PROPOSED PERMANENT IMPOUNDMENTS
FOR THE
N-2 COAL RESOURCE AREA

KAYENTA MINE

PERMIT AZ 0001

ARIZONA DIVISION
PEABODY COAL COMPANY

FEBRUARY, 1983

*EXTRACTED FROM AZ-0001
*PERMIT APPLICATION,
*VOLUME 38.

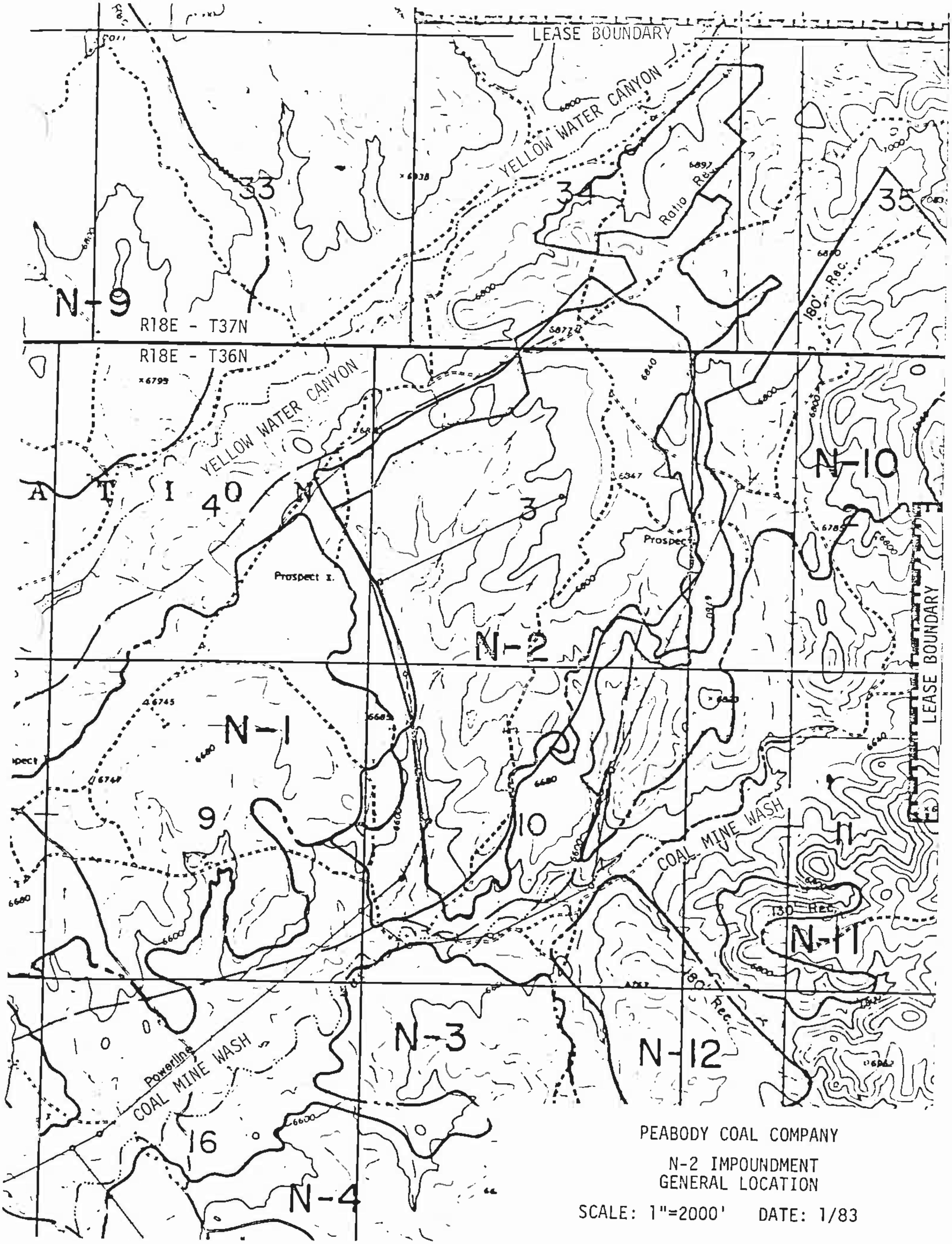
GENERAL SITE DESCRIPTION

The proposed permanent impoundment drainage area consists of approximately 770 acres within N-2 coal resource area at the Kayenta Mine on Black Mesa, Navajo County, Arizona. Specifically, the impoundment area is contained in the S1/4 Section 34, T37N, R18E; E1/4 Section 4, Section 3, E1/4 Section 9, N1/2 Section 10, SW1/4 Section 10 all of T36N, R18E (see Figure 2).

The mine lease area is situated on a plateau-like feature ranging in elevation from about 6200 feet to over 7200 feet. Original topography in the impoundment area ranged from approximately 6500 feet to 6800 feet. The proposed site is located between two ephemeral drainages, Yellow Water Canyon and Coal Mine Wash. Surface drainage is almost exclusively to the southwest towards Coal Mine Wash.

The climate is semiarid with a mean annual rainfall of slightly less than 12 inches, as indicated from NOAA, Betatakin Station data. The Many Farms weather station reports an average pan evaporation of approximately 86 inches per year. Wind direction is generally from the southwest.

Historically, the land use in this area has been primarily livestock grazing with some dry land farming and a small amount of game hunting. During the late 1960's and early 1970's, coal mining became a land use when the first of Peabody's mines started in 1969 and the other in 1973.



PEABODY COAL COMPANY

N-2 IMPOUNDMENT
GENERAL LOCATION

SCALE: 1"=2000'   DATE: 1/83

FIGURE 2

Mining began in the N-2 area in 1976 and was completed five years later in 1981. Initially, mining commenced on the east side with pits progressing to the west. Later, the pits were extended along the north and west sides and progressed south and east respectively until the area was mined out. This particular mining plan developed a final pit within the interior of the area rather than along the exterior. The proposed permanent impoundments will be located in the final pits.

ENGINEERING DESIGN

The design of the impoundments in the N-2 mining area is based upon Hydrologic and Engineering Studies at the Peabody Coal Company Mines near Kayenta, Arizona, October, 1981, by Water, Waste and Land, Incorporated. The Water, Waste and Land (WWL) report addressed the quantity, quality, and persistence of water impounded within graded and topsoiled spoil banks, together with stability of graded spoil and impoundments. In essence, the WWL study concluded that there should be no problems concerning impoundment stability and water quality, and that persistence of water in the impoundments was dependent on drainage area and impoundment size. To maximize the amount of time an impoundment might contain water the WWL study made the following recommendations:

1. The pond should be constructed so that the resultant surface area is as small as possible.
2. The pond should have side slopes as steep as permissible so that surface area does not vary greatly with depth.
3. The bottom of the pond should be compacted during construction to minimize seepage through the bottom of the pond during the early years of operation.

DESIGN CRITERIA

Based on site visits and infiltrometer tests, WWL personnel determined that the most reasonable values for Soil Conservation Service (SCS) runoff curve numbers fell within the range of 80 to 75. No attempt has been made to further refine these values. Curve numbers of 80 and 75 have been used to design the N-2 impoundments. A curve number of 80 has been used to insure adequate impoundment capacity. In examining the minimum probability of water in the impoundments, a curve number of 75 was used so as to establish a probable lower bound.

To insure adequate capacity, the impoundment was sized to contain the runoff from a 100-year, 24-hour precipitation event after the mean water volume and five year sediment load had been achieved. The runoff and mean water volume was calculated using a curve number of 80. The five year sediment load was calculated from an annual rate of 3.2 tons per acre. This sediment loading is higher than suggested in the WWL report; however, it represents the observed sediment loading noted by WWL in the J-1/N-6 area. The total volumes above were then checked using an actual depth-capacity curve to insure adequate capacity as explained below.

WATER, WASTE & LAND IMPOUNDMENT DESIGN METHODOLOGY

The WWL study produced the concept of an "Area Index": the ratio of the total watershed area of a theoretical impoundment to the water surface area of the same theoretical impoundment. A computer watershed model was developed to simulate characteristics of mined spoil impoundments. This model was analyzed for various values of SCS runoff curve numbers, and various values of the Area Index. Generated data for a theoretical impoundment include probability of water, mean depth of water, probability of dissolved solids exceeding a specified amount, together with various statistical parameters resulting from the computer simulation. As might be expected, the probability of water and the mean depth of water in a theoretical impoundment varied directly with the Area Index, i.e., the larger the watershed, the greater chance for water to exist in the impoundment and the higher the mean depth of water.

The WWL computer model is based on the assumption of watersheds of constant Area Index. This condition is impossible to achieve in practice: the boundaries of the watershed can reasonably be expected to remain constant; the water surface area however, will vary with the depth of water in the impoundment. This is due to the fact that the impoundment sides cannot be vertical for stability and safety reasons. Typically, the impoundment sides are on a slope of three horizontal to one vertical. Where access to water in the impoundment is desirable, slopes of five horizontal to one vertical or flatter are necessary. As impoundment area increases with the square of the increasing sides, the variation in Area Index over the possible range of water depths becomes very substantial. It became necessary to account for this variability of Area Index when designing of the N-2 impoundments.

ADAPTATION OF WATER, WASTE & LAND METHODOLOGY

As the WWL study established mean depths for various Area Indexes, it became possible to graph the mean depth as a function of Area Index for curve numbers of 75 and 80 (see Figure 3). In addition, the standard deviation of the mean depth was added to the mean depth and graphed as a

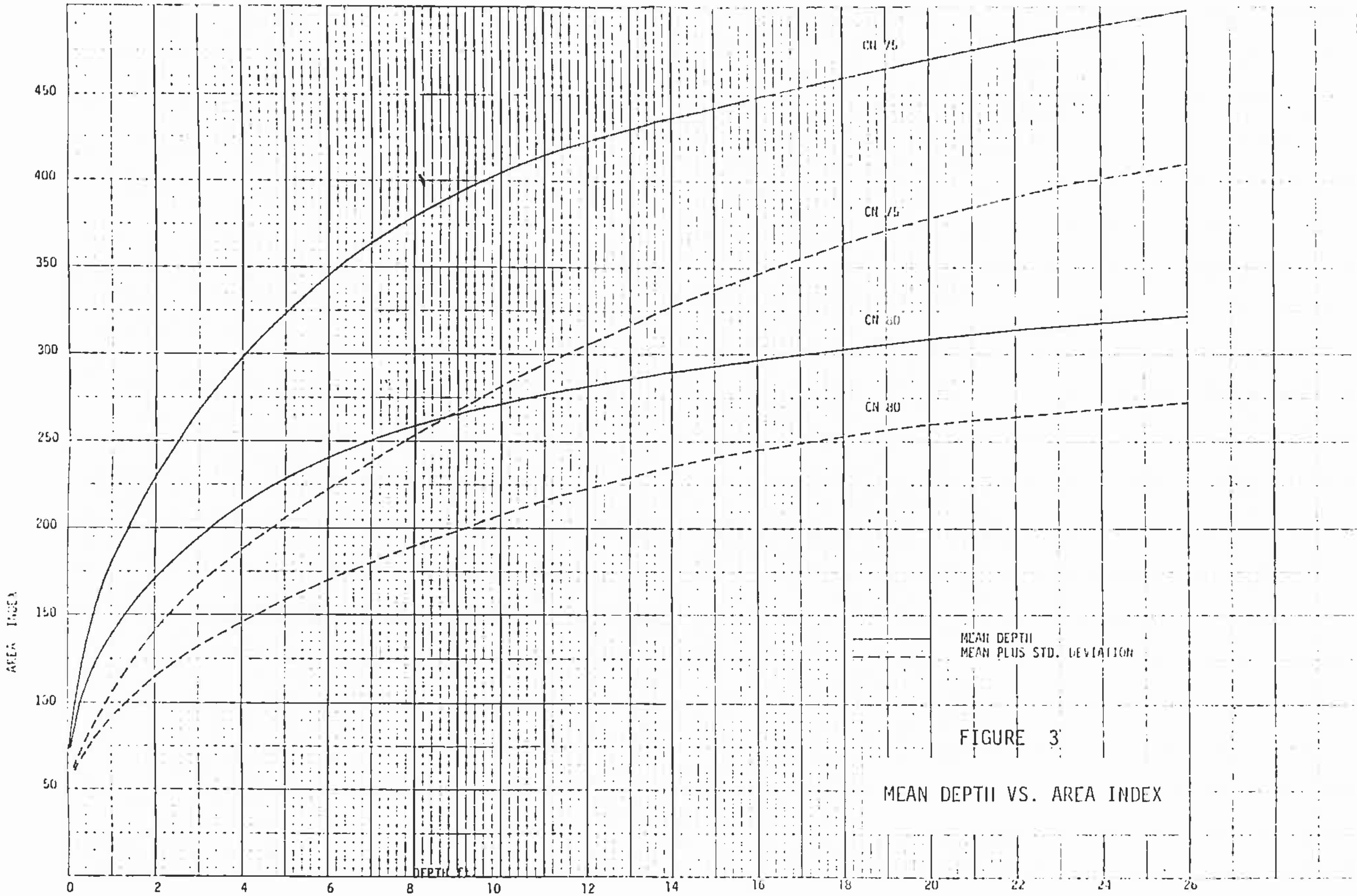


FIGURE 3

MEAN DEPTH VS. AREA INDEX

function of the Area Index for both curve numbers. This was done to give some general idea of the upper range of depths at which water might reasonably be expected to persist. It should be noted that the reported values in inches in the WWL report were changed to feet for this graph.

Once the proposed design for an impoundment was determined, it was also possible to determine water surface area, and hence Area Indexes for various depths. Thus, each impoundment also has a depth-Area Index curve. If this curve is superimposed over the mean depth-Area Index curve for a specific curve number (Figure 4), the two curves will intersect at a unique value of mean depth and Area Index. This intersection gives a first approximation of depth and Area Index at which an impoundment might tend to stabilize.

It should be noted that the "depth" term of each graph has a slightly different meaning. Depth in the graphs of mean depths-Area Index means depth of a theoretical impoundment with vertical sides, as that was assumed in the WWL analysis. As WWL methodology does not assume gains (runoff) and losses (infiltration, evaporation) to be proportionate to depth of water, only to surface area, it can be seen that a theoretical impoundment will contain a larger volume of water than an actual impoundment at the same depth "d". The theoretical impoundment will have a bottom area equal to the surface area, while the actual impoundment will have a bottom area sometimes much less than the surface area, due to the sloping sides.

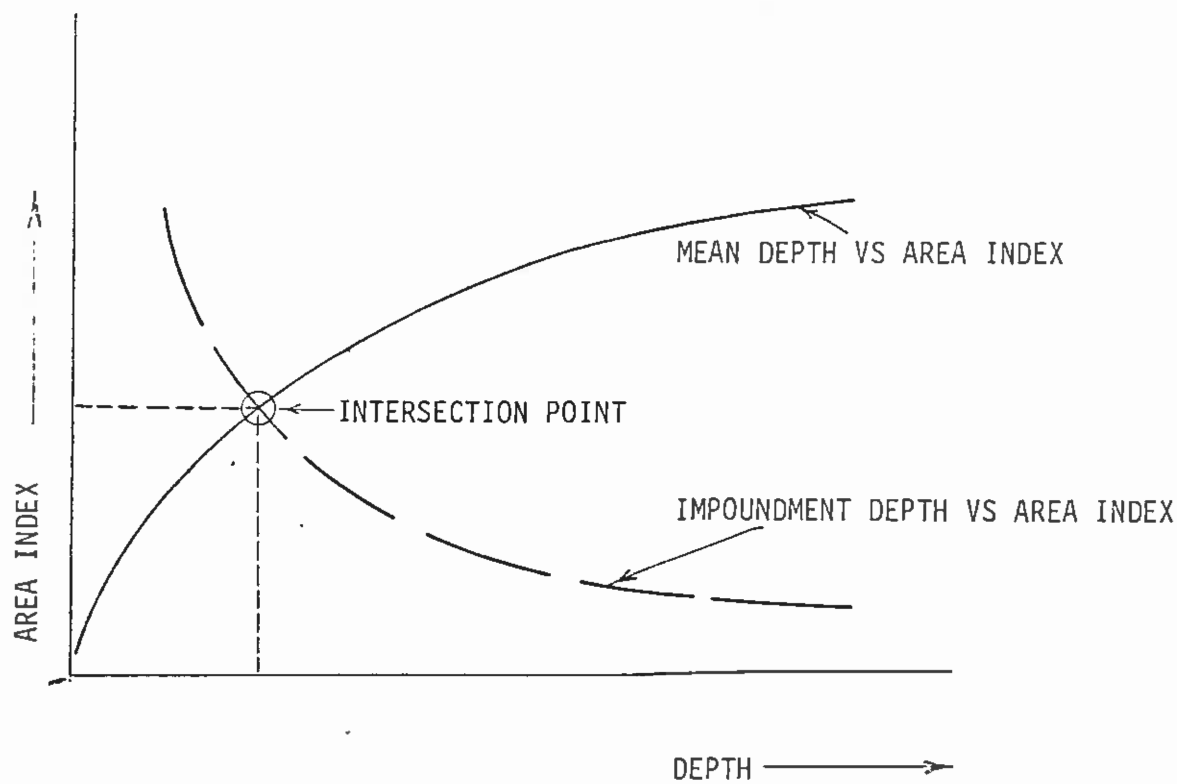


FIGURE 4. MEAN DEPTH AND AREA INDEX.

The solution to this problem requires the construction of two more graphs plotted along the same depth ordinate used in the previous two graphs. The first graph is simply the depth-capacity curve for the actual impoundment to be constructed. The second is the depth-capacity curve of an impoundment whose surface area varies with depth in the same fashion as the proposed impoundment does, but whose volume meets the criteria of the WWL study, i.e., with vertical sides and bottom area equal to surface area. Thus the volume of this theoretical impoundment is always the surface area multiplied by the depth, $A_y(y)$, where the volume of the actual impoundment is determined by the integral

$$V = \int_{y=0}^{y=y_{max}} A_y \, dy$$

where A is a function of y. During the design of impoundments of irregular shape the above integral is approximated by the average end area method of determining volume.

DESIGN PROCEDURE

Being a permanent impoundment, the runoff is determined from a 100-year, 24-hour event. The flow rate into the impoundment is calculated for each curve number.

Various design parameters such as actual impoundment depth and volume must be determined. In order to do this, a series of curves are presented on a graph. This graphical method facilitates solving four equations for four unknowns when none of the equations can be easily represented by mathematical formulae.

Data for the first set of curves is obtained from the WWL documents. For each curve number utilized, a theoretical mean depth and theoretical mean depth plus standard deviation-Area Index curve is plotted (see Figure 3). This basic curve set can be used for any impoundment design. The use of the curves will be explained below.

A second set of curves is generated from data specific to the proposed impoundment. This data includes water surface area, theoretical volume, Area Index and actual volume for various water depths. Both sets of curves are plotted on the same graph.

The basic design calculations are as follows:

1. Determine required sediment capacity.
2. Determine maximum design water capacity.
3. Determine impoundment required capacity and depth.
4. Determine worst case storage requirements and resulting water depth.
5. Compare actual impoundment capacity to required storage.
6. Compare actual impoundment capacity to the standard deviation depth to worst case storage requirements.
7. Determine water persistence.

The procedure for determining mean depth and volume of water in each impoundment as follows: (Refer to Figure 5) locate the intersection of the actual depth-Area Index curve and the theoretical mean depth-Area

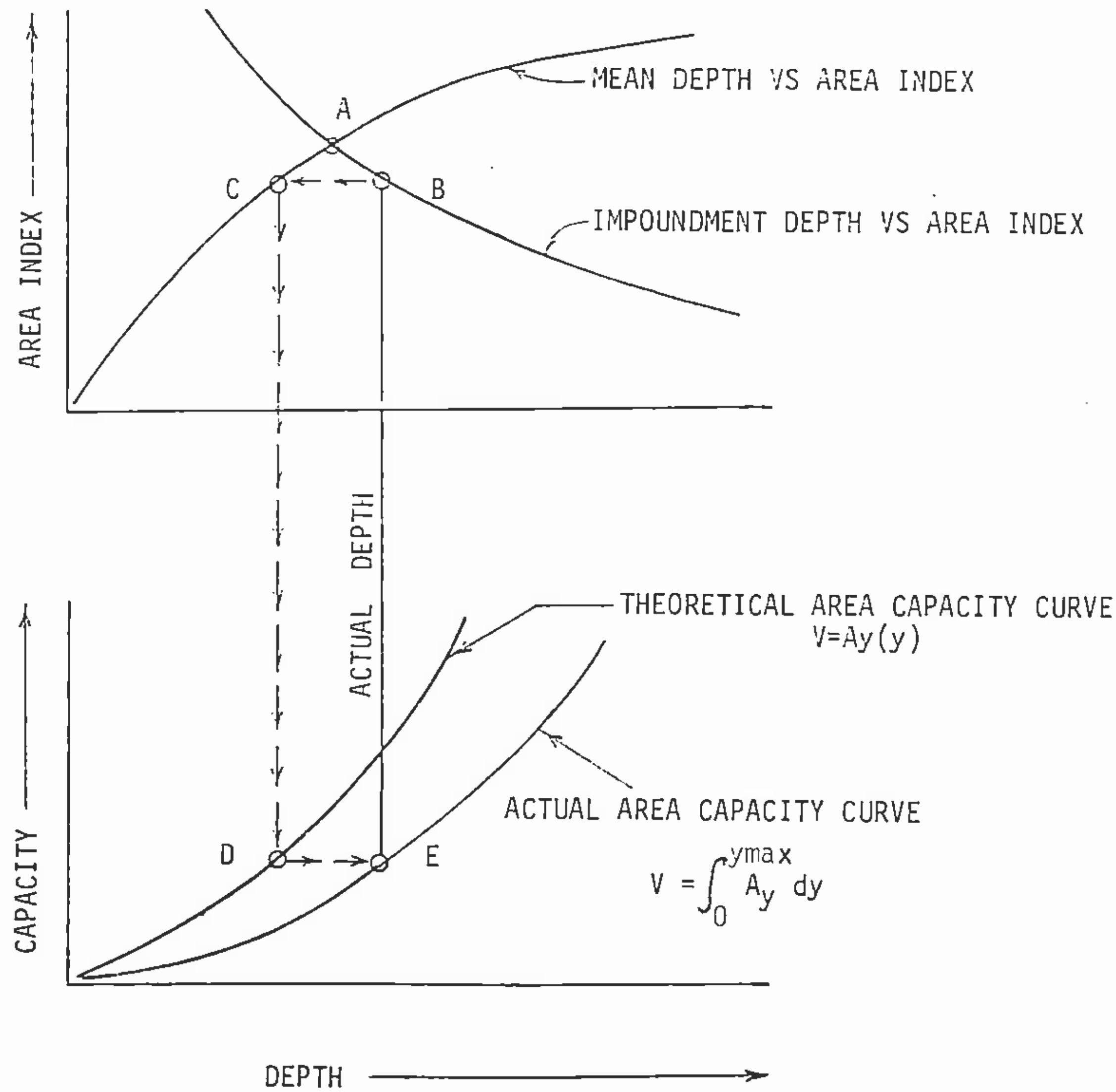


FIGURE 5. MEAN DEPTH AND VOLUME DETERMINATION

Index curve (PT. A). Assume an actual depth approximately equal to 1.1 times the mean depth located by intersection. Determine the Area Index corresponding to this actual depth for the impoundment in question from the actual depth-Area Index curve (PT. B). For this Area Index, determine the theoretical mean depth from the theoretical mean depth-Area Index curve (PT. C). This depth assumes an impoundment with vertical sides. For this theoretical depth, determine the theoretical mean impoundment volume from the theoretical mean depth-capacity curve (PT. D). Finally, determine the actual depth required for this volume from the actual depth-capacity curve (PT. E), and compare to the initial assumed actual depth. If these two depths are not approximately equal, adjust the assumed depth and repeat the above procedure until these depths are equal. The procedure to determine the depths and volumes based on the mean depth plus the standard deviation is similar.

From the calculations (Part II), assuming a SCS runoff curve number of 75, it can be seen that impoundments "A", "B" and "C" tend to stabilize at Area Indexes of 300, 215, and 210, respectively. The corresponding annual probability of water existing for these Area Indexes is 65%, 51% and 50%, respectively. In addition, it should be emphasized that there will be a substantial increase in Area Index for decreasing impoundment depths. As depths approach zero, the Area Indexes for each impoundment "A", "B" and "C" approach respective upper bounds of 715, 563, and 1016.

Annual probabilities for water existing at these Area Indexes is approximately 90% or above.

These probabilities illustrate the concept that the impoundments should tend to be self-stabilizing with respect to water level, and should always have a high probability of containing water. As the depth of water increases, the Area Index decreases, and the probability of water existing decreases, however, since by definition the impoundment already has water in it, the increased probability would seem meaningless. Thus, the 90% annual probability figure for a curve number of 75 would appear reasonable.

MAINTENANCE

As noted elsewhere in this narrative, the impoundment will receive additional landscaping to enhance its usefulness as a wildlife habitat after construction. It is possible that this landscaping will intercept a certain portion of the sediment which would otherwise enter the pond. Sediment levels will, however, be monitored and sediment will be removed should it approach the five-year design sediment level. It is anticipated that no other maintenance will be necessary other than possible correction of surficial erosion.

WILDLIFE HABITAT ENHANCEMENT PROGRAM

Wildlife habitat enhancement techniques will be employed in and around the N-2 internal impoundments to encourage utilization of the area by a wide range of wildlife species.

Clusters of boulders will be placed in close proximity to each impoundment to simulate rock outcrops found in the original landscape. The boulder clusters are expected to provide nest and den habitat for small mammals and carnivores, and hunting or singing perches for passerines and raptors.

Aquatic plants and shoreline grasses, shrubs and/or trees will be established at the impoundments to provide food and cover for aquatic associated avian fauna. Natural establishment of willows (Salix spp.), tamarix (Tamarix pentandra), sedges (Cyperaceae), rushes (Juncaceae), cat-tails (Typhaceae) and assorted pond weeds and naiads have been observed at pre-law impoundments and sediment ponds throughout the lease area. These species are probably introduced by waterfowl and other aquatic associated birds. If natural establishment of these desired species does not appear to be occurring at a reasonable rate, seeding such species will be done to accelerate their development.

Woody shrubs will be established on a minimum ten-acre plot behind and surrounding three sides of each impoundment. The shrub clusters will conform to specifications prepared in response to Stipulation #23 (Permit #AZ-0001) requiring the development of a shrub planting program to augment the revegetation plan. The shrub clusters will provide food and cover for lagamorphs and birds and nesting habitat for shrubland adapted birds.

The entire vegetation enhancement area will be fenced to protect the vegetation from livestock. Fencing will be designed in such a manner so as to allow livestock free access to one end of the impoundment. Fencing will be constructed in a manner that will allow passage by medium and large mammals.

The remainder of the watershed area outside of the fenced enhancement area will be revegetated with the standard seed mix as was approved in the MRP.

MONITORING PLAN

Peabody Coal Company will monitor one and possibly all three of the permanent impoundments proposed in this submittal. Parameters to be monitored include rainfall amounts and intensities, runoff, seepage and sediment yields. Rainfall will be monitored using tipping bucket rain gages. Seepage will be estimated through the use of shallow piezometers. Runoff will be estimated from pond depth changes and flow measurements. Sediment yield will be determined from buried stakes and/or discharge measurement structures in combination with sediment samplers.

SUMMARY

Each of the seven criteria for approval contained in SMCRA Section 515(b)(8) have been addressed in Peabody Coal Company's April 29, 1982, Response to Special Stipulations 20 and 21, Permit AZ-0001. The criteria pertaining to impoundment size, stability, water persistence and access safety are addressed in the Response to Special Stipulations 20 and 21, the WWL study report, which was submitted as an attachment to Response to Special Stipulations 20 and 21, and in the engineering design section of this report. The criteria pertaining to water quality and water persistence are addressed in the Response to Special Stipulations 20 and 21, the WWL study report and in the following attachment which was presented to members of OSM's technical staff at a November 16, 1982, meeting in Flagstaff.

PCC MONITORING DATA

A. During 1981 and 1982 thirty-one pond water quality analyses were performed

B. The recommended limits of the following chemical parameters in livestock drinking water are as follows:

Parameter	Concentration (mg/l)
TDS	3,000
Na	2,000
Ca	1,000
Mg	500
Cl	1,500
SO_4	500 - 1,000
HCO_3	172

C. The results of the pond water quality analyses indicate that a recommended parameter level was only exceeded four times. One was sulfate and three were bicarbonate values (see Table 2)

D. It should be noted that these are limits below which no detrimental effects have been reported to occur. The highest alkalinity was 229 and it is questionable as to whether this would render the water unsuitable for livestock

E. Typical streamflow alkalinities range from 90 to 1035 mg/l

F. The pond water quality analyses substantiate the findings of the W, W & L water quality model. Interestingly, the highest TDS found was only 1292 mg/l, well below the 3,000 mg/l limit

TABLE 2

POND	DATE	pH	COND	TDS	Na	Ca	Mg	Cl	SO4	HCO3
116	3/25/81	9.0	850	980	60	92	53	23	420	96
116	8/19/81	7.9	700	497	19	68	23	16	160	163
116	11/12/81	8.4	1420	1288	194	98	116	34	870	140
116	3/10/82	8.6	750	812	89	46	50	24	450	60
116	9/3/82	8.6	2200	1878	139	132	100	23	1139	89
117	3/25/81	8.8	360	368	24	31	23	13	110	141
117	7/27/81	7.4	490	2739	15	47	26	19	60	214
117	11/19/81	7.4	211	347	8	29	12	9	15	132
117	3/10/82	8.2	173	208	5	25	12	12	20	103
117	9/3/82	7.7	205	234	7	28	12	1	46	91
118	3/25/81	8.2	330	297	19	31	22	12	36	156
118	7/27/81	7.35	386	419	11	38	20	19	26	180
118	11/19/81	7.3	205	243	4	30	12	9	8	138
118	3/10/82	8.4	189	185	4	25	13	12	8	107
118	9/3/82	8.35	170	282	5	26	9	3	48	97
119	3/31/81	8.5	610	722	60	73	46	19	490	110
119	7/27/81	8.2	308	160	7	44	11	19	44	125
119	11/19/81	8.5	190	233	11	31	12	11	32	106
119	3/10/82	9.5	130	169	8	15	8	11	63	20
119	9/3/82	9.2	700	486	26	51	17	6	215	58
120	3/31/81	8.25	1050	1292	98	14	74	17	750	120
120	8/19/81	7.6	465	406	25	55	25	13	119	170
120	11/19/81	9.5	263	1070	44	41	18	9	82	97
120	3/10/82	7.9	185	258	19	25	12	11	70	98
121	7/27/81	9.7	1160	968	43	150	37	32	498	65
121	11/20/81	9.4	258	370	10	41	16	12	98	69
121	3/10/82	9.0	57	83	18	13	9	.3	<.5	26
121	9/3/82	8.9	470	374	15	47	20	6	157	105
122	11/24/81	8.3	190	299	6	35	11	10	17	138
122	9/3/82	7.4	245	378	7	30	9	2	94	107
123	11/24/81	8.0	460	549	47	69	24	22	175	229

PCC MONITORING DATA

A. During 1981 and 1982 one pond was continuously monitored for water level fluctuations
B. Over a period of 19 months, the pond continuously monitored was dry 2 of the months. Water levels ranged from 0-2.47 feet (Table 3)
C. Over the same time period 8 other ponds were visually monitored for water level persistence. In only 2 out of 42 observations were ponds found dry (Table 4)
D. Since these ponds were not properly designed to minimize evaporation and seepage, they demonstrate that a high degree of water persistence is possible
E. The pond studies to date also verify that Area Indexes in the 50-200 range are quite suitable for achieving water persistence

TABLE 3

Continuously Recorded Pond #113.

Depth of Water

	Depth of Water
4/28/81	2.10
5/19/81	1.75
6/19/81	1.24
7/21/81	1.98
8/19/81	2.47
9/19/81	2.18
10/19/81	1.67
11/19/81	1.25
12/19/81	1.12
1/19/82	1.07
2/19/82	1.53
3/19/82	1.77
4/19/82	1.23
5/27/82	.96
6/19/82	.58
7/19/82	dry
8/19/82	dry
9/15/82	0.03
10/9/82	0.02

TABLE 4

POND	DATE	WATER PERSISTENCE DOCUMENTED			
112	3/31/81	7/27/81	11/19/81	3/10/82	dry
113	3/31/81	6/30/81	11/19/81	3/10/82	9/3/82
116	3/25/81	8/19/81	11/12/81	3/10/82	9/3/82
117	3/25/81	7/27/81	11/19/81	3/10/82	9/3/82
118	3/25/81	7/27/81	11/19/81	3/10/82	9/3/82
119	3/31/81	7/27/81	11/19/81	3/10/82	9/3/82
120	3/31/81	8/19/81	11/19/81	3/10/82	9/30/82
121	Station not Established	7/27/81	11/20/81	3/10/82	9/3/82
122	Station not	Established	11/24/81	dry	9/3/82

PART II

ENGINEERING DESIGN CALCULATIONS

N/Z Impoundments

For drainage areas see drawing 0252-83301-01

POND "A"

AREA TRIBUTARY @ 1" = 200' mapping

$$338.1\ in^2 \times \frac{200^2}{43560} = 310.5\ ac$$

Total Runoff from 100 year storm

$P100_{24} = 3.0"$

SCS Hydrology $\quad Q = \frac{(P - 0.2S)^2}{P + 0.8S}$

For CN = 75, S = 3.33 $\quad Q = \frac{(3.0 - 0.2 \times 3.33)^2}{3.0 + 0.8 \times 3.33}$

$= 0.961"$

$$\frac{0.961}{12} = 0.0801\ \frac{\text{acre feet}}{\text{acre}} \times 310.5\ ac = 24.9\ ac\text{-}ft$$

FOR CN = 80, S = 2.50 $\quad Q = \frac{(3.0 - 0.5)^2}{3.0 + 2.0} = 1.25"$

$$\frac{1.25}{12} = 0.104\ \frac{\text{Acre feet}}{\text{Acre}} \times 310.5\ ac = 32.3\ ac\text{-}ft$$

Approximate q_{peak} from SCS TP 149

Slopes > 8.0% "STEEP"

For CN = 75, q_{peak} = 180 cfs (p.1-A)

For CN = 80, q_{peak} = 285 cfs. (p.1-B)

PEABODY COAL COMPANY
ARIZONA DIVISION
P. O. BOX 605
KAYENTA, ARIZONA 86033

PERMANENT IMPOUNDMENTS

N-2 MINING AREA

ENGINEERING DESIGN CALCULATIONS

Registered Professional Engineer (Civil)
CERTIFICATE NO.
14265
JAMES DART
HALL
Signed
ARIZONA, U.S.A.

2/4/85

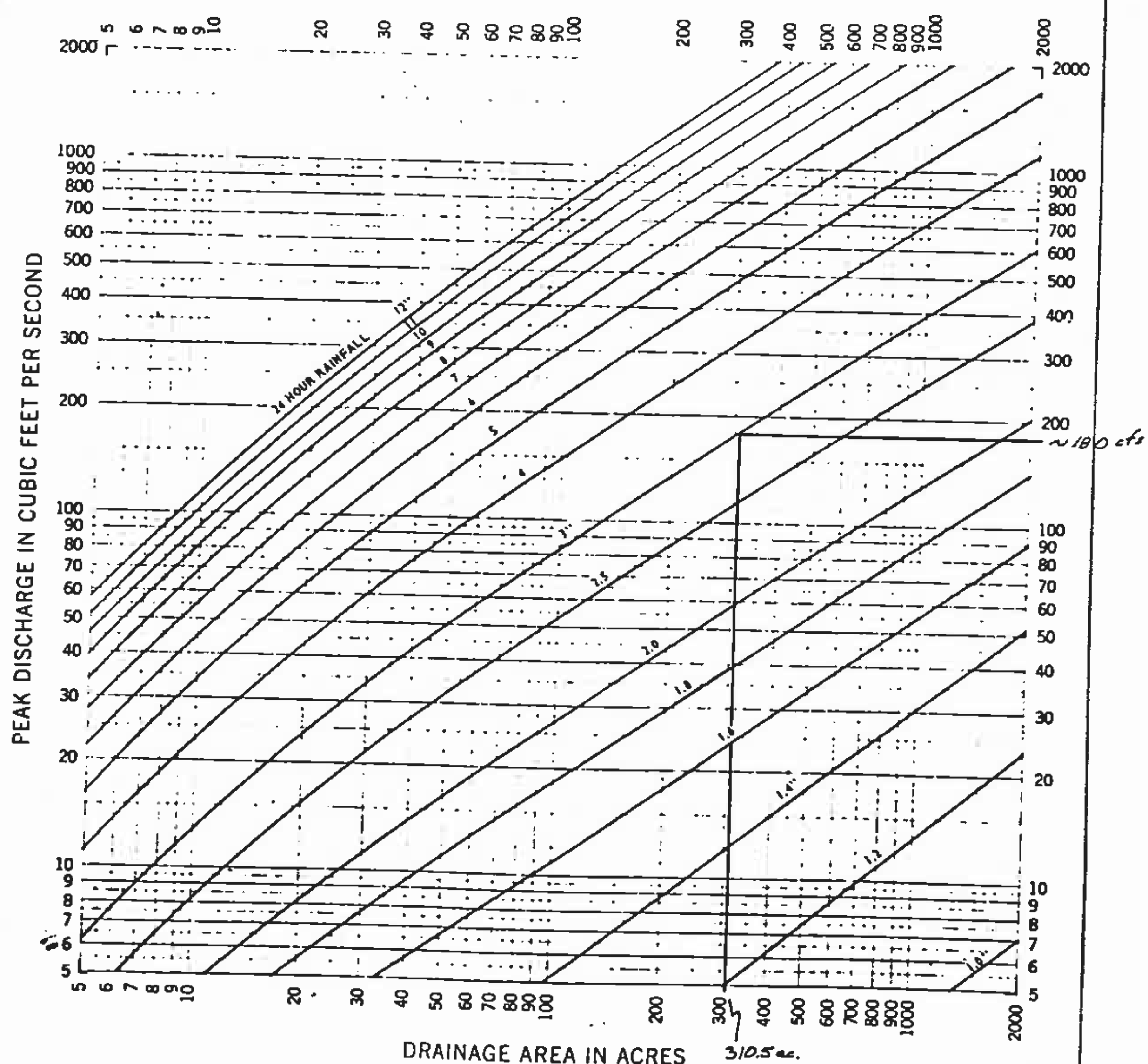
James D. Hall, P.E.

PEAK RATES OF DISCHARGE FOR SMALL WATERSHEDS
TYPE II STORM DISTRIBUTION

IMPOUNDMENT A

SLOPES - STEEP
CURVE NUMBER - 75

24 HOUR RAINFALL FROM US WB TP-40



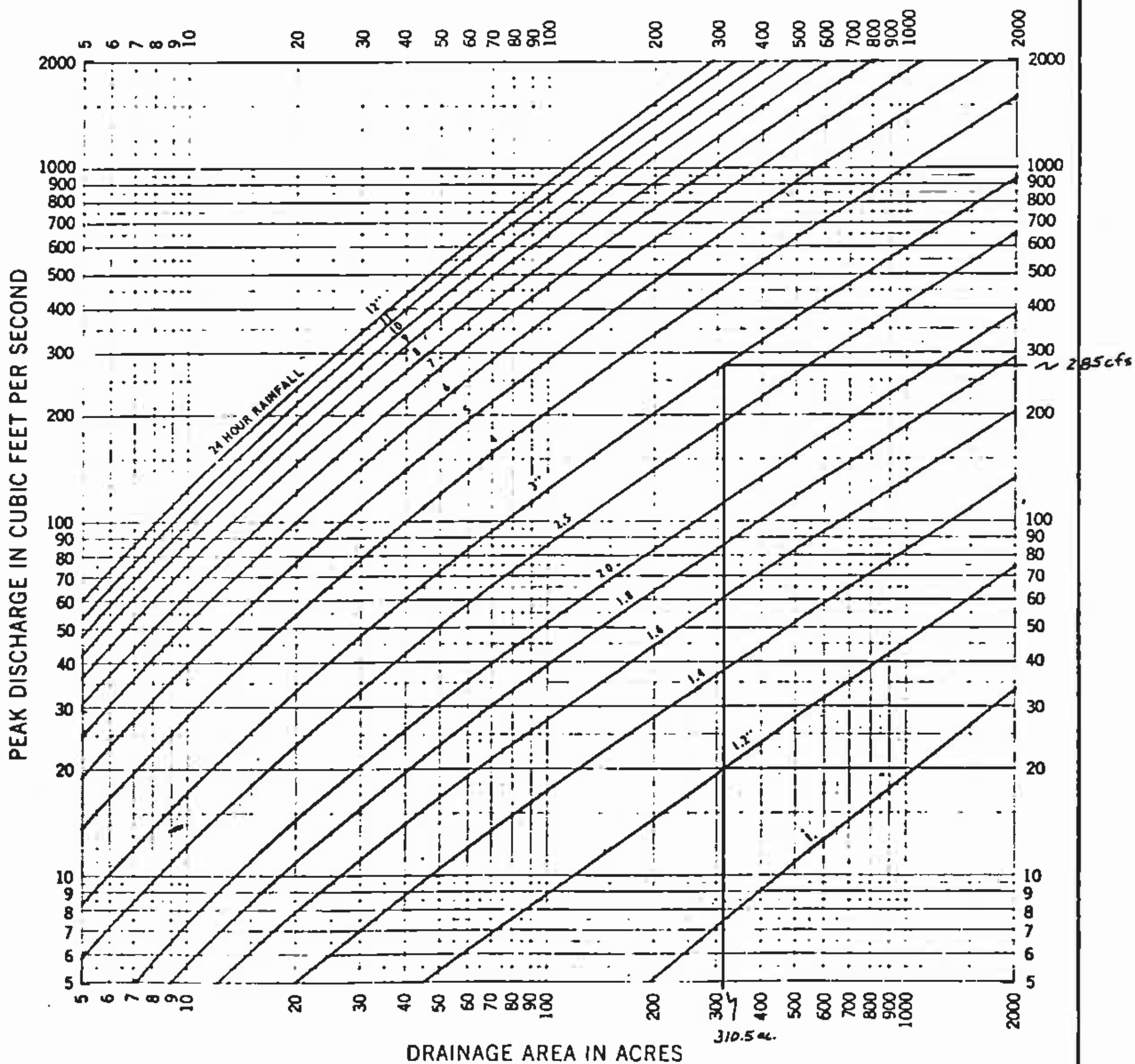
STANDARD DWG. NO.
ES-1027
SHEET 18 OF 21
DATE 2-15-71

PEAK RATES OF DISCHARGE FOR SMALL WATERSHEDS
TYPE II STORM DISTRIBUTION

IMPOUNDMENT A

SLOPES - STEEP
CURVE NUMBER - 80

24 HOUR RAINFALL FROM US WB TP 40



STANDARD DWG. NO.
ES-1027
SHEET 19 OF 21
DATE 2-19-71

Pond "B"

AREA TRIBUTARY

$495.6 \times \frac{200^2}{43,560}$ 455.1 ac

100yr runoff

CN 75 455.1 × 0.0801 = 36.5 ac-ft

CN 80 455.1 × 0.104 = 47.3 ac-ft

Approx q peak into pond from SCS TP 149

CN 75, q peak ≈ 235 cfs (p. 2-A)

CN 80, q peak ≈ 350 cfs (p. 2-B)

Pond "C"

AREA TRIBUTARY

$12.2\ in^2 \times \frac{200^2}{43560}$ = 11.2 acres

100-year runoff

CN 75 11.2 × 0.0801 = 0.90 Ac-ft

CN 80 11.2 × 0.104 = 1.16 Ac-ft

Approx Q peak into pond from SCS T.P 149

CN 75, q peak ≈ 14 cfs (p. 3)

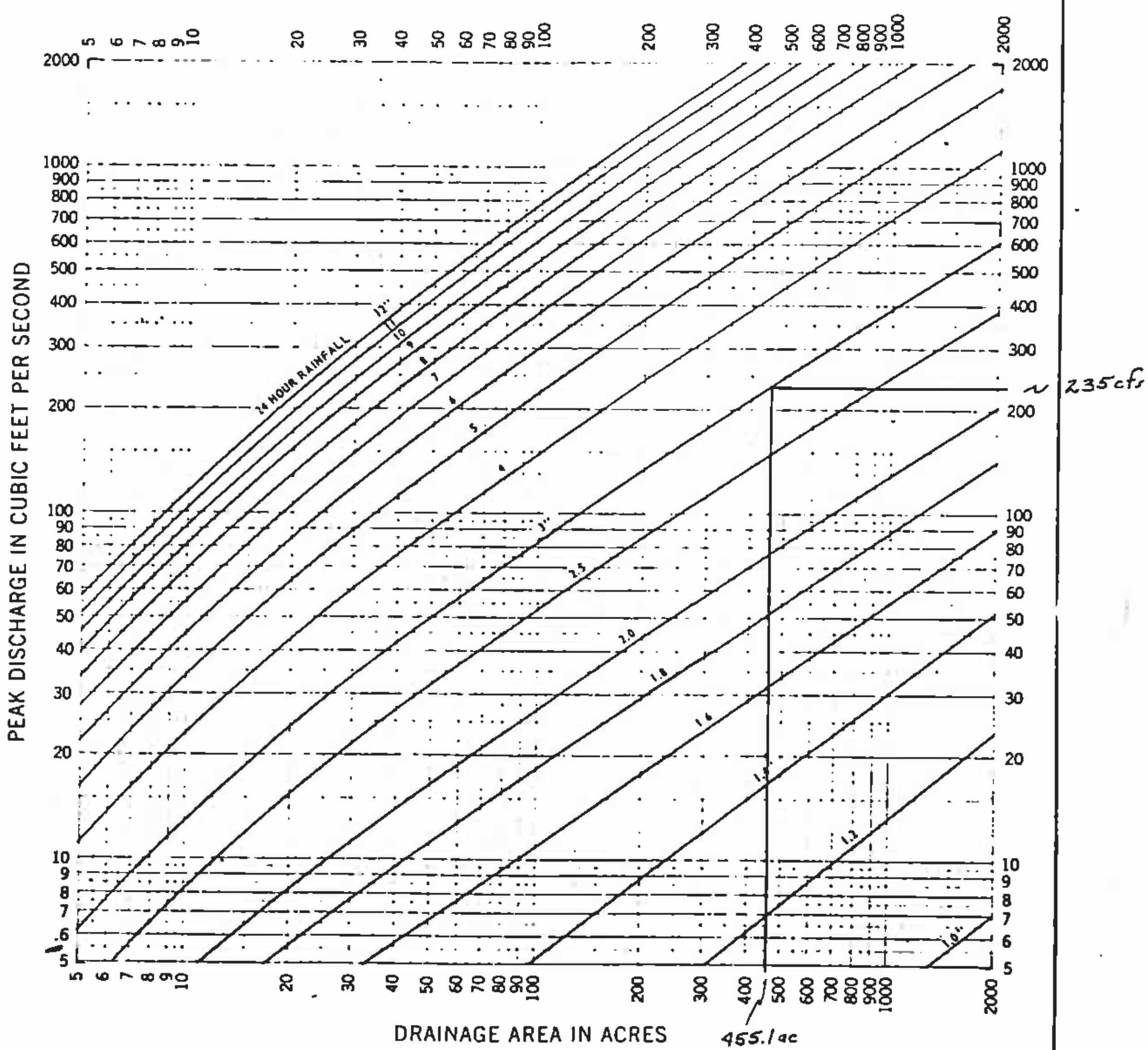
CN 80, q peak ≈ 19 cfs. (p. 3-A)

PEAK RATES OF DISCHARGE FOR SMALL WATERSHEDS
TYPE II STORM DISTRIBUTION

IMPOUNDMENT B

SLOPES - STEEP
CURVE NUMBER - 75

24 HOUR RAINFALL FROM US WB TP 40



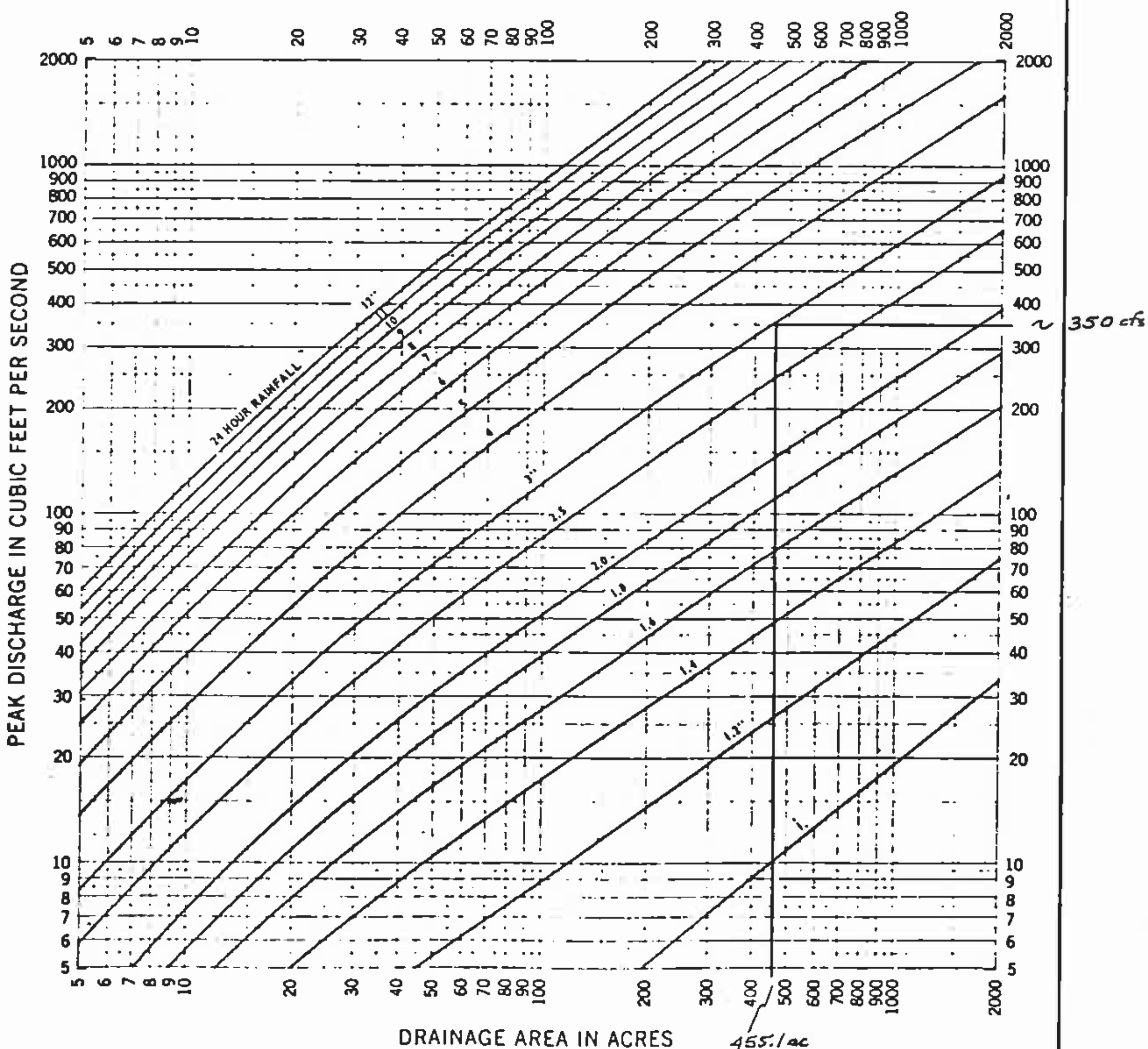
STANDARD DWG. NO.
ES-1027
SHEET 18 OF 21
DATE 2-15-71

PEAK RATES OF DISCHARGE FOR SMALL WATERSHEDS
TYPE II STORM DISTRIBUTION

IMPOUNDMENT B

SLOPES - STEEP
CURVE NUMBER - 80

24 HOUR RAINFALL FROM US WB TP-40



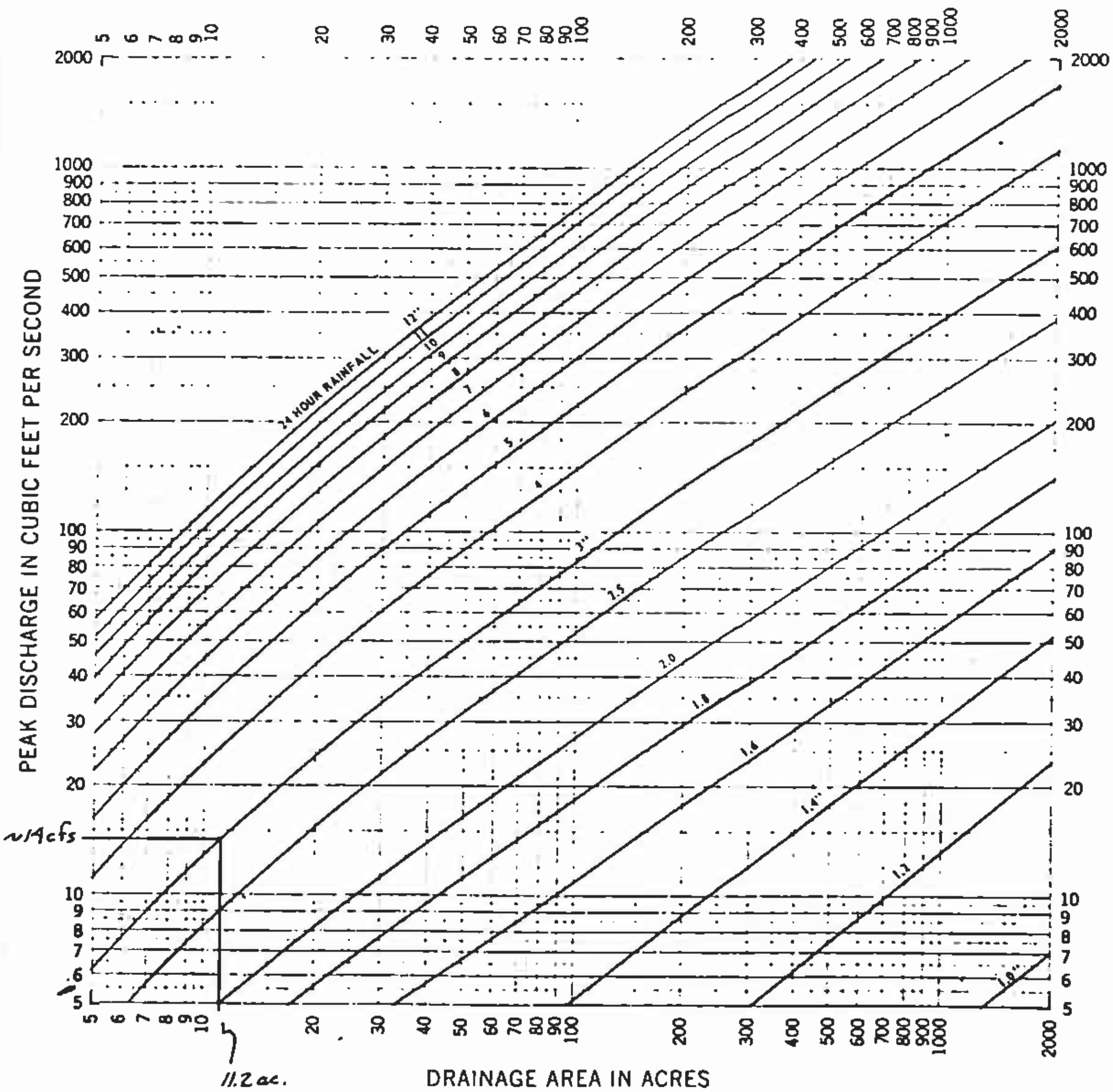
STANDARD DWG. NO.
ES-1027
SHEET 19 OF 21
DATE 2-15-71

PEAK RATES OF DISCHARGE FOR SMALL WATERSHEDS
TYPE II STORM DISTRIBUTION

IMPOUNDMENT C

SLOPES - STEEP
CURVE NUMBER - 75

24 HOUR RAINFALL FROM US WB TP 40



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SHEET 18 OF 21
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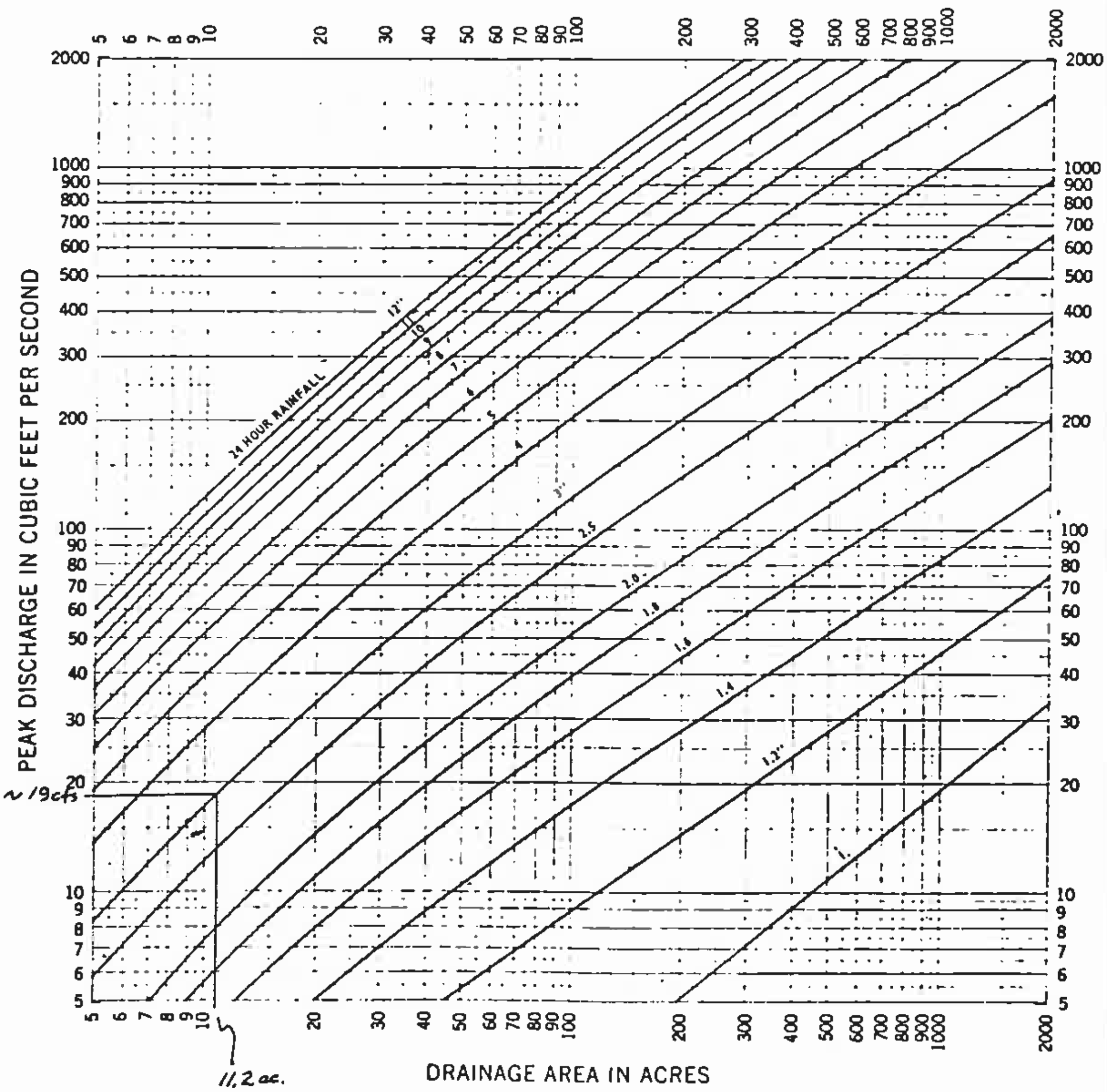
PEAK RATES OF DISCHARGE FOR SMALL WATERSHEDS
TYPE II STORM DISTRIBUTION

IMPOUNDMENT C

SLOPES - STEEP
CURVE NUMBER - 80

24 HOUR RAINFALL FROM US WB TP 40



STANDARD DWG. NO
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SHEET 19 OF 21
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Pond A Areas by planimeter of pond design plans

Elev	depth (ft)	Area (ft²)	Area × depth (ft³)	Area Index	Volume (ac-ft)
6520	0	18,925	0	715	0
6525	5	35,200	4.04	384	3.11
6530	10	54,225	12.45	249	8.24
6535	15'	76,325	26.28	177	15.73
6540	20'	101,600	46.65	133	25.94
6545	25'	137,200	75.87	102	39.36
6550	30'	183,575	126.43	74	57.48

Depth vs Area Index, vs Area × depth, and vs Volume plotted p 7

Assume sediment loading of 3.2 tons/acre year @ density = 80 pcf (Maximum observed sediment loading, W.W.L. study, pg 2-41)

Design sediment capacity - say 5-years.

$$\frac{3.2 \times 2000 \times 5 \times 310.5}{80 \times 43{,}560} = 2.9 \text{ ac-ft}$$

Maximum design volume - 100 year storm @ C.N. = 80 = 32.3 ac-ft, p 1

Mean pond volume @ C.N. 80 = 11.3 ac-ft, p5

Worst design storage case: 100 year storm, assuming pond storage already @ mean volume, plus provisions for 5-year sediment volume, all @ CN = 80

2.9 + 32.3 + 11.3 = 46.5 ac-ft

Depth of water @ 46.5 ac ft = 27 feet from plot p 7

Pond "A" cont.

Mean depth of water in pond - CN=75

Intersection of graphs: Mean depth vs Area Index for CN 75, and Area Index vs depth for Pond "A" is @ d=7.35', Area Index=320

For Area Index=320, depth of 7.35' assumes pond with vertical (square) sides. Pond volume of this theoretical pond is ≈ 8.0 acre-feet (read from plot, p 7)
To achieve 8.0 acre feet in Pond A, depth would need to be 9.75' instead of 7.35'

For depth of 7.35' Actual Area index would be 256 instead of 320. (Process is illustrated by dashed line on graph p 7)

Therefore:

Assume d actual = 8.1 feet, Area Index = 300, corresponding $d_{(square\ sided\ pond)}$ = 6.25' CN 75

For $d_{(sq\ sd)}$ = 6.25', $Volume_{(sq\ sd)}$ = 6.2 acre-feet

For Actual Volume = 6.2 acre-feet, required d actual = 8.1'

Mean depth for CN=75 = 8.1'
Area Index = 300

"Mean" depth of water in pond - CN=80

Assume actual depth = 12.1', resulting Area Index = 218, corresponding $d_{(sq\ sd)}$ = 9.35' for AI=218

For $d_{(sq\ sd)}$ = 9.35', Volume = 11.3 ac ft

For required volume = 11.3 ac-ft, $depth_{(reqd)}$ = 12.1'

Mean depth for CN=80 = 12.1'
AREA INDEX = 218

Pond "A" cont

Upper bound Standard Deviation depth
CN 80
Depth equals mean depth plus standard deviation

Assume actual depth = 15.65', resulting Area Index = 171, theoretical depth for square-sided pond equals 11.65'

For $d_{(sq\ sd)}$ = 11.65' volume ≈ 17.0 ac-ft

For vol = 17.0 ac-ft, d_{actual} = 15.65' —

Probability of water in pond (Annual)
@ Mean depth see chart, p 16
@ CN 75, AI = 300 ≈ 65.5%

@ CN 80 AI = 218 ≈ 81 %

@ Minimum pond Area Index ≤ 715 (Annual)

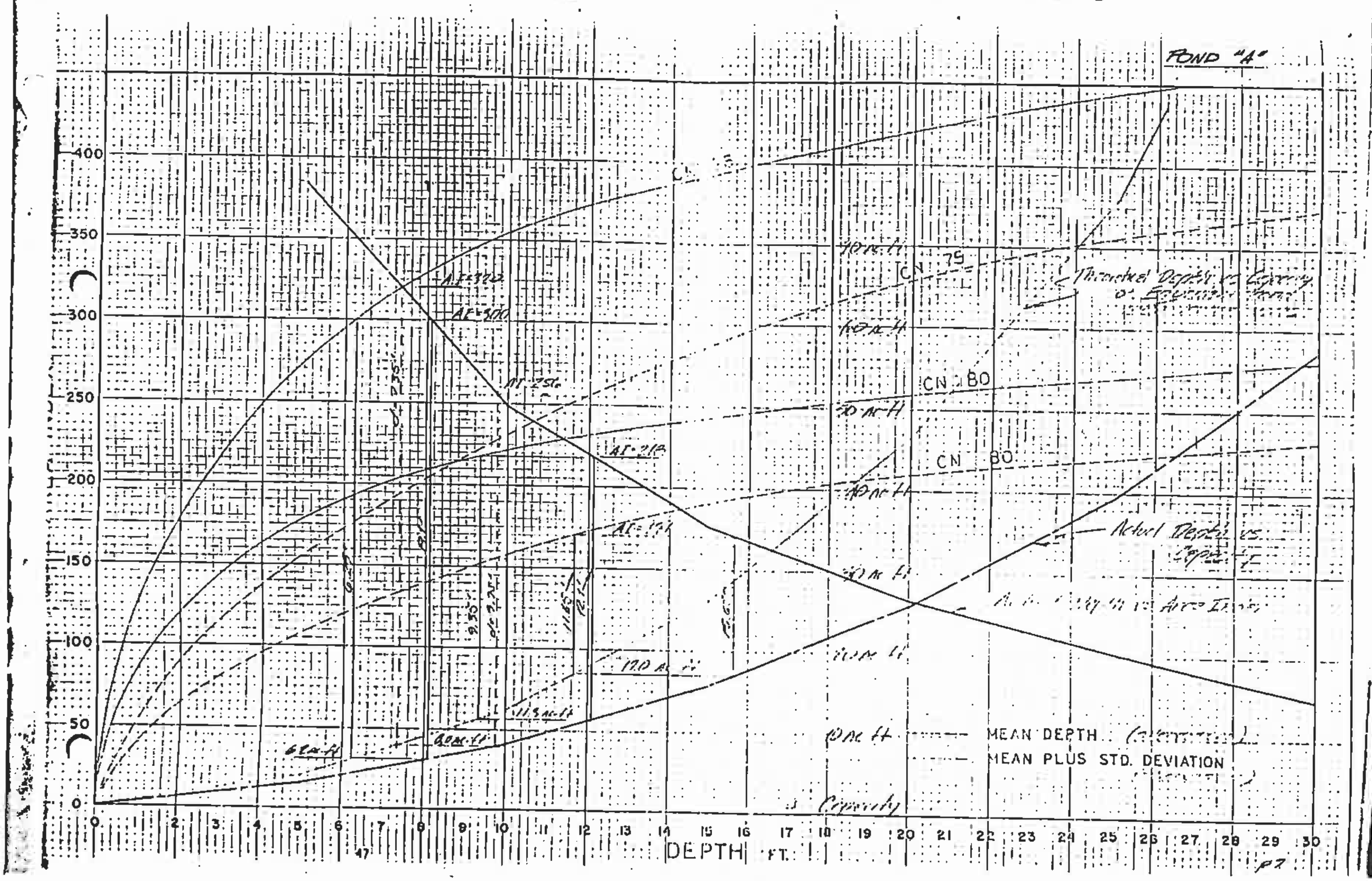
d ≥ 0'

@ CN 75 for AI = 715 ≈ 91.0%

@ CN 80 for AI = 715 ≈ 98.4%

Lowest Monthly . p 17

@ CN 75 for AI = 715 ≈ 87.3% (July)
@ CN = 80 for AI = 715 ≈ 98.0% (July)


POND "A"
CN 75
CN 80
CN 80
AF=300
AF=218
MEAN DEPTH
MEAN PLUS STD. DEVIATION
DEPTH FT.
0
50
100
150
200
250
300
350
400
0
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
47

Pond B Areas by planimeter of Pond design plans.

Elev	d	Area ft²	Area x d (acre ft)	Area Index	Volume (ac-ft)
6640	0	35,200	θ	663	θ
6645	5	110,000	12.63	180	8.33
6650	10	150,400	34.53	132	23.27
6655	15	193,200	66.53	102	42.99
6660	20	238,000	109.28	83	67.74

d vs AI, vs Axd, and vs Volume plotted p 11.

Assume Sediment loading of 3.2 tons/acre-year (Maximum observed WWL Study). Density = 80 pcf (WWL)

Design Sediment Capacity - 5 years -

$$\frac{3.2 \times 2000 \times 5 \times 455.1}{80 \times 43560} = 4.2 \text{ acre-feet}$$

Design Volume - 100-year storm = 47.3 ac ft. (p 2) for CN 80

Mean pond volume, CN 80 = 11.4 ac-ft (p.2.)

Worst design storage case: 100-year storm + mean pond storage + 5 years sediment volume. (CN 80)

62.9 acre feet.

Depth of pond = 19', p ..11.. for Worst design storage case

Pond "B" cont

Mean depth of Water in pond - CN 75

AI = 250, d = 4.1' (Assumes square sided pond)

For square sided pond, @ d = 4.1', V = 10.5 acre feet. ✓ (see tabulation p 8 and plot p 11)

For pond to be constructed, $V_{req'd}$ = 10.5 acre feet d_{actual} = 5.7' (p 11). AI = 176

Therefore

Assume d_{actual} = 4.55' AI = 215, $d_{(sq\ sd)}$ = 2.95'

Vol (sq sd) = 7.6 Ac ft for $d_{(sq\ sd)}$ = 2.95'

For vol req'd. 7.6 Ac-ft, $d_{req'd}$ = 4.55'

Mean depth of water in pond CN 80

Assume d_{ACTUAL} = 6.0' AI = 171, $d_{(sq\ sd)}$ = 4.5'

Vol (sq sd) = 11.4 Ac-ft for $d_{(sq\ sd)}$ = 4.5'

for Vol = 11.4 Ac ft, $d_{actual\ P_B}$ = 6.0'

Mean depth of water + std deviation depth CN 80

Assume d_{ACTUAL} ≈ 9.9', AI = 132.5, d (sq sd) = 7'

Vol (sq sd) = 22.9 Ac ft for $d_{(sq\ sd)}$ = 7'

for Vol = 22.9 Af ft, d_{ACTUAL} = 9.9'

Pond B cont.

Probability of water in pond - Annual
@ Mean depth
See chart, p 16

@ CN=75, AI = 215 ≈ 51%

@ CN=80, AI = 171 ≈ 68.5%

@ Minimum pond Area Index ≤ 563 - Annual
d ≐ 0'

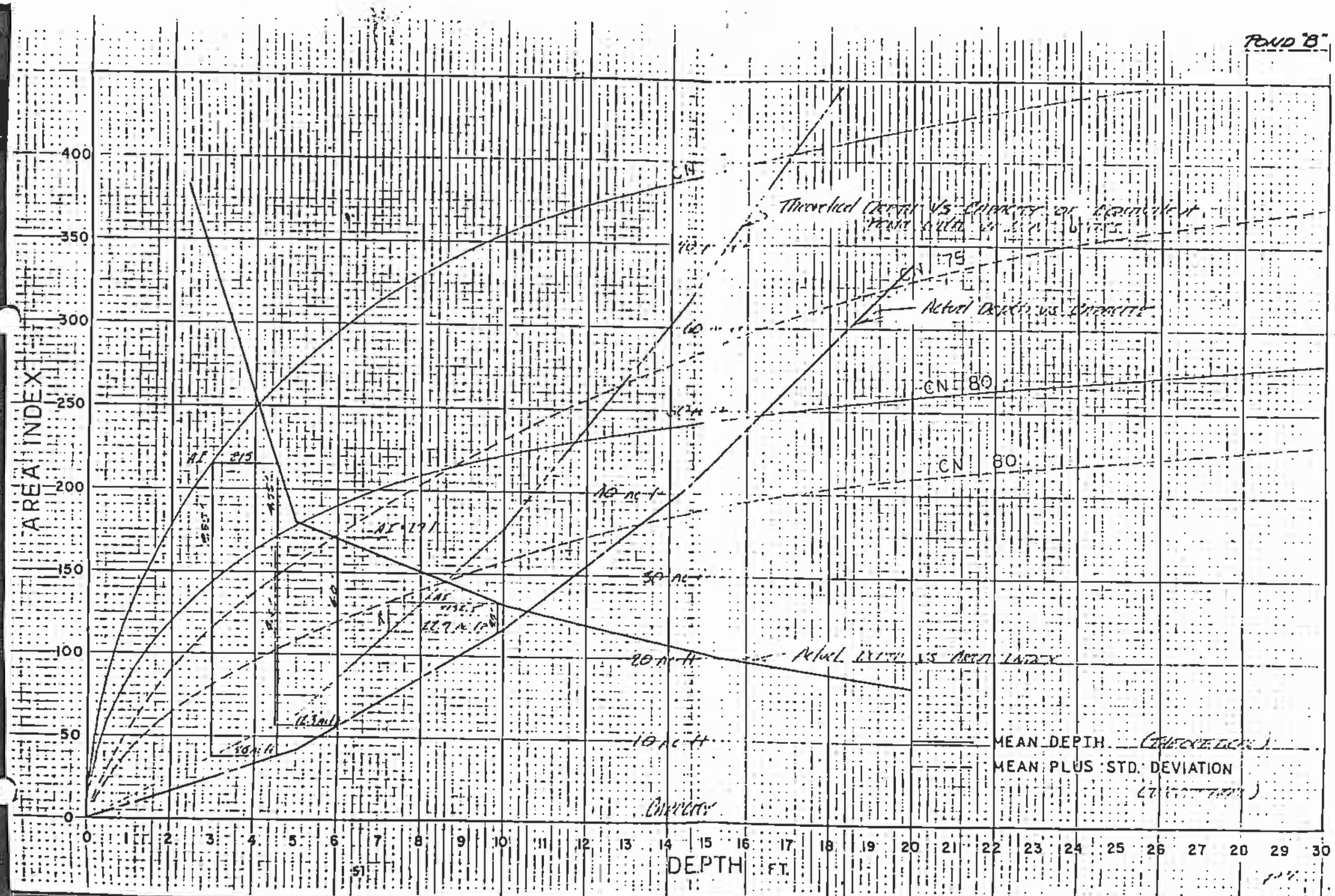
@ CN=75, AI = 563 ≈ 89.5%

@ CN=80, AI = 563 ≈ 98.0%

Lowest Monthly Probability p 17

@ CN=75, AI = 563 ≈ 85.5% (July)

@ CN=80, AI = 563 ≈ 97.5% (July)



POND "B"
AREA INDEX
0
50
100
150
200
250
300
350
400
DEPTH FT.
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 20 29 30
CN 75
CN 80
CN 80
MEAN DEPTH
MEAN PLUS STD. DEVIATION

Pond C — Areas & Volumes by mathematical calculation to d = 9.0' (See sketch p 14)

Areas for d > 9.0 by planimeter

Elev.	d	Area (ft²)	Area x depth (ac-ft)	Area Index	Volume (ac-ft)
6790	0	480	0	1016	0
6791	1	832	0.019	586	0.015
6792	2	1,280	0.059	381	0.039
6793	3	1,824	0.126	267	0.074
6794	4	2,464	0.226	198	0.123
6795	5	3,200	0.367	152	0.188
6796	6	4,032	0.555	121	0.271
6797	7	4,960	0.797	98	0.374
6798	8	5,984	1.099	82	0.500
6799	9	7,104	1.468	69	0.650
6800	10	22,040	5.060	22	0.985
6801	11	27,070	6.836	18	1.549
6802	12	32,940	9.074	15	2.237
6803	13	39,690	11.845	12	3.065
6804	14	46,860	15.061	10	4.053
6805	15	55,150	18.991	9	5.224

Depth vs Area Index, vs Area x depth, and vs Volume plotted pg 15

Assume sediment loading at 3.2 tons/acre-year, density 80 pcf, 5 years sediment

$$\frac{3.2 \times 2000 \times 5 \times 11.2\text{ Ac.}}{80 \times 43{,}560} = 0.103 \text{ acre feet}$$

Mean Pond Volume ≈ 0.18 acre feet — from p 15 (CN 80)

100 year storm volume for CN 80 = 1.16 ac ft

Max. Design Capacity —

1.16
0.18
0.103
———
1.443

1.45 acre feet

Depth for 1.45 acre feet 10.85' from plot p 15

Pond "C" cont

Mean depth of water, CN 75

A.I = 233, d = 3.5' (for square-sided pond)

Volume - (square sided) for d = 3.5' = 0.175 Ac-ft

for volume = 0.175 Ac-ft, d actual required = 4.8'

for d = 4.8', AI = 175 (Ref plot p 15)

Therefore: Assume d = 3.8', AI = 210,

For AI = 210, corresponding $d_{(sq\ sd)}$ = 2.8'

For $d_{(sq\ sd)}$ = 2.0', Volume = 0.115 Ac-ft

For Volume = 0.115 Ac-ft, d required = 3.8'

Mean depth of water, CN 80

Assume d = 4.95', AI = 155

For AI = 155, $d_{(sq\ sd)}$ = 3.55'

For $d_{(sq\ sd)}$ = 3.55', Volume = 0.18 Ac ft

For Volume = 0.18 Ac-ft, $d_{required}$ = 4.95'

Mean + Std Deviation depth - CN80

Assume d = 6.65', AI = 106

For AI = 106, $d_{(sq\ sd)}$ = 4.8'

For $d_{(sq\ sd)}$ = 4.8', Volume = 0.340 Ac. ft

For Volume = 0.340 Ac. ft, $d_{required}$ = 6.65'

Pond C cont

Probability of water in pond — Annual
@ Mean Depth — See chart p 16

@ CN = 75, AI = 210 ≈ 50%

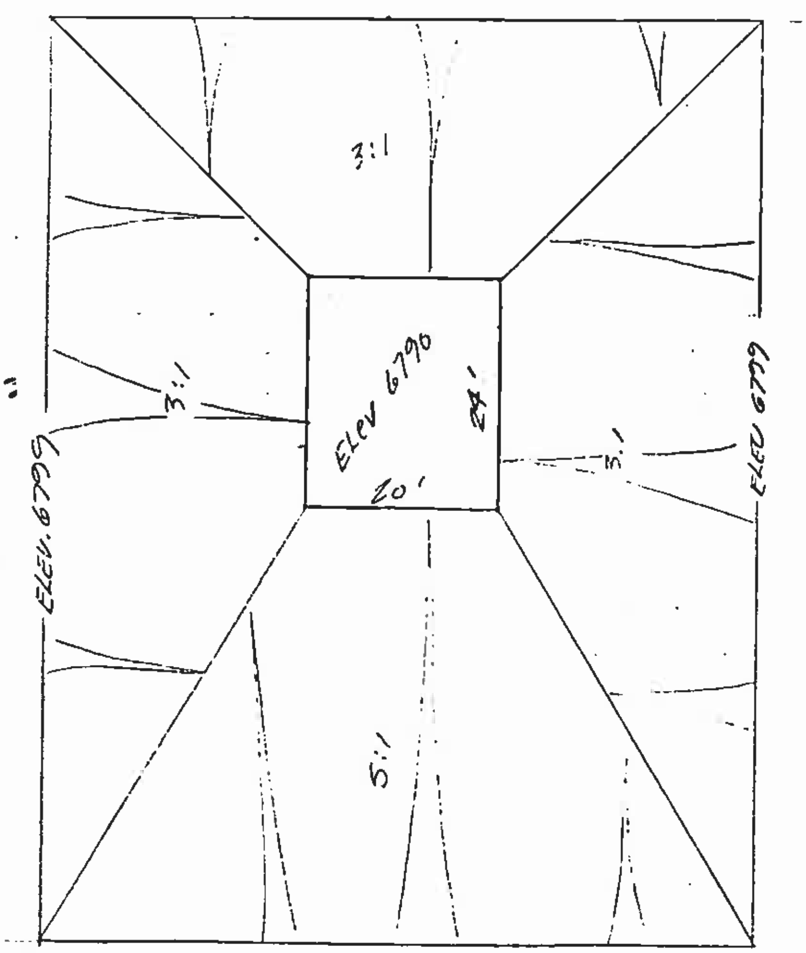
@ CN = 80, AI = 155 ≈ 64%

@ Minimum Pond Area Index ≅ 1016 (Annual)

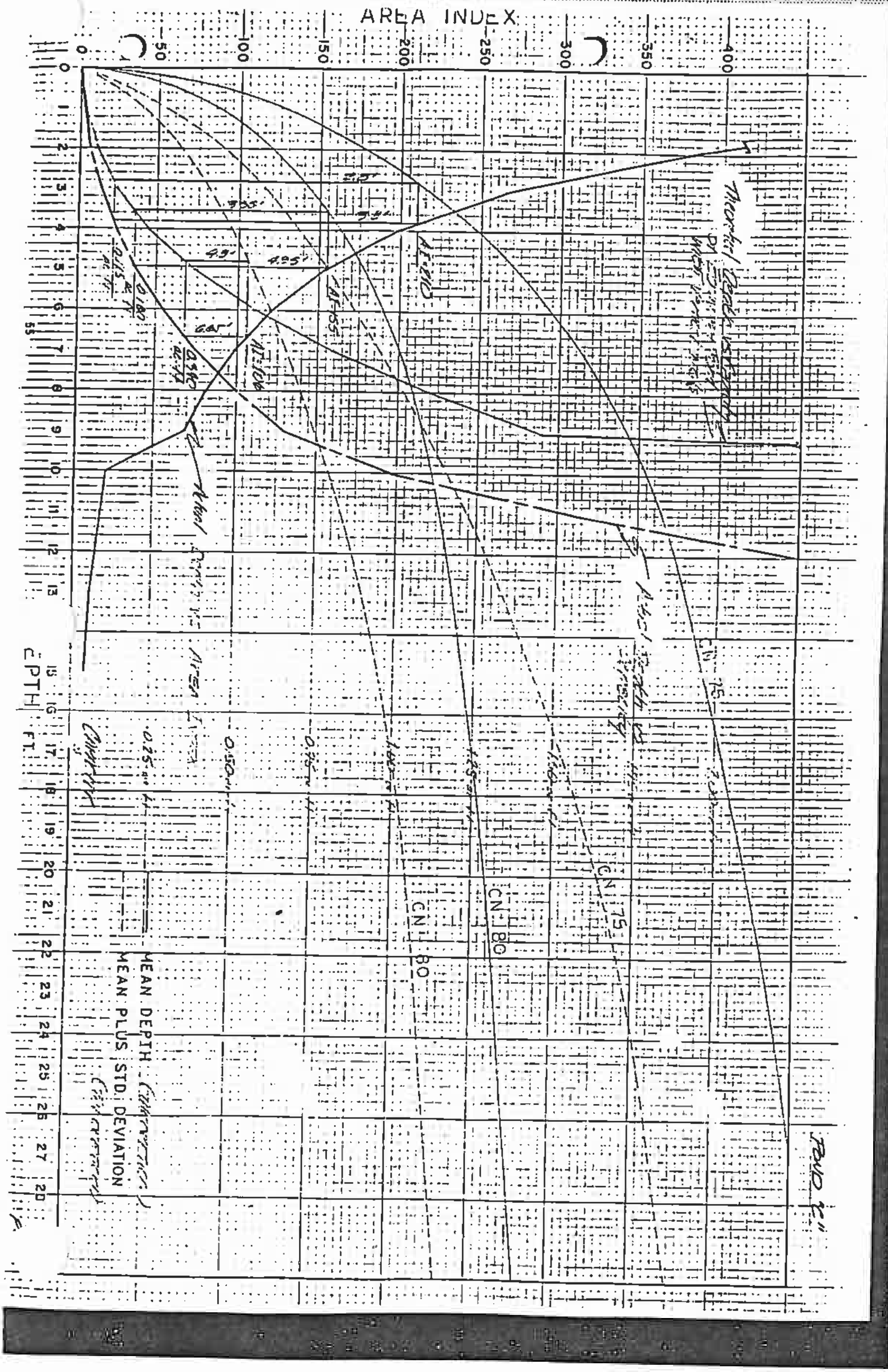
d ≧ 0'

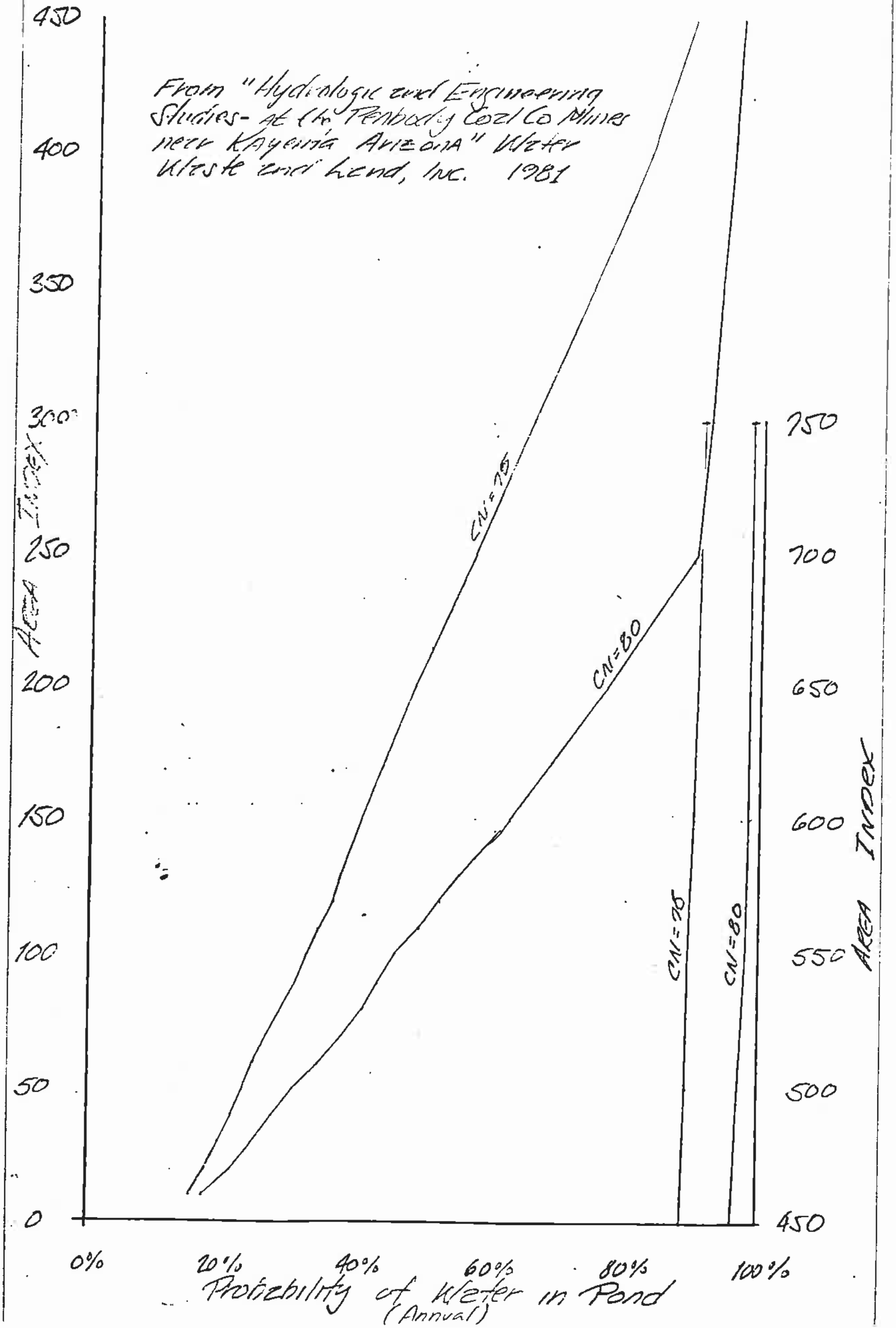
@ CN = 75, AI = 1016 ≧ 91% (@ AI 750)
@ CN = 80, AI = 1016 ≧ 98% (@ AI 750)

Lowest Monthly Probability — p17
@ CN = 75 AI = 1016 ≈ 88% (July)
@ CN = 80 AI = 1016 98% (July)

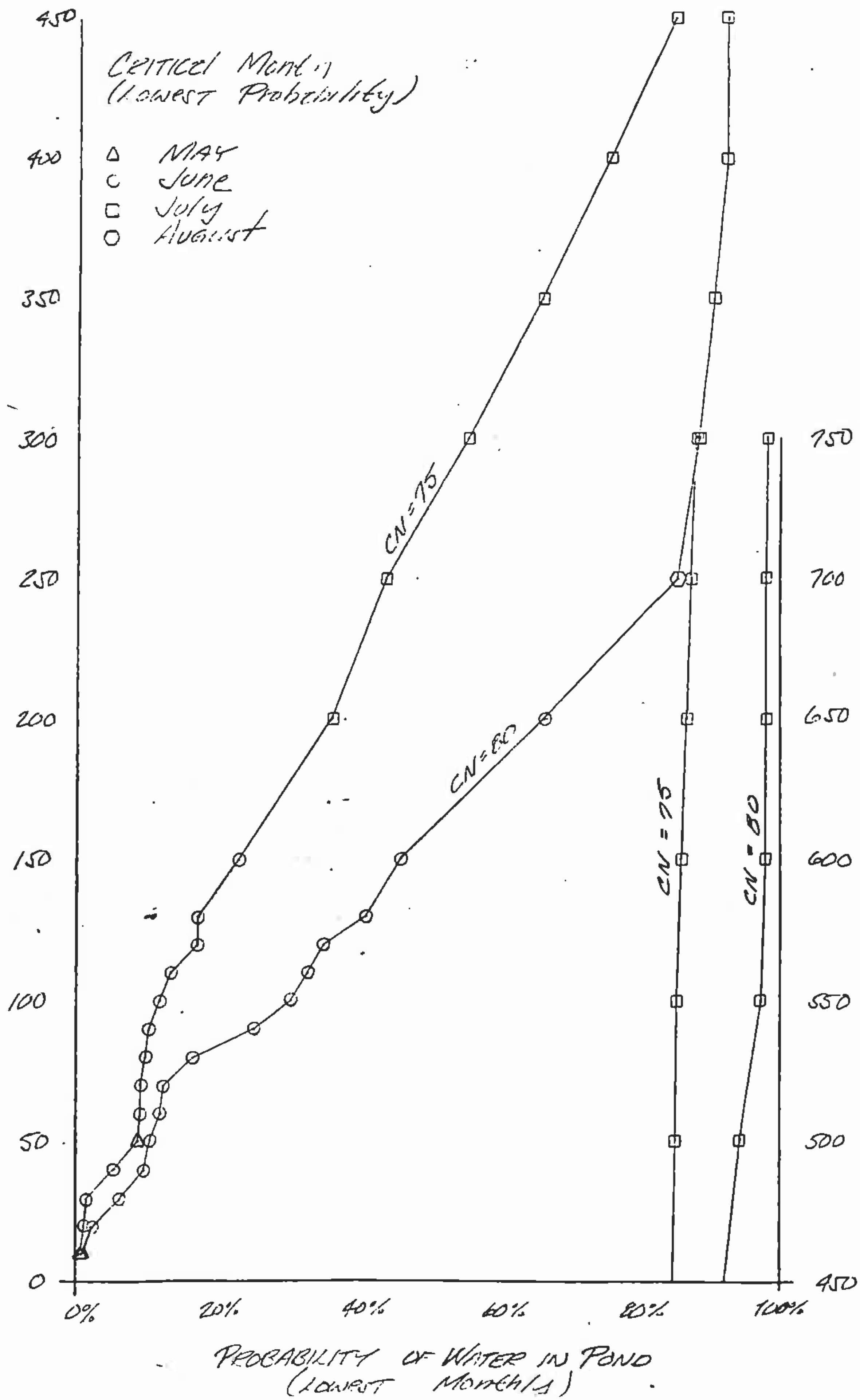


Pond C


AREA INDEX
0
50
100
150
200
250
300
350
400
DEPTH FT.
MEAN DEPTH
MEAN PLUS STD. DEVIATION
CN 75
CN 80
CN 80
CN 75



From "Hydrologic and Engineering Studies- at the Peabody Coal Co Mines near Kayenta Arizona" Water Waste and Land, Inc. 1981
Area Index
450
400
350
300
250
200
150
100
50
0
CN=75
CN=80
CN=75
CN=80
750
700
650
600
550
500
450
Area Index
0%
20%
40%
60%
80%
100%
Probability of Water in Pond
(Annual)



Critical Month
(Lowest Probability)
Δ May
○ June
□ July
○ August
CN=75
CN=80
CN = 75
CN = 80
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
750
0%
20%
40%
60%
80%
100%
PROBABILITY OF WATER IN POND
(LOWEST MONTH/S)

Pond volumes @ CN 75

Pond A

sediment	2.9 ac-ft		pg 4
mean volume	6.2 ac-ft	(CN 75)	pg 5
100-yr runoff	24.9 ac-ft	(CN 75)	pg 1
Total	34.0 ac-ft		

depth = 23'   chart, p 7

Pond B

sediment	4.2 ac-ft		pg 8
mean volume	7.6 ac-ft	(CN 75)	pg 9
100-yr runoff	36.5 ac-ft	(CN 75)	pg 2
Total	48.3 ac ft		

depth = 16.1'   chart p11

Pond C

sediment	0.11 ac-ft		pg 12
mean volume	0.12 ac-ft	(CN 75)	pg 13
100-yr runoff	0.90 ac-ft	(CN 75)	pg 2
Total	1.13 ac ft		

depth = 10.3'   chart p15