BORING

BY **Dames & Moore**

Figure 3-30

BORING N10-D1

SURFACE ELEVATION: 6584.6 FEET
PCC COORDINATES
S 2138
E 31628

LABORATORY TEST DATA

Depth	TESTS REPORTED ELSEWHERE	ATTERBERG LIMITS: LIQUID LIMIT (%)	ATTERBERG LIMITS: PLASTICITY INDEX (%)	STRENGTH TEST DATA: TYPE OF TEST	STRENGTH TEST DATA: NORMAL OR CONFINING PRESSURE (PSF)	STRENGTH TEST DATA: SHEAR STRENGTH (PSF)	STRENGTH TEST DATA: DEVIATOR STRESS (PSF)	MOISTURE CONTENT (%)	DRY DENSITY (PCF)	BLOWS/FT.	SAMPLES
0–5	Cu			DS-UU	500	2200		9.6	120.0	58	
5–10		17.8	0.1	TXCUPP	–	–		10.5	119.4	50	
10–15		19.2	0.1	TXCUPP	–	–				43	
15–20		25.1	4.3	DS-UU	5000	3940		10.2	101.2	11	
20–25	G MA,C			DS-UU	2000	1400		10.0	110.6	27	
25–30										60	

SYMBOLS / DESCRIPTION

Symbol	Description
SM	BROWN SILTY FINE SANDS (MEDIUM DENSE)
	MEDIUM DENSE
	MEDIUM DENSE
SP	LIGHT BROWN FINE SAND WITH SOME SILT (LOOSE)
	BROWN SAND WITH SOME SILT AND A TRACE OF GRAVEL (MEDIUM DENSE)
SS	LIGHT GREY SANDSTONE (DENSE)

FILL

BORING TERMINATED AT 29.0 FEET ON 9/23/85.
GROUNDWATER ENCOUNTERED AT 26.0 FEET ON 9/23/85.

LOG OF BORING

BY **Dames & Moore**

Figure 3-3P

BORING N10-D2

SURFACE ELEVATION: 6585.5 FEET
PCC COORDINATES
S 2059
E 31669

LABORATORY TEST DATA

Depth	TESTS REPORTED ELSEWHERE	ATTERBERG LIMITS: LIQUID LIMIT (%)	ATTERBERG LIMITS: PLASTICITY INDEX (%)	STRENGTH TEST DATA: TYPE OF TEST	STRENGTH TEST DATA: NORMAL OR CONFINING PRESSURE (PSF)	STRENGTH TEST DATA: SHEAR STRENGTH (PSF)	STRENGTH TEST DATA: DEVIATOR STRESS (PSF)	MOISTURE CONTENT (%)	DRY DENSITY (PCF)	BLOWS/FT. SAMPLES
0										
5				DS-UU	500	1800		6.9	110.5	60
10		20.4	2.9					11.3	119.7	64
15										56
20										24
25				DS-UU	3000	3240		8.1	111.5	48
30								12.2	110.3	95/8"
35										
40										
45										
50										
55										
60										
65										
70										
75										
80										

SYMBOLS	DESCRIPTION
SM	BROWN SILTY FINE SANDS WITH TRACE OF CLAY (DENSE)
	DENSE
	MEDIUM DENSE
	GRADES WITH RED SANDSTONE FRAGMENTS (LOOSE)
SP	BROWN SAND WITH GRAVEL (MEDIUM DENSE)
SHALE	GRAY SHALE SLIGHTLY WEATHERED

FILL

BORING TERMINATED AT 29.2 FEET ON 9/23/85.
NO GROUNDWATER ENCOUNTERED.

LOG OF BORING

BY **Dames & Moore**

Figure 3-3Q

BORING N10-D3

SURFACE ELEVATION:6583.9 FEET
PCC COORDINATES
S 1966
E 31718

LABORATORY TEST DATA

	TESTS REPORTED ELSEWHERE	ATTERBERG LIMITS: LIQUID LIMIT (%)	ATTERBERG LIMITS: PLASTICITY INDEX (%)	STRENGTH TEST DATA: TYPE OF TEST	STRENGTH TEST DATA: NORMAL OR CONFINING PRESSURE (PSF)	STRENGTH TEST DATA: SHEAR STRENGTH (PSF)	STRENGTH TEST DATA: DEVIATOR STRESS (PSF)	MOISTURE CONTENT (%)	DRY DENSITY (PCF)
0									
5								10.4	82.7
10									
15									
20	MA			DS-UU	2000	2560		9.0	112.8
25								15.1	117.1
30									
35									
40									
45									
50									
55									
60									
65									
70									
75									
80									

BLOWS/FT.	SAMPLES
16	■
18	■
8	■
22	■
90/8"	■

SYMBOLS	DESCRIPTION
SM	LIGHT BROWN SILTY VERY FINE SAND WITH SOME CLAY (LOOSE)
	LOOSE
	VERY LOOSE
ML	DARK BROWN SANDY SILT
GP	BROWN SANDY GRAVEL (MEDIUM DENSE)
SS	LIGHT GRAY SANDSTONE (VERY DENSE)

FILL

BORING TERMINATED AT 27.5 FEET ON 9/23/85.
GROUNDWATER ENCOUNTERED AT 25.2 FEET ON 9/23/85.

LOG OF BORING

BY **Dames & Moore**

Figure 3-3R

BORING N14-01

SURFACE ELEVATION: 6604.7 FEET
PCC COORDINATES
S 15814
E 53870

LABORATORY TEST DATA

TESTS REPORTED ELSEWHERE	ATTERBERG LIMITS: LIQUID LIMIT (%)	ATTERBERG LIMITS: PLASTICITY INDEX (%)	STRENGTH TEST DATA: TYPE OF TEST	STRENGTH TEST DATA: NORMAL OR CONFINING PRESSURE (PSF)	STRENGTH TEST DATA: SHEAR STRENGTH (PSF)	STRENGTH TEST DATA: DEVIATOR STRESS (PSF)	MOISTURE CONTENT (%)	DRY DENSITY (PCF)
							6.8	105.2
							8.0	96.5
							8.0	100.9

BLOWS/FT.	SAMPLES
101	
23	
30	
38	
32	
56	
56	

SYMBOLS	DESCRIPTION
SM	BROWN SILTY FINE SAND WITH SOME SMALL FRAGMENTS OF SANDSTONE (DENSE)
	MEDIUM DENSE
	MEDIUM DENSE
	BROWN WITH TAN STREAKS SILTY FINE SAND (MEDIUM DENSE)

FILL

BORING TERMINATED AT 31.5 FEET ON 9/19/85.
NO GROUNDWATER ENCOUNTERED.

0, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80

LOG OF BORING

BY **Dames & Moore**

Figure 3-3S

BORING N14-02

SURFACE ELEVATION: 6604.6 FEET
PCC COORDINATES
S 15726
E 53781

LABORATORY TEST DATA

	TESTS REPORTED ELSEWHERE	ATTERBERG LIMITS: LIQUID LIMIT (%)	ATTERBERG LIMITS: PLASTICITY INDEX (%)	STRENGTH TEST DATA: TYPE OF TEST	STRENGTH TEST DATA: NORMAL OR CONFINING PRESSURE (PSF)	STRENGTH TEST DATA: SHEAR STRENGTH (PSF)	STRENGTH TEST DATA: DEVIATOR STRESS (PSF)	MOISTURE CONTENT (%)	DRY DENSITY (PCF)	BLOWS/FT. SAMPLES
0										
5								11.1	114.6	25
10	MA							7.0	90.1	22
15								6.4	93.4	28
20		25.9	9.4					8.8	96.4	65
25										27
30								10.8	105.2	52
35										
40										
45										
50										
55										
60										
65										
70										
75										
80										

SYMBOLS	DESCRIPTION
SM	BROWN SILTY FINE SAND WITH SOME FRAGMENTS OF SANDSTONE (MEDIUM DENSE)
ML	BROWN SANDY CLAYEY SILT (MEDIUM DENSE)
CL	BROWN SANDY CLAY (MEDIUM DENSE)
	GRADES TO DENSE
ML	BROWN WITH TAN STREAKS, CLAYEY SILT (MEDIUM DENSE)
SM	BROWN WITH TAN STREAKS, SILTY FINE SAND (MEDIUM DENSE)

FILL

BORING TERMINATED AT 32.5 FEET ON 9/19/85.
NO GROUNDWATER ENCOUNTERED.

LOG OF BORING

BY **Dames & Moore**

Figure 3-3T

BORING N14-03

SURFACE ELEVATION: 6604.9 FEET
PCC COORDINATES
S 15823
E 53706

LABORATORY TEST DATA

Depth	TESTS REPORTED ELSEWHERE	ATTERBERG LIMITS: LIQUID LIMIT (%)	ATTERBERG LIMITS: PLASTICITY INDEX (%)	STRENGTH TEST DATA: TYPE OF TEST	STRENGTH TEST DATA: NORMAL OR CONFINING PRESSURE (PSF)	STRENGTH TEST DATA: SHEAR STRENGTH (PSF)	STRENGTH TEST DATA: DEVIATOR STRESS (PSF)	MOISTURE CONTENT (%)	DRY DENSITY (PCF)	BLOWS/FT.	SAMPLES
0											
5								10.9	113.5	64	
10								8.8	107.9	62	
15										23	
20								3.9	100.0	38	
25				DS-UU	3000	3040		6.5	97.5	46	
30	MA	29.3	11.4					5.3	102.9	67	
35											
40										36	
45										100/0.25"	
50											
55											
60											
65											
70											
75											
80											

SYMBOLS	DESCRIPTION
SM	BROWN SILTY FINE SAND WITH SOME SMALL FRAGMENTS OF SANDSTONE (DENSE)
	DENSE
	MEDIUM DENSE
	MEDIUM DENSE
CL	MOTTLED OLIVE BROWN AND TAN SANDY CLAY WITH FRAGMENTS OF SANDSTONE (DENSE)
SM	BROWN SILTY SAND (MEDIUM DENSE)
	SANDSTONE

FILL

BORING TERMINATED AT 47.0 FEET ON 9/20/85.
NO GROUNDWATER ENCOUNTERED.

LOG OF BORING

BY **Dames & Moore**

Figure 3-3U

MAJOR DIVISIONS			GRAPHIC SYMBOL	LETTER SYMBOL	TYPICAL DESCRIPTIONS
COARSE GRAINED SOILS MORE THAN 50% OF MATERIAL IS LARGER THAN NO. 200 SIEVE SIZE	GRAVEL AND GRAVELLY SOILS MORE THAN 50% OF COARSE FRACTION RETAINED ON NO. 4 SIEVE	CLEAN GRAVELS (LITTLE OR NO FINES)		GW	WELL-GRADED GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES
				GP	POORLY-GRADED GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES
		GRAVELS WITH FINES (APPRECIABLE AMOUNT OF FINES)		GM	SILTY GRAVELS, GRAVEL-SAND-SILT MIXTURES
				GC	CLAYEY GRAVELS, GRAVEL-SAND-CLAY MIXTURES
	SAND AND SANDY SOILS MORE THAN 50% OF COARSE FRACTION PASSING NO. 4 SIEVE	CLEAN SAND (LITTLE OR NO FINES)		SW	WELL-GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES
				SP	POORLY-GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES
		SANDS WITH FINES (APPRECIABLE AMOUNT OF FINES)		SM	SILTY SANDS, SAND-SILT MIXTURES
				SC	CLAYEY SANDS, SAND-CLAY MIXTURES
FINE GRAINED SOILS MORE THAN 50% OF MATERIAL IS SMALLER THAN NO. 200 SIEVE SIZE	SILTS AND CLAYS	LIQUID LIMIT LESS THAN 50		ML	INORGANIC SILTS AND VERY FINE SANDS, ROCK FLOUR, SILTY OR CLAYEY FINE SANDS OR CLAYEY SILTS WITH SLIGHT PLASTICITY
				CL	INORGANIC CLAYS OF LOW TO MEDIUM PLASTICITY, GRAVELLY CLAYS, SANDY CLAYS, SILTY CLAYS, LEAN CLAYS
				OL	ORGANIC SILTS AND ORGANIC SILTY CLAYS OF LOW PLASTICITY
	SILTS AND CLAYS	LIQUID LIMIT GREATER THAN 50		MH	INORGANIC SILTS, MICACEOUS OR DIATOMACEOUS FINE SAND OR SILTY SOILS
				CH	INORGANIC CLAYS OF HIGH PLASTICITY, FAT CLAYS
				OH	ORGANIC CLAYS OF MEDIUM TO HIGH PLASTICITY, ORGANIC SILTS
HIGHLY ORGANIC SOILS				PT	PEAT, HUMUS, SWAMP SOILS WITH HIGH ORGANIC CONTENTS

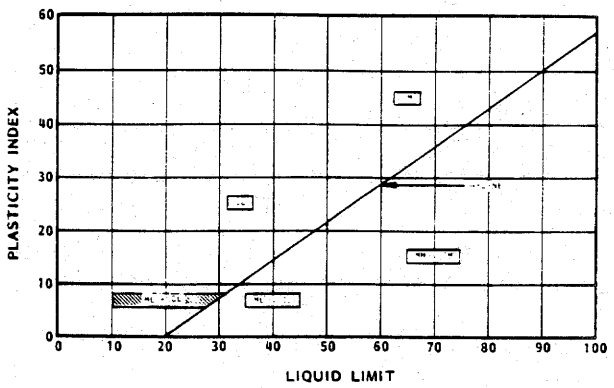
NOTE: DUAL SYMBOLS ARE USED TO INDICATE BORDERLINE SOIL CLASSIFICATIONS

UNIFIED SOIL CLASSIFICATION SYSTEM

BY **Dames & Moore** Figure 3-4A

SYMBOL	TYPE OF TEST
M	MOISTURE
QD	QUICK MD TEST BASED ON ASSUMED SPECIFIC GRAVITY
MD	MOISTURE-DENSITY
CD	CHUNK DENSITY ON BULK SAMPLE
RD	RELATIVE DENSITY
COMP	COMPACTION CURVE
CI	CALIFORNIA IMPACT
CC	COMPACTED CORE
G	SPECIFIC GRAVITY
pH	HYDROGEN ION CONCENTRATION
MA	MECHANICAL ANALYSIS*
SA	SIEVE ANALYSIS (+200 ONLY)
HA	HYDROMETER ANALYSIS (-200 ONLY)
AL	ATTERBERG LIMITS (LL & PL)
SL	SHRINKAGE LIMIT
FS	FREE SWELL
SS	SHRINK-SWELL
EXP	EXPANSION
C (COL)	CONSOLIDATION (COLLAPSE)
VC	VIBRATING CONSOLIDATION
P	PERMEABILITY
FP	FIELD PERMEABILITY
UC	UNCONFINED COMPRESSION
	TRIAXIAL COMPRESSION TEST
TXUU	1. UNCONSOLIDATED-UNDRAINED
TXCU	2. CONSOLIDATED-UNDRAINED
TXCUM	3. CU/MULTIPHASE**
TXCUPP	4. CU/WITH PORE PRESSURE MEASUREMENTS
TXCD	5. CONSOLIDATED-DRAINED
	DIRECT SHEAR TEST
DS/UU	1. UNCONSOLIDATED-UNDRAINED
DS/CU	2. CONSOLIDATED-UNDRAINED
DS/CD	3. CONSOLIDATED-DRAINED
DS/CD/MΦ	4. CD/MULTIPHASE**
LV	TORVANE SHEAR (LAB VANE SHEAR)

* INCLUDES COMPLETE ANALYSIS, SIEVING AND HYDROMETER
** SERIES OF TESTS RUN ON SAMPLE



PLASTICITY CHART

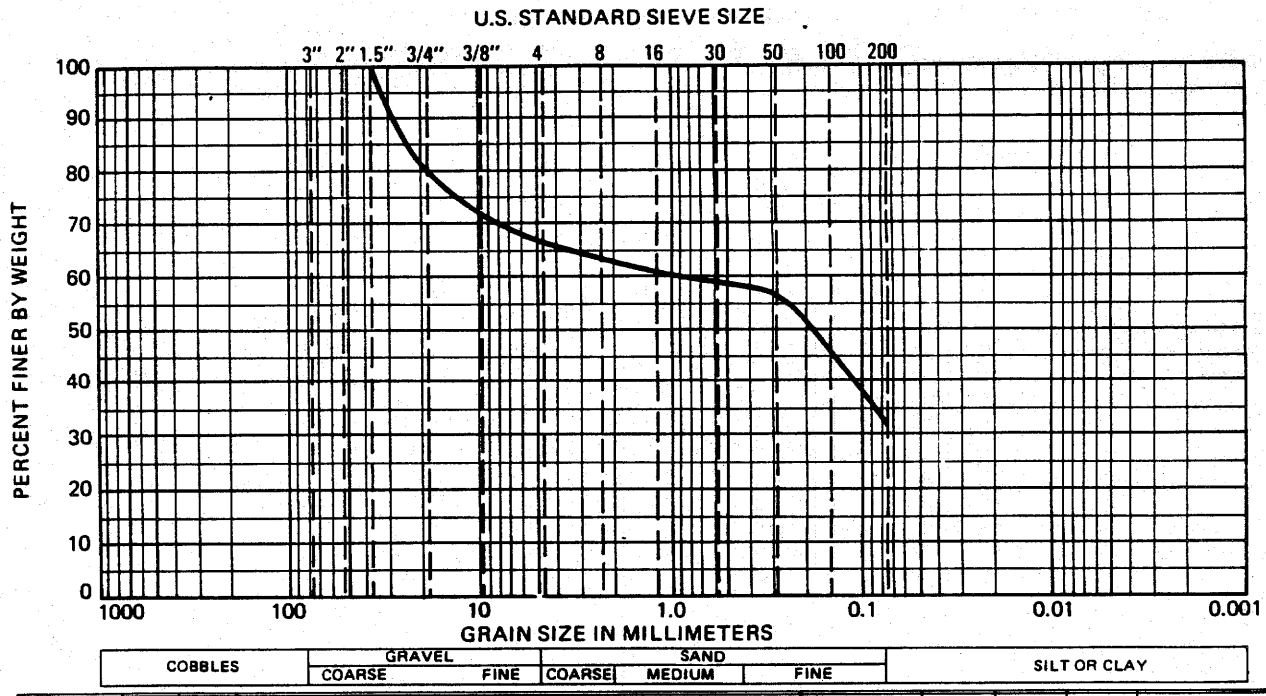
- INDICATES DEPTH OF AUGER CUTTINGS SAMPLE
- INDICATES DEPTH OF UNDISTURBED SAMPLE
- INDICATES DEPTH OF DISTURBED SAMPLE
- INDICATES DEPTH OF SAMPLING ATTEMPT WITH NO RECOVERY
- INDICATES DEPTH OF STANDARD PENETRATION TEST
- INDICATES DEPTH OF STANDARD PENETRATION TEST WITH NO RECOVERY
- 70% I 5% INDICATES DEPTH AND LENGTH OF CORE RUN
  - 5% — RQD (ROCK QUALITY DETERMINATION) PERCENT OF THE TOTAL CORE RUN HAVING AN UNFRACTURED LENGTH OF 4" OR MORE
  - 70% — PERCENT OF CORE RUN RECOVERED
- INDICATES DEPTH OF FIELD VANE SHEAR TEST

NOTE:
UNLESS OTHERWISE NOTED SAMPLING RESISTANCE IS MEASURED IN BLOWS PER FOOT REQUIRED TO DRIVE SAMPLER 12-INCHES AFTER SAMPLER HAS BEEN SEATED 6-INCHES. A 140-POUND HAMMER, FREE FALLING A DISTANCE OF 30 INCHES IS USED TO DRIVE THE SAMPLER.

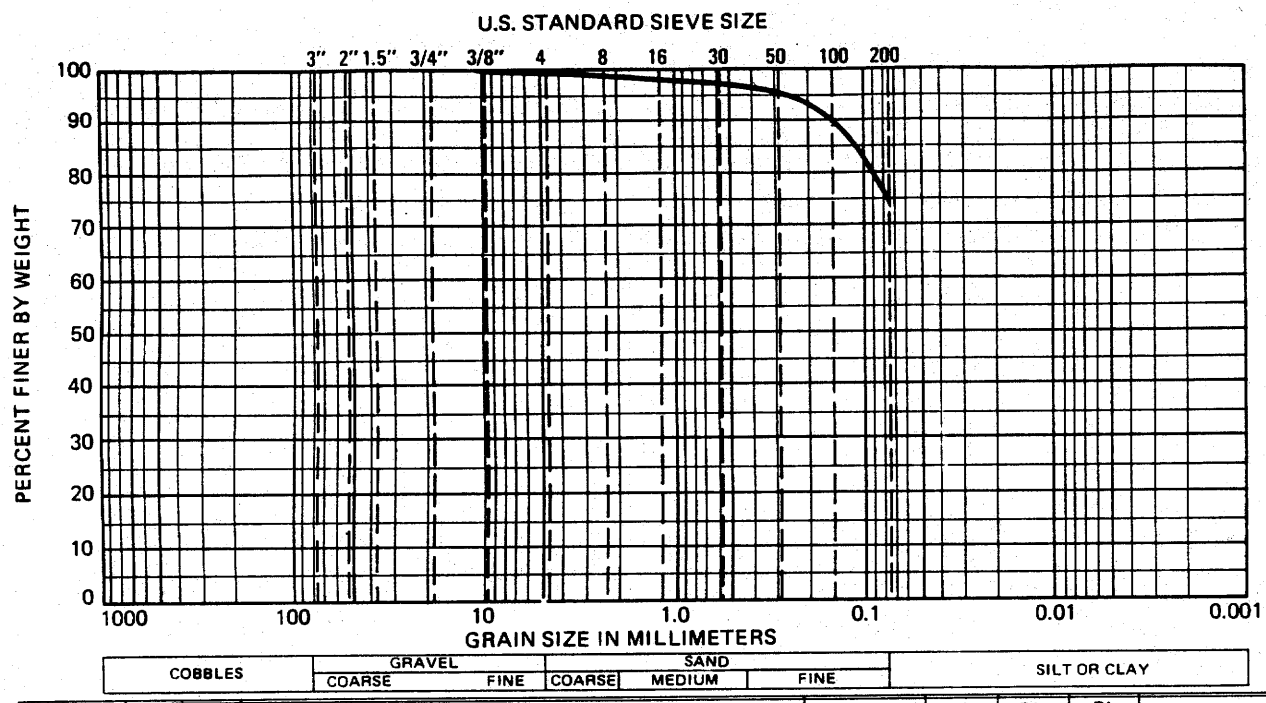
KEY TO SAMPLES

KEY TO LOG OF BORINGS

BY **Dames & Moore** Figure 3-4B



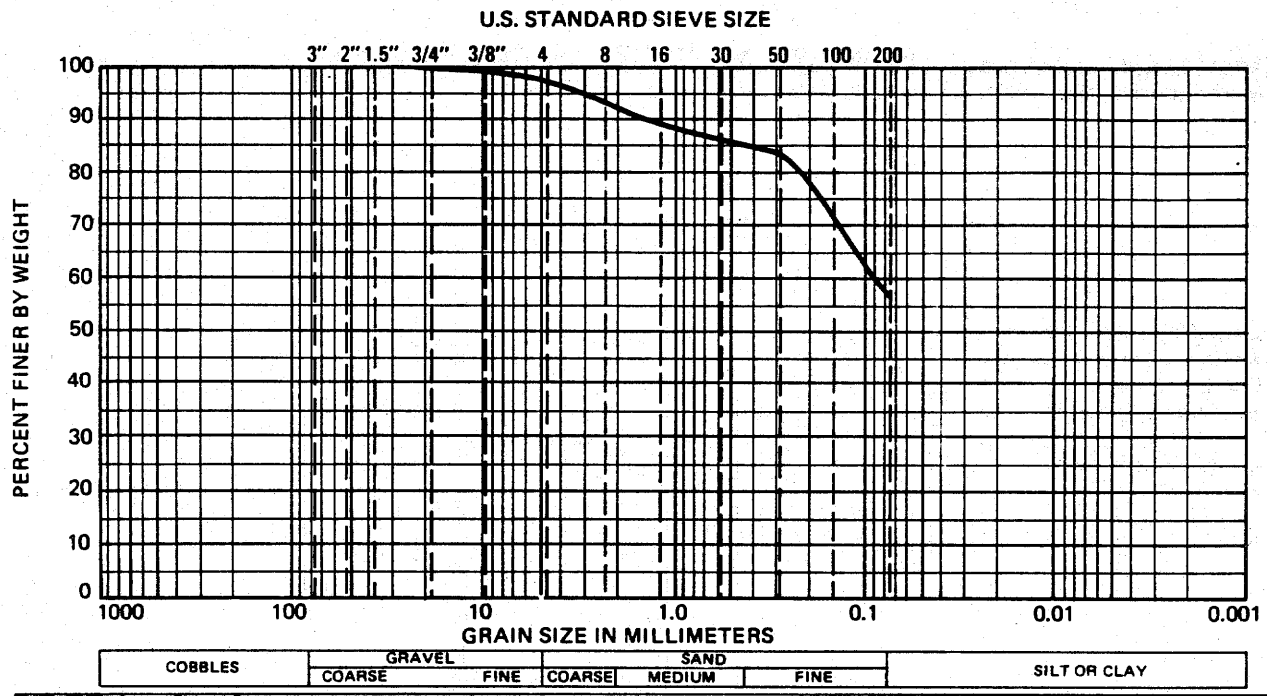
J3-E1	DEPTH		CLASSIFICATION	NAT. W C	LL	PL	PI	
SAMPLE 3	13.0'-13.5'	SC	BROWN CLAYEY SAND WITH SOME GRAVEL	11.9	22.9	15.6	7.3	



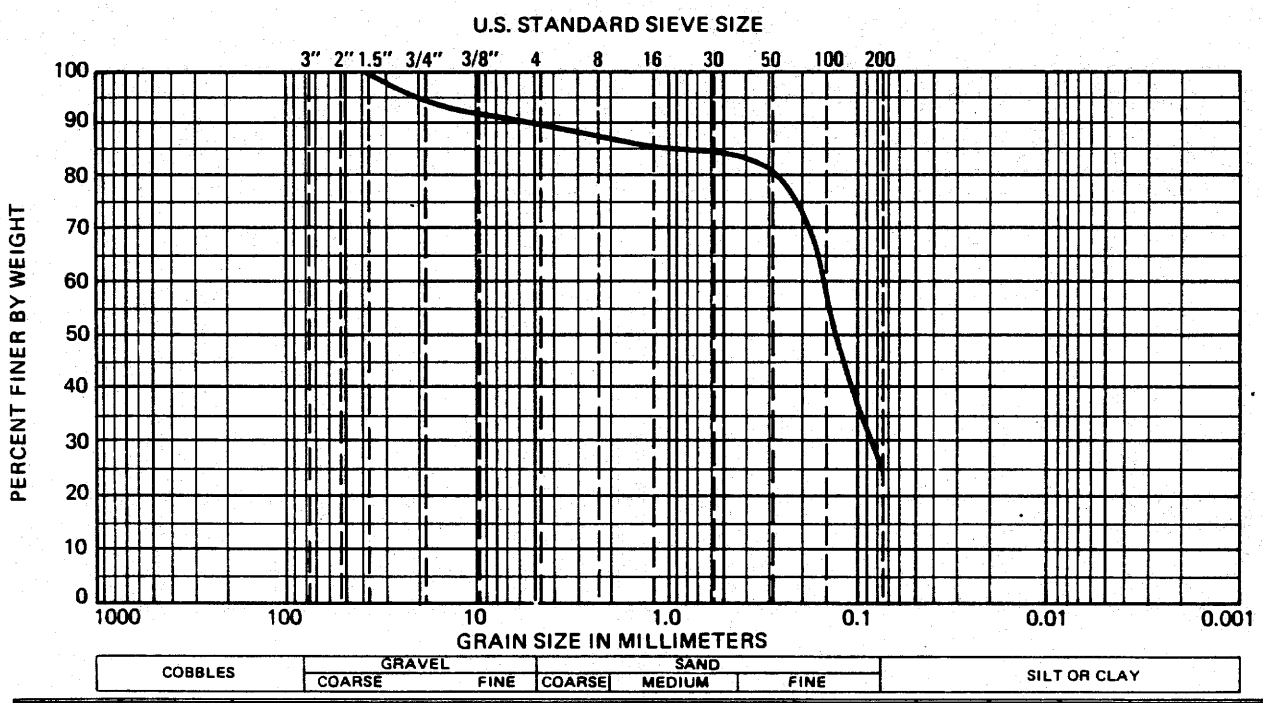
J28-C1	DEPTH		CLASSIFICATION	NAT. W C	LL	PL	PI	
SAMPLE 1	3.0'	ML	MOTTLED TAN & BROWN FINE SANDY SILT WITH TRACE CLAY	8.3	27.1	17.7	9.4	

GRADATION CURVES

BY **Dames & Moore** Figure 3-5A



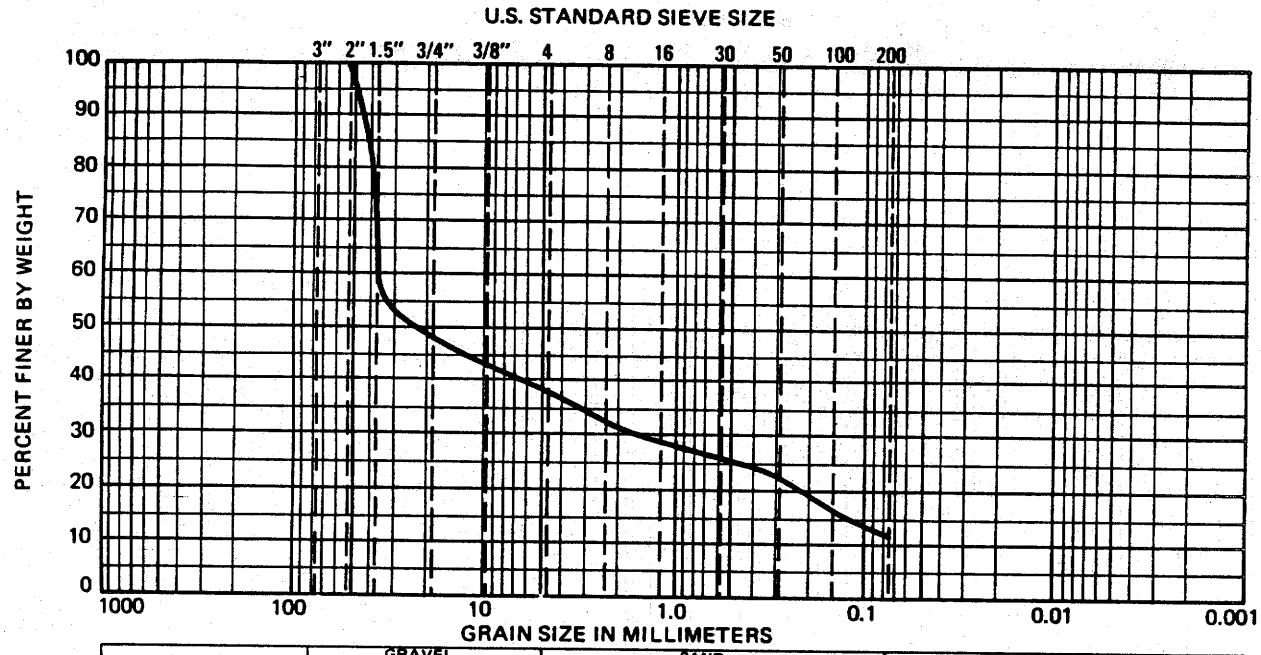
N1-AC3	DEPTH		CLASSIFICATION	NAT. W C	LL	PL	PI	
SAMPLE 5	23.0'-23.5'	ML	DARK BROWN FINE SANDY SILT	13.2	23.6	18.3	5.3	



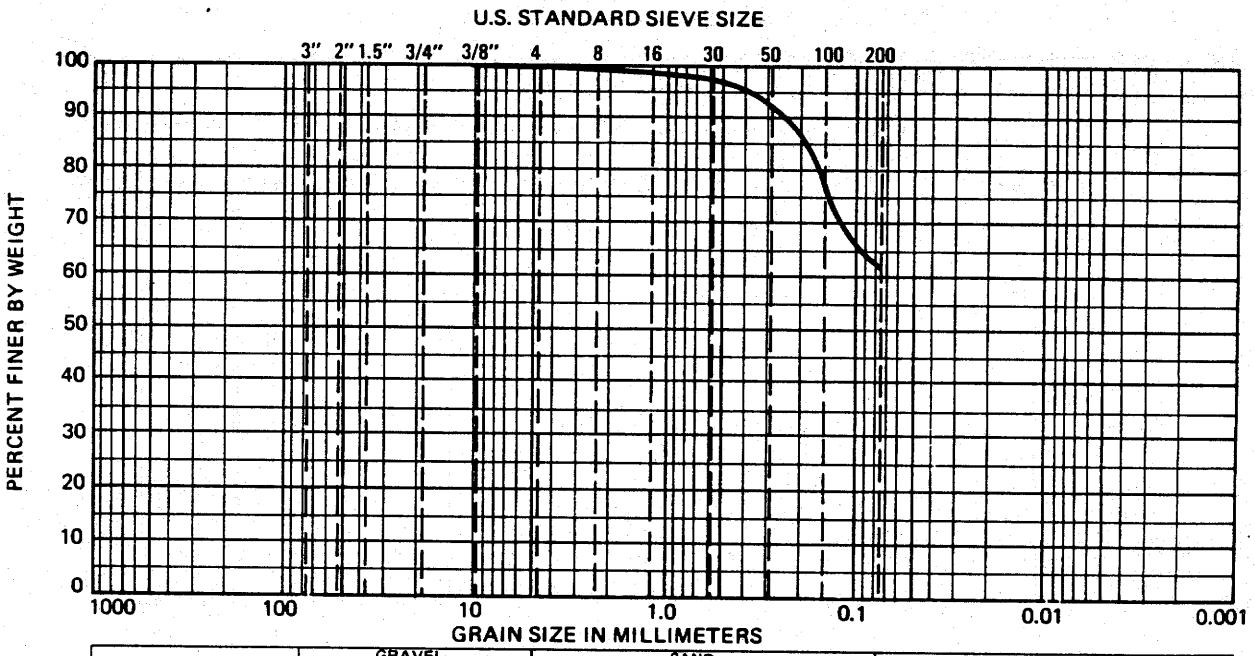
N10-O1	DEPTH		CLASSIFICATION	NAT. W C	LL	PL	PI	
SAMPLE 5	23.0'	SP	BROWN SAND W/SOME SILT AND A TRACE GRAVEL	12.5	-	-	-	

GRADATION CURVES

BY **Dames & Moore** Figure 3-5B



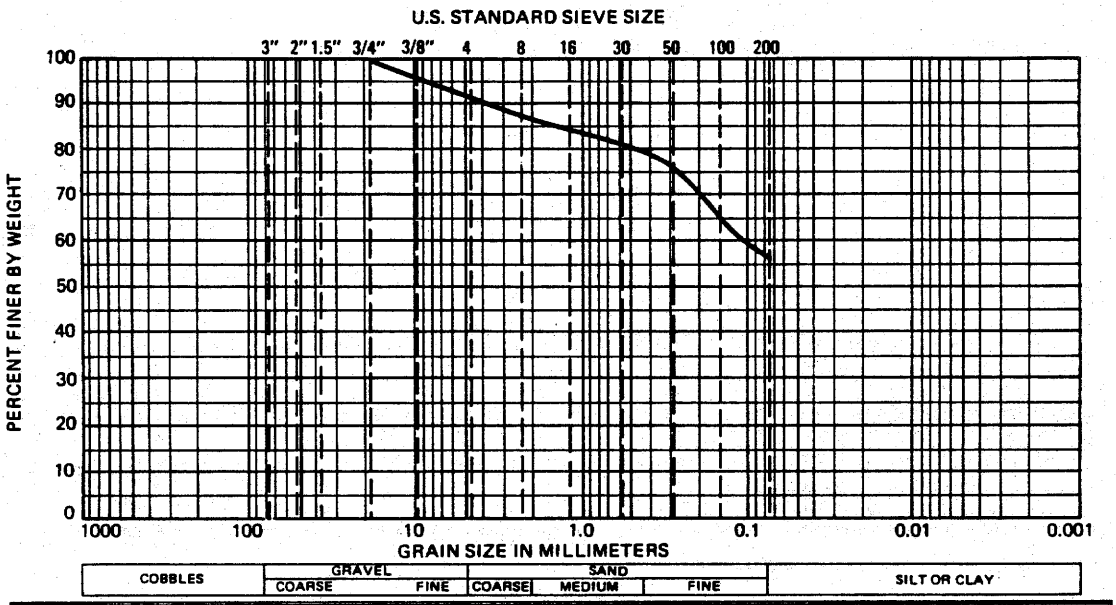
N10-O3	DEPTH		CLASSIFICATION	NAT. W C	LL	PL	PI	
SAMPLE 4	20.5'	GP	BROWN SANDY GRAVEL	9.6	-	-	-	



N14-O2	DEPTH		CLASSIFICATION	NAT. W C	LL	PL	PI	
SAMPLE 2	11.5'-12.0'	ML	BROWN SANDY CLAYEY SILT	6.9	-	-	-	

GRADATION CURVES

BY **Dames & Moore** Figure 3-5C



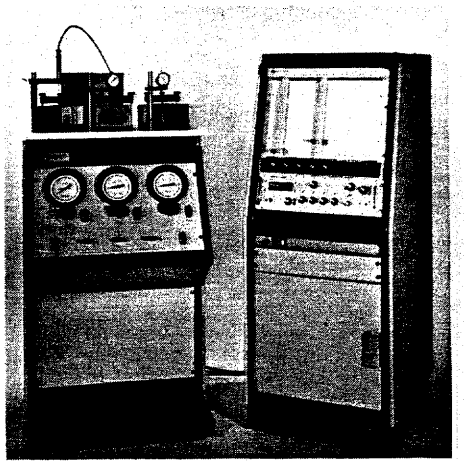
N14-O3	DEPTH		CLASSIFICATION	NAT. W C	LL	PL	PI	
SAMPLE 6	29.5'-30.0'	CL	BROWN AND TAN SANDY CLAY W/SOME SILT	8.5	29.3	17.9	11.4	

GRADATION CURVES

BY **Dames & Moore** Figure 3-5D

Method Of Performing Direct Shear and Friction Tests

Direct shear tests are performed to determine the shearing strengths of soils. Friction tests are performed to determine the frictional resistances between soils and various other materials such as wood, steel, or concrete. The tests are performed in the laboratory to simulate anticipated field conditions.



DIRECT SHEAR APPARATUS WITH ELECTRONIC RECORDER

Each sample is tested in a split sample holder, two and one-half inches in diameter and one inch high. Undisturbed samples of in-place soils are extruded from rings taken from the sampling device in which the samples were obtained. Loose samples of soils to be used in constructing earth fills are compacted in rings to predetermined conditions and tested.

Direct Shear Tests

A one-inch length of the sample is tested in direct single shear. A constant pressure, appropriate to the conditions of the problem for which the test is being performed, is applied normal to the ends of the sample through porous stones. A shearing failure of the sample is caused by moving the upper sample holder in a direction perpendicular to the axis of the sample. Transverse movement of the lower sample holder is prevented.

The shearing failure is accomplished by applying to the upper sample holder a constant rate of deflection. The shearing load and the deflections in both the axial and transverse directions are recorded and plotted. The shearing strength of the soils is determined from the resulting load-deflection curves.

Friction Tests

In order to determine the frictional resistance between soil and the surfaces of various materials, the lower sample holder in the direct shear test is replaced by a disk of the material to be tested. The test is then performed in the same manner as the direct shear test by forcing the soil over the friction material surface.

3.6.6 Triaxial Compression Test

Triaxial consolidated undrained compression tests with pore pressure measurements were completed to evaluate shear strength of residual sandstone and residual shale soils under simulated loading conditions similar to those expected in the field. Samples were subjected first to an all-round confining pressure and allowed to consolidate. A shearing force was then applied vertically in the form of a constant rate of deflection. Measurements taken during a test define successive stress states within the sample and can be plotted as points on a stress path. The test results are presented on Figures 3-7A through 3-7B. A general description of the test procedure is presented on Figure 3-8.

3.6.7 Consolidation/Collapse Test

A consolidation test was performed on a representative sample extracted from borings to provide information on the settlement characteristics of the soil. The test was performed in the manner described on Figure 3-9. In addition, in order to evaluate the collapse potential of the soils, the sample was loaded to a specific consolidation pressure at the field moisture content. Once the consolidation process was completed at the field moisture content, the sample was saturated and allowed to consolidate further. The collapse potential of the sample was then evaluated based on the additional consolidation that occurred during saturation. The results of the test are presented on Figure 3-10.

based on published literature and our experience. The strength parameters selected for the soil and rock encountered at the site are listed in Table 3-5.

Table 3-5

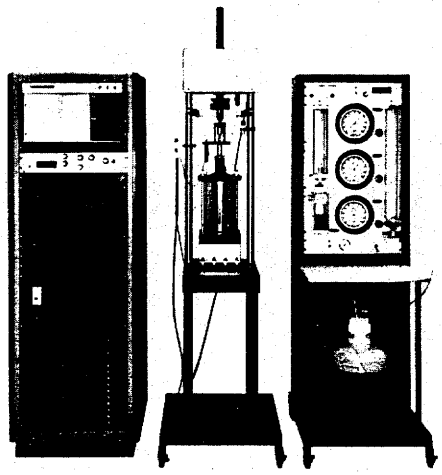
EFFECTIVE STRESS STRENGTH PARAMETERS

	Soil or Rock Type	Friction Angle (degrees)	Cohesion (psf)
SP, SM, GP	Residual Sandstone Soils	36	0
SM, ML, CL, GP	Residual Shale Soils	33	200
SP GP	Alluvial Soils	36	0
	Sandstone Bedrock	25	20,000
	Shale Bedrock	25	20,000

METHODS OF PERFORMING UNCONFINED COMPRESSION AND TRIAXIAL COMPRESSION TESTS

THE SHEARING STRENGTHS OF SOILS ARE DETERMINED FROM THE RESULTS OF UNCONFINED COMPRESSION AND TRIAXIAL COMPRESSION TESTS. IN TRIAXIAL COMPRESSION TESTS THE TEST METHOD AND THE MAGNITUDE OF THE CONFINING PRESSURE ARE CHOSEN TO SIMULATE ANTICIPATED FIELD CONDITIONS.

UNCONFINED COMPRESSION AND TRIAXIAL COMPRESSION TESTS ARE PERFORMED ON UNDISTURBED OR REMOLDED SAMPLES OF SOIL APPROXIMATELY SIX INCHES IN LENGTH AND TWO AND ONE-HALF INCHES IN DIAMETER. THE TESTS ARE RUN EITHER STRAIN-CONTROLLED OR STRESS-CONTROLLED. IN A STRAIN-CONTROLLED TEST THE SAMPLE IS SUBJECTED TO A CONSTANT RATE OF DEFLECTION AND THE RESULTING STRESSES ARE RECORDED. IN A STRESS-CONTROLLED TEST THE SAMPLE IS SUBJECTED TO EQUAL INCREMENTS OF LOAD WITH EACH INCREMENT BEING MAINTAINED UNTIL AN EQUILIBRIUM CONDITION WITH RESPECT TO STRAIN IS ACHIEVED.



TRIAXIAL COMPRESSION TEST UNIT

YIELD, PEAK, OR ULTIMATE STRESSES ARE DETERMINED FROM THE STRESS-STRAIN PLOT FOR EACH SAMPLE AND THE PRINCIPAL STRESSES ARE EVALUATED. THE PRINCIPAL STRESSES ARE PLOTTED ON A MOHR'S CIRCLE DIAGRAM TO DETERMINE THE SHEARING STRENGTH OF THE SOIL TYPE BEING TESTED.

UNCONFINED COMPRESSION TESTS CAN BE PERFORMED ONLY ON SAMPLES WITH SUFFICIENT COHESION SO THAT THE SOIL WILL STAND AS AN UNSUPPORTED CYLINDER. THESE TESTS MAY BE RUN AT NATURAL MOISTURE CONTENT OR ON ARTIFICIALLY SATURATED SOILS.

IN A TRIAXIAL COMPRESSION TEST THE SAMPLE IS ENCASED IN A RUBBER MEMBRANE, PLACED IN A TEST CHAMBER, AND SUBJECTED TO A CONFINING PRESSURE THROUGHOUT THE DURATION OF THE TEST. NORMALLY, THIS CONFINING PRESSURE IS MAINTAINED AT A CONSTANT LEVEL, ALTHOUGH FOR SPECIAL TESTS IT MAY BE VARIED IN RELATION TO THE MEASURED STRESSES. TRIAXIAL COMPRESSION TESTS MAY BE RUN ON SOILS AT FIELD MOISTURE CONTENT OR ON ARTIFICIALLY SATURATED SAMPLES. THE TESTS ARE PERFORMED IN ONE OF THE FOLLOWING WAYS:

UNCONSOLIDATED-UNDRAINED: THE CONFINING PRESSURE IS IMPOSED ON THE SAMPLE AT THE START OF THE TEST. NO DRAINAGE IS PERMITTED AND THE STRESSES WHICH ARE MEASURED REPRESENT THE SUM OF THE INTERGRANULAR STRESSES AND PORE WATER PRESSURES.

CONSOLIDATED-UNDRAINED: THE SAMPLE IS ALLOWED TO CONSOLIDATE FULLY UNDER THE APPLIED CONFINING PRESSURE PRIOR TO THE START OF THE TEST. THE VOLUME CHANGE IS DETERMINED BY MEASURING THE WATER AND/OR AIR EXPELLED DURING CONSOLIDATION. NO DRAINAGE IS PERMITTED DURING THE TEST AND THE STRESSES WHICH ARE MEASURED ARE THE SAME AS FOR THE UNCONSOLIDATED-UNDRAINED TEST.

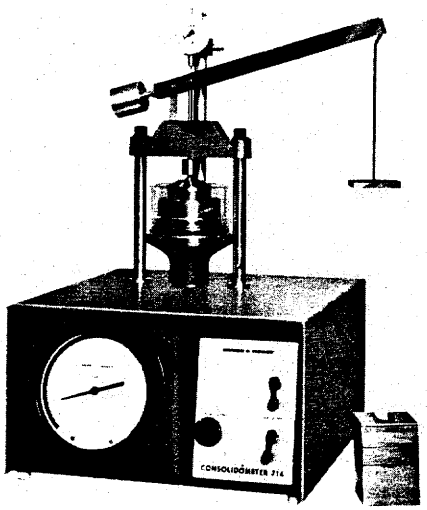
DRAINED: THE INTERGRANULAR STRESSES IN A SAMPLE MAY BE MEASURED BY PERFORMING A DRAINED, OR SLOW, TEST. IN THIS TEST THE SAMPLE IS FULLY SATURATED AND CONSOLIDATED PRIOR TO THE START OF THE TEST. DURING THE TEST, DRAINAGE IS PERMITTED AND THE TEST IS PERFORMED AT A SLOW ENOUGH RATE TO PREVENT THE BUILDUP OF PORE WATER PRESSURES. THE RESULTING STRESSES WHICH ARE MEASURED REPRESENT ONLY THE INTERGRANULAR STRESSES. THESE TESTS ARE USUALLY PERFORMED ON SAMPLES OF GENERALLY NON-COHESIVE SOILS, ALTHOUGH THE TEST PROCEDURE IS APPLICABLE TO COHESIVE SOILS IF A SUFFICIENTLY SLOW TEST RATE IS USED.

AN ALTERNATE MEANS OF OBTAINING THE DATA RESULTING FROM THE DRAINED TEST IS TO PERFORM AN UNDRAINED TEST IN WHICH SPECIAL EQUIPMENT IS USED TO MEASURE THE PORE WATER PRESSURES. THE DIFFERENCES BETWEEN THE TOTAL STRESSES AND THE PORE WATER PRESSURES MEASURED ARE THE INTERGRANULAR STRESSES.

METHOD OF PERFORMING CONSOLIDATION TESTS

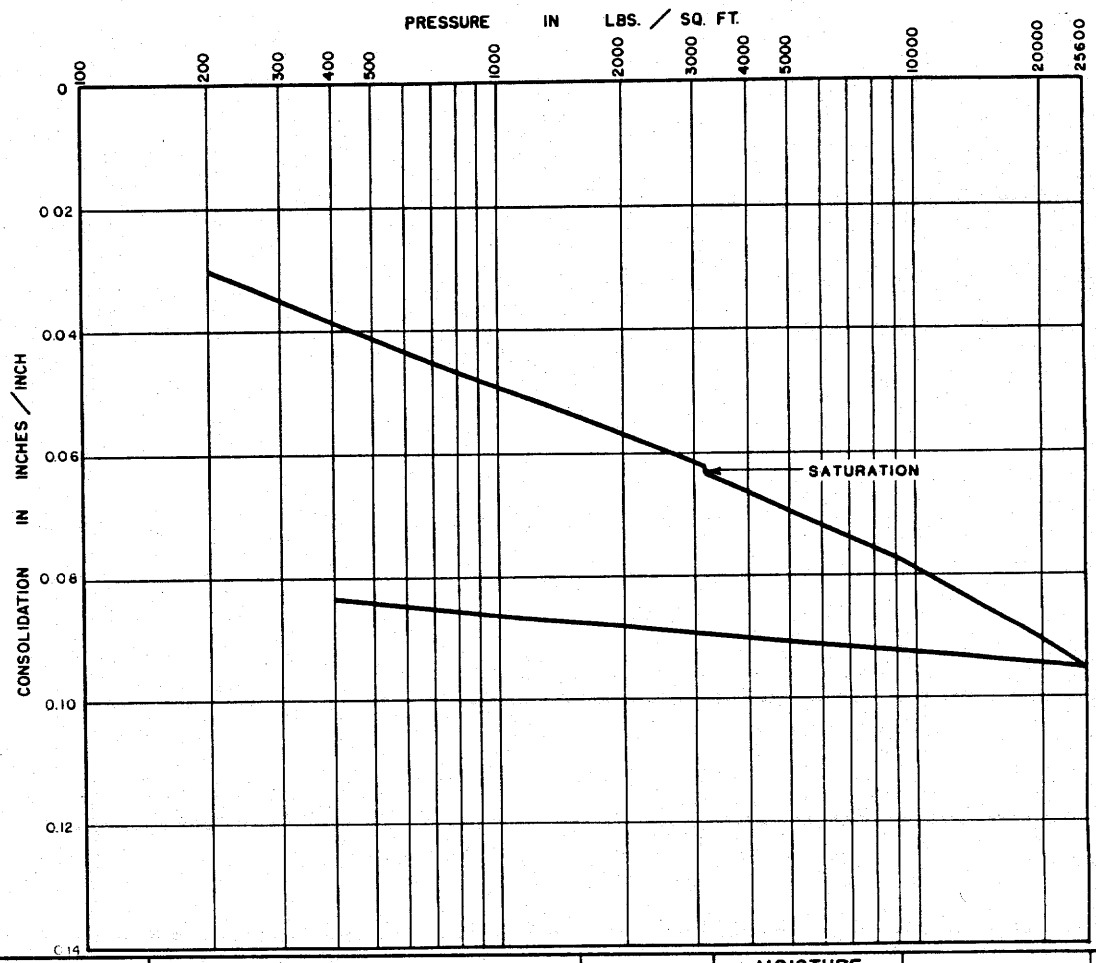
CONSOLIDATION TESTS ARE PERFORMED TO EVALUATE THE VOLUME CHANGES OF SOILS SUBJECTED TO INCREASED LOADS. TIME-CONSOLIDATION AND PRESSURE-CONSOLIDATION CURVES MAY BE PLOTTED FROM THE DATA OBTAINED IN THE TESTS. ENGINEERING ANALYSES BASED ON THESE CURVES PERMIT ESTIMATES TO BE MADE OF THE PROBABLE MAGNITUDE AND RATE OF SETTLEMENT OF THE TESTED SOILS UNDER APPLIED LOADS.

EACH SAMPLE IS TESTED WITHIN BRASS RINGS TWO AND ONE-HALF INCHES IN DIAMETER AND ONE INCH IN LENGTH. UNDISTURBED SAMPLES OF IN-PLACE SOILS ARE TESTED IN RINGS TAKEN FROM THE SAMPLING DEVICE IN WHICH THE SAMPLES WERE OBTAINED. LOOSE SAMPLES OF SOILS TO BE USED IN CONSTRUCTING EARTH FILLS ARE COMPACTED IN RINGS TO PREDETERMINED CONDITIONS AND TESTED.



DEAD LOAD-PNEUMATIC CONSOLIDOMETER

IN TESTING, THE SAMPLE IS RIGIDLY CONFINED LATERALLY BY THE BRASS RING. AXIAL LOADS ARE TRANSMITTED TO THE ENDS OF THE SAMPLE BY POROUS DISKS. THE DISKS ALLOW DRAINAGE OF THE LOADED SAMPLE. THE AXIAL COMPRESSION OR EXPANSION OF THE SAMPLE IS MEASURED BY A MICROMETER DIAL INDICATOR AT APPROPRIATE TIME INTERVALS AFTER EACH LOAD INCREMENT IS APPLIED. EACH LOAD IS ORDINARILY TWICE THE PRECEDING LOAD. THE INCREMENTS ARE SELECTED TO OBTAIN CONSOLIDATION DATA REPRESENTING THE FIELD LOADING CONDITIONS FOR WHICH THE TEST IS BEING PERFORMED. EACH LOAD INCREMENT IS ALLOWED TO ACT OVER AN INTERVAL OF TIME DEPENDENT ON THE TYPE AND EXTENT OF THE SOIL IN THE FIELD.



BORING NUMBER		SOIL TYPE	SYMBOL	MOISTURE CONTENT IN PERCENT		DRY DENSITY IN pcf		KEY
NO.	DEPTH			BEFORE	AFTER	BEFORE	AFTER	
N10-D1	23'	BROWN SAND WITH SOME SILT AND TRACE OF GRAVEL	SP	15.5	19.5	99.6	110.6	——

CONSOLIDATION TEST DATA

BY **Dames & Moore** Figure 3-10

3.8 STABILITY ANALYSES

3.8.1 Stability Requirements

Regulation 30 CFR Part 816.49 (a,3) states that "impoundments shall have a minimum static safety factor of 1.5 for the normal pool with steady seepage saturation conditions, and a seismic safety factor of at least 1.2". Strict interpretation of this requirement leads to the conclusion that embankments need only satisfy the stability requirements under normal (or spillway-level) pool conditions; however, from a slope stability standpoint, it was assumed that the critical condition for the upstream slope will be when the impoundment is empty (no restraining water force). However, as there can never be a restraining water force on the downstream slope, the critical condition for the downstream slope will be under normal pool conditions.

The stability of upstream embankment slopes was evaluated under empty (termed "end-of-construction") and normal pool conditions to reflect reasonable operating conditions and regulatory requirements; downstream slope stability was evaluated only under the more critical normal pool conditions.

Consideration of the stability of embankments composed of low-cohesion materials generally leads to a need to distinguish potential serious failures (often termed "deep-seated") from surficial, shallow sloughs which can be treated merely as a maintenance problem. Through

discussions with OSM staff (OSM, 1985b), it was determined that OSM considers a failure surface greater than 5 feet in depth (measured vertically) on either the upstream or downstream slope a failure; any slump or sloughing less than 5 feet in depth can be considered as a maintenance problem.

3.8.2 Description of Analyses

The stability analyses performed used the effective stress shear strength parameters shown in Table 3-5. These parameters were developed from shear strength testing results on representative soil samples recovered from the eight sedimentation structures identified in Table 3-3. We have previously stated that the structures, identified in Table 3-3, are considered representative of the least stable of the inspected structures and therefore would be considered "worst case" examples in terms of slope stability. In analyzing structures and soils exhibiting the least stability or "worst case" condition, it is considered that the remaining structures will have factors of safety equal to or greater than the analyzed structures.

The stability of the upstream and downstream slopes of the sedimentation structures was analyzed by computer using the STABL2 program, which is capable of analyzing both circular and non-circular failure surfaces. In this set of analyses, the Modified Bishop Method of Slices was used to evaluate the stability of circular failure surfaces.

Earthquake loading conditions were considered in the stability analyses by use of conventional pseudostatic techniques and an applied

horizontal acceleration of 0.04 g. For purposes of consistency, safety factors under seismic conditions have been reported for the same "critical" surface identified under static conditions. In all cases, the required slope was controlled by static, rather than seismic, considerations.

Under normal pool, steady state seepage conditions, the phreatic line within an embankment (which defines the boundary between saturated and unsaturated material) would exit above the toe of the downstream slope since the structures are homogenous embankments with no internal drains. A generally-accepted technique (Casagrande, 1937) was used to estimate the

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exit point of the phreatic line on the downstream slope under normal pool, steady state seepage conditions. In the end-of-construction situation, the entire embankment was considered to be unsaturated.

A maximum embankment height of 30 feet was chosen for the study, based on the 20-foot maximum height for OSM-regulated structures (defined as the difference between the original upstream toe and spillway crest elevations) and an assumed maximum height difference of 10 feet between the spillway and embankment crests. A minimum required slope of 2.5:1 (horizontal to vertical) for downstream slopes was chosen based on experience, long-term stability considerations, and maintenance considerations. Similarly, minimum required upstream slopes of 1.5:1 for 10-foot- high embankments, 1.75:1 for 15-foot-high embankments, and 2.0:1 for 20-foot and higher embankments were chosen.

The embankment model used in our stability analyses included embankment heights of 10, 15, 20, and 30 feet and a uniform crest width of 10 feet. The embankment height was defined as the difference in elevation of the upstream toe and embankment crest. The slope of the foundation under the embankment was assumed to be 5 percent. In the few instances where the foundation slopes were found to be greater than 5 percent, stability results and required slopes have been reported based on a higher height category; thus, in these few cases, the upstream and downstream slopes fall into different height categories.

The results of the stability analyses for the categories of structures at various embankment heights are presented in Table 3-6. The

required slope, shown for each category and embankment height, is defined as the minimum slope required to satisfy the safety factor requirements discussed previously. In certain cases, when the stability analyses suggested allowable slopes steeper than the limiting values described above, the limiting value is shown.

Table 3-6

RESULTS OF STABILITY ANALYSES

		Upstream Slope					Downstream Slope		
Category	Height of Embankment (ft)	Required Slope (:1)	End of Construction Factor of Safety Static	End of Construction Factor of Safety Seismic	Long-Term Steady State Seepage Factor of Safety Static	Long-Term Steady State Seepage Factor of Safety Seismic	Required Slope (:1)	Long-Term Steady State Seepage Factor of Safety Static	Long-Term Steady State Seepage Factor of Safety Seismic
A1-A5 and C1	30	2.00	1.50	1.37	1.72	1.40	4.25	1.54	1.32
	20	2.00	1.54	1.29	1.63	1.41	4.00	1.52	1.31
	15	1.75	1.51	1.38	1.63	1.42	3.25	1.51	1.32
	10	1.50	1.53	1.39	1.71	1.50	2.50	1.52	1.35
B1-B5	30	2.00	2.00	1.82	3.04	2.52	2.50	1.54	1.38
	20	2.00	2.45	2.21	3.43	2.84	2.50	1.91	1.71
	15	1.75	2.49	2.27	3.50	2.95	2.50	2.33	2.09
	10	1.50	2.76	2.51	3.84	3.28	2.50	2.80	2.49

3.8.3 Application of Stability Results

The results of the stability analyses were applied to the existing sedimentation structure embankments in the following manner. Each structure was classified according to its embankment and foundation materials and then the existing slopes were compared to the safe slopes determined by the stability analyses. If the existing slope(s) was steeper than that deemed

necessary by the stability study to meet the minimum standard, a recommendation to flatten the slope(s) was included in the remedial compliance plan.

Safe slopes for future sedimentation structures may be selected with the use of Table 3-6. The identification of embankment and foundation materials for the new structure will place it in one of the categories listed in Tables 3-1 and 3-6.

4.0 HYDROLOGY

4.1 GENERAL

For each sedimentation structure, the relationship between rainfall and runoff was determined through a hydrologic analysis of the tributary drainage area. Unit hydrographs were developed for each structure based on the characteristics of the tributary drainage area. Precipitation depths developed for the mine site were combined with the unit hydrographs to determine the inflow hydrograph for each structure. A computer program was used to develop the inflow hydrographs and determine the storage and spillway capacity requirements at each structure.

4.2 CHOICE OF DESIGN STORM

The storm events used for designing spillway capacity and storage capacity of sedimentation structures are specified in OSM regulation 30 CFR 816.46. This regulation requires that each sedimentation structure or series of structures have sufficient capacity to contain runoff from the 10-year, 24-hour storm. Each structure must also have a spillway with sufficient capacity to safely pass runoff from the 25-year, 6-hour storm.

A conservative approach has been used to design spillways for structures located in series along the same water course. When the combined active storage capacity of a particular structure and all upstream structures exceeds 20 acre-feet, the 100-year storm was used to design the spillway for that structure. When the combined active storage capacity is

less than 20 acre-feet, the 25-year, 6-hour storm was used. This approach is not a regulation or policy that is applicable to future structure designs. The approach will be evaluated by Peabody Coal Company on a case by case basis to determine its applicability for future designs.

Several sedimentation structures have been designed without spillways. In these cases the structure has been sized to contain the runoff from the Probable Maximum Precipitation (PMP) event producing the largest runoff volume. (This procedure was presented and agreed upon at a meeting on August 27, 1985 attended by personnel from OSM, Peabody Coal Company, and Dames & Moore.)

The following sections describes the methods used to determine the rainfall and runoff associated with each design storm.

4.3 PRECIPITATION

Precipitation depths for the 10-year, 25-year and 100-year storms were developed using procedures and data published in the National Oceanic and Atmospheric Administration Atlas 2, (NOAA, 1973). Table 4-1 shows the precipitation frequency-depth-duration data developed for the Kayenta and Black Mesa Mines.

Table 4-1

PRECIPITATION FREQUENCY - DEPTH - DURATION
KAYENTA AND BLACK MESA MINES, ARIZONA

Duration	Precipitation (inches)		
	10-Year Storm	25-Year Storm	100-Year Storm
5 min	0.35	0.42	0.56
10 min	0.54	0.65	0.86
15 min	0.68	0.83	1.09
30 min	0.95	1.15	1.52
1 h	1.20	1.45	1.92
2 h	1.34	1.60	2.08
3 h	1.43	1.71	2.19
6 h	1.60	1.90	2.40
12 h	1.80	2.20	2.75
24 h	2.10	2.50	3.05

PMP depths were calculated using procedures from Hydrometeorological Report No. 49 of the National Weather Service (1977). Precipitation depths were developed for both the general storm and the local storm. August proved to be the month with the greatest general storm precipitation depth. The precipitation depths for each storm are summarized in Table 4-2.

Table 4-2

PROBABLE MAXIMUM PRECIPITATION
KAYENTA AND BLACK MESA MINES, ARIZONA

General Storm - August		Local Storm	
Duration (hr)	Precipitation Depth (in)	Duration (hr)	Precipitation Depth (in)
6	4.7	0.25	5.4
12	6.2	0.5	6.5
18	7.3	0.75	6.9
24	8.0	1	7.3
48	10.2	2	8.0
72	11.1	3	8.4
		4	8.6
		5	8.7
		6	8.8

4.4 RUNOFF

4.4.1 General

The inflow hydrograph for each sedimentation structure was calculated using the computer program HEC-1 Flood Hydrograph Package developed by the U.S. Army Corps of Engineers (1981). HEC-1 provides several unit hydrograph methods for modeling the hydrologic response of a watershed. It includes procedures to account for rainfall-depth-duration, precipitation losses, and unit hydrograph shape. Hydrographs can be combined and routed through single sedimentation structures or a network of several structures.

The tributary drainage area for many structures includes local depressions that will trap some part of the surface runoff. The effect of these depressions is to reduce the runoff volume and peak flowrate reaching

the sediment structure. These local depressions have been ignored in the analysis of each structure. This is a conservative procedure that may result in a slight overestimate of the inflow to each structure.

Synthetic storms for each storm frequency were developed by HEC-1 using the depth-duration data from Tables 4-1 and 4-2. A triangular precipitation distribution was constructed such that the depth specified for the duration occurred during the central part of the storm. This distribution is referred to as a balanced storm.

Interception and infiltration losses were calculated using the Soil Conservation Service (SCS) curve number method (SCS, 1972). Each tributary watershed was assigned a curve number describing the drainage characteristics of the watershed. Values throughout the mine ranged from 60 to 94 where the lower value corresponds to the lowest runoff rate and the higher value to the highest runoff rate. Since the SCS method gives total precipitation excess for a storm, HEC-1 calculates the incremental excess for each time period in the hydrograph analysis as the difference between the accumulated excess at the end of the current time period and the accumulated excess at the end of the previous period.

The initial precipitation abstraction was calculated by HEC-1 using the formula:

$$IA = 0.2 \left(\frac{1000 - 10(CN)}{(CN)}\right)$$

Where CN = the SCS curve number
IA = the initial abstraction in inches.

A synthetic unit hydrograph for each structure was developed by HEC-1 using the SCS dimensionless unit hydrograph shown in Figure 4-1. The time to peak and the peak flow for the unit hydrograph were calculated based on a single parameter, lag time. Lag time is defined as the time between the center of mass of rainfall excess and the peak of the unit hydrograph. The time to peak is calculated using

$$Tp = 0.5\ (t) + LAG$$

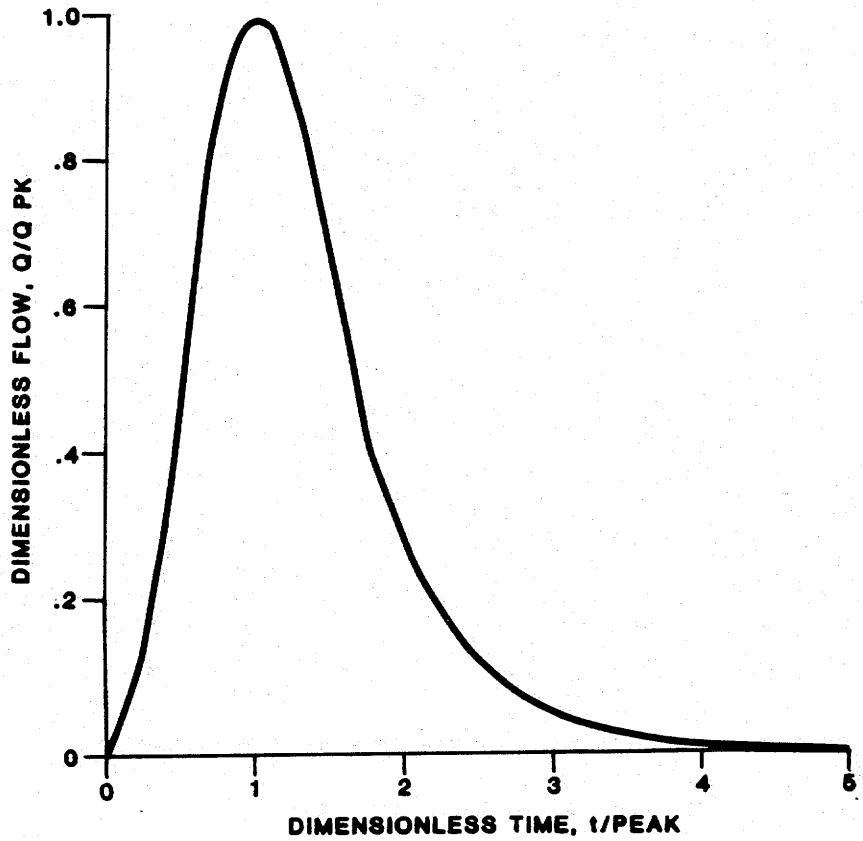
Where T_p = time to peak,
t = the storm duration
LAG = the lag time.

The peak flow of this unit hydrograph is calculated using

$$Qp = 484\ (AREA)/Tp$$

Where Qp = peak flow in cfs
AREA = the drainage area in square miles
484 = units conversion.

The synthetic storm, precipitation losses, and synthetic unit hydrograph were used by HEC-1 to calculate the inflow hydrograph to each sedimentation structure. From the above discussion, it is apparent that the HEC-1 model requires the SCS curve number, lag time, and drainage area for the watershed draining into each sedimentation pond. These parameters were developed for each sedimentation structure using the following procedures.



SCS DIMENSIONLESS
UNIT HYDROGRAPH

BY **Dames & Moore** Figure 4-1

4.4.2 Curve Numbers

SCS curve numbers were estimated for each tributary drainage area based on the cover type, percent vegetation cover, hydrologic conditions and hydrologic soil type. Several sources were used to obtain this data:

1. Cover Type -- Aerial photographs of the mine site were used to identify the existing cover type. Maps delineating the proposed mining plan were used to identify areas that will be disturbed by mining. Three general categories of cover type were used: reclaimed, undisturbed and disturbed. Further sub-classifications were made in each category as shown in Table 4-3.

   The cover type (and the tributary drainage area) for some structures will vary throughout the life of the structure as mining and subsequent reclamation occurs. For these cases, the worst condition was assumed for the hydrologic analysis. Usually the worst condition is the maximum disturbed area at the end of the mining activity and just prior to the start of land reclamation.

2. Percent Vegetation Cover -- The percent of the ground surface covered by vegetation in undisturbed areas was estimated from field inspections.

3. Hydrologic Conditions -- The hydrologic condition was directly related to the percent vegetation cover as shown in Table 4-3.

4. Hydrologic Soil Type -- Soil survey maps (Espey, Huston & Assoc., 1980; Intermountain Soils, Inc., 1985) provided the basis for determining hydrologic soil type. Tables 4-4 and 4-5 show the soil type for each soil series name.

The above data were collected and compiled for each tributary drainage area. Cover types and hydrologic soil types were delineated on topographic maps showing the drainage area contributing to each structure. A curve number was assigned to each distinct hydrologic region of the watershed, using the values in Table 4-3. An overall curve number for the watershed was derived by calculating a watershed weighted average, based on the relative acreage of each distinct hydrologic region.

Table 4-3

SCS CURVE NUMBERS
KAYENTA AND BLACK MESA MINES, ARIZONA

Cover Type	Vegetation Cover	Hydrologic Conditions	Hydrologic Soil Type B	C	D
Reclaimed Areas (Herbaceous)					
Pre-Law (1977)		poor	--	87	--
Post-Law (1977) Contoured		fair	--	81	--
Undisturbed Areas					
Pinion-Juniper					
Poor Conditions	0-30%	poor	75	85	89
Average Mine Conditions	35%	--	65	78	83
Fair Conditions	30-70%	fair	58	73	80
Sagebrush-Grass					
Poor Conditions	0-30%	poor	67	80	85
Average Mine Conditions	30%	--	60	73	79
Fair Conditions	30-70%	fair	51	63	70
Disturbed Areas					
Paved w/open ditches (including right-of-way)		--	89	92	93
Gravel roads (including right-of-way)		--	85	89	91
Dirt roads (including right-of-way)		--	82	87	89
Newly graded areas or bare ground		--	86	91	94

Sources: Revised SCS Technical Release No. 55.
Communication with Colorado and Arizona SCS State Hydrologist (8-5-85).

Table 4-4

HYDROLOGIC SOIL TYPES
BLACK MESA AND KAYENTA MINES, ARIZONA

Hydrologic Soil Type	Map Symbol*	Map Unit Name
D	1	Zyme very channery loam, 0 to 8 percent slopes
D	2	Zyme very channery loam, 8 to 30 percent slopes
D	3	Zyme-Travessilla complex, 15 to 30 percent slopes
D	4	Zyme-Travessilla complex, 8 to 15 percent slopes
B	5	Cahonavery fine sandy loam, 0 to 3 percent slopes
B	6	Begay loam, 0 to 3 percent slopes
B	7	Las Lucas sandy clay loam, 0 to 8 percent slopes
B	8	Las Lucas sandy clay loam, severely eroded, 0 to 8 percent slopes
D	9	Travessilla gravelly fine sandy loam, 0 to 8 percent slopes
D	10	Travessilla gravelly fine sandy loam, 8 to 15 percent slopes
D	11	Travessilla gravelly fine sandy loam, 15 to 30 percent slopes
C	20	Zyme-Cahona-Dulce association, 0 to 30 percent slopes
C	21	Zyme-Las Lucas complex, 0 to 15 percent slopes

Table 4-4 (Continued)

Hydrologic Soil Type	Map Symbol*	Map Unit Name
C	22	Zyme-Las Lucas-Dulce association, 0 to 30 percent slopes
D	23	Zyme-Dulce complex, severely eroded, 0 to 30 percent slopes
D	24	Zyme-Dulce association, 8 to 30 percent slopes
D	25	Zyme-Dulce-Las Lucas association, 0 to 30 percent slopes
C	26	Cahona-Zyme association, 0 to 30 percent
B	27	Begay-Las Lucas association, 0 to 8 percent slopes
C	28	Las Lucas-Zyme-Dulce complex, 0 to 8 percent slopes
D	29	Dulce gravelly find sandy loam, 0 to 30 percent slopes
D	30	Dulce-Zyme association, 15 to 30 percent slopes
C	31	Dulce-Cahona association, 0 to 30 percent slopes
C	32	Dulce-Las Lucas association, 0 to 15 percent slopes
D	33	Dulce-Las Lucas-Zyme association, 8 to 30 percent slopes
D	34	Pits and dumps

Table 4-4 (Continued)

Hydrologic Soil Type	Map Symbol*	Map Unit Name
D	35	Torriorthents, reclaimed
B	36	San Mateo silt loam, 0 to 8 percent slopes

*Map symbol refers to symbols in Espey, Huston & Assoc., 1980
Sources: Espey, Huston & Assoc., Soil Survey, 1980
Intermountain Soils Inc., 1985

Table 4-5

HYDROLOGIC SOIL GROUP
BLACK MESA AND KAYENTA MINES, ARIZONA

Soil Series	Hydrologic Group
Begay	B
Bond	D
Cahona	B
Chilton	B
Dulce	D
Las Lucas	B
Oelop	B
Pulpit	B
San Mateo	B
Sharps	B
Travessilla	D
Zyme	D
Soil A	B
Soil B	B

Source: Intermountain Soils Inc., 1985

4.4.3 Drainage Area

The tributary drainage area for each sediment structure was measured on 1 inch equals 400 feet topographic maps supplied by Peabody Coal Company (Drawing No. 84500, Sheets 1 to 26 of 26).

In some cases, mining will cause the drainage area to change during the life of the sediment structure. When the pit moves into the watershed, runoff is intercepted by the pit and diverted away from the structure. In these cases a conservative procedure was used; the structure was analyzed for the largest anticipated drainage area that will contribute runoff to the structure. This condition usually occurs at the start of mining and again during the reclamation period.

4.4.4 Time of Concentration and Lag Time

The runoff time of concentration was calculated using the following equation (USBR, 1977):

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

Where: L = length of longest water course in miles
H = watershed elevation difference in feet
T_c = time of concentration in hours

The lag time was calculated as 60 percent of the time of concentration (SCS, 1972).

5.0 HYDRAULIC ANALYSIS

5.1 GENERAL

The hydraulic analysis of each sedimentation structure was completed using the computer program HEC-1 (USACE, 1981). The inflow hydrograph was routed through the structure to determine the peak stage and peak outflow. The Modified Puls method was used for storage routing (USACE, 1981; Linsley and Franzini, 1972).

The storage capacity of each structure was analyzed assuming the structure to be empty at the start of the storm. The existing storage capacity-elevation relationship was used in the routing analysis. As the hydrograph was routed into the structure, any unused storage between the peak stage and the spillway elevation was assumed available for sediment storage. The available storage divided by the calculated annual sediment inflow rate gives the number of years of sediment storage life for the structure. When the structure has less than one year of sediment storage remaining, it will need excavation or other modifications to restore its capacity for containing precipitation runoff and the continuing sediment inflow.

The spillway capacity of each structure was analyzed assuming the structure to be full of water to the spillway elevation at the start of the storm. This is a conservative assumption that allows for the possibility of several large storms occurring prior to the spillway design storm. The existing storage capacity-elevation curve and spillway dimensions were used

in the routing. The peak stage during the storm was compared with the embankment crest elevation to determine if adequate freeboard was available to safely pass the storm through the spillway.

If the hydraulic analysis showed that the structure's storage capacity or spillway capacity was inadequate, the structure was redesigned to correct the deficiency and the routing analysis repeated to assure that the redesigned structure could meet the storage and spillway capacity requirements.

Special analysis procedures were used to analyze structures in series on the same watercourse. The procedures varied depending on whether or not the combined active storage capacity of the structures exceeded 20 acre-feet.

Storage capacity for structures in series was analyzed using the 10-year, 24-hour storm. The storm was routed through each structure to determine whether or not the storage capacity was adequate. In some cases the upstream structure could not contain the storm and contributed excess flow to the downstream structure. Analyzing the two structures together showed whether or not the combined storage capacity was adequate to contain the storm.

Spillway capacity for structures in series was analyzed using the 25-year storm in cases where the combined storage capacity of the structures was less than 20 acre-feet. The storm was routed through both structures similar to the analysis for storage capacity.

In cases where the combined storage capacity of the structures was greater than 20 acre-feet, the 100-year storm was used to analyze the spillway capacity for the downstream structure and the 25-year storm was used for the upstream structure. Each structure was in turn analyzed neglecting the other structure. The downstream structure used the combined watershed area to calculate the 100-year storm runoff. This required a reevaluation of the hydrologic parameters for the combined watershed.

5.2 STORAGE CAPACITY

The storage capacity of the sedimentation structure was determined using the most current topographic information supplied by Peabody Coal Company (Plate 1 in each sedimentation structure inspection or design report). This included 1 inch equals 100 feet scale maps and surveyed elevations for the bottom of the structure, spillway, and embankment crest. Areas within contours on the topographic maps were planimetered and cumulative storage volumes calculated by the average-end area method. These volumes are presented on the volume-elevation curves in each sedimentation structure report (Plate 3 in each report).

5.3 SEDIMENT INFLOW

5.3.1 General

The sediment inflow rate for each structure was calculated in order to determine the number of years before sediment accumulation reduces the storage capacity to a point where the 10-year storm cannot be contained.

The sediment inflow rates for sheet flow and rill erosion were calculated using the SCS Universal Soil Loss Equation (USLE) (SCS, 1976). This method predicts the annual soil loss from a drainage basin using the equation:

$$A = (R)(K)(LS)(C)(P)$$

Where: A = estimated annual soil loss in tons per acre
R = rainfall factor
K = soil erodibility factor
LS = length and slope steepness factor
C = plant cover factor
P = erosion control factor

The annual soil loss in tons per acre was converted to a sediment inflow rate for each structure using the equation:

$$SI = (A)(DA)(SDR)(94)/192{,}400$$

Where: SI = sediment inflow rate in acre-feet per year
A = soil loss in tons per acre per year from the USLE
DA = drainage basin area in acres
SDR = sediment delivery ratio
94 = sediment unit weight in pounds per cubic foot
192,400 = units conversion factor

The sediment delivery ratio for Black Mesa and Kayenta Mines was conservatively estimated as:

SDR = 0.95 for drainage basins less than 100 acres
SDR = 0.90 for drainage basins greater than 100 acres

This conservative estimate recognizes that some sediment will be deposited in small local depressions prior to reaching the sedimentation structure and that some channel erosion may occur which is not predicted by the USLE. Sediment delivery ratios reported in the literature are often as low as 50 percent and therefore the assumptions used here are very conservative.

The average sediment unit weight was estimated at 94 pounds per cubic foot based on samples collected by Peabody Coal Company.

Data for calculating the annual soil loss rate were obtained from tables and figures contained in Conservation Planning Note No. 11 - Arizona (SCS, 1976), field inspections, and measurements made on topographic maps and aerial photographs of the mine.

5.3.2 Rainfall Factor

Conservation Planning Note No. 11 (SCS, 1976) gives average annual values of the rainfall factor (R) for Arizona. Values from the figure include the effects of snow fall where applicable. For Black Mesa and Kayenta Mines an R value of 40 was used.

5.3.3 Soil Erodibility Factor

The soil survey for the mine (Espey, Huston & Assoc., 1980; Intermountain Soils, Inc., 1985) and Conservation Planning Note No. 11 (SCS, 1976) were used to determine the soil erodibility factor. Tables 5-1 and 5-2 show the values for each soil type. The drainage area for each structure was subdivided according to soil type and a weighted average K value was determined based on relative areas.

Table 5-1

SOIL ERODIBILITY FACTORS
BLACK MESA AND KAYENTA MINES, ARIZONA

Soil Series	"K" Factor
Begay	0.43
Bond	0.43
Cahona	0.49
Chilton	0.13
Dulce	0.13
Las Lucas	0.28
Oelop	0.37
Pulpit	0.49
San Mateo	0.37
Sharps	0.49
Travessilla	0.12
Zyme	0.22
Soil A	0.04
Soil B	0.04

Source: Intermountain Soils Inc., 1985

Table 5-2

SOIL ERODIBILITY FACTORS
BLACK MESA AND KAYENTA MINES, ARIZONA

Map Symbol*	Percent of Area							Weighted K
	Zyme	Travessilla	Cahona	Begay	Las Lucas	San Mateo	Rock	
20	40	25	25	--	--	--	10	0.24
21	65	--	--	--	30	--	5	0.27
22	60	15	--	--	15	--	10	0.22
23	75	15	--	--	--	--	10	0.18
24	45	45	--	--	--	--	10	0.16
25	55	25	--	--	15	--	5	0.22
26	45	--	45	--	--	--	10	0.32
27	--	--	--	65	20	--	15	0.36
28	30	20	--	--	40	--	10	0.20
29	--	85	--	--	--	--	15	0.11
30	60	--	--	--	--	--	10	0.14
31	--	50	40	--	--	--	10	0.26
32	--	60	--	--	30	--	5	0.22
33	20	50	--	--	25	--	5	0.22
34 - Pits	--	--	--	--	--	--	--	0.22
35 - Reclaimed		--	--	--	--	--	--	0.42
36	--	--	--	--	--	90	10	0.33
K Values	0.22	0.13	0.49	0.43	0.43	0.43	0.37	

*Refers to symbols used in Espey, Huston & Assoc., 1980
Sources: Espey, Huston & Assoc. Soil Survey, 1980.
Intermountain Soils Inc., 1985.

5.3.4 Length and Steepness Factor

The length and steepness factor was determined using tables and figures in Conservation Planning Note No. 11 (SCS, 1976). The slope length in feet and slope in percent were measured on 1" = 400' scale topographic maps (Drawing No. 85400 Sheets 1 to 26 of 26). An area weighting was used to calculate a weighted factor for each drainage basin.

5.3.5 Cover Factor

The cover factor was calculated using data from Conservation Planning Note No. 11 (SCS, 1976). Portions of that data assumed applicable to the mine site are reproduced in Table 5-3.

Table 5-3

COVER FACTOR
BLACK MESA AND KAYENTA MINES, ARIZONA

Type and Height of Raised Canopy[1]	Canopy Cover[2] %	Type[3]	Percent Ground Cover 10	20	40	60	80
Reclaimed (no appreciable canopy)			0.45	0.24	0.15	0.09	0.043
Sagebrush-Grass (0.5m fall height)	25	W	0.36	0.20	0.13	0.082	0.041
	50	W	0.26	0.16	0.11	0.075	0.039
	75	W	0.17	0.12	0.09	0.067	0.038
Pinion-Juniper (2m fall height)	25	W	0.40	0.22	0.14	0.085	0.042
	50	W	0.34	0.19	0.13	0.081	0.041
	75	W	0.28	0.17	0.12	0.077	0.040
Disturbed Area			----------1.00----------				

*Source: Conservation Planning Note No. 11 (SCS, 1976)

1 Average fall height of waterdrops from canopy to soil surface.

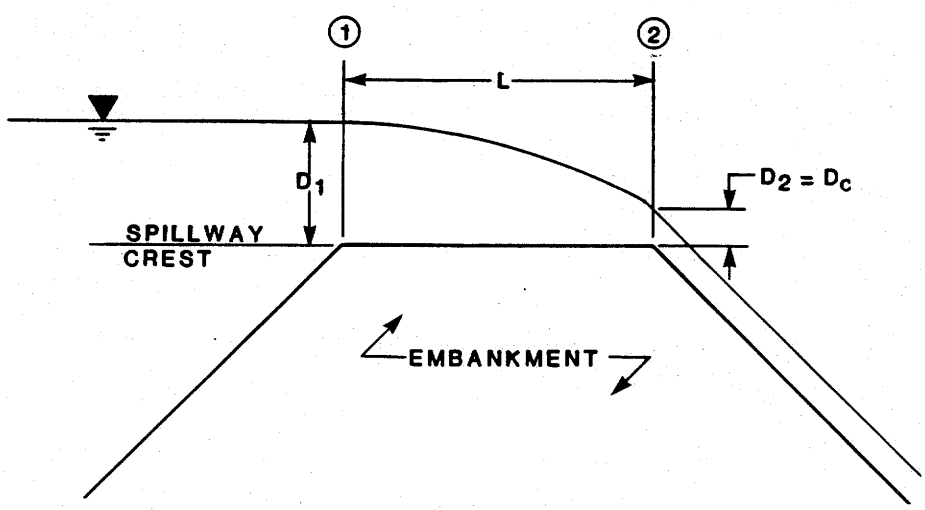
2 Portion of surface area that would be hidden from view by canopy in a vertical position.

3 W = cover at surface is mostly broadleaf herbaceous plants with little lateral-root network near the surface and/or undecayed residue.

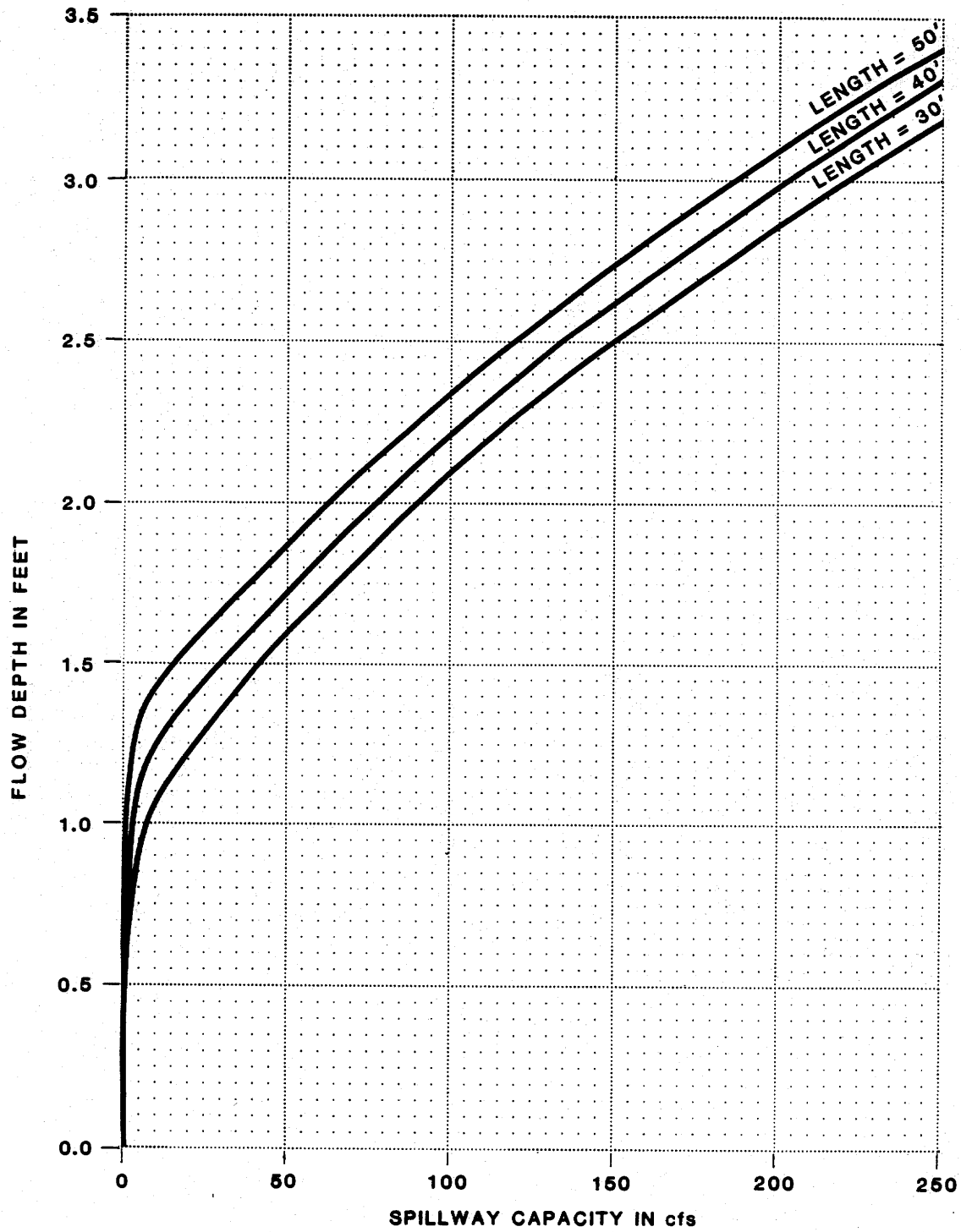
5.4 SPILLWAY CAPACITY

Most sedimentation structures on the mine site have a trapezoidal open channel spillway. Some structures have a CMP spillway. Spillway capacity curves for the open channel spillways were prepared for typical standard dimensions. Figures 5-1 through 5-12 show the calculated capacity for widths ranging from 15 feet to 100 feet, lengths ranging from 30 feet to 50 feet and Manning's "n" values of 0.035 and 0.040.

The open channel spillway capacity curves were developed from a hydraulic analysis of flow over a horizontal, trapezoidal shaped spillway crest illustrated below:



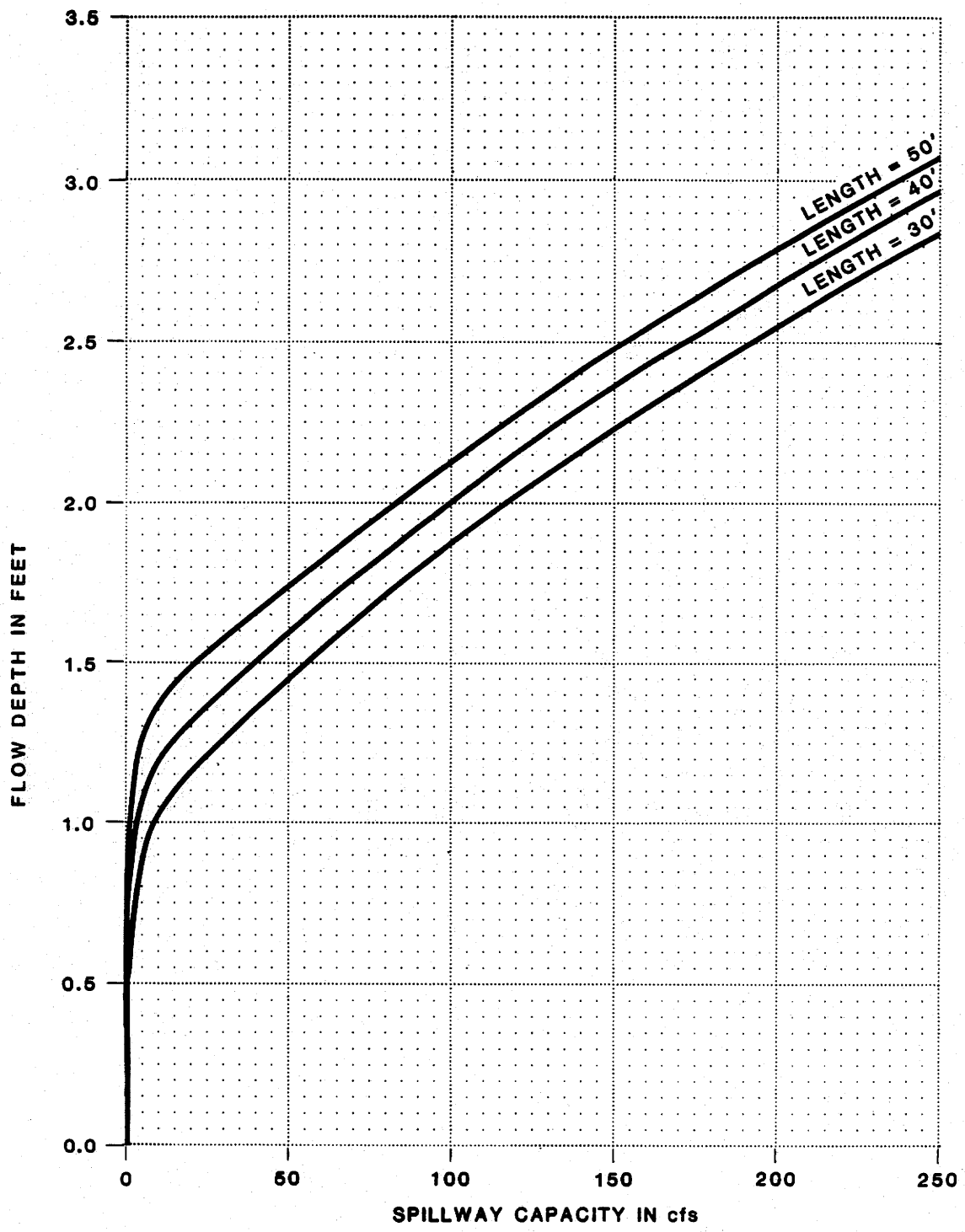
SPILLWAY PROFILE



TRAPAZOIDAL CHANNEL
SIDE SLOPE = 2H/1V
MANNINGS N = 0.040

SPILLWAY CAPACITY
15′ WIDE CHANNEL

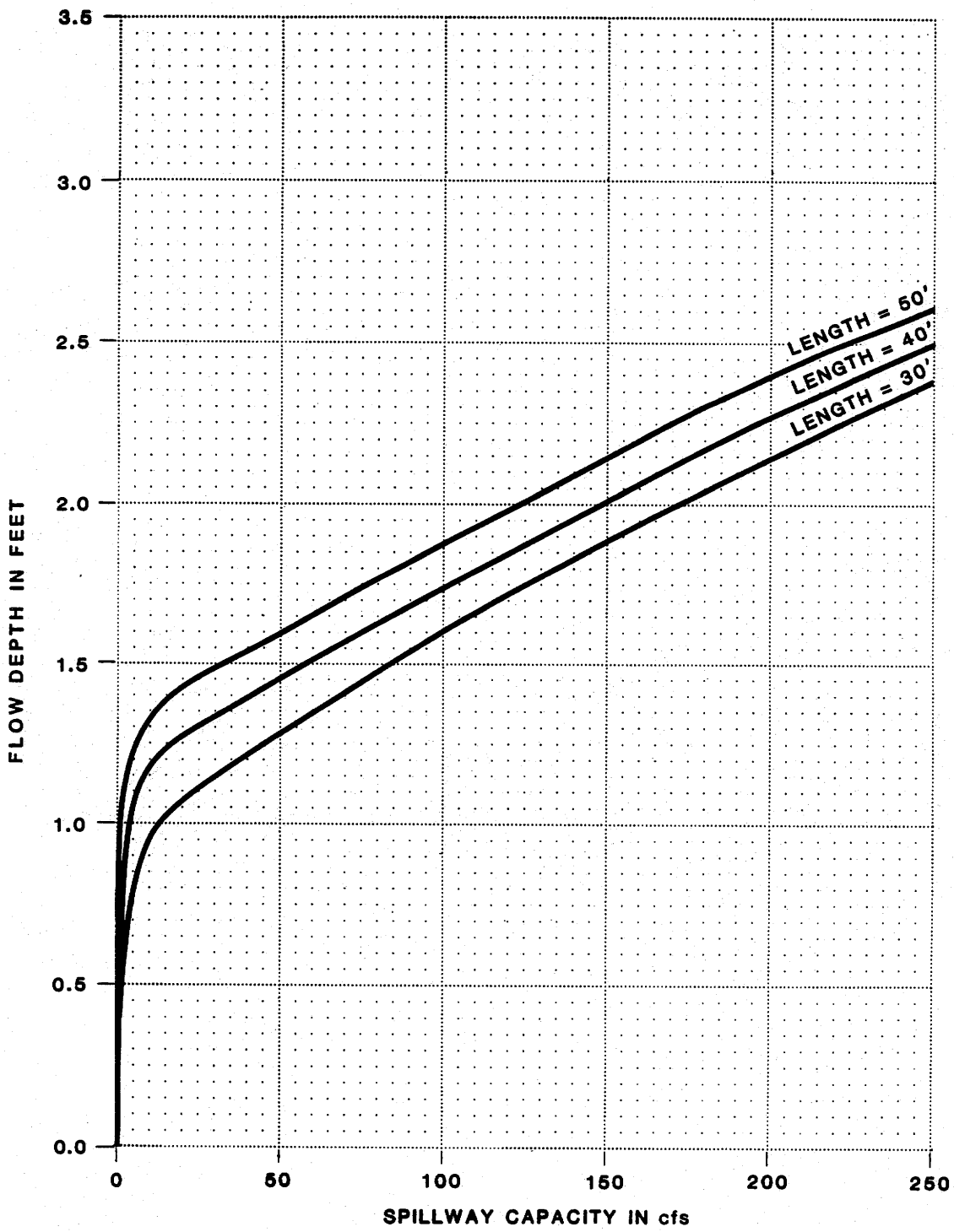
BY **Dames & Moore** Figure 5-1



TRAPAZOIDAL CHANNEL
SIDE SLOPE = 2H/1V
MANNINGS N = 0.040

SPILLWAY CAPACITY 20' WIDE CHANNEL

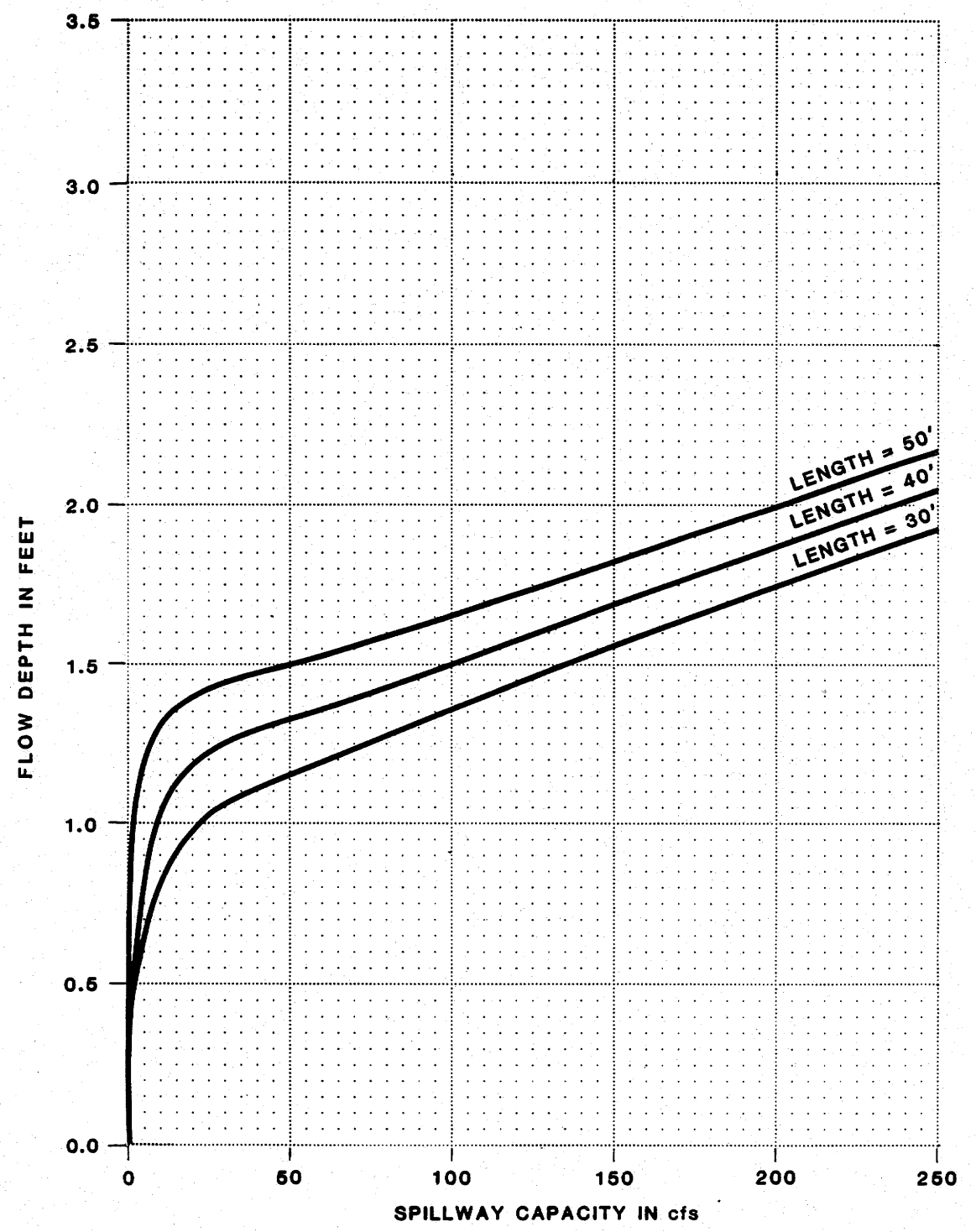
BY **Dames & Moore** Figure 5-2



TRAPAZOIDAL CHANNEL
SIDE SLOPE = 2H/1V
MANNINGS N = 0.040

SPILLWAY CAPACITY 30' WIDE CHANNEL

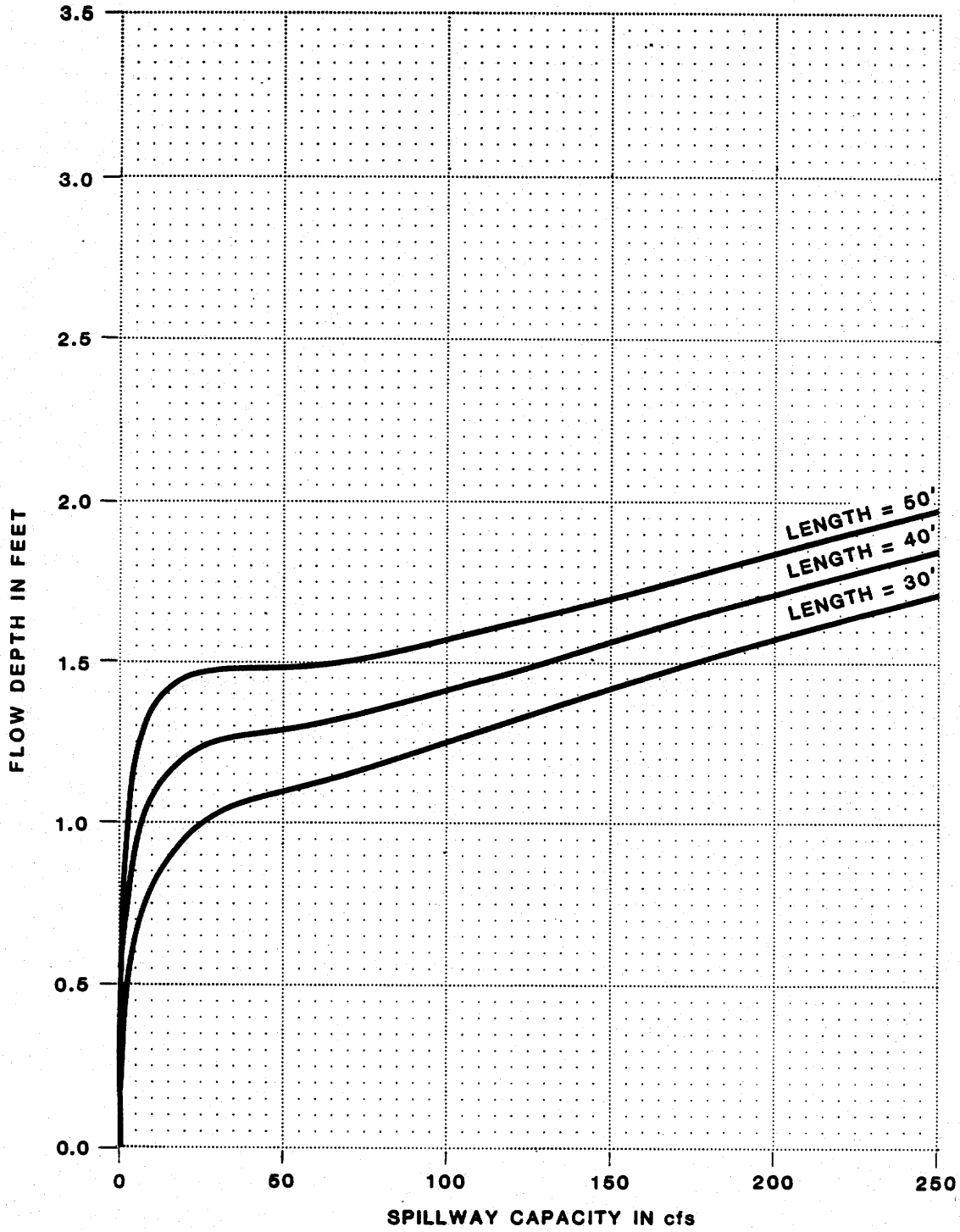
BY **Dames & Moore** Figure 5-3



TRAPAZOIDAL CHANNEL
SIDE SLOPE = 2H/1V
MANNINGS N = 0.040

SPILLWAY CAPACITY 50' WIDE CHANNEL

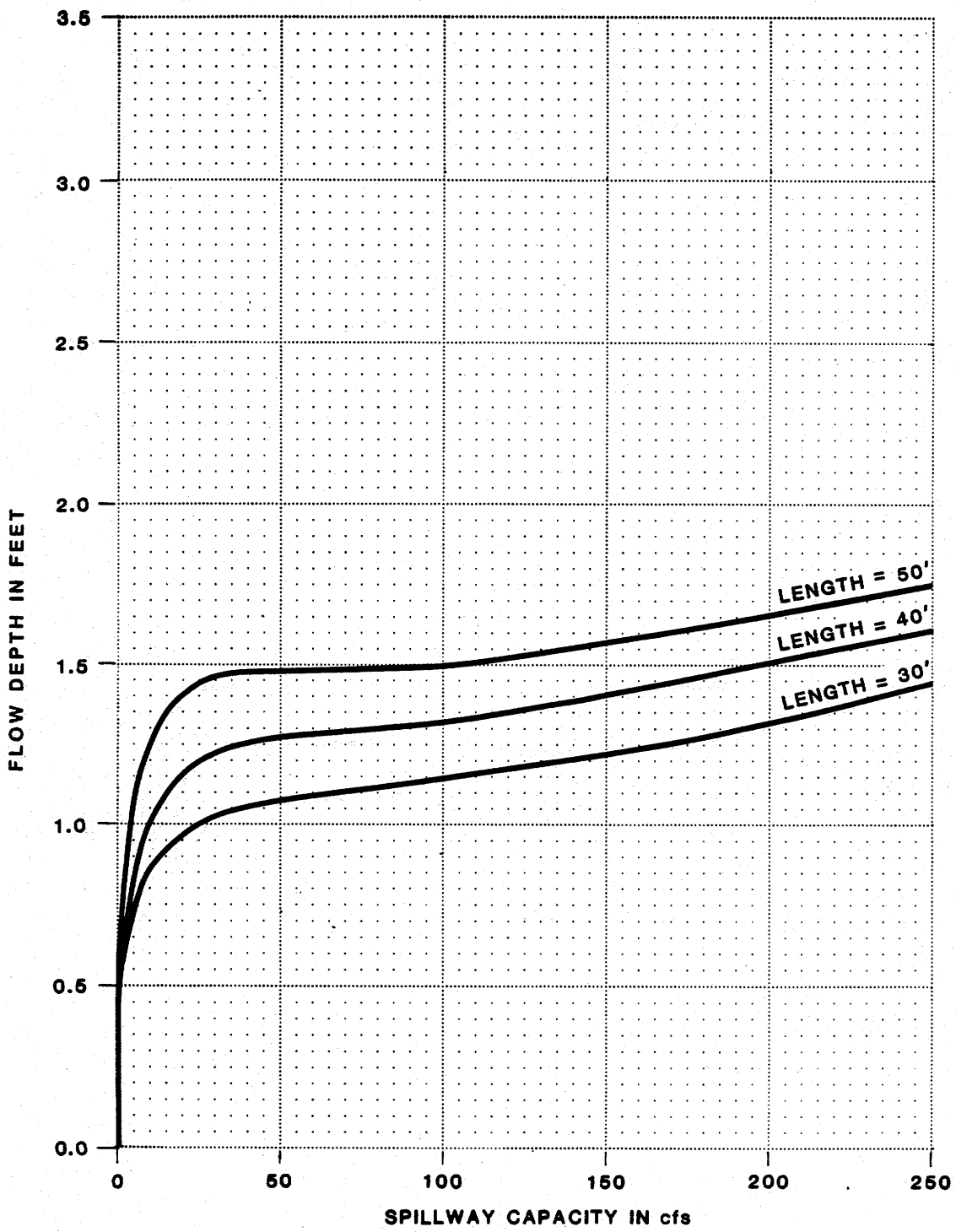
BY **Dames & Moore** Figure 5-4



TRAPAZOIDAL CHANNEL
SIDE SLOPE = 2H/1V
MANNINGS N = 0.040

SPILLWAY CAPACITY
65' WIDE CHANNEL

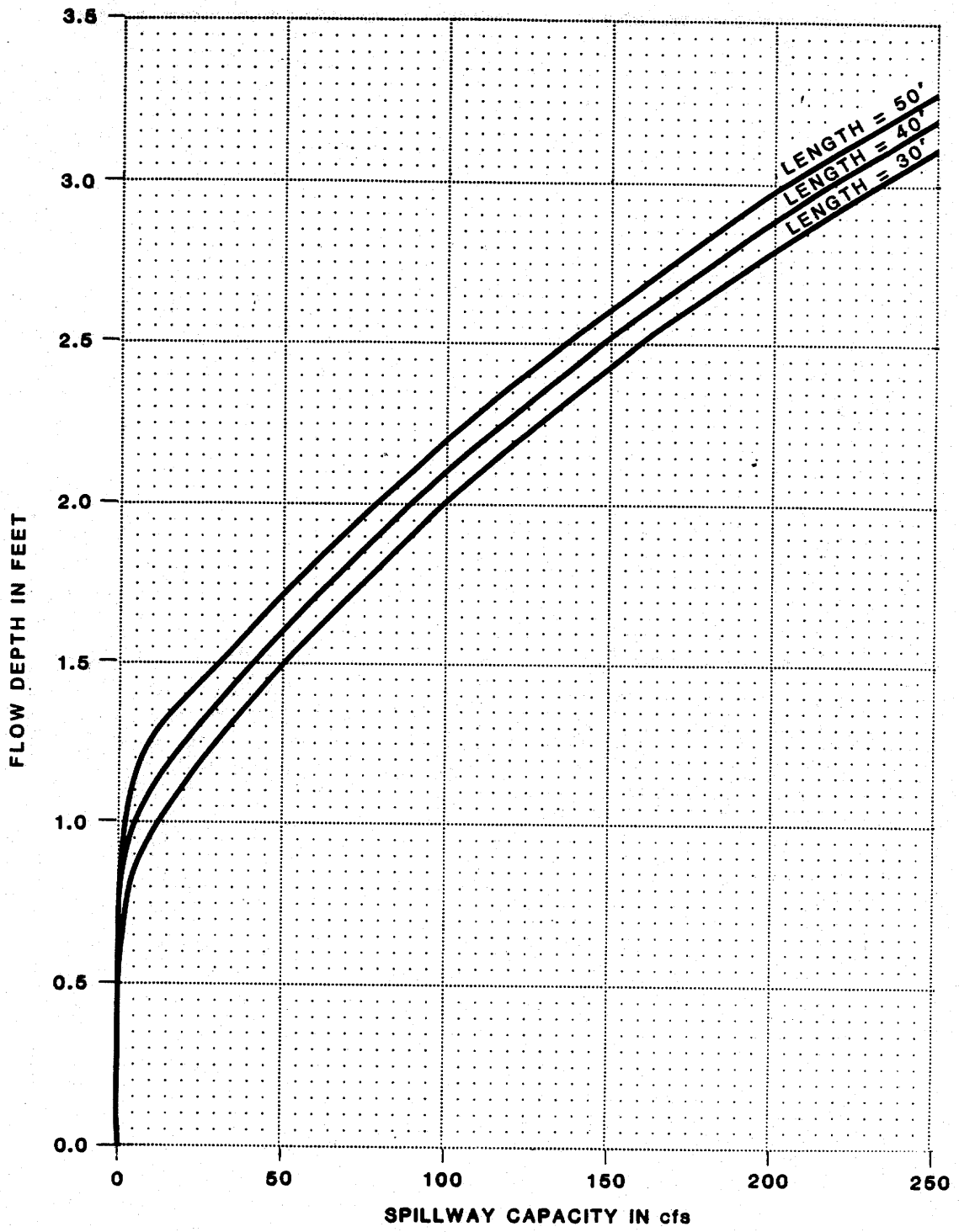
BY **Dames & Moore** Figure 5-5



TRAPAZOIDAL CHANNEL
SIDE SLOPE = 2H/1V
MANNINGS N = 0.040

SPILLWAY CAPACITY
100' WIDE CHANNEL

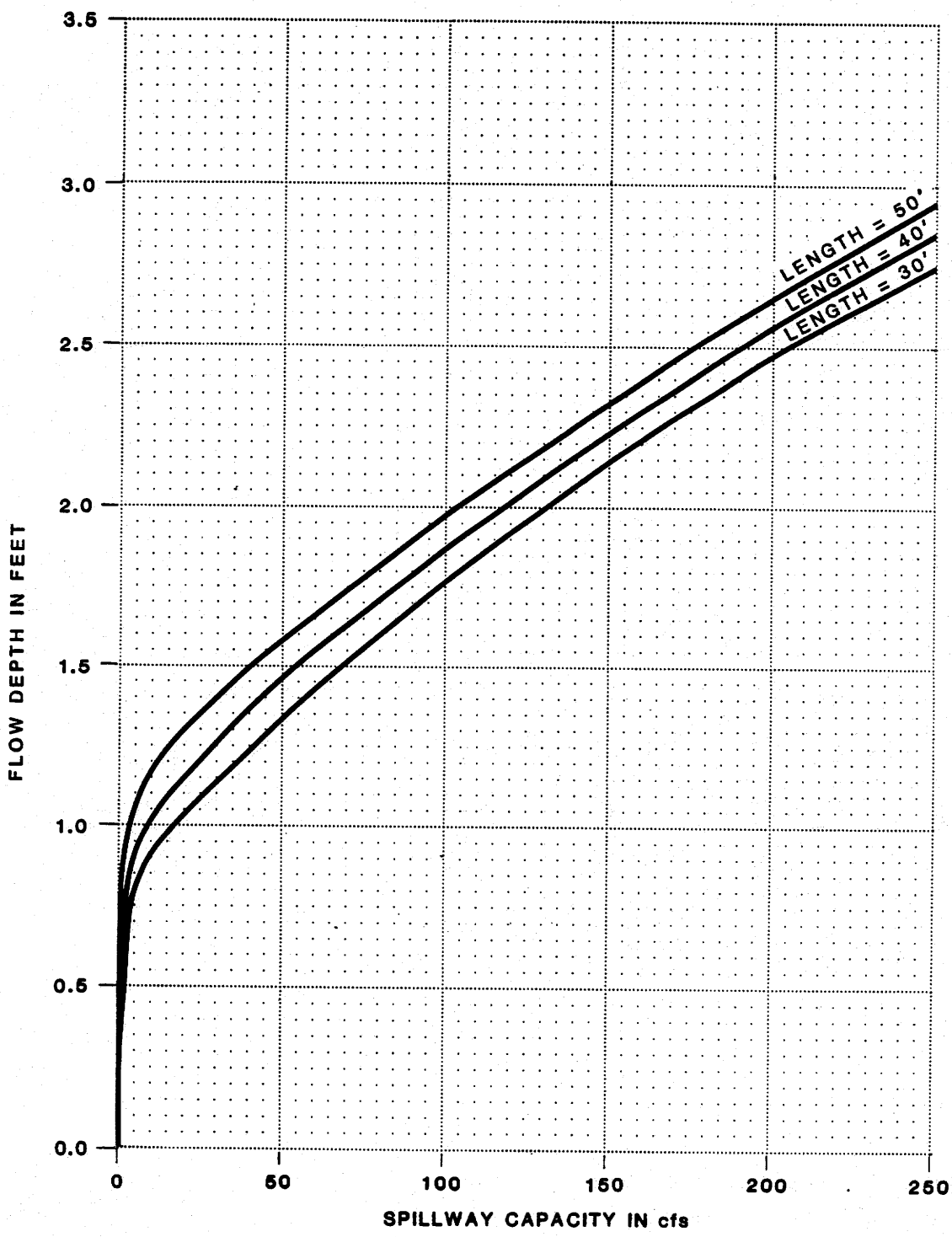
BY **Dames & Moore** Figure 5-6



TRAPAZOIDAL CHANNEL
SIDESLOPE = 2H/1V
MANNINGS N = 0.035

SPILLWAY CAPACITY 15' WIDE CHANNEL

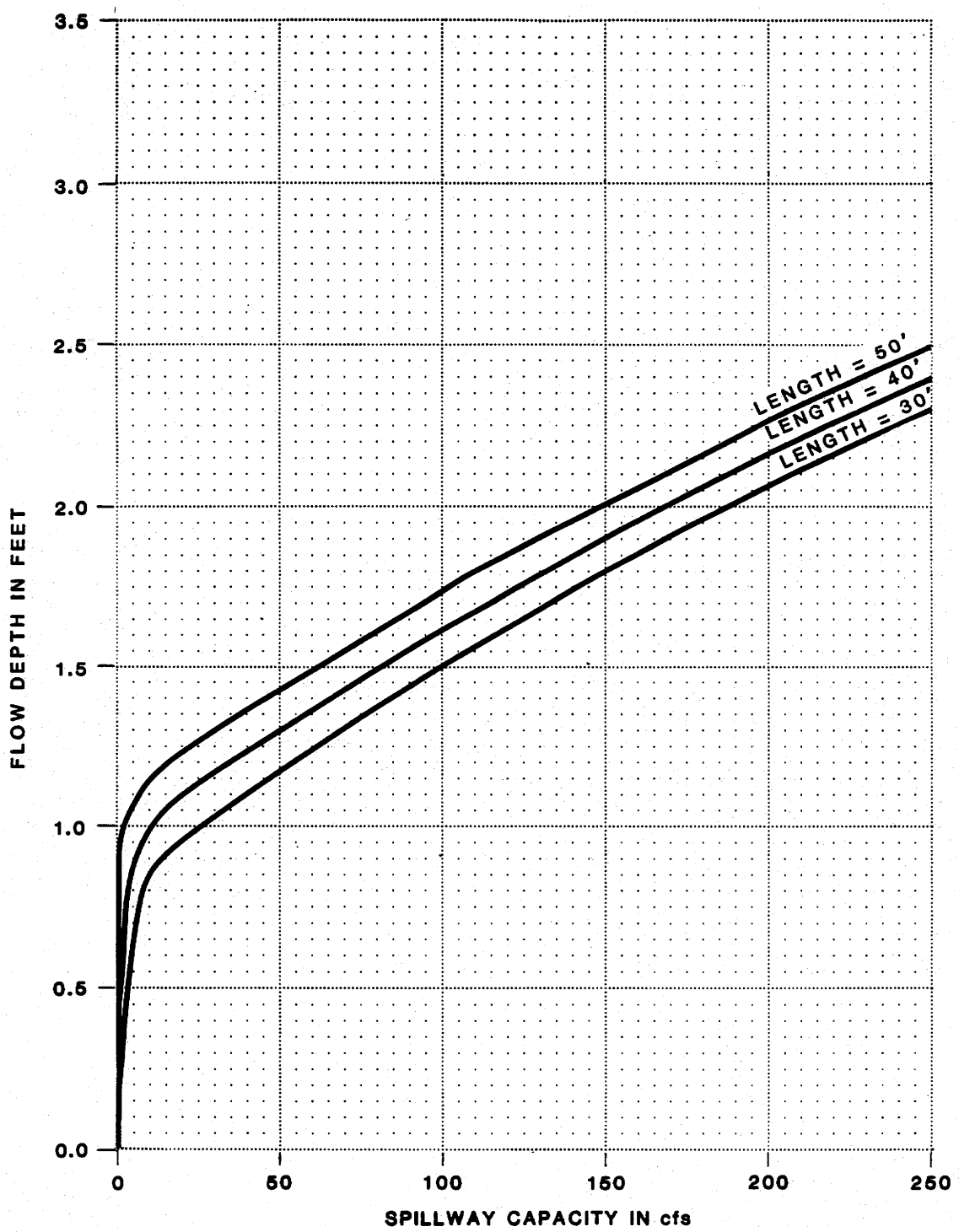
BY **Dames & Moore** Figure 5-7



TRAPAZOIDAL CHANNEL
SIDESLOPE = 2H/1V
MANNINGS N = 0.035

SPILLWAY CAPACITY 20' WIDE CHANNEL

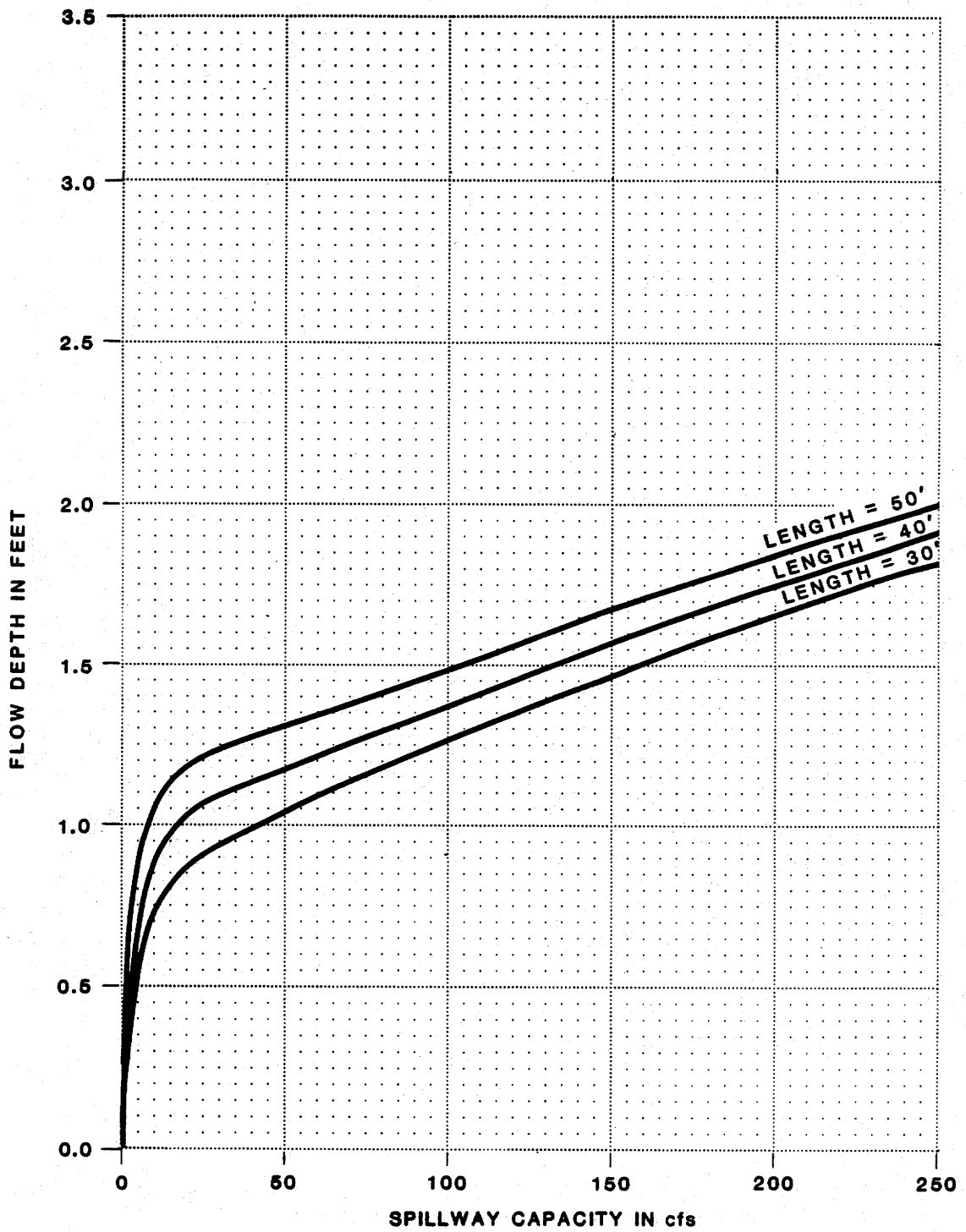
BY **Dames & Moore** Figure 5-8



TRAPAZOIDAL CHANNEL
SIDESLOPE = 2H/1V
MANNINGS N = 0.035

SPILLWAY CAPACITY 30' WIDE CHANNEL

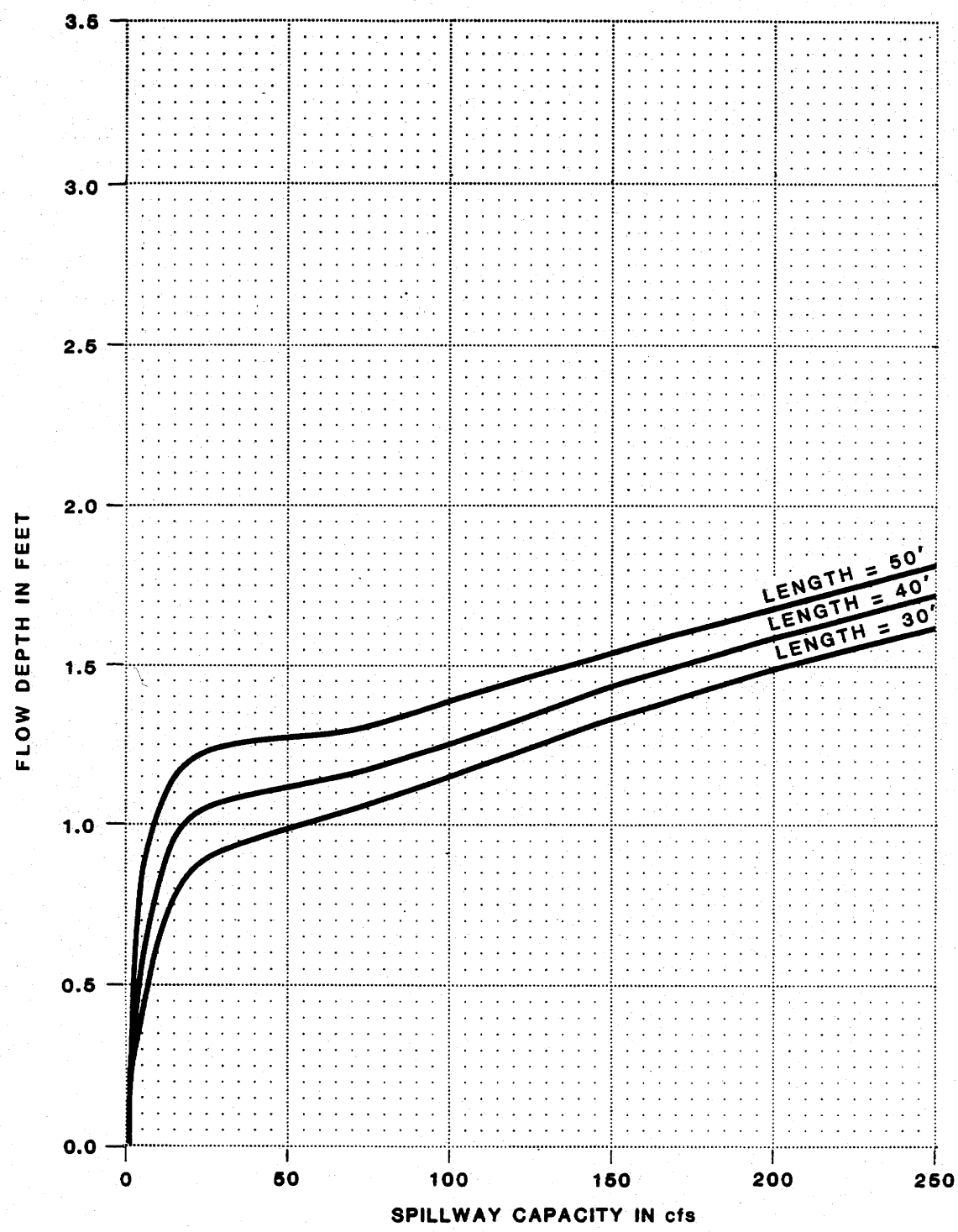
BY **Dames & Moore** Figure 5-9



TRAPAZOIDAL CHANNEL
SIDESLOPE = 2H/1V
MANNINGS N = 0.035

SPILLWAY CAPACITY 50' WIDE CHANNEL

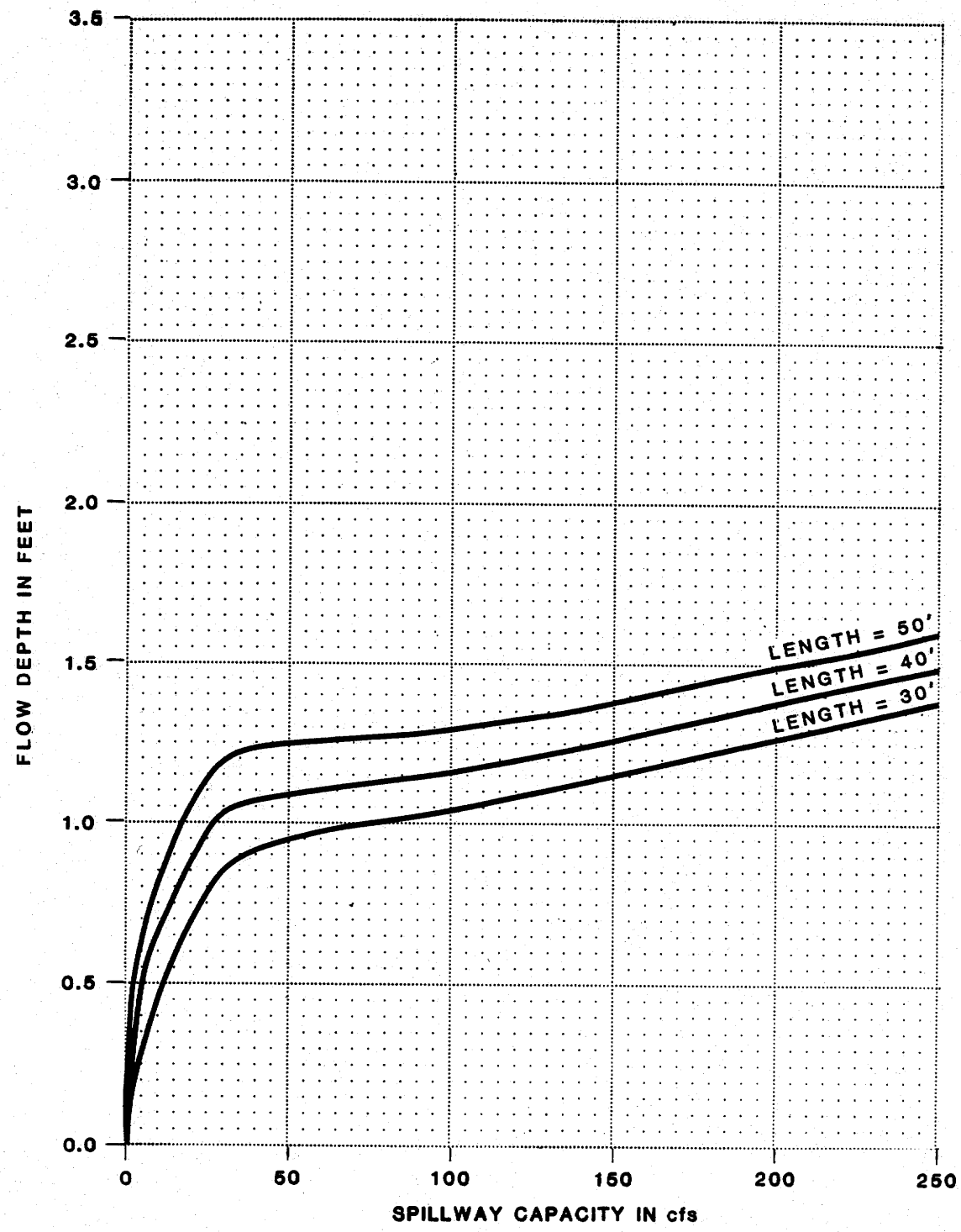
BY **Dames & Moore** Figure 5-10



TRAPAZOIDAL CHANNEL
SIDESLOPE = 2H/1V
MANNINGS N = 0.035

SPILLWAY CAPACITY 65' WIDE CHANNEL

BY **Dames & Moore** Figure 5-11



TRAPAZOIDAL CHANNEL
SIDESLOPE = 2H/1V
MANNINGS N = 0.035

SPILLWAY CAPACITY 100' WIDE CHANNEL

BY **Dames & Moore** Figure 5-12

At (2) the flow passes through critical depth, calculated using:

$$Q = \frac{5.671[(b + zD_c)D_c]^{1.5}}{[b + 2zD_c]^{0.5}}$$

Where Q = flow in cfs

b = trapezoidal channel bottom width in feet

z = channel side slope (H/V)

$D_c = D_2$ = critical depth in feet

At (1) the depth of flow was calculated using the energy equation, neglecting the energy head at 1 because the velocity is low.

$$D_2 = D_1 + \frac{(V_1)^2}{2g} + h_1$$

Where D = depth of flow in feet

V = flow velocity in fps

g = gravitational constant

h_1 = head loss in feet

The head loss in the spillway channel was calculated using Manning's equation for the average conditions in the channel:

$$h_1 = \frac{L\,n^2}{2.21}\left[\frac{V_1^{\,2}}{R_1^{\,1.33}} + \frac{V_2^{\,2}}{R_2^{\,1.33}}\right] \times (0.5)$$

Where h_1 = head loss in feet

n = Mannings "n"

R = hydraulic radius in feet

V = velocity in fps

L = length of spillway in feet

Calculations using the above listed methods were selectively checked against charts developed by the Soil Conservation Service (SCS, 1968). The calculation methods indicated results that were more conservative than those obtained from the SCS charts. Spillway capacity curves for CMP spillways were calculated using standard hydraulic capacity charts (U.S. Department of Commerce, 1964).

6.0 HYDRAULIC DESIGN

6.1 GENERAL

Structures with inadequate spillway capacity or storage capacity were redesigned to bring them into compliance with the regulations. A spillway was considered inadequate if it could not pass the spillway design storm with a minimum of 1 foot between the maximum water surface and the embankment crest elevation. A spillway was also considered inadequate if it did not have erosion protection or a spillway outflow channel capable of safely carrying the spillway discharge to a natural channel downstream.

Storage capacity was considered inadequate if the 10-year, 24-hour storm and two years of sediment inflow could not be contained with no spillway discharge.

Remedial compliance plans to bring the spillway and/or storage capacity into compliance with the regulations were developed based on the best available topographic information. Conditions encountered during construction may make it impossible or impractical to carry out the modifications exactly as shown in the report for each sedimentation structure. For example, bedrock may be encountered in areas designated for excavation; or the actual topography may vary from the map. In these cases the recommended remedial compliance plan may need alteration in order to minimize construction costs and difficulties. Data from the hydrologic and hydraulic analyses provide the basis for revising the plan. In all cases the storage capacity must be adequate to contain the runoff and sediment inflow (2 years

minimum) calculated in the hydrologic analysis. The spillway must have adequate capacity and freeboard to carry the spillway design flow calculated in the hydraulic analysis.

If modifications to the proposed plan are made, a new hydraulic analysis must be completed to determine outflow hydrographs and reservoir peak stage. Modifications to the proposed pond excavation, or the proposed spillway and outflow channel alignment or slope, will change the peak storage, flow rate and velocity. The results of the new analysis must be used to resize the spillway and/or storage capacity and the spillway erosion protection.

Several types of remedial action were specified for sedimentation structures. The following sections describe general procedures and criteria used in preparing remedial compliance plans.

6.2 STORAGE CAPACITY

Plans for increasing storage capacity used a combination of excavating the impoundment and/or raising the spillway and embankment. Excavation was assumed at maximum slopes of 3H:1V. Embankment construction follows the stability requirements described in Section 3.9.

6.3 SPILLWAY CHANNEL

Trapezoidal spillway channels were sized to pass the design storm with a minimum freeboard of 1 foot. In all cases the channels are lined with geotextile and either riprap or gravel as shown on Figures 6-1 and 6-2. Discussions between OSM and Dames & Moore on November 8, 1985 led to the agreement that in cases where the calculated critical velocity for a gravel lined spillway was less than 4 feet per second (fps), gravel lining would be adequate to protect the channel from erosion. When the velocity exceeds 4 fps, riprap lining is required.

The flow velocity in the spillway channel varies from a minimum value at the upstream end to a maximum value at the downstream end. The flow passes through critical depth at the grade break between the horizontal spillway channel and the sloping outflow channel. The calculated critical velocity at this point was used to determine the type of lining (gravel or riprap) required to protect the spillway. Riprap lining was sized using the design chart on Figure 6-3. Gravel lining (3" maximum size, D_{50} = 2") was assumed stable up to a velocity of 4 fps.

6.4 OUTFLOW CHANNEL

Outflow channels were located to carry flow from the spillway to the natural channel below the toe of the embankment. Flow depth and velocity in the outflow channel were calculated using Manning's equation. The channels were assumed to have either riprap lining with a Manning's "n" of 0.040 or gravel lining with an "n" of 0.035 (USBR, 1977 and Chow, 1959).

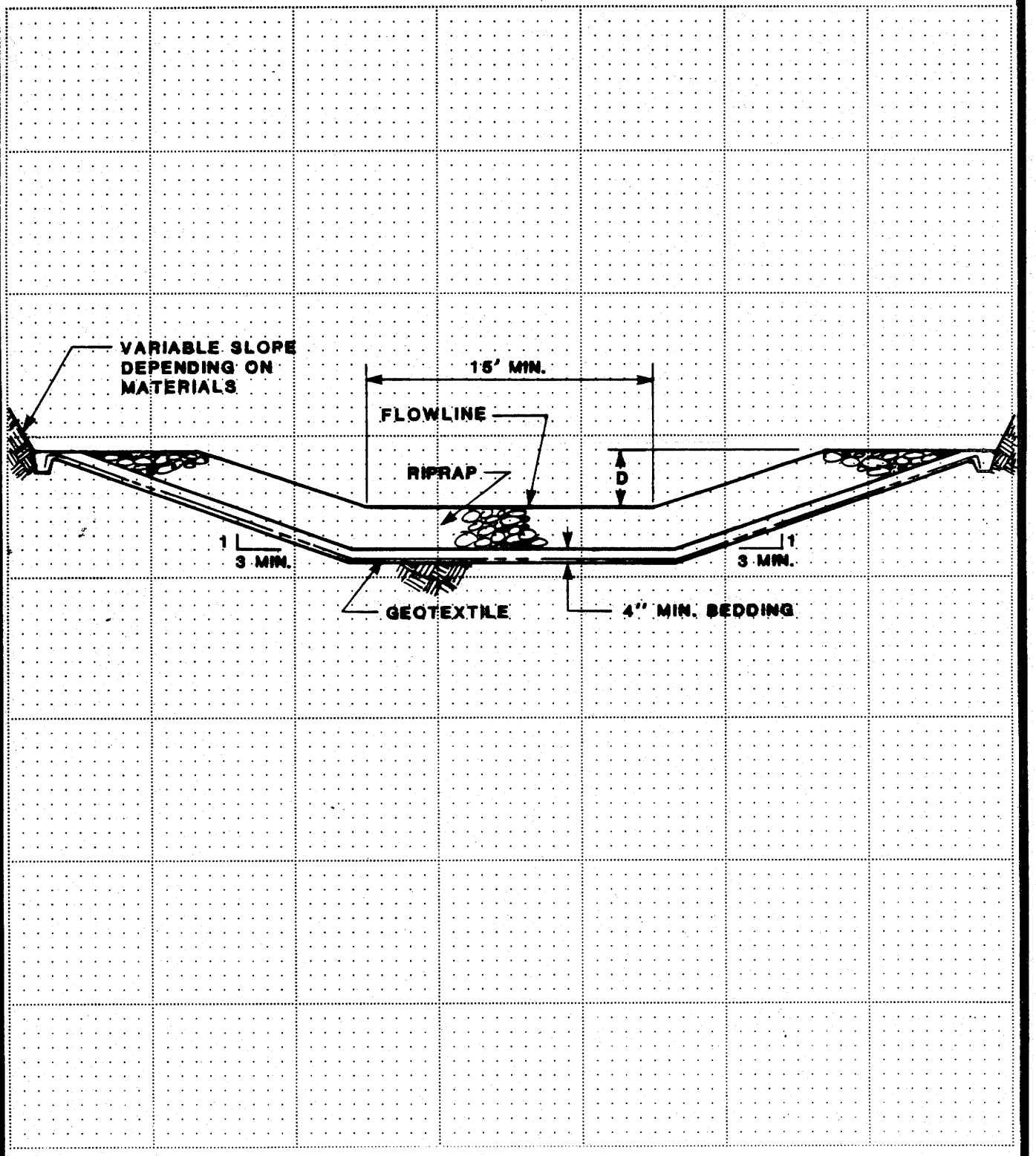
The discussions mentioned previously between OSM and Dames & Moore also led to the agreement that outflow channels with a calculated normal velocity less than 4 fps could be lined with geotextile and gravel to protect against erosion. If the calculated velocity exceeds 4 fps riprap protection is required. Figures 6-1 and 6-2 show typical riprap and gravel lined outflow channels.

In many cases the outflow channel flowline has several slope changes in order to conform to the natural topography. The steepest slope in the outflow channel produces the highest velocity for sizing the riprap or gravel protection. The flattest slope produces the deepest flow depth for sizing the channel depth.

Channel design depths were set equal to the calculated flow depth plus 1 foot. All design depths were rounded to the nearest 0.5 foot. This procedure gives a freeboard ranging from 0.75 to 1.25 feet.

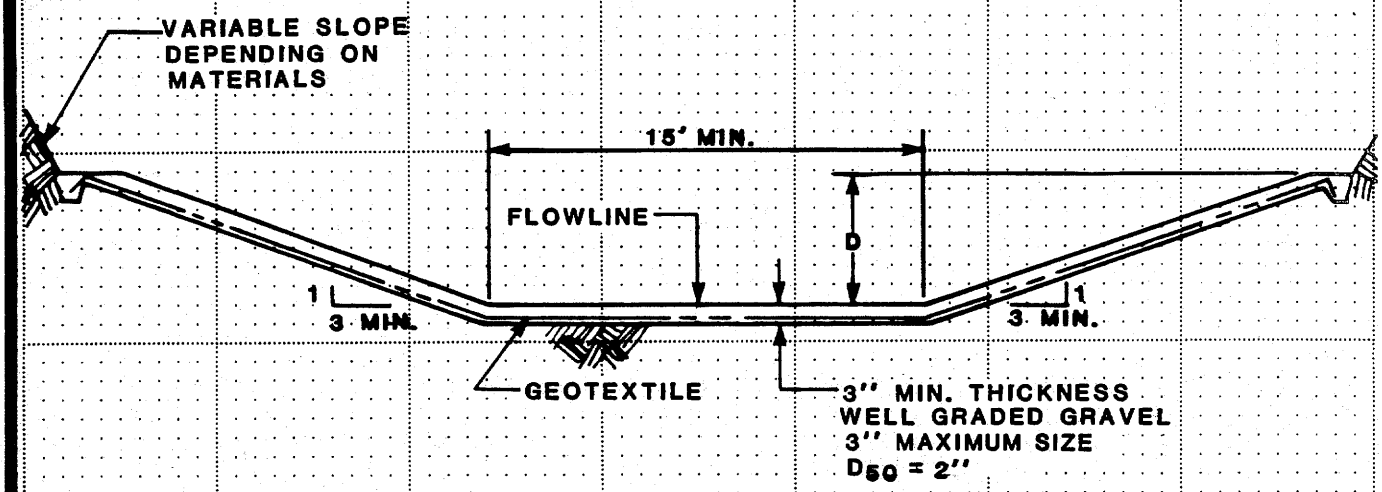
6.5 STILLING BASIN

Stilling basins were designed for spillways where large discharges and high flow velocities may cause severe erosion at the end of the outflow channel. A hydraulic jump-type stilling basin lined with riprap was sized using procedures described in Design of Small Dams, (USBR, 1977). The conjugate depth for the hydraulic jump was estimated using Figure 268 in Design of Small Dams with an estimated head loss of 30 percent. The tailwater depth below the stilling basin was estimated using Manning's equation for a trapezoidal channel with dimensions similar to the outflow



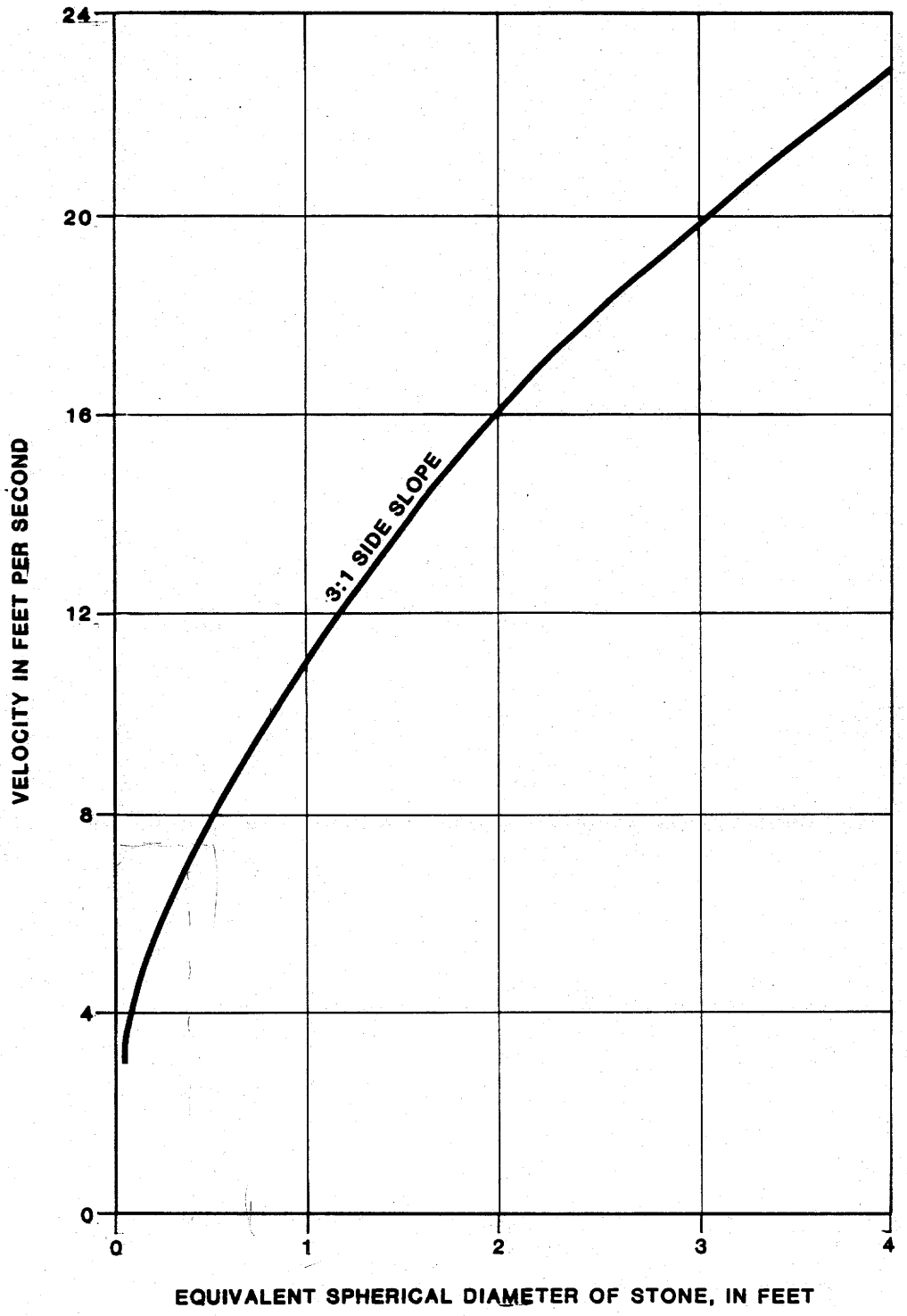
TYPICAL SPILLWAY AND OUTFLOW CHANNEL CROSS SECTION

BY **Dames & Moore** Figure 6-1



SPILLWAY AND OUTFLOW CHANNEL CROSS SECTION

BY **Dames & Moore** Figure 6-2



FOR STONE WEIGHING 165 LBS.
PER CU. FT.

ADAPTED FROM REPORT OF
THE SUBCOMMITTEE ON SLOPE
PROTECTION, AMERICAN
SOCIETY OF CIVIL ENGINEERS
PROCEEDINGS, JUNE 1948

RIPRAP DESIGN CHART

BY **Dames & Moore** Figure 6-3

channel. The length of the stilling basin was estimated based on research reported in Hydraulic Design of Spillways (USACE, 1965), where basin lengths of five times the hydraulic jump conjugate depth proved adequate. The depth of the stilling basin below the natural stream bed elevation was calculated by subtracting the tailwater depth from the hydraulic jump conjugate depth.

Riprap lining for the stilling basin was sized using the calculated velocity in the outflow channel leading to the stilling basin. The minimum height of riprap along the sidewalls of the stilling basin was set equal to the hydraulic jump conjugate depth plus freeboard. Freeboard was calculated using the following empirical equation from Design of Small Dams (USBR, 1977).

$$FB = 0.1\ (V + d_2)$$

Where FB = freeboard in feet

V = velocity of flow entering the basin in feet per second

d_2 = hydraulic jump conjugate depth in feet

Freeboard values were rounded to the nearest half foot.

Stilling basins were not designed for cases where: 1) the flow is very low or 2) the natural channel has a slope equal to or greater than the spillway outflow channel. In these cases, local erosion could occur where the outflow channel enters the natural channel at an angle to the natural flow direction. If the natural channel does not have natural armoring to protect against erosion, it will be necessary to provide riprap protection. The need for riprap and the location should be determine based on conditions

encountered during construction. If the natural channel has a sandy bottom and sides, riprap will be required. If the natural channel consists of cobbles, riprap will not be required.

7.0 SELECTED REFERENCES

Akers, J.P. and Harshbarger, J.W., 1958, Ground water in Black Mesa Basin and adjacent areas in Guidebook of the Black Mesa Basin, Northeastern Arizona. New Mexico Geological Society, p. 172-183.

Algermissen, S.T., Perkins, D.M., Thenhaus, P.C., Hanson, S.L., and Bender B.L., 1982, Probabilistic estimates of maximum acceleration and velocity in rock in the contiguous United Sates. USGS Open-File Report 82-1033.

Anderson, R.Y. and Harshbarger, J.W. (editors), 1958, Guidebook of the Black Mesa Basin, Northeastern Arizona. New Mexico Geological Society, October 1958, 212p.

Casagrande, A., 1937, Seepage through dams. Journal of the New England Water Works Association, June 1937, pp. 295-336.

Chow, V.T., 1959, Open channel hydraulics. McGraw Hill, New York.

Cooley, M.E., 1958, Physiography of the Black Mesa Basin Area, Arizona in Guidebook of the Black Mesa Basin, Northeastern Arizona. New Mexico Geological Society, p. 146-149.

Cooley, M.E., Harshbarger, J.W., Akers, J.P., and Hardt, W.F., 1969, Regional hydrogeology of the Navajo and Hopi Indian Reservations, Arizona, New Mexico, and Utah. USGS Professional Paper 521-A, 61p.

Dubois, S.M., 1979, Earthquakes, Fieldnotes, Vol. 9, No. 1. Arizona Bureau of Geology and Mineral Technology, March, 1979.

Espey, Huston & Associates, 1980, Soil baseline studies, Black Mesa and Kayenta Mines, September 1981.

Fassett, J.E. (editor), 1973, Cretaceous and tertiary rocks of the southern Colorado Plateau. A Memoir of the Four Corners Geological Society, 218p.

Intermountain Soils, Inc., 1985, 1985 intermountain soil survey for Peabody Leasehold.

Kelley, V.C., 1958, Tectonics of the Black Mesa Basin Region of Arizona in Guidebook of the Black Mesa Basin, Northeastern Arizona. New Mexico Geological Society, p. 136-145.

Linsley, R. and Franzini, J., 1972, Water resources engineering. McGraw Hill, New York.

National Oceanic and Atmospheric Administration (NOAA), 1973, Precipitation-frequency atlas of the western United States, atlas 2, vol. VIII, Arizona.

National Weather Service, 1977, Probable maximum precipitation estimates, Colorado River and Great Basin Drainages, hydrometeorological report no. 49.

Office of Surface Mining (OSM), U.S. Department of Interior, 1985a, Undated letter received by Peabody Coal Company March 22, 1985 from Allen D. Klein, Administrator, Western Technical Center.

_____, 1985b, Communication with Mike Rosenthal and Keith Kirk of OSM, October 18, 1985.

O'Sullivan, R.B., Repenning, C.A., Beaumont, E.C., and Page, H.G., 1969, Stratigraphy of the cretaceous rocks and the tertiary Ojo Alamo Sandstone, Navajo and Hopi Indian Reservations, Arizona, New Mexico, and Utah. USGS Professional Paper 521-E, 63p.

Page, H.G. and Repenning, C.A., 1958, Late Cretaceous stratigraphy of Black Mesa, Navajo and Hopi Indian Reservations, Arizona in Guidebook of the Black Mesa Basin, Northeastern Arizona. New Mexico Geological Society, p. 115-122.

Peterson, F. and Kirk, A.R., 1977, Correlation of the cretaceous rocks in the San Juan, Black Mesa, Kaiparowits, and Henry Basins, Southern Colorado Plateau in Guidebook of San Juan Basin III, Northwestern New Mexico. New Mexico Geological Society, p. 167-178.

Reynolds, S.J., 1982, Geologic Features of Northeastern Arizona in Fieldnotes. Arizona Bureau of Geology and Mineral Technology, Vol. 12, Number 1, p. 1-8.

Soil Conservation Service (SCS), U.S. Department of Agriculture, 1968, T.R. No. 39, Hydraulics of broad-crested spillways. Washington, D.C.

Soil Conservation Service (SCS), U.S. Department of Interior, 1972, National engineering handbook. Washington, D.C., sec. 4 (hydrology).

Soil Conservation Service (SCS), 1976, U.S. Department of Agriculture, 1976, Universal soil loss equation, conservation planning note no. 11, Arizona, September 1, 1976.

Stokes, W.L., 1973, Geomorphology of the Navajo Country in Guidebook of Monument Valley and Vicinity, Arizona and Utah. New Mexico Geological Society, p. 61-67.

Sumner, J.S., 1976, Earthquakes in Arizona. Fieldnotes Vol. 6, No. 1, Arizona Bureau of Mines, March 1976.

U.S. Army Corps of Engineers (USACE), 1965, Hydraulic design of spillways, EM110-2-1603.

_____1981, Users manual, HEC-1 flood hydrograph package, September 1981.

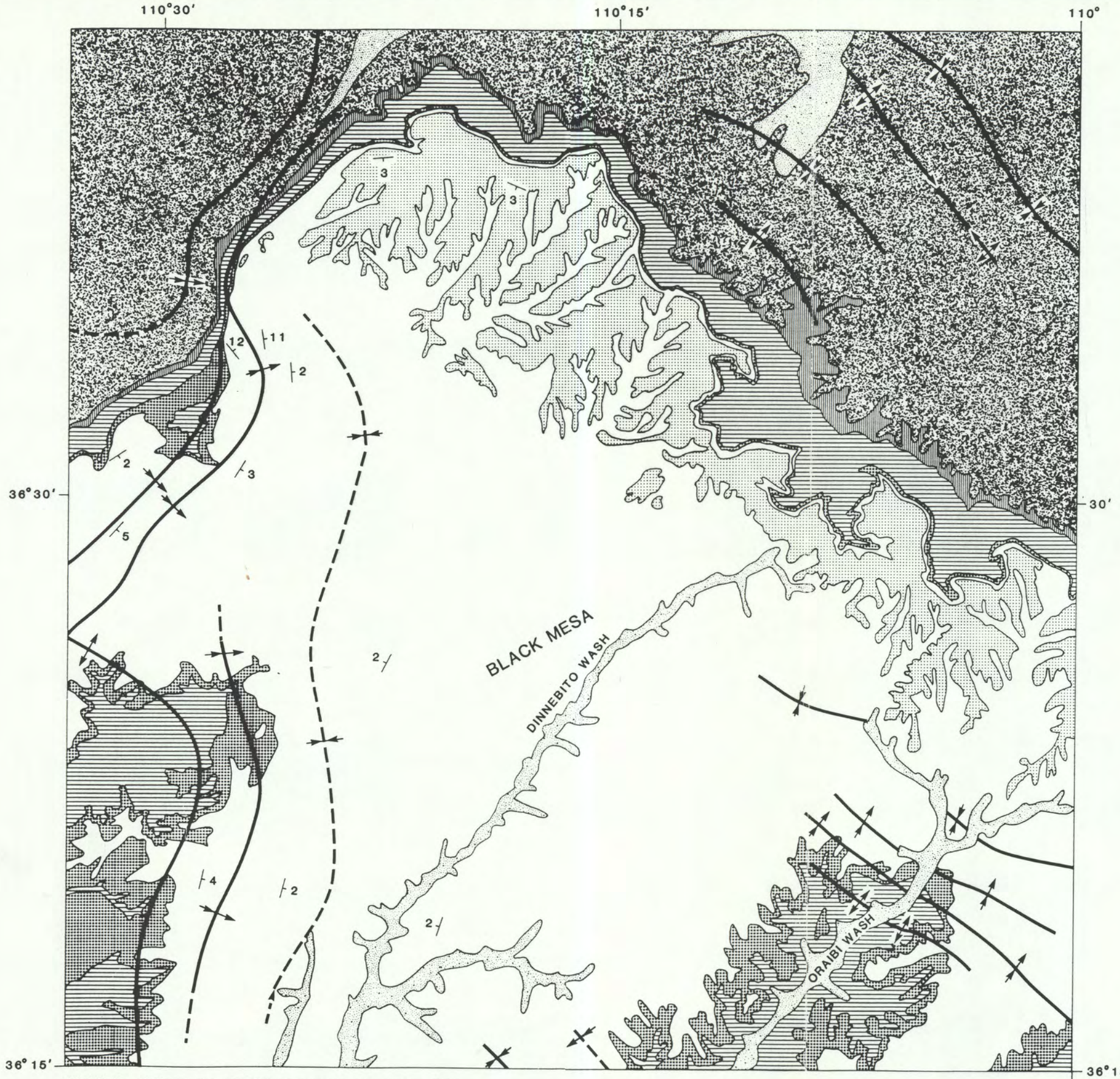
U.S. Department of Commerce, Bureau of Public Roads, 1961, Hydraulic engineering circular no. 5. April 1961.

U.S Bureau of Reclamation (USBR), 1977, Design of small dams.

Woodward, L.A., 1973, Structural framework and tectonic evolution of the Four Corners Region of the Colorado Plateau in Guidebook of Monument Valley and Vicinity, Arizona and Utah. New Mexico Geological Society, p. 94-98.

Woodward, L.A. and Callender, J.F., 1977, Tectonic framework of San Juan Basin in Guidebook of San Juan Basin III, Northwestern New Mexico. New Mexico Geological Society, p. 209-212.

Young, R.G., 1973, Cretaceous Stratigraphy of the Four Corners Area in Guidebook of Monument Valley and Vicinity, Arizona and Utah. New Mexico Geological Society, p. 86-93.



REFERENCE: GEOLOGIC MAP MODIFIED FROM COOLEY AND OTHERS, 1969

LEGEND

QUATERNARY

- **Qal** — ALLUVIUM - SILTS, SANDS AND GRAVELS. SHOWN ONLY WHERE OF APPRECIABLE EXTENT

CRETACEOUS

- **Ky** — YALE POINT SANDSTONE - YELLOWISH GRAY TO GRAYISH ORANGE SANDSTONE
- **Kw** — WEPO FORMATION - ALTERNATING BEDS OF DARK GRAY TO LIGHT GRAY SILTSTONES AND MUDSTONES; YELLOWISH GRAY SANDSTONES; COAL BEDS AND RED BAKED SHALES
- **Kt** — TOREVA FORMATION - YELLOWISH GRAY TO GRAYISH ORANGE-PINK SANDSTONE; CARBONACEOUS MUDSTONE AND VARICOLORED SILTSTONES WITH COAL; YELLOWISH GRAY SANDSTONE
- **Km** — MANCOS SHALE - LIGHT TO DARK GRAY TO YELLOWISH GRAY SHALE WITH SANDSTONES
- **Kd** — DAKOTA SANDSTONE - TAN, BROWN, AND GRAY SANDSTONES AND CONGLOMERATES WITH CARBONACEOUS SILTSTONES AND LENSES OF COAL

JURASSIC TRIASSIC

- **JTR** — UNDIFFERENTIATED - INCLUDES SAN RAFAEL GROUP, GLEN CANYON GROUP, CHINLE FORMATION AND MOENKOPI FORMATION

ANTICLINE - SHOWING TRACE OF AXIAL PLANE AND DIRECTION OF PLUNGE. DASHED WHERE APPROXIMATELY LOCATED

SYNCLINE - SHOWING TRACE OF AXIAL PLANE AND DIRECTION OF PLUNGE. DASHED WHERE APPROXIMATELY LOCATED

MONOCLINE - COMPOSED OF BEDS INCLINED IN A SINGLE DIRECTION. DASHED WHERE APPROXIMATELY LOCATED

5 STRIKE AND DIPS OF BEDS

SCALE

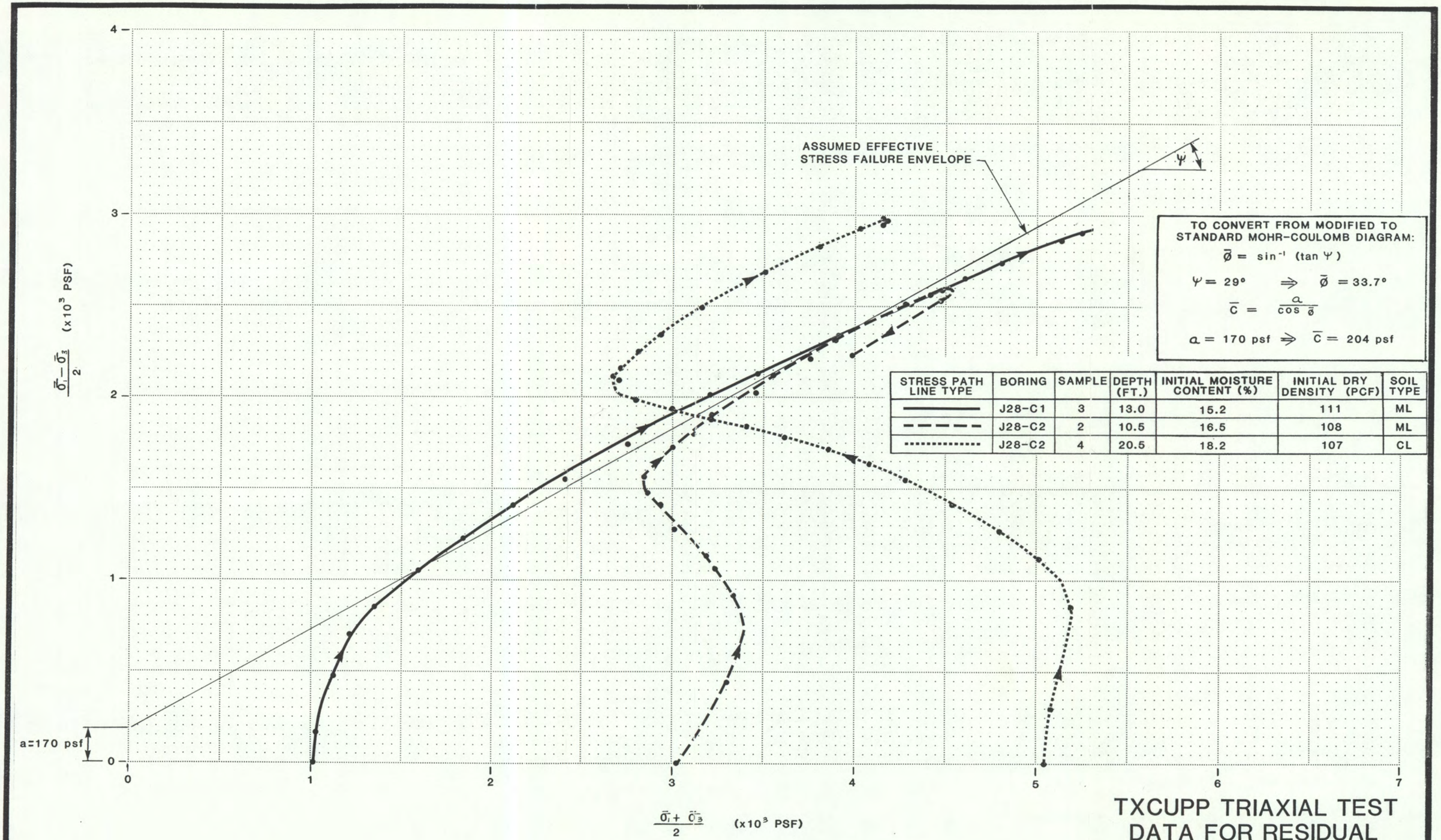
0 5

MILES

N

GEOLOGIC MAP OF A PORTION OF BLACK MESA

BY **Dames & Moore** Figure 2-1



TO CONVERT FROM MODIFIED TO STANDARD MOHR-COULOMB DIAGRAM:

$\bar{\phi} = \sin^{-1}(\tan \Psi)$

$\Psi = 29° \Rightarrow \bar{\phi} = 33.7°$

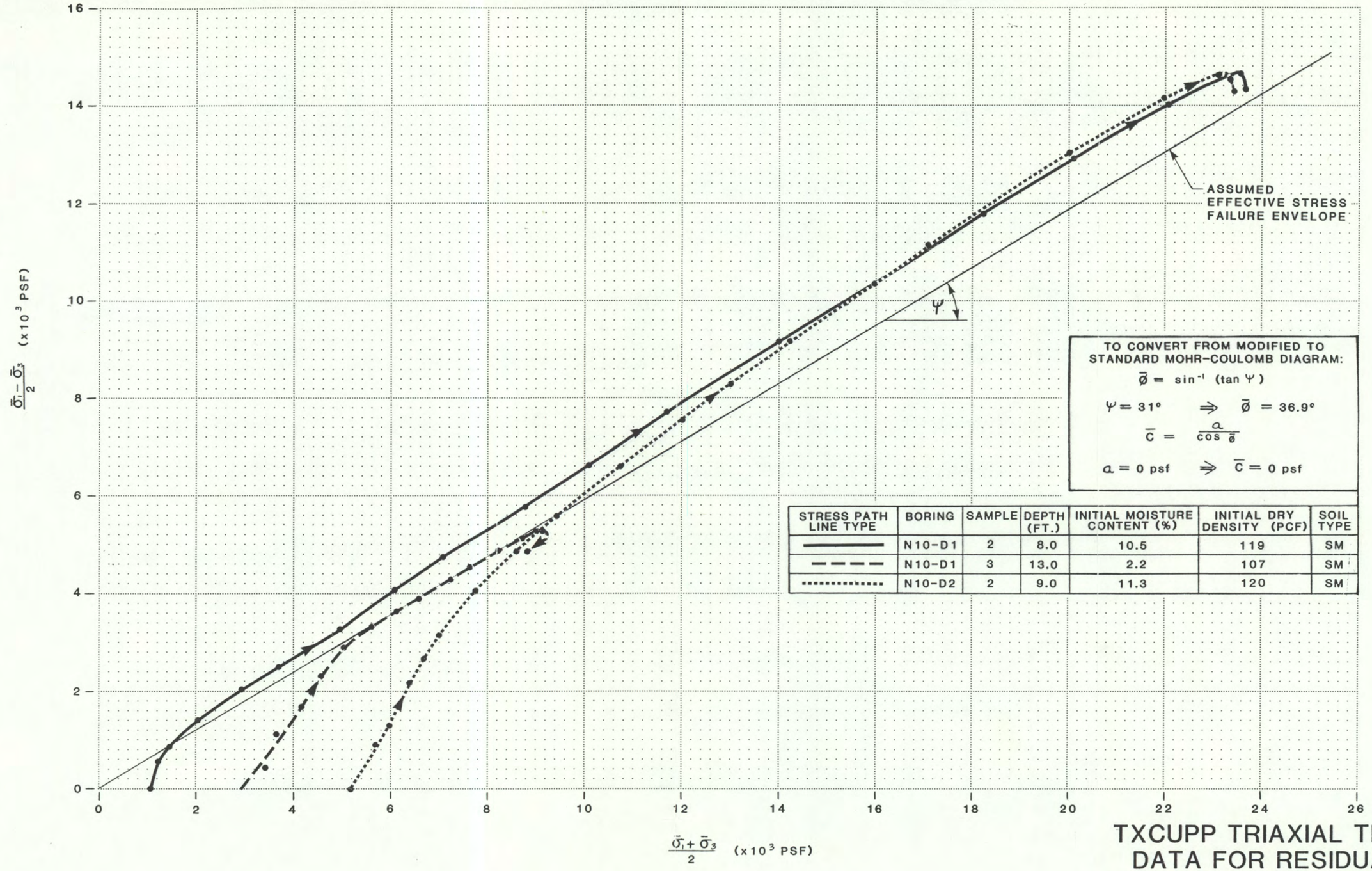
$\bar{c} = \frac{a}{\cos \bar{\phi}}$

$a = 170$ psf $\Rightarrow \bar{c} = 204$ psf

STRESS PATH LINE TYPE	BORING	SAMPLE	DEPTH (FT.)	INITIAL MOISTURE CONTENT (%)	INITIAL DRY DENSITY (PCF)	SOIL TYPE
———	J28-C1	3	13.0	15.2	111	ML
— — — —	J28-C2	2	10.5	16.5	108	ML
·····	J28-C2	4	20.5	18.2	107	CL

TXCUPP TRIAXIAL TEST DATA FOR RESIDUAL SHALESTONE SOILS

BY **Dames & Moore** Figure 3-7A



TO CONVERT FROM MODIFIED TO STANDARD MOHR-COULOMB DIAGRAM:

$\bar{\phi} = \sin^{-1}(\tan \Psi)$

$\Psi = 31° \Rightarrow \bar{\phi} = 36.9°$

$\bar{C} = \frac{a}{\cos \bar{\phi}}$

$a = 0$ psf $\Rightarrow \bar{C} = 0$ psf

STRESS PATH LINE TYPE	BORING	SAMPLE	DEPTH (FT.)	INITIAL MOISTURE CONTENT (%)	INITIAL DRY DENSITY (PCF)	SOIL TYPE
———	N10-D1	2	8.0	10.5	119	SM
— — — —	N10-D1	3	13.0	2.2	107	SM
·····	N10-D2	2	9.0	11.3	120	SM

TXCUPP TRIAXIAL TEST DATA FOR RESIDUAL SANDSTONE SOILS

BY **Dames & Moore** Figure 3-7B

ATTACHMENT E

INSPECTION FORMS:

Annual Impoundment Inspection Report

Annual MSHA Report

Monthly MSHA Report

1985 Dames & Moore's Inspection Checklist

APPROVED
APR 1999

Revised 02/03/99

ANNUAL IMPOUNDMENTS INSPECTION SUMMARY

PEABODY WESTERN COAL COMPANY - BLACK MESA COMPLEX

LAST REV:

#	IMPOUNDMENT ID	EMBANKMENT	PONDING AREA				COMMENTS
	(1)	(2)	(3)	(4)	(5)	(6)	
		Instability*	Water Depth	Water Elevation	Existing Storage Capacity (Ac-Ft)	Monitoring Instrumentation Required	

APPROVED
APR 1999

*NOTE: SEE BM-PAP CHAPTER 6, DRAWING NO. 85406 for REMEDIAL WORK CONSTRUCTION SCHEDULE.
ELEVATIONS SURVEYED UTILIZING GLOBAL POSITIONING SURVEYING (GPS) TECHNIQUES

PEABODY WESTERN COAL COMPANY
P.O. Box 605
Kayenta, Arizona 86033
Telephone (520) 677-3201

Date: _____

District Manager
Mine Safety and Health Administration
Post Office Box 25367, DFC
Denver, Colorado 80225

RE: Annual Report per 30 CFR 77.216-4
ID No: _____
Other: _____
Mine: _____

Gentlemen:

In accordance with 30 CFR 77.261-4, the following status report at the above site during the period _____ to _____ is submitted:

	STATUS
1. Geometry	_____
2. Instrumentation	_____
3. Current Water Elevation	_____
4. Storage Capacity	_____
5. Water Volume	_____
6. Stability	_____
7. Spillway Elevation	_____
8. Other	

ENGINEER'S CERTIFICATE

All work at the above site during the period _____ to _____ was performed in accordance with the approved plan to the best of my knowledge and belief.

APPROVED
APR 1999

_____
By:
Peabody Western Coal Company

MONTHLY KAYENTA MINE VISUAL INSPECTION REPORT
WATER, SEDIMENT, OR SLURRY IMPOUNDING STRUCTURES
(MSHA 30CFR77.216-3)

STRUCTURE NO. _____ DATE _____

STRUCTURE NAME _____

STRUCTURE OWNER _____ SIGN IN PLACE ☐

1. CONDITION OF UPSTREAM (LAKESIDE) SLOPE OF DAM

Grass cover or riprap _____ ☐
Erosion _____ ☐
Drift and debris _____ ☐
Animal burrows _____ ☐
Slumps, slides, cracks _____ ☐

2. CONDITION OF DOWNSTREAM SLOPE OF DAM

Grass cover _____ ☐
Erosion _____ ☐
Seepage, soft spots, boils _____ ☐
Animal burrows _____ ☐
Slumps, slides, cracks _____ ☐
Drains _____ ☐
Top ditch and area beyond _____ ☐

3. CONDITION OF CROWN (TOP) OF DAM

Grass cover _____ ☐
Animal burrows _____ ☐
Erosion, cracks, depressions, uplifting _____ ☐
Overtopping _____ ☐

4. CONDITION OF PRINCIPAL SPILLWAY OR OUTLET Type _____ ☐

Description _____ ☐
_____ ☐
_____ ☐

5. CONDITION OF EMERGENCY SPILLWAY OR OUTLET Type _____ ☐

Description _____ ☐
_____ ☐
_____ ☐

6. ABUTMENTS _____ ☐

7. GENERAL COMMENTS _____ ☐
_____ ☐
_____ ☐

APR 1999 APPROVED

Inspected by _____ Owner Official _____

Title _____ Title _____

Date _____ Date _____

* If this is a changed condition from previous week, so indicate with a red X.

PEABODY COAL COMPANY

Arizona Division

GENERAL DATA SHEET AND VISUAL INSPECTION CHECKLIST

Name of Sediment Impoundment:

Name of Inspectors: **Date**

Geotechnical	☐	_____	_____
Hydrology	☐	_____	_____
Hydraulic	☐	_____	_____

APPROVED APR 1999

	No	Yes
Remedial Geotechnical Action Required	☐	☐
Remedial Hydrological Action Required	☐	☐

Dames & Moore
10139-011-22

INSPECTION CHECK LIST

ITEM	YES	NO	REMARKS
1. CREST			
a. Any visual settlements?			
b. Misalignment?			
c. Cracking?			
2. UPSTREAM SLOPE			
a. Adequate grass cover?			
b. Any erosion?			
c. Are trees growing on slope?			
d. Longitudinal cracks?			
e. Transverse cracks?			
f. Adequate riprap protection?			
g. Any stone deterioration?			
h. Visual depressions or bulges?			
i. Visual settlements?			
j. Animal burrows?			
3. DOWNSTREAM SLOPE			
a. Adequate grass cover?			
b. Any erosion?			
c. Are trees growing on slope?			
d. Longitudinal cracks?			
e. Transverse cracks?			
f. Visual depressions or bulges?			
g. Visual settlements?			
h. Is the toe drain dry?			
i. Are the relief wells flowing?			
j. Are boils present at the toe?			
k. Is seepage present?			
l. Animal burrows?			
4. ABUTMENT CONTACT. RIGHT			
a. Any erosion?			
b. Visual differential movement?			
c. Any cracks noted?			
d. Is seepage present?			
e. Type of Material?			
5. ABUTMENT CONTACT. LEFT			
a. Any erosion?			
b. Visual differential movement?			
c. Any cracks noted?			
d. Is seepage present?			
e. Type of Material?			

APPROVED APR 1999

ITEM	YES	NO	REMARKS
6. SPILLWAY/NORMAL			
a. Location:			
Left abutment?			
Right abutment?			
Crest of Embankments?			
b. Approach Channel:			
Are side slopes eroding?			
Are side slopes sloughing?			
Bottom of channel eroding?			
Obstructed?			
Erosion protection?			
c. Spillway Channel:			
Are side slopes eroding?			
Are side slopes sloughing?			
Bottom of channel eroding?			
Obstructed?			
Erosion protection?			
d. Outflow Channel:			
Are side slopes eroding?			
Are side slopes sloughing?			
Bottom of channel eroding?			
Obstructed?			
Erosion protection?			
e. Weir:			
Condition?			
7. SPILLWAY/EMERGENCY			
a. Location:			
Left abutment?			
Right abutment?			
Crest of Embankments?			
b. Approach Channel:			
Are side slopes eroding?			
Are side slopes sloughing?			
Bottom of channel eroding?			
Obstructed?			
Erosion protection?			
c. Spillway Channel:			
Are side slopes eroding?			
Are side slopes sloughing?			
Bottom of channel eroding?			
Obstructed?			
Erosion protection?			
d. Outflow Channel:			
Are side slopes eroding?			
Are side slopes sloughing?			
Bottom of channel eroding?			
Obstructed?			
Erosion protection?			
e. Weir:			
Condition?			

APPROVED
APR 1999

8. GENERAL COMMENTS

_____
_____
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_____
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_____
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_____

APR 1999
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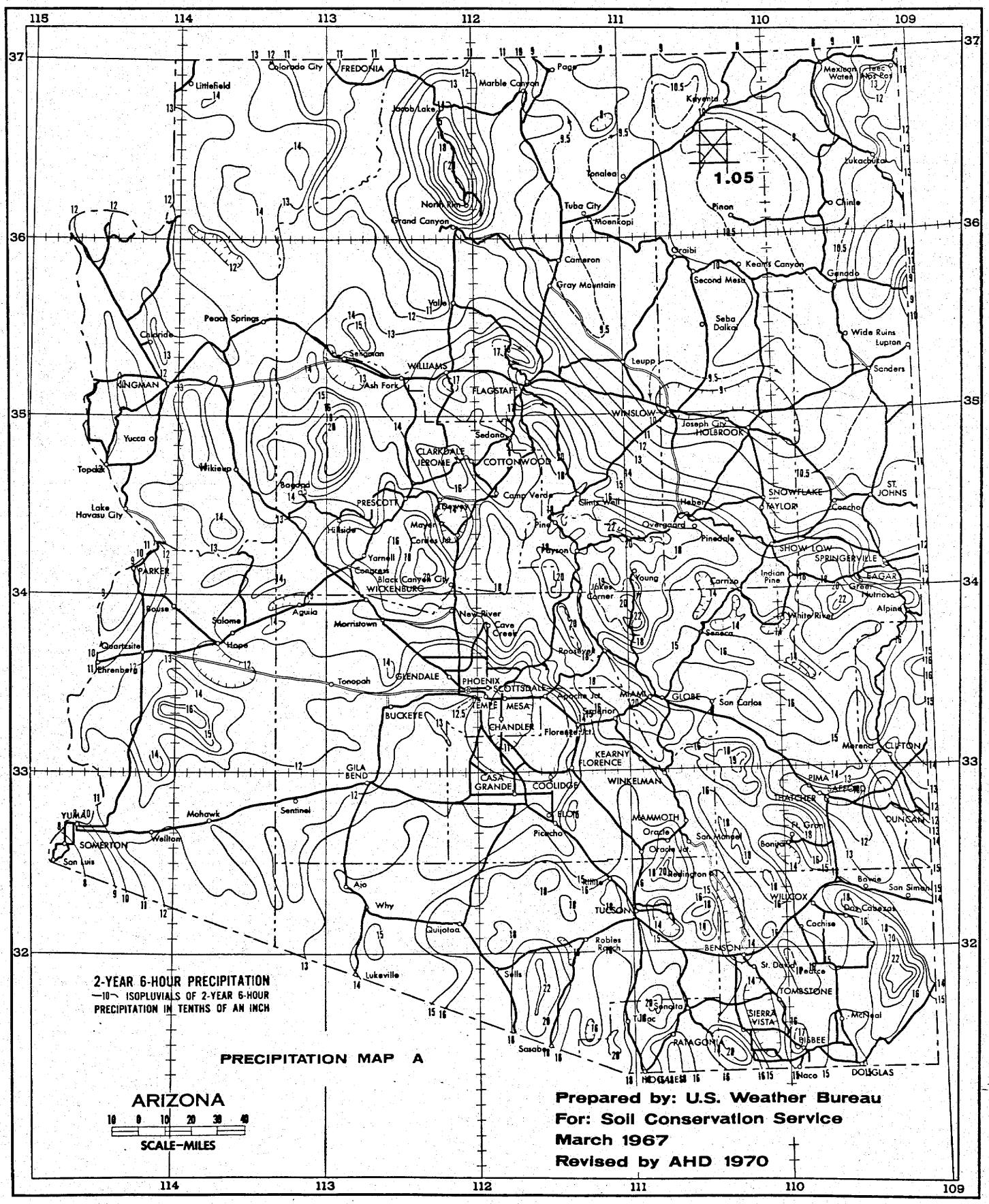
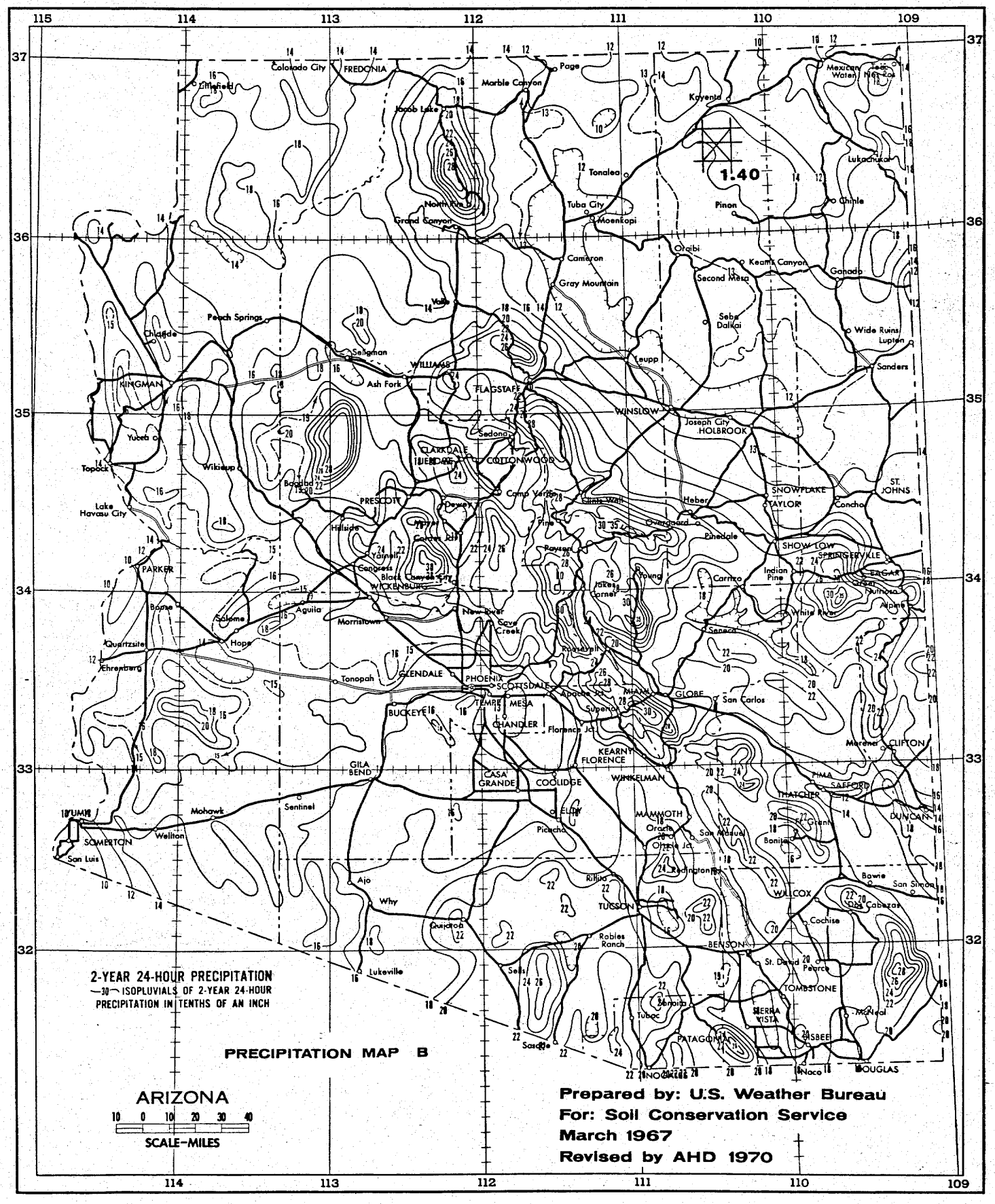
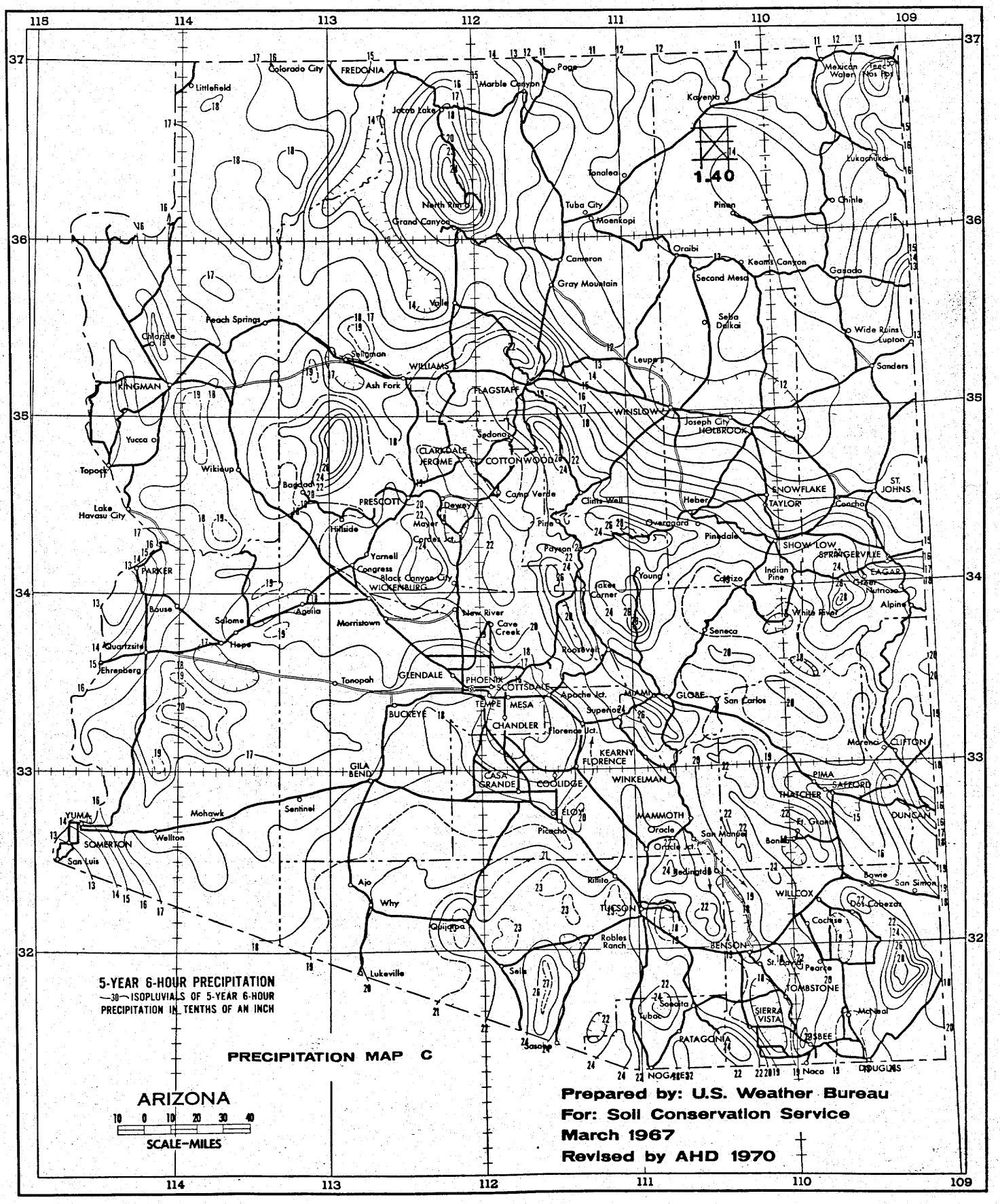
ATTACHMENT F

Precipitation Maps


2-YEAR 6-HOUR PRECIPITATION
—10— ISOPLUVIALS OF 2-YEAR 6-HOUR PRECIPITATION IN TENTHS OF AN INCH
PRECIPITATION MAP A
ARIZONA
SCALE-MILES
Prepared by: U.S. Weather Bureau
For: Soil Conservation Service
March 1967
Revised by AHD 1970
1.05
Colorado City
FREDONIA
Page
Marble Canyon
Jacob Lake
Kayenta
Mexican Water
Lukachukai
Tonalea
Tuba City
Moenkopi
North Rim
Grand Canyon
Pinon
Chinle
Oraibi
Keams Canyon
Second Mesa
Cameron
Gray Mountain
Ganado
Seba Dalkai
Wide Ruins
Lupton
Sanders
Leupp
Peach Springs
Chloride
Seligman
WILLIAMS
Ash Fork
FLAGSTAFF
KINGMAN
WINSLOW
Joseph City
HOLBROOK
Sedona
CLARKDALE
JEROME
COTTONWOOD
Yucca
Topock
Wikieup
Bagdad
Camp Verde
Lake Havasu City
PRESCOTT
Chino Valley
Heber
SNOWFLAKE
TAYLOR
ST. JOHNS
Coyote
Hillside
Mayer
Cornes Jct.
Pine
Overgaard
Pinedale
Yarnell
Cordes
Payson
SHOW LOW
SPRINGERVILLE
EAGAR
PARKER
Black Canyon City
WICKENBURG
Young
Jakes Corner
Carrizo
Indian Pine
Greer
Nutrioso
Alpine
Bouse
Salome
Aguila
Morristown
New River
Cave Creek
White River
Seneca
Quartzsite
Hope
Ehrenberg
Roosevelt
Tonopah
GLENDALE
PHOENIX
SCOTTSDALE
Apache Jct.
MIAMI
GLOBE
San Carlos
TEMPE
MESA
BUCKEYE
CHANDLER
Superior
Florence Jct.
Morenci
CLIFTON
KEARNY
FLORENCE
GILA BEND
CASA GRANDE
COOLIDGE
WINKELMAN
PIMA
SAFFORD
STAFFORD
YUMA
Mohawk
Sentinel
ELOY
MAMMOTH
Oracle
San Manuel
Bonita
DUNCAN
SOMERTON
Wellton
San Luis
Picacho
Oracle Jct.
Redington
Bowie
San Simon
Ajo
Why
Quijotoa
TUCSON
WILCOX
Cochise
Dos Cabezas
Robles Ranch
BENSON
Lukeville
Sells
St. David
Pearce
TOMBSTONE
Sonoita
Tubac
SIERRA VISTA
McNeal
Sasabe
PATAGONIA
BISBEE
NOGALES
Naco
DOUGLAS


2-YEAR 24-HOUR PRECIPITATION
—30— ISOPLUVIALS OF 2-YEAR 24-HOUR PRECIPITATION IN TENTHS OF AN INCH
PRECIPITATION MAP B
ARIZONA
SCALE-MILES
Prepared by: U.S. Weather Bureau
For: Soil Conservation Service
March 1967
Revised by AHD 1970
1.40
Colorado City
FREDONIA
Page
Marble Canyon
Kayenta
Tonalea
Tuba City
Moenkopi
Pinon
Chinle
Grand Canyon
Cameron
Oraibi
Keams Canyon
Second Mesa
Ganado
Gray Mountain
Peach Springs
Seligman
WILLIAMS
Ash Fork
FLAGSTAFF
KINGMAN
Yucca
Topock
Lake Havasu City
Wikieup
Sedona
WINSLOW
Joseph City
HOLBROOK
Leupp
Sanders
Wide Ruins
Lupton
CLARKDALE
JEROME
COTTONWOOD
Camp Verde
PRESCOTT
Dewey
Hillside
Cottonwood
Yarnell
Congress
Black Canyon
WICKENBURG
Aguila
Morristown
Cave Creek
New River
Rock Springs
Fine
Heber
Overgaard
Pinedale
SNOWFLAKE
TAYLOR
Concho
ST. JOHNS
SHOW LOW
SPRINGERVILLE
EAGAR
Nutrioso
Alpine
White River
Indian Pine
Carrizo
Young
Jakes Corner
Roosevelt
Seneca
PARKER
Bagdad
Salome
Hope
Quartzsite
Ehrenberg
Tonopah
GLENDALE
PHOENIX
SCOTTSDALE
TEMPE
MESA
CHANDLER
BUCKEYE
Apache Jct.
Superior
MIAMI
GLOBE
San Carlos
Florence Jct.
KEARNY
FLORENCE
Mariner
CLIFTON
GILA BEND
CASA GRANDE
COOLIDGE
WINKELMAN
PIMA
SAFFORD
THATCHER
Graham
DUNCAN
YUMA
SOMERTON
San Luis
Mohawk
Wellton
Sentinel
ELOY
Picacho
MAMMOTH
Oracle
San Manuel
Oracle Jct.
Kearny
Bonita
Ajo
Why
Quijotoa
Rillito
TUCSON
Robles Ranch
BENSON
WILCOX
Bowie
San Simon
Dos Cabezas
Cochise
St. David
Pearce
TOMBSTONE
Lukeville
Sells
Tubac
Amado
SIERRA VISTA
Mescal
PATAGONIA
ISABEE
Sasabe
NOGALES
Naco
DOUGLAS


5-YEAR 6-HOUR PRECIPITATION
—30— ISOPLUVIALS OF 5-YEAR 6-HOUR PRECIPITATION IN TENTHS OF AN INCH
PRECIPITATION MAP C
ARIZONA
SCALE-MILES
Prepared by: U.S. Weather Bureau
For: Soil Conservation Service
March 1967
Revised by AHD 1970
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Colorado City
FREDONIA
Page
Marble Canyon
Jacob Lake
Littlefield
Kayenta
Mexican Water
Teec Nos Pos
Tonalea
Tuba City
Moenkopi
Pinon
Chinle
Lukachukai
North Rim
Grand Canyon
Cameron
Gray Mountain
Oraibi
Keams Canyon
Second Mesa
Gasado
Valle
Peach Springs
Seligman
Chloride
Sells
Dilkai
Wide Ruins
Lupton
Sanders
Leupp
WILLIAMS
Ash Fork
KINGMAN
FLAGSTAFF
WINSLOW
Joseph City
HOLBROOK
Yucca
Sedona
CLARKDALE
JEROME
COTTONWOOD
Topock
Wikieup
Bagdad
Camp Verde
Clints Well
Heber
SNOWFLAKE
TAYLOR
ST. JOHNS
Concho
Lake Havasu City
PRESCOTT
Dewey
Mayer
Hillside
Cordes Jct.
Pine
Overgaard
Pinedale
SHOW LOW
SPRINGERVILLE
EAGAR
Payson
Yarnell
Congress
Black Canyon City
WICKENBURG
Young
Cakes Corner
Calizo
Indian Pine
Nutrioso
Alpine
PARKER
Bouse
Salome
Aguila
Morristown
New River
Cave Creek
White River
Seneca
Quartzsite
Hope
Ehrenberg
Roosevelt
Tonopah
GLENDALE
PHOENIX
SCOTTSDALE
Apache Jct.
MIAMI
GLOBE
San Carlos
BUCKEYE
TEMPE
MESA
Superior
CHANDLER
Florence Jct.
KEARNY
FLORENCE
Morenci
CLIFTON
GILA BEND
CASA GRANDE
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San Manuel
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Dos Cabezas
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TUCSON
Cochise
Quijotoa
Robles Ranch
BENSON
St. David
Pearce
Lukeville
Sells
TOMBSTONE
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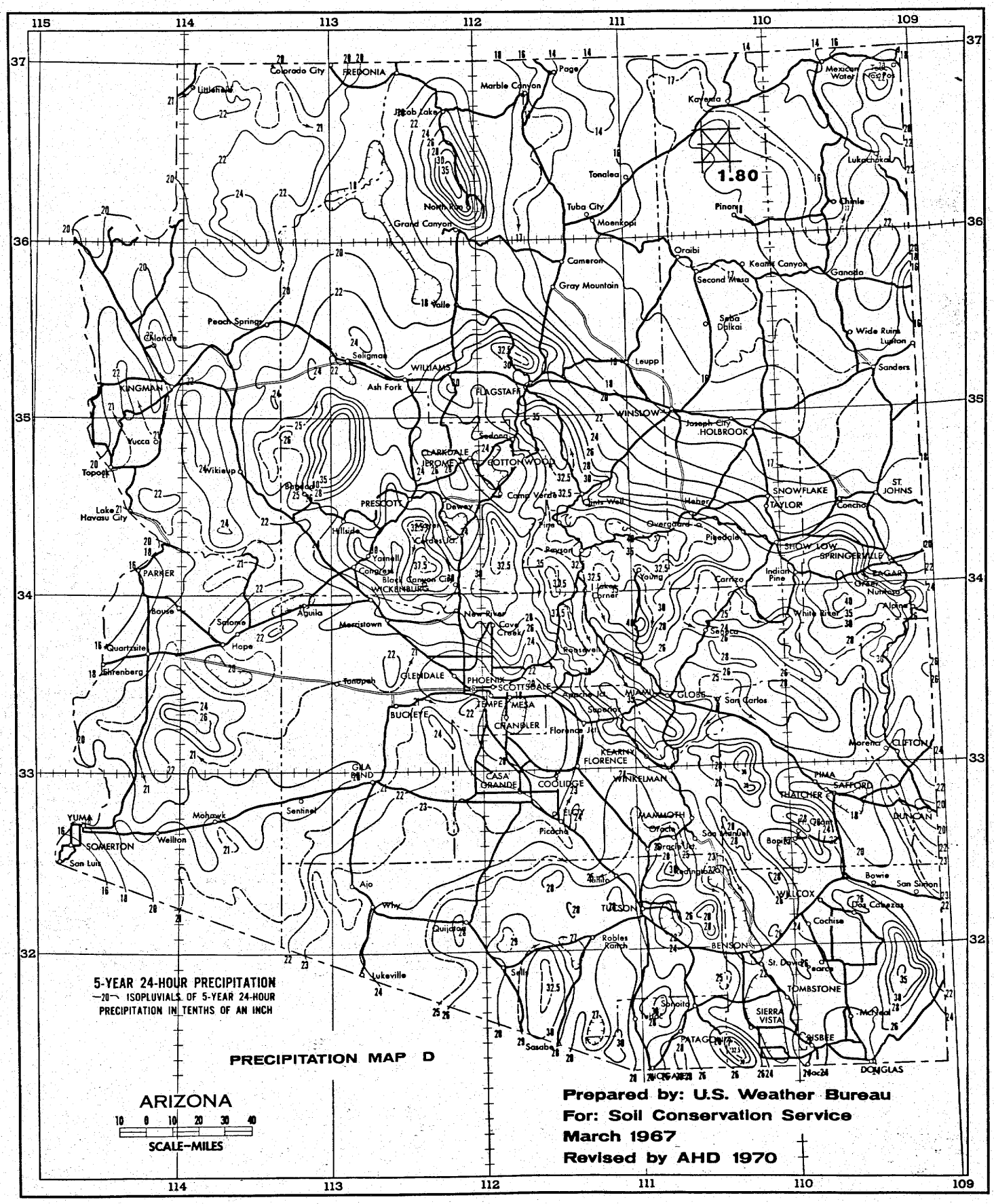
Naco
DOUGLAS


5-YEAR 24-HOUR PRECIPITATION
—20— ISOPLUVIALS OF 5-YEAR 24-HOUR PRECIPITATION IN TENTHS OF AN INCH
PRECIPITATION MAP D
ARIZONA
SCALE-MILES
Prepared by: U.S. Weather Bureau
For: Soil Conservation Service
March 1967
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1.80
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FREDONIA
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Marble Canyon
Kayenta
Mexican Water
Lukachukai
Tonalea
Tuba City
Pinon
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North Rim
Grand Canyon
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Cameron
Oraibi
Keams Canyon
Second Mesa
Ganado
Gray Mountain
Valle
Peach Springs
Seligman
Leupp
Wide Ruins
Lupton
Sanders
WILLIAMS
Ash Fork
FLAGSTAFF
KINGMAN
WINSLOW
Joseph City
HOLBROOK
Yucca
Topock
Sedona
CLARKDALE
JEROME
COTTONWOOD
Wikieup
Camp Verde
SNOWFLAKE
TAYLOR
ST. JOHNS
Concho
Lake Havasu City
PRESCOTT
Dewey
Heber
Overgaard
Pinedale
SHOW LOW
SPRINGERVILLE
EAGAR
Hillside
Chino Jct.
Paxon
Yarnell
Young
Indian Pine
Carrizo
Nutrioso
Alpine
PARKER
Congress
Black Canyon City
WICKENBURG
Lakes Corner
Bouse
Salome
Aguila
Morristown
New River
Cave Creek
White River
Seneca
Quartzsite
Hope
Roosevelt
Ehrenberg
Tonopah
GLENDALE
PHOENIX
SCOTTSDALE
Apache Jct.
MIAMI
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BUCKEYE
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CHANDLER
Florence Jct.
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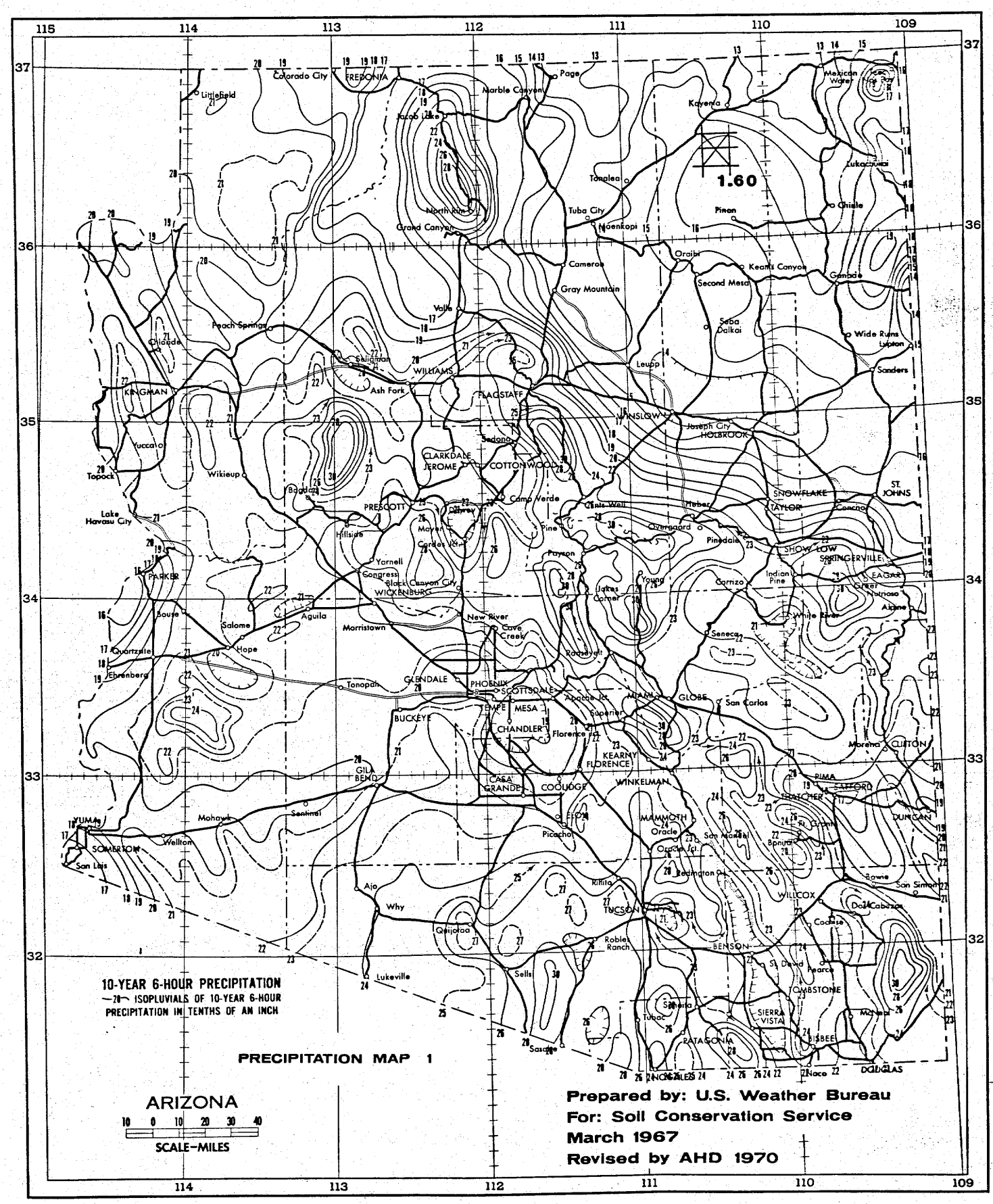
10-YEAR 6-HOUR PRECIPITATION
—20— ISOPLUVIALS OF 10-YEAR 6-HOUR PRECIPITATION IN TENTHS OF AN INCH
PRECIPITATION MAP 1
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SCALE-MILES
Prepared by: U.S. Weather Bureau
For: Soil Conservation Service
March 1967
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1.60
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Marble Canyon
Kayenta
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Grand Canyon
Cameron
Oraibi
Keams Canyon
Second Mesa
Gambo
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Valle
Peach Springs
Seba Dalkai
Wide Ruins
Leupp
Sanders
Chloride
Seligman
WILLIAMS
Ash Fork
FLAGSTAFF
KINGMAN
WINSLOW
Joseph City
HOLBROOK
Sedona
Yucca
CLARKDALE
JEROME
COTTONWOOD
Topock
Wikieup
Bagdad
Camp Verde
SNOWFLAKE
TAYLOR
ST. JOHNS
Lake Havasu City
PRESCOTT
Prescott Valley
Mayer
Cordes Jct.
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Pine
Overgaard
Pinedale
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Alpine
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Salome
Aguila
Morristown
New River
Cave Creek
Seneca
Quartzsite
Hope
Ehrenberg
Roosevelt
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FORT GRAHAM
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Redington
Bowie
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Why
Ritito
TUCSON
WILLCOX
Dos Cabezas
Cochise
Quitotoa
Robles Ranch
BENSON
St. David
Pearce
Lukeville
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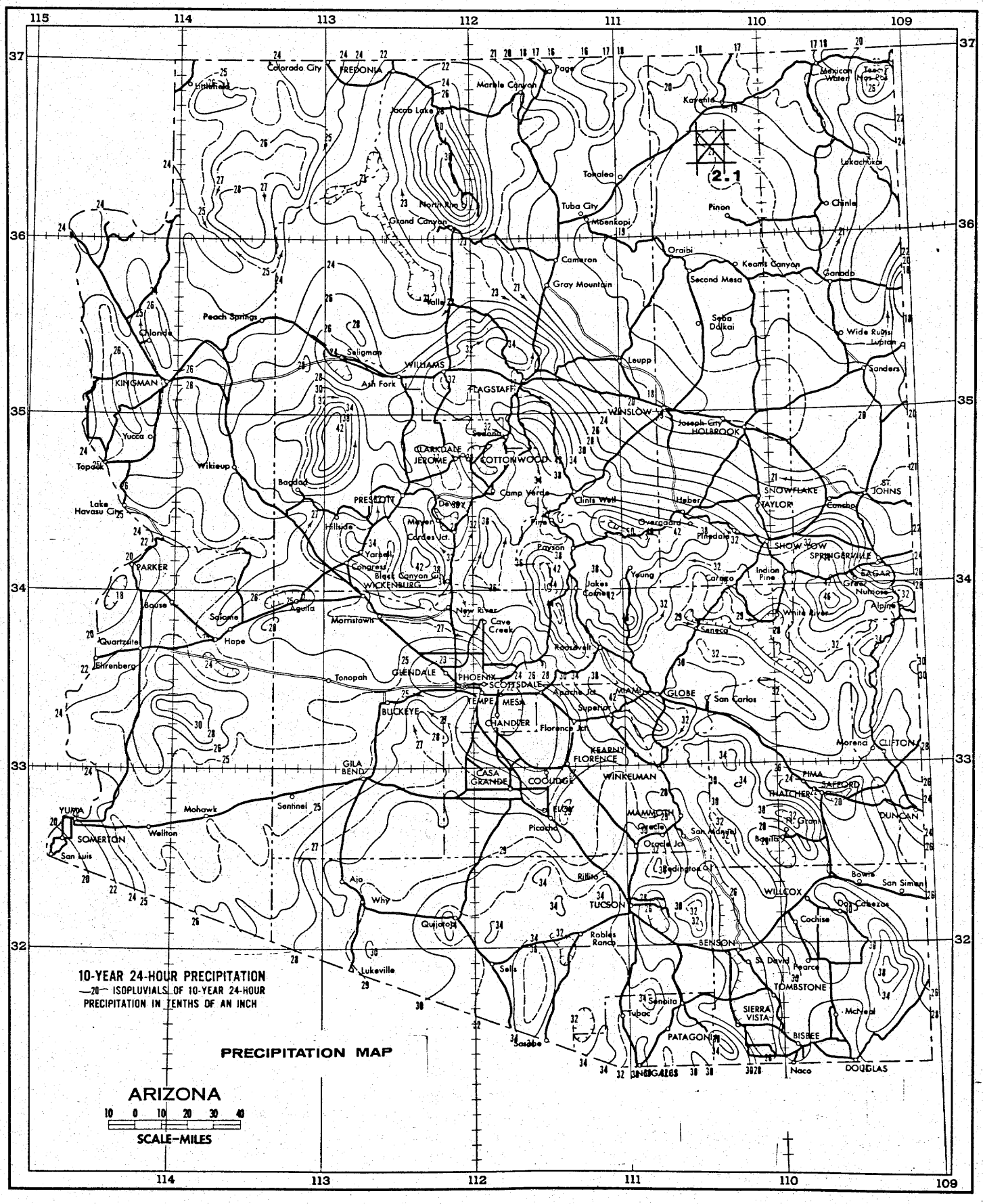
10-YEAR 24-HOUR PRECIPITATION
—20— ISOPLUVIALS OF 10-YEAR 24-HOUR PRECIPITATION IN TENTHS OF AN INCH
PRECIPITATION MAP
ARIZONA
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SCALE-MILES
Colorado City
FREDONIA
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Marble Canyon
Jacob Lake
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Grand Canyon
Tuba City
Moenkopi
Tonalea
Kayenta
Pinon
Chinle
Lukachukai
Mexican Water
Teec Nos Pos
Cameron
Gray Mountain
Oraibi
Second Mesa
Keams Canyon
Ganado
Sawmill
Valle
Peach Springs
Seligman
Chloride
KINGMAN
Yucca
Topock
Lake Havasu City
Wikieup
Bagdad
WILLIAMS
Ash Fork
FLAGSTAFF
Leupp
Seba Dalkai
Wide Ruins
Lupton
Sanders
WINSLOW
Joseph City
HOLBROOK
Sedona
CLARKDALE
JEROME
COTTONWOOD
Camp Verde
Clints Well
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SNOWFLAKE
TAYLOR
Concho
ST. JOHNS
PRESCOTT
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Mayer
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Pine
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Black Canyon City
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Jakes Corner
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Carrizo
Indian Pine
Greer
Nutrioso
Alpine
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Bouse
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Morristown
New River
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Roosevelt
White River
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Quartzsite
Hope
Ehrenberg
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CHANDLER
Florence Jct.
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DUNCAN
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San Luis
Oracle Jct.
Redington Jct.
Aja
Why
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TUCSON
WILLCOX
Bowie
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Dos Cabezas
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Quijotoa
Robles Ranch
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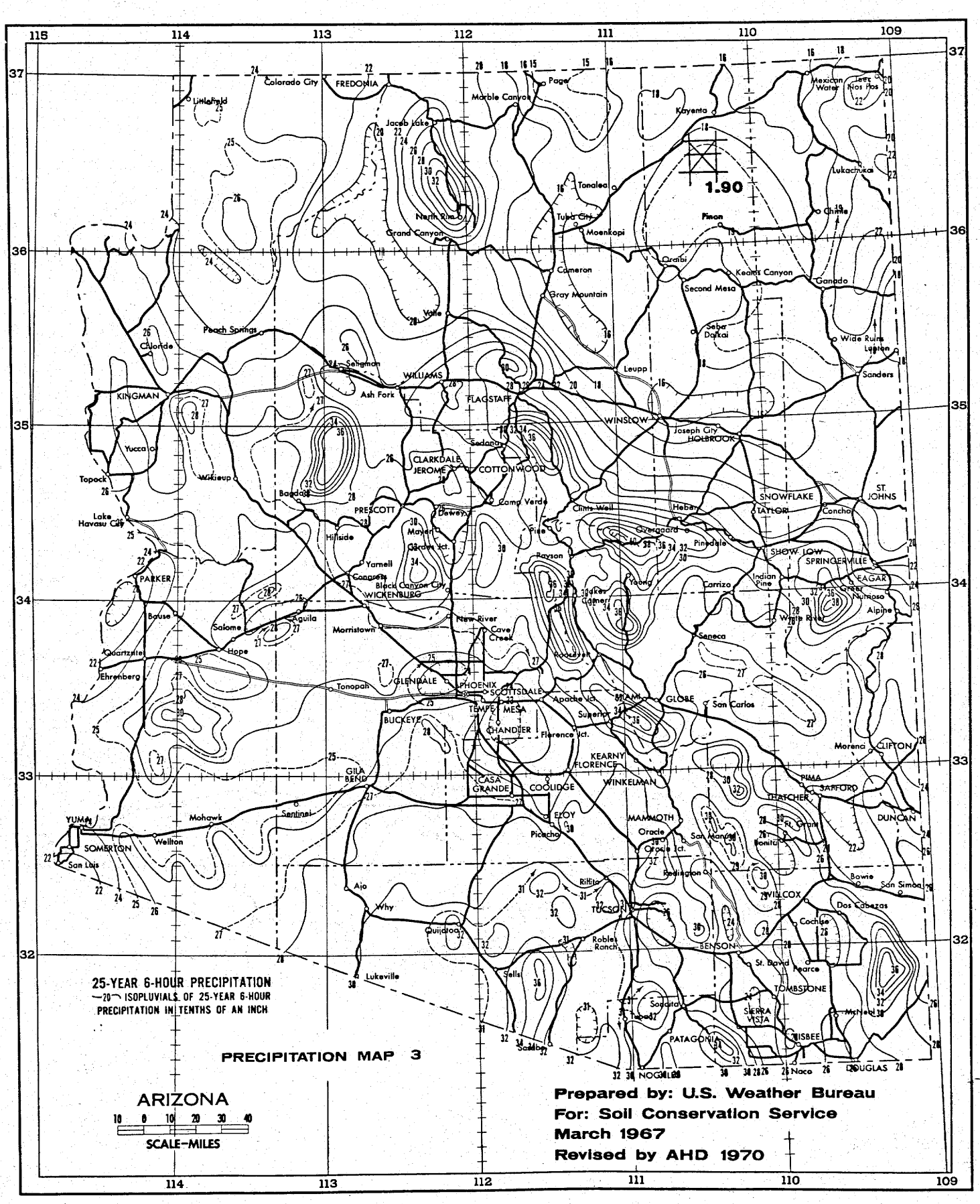
NOGALES
Naco
DOUGLAS


25-YEAR 6-HOUR PRECIPITATION
ISOPLUVIALS OF 25-YEAR 6-HOUR PRECIPITATION IN TENTHS OF AN INCH
PRECIPITATION MAP 3
ARIZONA
SCALE-MILES
Prepared by: U.S. Weather Bureau
For: Soil Conservation Service
March 1967
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1.90
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Gray Mountain
Oraibi
Keams Canyon
Second Mesa
Ganado
Peach Springs
Seligman
WILLIAMS
Ash Fork
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Joseph City
HOLBROOK
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CLARKDALE
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COTTONWOOD
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Clints Well
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SNOWFLAKE
TAYLOR
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Concho
Topock
Lake Havasu City
PRESCOTT
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SPRINGERVILLE
EAGAR
Alpine
PARKER
Yarnell
Congress
Black Canyon City
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Rayson
Yuma
Carrizo
Indian Pine
Morristown
New River
Cave Creek
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Ehrenberg
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GLENDALE
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Dos Cabezas
Cochise
Quijotoa
Robles Ranch
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Pearce
Lukeville
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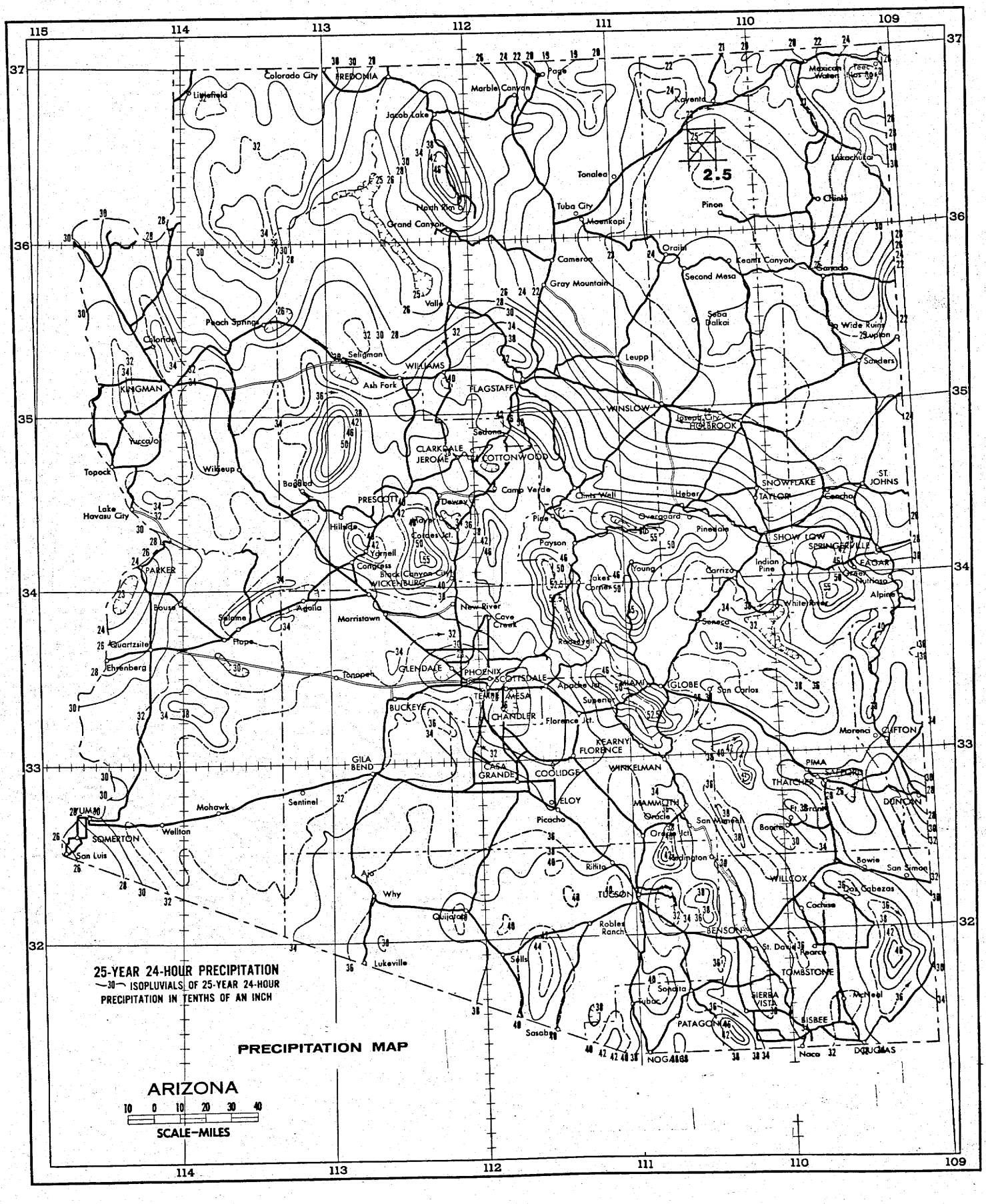
25-YEAR 24-HOUR PRECIPITATION
30 ISOPLUVIALS OF 25-YEAR 24-HOUR PRECIPITATION IN TENTHS OF AN INCH
PRECIPITATION MAP
ARIZONA
SCALE-MILES
2.5
Colorado City
FREDONIA
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Marble Canyon
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Tuba City
Moenkopi
Pinon
Grand Canyon
Cameron
Gray Mountain
Second Mesa
Keams Canyon
Sanders
Peach Springs
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Camp Verde
Chino Well
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Overgaard
Pinedale
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Carrizo
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Aguila
Morristown
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Florence Jct.
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CLIFTON
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Redington
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Dos Cabezas
TUCSON
Quijotoa
Cochise
Robles Ranch
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Lukeville
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St. David
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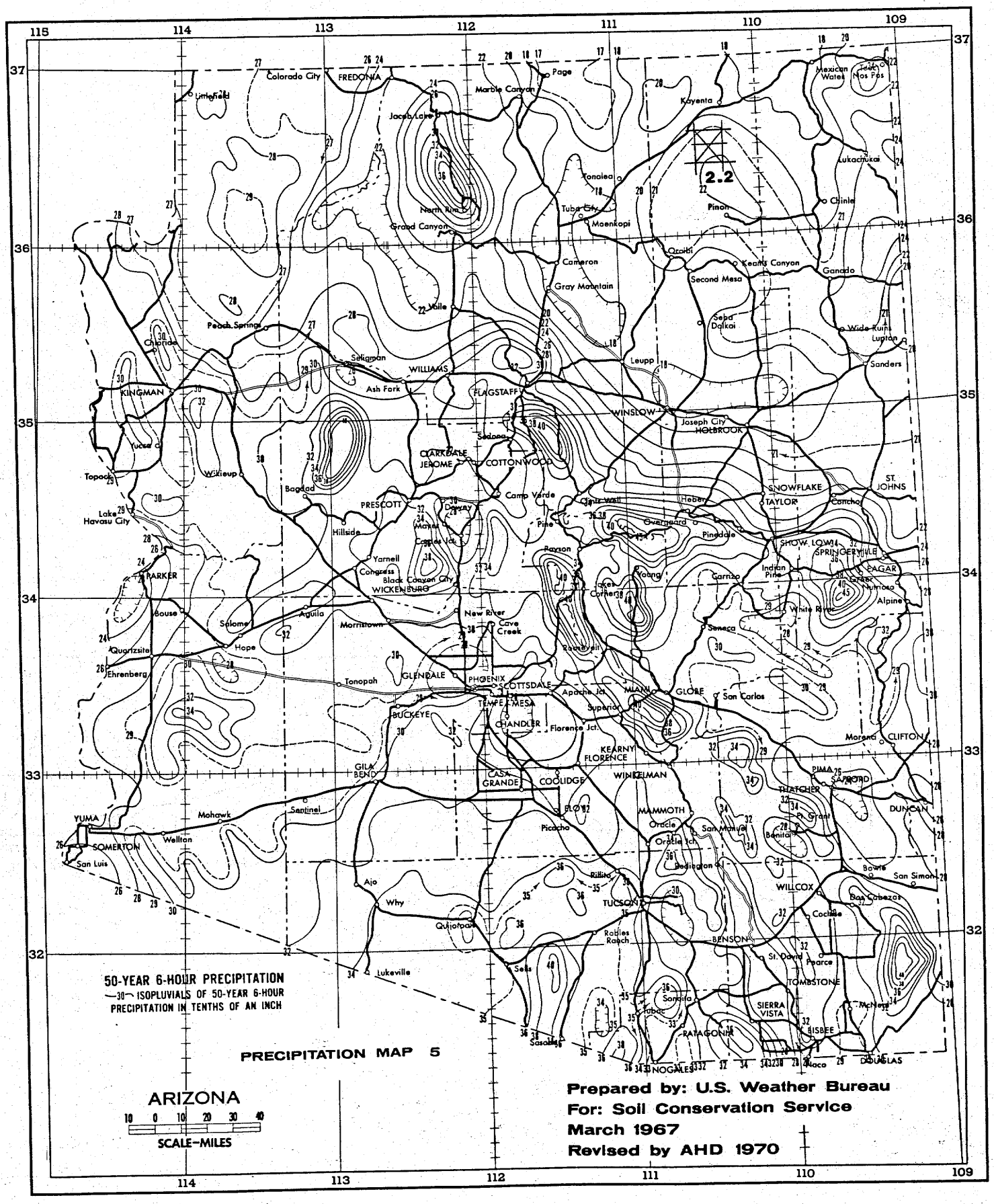
50-YEAR 6-HOUR PRECIPITATION
—30— ISOPLUVIALS OF 50-YEAR 6-HOUR PRECIPITATION IN TENTHS OF AN INCH
PRECIPITATION MAP 5
ARIZONA
SCALE-MILES
Prepared by: U.S. Weather Bureau
For: Soil Conservation Service
March 1967
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2.2
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Marble Canyon
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Tuba City
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Lukachukai
Chinle
Pinon
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Keams Canyon
Second Mesa
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Peach Springs
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Alpine
Indian Pine
Garrisa
Seneca
White River
Rainbow
Morenci
CLIFTON
KEARNY
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Lukeville
Rillito
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Robles Ranch
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St. David
Pearce
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WILLCOX
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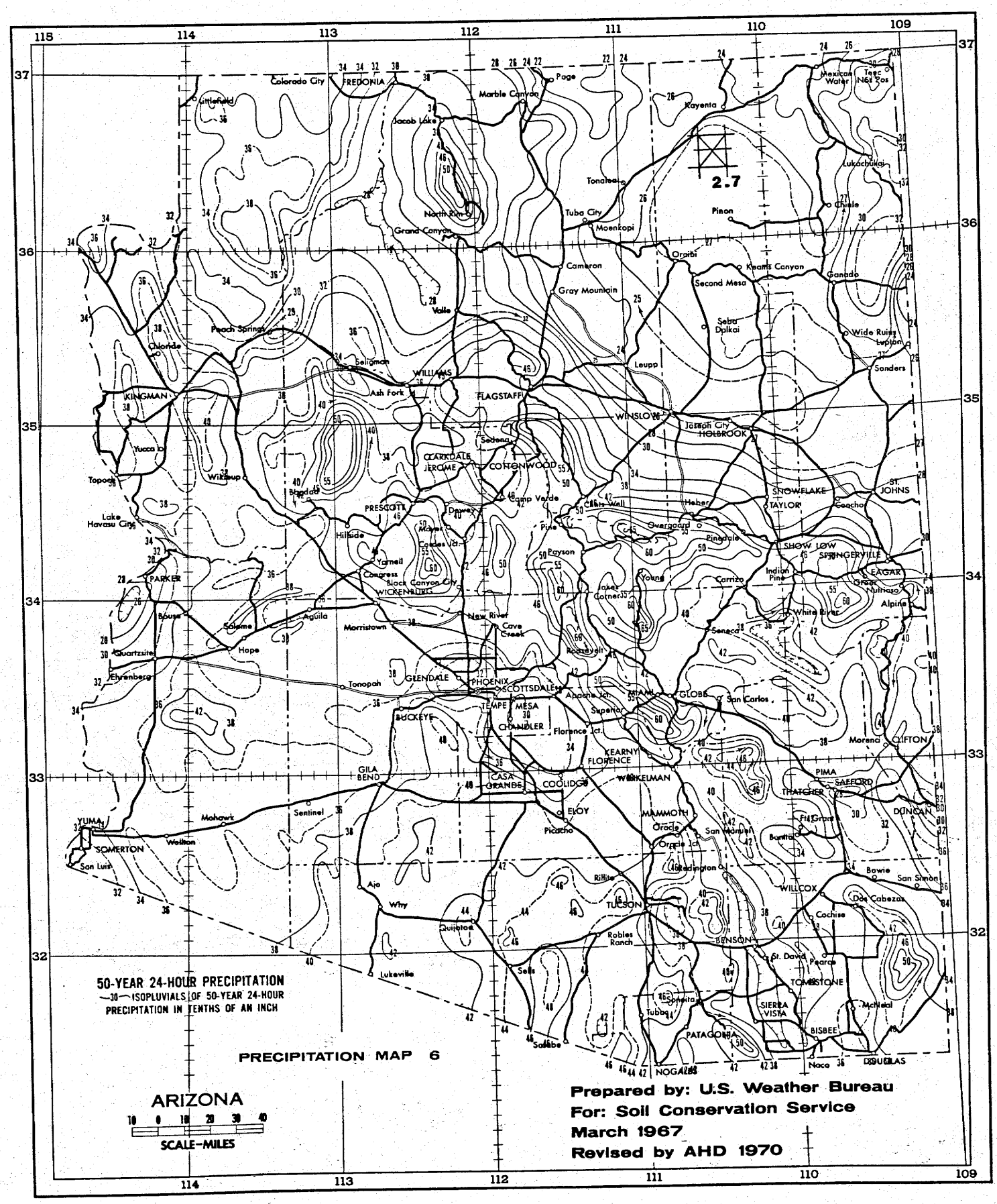
50-YEAR 24-HOUR PRECIPITATION
—30— ISOPLUVIALS OF 50-YEAR 24-HOUR PRECIPITATION IN TENTHS OF AN INCH
PRECIPITATION MAP 6
ARIZONA
SCALE-MILES
Prepared by: U.S. Weather Bureau
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2.7
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Leupp
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Lupton
Sonders
KINGMAN
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Nutrioso
Alpine
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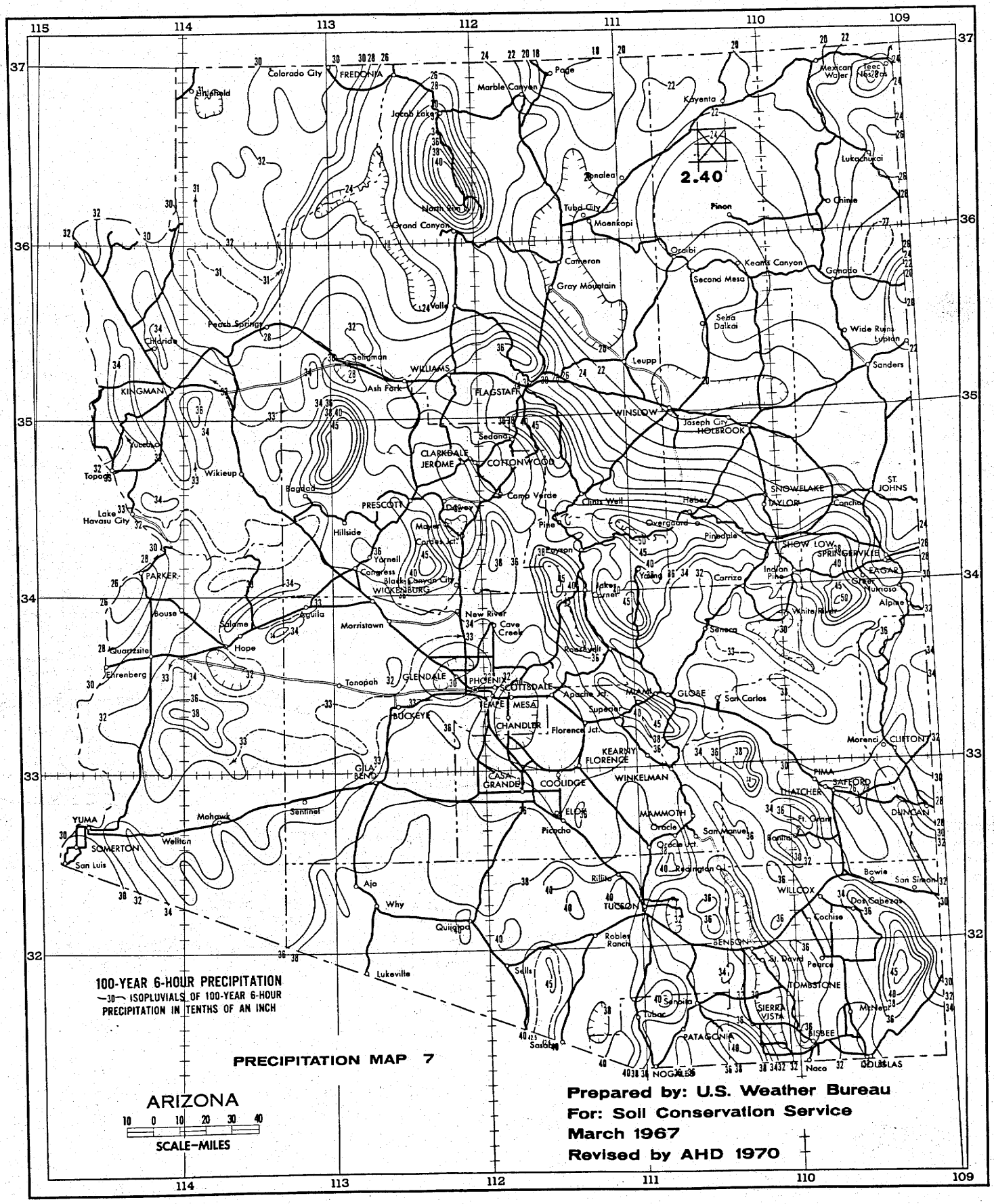
100-YEAR 6-HOUR PRECIPITATION
ISOPLUVIALS OF 100-YEAR 6-HOUR PRECIPITATION IN TENTHS OF AN INCH
PRECIPITATION MAP 7
ARIZONA
SCALE-MILES
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Cave Creek
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Roosevelt
Quartzsite
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San Manuel
Ft. Grant
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Quijotoa
Robles Ranch
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St. David
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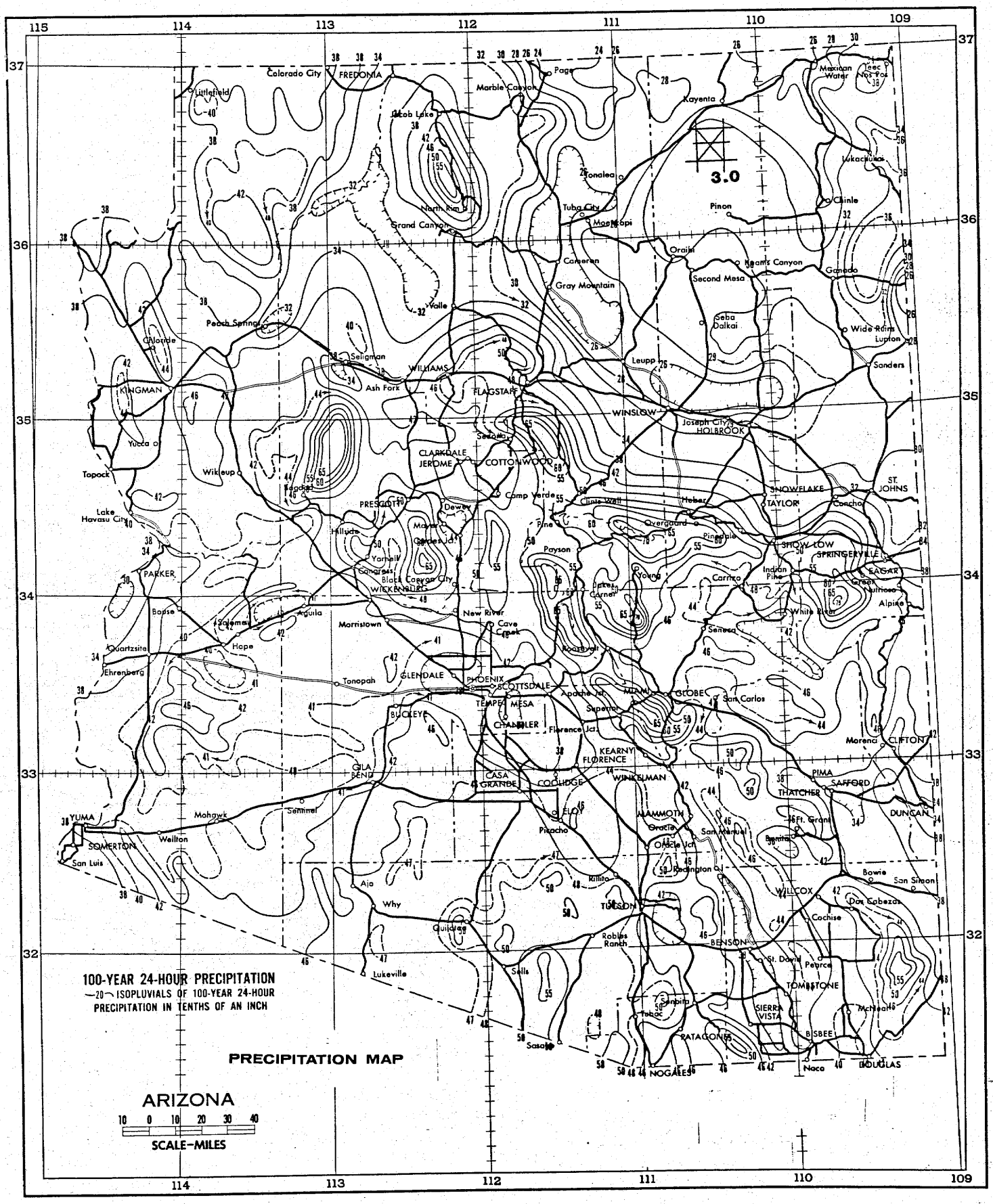
100-YEAR 24-HOUR PRECIPITATION
—20— ISOPLUVIALS OF 100-YEAR 24-HOUR PRECIPITATION IN TENTHS OF AN INCH
PRECIPITATION MAP
ARIZONA
SCALE-MILES
Colorado City
FREDONIA
Page
Marble Canyon
Kayenta
Mexican Water
Lake Powell
Tonalea
Tuba City
Moenkopi
Pinon
Chinle
Lukachukai
North Rim
Grand Canyon
Cameron
Oraibi
Ganado
Second Mesa
Gray Mountain
Valle
Peach Springs
Seba Dalkai
Wide Ruins
Lupton
Sanders
Seligman
WILLIAMS
Ash Fork
FLAGSTAFF
Leupp
KINGMAN
WINSLOW
Joseph City
HOLBROOK
Yucca
Sedona
CLARKDALE
JEROME
COTTONWOOD
Topock
Wikieup
Kingman
Camp Verde
Clints Well
Heber
SNOWFLAKE
TAYLOR
ST. JOHNS
Concho
Lake Havasu City
PRESCOTT
Dewey
Mayer
Hillside
Gardes Jct.
Overgaard
Pinetop
Pine
Payson
SHOW LOW
SPRINGERVILLE
EAGAR
Yarnell
Congress
Black Canyon City
WICKENBURG
Young
Tonto Creek
Carrizo
Indian Pike
Greer
Nutrioso
PARKER
Aguila
New River
Cave Creek
White River
Alpine
Boise
Salome
Morristown
Seneca
Quartzsite
Hope
Roosevelt
Ehrenberg
Tonopah
GLENDALE
PHOENIX
SCOTTSDALE
Apache Jct.
MIAMI
GLOBE
San Carlos
TEMPE
MESA
BUCKEYE
CHANDLER
Superior
Florence Jct.
Morenci
CLIFTON
KEARNY
FLORENCE
GILA BEND
CASA GRANDE
COOLIDGE
WINKELMAN
PIMA
SAFFORD
THATCHER
DUNCAN
YUMA
Mohawk
Sentinel
FLOY
Pinacho
MAMMOTH
Ft. Grant
Bonita
SOMERTON
Wellton
San Luis
San Manuel
Oracle Jct.
Redington
Bowie
San Simon
Aja
Why
Rillito
WILLCOX
TUCSON
Don Cabezas
Cochise
Quijotoa
Robles Ranch
BENSON
St. David
Pearce
Lukeville
Sells
TOMBSTONE
Tubac
SIERRA VISTA
McNeal
BISBEE
Sasabe
PATAGONIA
NOGALES
Naco
DOUGLAS

ATTACHMENT G

Curve Numbers

Runoff Curve Numbers (Average ARC, $I_a = 0.25$)

Cover Description		Curve Numbers (CN) for Hydrologic Soil Group			
Land Use and Hydrologic Condition		A	B	C	D
Fully Developed Urban Areas (Vegetation Established)					
Open Space including lawns, parks, golf courses, cemetaries, etc. 1/					
poor condition: grass cover on 50% or less of the area		68	79	86	89
fair condition: grass cover on 50% to 75% of the area		49	69	79	84
good condition: grass cover on 75% or more of the area		39	61	74	80
Impervious Areas					
Paved parking lots, roofs, driveways, etc. (excluding right-of-way		98	98	98	98
Streets and roads:					
paved with curbs and storm sewers (excluding right-of-way)		98	98	98	98
paved with open ditches (including right-of-way)		83	89	92	93
gravel (including right-of-way)		76	85	89	91
dirt (including right-of-way)		72	82	87	89
Western Desert Urban Areas					
Natural desert landscaping (pervious areas only) 2/		63	77	85	88
Artificial desert landscaping (impervious weed barrier, desert shrub with 1"-2" sand/gravel mulch and basin borders)		96	96	96	96
	Average % Impervious Areas				
Urban Districts 3/					
Commercial and business districts	85	89	92	94	95
Industrial districts	72	81	88	91	93
Residential districts - average lot size					
1/8 acre or less (row houses and town houses)	65	77	85	90	92
1/4 acre	38	61	75	83	87
1/3 acre	30	57	72	81	86
1/2 acre	25	54	70	80	85
1 acre	20	51	68	79	84
2 acre	12	46	65	77	82

Runoff Curve Numbers (Average ARC, $I_a = 0.25$) - (Cont.)

Cover Description	Curve Numbers (CN) for Hydrologic Soil Group			
Land Use and Hydrologic Condition	A	B	C	D
Developing Urban Areas				
Newly graded areas (pervious areas only - with no vegetation) 4/	77	86	91	94
Idle lands (CN's are determined using other land uses in Exhibit 2-1)				

1/ Open space CN's shown are equivalent to those of pasture. Other CN's may be selected or computed using other land uses in Exhibit 2-1.

2/ Composite CN for natural desert landscape urban areas should be computed using Figures 2-2 or 2-3 based on the % impervious area (CN - 98) and the pervious area CN (equivalent to desert shrub in poor hydrologic condition).

3/ Composite CN's are computed assuming the average % impervious areas shown (including paved roads) are directly connected to the drainage system. Impervious areas have a CN of 98. Pervious areas are considered to be equivalent to lawns in good hydrologic condition. Other combinations of conditions may be computed using Figure 2-2 or 2-3.

4/ Composite CN's to use for the design of temporary measures during grading and construction should be computed using Figures 2-2 or 2-3, based on the degree of development (% impervious area) and the newly graded CN's for the pervious areas.

Runoff Curve Numbers (Average ARC, $I_a = 0.25$) - (Cont.)

Cover Description			Curve Numbers (CN) for Hydrologic Soil Group			
Land Use	Treatment or Practice 5/	Hydrologic Condition 6/	A	B	C	D
Cultivated Agricultural Lands						
Fallow	Bare ground	-	77	86	91	94
	Crop residue cover	poor	76	85	90	93
	Crop residue cover	good	74	83	88	90
Row Crops	Straight row (SR)	poor	72	81	88	91
	Straight row (SR)	good	67	78	85	89
	SR + Crop residue cover	poor	71	80	87	90
	SR + Crop residue cover	good	64	75	82	85
	Contoured (C)	poor	70	79	84	88
	Contoured (C)	good	65	75	82	86
	C + Crop residue cover	poor	69	78	83	87
	C + Crop residue cover	good	64	74	81	85
	Contoured & terraced (C&T)	poor	66	74	80	82
	Contoured & terraced (C&T)	good	62	71	78	81
	C&T + Crop residue cover	poor	65	73	79	81
	C&T + Crop residue cover	good	61	70	77	80
Small Grain	Straight row (SR)	poor	65	76	84	88
	Straight row (SR)	good	63	75	83	87
	SR + Crop residue cover	poor	64	75	83	86
	SR + Crop residue cover	good	60	72	80	84
	Contoured (C)	poor	63	74	82	85
	Contoured (C)	good	61	73	81	84
	C + Crop residue cover	poor	62	73	81	84
	C + Crop residue cover	good	60	72	80	83

Runoff Curve Numbers (Average ARC, $I_a = 0.25$) - (Cont.)

Cover Description			Curve Numbers (CN) for Hydrologic Soil Group			
Land Use	Treatment or Practice 5/	Hydrologic Condition 6/	A	B	C	D
	Contoured & terraced (C&T)	poor	61	72	79	82
	Contoured & terraced (C&T)	good	59	70	78	81
	C&T + Crop residue cover	poor	60	71	78	81
	C&T + Crop residue cover	good	58	69	77	80
Close-seeded	Straight row	poor	66	77	85	89
Legumes 7/	Straight row	good	58	72	81	85
or	Contoured	poor	64	75	83	85
Rotation Meadow	Contoured	good	55	69	78	83
	Contoured & terraced	poor	63	73	80	83
	Contoured & terraced	good	51	67	76	80

5/ Crop residue cover is a by-product of conservation tillage (noninversion tillage) and retains protective amounts of residue mulch on at least 5% of the surface throughout the year.

6/ Hydrologic condition for tilled land is based on the effectiveness of the ground cover.

Poor refers to areas with poor plant stands, lack of year-round vegetative cover, rotation without close-seeded legumes or grass, or crop residue that covers less than 20% of the surface.

Good refers to areas with good plant stands, vegetative cover most of the year, rotations with close-seeded legumes or grass, tillage practices that leave a rough surface, and/or crop residue that covers over 20% of the surface.

7/ Close-drilled or broadcast legumes.

Runoff Curve Numbers (Average ARC, $I_a = 0.25$) - (Cont.)

Cover Description		Curve Numbers (CN) for Hydrologic Soil Group			
Land Use	Hydrologic Condition 6/	A	B	C	D
Other Agricultural Land					
Pasture or Range (Grassland) 8/ 9/	poor	68	79	86	89
(continuous forage for grazing)	fair	49	69	79	84
	good	39	61	74	80
Meadow (continuous grass, protected from grazing and generally mowed for hay)	-	30	58	71	78
Brush 10/	poor	48	67	77	83
(brush-weed-grass mixture with brush the major element)	good	*	48	65	73
Woods-Grass 11/	poor	55	73	82	86
(evergreen or deciduous trees with an understory of grass)	fair	44	65	76	82
	good	32	58	72	79
Woods 12/	poor	45	66	77	83
(evergreen or deciduous trees the predominant element)	fair	36	60	73	79
	good	*	55	70	77
Farmsteads (includes farm buildings, lanes, driveways, and surrounding lots)	-	59	74	82	86

8/ For range in predominantly arid and semi-arid regions, use CN's from the RANGE section of Exhibit 2-1.

9/ Hydrologic conditions for forage is based on the effectiveness of the ground cover.
Poor refers to less than 50% ground cover or heavily grazed with no mulch.
Fair refers to between 50 and 75% ground cover and not heavily grazed.
Good refers to more than 75% ground cover and lightly or only occasionally grazed.

10/ Hydrologic condition for brush is based on the effectiveness of the ground cover.
Poor has less than 70% ground cover.
Good has more than 70% ground cover.

11/ Composite CN's for woods-grass are computed for areas with 50% woods and 50% pasture with their appropriate hydrologic conditions. Other combinations of conditions may be computed from the CN's for woods and pasture.

Runoff Curve Numbers (Average ARC, $I_a = 0.25$) - (Cont.)

Cover Description		Curve Numbers (CN) for Hydrologic Soil Group			
Land Use	Hydrologic Condition 6/	A	B	C	D

12/ Hydrologic condition for woods is based on the effectiveness of the ground cover.

Poor refers to heavily grazed or regularly burned woods where forest, litter, small trees, and brush are destroyed.

Fair refers to woods that are grazed, but not burned, where some forest litter may cover the soil.

Good refers to woods protected from grazing where litter and brush adequately cover the soil.

* Curve numbers are less than 30. Use 30 for runoff computations.

Range 14/					
Herbaceous (grass-weed-low growing brush mixture with brush the minor element)	poor	15/	80	87	93
	fair		71	81	89
	good		62	74	85
Oak-Aspen (mountain brush mixture of oak brush, aspen, mountain mahogany, bitter brush, maple, and other brush)	poor		66	74	79
	fair		48	57	63
	good		30	41	48
Pinon-Juniper (pinon and/or juniper with an understory of grass)	poor		75	85	89
	fair		58	73	80
	good		41	61	71
Sagebrush-Grass (sagebrush with an understory of grass)	poor		67	80	85
	fair		51	63	70
	good		35	47	55
Desert Shrub (major plants include salt bush, greasewood, cresote bush, blackbrush, bur sage, palo verde, mesquite, and cactus)	poor	63	77	85	88
	fair	55	72	81	86
	good	49	68	79	84

13/ Hydrologic condition is based on the effectiveness of the ground cover. The amount of litter, grass, and brush overstory is taken into account when estimating the percent of cover. Poor has less than 30 percent ground cover. Fair has between 30 and 70 percent ground cover. Good has more than 70 percent ground cover.

14/ Range CN's are for predominantly western arid and semi-arid regions. For other regions, see Pasture - Range (Grassland) CN's.

15/ Hydrologic soil Group A curve numbers have only been developed for desert shrub.

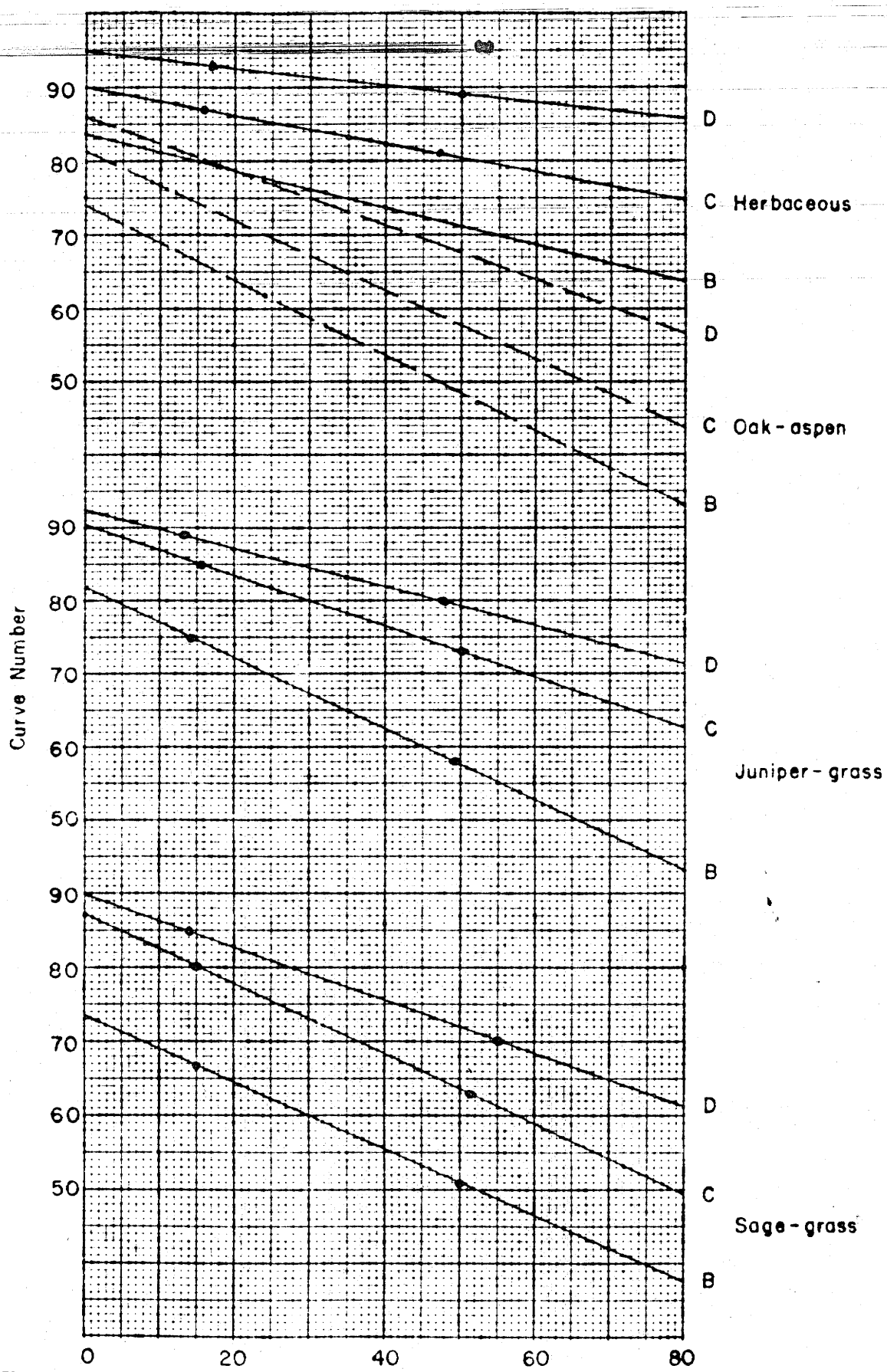

Figure S-3

HYDROLOGIC SOIL COVER COMPLEX & ASSOCIATED CURVE NUMBERS