The Phase III Expansion of the White Street Sanitary Landfill

Greensboro, North Carolina

Construction Permit Application

November 1995

Prepared by:

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WHITE STREET SANITARY LANDFILL
GREENSBORO, NORTH CAROLINA

CALCULATIONS

Prepared for:

The City of Greensboro

Prepared by:

HDR Engineering, Inc.
of North Carolina

HDR

Project No. 06770-021-018

Final Report

January 7, 1997

CALCULATIONS

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Job No. 6770-021-018 | No.

HDR Computation

HDR

Project: City Of Greensboro	Computed: DTD	Date: 11/6/96	
Subject: Volumes	Checked: CDM	Date: 11/7/96	
Task:	Sheet:	Of:	

Volume/Site Life Calculations Are Based On Hand-Computed (Planimeter) Calculations. The Computer Calculations Were Performed To Verify Volumes Calculated Using A Planimeter.

CB0203

11/6/96

Site Volume Table: Unadjusted

Cut yards	Fill yards	Net yards	Method
Site: cell1-v3			
tratum: vol-3 opcov 1-opc			
35199.51	1782716.98	1747517.47 (F)	End area
32505.03	1780632.54	1748127.51 (F)	Grid
cell 1&2			
Site: cell2-v4			
Stratum: vol-4 opcov 2-opc			
35322.48	3356754.68	3321432.21 (F)	End area
30547.08	3354635.48	3324088.40 (F)	Grid
cut is match error			

CB0203

Site Volume Table: Unadjusted

Cut yards	Fill yards	Net yards	Method
Site: cell3-v			
Stratum: vol-5 opcov cell3			
0.00	5236765.81	5236765.81 (F)	End area
0.00	5223310.78	5223310.78 (F)	Grid

Phase III final cover vs. operational cover

Job No. 6-70-031-018 | No.

HDR Computation

HDR

Project	CITY OF GREENSBORO	Computed DTD	Date 11/6/96
Subject	CELL 1	Checked CDM	Date 11/7/96
Task	VOLUME / AIRSPACE AVAILABLE	Sheet 1	Of 3

DWG C-5R & C-4R

ELEV.	AREA, FT²	VOLUME, CY (TRUNCATED PYRAMID)
744'	13,600	
		15,900
750'	154,900	
		139,100
760'	653,600	
		293,700
770'	941,100	
		663,700
792'	694,300	
		47,800
794'	598,600	
		539,800
832'	203,200	
		35,700
840'	53,600	
		5,100
846'	2,700	

VOLUMES TAKEN FROM TOP OF OPERATIONAL COVER.

CAP => 6" TOPSOIL
18" VEGETATIVE SUPPORT LAYER
18" COMPACTED SOIL BARRIER

CAP = 3.5' x 10 AC x 43560 ÷ 27 = 55,000 CY

1,740,000 CY − 55,000 CY = 1,685,000 CY

VOLUME REPRESENTS AIRSPACE FOR WASTE, D&I COVER, + CAP

CELL 1 VOLUME AVAILABLE FOR WASTE + D&I COVER

Job No. 6770-021-018 | No.

HDR Computation

HDR

Project	City of Greensboro	Computed DTD	Date 11/6/96
Subject	Cell 2	Checked CDM	Date 11/7/96
Task	Volume/Airspace Available	Sheet 2	Of 3

DWG C-4R + C-6R

Elev.	Area, ft²	Volume, cy	(Truncated Pyramid)
754'	10,200		
		11,200	
760'	107,800		
		84,800	
770'	377,300		
		170,700	
780'	549,700		
		240,100	
792'	530,700		
		38,500	
794'	508,400		
		602,300	
832'	352,200		
		24,800	
834'	317,800		
		74,200	
840'	330,300 403,900 - 53,600		
		76,800	
846'	340,000 343,300 - 2,700		
		213,900	
872'	122,000		
		12,800	
878'	12,200		

Volumes Taken From Top of Operational Cover

Cap => 6" Topsoil
18" Vegetative Support Layer
18" Compacted Soil Barrier

Cover = 3.5' x 15 ac x 43560 ÷ 27 = 85,000 cy

1,550,000 cy − 85,000 cy = 1,465,000 cy

Volume Represents Airspace for Waste, D&I Cover, & Cap

Cell 2 Volume Available for Waste & D&I Cover

Job No. 6770-021-018 | No.

HDR Computation

HDR

Project	CITY OF GREENSBORO	Computed DTD	Date 11/6/96
Subject	CELL 3	Checked CDM	Date 11/7/96
Task	VOLUME/AIRSPACE AVAILABLE	Sheet 3	Of 3

ELEV.	AREA, FT²	VOLUME, CY (TRUNCATED PYRAMID)
766'	4,900	
		64,400
780'	327,500	
		199,000
792'	579,700	
		43,800
794'	603,600	
		251,300
806'	527,900	
		469,900
832'	449,100	
		32,400
834'	426,500	
		510,100
872'	301,900	
		18,200
874'	274,600 - 80,900	
		36,300
878'	312,600 - 12,200	
		214,800
910'	84,200	
		10,400
920'	0	

VOLUMES TAKEN FROM TOP OF OPERATION COVER.

CAP => 6" TOPSOIL
18" VEGETATIVE SUPPORT LAYER
18" COMPACTED SOIL BARRIER

CELL 3 CAP = 3.5' x 26.32 AC x 43560 ÷ 27 = 145,000 CY

TOTAL CAP = 3.5 x 51.32 AC x 43560 ÷ 27 = 290,000 CY

CELL 1 => 1,740,000 CY
CELL 2 => 1,550,000 CY
CELL 3 => + 1,850,000 CY
5,140,000 CY
CAP => - 290,000 CY
4,850,000 CY ← CELLS 1,2,

VOLUME AVAILABLE FOR WASTE & D&I COVER

1,850,000 CY − 145,000 CY = 1,705,000 CY

VOLUME REPRESENTS AIRSPACE FOR WASTE, D&I COVER, & CAP

CELL 3 VOLUME AVAILABLE FOR WASTE & D&I COVER

Job No. 6770-021-018 | No.

HDR Computation

HDR

Project	CITY OF GREENSBORO	Computed DTD	Date 11/6/96
Subject	SITE LIFE	Checked CDM	Date 11/7/96
Task		Sheet 1	Of 2

CELL 1

GROSS VOLUME = 1,740,000 CY
CAP VOLUME = - 55,000 CY
1,685,000 CY

WASTE-TO-SOIL = 4:1
D+I COVER = $\frac{1,685,000}{5}$ = 335,000 CY
NET REFUSE VOLUME = 1,685,000 - 335,000 = 1,350,000 CY
REFUSE DENSITY = 1000 LB/CY
INTAKE = 22,300 TONS/MONTH
LIFE = 30 MONTHS

CELL 2

GROSS VOLUME = 1,550,000 CY
CAP VOLUME = 85,000 CY
1,465,000 CY

WASTE-TO-SOIL = 4:1
D+I COVER = $\frac{1,465,000}{5}$ = 295,000 CY
NET REFUSE VOLUME = 1,465,000 - 295,000 = 1,170,000 CY
REFUSE DENSITY = 1000 LB/CY
INTAKE = 22,300 TONS/MONTH
LIFE = 26 MONTHS

Job No. 6770-021-018 | No.

HDR Computation

HDR

Project CITY OF GREENSBORO	Computed DTD	Date 11/6/96	
Subject SITE LIFE	Checked CDM	Date 11/7/96	
Task	Sheet 2	Of 2	

CELL 3

GROSS VOLUME = 1,850,000 CY
CAP VOLUME = - 145,000 CY
1,705,000 CY

WASTE-TO-SOIL = 4:1
DAI COVER = $\frac{1,705,000}{5}$ = 340,000 CY
NET REFUSE VOLUME = 1,705,000 - 340,000 = 1,365,000 CY
REFUSE DENSITY = 1000 LB/CY
INTAKE = 22,300 TONS/MONTH
LIFE = 31 MONTHS

Job No. 6770-021-018 | No.

HDR Computation

HDR

Project	CITY OF GREENSBORO	Computed PTD	Date 11/6/96
Subject	WHITE STREET SANITARY LANDFILL	Checked	Date
Task	DRAINAGE	Sheet	Of

DURING INITIAL PHASES OF CONSTRUCTION STORMWATER PIPES WILL DRAIN RUNOFF INTO THE SURROUNDING BASINS. THE 10" Φ STORMWATER PIPE ON THE EAST SIDE WILL DRAIN APPROXIMATELY 13 ACRES. THE CENTER 12" Φ STORMWATER PIPE WILL DRAIN APPROXIMATELY 19 ACRES. THE NORTHERN 10" Φ STORMWATER PIPE WILL DRAIN APPROXIMATELY 6 ACRES. THE WESTERN 6" Φ STORMWATER PIPE WILL DRAIN APPROXIMATELY 5 ACRES. THE WESTERN 10" Φ STORMWATER PIPE WILL DRAIN APPROXIMATELY 9 ACRES.

SUBCELL BERMS WILL DIVERT RUNOFF TO THE PIPE, OF WHICH RUNOFF WILL ENTER THROUGH A "T" SECTION. AS REFUSE IS PLACED IN A SUBCELL, THE OPENING AT THE "T" WILL BE SEALED CLOSED. THE RUNOFF INTO THE STORMWATER PIPES SHALL CAUSE SOME PONDING AT THE ENTRANCE OF EACH "T" SECTION. A MINIMAL AMOUNT OF HEADWATER WILL BE MAINTAINED SO AS TO NOT EXCEED THE HEIGHT OF THE SUBCELL BERM.

DURING THE INITIAL PHASES OF FILLING RUNOFF WILL DRAIN TO THE NORTH AND NORTHEAST SEDIMENT BASINS. THE NORTH SEDIMENT BASIN IS CAPABLE OF HANDLING A DRAINAGE AREA OF 15 ACRES (SEE SEDIMENT BASIN CALC'S), BUT WILL ONLY BE ACCEPTING 14 ACRES. THE NORTHEAST SEDIMENT BASIN WILL ACCEPT AN AREA OF 37 ACRES (DESIGN AND ACTUAL DRAINAGE SIZE, SEE SEDIMENT BASIN DESIGN CALCULATIONS).

THE NORTHWEST, EAST, AND SOUTH SEDIMENT BASINS WERE DESIGNED TO ACCEPT DRAINAGE FROM THE FINAL GRADES. PLEASE REFER TO SEDIMENT BASIN DESIGN CALCULATIONS.

Job No. 6770-021-018 | No.

HDR Computation

HDR

Project	CITY OF GREENSBORO	Computed DTD	Date 11-22-
Subject	WHITE STREET SANITARY LANDFILL	Checked	Date
Task	DRAINAGE	Sheet	Of

DESIGN CULVERT FOR SOUTH SEDIMENT BASIN, $Q_{25} = 71$ CFS FOR 55 ACRE PHASE. EAST SEDIMENT BASIN PROVIDES DRAINAGE FOR 15.8 ACRES.

$Q = 15.8/55 = 0.29 \Rightarrow 71 \text{ CFS} \times 0.29 = \underline{\underline{20.6 \text{ CFS}}}$

TRY 24" C.M.P. CULVERT

CHECK INLET CONTROL

$HW/D = 1.5$ (FROM CHART 2)

$HW = 1.5(2)$

$HW = \underline{\underline{3.0 \text{ FT}}}$

CHECK OUTLET CONTROL

$L = 80$ FT

$S = \frac{756 - 729}{80} = 0.21$

$d_c = 1.6$ (FROM CHART 4)

FROM HEADLOSS NOMOGRAPH (CHART 6) $\Rightarrow$ $H = 3.4$ FT

$h_o = \frac{d_c + D}{2} = \frac{1.6 + 2}{2} = 1.8$

$LS_o = 80(0.21) = 16.8$

$H_{w1} = H + h_o - LS_o$

$= 3.4 + 1.8 - 16.8$

$= -11.6$ FT

SAY $\underline{\underline{0 \text{ FT}}}$

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******************************************************************************
******************************************************************************
**                                                                          **
**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**                HELP MODEL VERSION 3.06    (17 AUGUST 1996)               **
**                  DEVELOPED BY ENVIRONMENTAL LABORATORY                   **
**                    USAE WATERWAYS EXPERIMENT STATION                     **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY              **
**                                                                          **
**                                                                          **
******************************************************************************
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PRECIPITATION DATA FILE:      G:\HELP3\GBORO.D4
TEMPERATURE DATA FILE:        g:\help3\GBORO.D7
SOLAR RADIATION DATA FILE:    g:\help3\GBORO.D13
EVAPOTRANSPIRATION DATA:      g:\help3\GBORO.D11
SOIL AND DESIGN DATA FILE:    g:\help3\GBORO3.D10
OUTPUT DATA FILE:             g:\help3\GBORO3.OUT


TIME:  16:02      DATE:  11/ 6/1996


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     TITLE:  Greensboro White Street Landfill (20' Waste, 5.75" storm)

******************************************************************************


     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
              COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.


                                  LAYER  1
                                  --------

                  TYPE 1 - VERTICAL PERCOLATION LAYER
                      MATERIAL TEXTURE NUMBER  11
          THICKNESS                    =      6.00   INCHES
          POROSITY                     =      0.4640 VOL/VOL
          FIELD CAPACITY               =      0.3100 VOL/VOL
          WILTING POINT                =      0.1870 VOL/VOL
          INITIAL SOIL WATER CONTENT   =      0.3485 VOL/VOL
          EFFECTIVE SAT. HYD. COND.    =  0.639999998000E-04 CM/SEC


                                  LAYER  2
                                  --------

                  TYPE 1 - VERTICAL PERCOLATION LAYER
                      MATERIAL TEXTURE NUMBER  18
          THICKNESS                    =    240.00   INCHES
          POROSITY                     =      0.6710 VOL/VOL
          FIELD CAPACITY               =      0.2920 VOL/VOL
          WILTING POINT                =      0.0770 VOL/VOL
          INITIAL SOIL WATER CONTENT   =      0.3038 VOL/VOL
          EFFECTIVE SAT. HYD. COND.    =  0.100000005000E-02 CM/SEC
```

LAYER 3

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 0

THICKNESS	=	12.00	INCHES
POROSITY	=	0.4640	VOL/VOL
FIELD CAPACITY	=	0.3100	VOL/VOL
WILTING POINT	=	0.1870	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.3710	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.199999995000E-04	CM/SEC

LAYER 4

TYPE 2 - LATERAL DRAINAGE LAYER
MATERIAL TEXTURE NUMBER 0

THICKNESS	=	12.00	INCHES
POROSITY	=	0.3970	VOL/VOL
FIELD CAPACITY	=	0.0320	VOL/VOL
WILTING POINT	=	0.0130	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0389	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.100000001000	CM/SEC
SLOPE	=	2.00	PERCENT
DRAINAGE LENGTH	=	250.0	FEET

LAYER 5

TYPE 4 - FLEXIBLE MEMBRANE LINER
MATERIAL TEXTURE NUMBER 36

THICKNESS	=	0.06	INCHES
POROSITY	=	0.0000	VOL/VOL
FIELD CAPACITY	=	0.0000	VOL/VOL
WILTING POINT	=	0.0000	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0000	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.399999993000E-12	CM/SEC
FML PINHOLE DENSITY	=	1.00	HOLES/ACRE
FML INSTALLATION DEFECTS	=	4.00	HOLES/ACRE
FML PLACEMENT QUALITY	=	3 - GOOD	

LAYER 6

TYPE 3 - BARRIER SOIL LINER
MATERIAL TEXTURE NUMBER 16

THICKNESS	=	24.00	INCHES
POROSITY	=	0.4270	VOL/VOL
FIELD CAPACITY	=	0.4180	VOL/VOL
WILTING POINT	=	0.3670	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.4270	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.100000001000E-06	CM/SEC

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE #11 WITH BARE GROUND CONDITIONS, A SURFACE SLOPE OF 2.% AND A SLOPE LENGTH OF 250. FEET.

SCS RUNOFF CURVE NUMBER	=	94.50	
FRACTION OF AREA ALLOWING RUNOFF	=	0.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	1.000	ACRES
EVAPORATIVE ZONE DEPTH	=	9.0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	2.919	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	4.797	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	1.353	INCHES
INITIAL SNOW WATER	=	0.000	INCHES
INITIAL WATER IN LAYER MATERIALS	=	90.167	INCHES
TOTAL INITIAL WATER	=	90.167	INCHES
TOTAL SUBSURFACE INFLOW	=	0.00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM GREENSBORO NORTH CAROLINA

STATION LATITUDE	=	36.10	DEGREES
MAXIMUM LEAF AREA INDEX	=	0.00	
START OF GROWING SEASON (JULIAN DATE)	=	90	
END OF GROWING SEASON (JULIAN DATE)	=	305	
EVAPORATIVE ZONE DEPTH	=	9.0	INCHES
AVERAGE ANNUAL WIND SPEED	=	7.60	MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	66.00	%
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	68.00	%
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	74.00	%
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	70.00	%

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR GREENSBORO NORTH CAROLINA

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
3.51	3.37	3.88	3.16	3.37	3.93
4.27	4.19	3.64	3.18	2.59	3.38

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR GREENSBORO NORTH CAROLINA

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
37.50	39.90	48.00	58.30	66.50	73.50
77.20	76.30	69.90	58.40	48.50	40.20

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR GREENSBORO NORTH CAROLINA AND STATION LATITUDE = 36.10 DEGREES

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MONTHLY TOTALS (IN INCHES) FOR YEAR 1

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION	1.44	3.88	2.94	1.20	1.91	5.16
	4.38	5.28	3.89	4.33	0.00	6.42
RUNOFF	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
EVAPOTRANSPIRATION	1.781	2.091	3.197	1.414	1.830	4.872
	3.511	4.395	2.438	3.138	0.740	1.079
LATERAL DRAINAGE COLLECTED FROM LAYER 4	1.8374	1.9010	0.8789	0.9691	0.2061	0.0969
	0.0789	0.5413	0.4888	0.4082	2.4411	0.4982
PERCOLATION/LEAKAGE THROUGH LAYER 6	0.0001	0.0001	0.0001	0.0001	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000

MONTHLY SUMMARIES FOR DAILY HEADS (INCHES)

AVERAGE DAILY HEAD ON TOP OF LAYER 5	1.307	1.498	0.625	0.713	0.147	0.071
	0.056	0.385	0.359	0.290	1.795	0.354
STD. DEVIATION OF DAILY HEAD ON TOP OF LAYER 5	0.869	0.738	0.567	0.410	0.042	0.009
	0.004	0.425	0.159	0.347	0.478	0.172

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MONTHLY TOTALS (IN INCHES) FOR YEAR 2

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION	4.31	3.06	6.00	3.04	5.84	7.42
	3.81	1.15	7.07	1.80	1.47	4.21
RUNOFF	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
EVAPOTRANSPIRATION	1.179	1.877	3.052	3.244	3.837	4.578
	3.679	0.742	3.455	2.130	1.228	0.723
LATERAL DRAINAGE COLLECTED FROM LAYER 4	1.4284	2.8002	2.5128	2.7265	1.6737	2.1667
	2.7049	0.8277	0.1664	2.4129	1.3812	0.2294
PERCOLATION/LEAKAGE THROUGH LAYER 6	0.0001	0.0002	0.0002	0.0002	0.0001	0.0001
	0.0002	0.0001	0.0000	0.0001	0.0001	0.0000

MONTHLY SUMMARIES FOR DAILY HEADS (INCHES)

AVERAGE DAILY HEAD ON TOP OF LAYER 5	1.016	2.206	1.788	2.005	1.191	1.593
	1.925	0.589	0.122	1.717	1.016	0.163
STD. DEVIATION OF DAILY HEAD ON TOP OF LAYER 5	0.692	0.348	0.468	0.399	0.771	0.488
	0.481	0.365	0.035	0.881	0.655	0.054

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MONTHLY TOTALS (IN INCHES) FOR YEAR 3

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION	7.53	4.25	2.16	1.38	2.92	7.72
	13.86	8.83	5.92	0.91	2.07	2.87
RUNOFF	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
EVAPOTRANSPIRATION	1.585	2.151	1.852	1.517	1.662	5.910
	6.281	3.938	3.731	2.192	1.319	1.234
LATERAL DRAINAGE COLLECTED FROM LAYER 4	0.3545	3.3672	3.7101	3.1750	0.5960	0.4562
	2.1318	3.9077	4.4774	3.3254	2.5379	0.3680
PERCOLATION/LEAKAGE THROUGH LAYER 6	0.0000	0.0002	0.0002	0.0002	0.0000	0.0000
	0.0001	0.0002	0.0003	0.0002	0.0002	0.0000

MONTHLY SUMMARIES FOR DAILY HEADS (INCHES)

AVERAGE DAILY HEAD ON TOP OF LAYER 5	0.252	2.653	2.640	2.334	0.424	0.335
	1.517	2.780	3.292	2.366	1.866	0.262
STD. DEVIATION OF DAILY HEAD ON TOP OF LAYER 5	0.245	0.932	0.323	0.567	0.244	0.257
	0.447	0.910	0.414	0.380	0.747	0.153

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MONTHLY TOTALS (IN INCHES) FOR YEAR 4

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION	3.40	3.86	2.07	2.88	2.76	2.84
	4.10	4.14	2.01	2.28	2.85	1.00
RUNOFF	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
EVAPOTRANSPIRATION	1.287	2.104	2.880	3.298	2.224	2.783
	3.568	3.936	1.664	2.369	1.427	1.461
LATERAL DRAINAGE COLLECTED FROM LAYER 4	0.7263	1.8112	2.0633	0.4087	0.1487	0.2354
	0.1430	0.2760	0.3814	0.1516	0.1287	0.5819
PERCOLATION/LEAKAGE THROUGH LAYER 6	0.0000	0.0001	0.0001	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

MONTHLY SUMMARIES FOR DAILY HEADS (INCHES)

AVERAGE DAILY HEAD ON TOP OF LAYER 5	0.517	1.378	1.468	0.300	0.106	0.173
	0.102	0.196	0.280	0.108	0.095	0.414
STD. DEVIATION OF DAILY HEAD ON TOP OF LAYER 5	0.376	0.328	0.490	0.137	0.031	0.024
	0.009	0.185	0.093	0.023	0.015	0.280

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MONTHLY TOTALS (IN INCHES) FOR YEAR 5

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION	1.37	3.33	6.84	2.47	5.58	0.77
	7.03	5.42	5.87	5.26	1.80	2.57
RUNOFF	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
EVAPOTRANSPIRATION	1.399	1.094	3.124	2.794	4.554	0.804
	4.895	3.613	4.212	2.989	2.121	1.596
LATERAL DRAINAGE COLLECTED FROM LAYER 4	0.3169	0.1225	0.2902	1.9623	2.1744	1.6050
	0.5087	1.7902	0.6285	1.9793	2.1649	0.7011
PERCOLATION/LEAKAGE THROUGH LAYER 6	0.0000	0.0000	0.0000	0.0001	0.0001	0.0001
	0.0000	0.0001	0.0000	0.0001	0.0001	0.0000

MONTHLY SUMMARIES FOR DAILY HEADS (INCHES)

AVERAGE DAILY HEAD ON TOP OF LAYER 5	0.225	0.097	0.206	1.443	1.547	1.180
	0.362	1.274	0.462	1.408	1.592	0.499
STD. DEVIATION OF DAILY HEAD ON TOP OF LAYER 5	0.075	0.016	0.153	0.685	0.751	0.481
	0.145	0.527	0.181	0.343	0.540	0.289

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AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 5

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	3.61	3.68	4.00	2.19	3.80	4.78
	6.64	4.96	4.95	2.92	1.64	3.41
STD. DEVIATIONS	2.53	0.48	2.25	0.85	1.79	2.98
	4.24	2.76	2.00	1.81	1.05	2.03
RUNOFF						
TOTALS	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
STD. DEVIATIONS	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
EVAPOTRANSPIRATION						
TOTALS	1.446	1.863	2.821	2.453	2.821	3.789
	4.387	3.325	3.100	2.564	1.367	1.219
STD. DEVIATIONS	0.240	0.443	0.554	0.924	1.296	2.014
	1.202	1.470	1.032	0.467	0.496	0.342

LATERAL DRAINAGE COLLECTED FROM LAYER 4

TOTALS	0.9327	2.0004	1.8911	1.8483	0.9598	0.9120
	1.1135	1.4686	1.2285	1.6555	1.7308	0.4757
STD. DEVIATIONS	0.6746	1.2329	1.3521	1.1608	0.9142	0.9199
	1.2194	1.4786	1.8240	1.3495	1.0041	0.1836

PERCOLATION/LEAKAGE THROUGH LAYER 6

TOTALS	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
	0.0001	0.0001	0.0001	0.0001	0.0001	0.0000
STD. DEVIATIONS	0.0000	0.0001	0.0001	0.0001	0.0001	0.0001
	0.0001	0.0001	0.0001	0.0001	0.0001	0.0000

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ON TOP OF LAYER 5

AVERAGES	0.6636	1.5660	1.3456	1.3590	0.6829	0.6706
	0.7923	1.0449	0.9033	1.1779	1.2726	0.3385
STD. DEVIATIONS	0.4800	0.9734	0.9621	0.8535	0.6505	0.6763
	0.8676	1.0521	1.3411	0.9602	0.7383	0.1306

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AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 5

	INCHES		CU. FEET	PERCENT
PRECIPITATION	46.59	(9.847)	169107.2	100.00
RUNOFF	0.000	(0.0000)	0.00	0.000
EVAPOTRANSPIRATION	31.156	(2.0128)	113097.78	66.879
LATERAL DRAINAGE COLLECTED FROM LAYER 4	16.21682	(8.57408)	58867.070	34.81051
PERCOLATION/LEAKAGE THROUGH LAYER 6	0.00099	(0.00049)	3.603	0.00213
AVERAGE HEAD ON TOP OF LAYER 5	0.985	(0.521)		
CHANGE IN WATER STORAGE	-0.788	(1.1724)	-2861.28	-1.692

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PEAK DAILY VALUES FOR YEARS 1 THROUGH 5

	(INCHES)	(CU. FT.)
PRECIPITATION	5.75	20872.500
RUNOFF	0.000	0.0000
DRAINAGE COLLECTED FROM LAYER 4	0.18367	666.73828
PERCOLATION/LEAKAGE THROUGH LAYER 6	0.000010	0.03756
AVERAGE HEAD ON TOP OF LAYER 5	4.051	
MAXIMUM HEAD ON TOP OF LAYER 5	6.526	
LOCATION OF MAXIMUM HEAD IN LAYER 4 (DISTANCE FROM DRAIN)	48.6 FEET	
SNOW WATER	1.73	6282.1865

MAXIMUM VEG. SOIL WATER (VOL/VOL)	0.4601
MINIMUM VEG. SOIL WATER (VOL/VOL)	0.1503

*** Maximum heads are computed using McEnroe's equations. ***

Reference: Maximum Saturated Depth over Landfill Liner
by Bruce M. McEnroe, University of Kansas
ASCE Journal of Environmental Engineering
Vol. 119, No. 2, March 1993, pp. 262-270.

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FINAL WATER STORAGE AT END OF YEAR 5

LAYER	(INCHES)	(VOL/VOL)
1	1.8548	0.3091
2	69.8186	0.2909
3	4.1993	0.3499
4	0.4988	0.0416
5	0.0000	0.0000
6	10.2480	0.4270
SNOW WATER	0.000	

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**                                                                          **
**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**              HELP MODEL VERSION 3.01  (14 OCTOBER 1994)                  **
**                 DEVELOPED BY ENVIRONMENTAL LABORATORY                    **
**                   USAE WATERWAYS EXPERIMENT STATION                      **
**            FOR USEPA RISK REDUCTION ENGINEERING LABORATORY               **
**                                                                          **
**                                                                          **
******************************************************************************
******************************************************************************


PRECIPITATION DATA FILE:      C:\HELP3\GBRONC.D4
TEMPERATURE DATA FILE:        C:\HELP3\GBRONCT.D7
SOLAR RADIATION DATA FILE:    C:\HELP3\GBRONCS.D13
EVAPOTRANSPIRATION DATA:      C:\HELP3\GBRONCE.D11
SOIL AND DESIGN DATA FILE:    C:\HELP3\ACT100CL.D10
OUTPUT DATA FILE:             C:\HELP3\ACT100CL.OUT


TIME:  11:55      DATE:  11/28/1995


******************************************************************************

     TITLE:  Greensboro, NC Landfill Closed

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     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
              COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.


                                  LAYER  1
                                  --------

                     TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER  10
          THICKNESS                    =      24.00   INCHES
          POROSITY                     =       0.3980 VOL/VOL
          FIELD CAPACITY               =       0.2440 VOL/VOL
          WILTING POINT                =       0.1360 VOL/VOL
          INITIAL SOIL WATER CONTENT   =       0.3980 VOL/VOL
          EFFECTIVE SAT. HYD. COND.    =  0.119999997000E-03 CM/SEC
        NOTE:  SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  1.80
                 FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.
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LAYER 2

TYPE 4 - FLEXIBLE MEMBRANE LINER
MATERIAL TEXTURE NUMBER 37

THICKNESS	=	0.04	INCHES
POROSITY	=	0.0000	VOL/VOL
FIELD CAPACITY	=	0.0000	VOL/VOL
WILTING POINT	=	0.0000	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0000	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.199999999000E-10	CM/SEC
FML PINHOLE DENSITY	=	0.00	HOLES/ACRE
FML INSTALLATION DEFECTS	=	5.00	HOLES/ACRE
FML PLACEMENT QUALITY	=	3 - GOOD	

LAYER 3

TYPE 3 - BARRIER SOIL LINER
MATERIAL TEXTURE NUMBER 15

THICKNESS	=	18.00	INCHES
POROSITY	=	0.4750	VOL/VOL
FIELD CAPACITY	=	0.3780	VOL/VOL
WILTING POINT	=	0.2650	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.4750	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.170000003000E-04	CM/SEC

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE #10 WITH A FAIR STAND OF GRASS, A SURFACE SLOPE OF 5.% AND A SLOPE LENGTH OF 100. FEET.

SCS RUNOFF CURVE NUMBER	=	86.80	
FRACTION OF AREA ALLOWING RUNOFF	=	0.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	1.000	ACRES
EVAPORATIVE ZONE DEPTH	=	21.0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	8.358	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	8.358	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	2.856	INCHES
INITIAL SNOW WATER	=	1.799	INCHES
INITIAL WATER IN LAYER MATERIALS	=	18.102	INCHES
TOTAL INITIAL WATER	=	19.901	INCHES
TOTAL SUBSURFACE INFLOW	=	0.00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
GREENSBORO NORTH CAROLINA

MAXIMUM LEAF AREA INDEX	=	1.00
START OF GROWING SEASON (JULIAN DATE)	=	90
END OF GROWING SEASON (JULIAN DATE)	=	305
AVERAGE ANNUAL WIND SPEED	=	7.60 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	66.00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	68.00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	74.00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	70.00 %

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR GREENSBORO NORTH CAROLINA

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
3.51	3.37	3.88	3.16	3.37	3.93
4.27	4.19	3.64	3.18	2.59	3.38

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR GREENSBORO NORTH CAROLINA

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
37.50	39.90	48.00	58.30	66.50	73.50
77.20	76.30	69.90	58.40	48.50	40.20

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR GREENSBORO NORTH CAROLINA

STATION LATITUDE = 35.13 DEGREES

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AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 20

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	2.71	3.27	4.10	2.81	3.05	3.96
	4.76	5.13	3.82	2.52	2.60	3.80

STD. DEVIATIONS	1.65	1.38	1.92	1.36	1.29	2.53
	1.98	2.38	2.39	1.71	1.91	1.80
RUNOFF						
TOTALS	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
STD. DEVIATIONS	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
EVAPOTRANSPIRATION						
TOTALS	1.280	1.882	3.485	4.842	5.412	4.816
	5.434	4.587	3.466	2.972	1.839	1.468
STD. DEVIATIONS	0.419	0.325	0.265	0.324	1.419	1.838
	1.476	1.249	1.214	0.654	0.541	0.206
PERCOLATION/LEAKAGE THROUGH LAYER 3						
TOTALS	0.0858	0.0783	0.0897	0.0862	0.0815	0.0709
	0.0678	0.0657	0.0674	0.0736	0.0698	0.0798
STD. DEVIATIONS	0.0104	0.0081	0.0031	0.0037	0.0118	0.0143
	0.0192	0.0211	0.0200	0.0198	0.0204	0.0143

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ACROSS LAYER 3						
AVERAGES	22.5078	22.9367	23.7522	23.5842	21.5602	19.3588
	17.8756	17.3175	18.3702	19.4382	19.0293	21.1069
STD. DEVIATIONS	2.6933	2.4014	0.8220	1.0100	3.1579	3.9495
	5.1472	5.6761	5.5557	5.3095	5.6688	3.8325

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AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 20

	INCHES		CU. FEET	PERCENT
PRECIPITATION	42.52	(7.072)	154363.9	100.00
RUNOFF	0.000	(0.0000)	0.00	0.000
EVAPOTRANSPIRATION	41.484	(5.8474)	150587.59	97.554
PERCOLATION/LEAKAGE THROUGH FROM LAYER 3	0.91641	(0.12464)	3326.554 ≈ 68.2 gpad	2.15501

AVERAGE HEAD ACROSS TOP OF LAYER 3	20.570 (	2.830)		
CHANGE IN WATER STORAGE	0.124	(4.2898)	449.79	0.291

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PEAK DAILY VALUES FOR YEARS 1 THROUGH 20

	(INCHES)	(CU. FT.)
PRECIPITATION	3.76	13648.800
RUNOFF	0.000	0.0000
PERCOLATION/LEAKAGE THROUGH LAYER 3	0.002924	10.61491
AVERAGE HEAD ACROSS LAYER 3	24.000	
SNOW WATER	11.58	42038.9375

MAXIMUM VEG. SOIL WATER (VOL/VOL)	0.3980
MINIMUM VEG. SOIL WATER (VOL/VOL)	0.1332

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FINAL WATER STORAGE AT END OF YEAR 20

LAYER	(INCHES)	(VOL/VOL)
1	9.5519	0.3980
2	0.0000	0.0000
3	8.5500	0.4750
SNOW WATER	0.000	

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Leachate Generation

Greensboro Phase III MSW Landfill, North Carolina
HELP version 3.06 Model: 20' waste with 25 year, 24 hour storm.

PER ACRE FLOWS	Days	inches	cubic feet	gallons	gpad	Scenario
Avg Annual	365	16.21682	58,867	440,384	1,207	Filled
Highest Avg Month (Feb)	28.25	2.0004	7,261	54,323	1,923	Active
Peak Daily	1	0.18367	667	4,988	4,988	Storm Active
Peak Monthly Avg (Sept)	30	4.4774	16,253	121,588	4,053	Storm Filled
Closed Avg Annual	365	0.91641	3,327	24,886	68	Closed

Assumptions:

	30	Days/month
	1000	#/cy
	4	:1 Waste to cover soil ratio
initial	267,666	tons of waste/year
initial	535,332	cy of waste/year
	0.00%	Annual Change in Disposal Rate
	4	:1 Final cover slope
	5	years in avg subcell

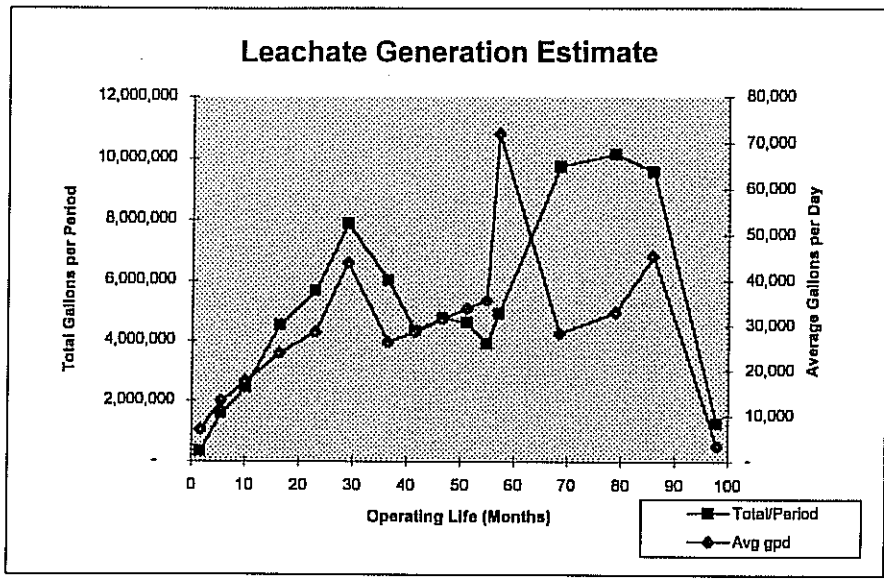
Tank Sizing

14	Holding Time (days)

Legend	
	user input

Acres	Volume
51.3	5,158,065

Shape Factor 0.93 adjustment for subcell volume estimate



SUBCELL	Disposal Rate Est. TPM	Estimated Acres	Cumulative Volume Cubic Yards	Total Landfill Life	Acreage Active	Acreage Filled	Acreage Closed	Months Normal	Months Storm	Gallons of Leachate Generated per Period: Normal Weather Active	Normal Weather Filled	Normal Weather Closed	Storm (25yr 24hr) Active	Storm (25yr 24hr) Filled	Total/Period	Period Avg gpd	Required Tank Size (gallons)
1A	22,306	3.6	90,117	2	3.6	0.0	0.0	1.6	0	337,480	-	-	-	-	337,480	6,961	97,454
1B	22,306	4.7	313,998	6	4.7	3.6	0.0	4.0	0	1,088,554	526,060	-	-	-	1,614,614	13,405	187,676
1C	22,306	4.1	569,242	10	4.1	8.3	0.0	4.6	0	1,069,409	1,378,436	-	-	-	2,447,844	17,826	249,567
1D	22,306	4.7	921,147	17	4.7	12.4	0.0	6.3	0	1,703,747	2,825,553	-	-	-	4,529,300	23,924	334,938
1E	22,306	4.3	1,288,021	23	4.3	17.1	0.0	6.6	0	1,620,613	4,060,227	-	-	-	5,680,840	28,782	402,952
1F	22,306	3.5	1,620,809	29	3.5	21.3	0.0	5.0	1	1,011,640	3,833,653	-	432,507	2,592,265	7,870,065	43,958	615,418
2A	22,306	4.1	2,041,220	37	4.1	14.9	10.0	7.5	0	1,796,214	4,052,368	154,208	-	-	6,002,790	26,541	371,568
2B	22,306	2.6	2,323,093	42	2.6	19.0	10.0	5.1	0	761,077	3,472,632	103,392	-	-	4,337,101	28,601	400,409
2C	22,306	2.5	2,604,250	47	2.5	21.6	10.0	5.0	0	727,148	3,940,124	103,129	-	-	4,770,401	31,538	441,535
2D	22,306	2.2	2,856,827	51	2.2	24.1	10.0	4.5	0	567,005	3,949,464	92,646	-	-	4,609,115	33,920	474,879
2E	22,306	1.7	3,061,280	55	1.7	26.3	10.0	3.7	0	361,680	3,484,960	74,994	-	-	3,921,634	35,654	499,150
2F	22,306	1.0	3,187,910	57	1.0	28.0	10.0	1.3	1	76,244	1,286,595	25,994	127,424	3,400,828	4,917,085	72,177	1,010,483
3A	22,306	5.1	3,826,564	69	5.1	14.0	25.0	11.5	0	3,336,494	5,807,798	585,649	-	-	9,729,942	28,319	396,464
3B	22,306	4.3	4,398,827	79	4.3	19.1	25.0	10.3	0	2,539,729	7,079,906	524,770	-	-	10,144,405	32,950	461,306
3C	22,306	2.8	4,790,630	86	2.8	23.4	25.0	6.0	1	983,807	5,093,129	308,150	346,741	2,839,089	9,570,916	45,406	635,689
Closure	0	51.2	4,810,300	98	0.0	0.0	51.2	12.0	0	-	-	1,256,221	-	-	1,256,221	3,490	48,853

Life (years) 7.2

Average Leachate Generation (gpd)	27,800	
Peak Leachate Generation (gpd)		72,200
Minimum Required Tank Size		1,010,000

Job No. 6770-021-018 | No.

HDR Computation

HDR

Project	CITY OF GREENSBORO	Computed DTD	Date
Subject	LEACHATE PIPE SPACING	Checked CDM	Date 11/7/96
Task		Sheet 1	Of 1

ASSUME:

METHOD: US EPA MOUNDING EQ -> SW 869

OPERATIONAL COVER PERMEABILITY = 2×10^{-5} cm/sec
DRAINAGE LAYER PERMEABILITY = 1×10^{-1} cm/sec
} FROM SPEC'S.

$$C = \frac{O.C.}{D.L.} = \frac{2 \times 10^{-5}}{1 \times 10^{-1}} = .0002$$

C	SLOPE	(α) SLOPE (DEG)	$\frac{C^{1/2}}{2}$	$\frac{\tan^2\alpha}{C}$	$\frac{\tan\alpha}{C}\sqrt{\tan^2\alpha + C}$	L
.0002	2%	1.15	0.0071	2.0148	2.4646	256 FT
.0002	3%	1.72	0.0071	4.5086	4.9836	268 FT
.0002	4%	2.29	0.0071	7.9957	8.4810	274 FT

USE 250 FT

$$h_{max} = \frac{L\sqrt{C}}{2}\left[\frac{\tan^2\alpha}{C} + 1 - \frac{\tan\alpha}{C}\sqrt{\tan^2\alpha + C}\right]$$

WHERE: h_{max} = MAX. ALLOWABLE HEAD (FT) = 1 FT
L = PIPE SPACING (FT)

PROJECT HDR – GBORO, LF

SUBJECT Leachate Collection Pipe Sizing

SHEET 1 OF 2
JOB NO. HDRGN-2
DATE 11/21/95
COMPUTED BY PKS
CHECKED BY

– Objective: Evaluate the required size of leachate collector, header, & outlet pipes based on the 25 yr, 24 hr storm.

– Assumptions:

1. Assume entire storm acts on system at one time. (Very Conservative)
2. Neglect influence of waste. (Conservative)
3. Drain rainfall from cell in at most 24 hrs. from end of rainfall event, neglecting removal during the storm. (Conservative)
4. All runoff is retained within the cell.

– Analysis:

1. Calculate volumes to be drained by each pipe.
2. Calculate required flow volumes to drain cell in 24 hrs.
3. Size each pipe.
4. Equations:

Volume = Depth of Storm (Ft) × Area (Ft^2)

Q_{Req} = Required Flow Volume To Drain in 24 hrs. (cfs)

= Volume / 86400 sec/24hrs.

Reqd. Pipe Diameter (D_{Req}) = $16 \left[\frac{Q_{Req} \cdot n}{\sqrt{s}}\right]^{.375}$ – Manning's Eq'n. For Circ. Pipes Flowing Just Full

n = Manning's Coef. s = slope of pipe

G.N. RICHARDSON & ASSOCIATES
CONSULTING ENGINEERING

DRAWN	JOB NO.	APPROVED	DATE	REVISED DATE

Project: Greensboro Phase III Lined Landfill Expansion

Task: Size Landfill Pipes (leachate & stormwater) based on the 25 year 24 hour storm

Date: 11/5/96 Calc'd by: EAW Checked by:

Circular pipe flowing just full: D=16(Qn/(s)^.5)^(3/8)
Q=(((D/16)^(8/3))/n)*(s)^.5

n =	0.01	HDPE
25 yr 24 hr storm	5.75	inches

Pipe Slope

Diameter (inches)	Q (cubic feet per second) 0.5%	1.0%	1.5%	2.0%	2.5%	3.0%
4	0.2	0.2	0.3	0.4	0.4	0.4
6	0.5	0.7	0.9	1.0	1.2	1.3
8	1.1	1.6	1.9	2.2	2.5	2.7
10	2.0	2.9	3.5	4.0	4.5	4.9
12	3.3	4.6	5.7	6.6	7.3	8.0
14	5.0	7.0	8.6	9.9	11.1	12.1
15	6.0	8.4	10.3	11.9	13.3	14.6
16	7.1	10.0	12.2	14.1	15.8	17.3
18	9.7	13.7	16.8	19.4	21.6	23.7
20	12.8	18.1	22.2	25.6	28.7	31.4
22	16.5	23.4	28.6	33.1	37.0	40.5
24	20.8	29.5	36.1	41.7	46.6	51.1

Diameter (inches)	Area Drained (acres per day) 0.5%	1.0%	1.5%	2.0%	2.5%	3.0%
4	0.7	1.0	1.3	1.5	1.6	1.8
6	2.1	3.0	3.7	4.3	4.8	5.2
8	4.6	6.5	8.0	9.2	10.3	11.3
10	8.4	11.8	14.5	16.7	18.7	20.5
12	13.6	19.2	23.5	27.2	30.4	33.3
14	20.5	29.0	35.5	41.0	45.8	50.2
15	24.6	34.8	42.7	49.3	55.1	60.4
16	29.3	41.4	50.7	58.5	65.4	71.7
18	40.1	56.7	69.4	80.1	89.6	98.2
20	53.1	75.1	91.9	106.1	118.7	130.0
22	68.4	96.8	118.5	136.9	153.0	167.6
24	86.3	122.0	149.5	172.6	193.0	211.4

Leachate Pipe
Stormwater Pipe

Job No. 06770-021-018 | No.

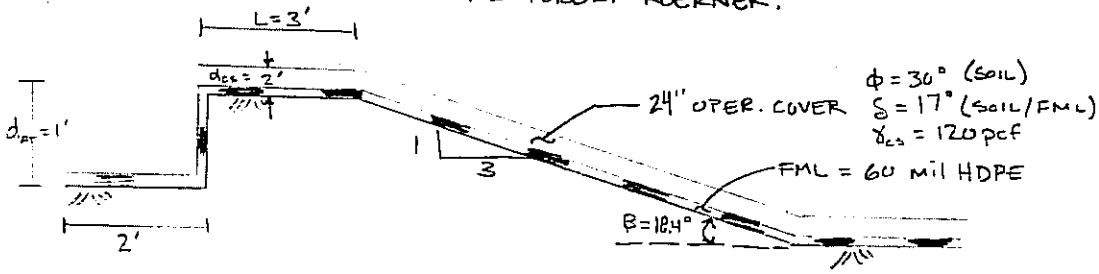
HDR Computation

HDR

Project	GREENSBORO WHITE STREET L/F	Computed	DTD	Date	10/16/96
Subject	PHASE III EXPANSION	Checked	EAV	Date	10/16/96
Task	ANCHOR TRENCH	Sheet	1	Of	2

OBJECTIVE: CALCULATE ANCHOR CAPACITY FOR FML. with operational cover.

REF: "GEOSYNTHETIC DESIGN GUIDANCE FOR HAZARDOUS WASTE LANDFILL CELLS AND SURFACE IMPOUNDMENTS, BY GREG RICHARDSON AND ROBERT KOERNER.



$$q = \gamma_{cs} \times d_{cs} = 120 \text{ pcf} \times 2 \text{ ft} = 240 \text{ psf}$$

active

$$K_a = \frac{1-\sin\phi}{1+\sin\phi} = \frac{1-\sin 30°}{1+\sin 30°} = 0.33$$

passive

$$K_p = \frac{1+\sin\phi}{1-\sin\phi} = \frac{1+\sin 30°}{1-\sin 30°} = 3.0$$

initial

$$K_o = 1-\sin\phi = 1-\sin 30° = 0.5$$

Trench Tension, T

$$T = \frac{qL\tan\delta + (K'+K_A)\tan\delta\left[0.5\gamma_{cs}d_{AT}^2 + q\,d_{AT}\right]}{d_{AT}\cos\beta - \sin\beta\tan\delta}$$

WHERE $K' = K_p$ OR K_o

$$T_{K_p} = \frac{240(3)(\tan 17°) + (3.0+0.33)(\tan 17°)\left[0.5(120)(1)^2 + 240(1)\right]}{(1)\cos 18.4° - \sin 18.4°(\tan 17°)} = \underline{617 \text{ lb/ft}}$$ ← GOVERNS

$$T_{K_o} = \frac{240(3)(\tan 17°) + (0.5+0.33)(\tan 17°)\left[0.5(120)(1)^2 + 240(1)\right]}{(1)\cos 18.4° - \sin 18.4°(\tan 17°)} = 348 \text{ lb/ft}$$

Ultimate Strength of 60 mil HDPE => σ_y = 2000 psi

$$\Rightarrow F_{all} = \sigma_y t = 2000(.06) = 120 \text{ lb/in}$$

$$F_{all} = 1440 \text{ lb/ft}$$

Active Forces

$F_{self\text{-}wt}$ = 3.9 lb/ft
$F_{drawdrag}$ = 58 lb/ft
F_{waste} = 102 lb/ft

see GNRA SPREADSHEET

F_{TOT} = 163.9 lb/ft

$F_{TOT} < T < F_{ALL}$
163.9 lb/ft < 617 lb/ft < 1440 lb/ft
OKAY

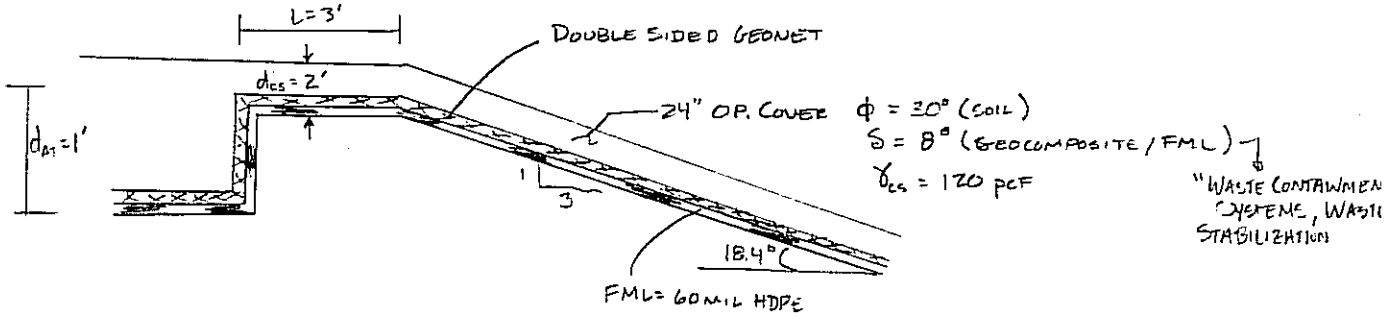
Job No. 6770-021-018 | No.

HDR Computation

HDR

Project: CITY OF GREENSBORO	Computed: DTD	Date: 11/7/96	
Subject: PHASE III EXPANSION	Checked:	Date:	
Task: ANCHOR TRENCH	Sheet: 2	Of: 2	

OBJECTIVE: CALCULATE ANCHOR TRENCH CAPACITY FOR GEOCOMPOSITE ON FML WITH OPERATIONAL COVER



$q = \gamma_{cs} \times d_{cs} = 120\ pcf \times 2\ ft = 240\ psf$

ACTIVE: $K_a = \frac{1-\sin\phi}{1+\sin\phi} = \frac{1-\sin 30°}{1+\sin 30°} = 0.33$

PASSIVE: $K_p = \frac{1+\sin\phi}{1-\sin\phi} = \frac{1+\sin 30°}{1-\sin 30°} = 3.0$

INITIAL: $K_o = 1-\sin\phi = 1-\sin 30° = 0.5$

$$T = \frac{qL\tan\delta + (K' + K_a)\tan\delta\,[0.5\gamma_{cs}d_{AT}^2 + q\,d_{AT}]}{d_{AT}\cos\beta - \sin\beta\tan\delta}$$

WHERE $K' = K_p$ OR K_o

$$T_{K_p} = \frac{240(3)\tan 8° + (3+0.33)\tan 8°\,[0.5(120)(1)^2 + 240(1)]}{(1)\cos 18.4° - \sin 18.4°\tan 8°} = \underline{267\ lb/ft} \leftarrow \text{GOVERNS}$$

$$T_{K_a} = \frac{240(3)\tan 8° + (0.5+0.33)\tan 8°\,[0.5(120)(1)^2 + 240(1)]}{(1)\cos 18.4° - \sin 18.4°\tan 8°} = 151\ lb/ft$$

GEOCOMPOSITE ULTIMATE STRENGTH = 40 psi = 5760 lb/ft

FROM PREVIOUS PAGE → ACTIVE FORCES = 163.9 lb/ft

$$\boxed{163.9\ lb/ft < 267\ lb/ft < 5760\ lb/ft \quad \text{OKAY}}$$

Job No. 06770-021-018 | No.

HDR Computation

HDR

Project: GREENSBORO WHITE ST. L/F	Computed: DTD	Date: 10/15/96
Subject: PHASE III EXPANSION	Checked: EAW	Date: 10/16/96
Task: SETTLEMENT	Sheet: 1	Of: 3

OBJECTIVE: CALCULATE SETTLEMENT AT HIGHEST POINT OF LANDFILL AND NORTHEAST CORNER

REF: "WASTE CONTAINMENT SYSTEMS, WASTE STABILIZATION, AND LANDFILLS; DESIGN AND EVALUATION" BY HARI SHARMA & SANGEETA LEWIS.

$$S = H_t \frac{C_c}{1+e_o} \log \frac{P_o + \Delta P}{P_o}$$

WHERE:
- S = SETTLEMENT
- H_t = LAYER THICKNESS
- C_c = COMPRESSION INDEX = $0.208 e_o + 0.0083$ ("PRINCIPLES OF FOUNDATION ENGINEERING" p.
- e_o = INITIAL VOID RATIO
- P_o = INITIAL STRESS
- ΔP = CHANGE IN STRESS

PARAMETERS @ HIGHEST POINT:

BORING 23 → GROUND EL. = 765'
SUBGRADE = 765' (DRAWING C-2 CONST PERMIT APP 11/95)
TOP OF LANDFILL EL. = 919' (DRAWING C-7A)

CLAY LAYER = 2' × 120 pcf = 240 psf
LCS = 1' × 120 pcf = 120 psf
OPERATIONAL COVER = 1' × 120 pcf = 120 psf
FINAL INTERMEDIATE COVER LAYER = 1' × 120 pcf = 120 psf
FINAL COMPACTED SOIL BARRIER = 1.5' × 120 pcf = 180 psf
FINAL VEGETATIVE SUPPORT SOIL = 1.5' × 120 pcf = 180 psf
FINAL TOP SOIL LAYER = 0.5' × 120 pcf = 60 psf
REFUSE = 919 − 765 − 2 − 1 − 1 − 1.5 − 1.5 − 0.5 = 146.5' × 60 pcf = 8790 psf

} 9,810 psf

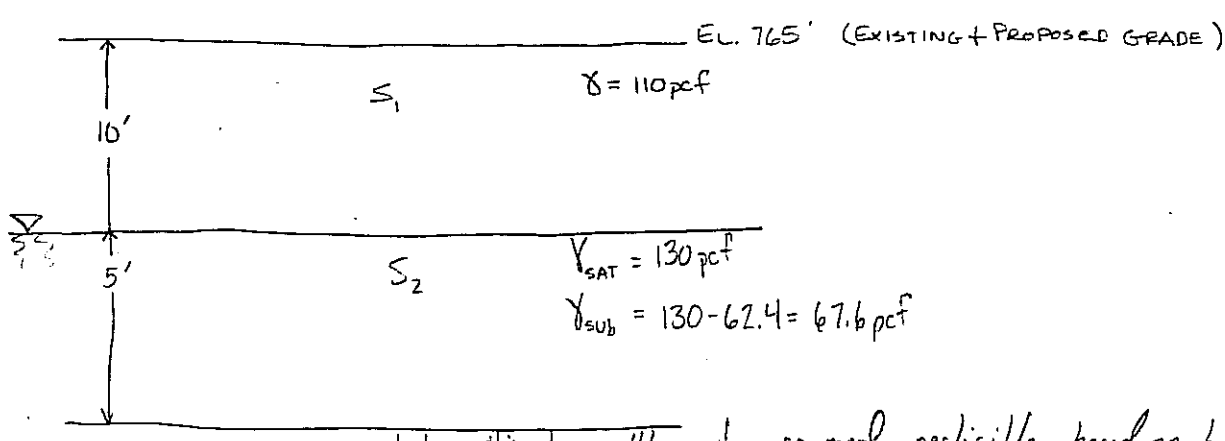
Job No. 06770-021-018 | No.

HDR Computation

HDR

Project	GREENSBORO WHITE STREET L/F	Computed	DTD	Date	10 / 15 / 96
Subject	PHASE III EXPANSION	Checked	EAW	Date	10/16/96
Task	SETTLEMENT	Sheet	2	Of	3

B-23



below this elev. settlement assumed negligible based on boring logs.

POROSITY, $n = 45\%$ $\quad e = \dfrac{\frac{n\%}{100\%}}{1 - \frac{n\%}{100\%}} = 0.81 \quad C_c = .208(.81) + .0083 = 0.177$

S_1

$P_{o_1} = \frac{10}{2}(110) = 550$ psf

$P_{f_1} = 9810 + \frac{10}{2}(110) = 10{,}360$ psf

$\Delta P_1 = 9810$ psf

$$S_1 = 10' \frac{0.177}{1+0.81} \log \frac{550+9810}{550} = \underline{1.25 \text{ ft}}$$

S_2

$P_{o_2} = 10(110) + \frac{5}{2}(67.6) = 1269$ psf

$P_{f_2} = 9810 + 10(110) + \frac{5}{2}(67.6) = 11{,}079$ psf

$\Delta P_2 = 9810$

$$S_2 = 5' \frac{0.177}{1+0.81} \log \frac{1269+9810}{1269} = \underline{0.46 \text{ ft}}$$

$$S_{TOT} = S_1 + S_2 = 1.25 + 0.46 = \boxed{1.71 \text{ ft}}$$

Job No. 06770-021-018 | No.

HDR Computation

HDR

Project	GREENSBORO WHITE STREET L/F	Computed	DTD	Date	10/16/96
Subject	PHASE III EXPANSION	Checked	EAW	Date	10/16/96
Task	SETTLEMENT	Sheet	3	Of	3

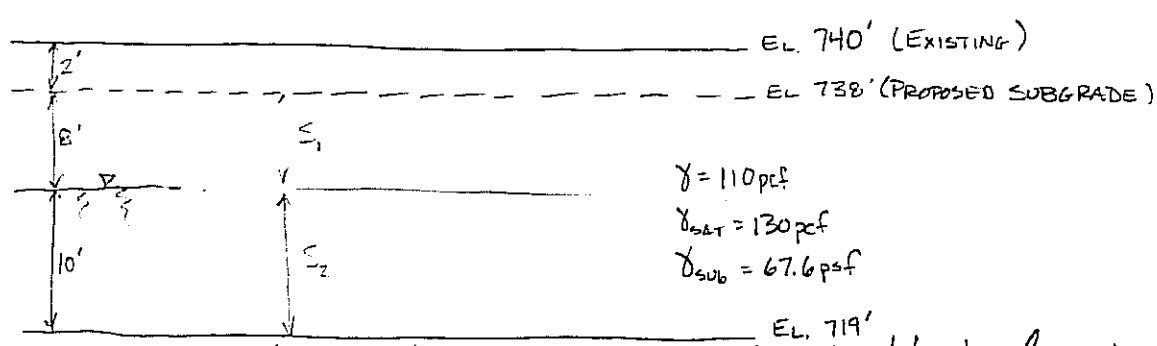
PARAMETERS @ NORTHEAST CORNER

BORING 30 → GROUND EL. = 739'
SUBGRADE = 738' (DRAWING C-2 CONST. PERMIT APP. 11/95)
CAP EL. = 766'
CLAY LINER = 2' × 120 pcf = 240 psf
LCS = 1' × 120 psf = 120 psf
OPERATIONAL COVER = 1' × 120 pcf = 120 pcf
FINAL INTERMEDIATE COVER LAYER = 1' × 120 pcf = 120 psf
FINAL COMPACTED SOIL BARRIER = 1.5' × 120 pcf = 180 psf
FINAL VEGETATIVE SUPPORT SOIL = 1.5' × 120 pcf = 180 psf
FINAL TOPSOIL LAYER = 0.5' × 120 pcf = 60 psf
REFUSE = 766 − 738 − 2 − 1 − 1 − 1.5 − 1.5 − 0.5 = 20.5' × 60 pcf = 1230 psf

} 2,250 psf

B-30

$e = 0.81$
$C_c = 0.177$



below this elevation settlement assumed negligible based on boring logs

S_1

$P_{o_1} = \frac{10}{2}(110) = 550$ psf
$P_{f_1} = 2{,}250 + \frac{8}{2}(110) = 2690$ psf
$\Delta P_1 = 2{,}690 - 550 = 2{,}140$ psf

$S_1 = 8' \frac{0.177}{1+0.81} \log \frac{550 + 2140}{550} = \underline{0.54 \text{ FT}}$

S_2

$P_{o_2} = 10(110) + \frac{10}{2}(67.6) = 1{,}438$ psf
$P_{f_2} = 2{,}250 + 8(110) + \frac{10}{2}(67.6) = 3{,}468$ psf
$\Delta P_2 = 3{,}468 - 1{,}438 = 2{,}030$ psf

$S_2 = 10' \frac{0.177}{1+0.81} \log \frac{1438 + 2030}{1438} = \underline{0.37 \text{ FT}}$

$S_{TOT} = S_1 + S_2 = 0.54 + 0.37 = \boxed{0.91 \text{ FT}}$

Change in slope ~1040' between locations. $\frac{1.71' - 0.91'}{1040'} = \underline{0.08\%}$ Negligible

Job No. 6770-021-018 No.

HDR Computation

HDR

Project	GREENSBORO L/F PHASE III	Computed	DTD	Date	7/18/96
Subject	CELL VOLUME CALCULATIONS	Checked	EAW	Date	7/19/96
Task		Sheet		Of	

CELL VOLUME HAS BEEN ADJUSTED FROM CALCULATIONS ON 10/26/95 AND 11/27/95. CELL 1 REMAINED THE SAME AS PREVIOUSLY DESIGNED AND CALCULATED. HOWEVER, CELL 2 BOUNDARY WAS SET BACK 300' FROM THE DUKE POWER STATIONS. CELL 3 REMAINED THE SAME.

	CELL 1	CELL 2	CELL 3	Total
COVER SOIL	250,800 CY	285,000 CY	456,400 CY	992,200
WASTE	1,003,200 CY	1,140,000 CY	1,825,600 CY	3,968,800
LIFE	22.5 MONTHS	25.6 MONTHS	41 MONTHS	89 months
Acreage	20	14.5	16.2	50.7
Total capacity	1,254,000 cy	1,427,000 cy	2,282,000 cy	4,963,000

Job No. 6770-021-018 | No.

HDR Computation

HDR

Project	GREENSBORO LF PHASE III	Computed DTD	Date 7/17/96
Subject	CELL VOLUME CALC'S	Checked CDM	Date 7/18/96
Task		Sheet 1	Of 3

REFERENCE: SHEETS C-4, C-5, C-6, C-7 OF CONST PERMIT APPLICATION - NOV. 1995

ASSUMPTIONS: 5 YEARS OF WASTE = 1,340,000 TONS
1000 #/CY DENSITY
4:1 WASTE-TO-SOIL RATIO

~ 20 acres

CELL 1

ELEV	AREA, SF	VOLUME, CY
750'	226,530	
		124,770
760'	460,970	
		218,070
770'	726,640	
		255,140
780'	651,780	
		256,120
792'	503,910	
		34,340
794'	424,470	
		345,000
830'	123,150	
		20,920
842'	2,070	

1,254,360 CY => 1,254,000 CY GROSS

COVER SOIL 250,800
WASTE 1,003,200
LIFE 22.5 MONTHS

Job No. 06770-021-018 | No.

HDR Computation

HDR

Project	GREENSBORO L/F PHASE III	Computed	DTD	Date	7/17/96
Subject	CELL VOLUME CALC'S	Checked	CDM	Date	7/18/96
Task		Sheet	2	Of	3

CELL 2 . 14.5 ACRES

ELEV	AREA, SF	VOLUME, CY	ELEV	AREA, SF	VOLUME, CY
750'	44,640		830'	321,010	
		40,810			27,350
760'	193,050		832'	419,740	
		115,770			28,180
770'	449,970		834'	342,400	
		194,570			168,290
780'	604,500		852'	172,130	
		256,670			17,720
792'	550,950		856'	73,940	
		39,490			3,990
794'	515,450		858'	36,010	
		552,550			2,200
830'	321,010		861'	1,400	
		1,199,860 CY			247,730 CY
			FROM CELL 1 >830'		− 20,920 CY
					226,810 CY

1,199,860 + 226,810 = 1,426,670 CY

GROSS = 1,42~~5~~7,000 CY

COVER SOIL = 285,000 CY

WASTE = 1,140,000 CY

LIFE = 25.5 MONTHS

Job No. 26770-021-018 | No.

HDR Computation

HDR

Project	GREENSBORO L/F PHASE III	Computed DTD	Date 7/17/96
Subject	CELL VOLUME CALC'S	Checked CDM	Date 7/18/96
Task		Sheet 3	Of 3

CELL 3 16.2 ACRES

ELEV	AREA, SF	VOLUME, CY
780'	458,410	
		310,140
794'	749,740	
		269,660
804'	706,650	
		50,420
806'	656,350	
		594,680
832'	579,550	
		41,890
834'	551,720	
		343,220
852'	478,800	

1,610,060 CY

ELEV	AREA, SF	VOLUME, CY
852'	644,180	
		390,220
872'	417,570	
		28,310
874'	347,980	
		266,310
910'	82,150	
		10,800
920'	310	
		695,640 CY
	FROM CELL 2 7852'	- 23,910 CY
		671,730 CY

1,610,060 CY + 671,730 CY = 2,281,790 CY

GROSS = 2,282,000 CY

COVER SOIL = 456,400 CY

WASTE = 1,825,600 CY

LIFE = 40 MONTHS

Job No. 6770-021-018 | No.

HDR Computation

HDR

Project	CITY OF GREENSBORO	Computed DTD	Date 11-22-95
Subject	WHITE STREET SANITARY LANDFILL	Checked	Date
Task	DRAINAGE	Sheet	Of

DURING INITIAL PHASES OF CONSTRUCTION, THE 15" ϕ STORMWATER PIPE WILL DRAIN ONLY CELL 1 INTO THE NORTHEAST SEDIMENT BASIN. SUBCELL BERMS WILL DIVERT RUNOFF TO THE PIPE, OF WHICH WILL ENTER THROUGH A "T" SECTION. AS REFUSE IS PLACED IN A SUBCELL, THE OPENING AT THE "T" SECTION WILL BE SEALED SHUT. RUNOFF FROM CELL 2 WILL BE DIVERTED INTO THE NORTH SEDIMENT BASIN BY A 12" ϕ STORMWATER PIPE. THE RUNOFF INTO THE STORMWATER PIPES SHALL CAUSE SOME PONDING AT THE ENTRANCE OF EACH "T" SECTION. A MINIMAL AMOUNT OF HEADWATER WILL BE MAINTAINED (NOT TO EXCEED THE HEIGHT OF THE SUBCELL BERM). RUNOFF FROM CELL 3 CAN POSSIBLY BE DIVERTED BY PLACING A DIVERSION DITCH ALONG THE ~~EDGES~~ (TOE OF SLOPE) OF CELLS 2 & 3. THE DIVERSION DITCH WOULD LEAD TO A CULVERT UNDERNEATH THE EASTER PORTION OF THE PERIMETER ROAD.

THE NORTHWEST, EAST, AND SOUTH SEDIMENT BASINS ARE FOR FINAL GRADING CONTOURS FOR ENTIRE PHASE III. THE NORTHWEST BASIN SHALL PROVIDE DRAINAGE FOR 17.5 ACRES. THE EAST SEDIMENT BASIN WILL PROVIDE DRAINAGE FOR 18.4 ACRES. THE SOUTH SEDIMENT BASIN WILL PROVIDE DRAINAGE FOR 15.8 ACRES. RUNOFF LEADING TO THESE BASINS FROM CULVERTS IN WHICH RUNOFF FROM A DOWNCHUTE BY WAY OF DRAINAGE TERRACES.

Job No. 6770-021-018 | No.

HDR Computation

HDR

Project: CITY OF GREENSBORO	Computed: DTD	Date: 11-22-	
Subject: WHITE STREET SANITARY LANDFILL	Checked:	Date:	
Task: DRAINAGE	Sheet:	Of:	

DESIGN CULVERT FOR SOUTH SEDIMENT BASIN, $Q_{25} = 71$ CFS FOR 55 ACRE PHASE.
EAST SEDIMENT BASIN PROVIDES DRAINAGE FOR 15.8 ACRES.

$Q = 15.8/55 = 0.29 \Rightarrow 71 \text{ CFS} \times 0.29 = \underline{20.6 \text{ CFS}}$

TRY 24" C.M.P. CULVERT

CHECK INLET CONTROL

$HW/D = 1.5$ (FROM CHART 2)

$HW = 1.5(2)$

$HW = \underline{3.0 \text{ FT}}$

CHECK OUTLET CONTROL

$L = 80$ FT

$S = \frac{796 - 779}{80} = 0.21$

$d_c = 1.6$ (FROM CHART 4)

FROM HEADLOSS NOMOGRAPH (CHART 6) $\Rightarrow H = 3.4$ FT

$h_o = \frac{d_c + D}{2} = \frac{1.6 + 2}{2} = 1.8$

$LS_o = 80(0.21) = 16.8$

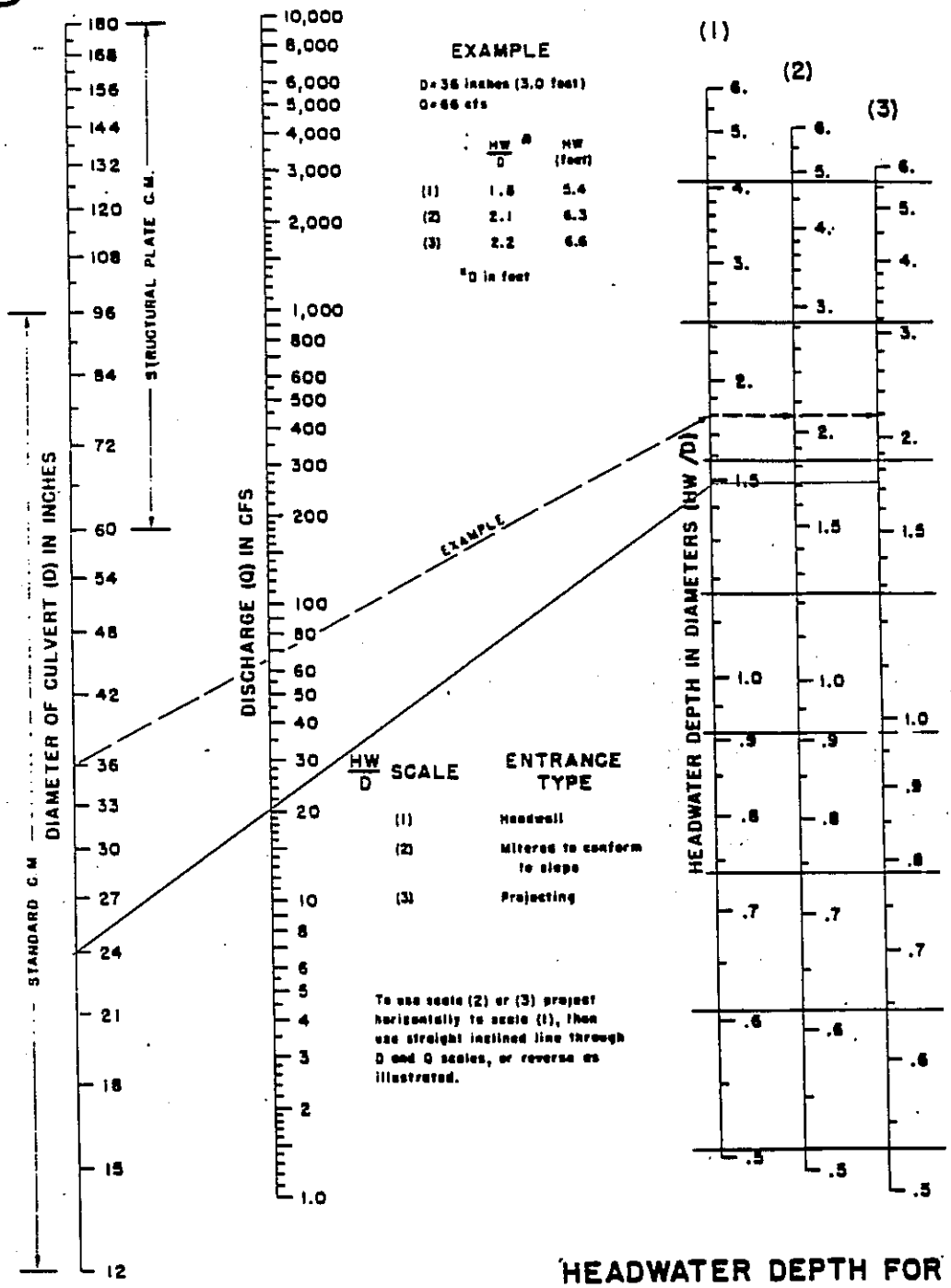
$H_W = H + h_o - LS_o$

$= 3.4 + 1.8 - 16.8$

$= -11.6$ FT

SAY $\underline{0 \text{ FT}}$

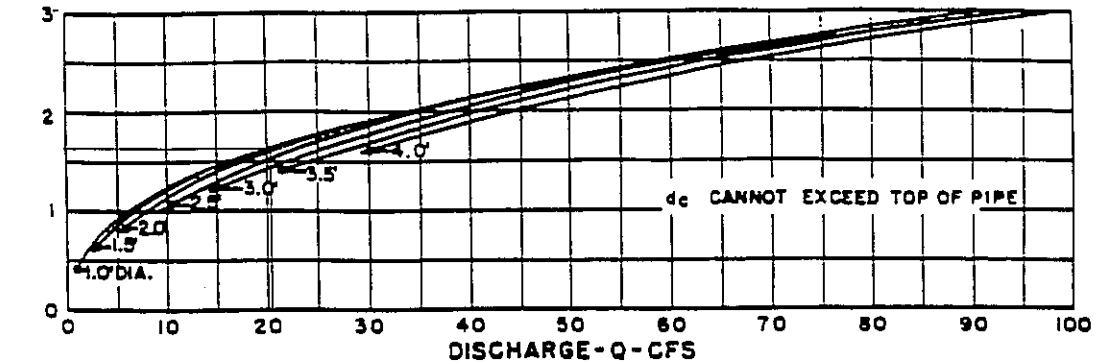
CHART 2

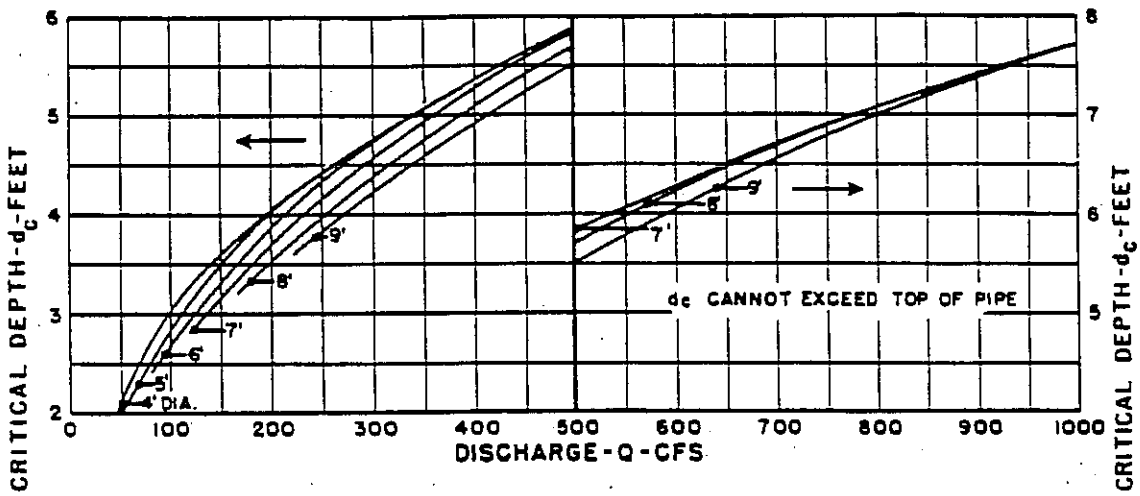


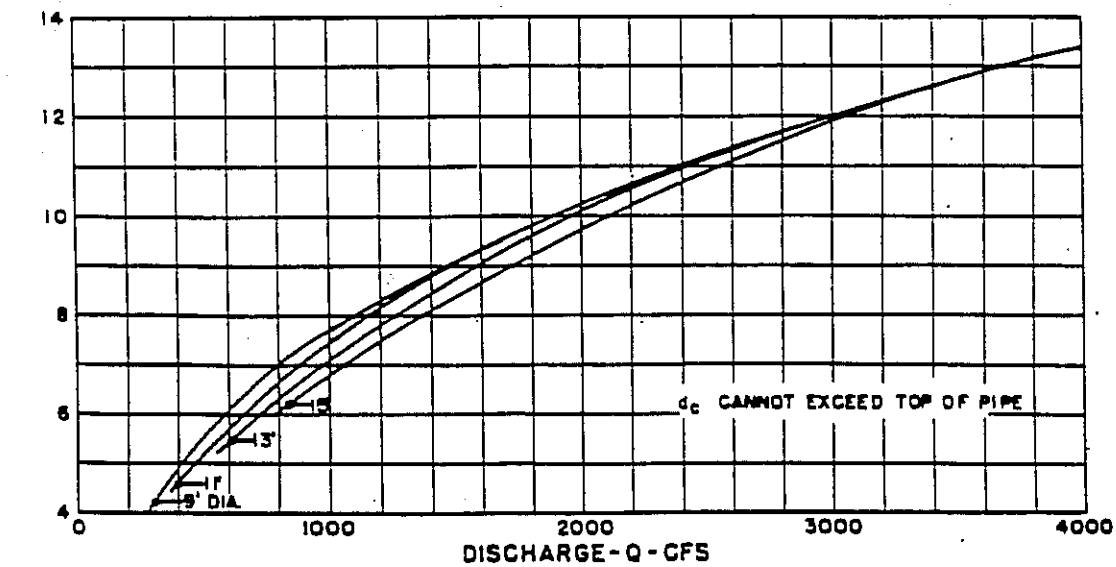
HEADWATER DEPTH FOR C. M. PIPE CULVERTS WITH INLET CONTROL

BUREAU OF PUBLIC ROADS JAN. 1963

CHART 4





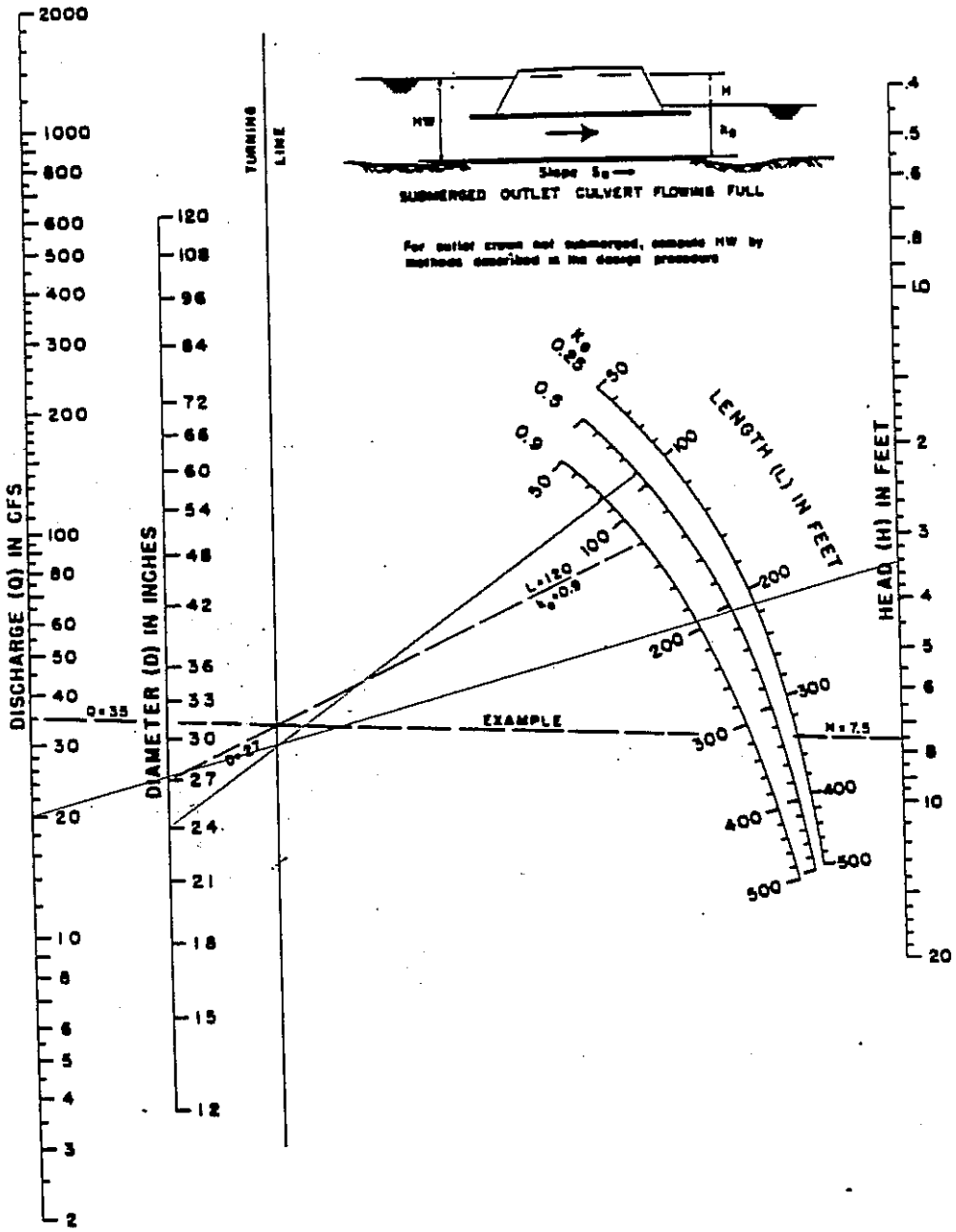


BUREAU OF PUBLIC ROADS

JAN. 1964

CRITICAL DEPTH
CIRCULAR PIPE

CHART 6



HEAD FOR
STANDARD
C. M. PIPE CULVERTS
FLOWING FULL
n = 0.024

BUREAU OF PUBLIC ROADS JAN. 1963

Job No. 6770-021-018 | No.

HDR Computation

HDR

Project	CITY OF GREENSBORO	Computed DTD	Date 11-22-..
Subject	WHITE STREET SANITARY LANDFILL	Checked	Date
Task	DRAINAGE	Sheet	Of

DESIGN CULVERT FOR NORTHWEST SEDIMENT BASIN. $Q_{25} = 71$ CFS FOR 55 ACRE PHASE
EAST SEDIMENT BASIN PROVIDES DRAINAGE FOR 17.5 ACRES.

$Q \Rightarrow 17.5/55 = 0.32 \Rightarrow 71 \text{ cfs} \times .32 = \underline{\underline{22.7 \text{ cfs}}}$

TRY 24" ϕ C.M.P. CULVERT

CHECK INLET CONTROL

$HW/D = 1.6$ (FROM CHART 2)

$HW = 1.6(2)$

$HW = \underline{\underline{3.2 \text{ FT}}}$

CHECK OUTLET CONTROL

$L = 120$ FT $\qquad d_c = 1.75$ (CHART 4)

$S = \frac{74-736}{120} = 0.25$

FROM HEADLOSS NOMOGRAPH (CHART 6) $\Rightarrow H = 5.8$ FT

$h_o = \frac{d_c + D}{2} = \frac{1.75+2}{2} = 1.875$

$LS_o = 120(0.25) = 30$

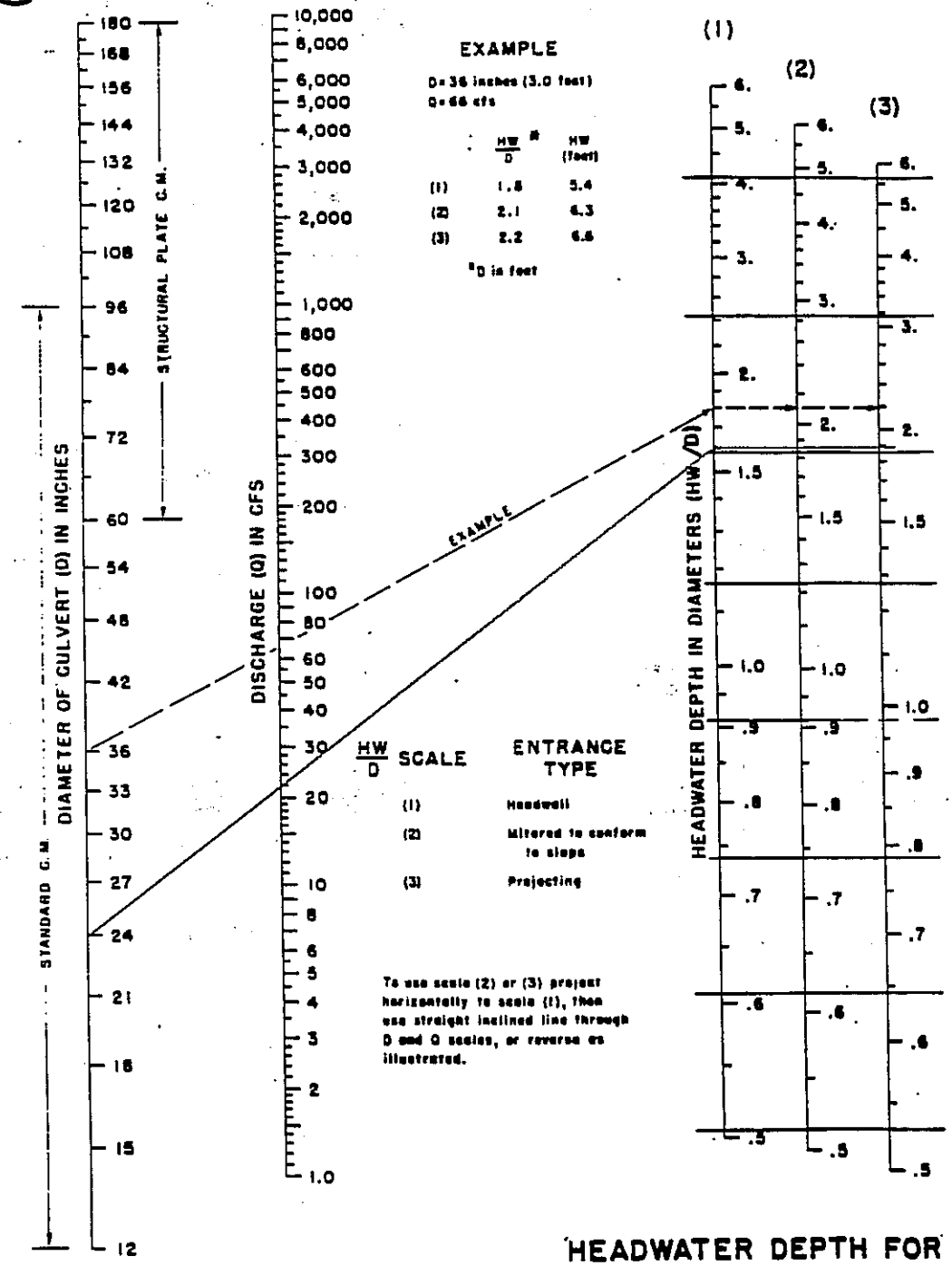
$HW = H + h_o - LS_o$

$= 5.8 + 1.875 - 30$

$= -22.3$ FT

SAY $\underline{\underline{0 \text{ FT.}}}$

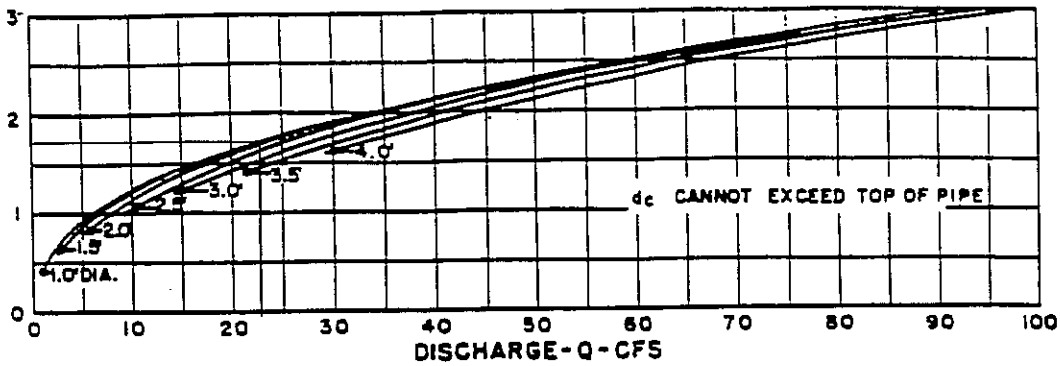
CHART 2

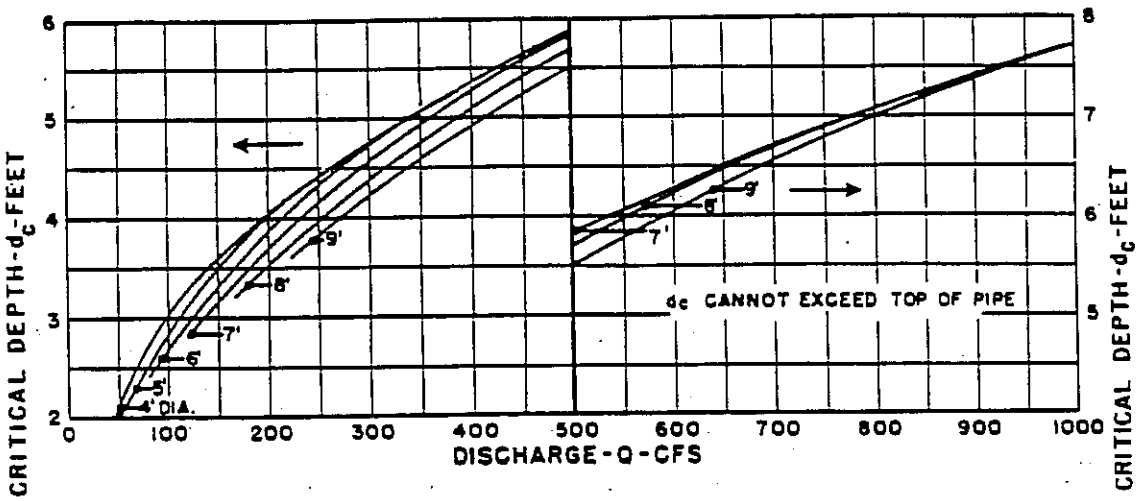


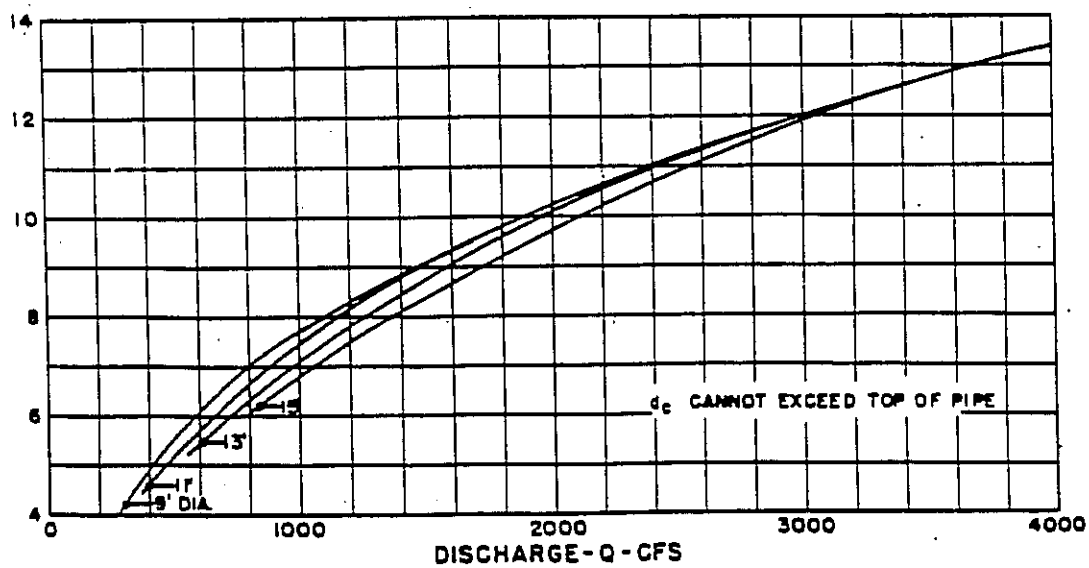
HEADWATER DEPTH FOR C. M. PIPE CULVERTS WITH INLET CONTROL

BUREAU OF PUBLIC ROADS JAN. 1963

CHART 4





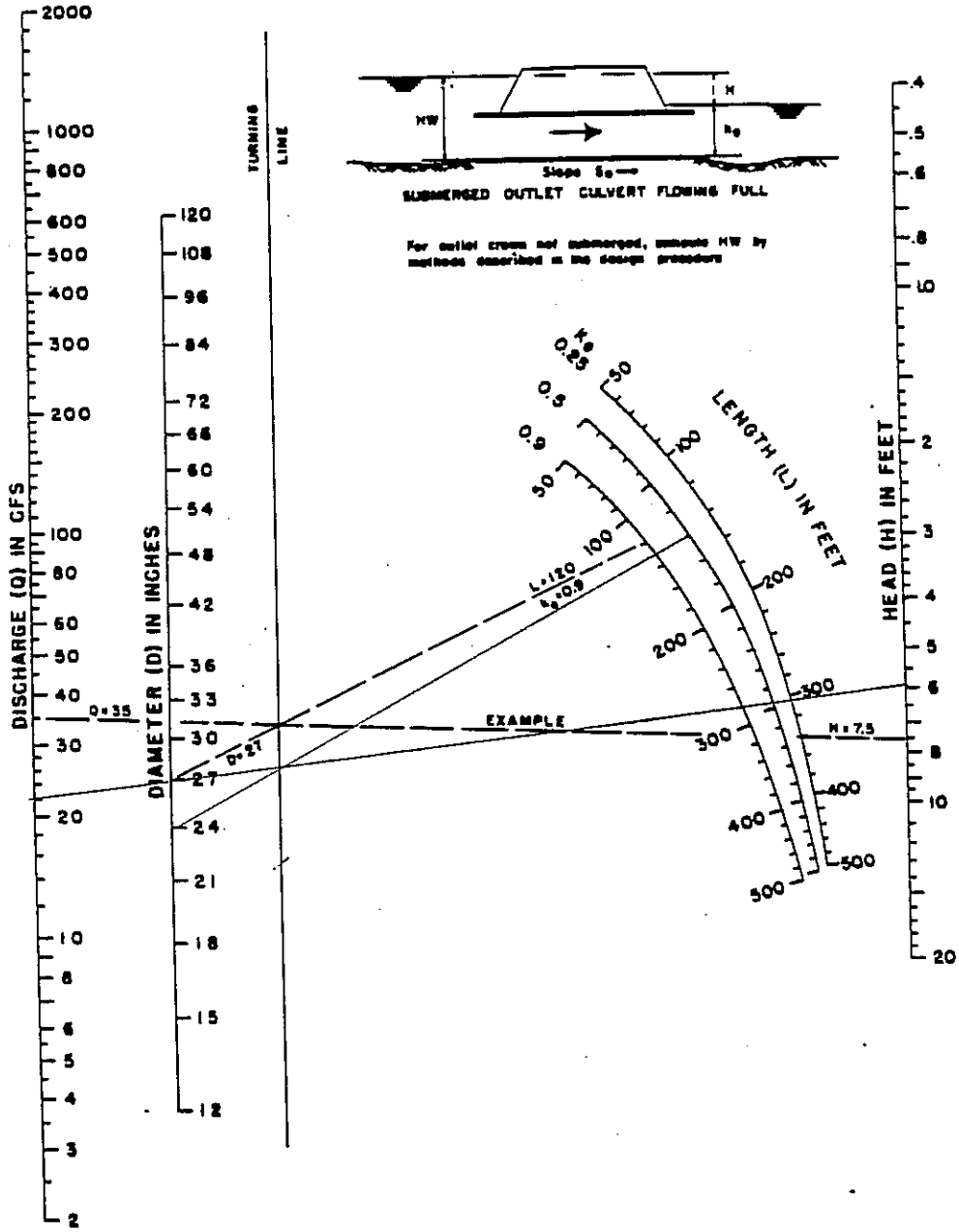


BUREAU OF PUBLIC ROADS

JAN. 1964

CRITICAL DEPTH
CIRCULAR PIPE

CHART 6



HEAD FOR
STANDARD
C. M. PIPE CULVERTS
FLOWING FULL
n = 0.024

BUREAU OF PUBLIC ROADS JAN. 1963

Job No. 6770-021-018 | No.

HDR Computation

HDR

Project	CITY OF GREENSBORO	Computed	Date
Subject	WHITE STREET SANITARY LANDFILL	Checked	Date
Task	DRAINAGE	Sheet	Of

DESIGN CULVERT FOR EAST SEDIMENT BASIN. $Q_{25} = 71$ CFS FOR 55 ACRE PHASE. EAST SEDIMENT BASIN PROVIDES DRAINAGE FOR 18.4 ACRES.

$Q \Rightarrow 18.4/55 = .33 \Rightarrow 71 \text{ CFS} \times .33 = \underline{23.4 \text{ CFS}}$

TRY 24" ϕ C.M.P. CULVERT

CHECK INLET CONTROL

$H_w/D = 1.6$ (FROM CHART 2)

$H_w = 1.6(2)$

$H_w = \underline{3.2 \text{ FT}}$

CHECK OUTLET CONTROL

$L = 120$ FT

$S = \frac{760-736}{120} = 0.2$

$d_c = 1.75$ FT (CHART 4)

FROM HEADLOSS NOMOGRAPH (CHART 6) $\Rightarrow H = 5.8$ FT

$h_o = \frac{d_c + D}{2} = \frac{1.75 + 2}{2} = 1.875$

$LS_o = 120(0.2) = 24$

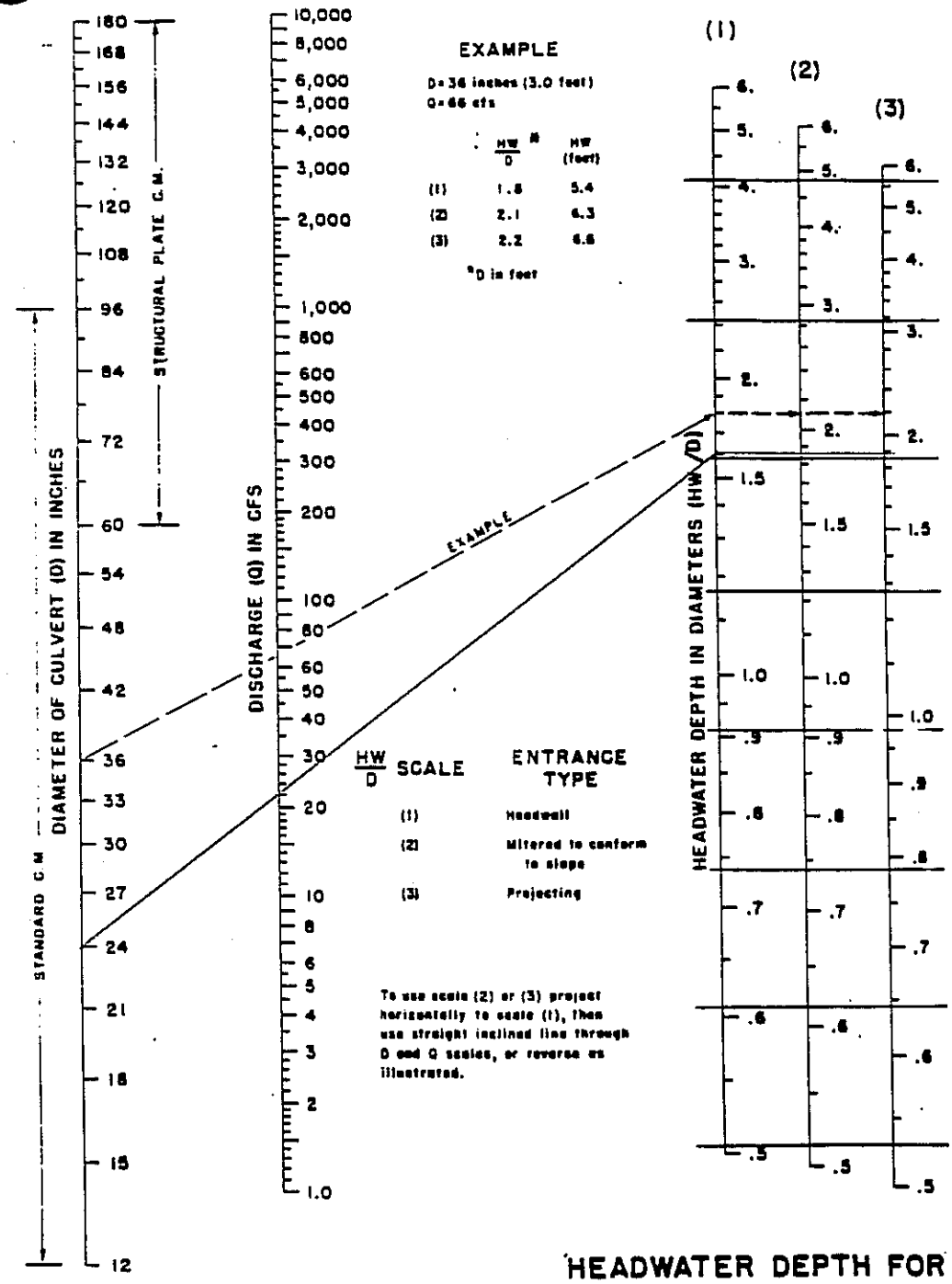
$H_w = H + h_o - LS_o$

$= 5.8 + 1.875 - 24$

$= -16.3$ FT

SAY $\underline{0 \text{ FT.}}$

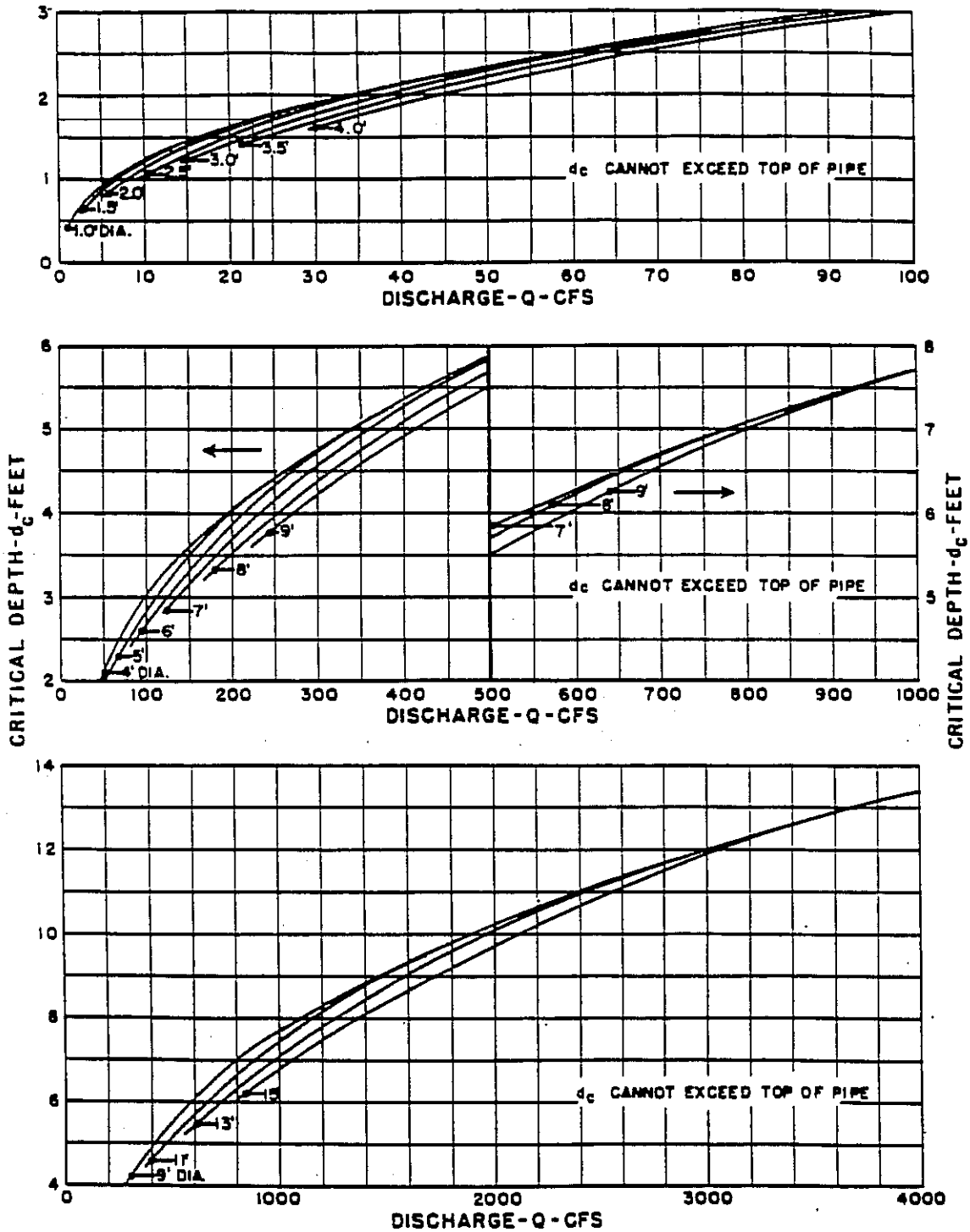
CHART 2



HEADWATER DEPTH FOR C. M. PIPE CULVERTS WITH INLET CONTROL

BUREAU OF PUBLIC ROADS JAN. 1963

CHART 4

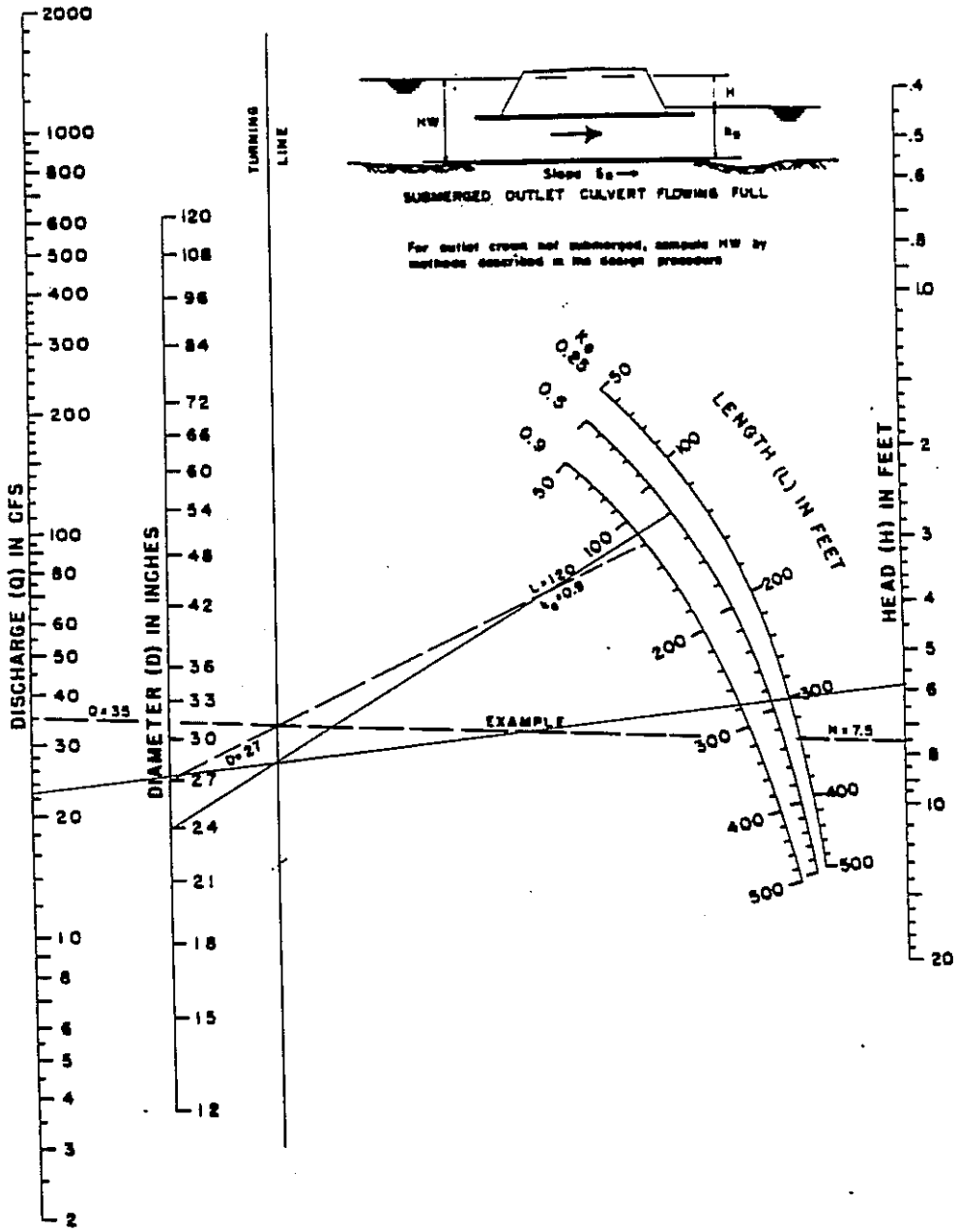


BUREAU OF PUBLIC ROADS

JAN. 1964

CRITICAL DEPTH
CIRCULAR PIPE

CHART 6



HEAD FOR
STANDARD
C. M. PIPE CULVERTS
FLOWING FULL
n = 0.024

BUREAU OF PUBLIC ROADS JAN. 1963

PROJECT HDR - GBORO. LF

SUBJECT Temporary Stormwater Pipe Sizing

SHEET 1 OF 2
JOB NO. HDRGN-2
DATE 11/21/95
COMPUTED BY PKS
CHECKED BY

— Objective: Evaluate the required size of temporary stormwater pipes based on the 25 yr storm.

— Assumptions:

1. Allow no overtopping of berms.
2. Assume entire storm acts on system at one time. (Very Conservative)

— Analysis: Use the Rational Method to calculate peak Flow (Q_p) in each pipe, based on area, intensity, infiltration, & design storm depth. Use Manning's Equation to size the pipe based on slope(s), peak flow, and Manning's number (n).

Equations:

Rational Method:

$$Q_p = CIA$$

Where: Q_p = Peak Flow (cfs)
C = Runoff Coef.
I* = Rainfall Intensity (in/hr)
A = Contributing Area (Ac)

*I is based on time of Concentration (t_c). Choose min. t_c = 5 min (Conservative)

Manning's Equation:

$$D_{req} = 16 \left[\frac{Q_p \cdot n}{\sqrt{S}} \right]^{.375}$$

— For Pipe Flowing Just Full

G.N. RICHARDSON & ASSOCIATES
CONSULTING ENGINEERING

DRAWN	JOB NO.	APPROVED	DATE	REVISED DATE

G.N. Richardson & Associates

ENGINEERING AND GEOLOGICAL SERVICES

SHEET: 2/2
JOB #: HDRGN-2
DATE: 11/21/95
BY: PKS
CHKD BY:

City of Greensboro
Analysis of Internal Cell Runoff
Temporary Stormwater Pipe Sizing

25 Year, 24 Hour Design Storm Depth = 6 inches (From NOAA HYDRO-35)

Size of Subcells:

Subcell #	Area (Ac.)	Subcell #	Area (Ac.)
1A	5.4	2C	3.9
1B	3.7	2D	2.5
1C	5.6	3A	6.7
1D	5.3	3B	6.0
2A	4.5	3C	4.1
2B	4.2		

Pipe Section	Pipe Slope (%)	Manning's Number	Contributing Subcells	Drainage Area (Ac.)	Runoff Coef. (c)	Volume (cf)	Qreq (cfs)	Dreq (in)	Pipe Selected (in)
Cell 1 Outlet	2.0	0.01	1B,1C,1D	14.6	0.5	317988	3.7	9.7	12" HDPE
Cell 1 Temporary	2.0	0.01	1B,1C,1D	14.6	0.5	317988	3.7	9.7	12" N12
Cell 2 Outlet	2.0	0.01	2A,2B,2C,2D	15.1	0.5	328878	3.8	9.8	12" HDPE
Cell 2 Temporary	2.5	0.01	2A,2B,2C,2D	15.1	0.5	328878	3.8	9.4	12" N12
Cell 3 Outlet	2.0	0.01	3A,3B,3C	16.8	0.5	365904	4.2	10.2	12" HDPE
Cell 3 Temporary	2.0	0.01	3A,3B,3C	16.8	0.5	365904	4.2	10.2	12" N12

USE 15" PIPE FOR EAST SIDE,
12" PIPE FOR INTERIOR DRAIN PIPE (CELL 1/2 INTERFACE)

TEMPPIP.WB1

Job No. 6770-021-018 | No.

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Project	CITY OF GREENSBORO	Computed DTD	Date 11-21-9.
Subject	WHITE STREET U/F	Checked	Date
Task	DRAINAGE	Sheet	Of

CHECK PIPE SIZE OF 15 ϕ STORMWATER PIPE DURING TOP OF OPERATIONAL COVER PHASE (SHEET C-4) FROM PREVIOUS SED BASIN CALC. BY EAW $Q_{25} = 71$ CFS FOR 55 ACRES THIS PARTICULAR PIPE WILL HANDLE 20 ACRES. THEREFORE Q FOR THIS PIPE IS $20/55 = .36 \Rightarrow Q = 71 \times .36 = \underline{25.6 \text{ CFS}}$.

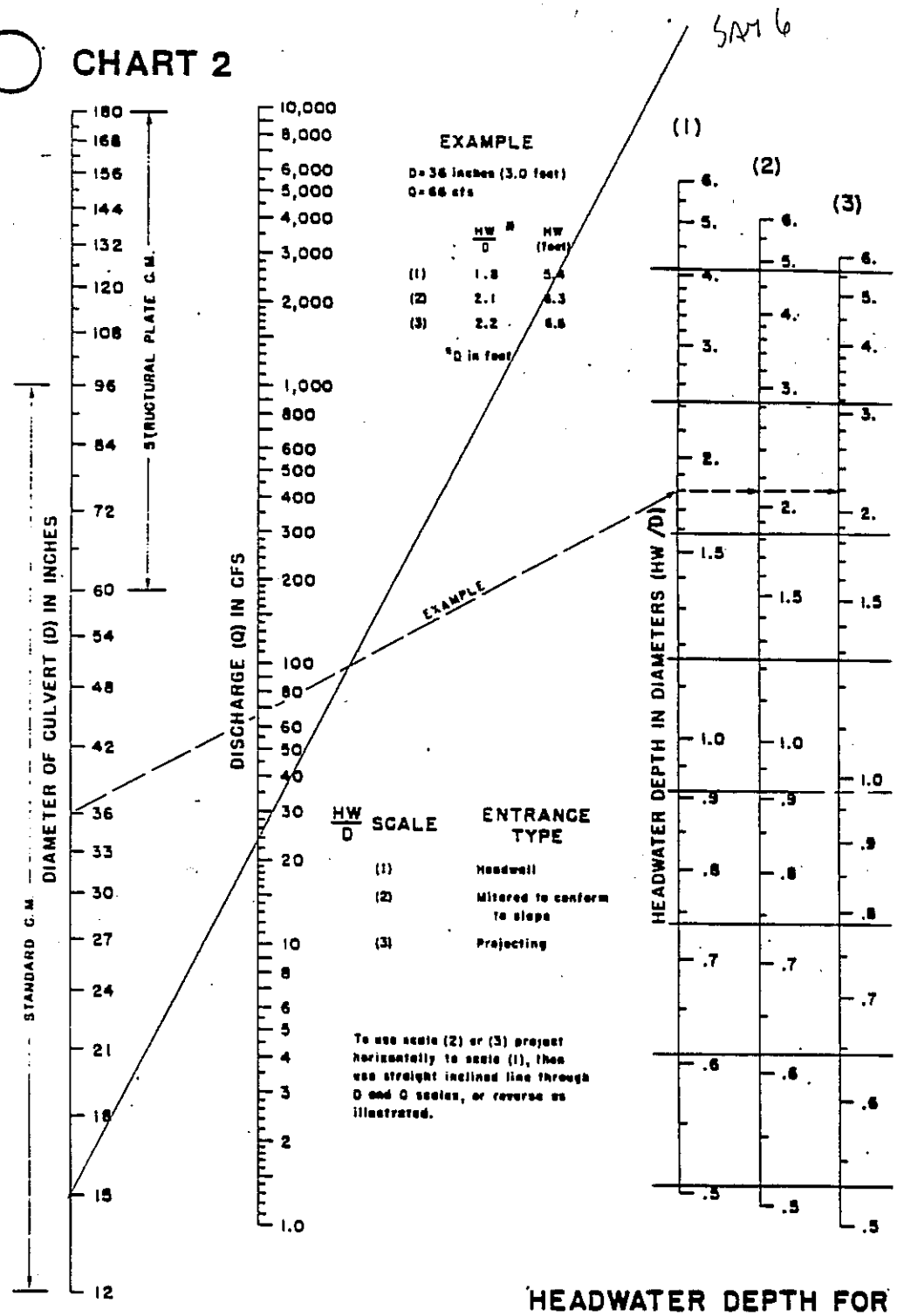
CHECK INLET CONTROL

$HW/D = 6.0$ (FROM CHART 2)

$HW = 1.25(6.0)$

$HW = \underline{7.5 \text{ FT}}$

CHART 2



HEADWATER DEPTH FOR C. M. PIPE CULVERTS WITH INLET CONTROL

BUREAU OF PUBLIC ROADS JAN. 1963

Job No. 6770-021-018 | No.

HDR Computation

HDR

Project	CITY OF GREENSBORO	Computed DTD	Date 11-22-95
Subject	WHITE STREET L/F	Checked	Date
Task	DRAINAGE	Sheet	Of

CHECK PIPE SIZE OF 12" ϕ STORMWATER PIPE DURING TOP OF OPERATIONAL COVER PHASE (SHEET C-4). FROM PREVIOUS SED. BASIN CALC. BY EAW $Q_{25} = 71$ CFS. FOR 55 ACRES. THIS PARTICULAR PIPE WILL HANDLE 15 ACRES. THEREFORE Q FOR THIS PIPE IS $15/55 = .27 \Rightarrow Q = 71 \times .27 = \underline{5.7 \text{ CFS}}$.

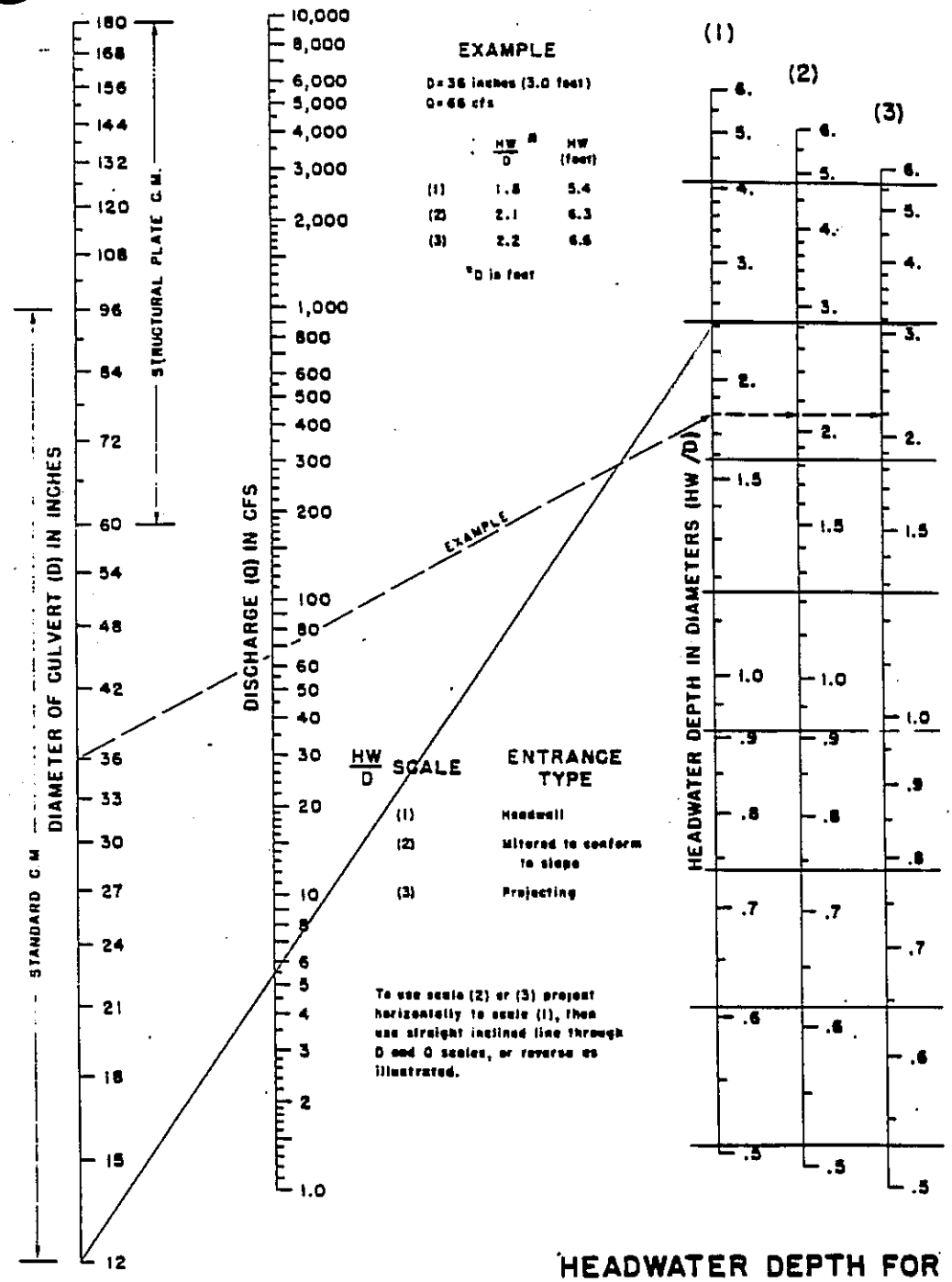
CHECK INLET CONTROL

$H_W/D = 2.4$ (FROM CHART 2)

$H_W = 1.0 (2.4)$

$H_W = \underline{2.4 \text{ FT}}$

CHART 2



HEADWATER DEPTH FOR C. M. PIPE CULVERTS WITH INLET CONTROL

BUREAU OF PUBLIC ROADS JAN. 1963

Job No. 6LN-021-018 | No.

HDR Computation

HDR

Project	CITY OF GREENSBORO	Computed DTD	Date 11-27-95
Subject	WHITE STREET SANITARY LANDFILL	Checked	Date
Task	TUMBLING FLOW CHANNEL	Sheet	Of

DESIGN CHANNEL LINING BETWEEN ELEMENTS

EVALUATE RIPRAP LINING USING THE FOLLOWING FORMULA AND FIGURE 165 FROM "HYDRAULIC DESIGN OF STILLING BASINS AND ENERGY DISSIPATORS"

$$V_{CR}^{1} = .663\left(2g\,\frac{w_s - w}{w}\right)^{1/2} \times d_{50}^{1/2} \times \left(3.38\cos\alpha - \sin\alpha\right)^{1/2}$$

V_{CR} = CRITICAL VELOCITY (FT/SEC)
g = gravitational acceleration ft/sec²
w_s = Specific gravity of stone = 2.65
w = Specific gravity of water = 1.00
d_{50} = STONE SIZE (50% PASSING) USE FIG. 165 = 6" = .5'
α = ANGLE MADE BY SURFACE W/ HORIZ. (°) = 14°

$$V_{CR} = .663\left(2(32.2)\,\frac{2.65-1.0}{1.0}\right)^{1/2} \times (.5)^{1/2} \times \left(3.38\cos 14° - \sin 14°\right)^{1/2}$$

$$= .663(10.31)(.707)(1.74) = 8.4 \text{ FT/SEC}$$

THE CRITICAL VELOCITY AS DEFINED IN REF (1) IS THE VALUE AT WHICH THE RIPRAP WILL BECOME UNSTABLE THEREFORE THE FOLLOWING COMPARISON IS MADE

SLOPE CRITICAL VELOCITY (V_{CR}) = 8.4 FT/SEC

DESIGN VELOCITY (V_c) = 5.2 FT/SEC

1 "CRITICAL VELOCITY AND SHEAR PROTECTION AT HYDRAULIC STRUCTURES" S. V. CHITALE

HDR Computation

HDR

Project	CITY OF GREENSBORO	Computed DTD	Date 11-27-95
Subject	WHITE STREET SANITARY LANDFILL	Checked	Date
Task	TUMBLING FLOW CHANNEL	Sheet	Of

CALCULATE DISTANCE BETWEEN ELEMENT

L/K IS 8.5 TO 10

$\therefore \quad L = 8.5(K) = 8.5(0.41) = 3.5$

$10(K) = 10(0.41) = 4.1$

CALCULATE CRITICAL VELOCITY

$$V_c = (g\,q)^{1/3}$$

$$V_c = ((32.2)(4.25\ i))^{1/3}$$

$$V_c = 5.2 \quad \text{FT/SEC}$$

REVIEW PARAMETERS

$Q_p = 17$ CFS
$b = 4$ FT
$S = 25$ %
$K = 0.41$ FT
$Y_1 = 0.92$ FT
$L = 4.0$ FT $\quad \therefore L/2 = 2$ FT
$V_c = 5.2$ FT/SEC
FREEBOARD = 0.5'

CALCULATE TOTAL DEPTH OF CHANNEL

$D_T = K + Y_1 + 0.5' = 1.83$ FT USE 2 FT

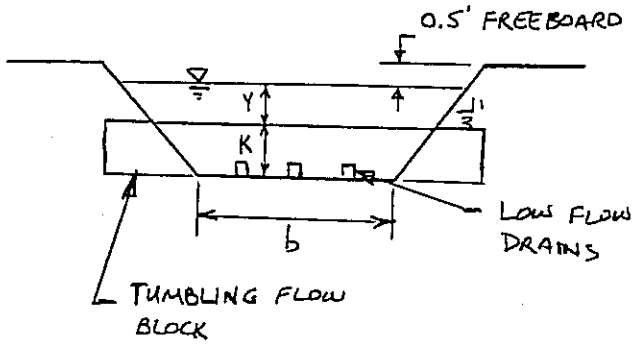
Job No. 6110-[illegible] No.

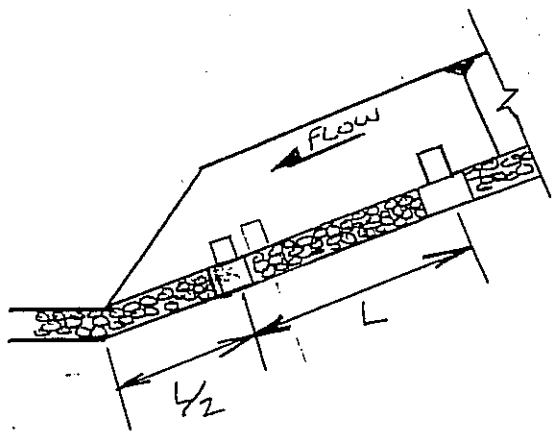
HDR Computation

HDR

Project	CITY OF GREENSBORO	Computed DTD	Date 11-27-9[illegible]
Subject	WHITE STREET SANITARY LANDFILL	Checked	Date
Task	TUMBLING FLOW CHANNEL	Sheet	Of

- THE DESIGN BASIS FOR TUMBLING FLOW CHANNELS IS PRESENTED IN THE TECHNICAL PAPER ENTITLED "HYDRAULICS OF ENERGY DISSIPATION IN STEEP ROUGH CHANNELS" BY HENRY MADISON MORRIS, NOVEMBER 1968, VIRGINIA POLYTECHNIC INSTITUTE, BLACKSBURG, VIRGINIA. ALSO IN A TECHNICAL PAPER TITLED "INNOVATION IN STORMWATER MANAGEMENT FOR LANDFILL CLOSURE" BY STEVEN M. GAMELSKY, SCS ENGINEERS
- THE DESIGN CONSISTS OF A TRAPEZOIDAL CHANNEL WITH CONCRETE OR TREATED LUMBER ACTING AS THE ENERGY DISSIPATOR ELEMENT WHICH ARE SPACED EVENLY THROUGHOUT THE DOWN CHUTE
- THE LAST BLOCK IS SPACED HALF THE SEPARATION DISTANCE UP SLOPE FROM THE PERIMETER CHANNEL





Job No. 6770-021-018 | No.

HDR Computation

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Subject	WHITE STREET SANITARY LANDFILL	Checked	Date
Task	TUMBLING FLOW CHANNEL	Sheet	Of

THE BASIC EQUATIONS WHICH GOVERN THE DESIGN ARE AS FOLLOWS:

1. $q = (16.5 - .206\ S)\ (K^{3/2})$

2. $Y_c = (q^2/g)^{1/3}$

3. $Y_1 = .35\ q^{2/3}$

4. $V_c = (gq)^{1/3}$

5. $L/K = 8.5$ to 10.0

6. $C_D = 1.4\ \left(\frac{(K)^3}{Y1} + 4\ \frac{(K)^2}{Y1} + 2.2\ \frac{(K)}{Y1} + .6 \right)$

7. $F_D = \frac{.97\ k\ q^2\ (C_D)}{(K + Y_1)^2}$

Where:

q = Unit discharge, cfs/ft of base width
S = Slope in percent
K = Height of element in ft.
g = 32.2 ft/sec^2
Y_1 = Control depth on maximum rise of water over element
V_c = Critical velocity; also the outlet velocity
C_D = Force coefficient
F_D = Force on elements, lbs/ft of transverse width
L = Length between elements, ft

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Task	TUMBLING FLOW CHANNEL	Sheet	Of

GIVEN A 25-YEAR, 24-HOUR STORM EVENT YIELDS A PEAK FLOW OF $Q_p = 17$ CFS FOR CHANNEL 3, DETERMINE A SIZE FOR A TUMBLING FLOW CHANNEL GIVEN THE BASIC EQUATIONS FOUND ON SHEET 2 :

ASSUME A BASE WIDTH (b) = 4 FT

CALCULATE UNIT DISCHARGE (q)

$$q = \frac{17 \text{ CFS}}{4 \text{ FT}} = 4.25 \text{ CFS/FT WIDTH}$$

CHANNEL SLOPE (S) = 25 (%)

CALCULATE THICKNESS (K) OF ENERGY DISSIPATOR ELEMENT

$$q = (16.5 - .206\,S)(K^{3/2})$$

SOLVE FOR K,

$$K = \left[\frac{4.25}{16.5 - .206(.25)}\right]^{2/3}$$

$$= 0.4056 \qquad \text{USE } 0.41$$

CALCULATE MAXIMUM RISE OF FLOW DEPTH OVER ELEMENT

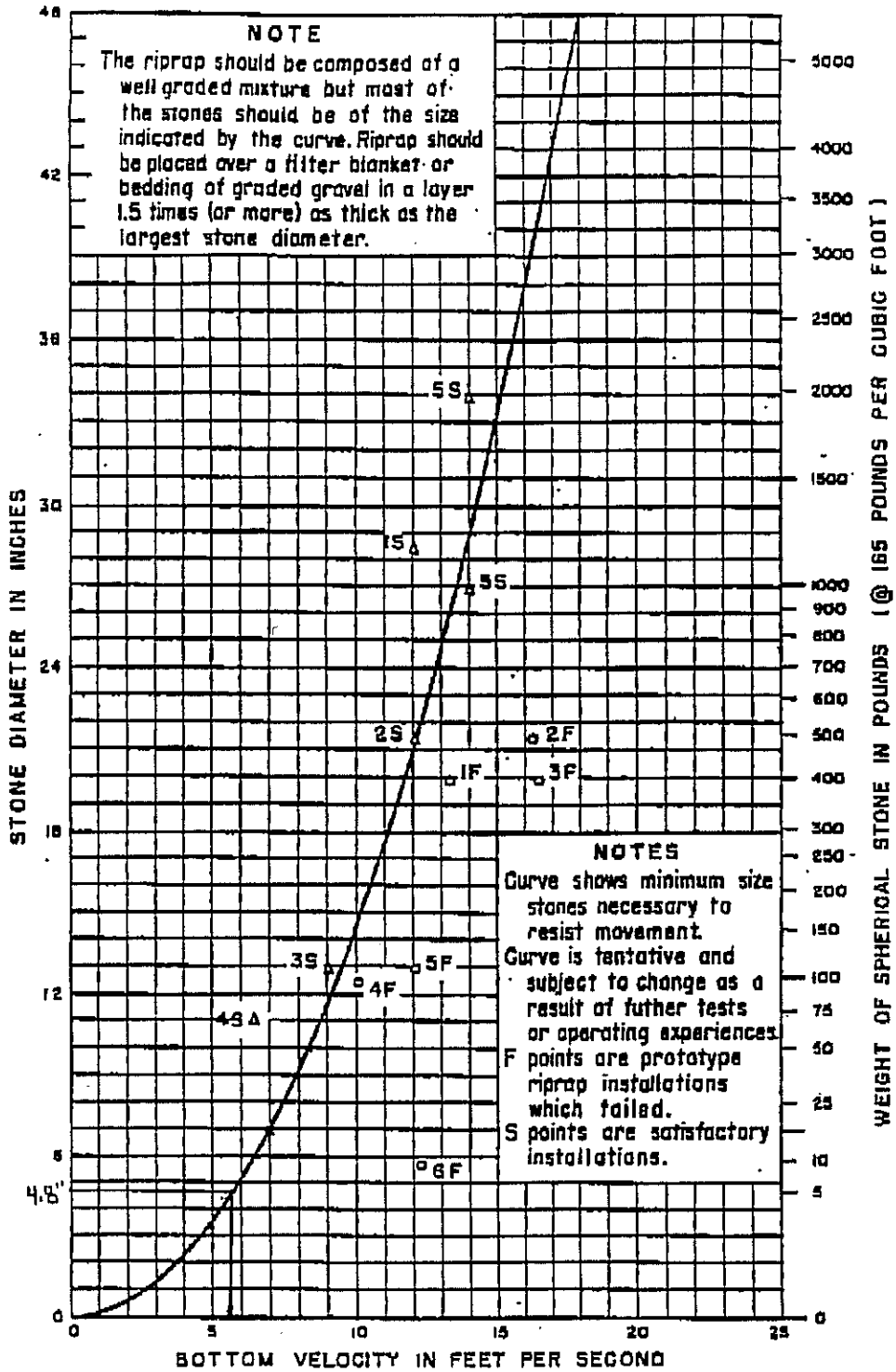
$$Y_1 = .35\, q^{2/3}$$

$$= .35\,(4.25)^{2/3}$$

$$= 0.92$$

Job No. 04093.PC
Sheet No. 5 of 5

SIZE OF RIPRAP TO BE USED DOWNSTREAM FROM STILLING BASINS



use d_{50}=6"

FIGURE 165.—*Curve to determine maximum stone size in riprap mixture.*

Source: Hydraulic Design of Stilling Basins and Energy Dissipators

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HDR Computation

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SEDIMENT

BASIN	FLOW (CFS)	VOL. (FT^3)	MIN. VOL (FT^3)	RISER	BARREL
NORTH (15 AC)	41.3	59,672	27,000	24" C.M.P.	18" C.M.P
NORTHWEST (17.5 AC)	59.5	88,704	31,500	24" C.M.P.	18" C.M.P.
SOUTHWEST (5.2 AC)	18.5	19,679	9,360	18" C.M.P.	12" C.M.P.
SOUTH (15.8 AC)	56.1	83,326	28,440	24" C.M.P.	18" C.M.P
EAST (18.4 AC)	65.3	195,100	33,120	24" C.M.P.	18" C.M.P
NORTHEAST (37 AC)	103.6	159,808	66,600	24" C.M.P.	18" C.M.P.

Table 8.03a
Value of Runoff Coefficient (C) for Rational Formula

Land Use	C
Business:	
Downtown areas	0.70-0.95
Neighborhood areas	0.50-0.70
Residential:	
Single-family areas	0.30-0.50
Multi units, detached	0.40-0.60
Multi units, attached	0.60-0.75
Suburban	0.25-0.40
Industrial:	
Light areas	0.50-0.80
Heavy areas	0.60-0.90
Parks, cemeteries	0.10-0.25
Playgrounds	0.20-0.35
Railroad yard areas	0.20-0.40
Unimproved areas	0.10-0.30
Streets:	
Asphalt	0.70-0.95
Concrete	0.80-0.95
Brick	0.70-0.85
Drives and walks	0.75-0.85
Roofs	0.75-0.85

Land Use	C
Lawns:	
Sandy soil, flat, 2%	0.05-0.10
Sandy soil, ave., 2-7%	0.10-0.15
Sandy soil, steep, 7%	0.15-0.20
Heavy soil, flat, 2%	0.13-0.17
Heavy soil, ave., 2-7%	0.18-0.22
Heavy soil, steep, 7%	0.25-0.35
Agricultural land:	
Bare packed soil	
Smooth	0.30-0.60
Rough	0.20-0.50
Cultivated rows	
Heavy soil no crop	0.30-0.60
Heavy soil with crop	0.20-0.50
Sandy soil no crop	0.20-0.40
Sandy soil with crop	0.10-0.25
Pasture	
Heavy soil	0.15-0.45
Sandy soil	0.05-0.25
Woodlands	0.05-0.25

NOTE: The designer must use judgment to select the appropriate C value within the range for the appropriate land use. Generally, larger areas with permeable soils, flat slopes, and dense vegetation should have lowest C values. Smaller areas with slowly permeable soils, steep slopes, and sparse vegetation should be assigned highest C values.

Source: American Society of Civil Engineers

The overland flow portion of flow time may be determined from Figure 8.03a. The flow time (in minutes) in the channel can be estimated by calculating the average velocity in feet per minute and dividing the length (in feet) by the average velocity.

Step 4. Determine the rainfall intensity, frequency, and duration (Figures 8.03b through 8.03g—source: North Carolina State Highway Commission; Jan. 1973). Select the chart for the locality closest to your location. Enter the "duration" axis of the chart with the calculated time of concentration, T_C. Move vertically until you intersect the curve of the appropriate design storm, then move horizontally to read the rainfall intensity factor, i, in inches per hour.

Step 5. Determine peak discharge, Q (ft^3/sec), by multiplying the previously determined factors using the rational formula (Sample Problem 8.03a).

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NORTH SEDIMENT BASIN (FIGURES AND TABLES COME FROM NC MANUAL)

TOTAL DRAINAGE AREA = 15 ACRES

$Q = CIA$ WHERE Q = RUNOFF, CFS
C = RUNOFF COEFFICIENT
I = RAINFALL INTENSITY, IN/HR
A = DRAINAGE AREA, ACRES

C = 0.5 ASSUMED (TABLE 8.03a)
L = 2050 FT
H = 46 FT
T_c = 12 min (FIG 8.03a)
I = 5.5 IN/HR (FIG. 8.03d)

$Q_{25} = 0.5\,(5.5)(15) = \underline{41.3 \text{ CFS}}$

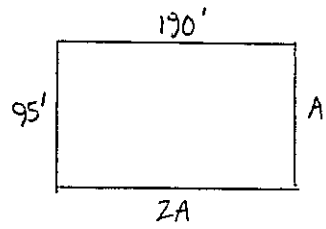
STORAGE REQUIRED = 1800 FT³/ACRE × 15 ACRES = 27,000 FT³

FOR 75% TRAPPING EFFICIENCY SURFACE AREA SHOULD BE:

.01 ACRE/CFS × 41.3 CFS = 0.413 ACRE = 17,990 FT²

APPROXIMATE SURFACE DIMENSIONS:

$2A^2 = 17{,}990 \text{ FT}^2$
$A = 95 \text{ FT}$



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MIN. DEPTH IN ORDER TO MEET STORAGE REQUIRED:

$$\frac{27{,}000\ FT^3}{17{,}900\ FT^2} = 1.5\ FT\ DEEP \quad (\text{IF SIDE SLOPES WERE } 0:1)$$

USE SIDE SLOPES 3:1

$$V = \left(\frac{A_1 + A_2}{2}\right)(H)$$

$$27{,}000\ FT^3 = \left(\frac{17{,}990\ FT^2 + A_2}{2}\right)(H)$$

H	A_2
1.5'	18,010 FT²
2.0'	9,010 FT²
3.0'	10 FT²

⟸ USE 2.0' DEPTH MIN.

$A_1 = 17{,}990\ FT^2$ BASIN SURFACE AREA (95' × 190')

$A_2 = 9{,}010\ FT^2$ BASIN FLOOR AREA

BASIN FLOOR DIMENSIONS: $2B^2 = 9{,}010\ FT^2$

$B = 67\ FT$

67' × 134'

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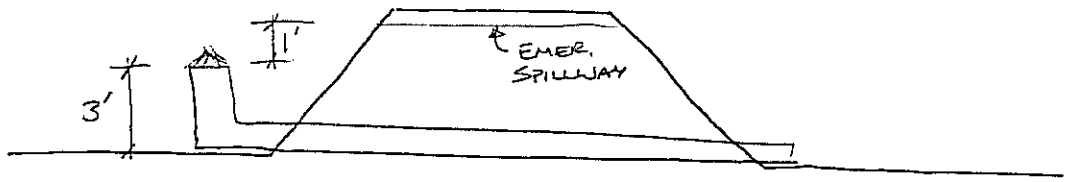
SIZE BARREL: MINIMUM CAPACITY FOR Q_P IS 0.2 CFS/ACRE

0.2 CFS/ACRE (15 ACRES) = 3 CFS

RISER HEIGHT
2x BARREL
DIAMETER



TRY 18" ϕ BARREL

$$H = 3' - \frac{18"\phi}{2(12)} = 2.25 \text{ FT}$$

FROM TABLE 8.07a, A 18" ϕ BARREL WILL CARRY A MIN. OF 7.73 CFS

USE 18" ϕ BARREL C.M.P.

SIZE RISER: FROM FIGURE 8.07b, H = 1 FT TRY A 24" ϕ RISER
FOR A 24" ϕ RISER WITH H = 1 FT., Q = 20.0 CFS

20 CFS > 7.73 CFS ∴ BARREL CONTROLS, OKAY

USE 24" ϕ RISER C.M.P.

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EMERGENCY SPILLWAY:

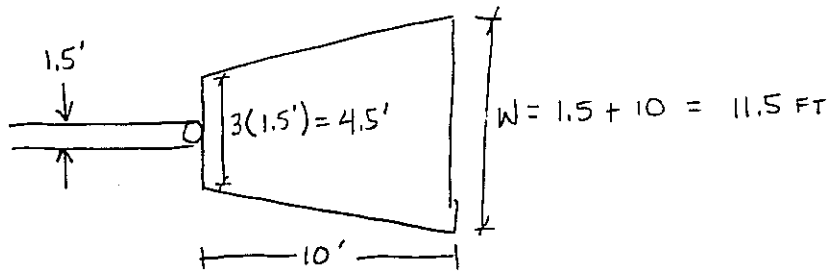
$$Q_e = Q_{25} - Q_p$$
$$= 41.3 \text{ CFS} - 7.73 \text{ CFS}$$
$$= 33.6 \text{ CFS}$$

FROM TABLE 8.07 c FOR Q = 35 CFS
BOTTOM WIDTH = 24 FT
MAX. SLOPE = 14.1 %
STAGE = 0.77 FT.

OUTLET STABILIZATION:

BARREL DISCHARGE = 7.73 CFS

FROM FIGURE 8.06 a: $d_{50} = 6''$; $L_a = 10$ FT



$d_{max} = 1.5\, d_{50} = 9''$

DEPTH = $1.5\, d_{max} = 13.5''$

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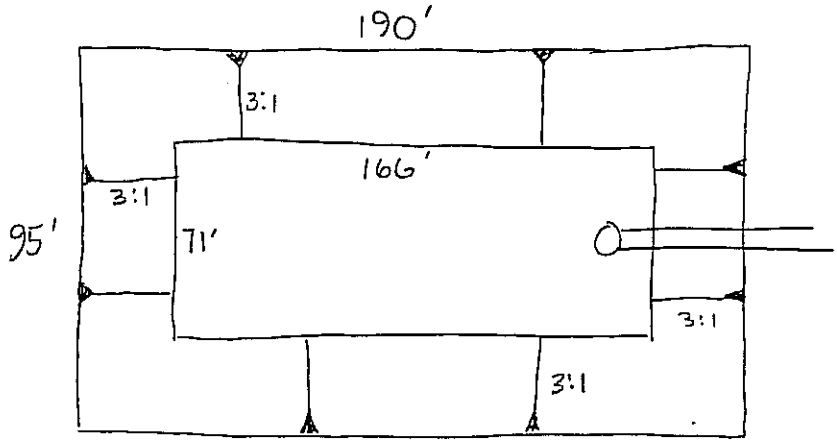
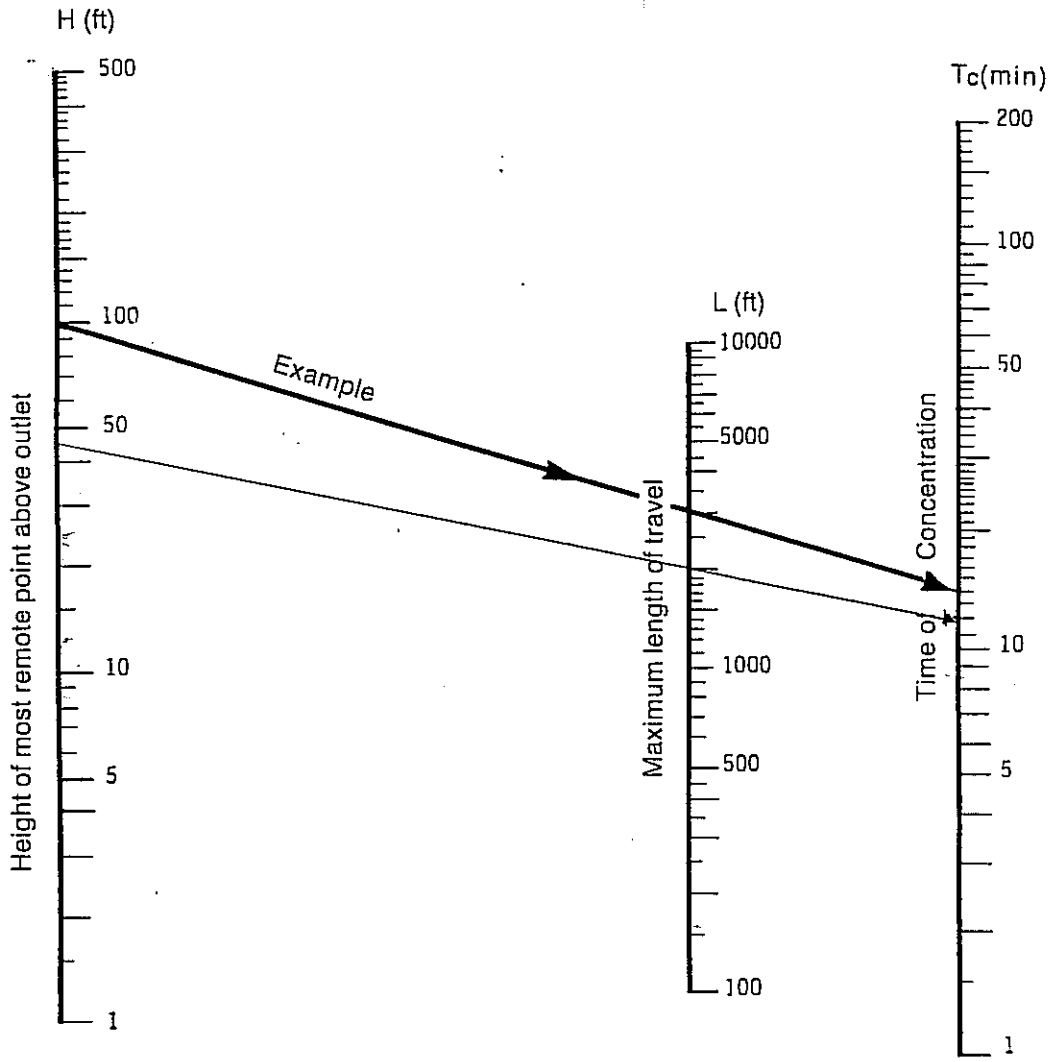


TOTAL VOLUME = A_1 = 18,050 FT^2

A_2 = 11,786 FT^2

H = 4 FT

VOL = 59,672 FT^3 > 27,000 FT^3 MIN



Note:
Use nomograph Tc for natural basins with well-defined channels, for overland flow on bare earth, and for mowed-grass roadside channels.

For overland flow, grassed surfaces, multiply Tc by 2.

For overland flow, concrete or asphalt surfaces, multiply Tc by 0.4.

For concrete channels, multiply Tc by 0.2.

Figure 8.03a Time of concentration of small drainage basins.

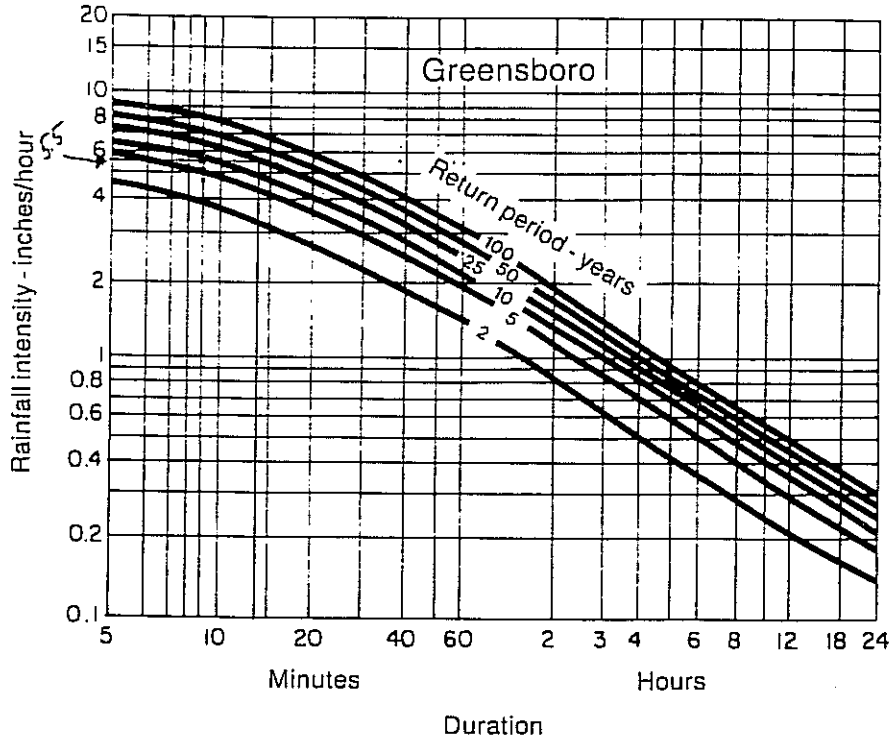


Figure 8.03d Rainfall intensity duration curves—Greensboro.

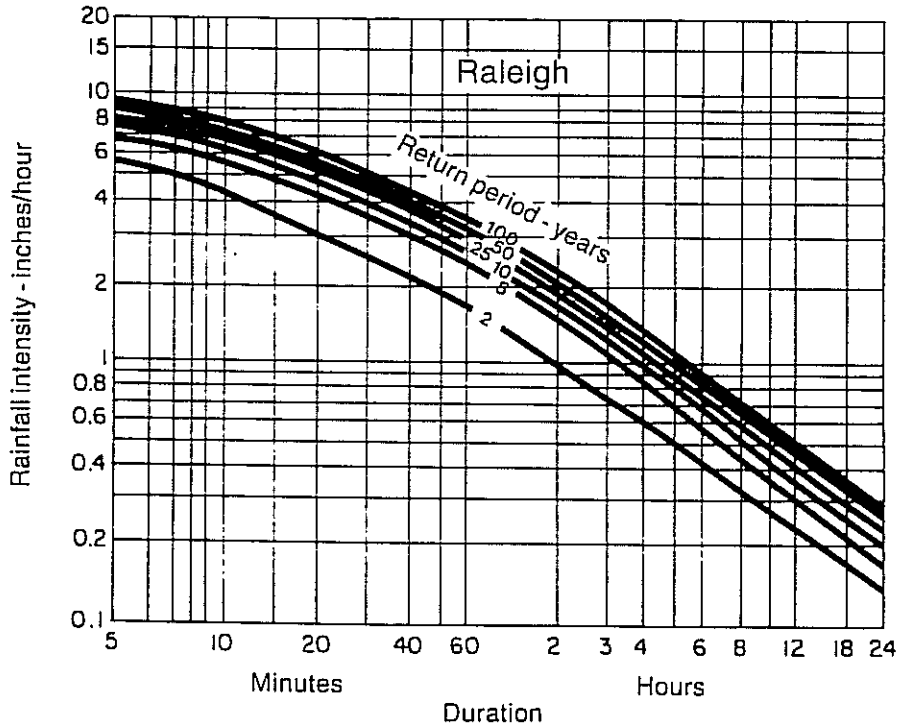


Figure 8.03e Rainfall intensity duration curves—Raleigh.

Table 8.07c
Design Table for Vegetated Spillways Excavated in Erosion Resistant Soils
(side slopes–3 horizontal:1 vertical)

Discharge Q CFS	Slope Range Minimum Percent	Slope Range Maximum Percent	Bottom Width Feet	Stage Feet
15	3.3	12.2	8	.83
	3.5	18.2	12	.69
20	3.1	8.9	8	.97
	3.2	13.0	12	.81
	3.3	17.3	16	.70
25	2.9	7.1	8	1.09
	3.2	9.9	12	.91
	3.3	13.2	16	.79
	3.3	17.2	20	.70
30	2.9	6.0	8	1.20
	3.0	8.2	12	1.01
	3.0	10.7	16	.88
	3.3	13.8	20	.78
35	2.8	5.1	8	1.30
	2.9	6.9	12	1.10
	3.1	9.0	16	.94
	3.1	11.3	20	.85
	3.2	14.1	24	.77
40	2.7	4.5	8	1.40
	2.9	6.0	12	1.18
	2.9	7.6	16	1.03
	3.1	9.7	20	.91
	3.1	11.9	24	.83
45	2.6	4.1	8	1.49
	2.8	5.3	12	1.25
	2.9	6.7	16	1.09
	3.0	8.4	20	.98
	3.0	10.4	24	.89
50	2.7	3.7	8	1.57
	2.8	4.7	12	1.33
	2.8	6.0	16	1.16
	2.9	7.3	20	1.03
	3.1	9.0	24	.94
60	2.6	3.1	8	1.73
	2.7	3.9	12	1.47
	2.7	4.8	16	1.28
	2.9	5.9	20	1.15
	2.9	7.3	24	1.05
	3.0	8.6	28	.97
70	2.5	2.8	8	1.88
	2.6	3.3	12	1.60
	2.6	4.1	16	1.40
	2.7	5.0	20	1.26
	2.8	6.1	24	1.15
	2.9	7.0	28	1.05
80	2.5	2.9	12	1.72
	2.6	3.6	16	1.51
	2.7	4.3	20	1.35
80	2.8	5.2	24	1.24
	2.8	5.9	28	1.14
	2.9	7.0	32	1.06
90	2.5	2.6	12	1.84
	2.5	3.1	16	1.61
	2.6	3.8	20	1.45
	2.7	4.5	24	1.32
	2.8	5.3	28	1.22
	2.8	6.1	32	1.14
100	2.5	2.8	16	1.71
	2.6	3.3	20	1.54
	2.6	4.0	24	1.41
	2.7	4.8	28	1.30
	2.7	5.3	32	1.21
	2.8	6.1	36	1.13
120	2.5	2.6	20	1.71
	2.6	3.2	24	1.56
	2.7	3.8	28	1.44
	2.7	4.2	32	1.34
	2.7	4.8	36	1.26
140	2.5	2.7	24	1.71
	2.5	3.2	28	1.58
	2.6	3.6	32	1.47
	2.6	4.0	36	1.38
	2.7	4.5	40	1.30
160	2.5	2.7	28	1.70
	2.5	3.1	32	1.58
	2.6	3.4	36	1.49
	2.6	3.8	40	1.40
	2.7	4.3	44	1.33
180	2.4	2.7	32	1.72
	2.4	3.0	36	1.60
	2.5	3.4	40	1.51
	2.6	3.7	44	1.43
200	2.5	2.7	36	1.70
	2.5	2.9	40	1.60
	2.5	3.3	44	1.52
	2.6	3.6	48	1.45
220	2.4	2.6	40	1.70
	2.5	2.9	44	1.61
	2.5	3.2	48	1.53
240	2.5	2.6	44	1.70
	2.5	2.9	48	1.62
	2.6	3.2	52	1.54
260	2.4	2.6	48	1.70
	2.5	2.9	52	1.62
280	2.4	2.6	52	1.70
300	2.5	2.6	56	1.69

Example of Use

Given: Discharge, Q = 87 c.f.s. Spillway slope, Exit section (from profile) = 4%.

Find: Bottom width and Stage in Reservoir.

Procedure: Enter table from left at 90 c.f.s. Note that spillway slope (4%) falls within slope ranges corresponding to bottom widths of 24, 28, and 32 ft. Use bottom width, 32 ft, to minimize velocity. Stage in Reservoir will be 1.14 ft.

Note: Computations based on: Roughness coefficient, n = .040. Maximum velocity = 5.50 ft per sec.

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HDR Computation

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NORTHWEST SEDIMENT BASIN (FIGURES AND TABLES COME FROM NC MANUAL)

TOTAL DRAINAGE AREA = 17.5 ACRES

$Q = CIA$ WHERE Q = RUNOFF, CFS
C = RUNOFF COEFFICIENT
I = RAINFALL INTENSITY, IN/HR
A = DRAINAGE AREA, ACRES

C = 0.5 ASSUMED (TABLE 8.03a)
L = 1860 FT
H = 94 FT
T_c = 8 min (FIG 8.03a)
I = 6.8 IN/HR (FIG. 8.03d)

$Q_{25} = 0.5\,(6.8)(17.5) = \underline{59.5 \text{ CFS}}$

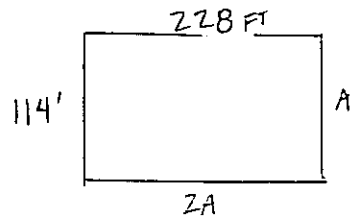
STORAGE REQUIRED = 1800 FT³/ACRE × 17.5 ACRES = 31,500 FT³

FOR 75% TRAPPING EFFICIENCY SURFACE AREA SHOULD BE:

.01 ACRE/CFS × 59.5 CFS = 0.595 ACRE = 25,918 FT²

APPROXIMATE SURFACE DIMENSIONS:

$2A^2 = 25{,}918 \text{ FT}^2$
$A = 114 \text{ FT}$



Job No. 6770-021-018 | No.

HDR Computation

HDR

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MIN. DEPTH IN ORDER TO MEET STORAGE REQUIRED:

$$\frac{31{,}500\ FT^3}{25{,}918\ FT^2} = 1.2\ FT\ DEEP \quad (\text{IF SIDE SLOPES WERE } 0:1)$$

USE SIDE SLOPES 3:1

$$V = \left(\frac{A_1 + A_2}{2}\right)(H)$$

$$31{,}500\ FT^3 = \left(\frac{25{,}918\ FT^2 + A_2}{2}\right)(H)$$

H	A_2
1.2'	26,582 FT²
2.0'	5,582 FT² ⟸ USE 2.0' DEPTH MIN.
3.0'	-4,918 FT²

$A_1 = 25{,}918\ FT^2$ BASIN SURFACE AREA (114' x 228')

$A_2 = 5{,}582\ FT^2$ BASIN FLOOR AREA

BASIN FLOOR DIMENSIONS: $2B^2 = 5{,}582\ FT^2$

$B = 53\ FT$

53' x 106'

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HDR

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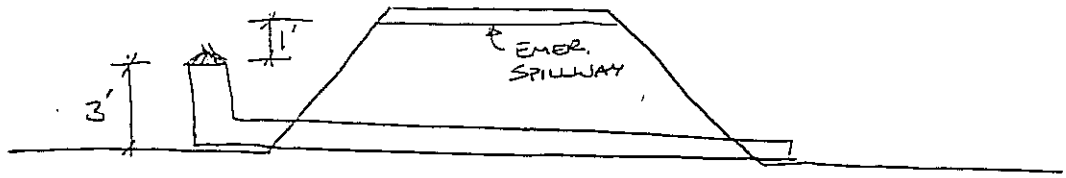
SIZE BARREL: MINIMUM CAPACITY FOR Q_P IS 0.2 CFS/ACRE

0.2 CFS/ACRE (17.5 ACRES) = 3.5 CFS

RISER HEIGHT
2x BARREL
DIAMETER



TRY 18" ϕ BARREL

$$H = 3' - \frac{18''\phi}{2(12)} = 2.25 \text{ FT}$$

FROM TABLE 8.07a, A 18" ϕ BARREL WILL CARRY A MIN. OF 7.73 CFS

USE 18" ϕ BARREL C.M.P.

SIZE RISER: FROM FIGURE 8.07b, H = 1 FT TRY A 24" ϕ RISER
FOR A 24" ϕ RISER WITH H = 1 FT., Q = 20.0 CFS

20.0 CFS > 7.73 CFS ∴ BARREL CONTROLS, OKAY

USE 24" ϕ RISER C.M.P.

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HDR Computation

HDR

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Task: DRAINAGE		Sheet	Of

EMERGENCY SPILLWAY:

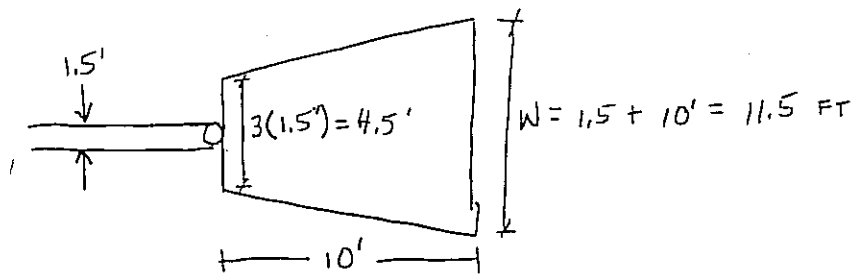
$$Q_e = Q_{25} - Q_p$$
$$= 59.5 \text{ CFS} - 7.73 \text{ CFS}$$
$$= 51.8 \text{ CFS}$$

FROM TABLE 8.07 c FOR Q = 50 CFS
BOTTOM WIDTH = 24 FT
MAX. SLOPE = 9.0 %
STAGE = 0.94 FT.

OUTLET STABILIZATION:

BARREL DISCHARGE = 7.73 CFS

FROM FIGURE 8.06 a: d_{50} = 6" ; L_2 = 10 FT



$d_{max} = 1.5\, d_{50} = 9''$

DEPTH = $1.5\, d_{max} = 13.5''$

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HDR

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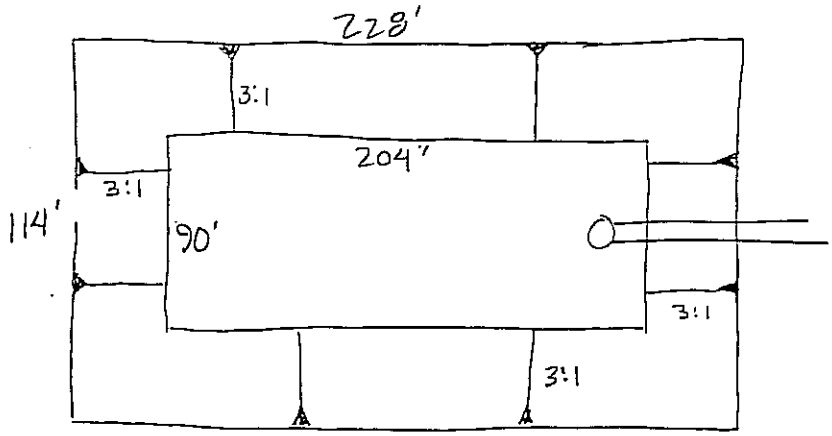
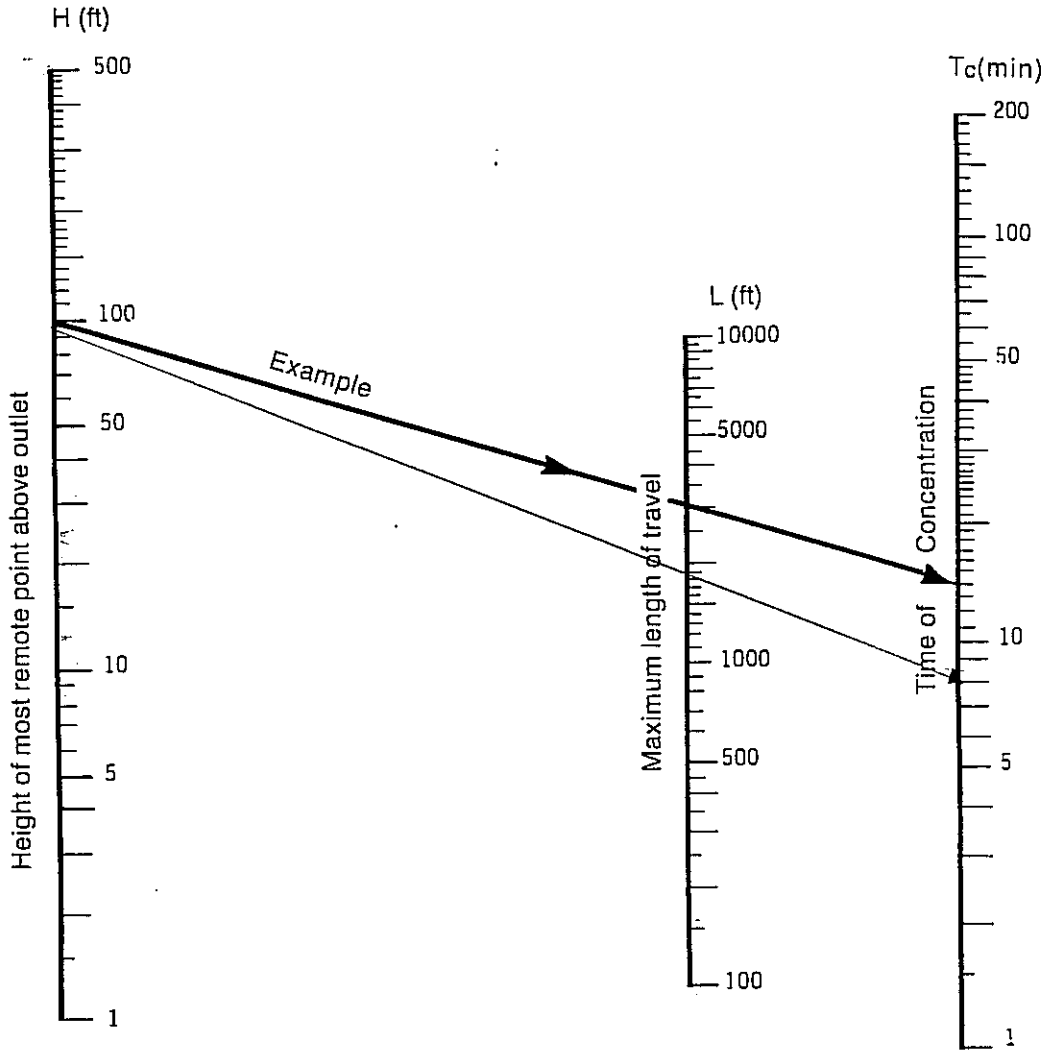


TOTAL VOLUME = A_1 = 25,992 FT^2

A_2 = 18,360 FT^2

H = 4 FT

VOL = 88,704 FT^3 > 31,500 FT^3 MIN



Note:
Use nomograph Tc for natural basins with well-defined channels, for overland flow on bare earth, and for mowed-grass roadside channels.

For overland flow, grassed surfaces, multiply Tc by 2.

For overland flow, concrete or asphalt surfaces, multiply Tc by 0.4.

For concrete channels, multiply Tc by 0.2.

Figure 8.03a Time of concentration of small drainage basins.

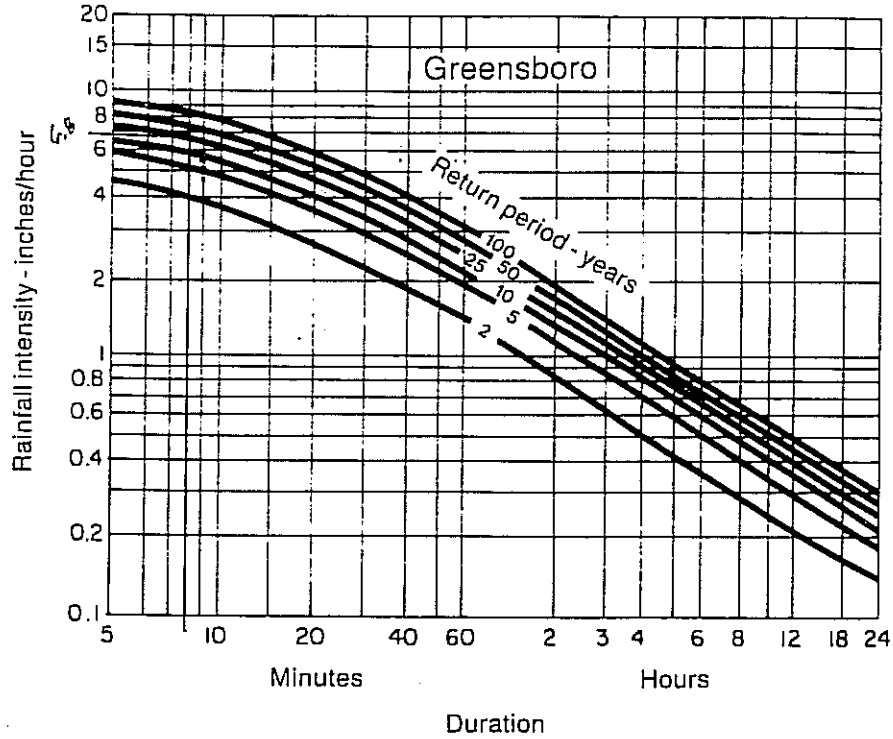


Figure 8.03d Rainfall intensity duration curves—Greensboro.

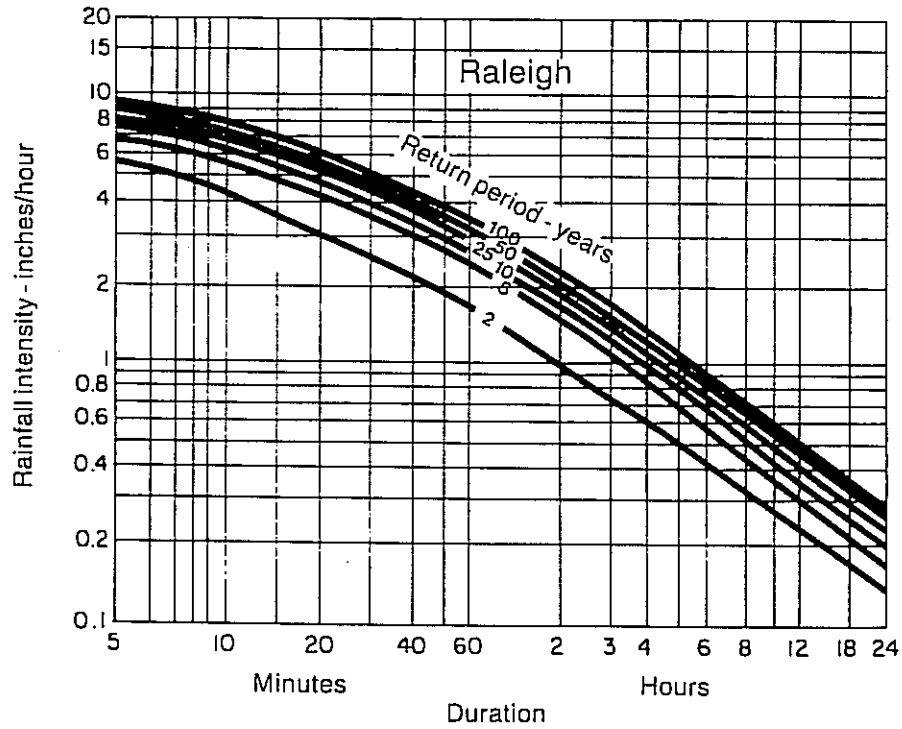


Figure 8.03e Rainfall intensity duration curves—Raleigh.

Table 8.07c
Design Table for Vegetated Spillways Excavated in Erosion Resistant Soils
(side slopes–3 horizontal:1 vertical)

Discharge Q CFS	Slope Range Minimum Percent	Slope Range Maximum Percent	Bottom Width Feet	Stage Feet
15	3.3	12.2	8	.83
	3.5	18.2	12	.69
20	3.1	8.9	8	.97
	3.2	13.0	12	.81
	3.3	17.3	16	.70
25	2.9	7.1	8	1.09
	3.2	9.9	12	.91
	3.3	13.2	16	.79
	3.3	17.2	20	.70
30	2.9	6.0	8	1.20
	3.0	8.2	12	1.01
	3.0	10.7	16	.88
	3.3	13.8	20	.78
35	2.8	5.1	8	1.30
	2.9	6.9	12	1.10
	3.1	9.0	16	.94
	3.1	11.3	20	.85
	3.2	14.1	24	.77
40	2.7	4.5	8	1.40
	2.9	6.0	12	1.18
	2.9	7.6	16	1.03
	3.1	9.7	20	.91
	3.1	11.9	24	.83
45	2.6	4.1	8	1.49
	2.8	5.3	12	1.25
	2.9	6.7	16	1.09
	3.0	8.4	20	.98
	3.0	10.4	24	.89
50	2.7	3.7	8	1.57
	2.8	4.7	12	1.33
	2.8	6.0	16	1.16
	2.9	7.3	20	1.03
	3.1	9.0	24	.94
60	2.6	3.1	8	1.73
	2.7	3.9	12	1.47
	2.7	4.8	16	1.28
	2.9	5.9	20	1.15
	2.9	7.3	24	1.05
	3.0	8.6	28	.97
70	2.5	2.8	8	1.88
	2.6	3.3	12	1.60
	2.6	4.1	16	1.40
	2.7	5.0	20	1.26
	2.8	6.1	24	1.15
	2.9	7.0	28	1.05
80	2.5	2.9	12	1.72
	2.6	3.6	16	1.51
	2.7	4.3	20	1.35

Discharge Q CFS	Slope Range Minimum Percent	Slope Range Maximum Percent	Bottom Width Feet	Stage Feet
80	2.8	5.2	24	1.24
	2.8	5.9	28	1.14
	2.9	7.0	32	1.06
90	2.5	2.6	12	1.84
	2.5	3.1	16	1.61
	2.6	3.8	20	1.45
	2.7	4.5	24	1.32
	2.8	5.3	28	1.22
	2.8	6.1	32	1.14
100	2.5	2.8	16	1.71
	2.6	3.3	20	1.54
	2.6	4.0	24	1.41
	2.7	4.8	28	1.30
	2.7	5.3	32	1.21
	2.8	6.1	36	1.13
120	2.5	2.8	20	1.71
	2.6	3.2	24	1.56
	2.7	3.8	28	1.44
	2.7	4.2	32	1.34
	2.7	4.8	36	1.26
140	2.5	2.7	24	1.71
	2.5	3.2	28	1.58
	2.6	3.6	32	1.47
	2.6	4.0	36	1.36
	2.7	4.5	40	1.30
160	2.5	2.7	28	1.70
	2.5	3.1	32	1.58
	2.6	3.4	36	1.49
	2.6	3.8	40	1.40
	2.7	4.3	44	1.33
180	2.4	2.7	32	1.72
	2.4	3.0	36	1.60
	2.5	3.4	40	1.51
	2.6	3.7	44	1.43
200	2.5	2.7	36	1.70
	2.5	2.9	40	1.60
	2.5	3.3	44	1.52
	2.6	3.6	48	1.45
220	2.4	2.6	40	1.70
	2.5	2.9	44	1.61
	2.5	3.2	48	1.53
240	2.5	2.6	44	1.70
	2.5	2.9	48	1.62
	2.6	3.2	52	1.54
260	2.4	2.6	48	1.70
	2.5	2.9	52	1.62
280	2.4	2.6	52	1.70
300	2.5	2.6	56	1.69

Example of Use

Given: Discharge, Q = 87 c.f.s. Spillway slope, Exit section (from profile) = 4%.

Find: Bottom width and Stage in Reservoir.

Procedure: Enter table from left at 90 c.f.s. Note that spillway slope (4%) falls within slope ranges corresponding to bottom widths of 24, 28, and 32 ft. Use bottom width, 32 ft, to minimize velocity. Stage in Reservoir will be 1.14 ft.

Note: Computations based on: Roughness coefficient, n = .040. Maximum velocity = 5.50 ft per sec.

Job No. 6 1 70- 0 0 0 0 | No.

HDR Computation

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SOUTHWEST SEDIMENT BASIN (FIGURES AND TABLES COME FROM NC MANUAL)

TOTAL DRAINAGE AREA = 5.2 ACRES

$Q = CIA$ WHERE Q = RUNOFF, CFS
C = RUNOFF COEFFICIENT
I = RAINFALL INTENSITY, IN/HR
A = DRAINAGE AREA, ACRES

C = 0.5 ASSUMED (TABLE 8.03a)
L = 600 FT
H = 30 FT
T_c = 3.5 min (FIG 8.03a)
I = 7.1 IN/HR (FIG. 8.03d)

$Q_{25} = 0.5\,(7.1)(5.2) = \underline{18.5 \text{ CFS}}$

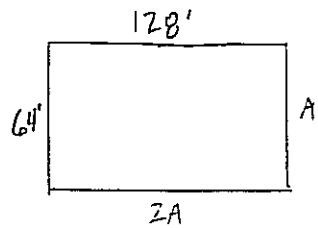
STORAGE REQUIRED = 1800 FT³/ACRE × 5.2 ACRES = 9,360 FT³

FOR 75% TRAPPING EFFICIENCY SURFACE AREA SHOULD BE:

.01 ACRE/CFS × 18.5 CFS = 0.185 ACRE = 8,059 FT²

APPROXIMATE SURFACE DIMENSIONS:

$2A^2 = 8{,}059$ FT²
$A = 64$ FT



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HDR Computation

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MIN. DEPTH IN ORDER TO MEET STORAGE REQUIRED:

$$\frac{9,360 \text{ FT}^3}{8,059 \text{ FT}^2} = 1.2 \text{ FT DEEP}$$ (IF SIDE SLOPES WERE 0:1)

USE SIDE SLOPES 3:1

$$V = \left(\frac{A_1 + A_2}{2}\right)(H)$$

$$9,360 \text{ FT}^3 = \left(\frac{8,059 \text{ FT}^2 + A_2}{2}\right)(H)$$

H	A_2
1.5	4,421 FT²
2.0	1,301 FT² ⟸ USE 2.0' DEPTH MIN.
3.0	-1,819 FT²

$A_1 = 8,059$ FT² BASIN SURFACE AREA (64' x 128')

$A_2 = 1,301$ FT² BASIN FLOOR AREA

BASIN FLOOR DIMENSIONS: $2B^2 = 1,301$ FT²

$B = 26$ FT

26' x 52'

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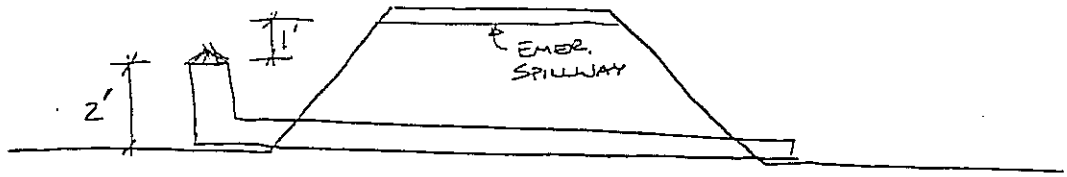
SIZE BARREL: MINIMUM CAPACITY FOR Q_P IS 0.2 CFS/ACRE

0.2 CFS/ACRE (5.2 ACRES) = 1.04 CFS

RISER HEIGHT 2x BARREL DIAMETER



TRY 12" ϕ BARREL

$$H = 2' - \frac{12''\phi}{2(12)} = 1.5 \text{ FT}$$

FROM TABLE 8.07a, A 12" ϕ BARREL WILL CARRY A MIN. OF 2.84 CFS

USE 12" ϕ BARREL C.M.P.

SIZE RISER: FROM FIGURE 8.07b, H = 1 FT TRY A 18" ϕ RISER
FOR A 18" ϕ RISER WITH H = 1 FT., Q = 15.5 CFS

15.5 CFS > 2.84 CFS ∴ BARREL CONTROLS, OKAY

USE 18" ϕ RISER C.M.P.

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EMERGENCY SPILLWAY:

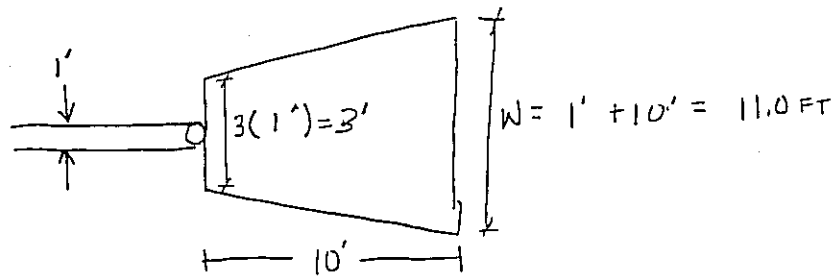
$$Q_e = Q_{25} - Q_p$$
$$= 18.5 \text{ CFS} - 2.84 \text{ CFS}$$
$$= 15.7 \text{ CFS}$$

FROM TABLE 8.07 c FOR Q = 15 CFS
BOTTOM WIDTH = 12 FT
MAX. SLOPE = 18.2 %
STAGE = 0.69 FT.

OUTLET STABILIZATION:

BARREL DISCHARGE = 2.84 CFS

FROM FIGURE 8.06 a: d_{50} = 6" ; L_2 = 10 FT



$d_{max} = 1.5\, d_{50} = 9''$

DEPTH = $1.5\, d_{max}$ = 13.5"

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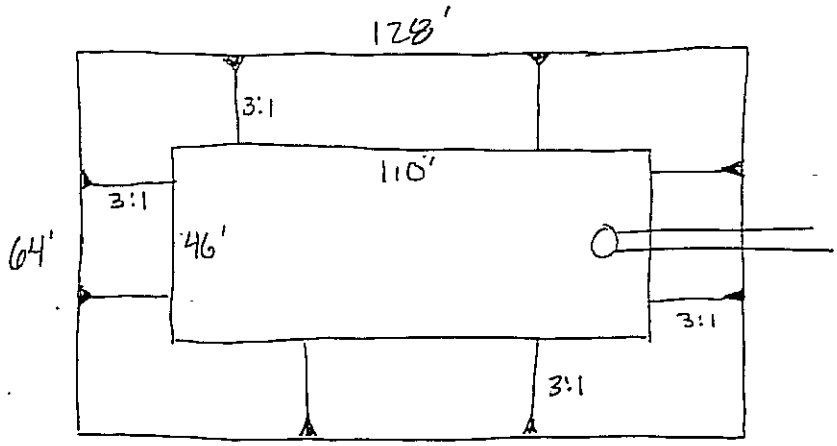
HDR Computation

HDR

Project	CITY OF GREENSBORO	Computed DTD	Date 11-27-95
Subject	WHITE STREET SANITARY LANDFILL	Checked	Date
Task	DRAINAGE	Sheet	Of

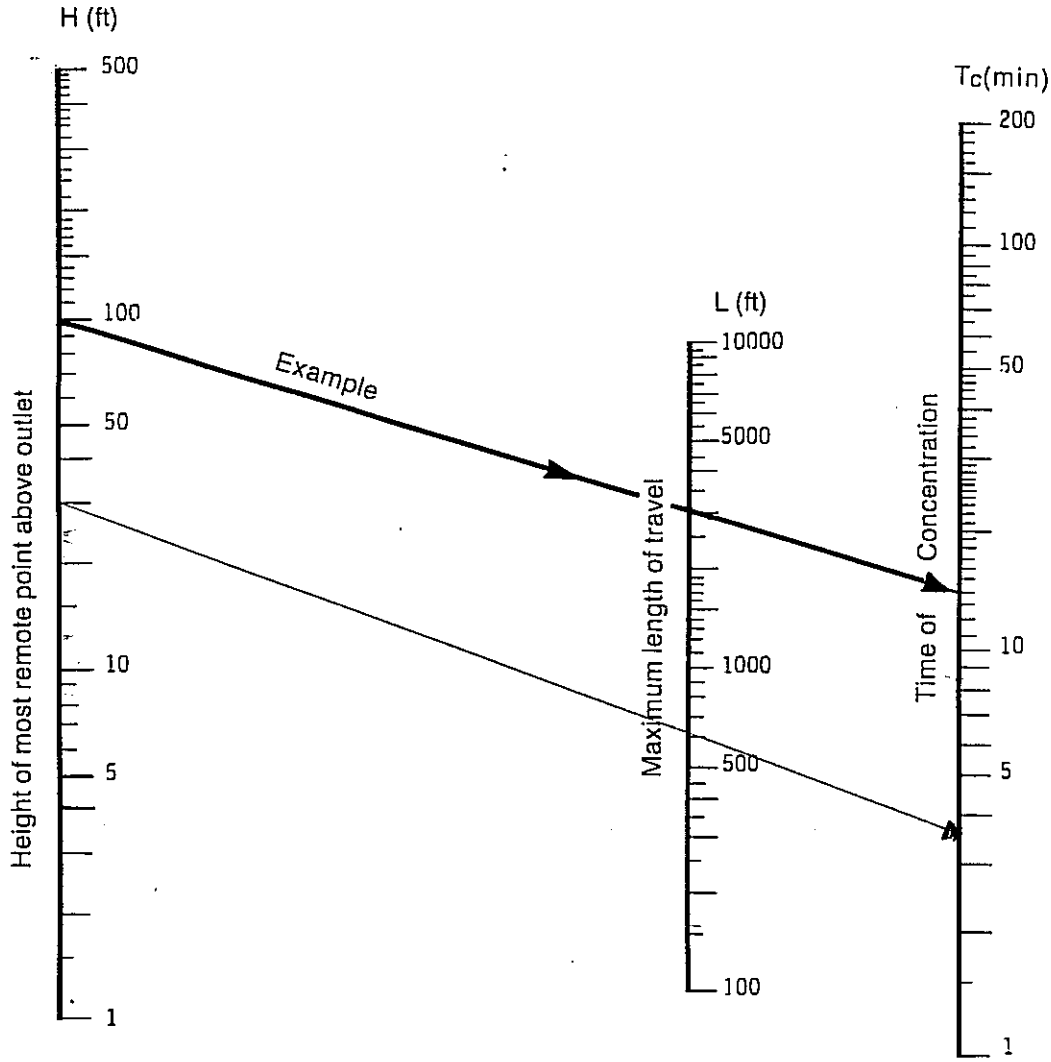


TOTAL VOLUME = A_1 = 8,059 FT^2

A_2 = 5,060 FT^2

H = 3 FT

VOL = 19,679 FT^3 > 9,360 FT^3 MIN



Note:
Use nomograph Tc for natural basins with well-defined channels, for overland flow on bare earth, and for mowed-grass roadside channels.

For overland flow, grassed surfaces, multiply Tc by 2.

For overland flow, concrete or asphalt surfaces, multiply Tc by 0.4.

For concrete channels, multiply Tc by 0.2.

Figure 8.03a Time of concentration of small drainage basins.

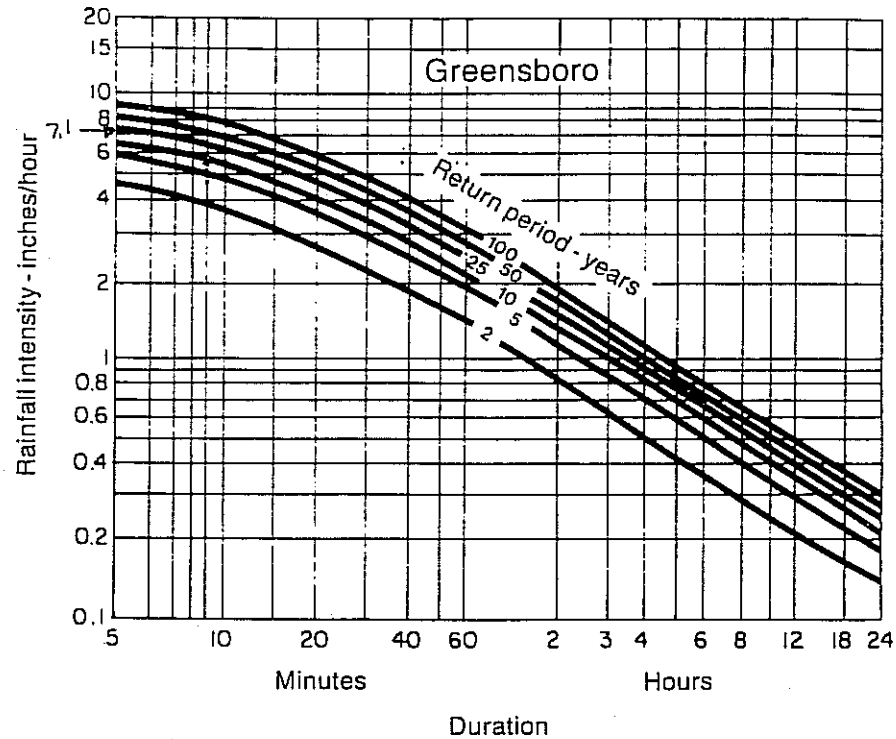


Figure 8.03d Rainfall intensity duration curves—Greensboro.

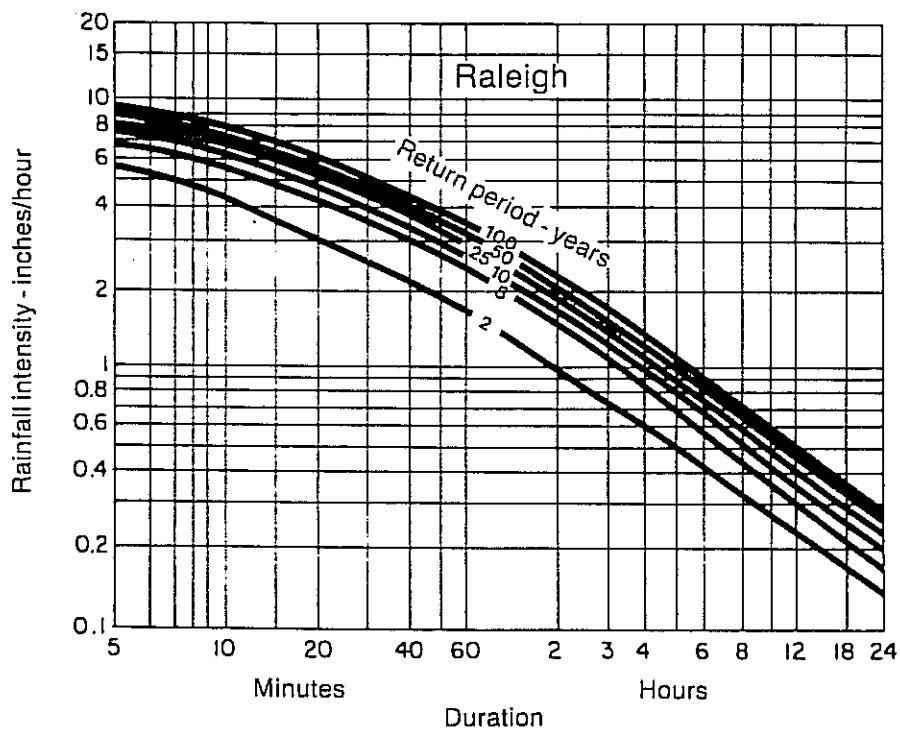


Figure 8.03e Rainfall intensity duration curves—Raleigh.

Table 8.07c
Design Table for Vegetated Spillways Excavated in Erosion Resistant Soils
(side slopes–3 horizontal:1 vertical)

Discharge Q CFS	Slope Range Minimum Percent	Slope Range Maximum Percent	Bottom Width Feet	Stage Feet
15	3.3	12.2	8	.83
	3.5	18.2	12	.69
20	3.1	8.9	8	.97
	3.2	13.0	12	.81
	3.3	17.3	16	.70
25	2.9	7.1	8	1.09
	3.2	9.9	12	.91
	3.3	13.2	16	.79
	3.3	17.2	20	.70
30	2.9	6.0	8	1.20
	3.0	8.2	12	1.01
	3.0	10.7	16	.88
	3.3	13.8	20	.78
35	2.8	5.1	8	1.30
	2.9	6.9	12	1.10
	3.1	9.0	16	.94
	3.1	11.3	20	.85
	3.2	14.1	24	.77
40	2.7	4.5	8	1.40
	2.9	6.0	12	1.18
	2.9	7.6	16	1.03
	3.1	9.7	20	.91
	3.1	11.9	24	.83
45	2.6	4.1	8	1.49
	2.8	5.3	12	1.25
	2.9	6.7	16	1.09
	3.0	8.4	20	.98
	3.0	10.4	24	.89
50	2.7	3.7	8	1.57
	2.8	4.7	12	1.33
	2.8	6.0	16	1.16
	2.9	7.3	20	1.03
	3.1	9.0	24	.94
60	2.6	3.1	8	1.73
	2.7	3.9	12	1.47
	2.7	4.8	16	1.28
	2.9	5.9	20	1.15
	2.9	7.3	24	1.05
	3.0	8.6	28	.97
70	2.5	2.8	8	1.88
	2.6	3.3	12	1.60
	2.6	4.1	16	1.40
	2.7	5.0	20	1.26
	2.8	6.1	24	1.15
	2.9	7.0	28	1.05
80	2.5	2.9	12	1.72
	2.6	3.6	16	1.51
	2.7	4.3	20	1.35
80	2.8	5.2	24	1.24
	2.8	5.9	28	1.14
	2.9	7.0	32	1.06
90	2.5	2.6	12	1.84
	2.5	3.1	16	1.61
	2.6	3.6	20	1.45
	2.7	4.5	24	1.32
	2.8	5.3	28	1.22
	2.8	6.1	32	1.14
100	2.5	2.8	16	1.71
	2.6	3.3	20	1.54
	2.6	4.0	24	1.41
	2.7	4.6	28	1.30
	2.7	5.3	32	1.21
	2.8	6.1	36	1.13
120	2.5	2.8	20	1.71
	2.6	3.2	24	1.56
	2.7	3.8	28	1.44
	2.7	4.2	32	1.34
	2.7	4.8	36	1.26
140	2.5	2.7	24	1.71
	2.5	3.2	28	1.58
	2.6	3.6	32	1.47
	2.6	4.0	36	1.38
	2.7	4.5	40	1.30
160	2.5	2.7	28	1.70
	2.5	3.1	32	1.58
	2.6	3.4	36	1.49
	2.6	3.8	40	1.40
	2.7	4.3	44	1.33
180	2.4	2.7	32	1.72
	2.4	3.0	36	1.60
	2.5	3.4	40	1.51
	2.6	3.7	44	1.43
200	2.5	2.7	36	1.70
	2.5	2.9	40	1.60
	2.5	3.3	44	1.52
	2.6	3.6	48	1.45
220	2.4	2.6	40	1.70
	2.5	2.9	44	1.61
	2.5	3.2	48	1.53
240	2.5	2.6	44	1.70
	2.5	2.9	48	1.62
	2.6	3.2	52	1.54
260	2.4	2.6	48	1.70
	2.5	2.9	52	1.62
280	2.4	2.6	52	1.70
300	2.5	2.6	56	1.69

Example of Use

Given: Discharge, Q = 87 c.f.s. Spillway slope, Exit section (from profile) = 4%.

Find: Bottom width and Stage in Reservoir.

Procedure: Enter table from left at 90 c.f.s. Note that spillway slope (4%) falls within slope ranges corresponding to bottom widths of 24, 28, and 32 ft. Use bottom width, 32 ft, to minimize velocity. Stage in Reservoir will be 1.14 ft.

Note: Computations based on: Roughness coefficient, n = .040. Maximum velocity = 5.50 ft per sec.

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HDR Computation

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SOUTH SEDIMENT BASIN (FIGURES AND TABLES COME FROM NC MANUAL)

TOTAL DRAINAGE AREA = 15.8 ACRES

$Q = CIA$ WHERE Q = RUNOFF, CFS
C = RUNOFF COEFFICIENT
I = RAINFALL INTENSITY, IN/HR
A = DRAINAGE AREA, ACRES

C = 0.5 ASSUMED (TABLE 8.03a)
L = 1,330 FT
H = 106 FT
T_c = 5.5 min (FIG 8.03a)
I = 7.1 IN/HR (FIG. 8.03d)

$Q_{25} = 0.5\,(7.1)(15.8) = \underline{56.1 \text{ CFS}}$

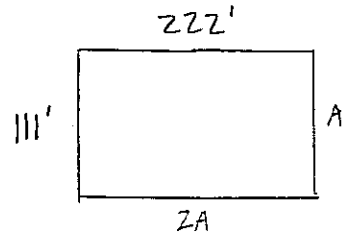
STORAGE REQUIRED = 1800 FT³/ACRE × 15.8 ACRES = 28,440 FT³

FOR 75% TRAPPING EFFICIENCY SURFACE AREA SHOULD BE:

.01 ACRE/CFS × 56.1 CFS = 0.561 ACRE = 24,437 FT²

APPROXIMATE SURFACE DIMENSIONS:

$2A^2 = 24{,}437 \text{ FT}^2$
$A = 111 \text{ FT}$



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HDR Computation

HDR

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Subject	WHITE STREET SANITARY LANDFILL	Checked	Date
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MIN. DEPTH IN ORDER TO MEET STORAGE REQUIRED:

$$\frac{28{,}440\ FT^3}{24{,}437\ FT^2} = 1.2\ FT\ DEEP \quad (\text{IF SIDE SLOPES WERE } 0:1)$$

USE SIDE SLOPES 3:1

$$V = \left(\frac{A_1 + A_2}{2}\right)(H)$$

$$28{,}440\ FT^3 = \left(\frac{24{,}437\ FT^2 + A_2}{2}\right)(H)$$

H	A_2
1.5	13,483 FT^2
2.0	4,003 FT^2 ⟸ USE 2.0' DEPTH MIN.
3.0	-5,477 FT^2

$A_1 = 24{,}437\ FT^2$ BASIN SURFACE AREA (111' x 222')

$A_2 = 4{,}003\ FT^2$ BASIN FLOOR AREA

BASIN FLOOR DIMENSIONS: $2B^2 = 4{,}003\ FT^2$

$B = 45\ FT$

45' x 90'

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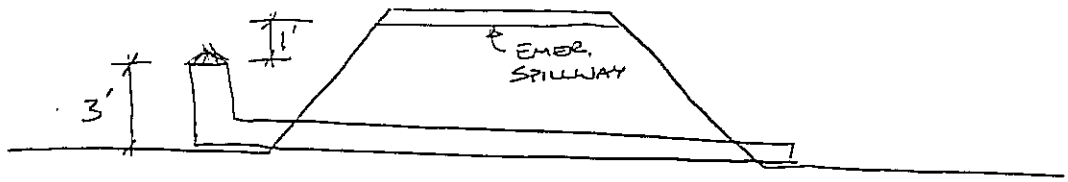
SIZE BARREL: MINIMUM CAPACITY FOR Q_P IS 0.2 CFS/ACRE

0.2 CFS/ACRE (15.8 ACRES) = 3.2 CFS

RISER HEIGHT
2x BARREL
DIAMETER



TRY 18" ϕ BARREL

$$H = 3' - \frac{18"\phi}{2(12)} = 2.25 \text{ FT}$$

FROM TABLE 8.07a, A 18" ϕ BARREL WILL CARRY A MIN. OF 7.73 CFS

USE 18" ϕ BARREL C.M.P.

SIZE RISER: FROM FIGURE 8.07b, H = 1 FT TRY A 24" ϕ RISER
FOR A 24" ϕ RISER WITH H = 1 FT., Q = 20.0 CFS

20.0 CFS > 7.73 CFS ∴ BARREL CONTROLS, OKAY

USE 24" ϕ RISER C.M.P.

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EMERGENCY SPILLWAY:

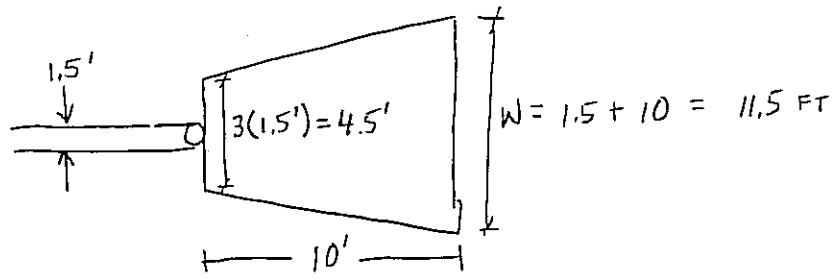
$$Q_e = Q_{25} - Q_p$$
$$= 56.1 \text{ CFS} - 7.73 \text{ CFS}$$
$$= 48.4 \text{ CFS}$$

FROM TABLE 8.07 c FOR Q = 50 CFS
BOTTOM WIDTH = 24 FT
MAX. SLOPE = 9.0 %
STAGE = 0.94 FT.

OUTLET STABILIZATION:

BARREL DISCHARGE = 7.73 CFS

FROM FIGURE 8.06 a: $d_{50} = 6''$; $L_2 = 10$ FT



$d_{max} = 1.5\, d_{50} = 9''$

DEPTH = $1.5\, d_{max} = 13.5''$

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HDR Computation

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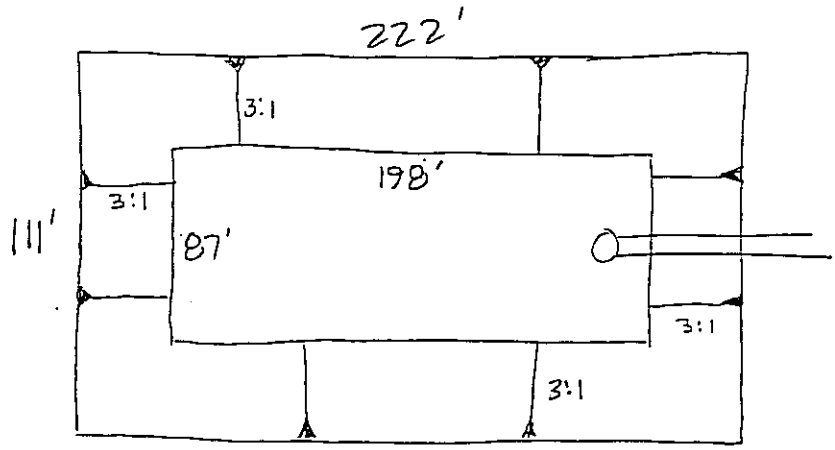
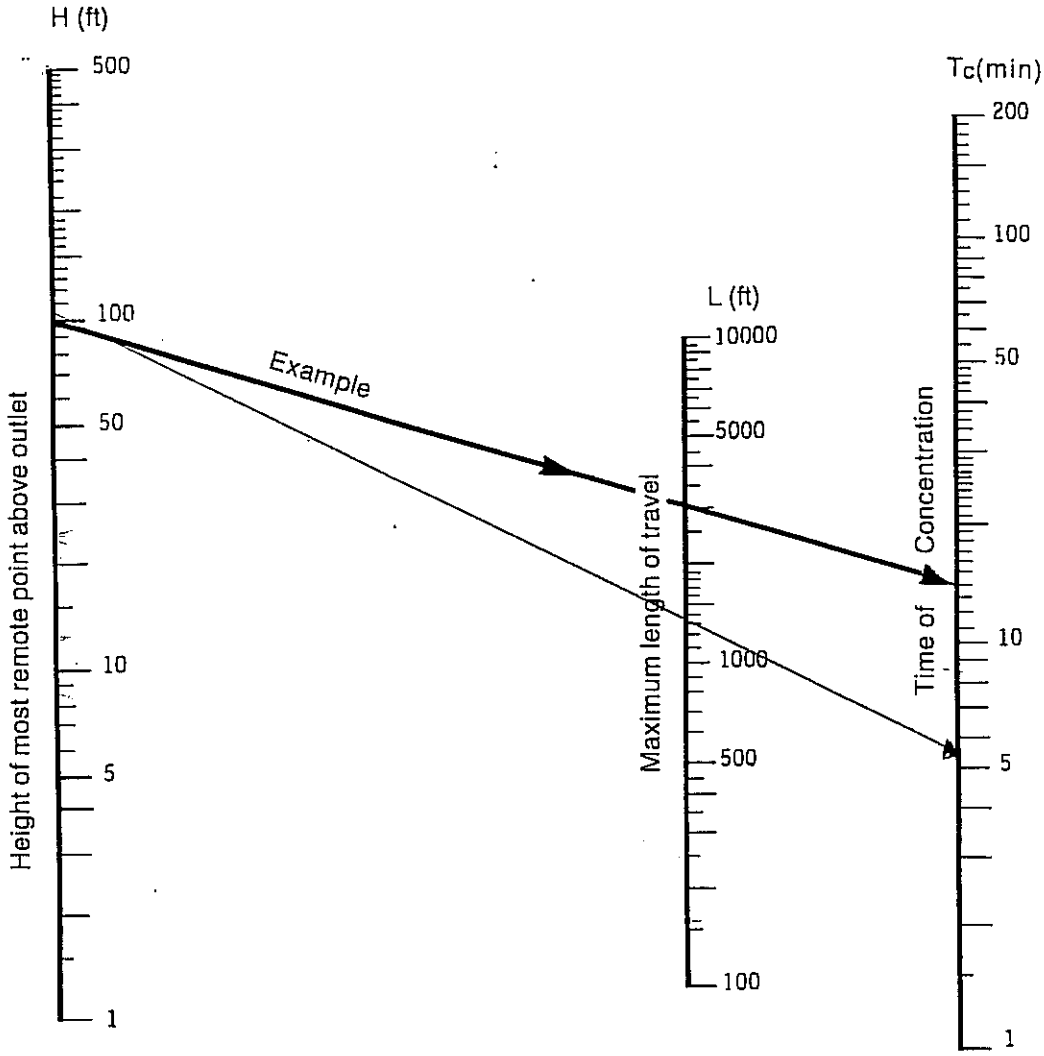
Project	CITY OF GREENSBORO	Computed DTD	Date 11-27-95
Subject	WHITE STREET SANITARY LANDFILL	Checked	Date
Task	DRAINAGE	Sheet	Of



TOTAL VOLUME = A_1 = 24,437 FT^2
A_2 = 17,226 FT^2
H = 4 FT

VOL = 83,326 FT^3 > 28,440 FT^3 MIN



Note:
Use nomograph Tc for natural basins with well-defined channels, for overland flow on bare earth, and for mowed-grass roadside channels.

For overland flow, grassed surfaces, multiply Tc by 2.

For overland flow, concrete or asphalt surfaces, multiply Tc by 0.4.

For concrete channels, multiply Tc by 0.2.

Figure 8.03a Time of concentration of small drainage basins.

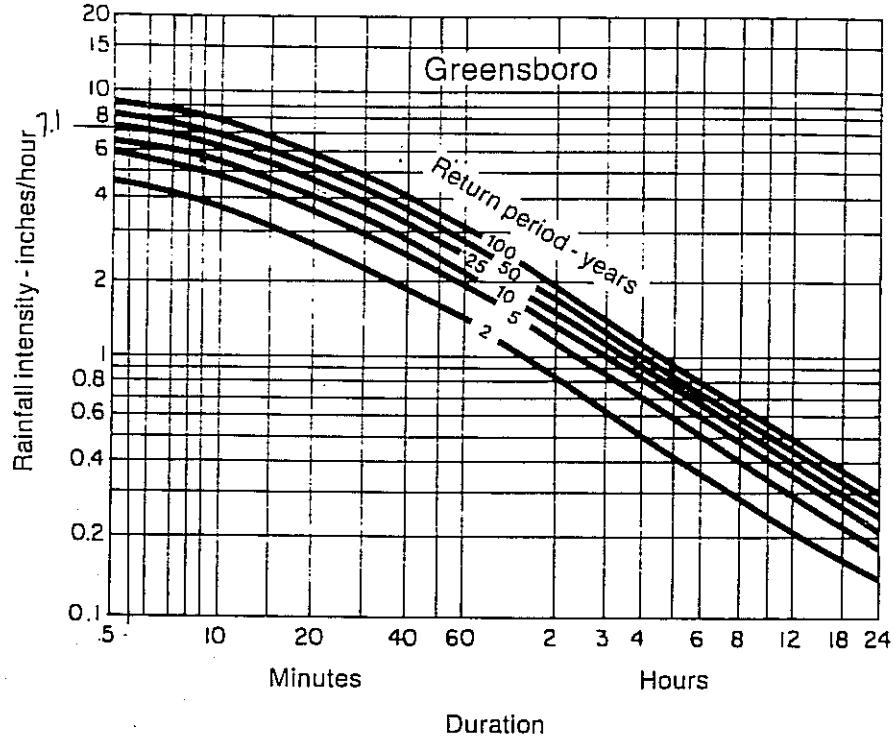


Figure 8.03d Rainfall intensity duration curves—Greensboro.

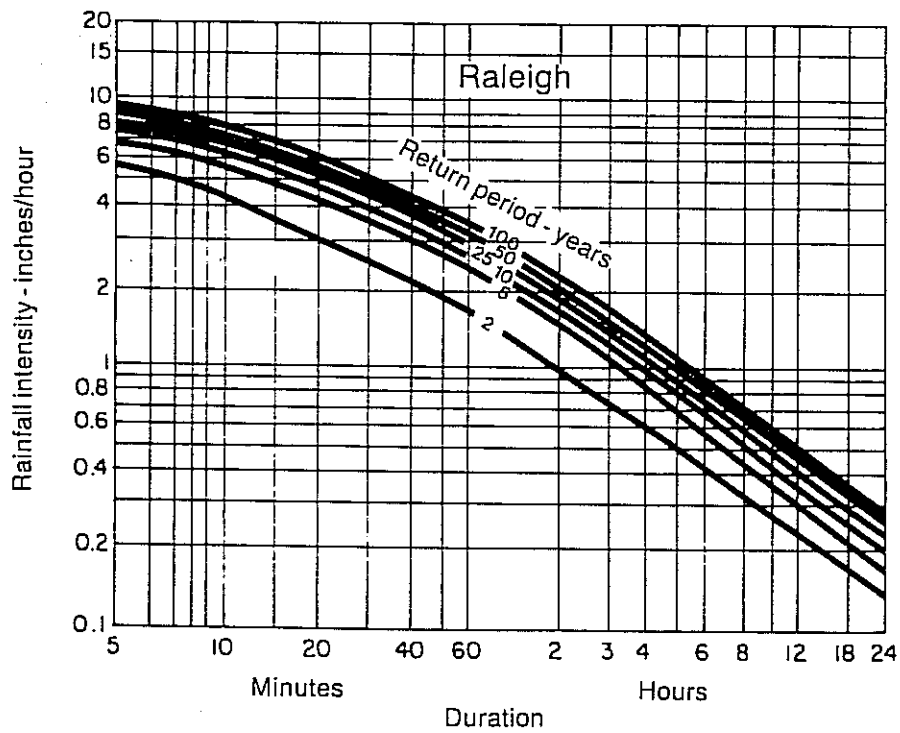


Figure 8.03e Rainfall intensity duration curves—Raleigh.

Table 8.07c
Design Table for Vegetated Spillways Excavated in Erosion Resistant Soils
(side slopes–3 horizontal:1 vertical)

Discharge Q CFS	Slope Range Minimum Percent	Slope Range Maximum Percent	Bottom Width Feet	Stage Feet
15	3.3	12.2	8	.83
	3.5	18.2	12	.69
20	3.1	8.9	8	.97
	3.2	13.0	12	.81
	3.3	17.3	16	.70
25	2.9	7.1	8	1.09
	3.2	9.9	12	.91
	3.3	13.2	16	.79
	3.3	17.2	20	.70
30	2.9	6.0	8	1.20
	3.0	8.2	12	1.01
	3.0	10.7	16	.88
	3.3	13.8	20	.78
35	2.8	5.1	8	1.30
	2.9	6.9	12	1.10
	3.1	9.0	16	.94
	3.1	11.3	20	.85
	3.2	14.1	24	.77
40	2.7	4.5	8	1.40
	2.9	6.0	12	1.18
	2.9	7.6	16	1.03
	3.1	9.7	20	.91
	3.1	11.9	24	.83
45	2.6	4.1	8	1.49
	2.8	5.3	12	1.25
	2.9	6.7	16	1.09
	3.0	8.4	20	.98
	3.0	10.4	24	.89
50	2.7	3.7	8	1.57
	2.8	4.7	12	1.33
	2.8	6.0	16	1.16
	2.9	7.3	20	1.03
	3.1	9.0	24	.94
60	2.6	3.1	8	1.73
	2.7	3.9	12	1.47
	2.7	4.8	16	1.28
	2.9	5.9	20	1.15
	2.9	7.3	24	1.05
	3.0	8.6	28	.97
70	2.5	2.8	8	1.88
	2.6	3.3	12	1.60
	2.6	4.1	16	1.40
	2.7	5.0	20	1.26
	2.8	6.1	24	1.15
	2.9	7.0	28	1.05
80	2.5	2.9	12	1.72
	2.6	3.6	16	1.51
	2.7	4.3	20	1.35

Discharge Q CFS	Slope Range Minimum Percent	Slope Range Maximum Percent	Bottom Width Feet	Stage Feet
80	2.8	5.2	24	1.24
	2.8	5.9	28	1.14
	2.9	7.0	32	1.06
90	2.5	2.8	12	1.84
	2.5	3.1	16	1.61
	2.6	3.8	20	1.45
	2.7	4.5	24	1.32
	2.8	5.3	28	1.22
	2.8	6.1	32	1.14
100	2.5	2.8	16	1.71
	2.6	3.3	20	1.54
	2.6	4.0	24	1.41
	2.7	4.8	28	1.30
	2.7	5.3	32	1.21
	2.8	6.1	36	1.13
120	2.5	2.8	20	1.71
	2.6	3.2	24	1.56
	2.7	3.8	28	1.44
	2.7	4.2	32	1.34
	2.7	4.8	36	1.26
140	2.5	2.7	24	1.71
	2.5	3.2	28	1.58
	2.6	3.6	32	1.47
	2.6	4.0	36	1.38
	2.7	4.5	40	1.30
160	2.5	2.7	28	1.70
	2.5	3.1	32	1.58
	2.6	3.4	36	1.49
	2.6	3.8	40	1.40
	2.7	4.3	44	1.33
180	2.4	2.7	32	1.72
	2.4	3.0	36	1.60
	2.5	3.4	40	1.51
	2.6	3.7	44	1.43
200	2.5	2.7	36	1.70
	2.5	2.9	40	1.60
	2.5	3.3	44	1.52
	2.6	3.6	48	1.45
220	2.4	2.6	40	1.70
	2.5	2.9	44	1.61
	2.5	3.2	48	1.53
240	2.5	2.6	44	1.70
	2.5	2.9	48	1.62
	2.6	3.2	52	1.54
260	2.4	2.6	48	1.70
	2.5	2.9	52	1.62
280	2.4	2.6	52	1.70
300	2.5	2.6	56	1.69

Example of Use

Given: Discharge, Q = 87 c.f.s. Spillway slope, Exit section (from profile) = 4%.

Find: Bottom width and Stage in Reservoir.

Procedure: Enter table from left at 90 c.f.s. Note that spillway slope (4%) falls within slope ranges corresponding to bottom widths of 24, 28, and 32 ft. Use bottom width, 32 ft, to minimize velocity. Stage in Reservoir will be 1.14 ft.

Note: Computations based on: Roughness coefficient, n = .040. Maximum velocity = 5.50 ft per sec.

HDR Computation

HDR

Project	CITY OF GREENSBORO	Computed DTD	Date 11-27-95
Subject	WHITE STREET SANITARY LANDFILL	Checked	Date
Task	DRAINAGE	Sheet	Of

EAST SEDIMENT BASIN (FIGURES AND TABLES COME FROM NC MANUAL)

TOTAL DRAINAGE AREA = 18.4 ACRES

$Q = CIA$ WHERE Q = RUNOFF, CFS
C = RUNOFF COEFFICIENT
I = RAINFALL INTENSITY, IN/HR
A = DRAINAGE AREA, ACRES

C = 0.5 ASSUMED (TABLE 8.03a)
L = 1,300 FT
H = 180 FT
T_c = 4.5 min (FIG 8.03a)
I = 7.1 IN/HR (FIG. 8.03d)

$Q_{25} = 0.5\,(7.1)(18.4) = \underline{65.3 \text{ CFS}}$

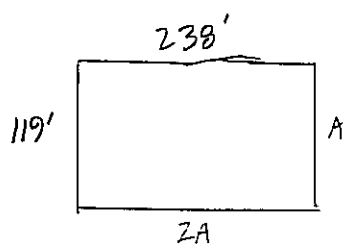
STORAGE REQUIRED = 1800 FT³/ACRE × 18.4 ACRES = 33,120 FT³

FOR 75% TRAPPING EFFICIENCY SURFACE AREA SHOULD BE:

.01 ACRE/CFS × 65.3 CFS = 0.653 ACRE = 28,445 FT²

APPROXIMATE SURFACE DIMENSIONS:

$2A^2 = 28{,}445 \text{ FT}^2$
$A = 119 \text{ FT}$



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MIN. DEPTH IN ORDER TO MEET STORAGE REQUIRED:

$$\frac{33{,}120\ FT^3}{28{,}445\ FT^2} = 1.2\ FT\ DEEP \quad (\text{IF SIDE SLOPES WERE } 0:1)$$

USE SIDE SLOPES 3:1

$$V = \left(\frac{A_1 + A_2}{2}\right)(H)$$

$$33{,}120\ FT^3 = \left(\frac{28{,}445\ FT^2 + A_2}{2}\right)(H)$$

H	A_2
1.5	15,715 FT^2
2.0	4,675 FT^2 ⟸ USE 2.0' DEPTH MIN.
2.5	-1,949 FT^2

$A_1 = 28{,}445\ FT^2$ BASIN SURFACE AREA (119' x 238')

$A_2 = 4{,}675\ FT^2$ BASIN FLOOR AREA

BASIN FLOOR DIMENSIONS: $2B^2 = 4{,}675\ FT^2$

$B = 48\ FT$

48' x 96'

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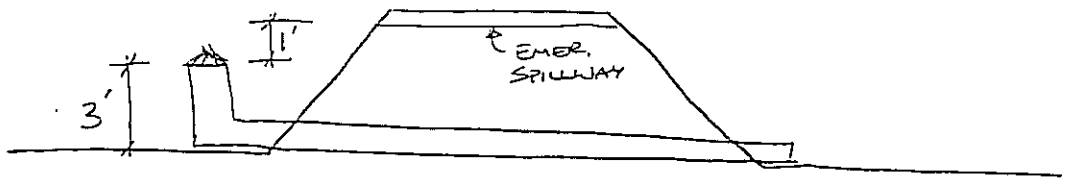
SIZE BARREL: MINIMUM CAPACITY FOR Q_P IS 0.2 CFS/ACRE

0.2 CFS/ACRE (18.4 ACRES) = 3.7 CFS

RISER HEIGHT
2x BARREL
DIAMETER



TRY 18" ϕ BARREL

$H = 3' - \frac{18,"\phi}{2(12)} = 2.25$ FT

FROM TABLE 8.07a, A 18" ϕ BARREL WILL CARRY A MIN. OF 7.73 CFS

USE 18" ϕ BARREL C.M.P.

SIZE RISER: FROM FIGURE 8.07b, H = 1 FT TRY A 24" ϕ RISER
FOR A 24" ϕ RISER WITH H = 1 FT., Q = 20.0 CFS

20.0 CFS > 7.73 CFS ∴ BARREL CONTROLS, OKAY

USE 24" ϕ RISER C.M.P.

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EMERGENCY SPILLWAY:

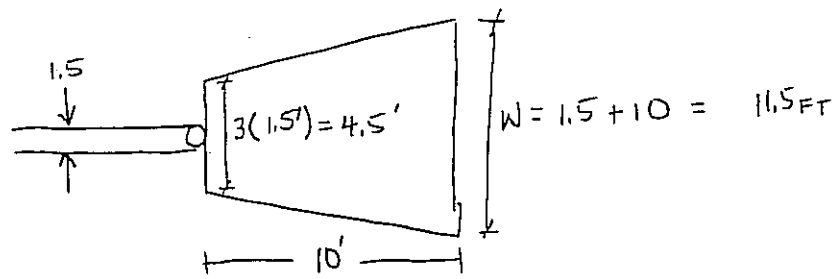
$$Q_c = Q_{25} - Q_p$$
$$= 65.3 \text{ CFS} - 7.73 \text{ CFS}$$
$$= 57.6 \text{ CFS}$$

FROM TABLE 8.07 c FOR Q = 60 CFS
BOTTOM WIDTH = 28 FT
MAX. SLOPE = 8.6 %
STAGE = 0.97 FT.

OUTLET STABILIZATION:

BARREL DISCHARGE = 7.73 CFS

FROM FIGURE 8.06 a: $d_{50} = 6''$; $L_a = 10$ FT



$$d_{max} = 1.5\, d_{50} = 9''$$

$$\text{DEPTH} = 1.5\, d_{max} = 13.5''$$

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Project	CITY OF GREENSBORO	Computed DTD	Date 11-27-95
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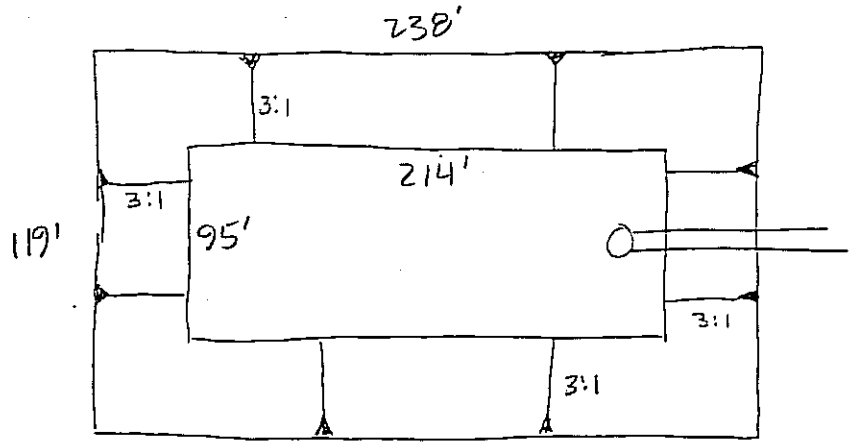
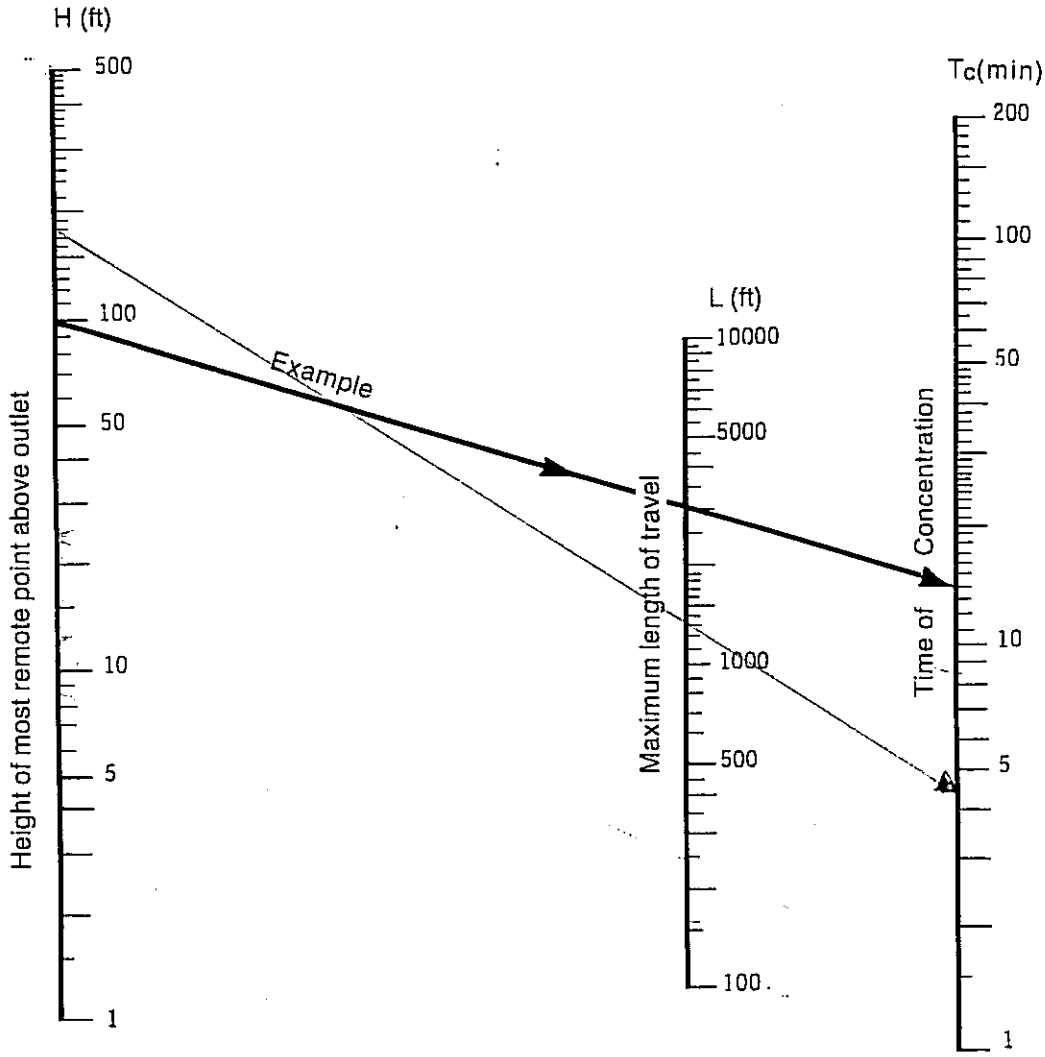
Task	DRAINAGE	Sheet	Of



TOTAL VOLUME = A_1 = 28,445 FT^2
A_2 = 20,330 FT^2
H = 4 FT

VOL = 195,100 FT^3 > 33,120 FT^3 MIN



Note:
Use nomograph Tc for natural basins with well-defined channels, for overland flow on bare earth, and for mowed-grass roadside channels.

For overland flow, grassed surfaces, multiply Tc by 2.

For overland flow, concrete or asphalt surfaces, multiply Tc by 0.4.

For concrete channels, multiply Tc by 0.2.

Figure 8.03a Time of concentration of small drainage basins.

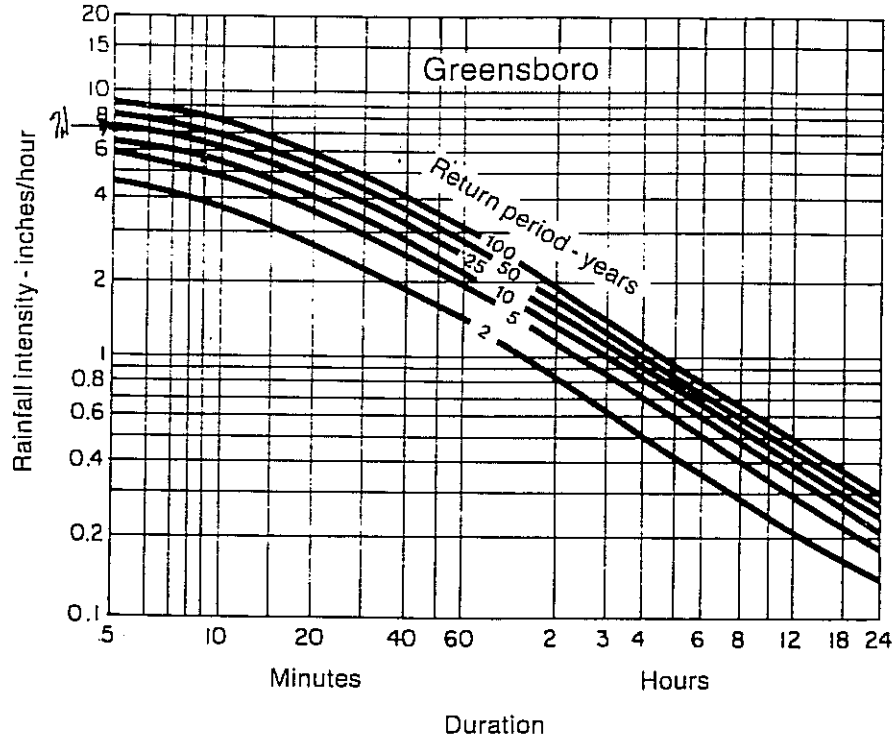


Figure 8.03d Rainfall intensity duration curves—Greensboro.

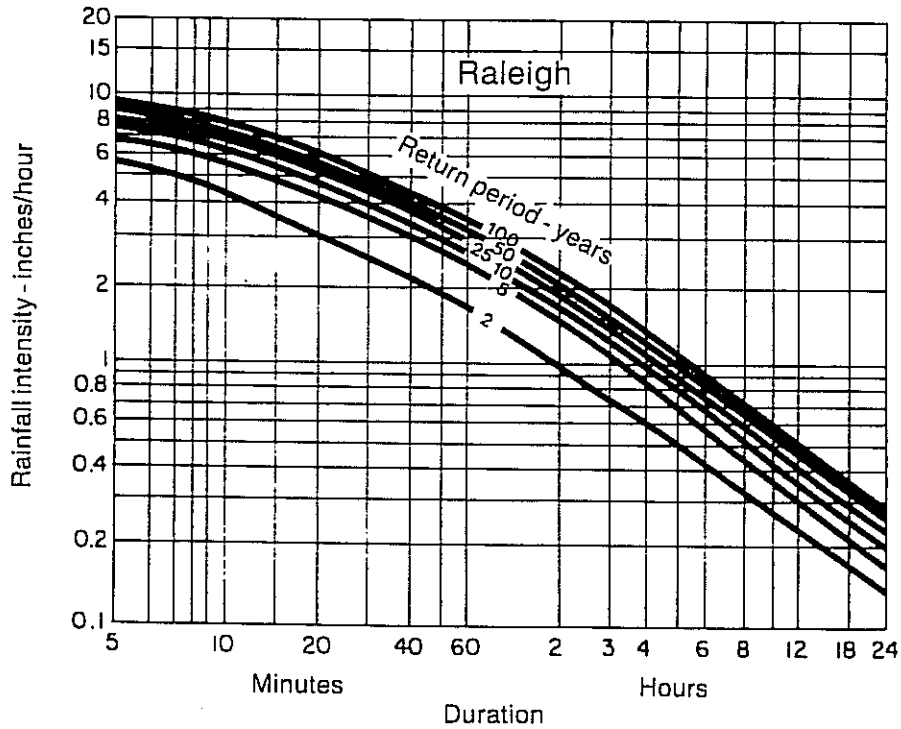


Figure 8.03e Rainfall intensity duration curves—Raleigh.

Table 8.07c
Design Table for Vegetated Spillways Excavated in Erosion Resistant Soils
(side slopes–3 horizontal:1 vertical)

Discharge Q CFS	Slope Range Minimum Percent	Slope Range Maximum Percent	Bottom Width Feet	Stage Feet
15	3.3	12.2	8	.83
	3.5	18.2	12	.69
20	3.1	8.9	8	.97
	3.2	13.0	12	.81
	3.3	17.3	16	.70
25	2.9	7.1	8	1.09
	3.2	9.9	12	.91
	3.3	13.2	16	.79
	3.3	17.2	20	.70
30	2.9	6.0	8	1.20
	3.0	8.2	12	1.01
	3.0	10.7	16	.88
	3.3	13.8	20	.78
35	2.8	5.1	8	1.30
	2.9	6.9	12	1.10
	3.1	9.0	16	.94
	3.1	11.3	20	.85
	3.2	14.1	24	.77
40	2.7	4.5	8	1.40
	2.9	6.0	12	1.18
	2.9	7.6	16	1.03
	3.1	9.7	20	.91
	3.1	11.9	24	.83
45	2.6	4.1	8	1.49
	2.8	5.3	12	1.25
	2.9	6.7	16	1.09
	3.0	8.4	20	.98
	3.0	10.4	24	.89
50	2.7	3.7	8	1.57
	2.8	4.7	12	1.33
	2.8	6.0	16	1.16
	2.9	7.3	20	1.03
	3.1	9.0	24	.94
60	2.6	3.1	8	1.73
	2.7	3.9	12	1.47
	2.7	4.8	16	1.28
	2.9	5.9	20	1.15
	2.9	7.3	24	1.05
	3.0	8.6	28	.97
70	2.5	2.8	8	1.88
	2.6	3.3	12	1.60
	2.6	4.1	16	1.40
	2.7	5.0	20	1.26
	2.8	6.1	24	1.15
	2.9	7.0	28	1.05
80	2.5	2.9	12	1.72
	2.6	3.6	16	1.51
	2.7	4.3	20	1.35

Discharge Q CFS	Slope Range Minimum Percent	Slope Range Maximum Percent	Bottom Width Feet	Stage Feet
80	2.8	5.2	24	1.24
	2.8	5.9	28	1.14
	2.9	7.0	32	1.06
90	2.5	2.6	12	1.84
	2.5	3.1	16	1.61
	2.6	3.8	20	1.45
	2.7	4.5	24	1.32
	2.8	5.3	28	1.22
	2.8	6.1	32	1.14
100	2.5	2.8	16	1.71
	2.6	3.3	20	1.54
	2.6	4.0	24	1.41
	2.7	4.8	28	1.30
	2.7	5.3	32	1.21
	2.8	6.1	36	1.13
120	2.5	2.8	20	1.71
	2.6	3.2	24	1.56
	2.7	3.6	28	1.44
	2.7	4.2	32	1.34
	2.7	4.8	36	1.26
140	2.5	2.7	24	1.71
	2.5	3.2	28	1.58
	2.6	3.6	32	1.47
	2.6	4.0	36	1.38
	2.7	4.5	40	1.30
160	2.5	2.7	28	1.70
	2.5	3.1	32	1.58
	2.6	3.4	36	1.49
	2.6	3.8	40	1.40
	2.7	4.3	44	1.33
180	2.4	2.7	32	1.72
	2.4	3.0	36	1.60
	2.5	3.4	40	1.51
	2.6	3.7	44	1.43
200	2.5	2.7	36	1.70
	2.5	2.9	40	1.60
	2.5	3.3	44	1.52
	2.6	3.6	48	1.45
220	2.4	2.6	40	1.70
	2.5	2.9	44	1.61
	2.5	3.2	48	1.53
240	2.5	2.6	44	1.70
	2.5	2.9	48	1.62
	2.6	3.2	52	1.54
260	2.4	2.6	48	1.70
	2.5	2.9	52	1.62
280	2.4	2.6	52	1.70
300	2.5	2.6	56	1.69

Example of Use

Given: Discharge, Q = 87 c.f.s. Spillway slope, Exit section (from profile) = 4%.

Find: Bottom width and Stage in Reservoir.

Procedure: Enter table from left at 90 c.f.s. Note that spillway slope (4%) falls within slope ranges corresponding to bottom widths of 24, 28, and 32 ft. Use bottom width, 32 ft, to minimize velocity. Stage in Reservoir will be 1.14 ft.

Note: Computations based on: Roughness coefficient, n = .040. Maximum velocity = 5.50 ft per sec.

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HDR Computation

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NORTHEAST SEDIMENT BASIN (FIGURES AND TABLES COME FROM NC MANUAL)

TOTAL DRAINAGE AREA = 37 ACRES (OF THE 52 ACRES, 15 AC WILL DRAIN INTO NORTH BASIN

$Q = CIA$ WHERE Q = RUNOFF, CFS
C = RUNOFF COEFFICIENT
I = RAINFALL INTENSITY, IN/HR
A = DRAINAGE AREA, ACRES

C = 0.5 ASSUMED (TABLE 8.03a)
L = 2600 FT
H = 58 FT
T_c = 14.5 min (FIG 8.03a)
I = 5.6 IN/HR (FIG. 8.03d)

$Q_{25} = 0.5\,(5.6)(37) = \underline{103.6 \text{ CFS}}$

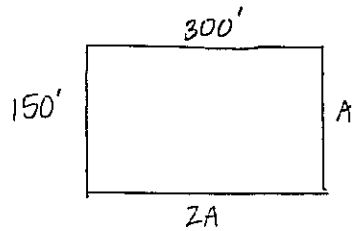
STORAGE REQUIRED = 1800 FT³/ACRE × 37 ACRES = 66,600 FT³

FOR 75% TRAPPING EFFICIENCY SURFACE AREA SHOULD BE:

.01 ACRE/CFS × 103.6 CFS = 1.036 ACRE = 45,128 FT²

APPROXIMATE SURFACE DIMENSIONS:

$2A^2 = 45{,}128 \text{ FT}^2$
$A = 150 \text{ FT}$



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HDR

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MIN. DEPTH IN ORDER TO MEET STORAGE REQUIRED:

$$\frac{66{,}600 \text{ FT}^3}{45{,}128 \text{ FT}^2} = 1.5 \text{ FT DEEP}$$ (IF SIDE SLOPES WERE 0:1)

USE SIDE SLOPES 3:1

$$V = \left(\frac{A_1 + A_2}{2}\right)(H)$$

$$66{,}600 \text{ FT}^3 = \left(\frac{45{,}128 \text{ FT}^2 + A_2}{2}\right)(H)$$

H	A_2
1.5	43,672 FT²
2.0	21,472 FT² ⟸ USE 2.0' DEPTH MIN.
3.0	-728 FT²

$A_1 = 45{,}128$ FT² BASIN SURFACE AREA (150' x 300')

$A_2 = 21{,}472$ FT² BASIN FLOOR AREA

BASIN FLOOR DIMENSIONS: $2B^2 = 21{,}472$ FT²

$B = 104$ FT

104' x 208'

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HDR

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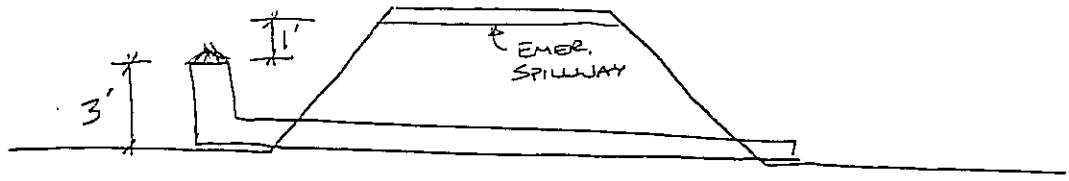
SIZE BARREL: MINIMUM CAPACITY FOR Q_P IS 0.2 CFS/ACRE

0.2 CFS/ACRE (37 ACRES) = 7.4 CFS

RISER HEIGHT
2x BARREL
DIAMETER



TRY 18" ϕ BARREL

$$H = 3' - \frac{18''\phi}{2(12)} = 2.25 \text{ FT}$$

FROM TABLE 8.07a, A 18" ϕ BARREL WILL CARRY A MIN. OF 7.73 CFS

USE 18" ϕ BARREL C.M.P.

SIZE RISER: FROM FIGURE 8.07b, H = 1 FT TRY A 24" ϕ RISER
FOR A 24" ϕ RISER WITH H = 1 FT., Q = 20.0 CFS

20 CFS > 7.73 CFS ∴ BARREL CONTROLS, OKAY

USE 24" ϕ RISER C.M.P.

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EMERGENCY SPILLWAY:

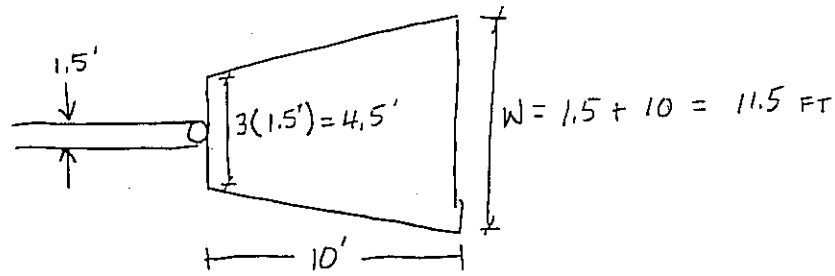
$$Q_e = Q_{25} - Q_p$$
$$= 103.6 \text{ CFS} - 7.73 \text{ CFS}$$
$$= 95.9 \text{ CFS}$$

FROM TABLE 8.07 c FOR Q = 90 CFS
BOTTOM WIDTH = 32 FT
MAX. SLOPE = 6.1 %
STAGE = 1.14 FT.

OUTLET STABILIZATION:

BARREL DISCHARGE = 7.73 CFS

FROM FIGURE 8.06 a: $d_{50} = 6''$; $L_2 = 10$ FT



$$d_{max} = 1.5\, d_{50} = 9''$$

$$\text{DEPTH} = 1.5\, d_{max} = 13.5''$$

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HDR

Project	CITY OF GREENSBORO	Computed DTD	Date 11-27-95
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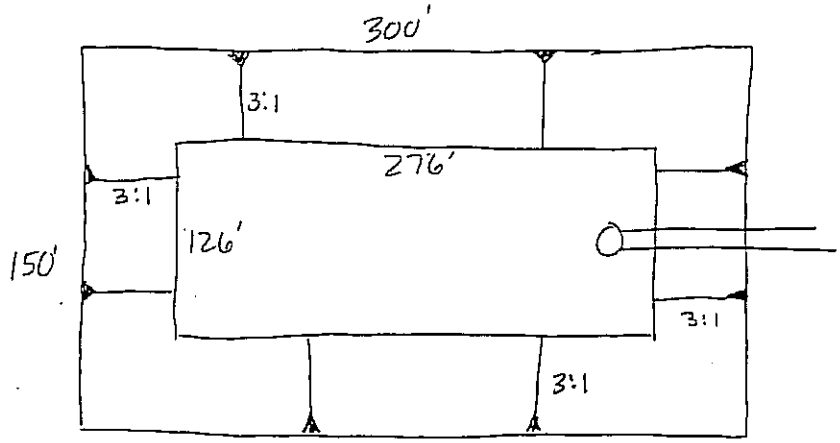
Task	DRAINAGE	Sheet	Of

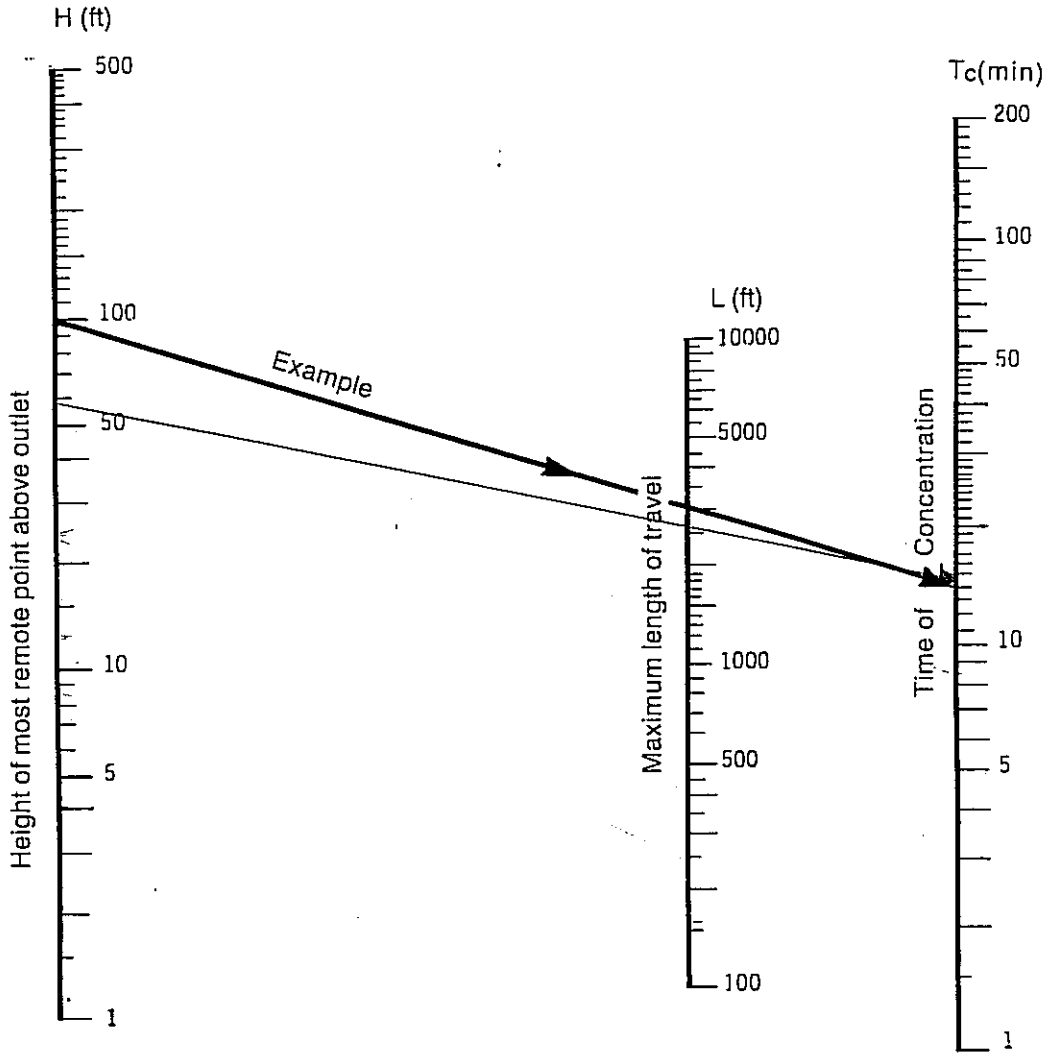


TOTAL VOLUME = A_1 = 45,128 FT^2

A_2 = 34,776 FT^2

H = 4 FT

VOL = 159,808 FT^3 > 66,600 FT^3 MIN



Note:
Use nomograph Tc for natural basins with well-defined channels, for overland flow on bare earth, and for mowed-grass roadside channels.

For overland flow, grassed surfaces, multiply Tc by 2.

For overland flow, concrete or asphalt surfaces, multiply Tc by 0.4.

For concrete channels, multiply Tc by 0.2.

Figure 8.03a Time of concentration of small drainage basins.

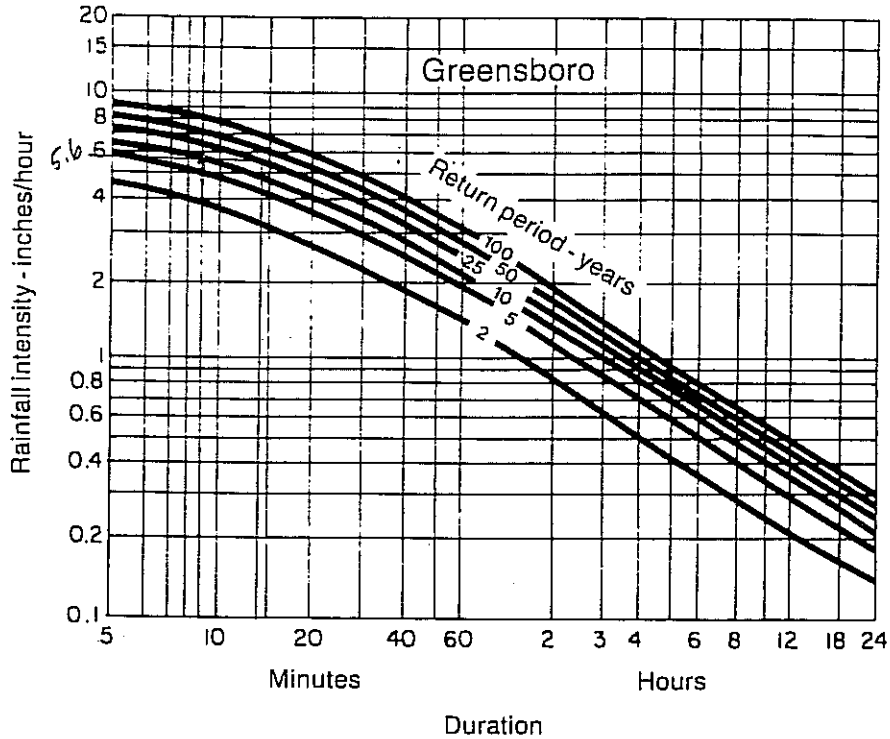


Figure 8.03d Rainfall intensity duration curves—Greensboro.

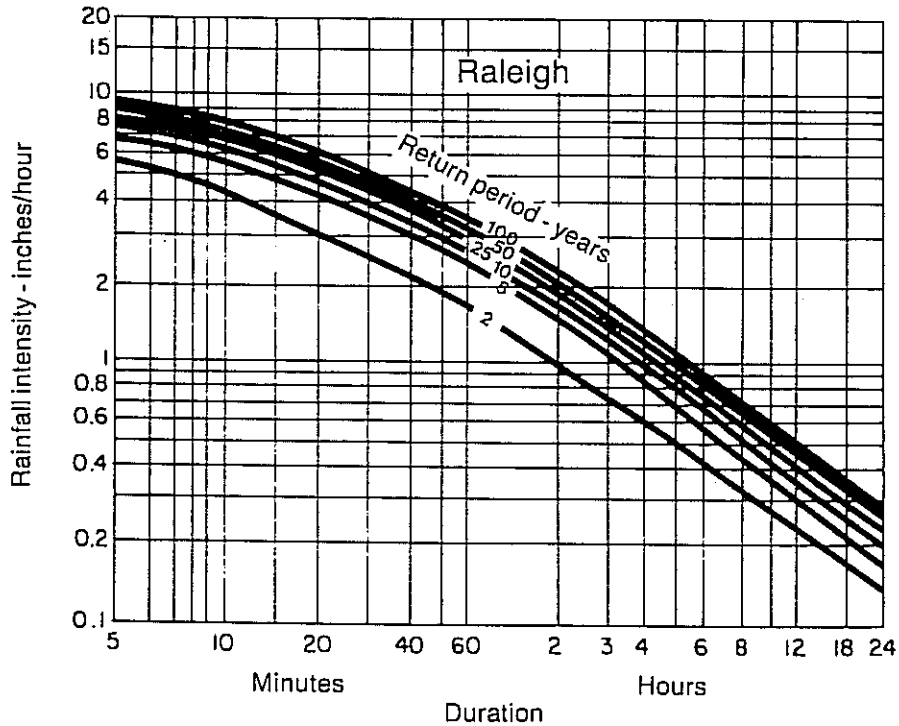


Figure 8.03e Rainfall intensity duration curves—Raleigh.

Table 8.07c
Design Table for Vegetated Spillways Excavated in Erosion Resistant Soils
(side slopes–3 horizontal:1 vertical)

Discharge Q CFS	Slope Range Minimum Percent	Slope Range Maximum Percent	Bottom Width Feet	Stage Feet
15	3.3	12.2	8	.83
	3.5	18.2	12	.69
20	3.1	8.9	8	.97
	3.2	13.0	12	.81
	3.3	17.3	16	.70
25	2.9	7.1	8	1.09
	3.2	9.9	12	.91
	3.3	13.2	16	.79
	3.3	17.2	20	.70
30	2.9	6.0	8	1.20
	3.0	8.2	12	1.01
	3.0	10.7	16	.88
	3.3	13.8	20	.78
35	2.8	5.1	8	1.30
	2.9	6.9	12	1.10
	3.1	9.0	16	.94
	3.1	11.3	20	.85
	3.2	14.1	24	.77
40	2.7	4.5	8	1.40
	2.9	6.0	12	1.18
	2.9	7.6	16	1.03
	3.1	9.7	20	.91
	3.1	11.9	24	.83
45	2.6	4.1	8	1.49
	2.8	5.3	12	1.25
	2.9	6.7	16	1.09
	3.0	8.4	20	.98
	3.0	10.4	24	.89
50	2.7	3.7	8	1.57
	2.8	4.7	12	1.33
	2.8	6.0	16	1.16
	2.9	7.3	20	1.03
	3.1	9.0	24	.94
60	2.6	3.1	8	1.73
	2.7	3.9	12	1.47
	2.7	4.8	16	1.28
	2.9	5.9	20	1.15
	2.9	7.3	24	1.05
	3.0	8.6	28	.97
70	2.5	2.8	8	1.88
	2.6	3.3	12	1.60
	2.6	4.1	16	1.40
	2.7	5.0	20	1.26
	2.8	6.1	24	1.15
	2.9	7.0	28	1.05
80	2.5	2.9	12	1.72
	2.6	3.6	16	1.51
	2.7	4.3	20	1.35
80	2.6	5.2	24	1.24
	2.8	5.9	28	1.14
	2.9	7.0	32	1.06
90	2.5	2.6	12	1.84
	2.5	3.1	16	1.61
	2.6	3.8	20	1.45
	2.7	4.5	24	1.32
	2.8	5.3	28	1.22
	2.8	6.1	32	1.14
100	2.5	2.6	16	1.71
	2.6	3.3	20	1.54
	2.6	4.0	24	1.41
	2.7	4.8	28	1.30
	2.7	5.3	32	1.21
	2.8	6.1	36	1.13
120	2.5	2.8	20	1.71
	2.6	3.2	24	1.56
	2.7	3.8	28	1.44
	2.7	4.2	32	1.34
	2.7	4.8	36	1.26
140	2.5	2.7	24	1.71
	2.5	3.2	28	1.58
	2.6	3.6	32	1.47
	2.6	4.0	36	1.38
	2.7	4.5	40	1.30
160	2.5	2.7	28	1.70
	2.5	3.1	32	1.58
	2.6	3.4	36	1.49
	2.6	3.8	40	1.40
	2.7	4.3	44	1.33
180	2.4	2.7	32	1.72
	2.4	3.0	36	1.60
	2.5	3.4	40	1.51
	2.6	3.7	44	1.43
200	2.5	2.7	36	1.70
	2.5	2.9	40	1.60
	2.5	3.3	44	1.52
	2.6	3.6	48	1.45
220	2.4	2.6	40	1.70
	2.5	2.9	44	1.61
	2.5	3.2	48	1.53
240	2.5	2.6	44	1.70
	2.5	2.9	48	1.62
	2.6	3.2	52	1.54
260	2.4	2.6	48	1.70
	2.5	2.9	52	1.62
280	2.4	2.6	52	1.70
300	2.5	2.6	56	1.69

Example of Use

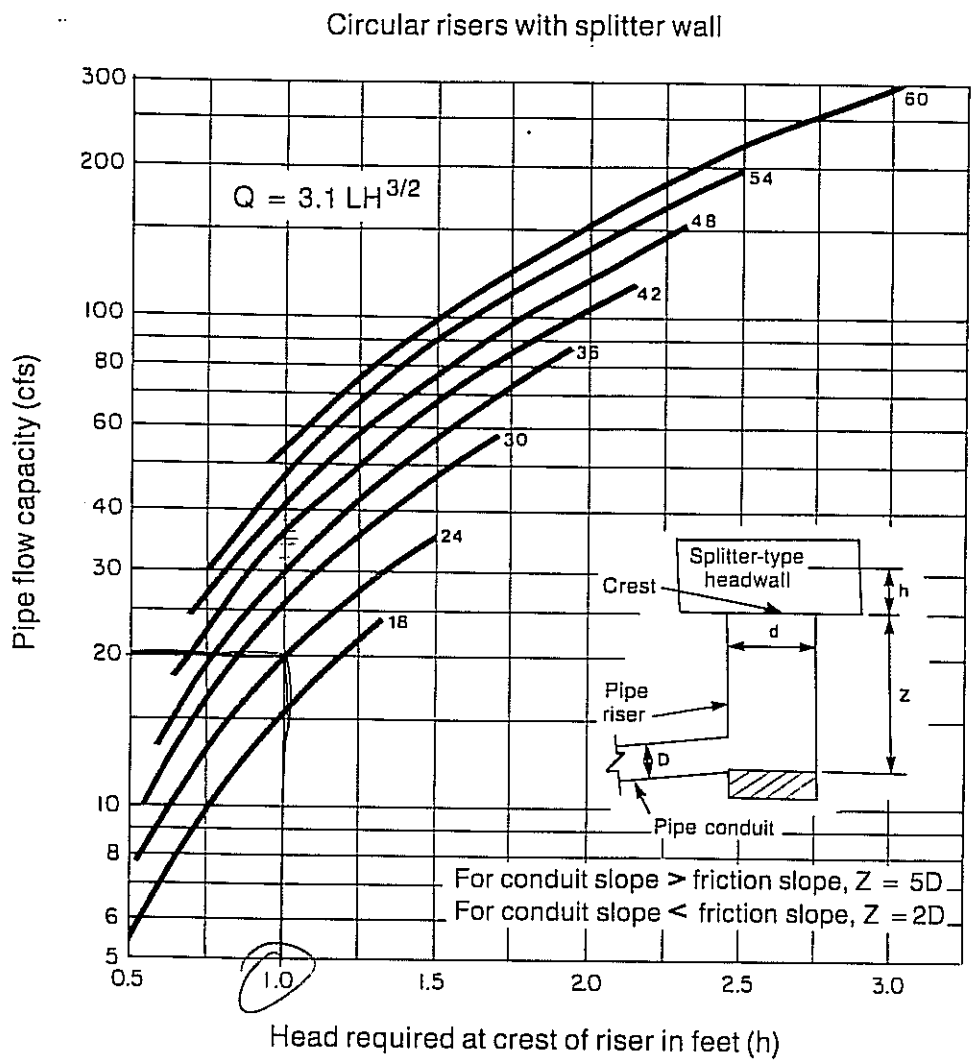
Given: Discharge, Q = 87 c.f.s. Spillway slope, Exit section (from profile) = 4%.

Find: Bottom width and Stage in Reservoir.

Procedure: Enter table from left at 90 c.f.s. Note that spillway slope (4%) falls within slope ranges corresponding to bottom widths of 24, 28, and 32 ft. Use bottom width, 32 ft, to minimize velocity. Stage in Reservoir will be 1.14 ft.

Note: Computations based on: Roughness coefficient, n = .040. Maximum velocity = 5.50 ft per sec.

24" CMP RISER



Inlet Proportions	
Pipe Conduit (D) - in	Pipe Riser (D) - in
8-12	18
15	21
18	24
21	30
24	30
30	36
36	48
42	54
48	60

Pipe drop inlet spillway design:

For a given Q and H, refer to Table 8.07a or 8.07b for conduit size. Then determine the riser diameter (d) from the Inlet Proportions Table on this figure. Next, refer to the above curves, using the conduit capacity and riser diameter, and find the head (h) required above the crest of the riser. The height of the riser should not be less than 5D - h, except as noted in the above sketch.

Example - Given: CMP; Q = 20 cfs; H = 14 ft, h max. 1.0 ft; L = 70 ft. From Table 8.07a find conduit size (D) = 18 inches. From Inlet Proportions Table, riser size = 24 inches. Head (h) required for Q = 20 and d = 24 is 1.0 ft.

Figure 8.07b Design chart for riser outlet.

18" C.M.P. Barrel

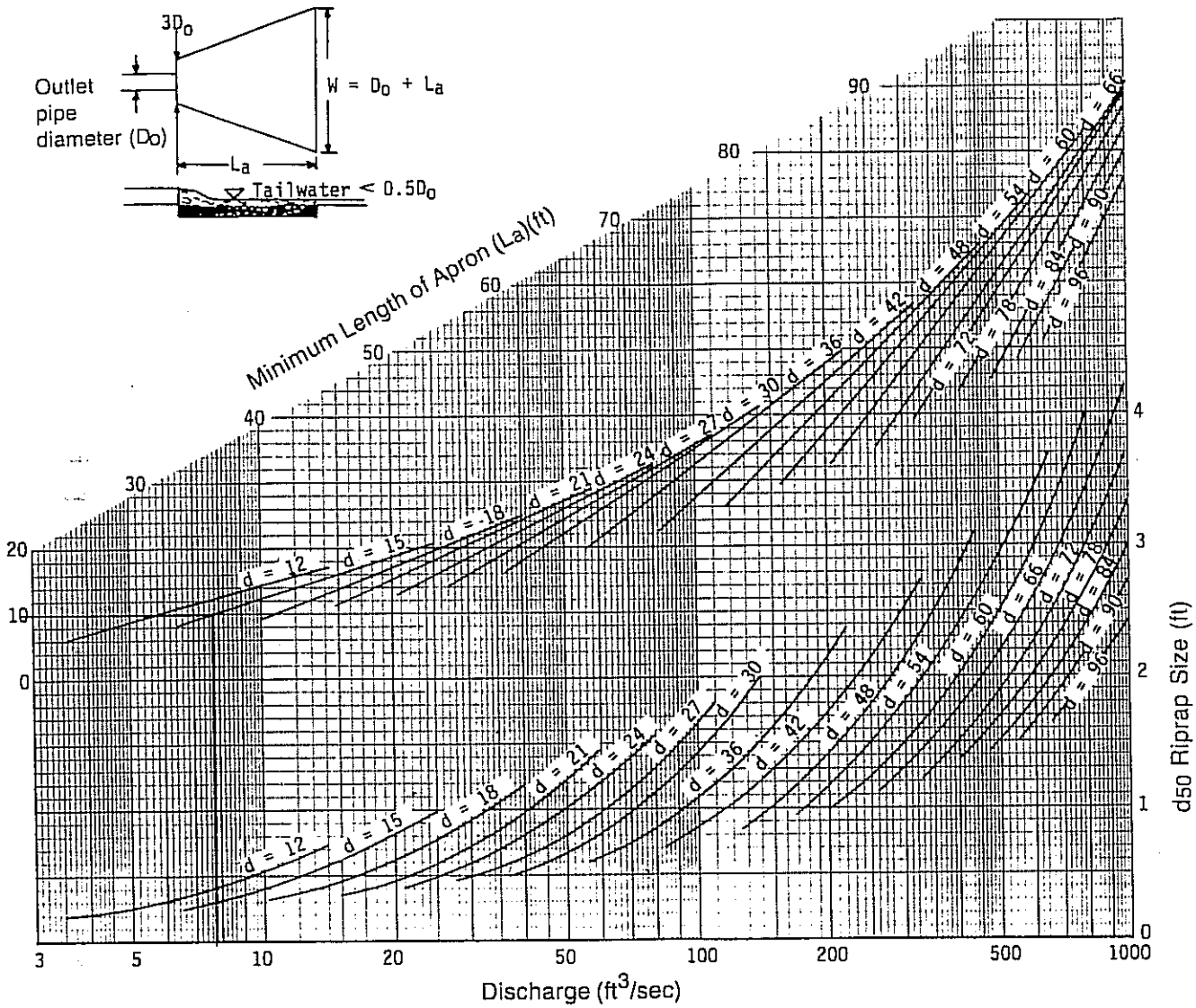
Table 8.07a
Pipe Flow Chart for Design of Corrugated Metal Outlet Conduit
(Q in cubic ft/sec)

For Corrugated Metal Pipe Inlet $K_e + K_b = 1.0$ and 70 feet of Corrugated Metal Pipe Conduit n = 0.025. Note correction factors for other pipe lengths.

2.25'

H \ Dia.	12"	15"	18"	21"	24"	30"	36"	42"
2	2.84	4.92	7.73	11.30	15.60	26.60	40.77	58.12
3	3.48	6.03	9.47	13.84	19.10	32.58	49.93	71.19
4	4.02	6.96	10.94	15.98	22.06	37.62	57.66	82.20
5	4.49	7.78	12.23	17.87	24.66	42.06	64.46	91.90
6	4.92	8.52	13.40	19.57	27.01	46.07	70.60	100.65
7	5.32	9.21	14.47	21.14	29.19	49.77	76.28	108.75
8	5.68	9.84	15.47	22.60	31.19	53.19	81.53	116.23
9	6.03	10.44	16.41	23.97	33.09	56.43	86.49	123.30
10	6.36	11.00	17.30	25.26	34.88	59.48	91.16	129.96
11	6.67	11.54	18.14	26.50	36.59	62.39	95.63	136.33
12	6.96	12.05	18.95	27.68	38.21	65.16	99.87	142.37
13	7.25	12.55	19.72	28.81	39.77	67.83	103.96	148.21
14	7.52	13.02	20.47	29.90	41.27	70.39	107.88	153.80
15	7.78	13.48	21.19	30.95	42.72	72.85	111.66	159.18
16	8.04	13.92	21.88	31.96	44.12	75.24	115.32	164.40
17	8.29	14.35	22.55	32.94	45.48	77.55	118.87	169.46
18	8.53	14.77	23.21	33.90	46.80	79.81	122.33	174.39
19	8.76	15.17	23.84	34.83	48.08	81.99	125.67	179.15
20	8.99	15.56	24.46	35.73	49.33	84.12	128.93	183.80
21	9.21	15.95	25.07	36.62	50.55	86.21	132.13	188.36
22	9.43	16.32	25.65	37.47	51.73	88.22	135.21	192.76
23	9.64	16.69	26.23	38.32	52.90	90.21	138.27	197.12
24	9.85	17.05	26.80	39.14	54.04	92.15	141.24	201.35
25	10.05	17.40	27.35	39.95	55.15	94.05	144.15	205.50
L	Correction Factors For Other Pipe Lengths							
40	1.23	1.22	1.20	1.19	1.16	1.14	1.13	1.11
50	1.14	1.13	1.12	1.11	1.10	1.09	1.08	1.07
60	1.07	1.06	1.06	1.05	1.05	1.04	1.04	1.03
70	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
80	0.95	0.95	0.95	0.96	0.96	0.96	0.97	0.97
90	0.90	0.91	0.91	0.92	0.92	0.93	0.94	0.94
100	0.86	0.87	0.88	0.89	0.89	0.90	0.91	0.92

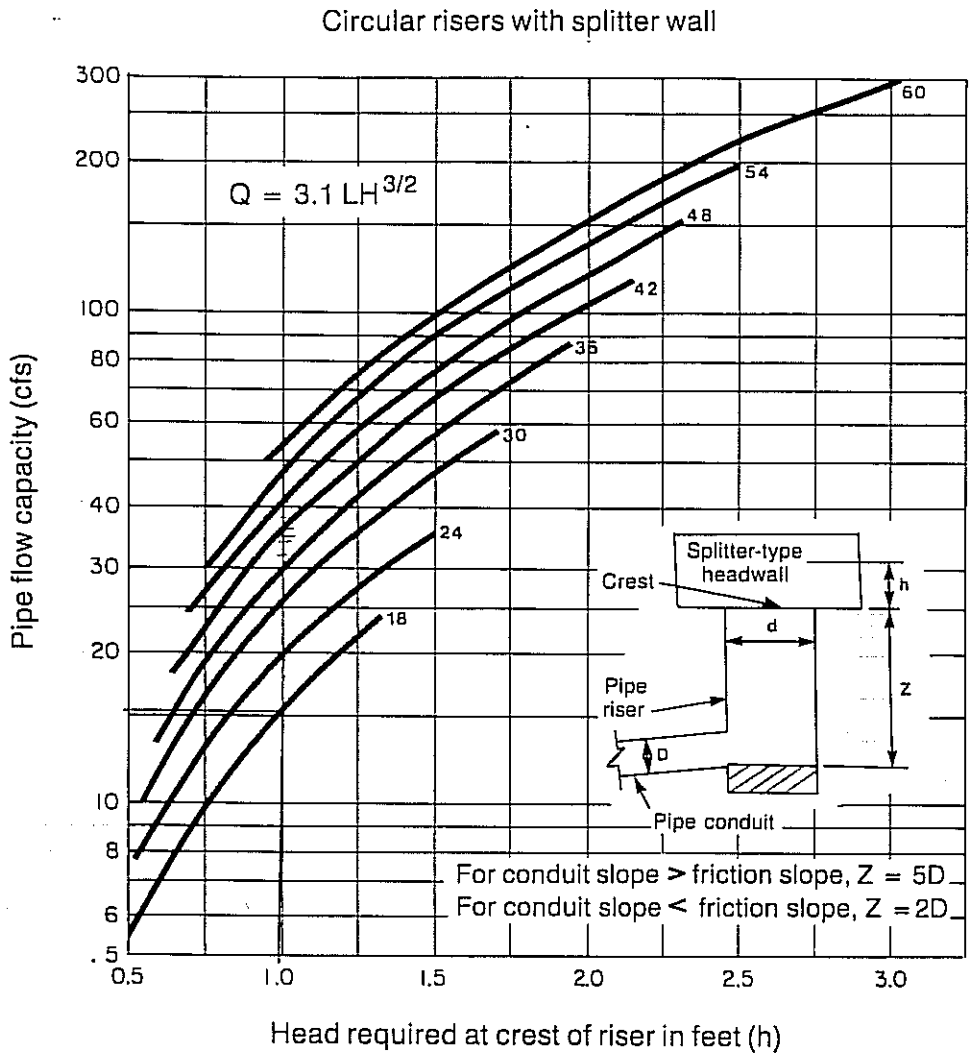
Rip Rap Apron 18" CMP Barrel



Curves may not be extrapolated.

Figure 8.06a Design of outlet protection protection from a round pipe flowing full, minimum tailwater condition (T_w < 0.5 diameter).

Southwest Basin only 18" CMP RISER



Inlet Proportions	
Pipe Conduit (D) - in	Pipe Riser (D) - in
8-12	18
15	21
18	24
21	30
24	30
30	36
36	48
42	54
48	60

Pipe drop inlet spillway design:

For a given Q and H, refer to Table 8.07a or 8.07b for conduit size. Then determine the riser diameter (d) from the Inlet Proportions Table on this figure. Next, refer to the above curves, using the conduit capacity and riser diameter, and find the head (h) required above the crest of the riser. The height of the riser should not be less than 5D - h, except as noted in the above sketch.

Example - Given: CMP; Q = 20 cfs; H = 14 ft, h max. 1.0 ft; L = 70 ft. From Table 8.07a find conduit size (D) = 18 inches. From Inlet Proportions Table, riser size = 24 inches. Head (h) required for Q = 20 and d = 24 is 1.0 ft.

Figure 8.07b Design chart for riser outlet.

8

Southwest Basin only 12" CMP Barrel

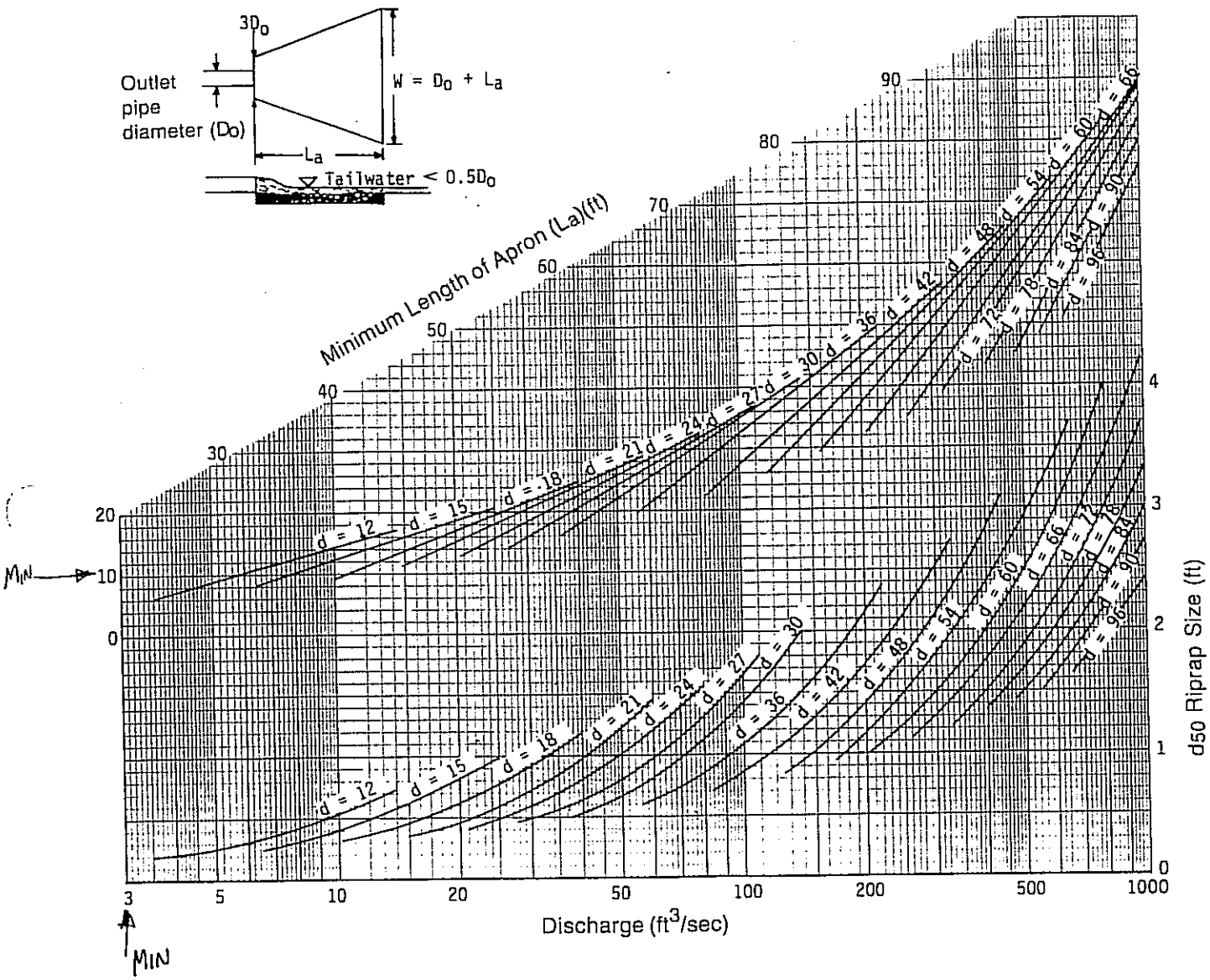
Table 8.07a
Pipe Flow Chart for Design of Corrugated Metal Outlet Conduit
(Q in cubic ft/sec)

For Corrugated Metal Pipe Inlet $K_e + K_b = 1.0$ and 70 feet of Corrugated Metal Pipe Conduit n = 0.025. Note correction factors for other pipe lengths.

1.5

Dia. / H	12"	15"	18"	21"	24"	30"	36"	42"
2	2.84	4.92	7.73	11.30	15.60	26.60	40.77	58.12
3	3.48	6.03	9.47	13.84	19.10	32.58	49.93	71.19
4	4.02	6.96	10.94	15.98	22.06	37.62	57.66	82.20
5	4.49	7.78	12.23	17.87	24.66	42.06	64.46	91.90
6	4.92	8.52	13.40	19.57	27.01	46.07	70.60	100.65
7	5.32	9.21	14.47	21.14	29.19	49.77	76.28	108.75
8	5.68	9.84	15.47	22.60	31.19	53.19	81.53	116.23
9	6.03	10.44	16.41	23.97	33.09	56.43	86.49	123.30
10	6.36	11.00	17.30	25.26	34.88	59.48	91.16	129.96
11	6.67	11.54	18.14	26.50	36.59	62.39	95.63	136.33
12	6.96	12.05	18.95	27.68	38.21	65.16	99.87	142.37
13	7.25	12.55	19.72	28.81	39.77	67.83	103.96	148.21
14	7.52	13.02	20.47	29.90	41.27	70.39	107.88	153.80
15	7.78	13.48	21.19	30.95	42.72	72.85	111.66	159.18
16	8.04	13.92	21.88	31.96	44.12	75.24	115.32	164.40
17	8.29	14.35	22.55	32.94	45.48	77.55	118.87	169.46
18	8.53	14.77	23.21	33.90	46.80	79.81	122.33	174.39
19	8.76	15.17	23.84	34.83	48.08	81.99	125.67	179.15
20	8.99	15.56	24.46	35.73	49.33	84.12	128.93	183.80
21	9.21	15.95	25.07	36.62	50.55	86.21	132.13	188.36
22	9.43	16.32	25.65	37.47	51.73	88.22	135.21	192.76
23	9.64	16.69	26.23	38.32	52.90	90.21	138.27	197.12
24	9.85	17.05	26.80	39.14	54.04	92.15	141.24	201.35
25	10.05	17.40	27.35	39.95	55.15	94.05	144.15	205.50
L	Correction Factors For Other Pipe Lengths							
40	1.23	1.22	1.20	1.19	1.16	1.14	1.13	1.11
50	1.14	1.13	1.12	1.11	1.10	1.09	1.08	1.07
60	1.07	1.06	1.06	1.05	1.05	1.04	1.04	1.03
70	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
80	0.95	0.95	0.95	0.96	0.96	0.96	0.97	0.97
90	0.90	0.91	0.91	0.92	0.92	0.93	0.94	0.94
100	0.86	0.87	0.88	0.89	0.89	0.90	0.91	0.92

Southwest Basin only Rip Rap Apron for 12" CMP Barrel



Curves may not be extrapolated.

Figure 8.06a Design of outlet protection protection from a round pipe flowing full, minimum tailwater condition (T_w < 0.5 diameter).

PROJECT: HDR- GREENSBORO LANDFILL
SUBJECT: DESIGN LEACHATE GENERATION RATE

SHEET 1 OF 3
JOB NO. HDRGN-2
DATE 11/24/95
COMPUTED BY GNR
CHECKED BY

OBJECTIVE: ESTIMATE PEAK LEACHATE GENERATION RATE OVER LIFETIME OF CELLS 1 THRU 3.

ASSUMPTIONS:

- CELL/SUBCELL SIZE -

		SIZE	
CELL #1	SUBCELL #1	5.6 ACRES	NORTH
	#2	3.7	↓
	#3	5.1	
	#4	3.1	SOUTH
CELL #2	SUBCELL #5	2.8 ACRES	NORTH
	#6	4.0	↓
	#7	3.9	
	#8	3.0	SOUTH
CELL #3	SUBCELL #9	5.8 ACRES	NORTH
	#10	6.0	↓
	#11	4.0	SOUTH

- DESIGN STORM - 1 YR - 24 HOUR = 3.0 INCHES = 81500 gPAD
- LEACHATE GENERATION RATES

	EMPIRICAL*	HELP3 (ATTACHED)
WORKING FACE	1200 gPAD	754
INTERIM COVER	500 gPAD	292
FINAL COVER	100 gPAD	2100

* EMPIRICAL LEACHATE GENERATION RATES ARE BASED ON BACK CALCULATIONS FROM OBSERVED GENERATION RATES. FACILITIES REVIEWED INCLUDE HIGH POINT & ALAMANCE, AND NY FACILITIES PROVIDED BY NY-DEC (REF ROBERT PHANEUF 518.457.2051)

⇒ USE EMPIRICAL SINCE THEY ARE > HELP3 PREDICTIONS

G.N. RICHARDSON & ASSOCIATES, INC.
Engineering and Geological Services
417 N. BOYLAN AVENUE RALEIGH, N.C. 27603
PHONE-919-828-0577 FAX-919-828-3899

PROJECT HDR- GREENSBORO LANDFILL
SUBJECT DESIGN LEACHATE GENERATION RATE

SHEET 2 OF 3
JOB NO. HDRGN-2
DATE 11/24/95
COMPUTED BY GWR
CHECKED BY

ASSUMPTIONS (CONT)

- WORKING FACE SIZE ≈ 3/4 ACRE w/ INTERIM PLACED ≈ EVERY 4 ACRES
- CRITICAL TIME IS WHEN NEW SUBCELL IS OPENED

PEAK LEACHATE GENERATION RATE w/ STORM

- SEE CALCS ON PAGE 3
- MAXIMUM DAILY GENERATION w/ STORM ≈ 0.514 GALLONS
- MAXIMUM DAILY GENERATION w/ STORM CAN BE REDUCED TO APPROXIMATELY 0.354 GAL. BY MAKING SUBCELLS UNIFORM IN SIZE.

⇒ RECOMMEND EVALUATION OF SUBCELL SIZING

PEAK LEACHATE GENERATION RATE w/o STORM

- SEE CALCS ON PAGE 3
- DAILY GENERATION RATE INCREASES FROM 6,000 TO 13,000 gpd
- NOTE THAT A FORCED MAIN DESIGNED TO HANDLE THE PEAK STORM EVENT WILL BE SIGNIFICANTLY OVERDESIGNED FOR THE LONG-TERM LEACHATE GENERATION RATE (<5000 gpd).

⇒ RECOMMEND STORM EVENTS TO BE HANDLED BY SUPPLEMENTARY FORCE MAIN SYSTEM THAT CAN BE DECOMMISSIONED AT CLOSURE.

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417 N. BOYLAN AVENUE RALEIGH, N.C. 27603
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PROJECT HDR - Greensboro Landfill
SUBJECT Design Leachate Generation Rate

SHEET 3 OF 3
JOB NO. HDR GW-2
DATE 11/24/95
COMPUTED BY GNR
CHECKED BY

Peak Leachate Generation Rate (Storm)

Cell #	Subcell #	Open Acre	Open GPD	Active Acre	Active GPD	Interim Acre	Interim GPD	Final Acre	Final GPD	Total GPD
1	1	5.6	456,000	0.0	—	0.0	—	0.0	—	456,000
	2	3.7	301,000	4.0	4800	1.6	800	0.0	—	307,000
	3	5.1	416,000	4.0	4800	5.3	2650	0.0	—	423,000
	4	3.1	253,000	4.0	4800	7.4	3700	3.0	300	262,000
2	5	2.8	228,000	4.0	4800	10.5	5250	3.0	300	238,000
	6	4.0	326,000	4.0	4800	10.5	5250	5.8	580	337,000
	7	3.9	318,000	4.0	4800	11.0	5500	9.3	930	329,000
	8	3.0	245,000	4.0	4800	11.0	5500	13.2	1320	257,000
3	9	5.8	472,000	4.0	4800	11.0	5500	16.2	1620	484,000
	10	6.0	489,000	4.0	4800	11.0	5500	22.0	2200	502,000
	11	4.0	326,000	4.0	4800	11.0	5500	28.0	2800	339,000
Post-Closure		0.0	—	0.0	—	0.0	—	47.0	4700	4700

∴ Maximum Design Storm Event ≈ 0.5M Gallons

Leachate Generation Rates w/o Storm

Subcell #1

2	307,000 -	301,000 =	6,000 GPD
3	423,000 -	416,000 =	7,000
4	262,000 -	253,000 =	9,000
5	238,000 -	228,000 =	10,000
6	337,000 -	326,000 =	11,000
7	329,000 -	318,000 =	11,000
8	257,000 -	245,000 =	12,000
9	484,000 -	472,000 =	12,000
10	502,000 -	489,000 =	13,000
11	339,000 -	326,000 =	13,000

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**                                                                          **
**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**               HELP MODEL VERSION 3.01    (14 OCTOBER 1994)               **
**                  DEVELOPED BY ENVIRONMENTAL LABORATORY                   **
**                    USAE WATERWAYS EXPERIMENT STATION                     **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY              **
**                                                                          **
**                                                                          **
******************************************************************************
******************************************************************************


PRECIPITATION DATA FILE:      C:\HELP3\GBRONC.D4
TEMPERATURE DATA FILE:        C:\HELP3\GBRONCT.D7
SOLAR RADIATION DATA FILE:    C:\HELP3\GBRONCS.D13
EVAPOTRANSPIRATION DATA:      C:\HELP3\GBRONCE.D11
SOIL AND DESIGN DATA FILE:    C:\HELP3\ACT10.D10
OUTPUT DATA FILE:             C:\HELP3\ACT10OUT.OUT


TIME:  17:36      DATE:  11/22/1995


******************************************************************************

     TITLE:  Greensboro, NC Landfill Active Cell - 10' Waste

******************************************************************************


     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
              COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.


                                  LAYER  1
                                  --------

                      TYPE 1 - VERTICAL PERCOLATION LAYER
                          MATERIAL TEXTURE NUMBER  18
          THICKNESS                    =    120.00   INCHES
          POROSITY                     =      0.6710 VOL/VOL
          FIELD CAPACITY               =      0.2920 VOL/VOL
          WILTING POINT                =      0.0770 VOL/VOL
          INITIAL SOIL WATER CONTENT   =      0.3010 VOL/VOL
          EFFECTIVE SAT. HYD. COND.    =  0.100000005000E-02 CM/SEC
        NOTE:  SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  1.80
                 FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.
```

LAYER 2

TYPE 3 - BARRIER SOIL LINER
MATERIAL TEXTURE NUMBER 22

THICKNESS	=	12.00	INCHES
POROSITY	=	0.4190	VOL/VOL
FIELD CAPACITY	=	0.3070	VOL/VOL
WILTING POINT	=	0.1800	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.4190	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.189999992000E-04	CM/SEC

LAYER 3

TYPE 2 - LATERAL DRAINAGE LAYER
MATERIAL TEXTURE NUMBER 5

THICKNESS	=	12.00	INCHES
POROSITY	=	0.4570	VOL/VOL
FIELD CAPACITY	=	0.1310	VOL/VOL
WILTING POINT	=	0.0580	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.3348	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.100000005000E-02	CM/SEC
SLOPE	=	2.00	PERCENT
DRAINAGE LENGTH	=	50.0	FEET

LAYER 4

TYPE 4 - FLEXIBLE MEMBRANE LINER
MATERIAL TEXTURE NUMBER 35

THICKNESS	=	0.06	INCHES
POROSITY	=	0.0000	VOL/VOL
FIELD CAPACITY	=	0.0000	VOL/VOL
WILTING POINT	=	0.0000	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0000	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.199999996000E-12	CM/SEC
FML PINHOLE DENSITY	=	0.00	HOLES/ACRE
FML INSTALLATION DEFECTS	=	4.00	HOLES/ACRE
FML PLACEMENT QUALITY	=	2 - EXCELLENT	

LAYER 5

TYPE 3 - BARRIER SOIL LINER
MATERIAL TEXTURE NUMBER 16

THICKNESS	=	24.00	INCHES
POROSITY	=	0.4270	VOL/VOL
FIELD CAPACITY	=	0.4180	VOL/VOL
WILTING POINT	=	0.3670	VOL/VOL

INITIAL SOIL WATER CONTENT = 0.4270 VOL/VOL
EFFECTIVE SAT. HYD. COND. = 0.100000001000E-06 CM/SEC

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS USER-SPECIFIED.

SCS RUNOFF CURVE NUMBER	=	0.00	
FRACTION OF AREA ALLOWING RUNOFF	=	0.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	1.000	ACRES
EVAPORATIVE ZONE DEPTH	=	21.0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	5.980	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	14.091	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	1.617	INCHES
INITIAL SNOW WATER	=	0.000	INCHES
INITIAL WATER IN LAYER MATERIALS	=	55.410	INCHES
TOTAL INITIAL WATER	=	55.410	INCHES
TOTAL SUBSURFACE INFLOW	=	0.00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
GREENSBORO NORTH CAROLINA

MAXIMUM LEAF AREA INDEX	=	1.00	
START OF GROWING SEASON (JULIAN DATE)	=	90	
END OF GROWING SEASON (JULIAN DATE)	=	305	
AVERAGE ANNUAL WIND SPEED	=	7.60	MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	66.00	%
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	68.00	%
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	74.00	%
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	70.00	%

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR GREENSBORO NORTH CAROLINA

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
3.51	3.37	3.88	3.16	3.37	3.93
4.27	4.19	3.64	3.18	2.59	3.38

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR GREENSBORO NORTH CAROLINA

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
37.50	39.90	48.00	58.30	66.50	73.50
77.20	76.30	69.90	58.40	48.50	40.20

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR GREENSBORO NORTH CAROLINA

STATION LATITUDE = 35.13 DEGREES

****

AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 20

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	2.71	3.27	4.10	2.81	3.05	3.96
	4.76	5.13	3.82	2.52	2.60	3.80
STD. DEVIATIONS	1.65	1.38	1.92	1.36	1.29	2.53
	1.98	2.38	2.39	1.71	1.91	1.80
RUNOFF						
TOTALS	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
STD. DEVIATIONS	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
EVAPOTRANSPIRATION						
TOTALS	1.432	1.708	2.931	3.026	3.049	4.062
	4.594	3.606	2.813	2.585	1.406	1.156
STD. DEVIATIONS	0.179	0.254	0.299	0.721	0.865	1.466
	1.511	0.969	0.793	0.770	0.418	0.204
PERCOLATION/LEAKAGE THROUGH LAYER 2						
TOTALS	1.5174	1.1908	1.8299	1.3562	0.5026	0.3133
	0.3551	0.3170	0.7112	1.0196	0.4783	0.5515
STD. DEVIATIONS	1.3255	0.9589	1.6143	0.9147	0.4042	0.5184
	0.8431	0.7272	1.0346	1.0853	0.6805	1.0592
LATERAL DRAINAGE COLLECTED FROM LAYER 3						
TOTALS	0.7782	0.7078	0.7933	0.7685	0.7908	0.7604

	0.7789	0.7739	0.7455	0.7696	0.7550	0.7797
STD. DEVIATIONS	0.0619	0.0469	0.0062	0.0049	0.0198	0.0413
	0.0731	0.0956	0.1079	0.1148	0.0654	0.06[illegible]

PERCOLATION/LEAKAGE THROUGH LAYER 5

TOTALS	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002
	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ACROSS LAYER 2

AVERAGES	0.0139	0.0124	0.0168	0.0130	0.0048	0.0031
	0.0034	0.0030	0.0069	0.0096	0.0048	0.0050
STD. DEVIATIONS	0.0117	0.0098	0.0143	0.0088	0.0038	0.0049
	0.0081	0.0067	0.0102	0.0104	0.0067	0.0095

DAILY AVERAGE HEAD ACROSS LAYER 5

AVERAGES	11.7617	11.8846	11.9818	11.9891	11.9571	11.9[illegible]
	11.8303	11.7673	11.7183	11.7069	11.8449	11.84[illegible]4
STD. DEVIATIONS	0.5923	0.5159	0.0594	0.0484	0.1918	0.4209
	0.7590	1.0408	1.2598	1.3109	0.6934	0.7126

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AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 20

	INCHES		CU. FEET	PERCENT
PRECIPITATION	42.52	(7.072)	154363.9	100.00
RUNOFF	0.000	(0.0000)	0.00	0.000
EVAPOTRANSPIRATION	32.368	(3.2473)	117495.55	76.116
PERCOLATION/LEAKAGE THROUGH FROM LAYER 2	10.14296	(4.24662)	36818.937	23.8520[illegible]
	8×10^{-7} cm/sec		754 gpad	
AVERAGE HEAD ACROSS TOP OF LAYER 2	0.008	(0.003)		
LATERAL DRAINAGE COLLECTED FROM LAYER 3	9.20143	(0.63781)	33401.180	21.63794

PERCOLATION/LEAKAGE THROUGH FROM LAYER 5	0.00195 (	0.00010)	7.094	0.00460
VERAGE HEAD ACROSS TOP OF LAYER 5	11.849 (	0.574)		
CHANGE IN WATER STORAGE	0.953 (	5.0281)	3459.95	2.241

****

ACT10.D10

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PEAK DAILY VALUES FOR YEARS 1 THROUGH 20

	(INCHES)	(CU. FT.)
PRECIPITATION	3.76	13648.800
RUNOFF	0.000	0.0000
PERCOLATION/LEAKAGE THROUGH LAYER 2	0.465527	1689.86316
AVERAGE HEAD ACROSS LAYER 2	0.136	
DRAINAGE COLLECTED FROM LAYER 3	0.02565	93.12045
PERCOLATION/LEAKAGE THROUGH LAYER 5	0.000005	0.01968
AVERAGE HEAD ACROSS LAYER 5	12.000	
SNOW WATER	2.87	10419.2432

MAXIMUM VEG. SOIL WATER (VOL/VOL)	0.4484
MINIMUM VEG. SOIL WATER (VOL/VOL)	0.0649

****

ACT 10, D10

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FINAL WATER STORAGE AT END OF YEAR 20

LAYER	(INCHES)	(VOL/VOL)
1	36.3891	0.3032
2	5.0280	0.4190
3	22.8082	1.9007
4	0.0000	0.0000
5	10.2480	0.4270
SNOW WATER	0.000	

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**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**               HELP MODEL VERSION 3.01    (14 OCTOBER 1994)               **
**                  DEVELOPED BY ENVIRONMENTAL LABORATORY                   **
**                    USAE WATERWAYS EXPERIMENT STATION                     **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY              **
**                                                                          **
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PRECIPITATION DATA FILE:      C:\HELP3\GBRONC.D4
TEMPERATURE DATA FILE:        C:\HELP3\GBRONCT.D7
SOLAR RADIATION DATA FILE:    C:\HELP3\GBRONCS.D13
EVAPOTRANSPIRATION DATA:      C:\HELP3\GBRONCE.D11
SOIL AND DESIGN DATA FILE:    C:\HELP3\ACT100CL.D10
OUTPUT DATA FILE:             C:\HELP3\ACT100CL.OUT


TIME:  11:55      DATE:  11/28/1995


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     TITLE:  Greensboro, NC Landfill Closed

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     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
              COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.


                                  LAYER  1
                                  --------

                     TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER  10
          THICKNESS                    =      24.00   INCHES
          POROSITY                     =       0.3980 VOL/VOL
          FIELD CAPACITY               =       0.2440 VOL/VOL
          WILTING POINT                =       0.1360 VOL/VOL
          INITIAL SOIL WATER CONTENT   =       0.3980 VOL/VOL
          EFFECTIVE SAT. HYD. COND.    =  0.119999997000E-03 CM/SEC
        NOTE:  SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  1.80
                 FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.
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LAYER 2

TYPE 4 - FLEXIBLE MEMBRANE LINER
MATERIAL TEXTURE NUMBER 37

THICKNESS	=	0.04	INCHES
POROSITY	=	0.0000	VOL/VOL
FIELD CAPACITY	=	0.0000	VOL/VOL
WILTING POINT	=	0.0000	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0000	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.199999999000E-10	CM/SEC
FML PINHOLE DENSITY	=	0.00	HOLES/ACRE
FML INSTALLATION DEFECTS	=	5.00	HOLES/ACRE
FML PLACEMENT QUALITY	=	3 - GOOD	

LAYER 3

TYPE 3 - BARRIER SOIL LINER
MATERIAL TEXTURE NUMBER 15

THICKNESS	=	18.00	INCHES
POROSITY	=	0.4750	VOL/VOL
FIELD CAPACITY	=	0.3780	VOL/VOL
WILTING POINT	=	0.2650	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.4750	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.170000003000E-04	CM/SEC

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE #10 WITH A FAIR STAND OF GRASS, A SURFACE SLOPE OF 5.% AND A SLOPE LENGTH OF 100. FEET.

SCS RUNOFF CURVE NUMBER	=	86.80	
FRACTION OF AREA ALLOWING RUNOFF	=	0.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	1.000	ACRES
EVAPORATIVE ZONE DEPTH	=	21.0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	8.358	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	8.358	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	2.856	INCHES
INITIAL SNOW WATER	=	1.799	INCHES
INITIAL WATER IN LAYER MATERIALS	=	18.102	INCHES
TOTAL INITIAL WATER	=	19.901	INCHES
TOTAL SUBSURFACE INFLOW	=	0.00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
GREENSBORO NORTH CAROLINA

MAXIMUM LEAF AREA INDEX	= 1.00	
START OF GROWING SEASON (JULIAN DATE)	= 90	
END OF GROWING SEASON (JULIAN DATE)	= 305	
AVERAGE ANNUAL WIND SPEED	= 7.60	MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	= 66.00	%
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	= 68.00	%
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	= 74.00	%
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	= 70.00	%

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR GREENSBORO NORTH CAROLINA

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
3.51	3.37	3.88	3.16	3.37	3.93
4.27	4.19	3.64	3.18	2.59	3.38

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR GREENSBORO NORTH CAROLINA

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
37.50	39.90	48.00	58.30	66.50	73.50
77.20	76.30	69.90	58.40	48.50	40.20

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR GREENSBORO NORTH CAROLINA

STATION LATITUDE = 35.13 DEGREES

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AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 20

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	2.71	3.27	4.10	2.81	3.05	3.96
	4.76	5.13	3.82	2.52	2.60	3.80

STD. DEVIATIONS	1.65	1.38	1.92	1.36	1.29	2.53
	1.98	2.38	2.39	1.71	1.91	1.80
RUNOFF						
TOTALS	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
STD. DEVIATIONS	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
EVAPOTRANSPIRATION						
TOTALS	1.280	1.882	3.485	4.842	5.412	4.816
	5.434	4.587	3.466	2.972	1.839	1.468
STD. DEVIATIONS	0.419	0.325	0.265	0.324	1.419	1.838
	1.476	1.249	1.214	0.654	0.541	0.206
PERCOLATION/LEAKAGE THROUGH LAYER 3						
TOTALS	0.0858	0.0783	0.0897	0.0862	0.0815	0.0709
	0.0678	0.0657	0.0674	0.0736	0.0698	0.0798
STD. DEVIATIONS	0.0104	0.0081	0.0031	0.0037	0.0118	0.0143
	0.0192	0.0211	0.0200	0.0198	0.0204	0.0143

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ACROSS LAYER 3						
AVERAGES	22.5078	22.9367	23.7522	23.5842	21.5602	19.3588
	17.8756	17.3175	18.3702	19.4382	19.0293	21.1069
STD. DEVIATIONS	2.6933	2.4014	0.8220	1.0100	3.1579	3.9495
	5.1472	5.6761	5.5557	5.3095	5.6688	3.8325

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AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 20

	INCHES		CU. FEET	PERCENT
PRECIPITATION	42.52	(7.072)	154363.9	100.00
RUNOFF	0.000	(0.0000)	0.00	0.000
EVAPOTRANSPIRATION	41.484	(5.8474)	150587.59	97.554
PERCOLATION/LEAKAGE THROUGH FROM LAYER 3	0.91641	(0.12464)	3326.554 ≈ 68.2 acad	2.15501

AVERAGE HEAD ACROSS TOP OF LAYER 3	20.570 (	2.830)		
CHANGE IN WATER STORAGE	0.124	(4.2898)	449.79	0.291

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PEAK DAILY VALUES FOR YEARS 1 THROUGH 20

	(INCHES)	(CU. FT.)
PRECIPITATION	3.76	13648.800
RUNOFF	0.000	0.0000
PERCOLATION/LEAKAGE THROUGH LAYER 3	0.002924	10.61491
AVERAGE HEAD ACROSS LAYER 3	24.000	
SNOW WATER	11.58	42038.9375

MAXIMUM VEG. SOIL WATER (VOL/VOL)	0.3980
MINIMUM VEG. SOIL WATER (VOL/VOL)	0.1332

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FINAL WATER STORAGE AT END OF YEAR 20

LAYER	(INCHES)	(VOL/VOL)
1	9.5519	0.3980
2	0.0000	0.0000
3	8.5500	0.4750
SNOW WATER	0.000	

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**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**              HELP MODEL VERSION 3.01    (14 OCTOBER 1994)                **
**                 DEVELOPED BY ENVIRONMENTAL LABORATORY                    **
**                   USAE WATERWAYS EXPERIMENT STATION                      **
**            FOR USEPA RISK REDUCTION ENGINEERING LABORATORY               **
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PRECIPITATION DATA FILE:      C:\HELP3\GBRONC.D4
TEMPERATURE DATA FILE:        C:\HELP3\GBRONCT.D7
SOLAR RADIATION DATA FILE:    C:\HELP3\GBRONCS.D13
EVAPOTRANSPIRATION DATA:      C:\HELP3\GBRONCE.D11
SOIL AND DESIGN DATA FILE:    C:\HELP3\ACT10I.D10
OUTPUT DATA FILE:             C:\HELP3\ACT10IOT.OUT


TIME:  17:59      DATE:  11/22/1995


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     TITLE:  Greensboro, NC Landfill Active Cell - 10' Waste&Interim Cvr.

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     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
              COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.


                                  LAYER  1
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                     TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER  10
          THICKNESS                    =      12.00   INCHES
          POROSITY                     =       0.3980 VOL/VOL
          FIELD CAPACITY               =       0.2440 VOL/VOL
          WILTING POINT                =       0.1360 VOL/VOL
          INITIAL SOIL WATER CONTENT   =       0.2832 VOL/VOL
          EFFECTIVE SAT. HYD. COND.    =  0.119999997000E-03 CM/SEC
       NOTE:  SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  1.80
                FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.
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LAYER 2

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 18

THICKNESS	=	120.00	INCHES
POROSITY	=	0.6710	VOL/VOL
FIELD CAPACITY	=	0.2920	VOL/VOL
WILTING POINT	=	0.0770	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.2940	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.100000005000E-02	CM/SEC

LAYER 3

TYPE 3 - BARRIER SOIL LINER
MATERIAL TEXTURE NUMBER 22

THICKNESS	=	12.00	INCHES
POROSITY	=	0.4190	VOL/VOL
FIELD CAPACITY	=	0.3070	VOL/VOL
WILTING POINT	=	0.1800	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.4190	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.189999992000E-04	CM/SEC

LAYER 4

TYPE 2 - LATERAL DRAINAGE LAYER
MATERIAL TEXTURE NUMBER 5

THICKNESS	=	12.00	INCHES
POROSITY	=	0.4570	VOL/VOL
FIELD CAPACITY	=	0.1310	VOL/VOL
WILTING POINT	=	0.0580	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.1953	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.100000005000E-02	CM/SEC
SLOPE	=	2.00	PERCENT
DRAINAGE LENGTH	=	50.0	FEET

LAYER 5

TYPE 4 - FLEXIBLE MEMBRANE LINER
MATERIAL TEXTURE NUMBER 35

THICKNESS	=	0.06	INCHES
POROSITY	=	0.0000	VOL/VOL
FIELD CAPACITY	=	0.0000	VOL/VOL
WILTING POINT	=	0.0000	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0000	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.199999996000E-12	CM/SEC
FML PINHOLE DENSITY	=	0.00	HOLES/ACRE

FML INSTALLATION DEFECTS	=	4.00	HOLES/ACRE
FML PLACEMENT QUALITY	=	2 - EXCELLENT	

LAYER 6

TYPE 3 - BARRIER SOIL LINER
MATERIAL TEXTURE NUMBER 16

THICKNESS	=	24.00	INCHES
POROSITY	=	0.4270	VOL/VOL
FIELD CAPACITY	=	0.4180	VOL/VOL
WILTING POINT	=	0.3670	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.4270	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.100000001000E-06	CM/SEC

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE #10 WITH BARE GROUND CONDITIONS, A SURFACE SLOPE OF 10.% AND A SLOPE LENGTH OF 100. FEET.

SCS RUNOFF CURVE NUMBER	=	94.40	
FRACTION OF AREA ALLOWING RUNOFF	=	100.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	1.000	ACRES
EVAPORATIVE ZONE DEPTH	=	21.0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	5.946	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	10.815	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	2.325	INCHES
INITIAL SNOW WATER	=	0.000	INCHES
INITIAL WATER IN LAYER MATERIALS	=	56.297	INCHES
TOTAL INITIAL WATER	=	56.297	INCHES
TOTAL SUBSURFACE INFLOW	=	0.00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM GREENSBORO NORTH CAROLINA

MAXIMUM LEAF AREA INDEX	=	1.00	
START OF GROWING SEASON (JULIAN DATE)	=	90	
END OF GROWING SEASON (JULIAN DATE)	=	305	
AVERAGE ANNUAL WIND SPEED	=	7.60	MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	66.00	%
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	68.00	%
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	74.00	%
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	70.00	%

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR GREENSBORO NORTH CAROLINA

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
3.51	3.37	3.88	3.16	3.37	3.93
4.27	4.19	3.64	3.18	2.59	3.38

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR GREENSBORO NORTH CAROLINA

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
37.50	39.90	48.00	58.30	66.50	73.50
77.20	76.30	69.90	58.40	48.50	40.20

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR GREENSBORO NORTH CAROLINA

STATION LATITUDE = 35.13 DEGREES

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AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 20

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	2.71	3.27	4.10	2.81	3.05	3.96
	4.76	5.13	3.82	2.52	2.60	3.80
STD. DEVIATIONS	1.65	1.38	1.92	1.36	1.29	2.53
	1.98	2.38	2.39	1.71	1.91	1.80
RUNOFF						
TOTALS	0.459	0.699	0.941	0.411	0.495	0.829
	1.041	1.355	1.271	0.663	0.451	1.0
STD. DEVIATIONS	0.499	0.607	0.860	0.638	0.482	0.910
	1.011	1.179	1.143	0.709	0.841	0.777
EVAPOTRANSPIRATION						

TOTALS	1.362	1.658	2.849	2.839	2.811	3.522
	3.918	2.874	2.574	2.283	1.205	1.078
STD. DEVIATIONS	0.168	0.273	0.306	0.724	0.802	1.454
	1.334	1.072	0.831	0.859	0.413	0.201

PERCOLATION/LEAKAGE THROUGH LAYER 3

TOTALS	0.7948	0.7767	1.0333	0.6021	0.1673	0.0863
	0.0334	0.0131	0.0674	0.0870	0.0580	0.2148
STD. DEVIATIONS	0.7480	0.6253	0.7729	0.4832	0.0997	0.0941
	0.0713	0.0278	0.2321	0.1837	0.1869	0.4944

LATERAL DRAINAGE COLLECTED FROM LAYER 4

TOTALS	0.2315	0.3060	0.4249	0.4757	0.4786	0.4121
	0.3602	0.3002	0.2495	0.2304	0.1949	0.1936
STD. DEVIATIONS	0.1555	0.1790	0.1968	0.1942	0.1932	0.1845
	0.1731	0.1560	0.1429	0.1248	0.0937	0.1093

PERCOLATION/LEAKAGE THROUGH LAYER 6

TOTALS	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ACROSS LAYER 3

AVERAGES	0.0072	0.0081	0.0100	0.0060	0.0016	0.0009
	0.0003	0.0001	0.0007	0.0009	0.0006	0.0019
STD. DEVIATIONS	0.0066	0.0065	0.0075	0.0048	0.0009	0.0009
	0.0007	0.0003	0.0023	0.0019	0.0018	0.0043

DAILY AVERAGE HEAD ACROSS LAYER 6

AVERAGES	5.0430	6.6032	7.7959	8.6684	8.5399	7.8870
	7.0452	6.2186	5.5783	5.1558	4.7064	4.5256
STD. DEVIATIONS	2.0655	2.6788	2.4727	2.2939	2.1863	2.2187
	2.1218	1.9989	1.9297	1.7936	1.5489	1.6912

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AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 20

	INCHES		CU. FEET	PERCENT
PRECIPITATION	42.52	(7.072)	154363.9	100.00
RUNOFF	9.621	(2.9091)	34925.86	22.626
EVAPOTRANSPIRATION	28.974	(3.3437)	105175.87	68.135
PERCOLATION/LEAKAGE THROUGH FROM LAYER 3	3.93417	(1.59449)	14281.031 292 gpad	9.25153
AVERAGE HEAD ACROSS TOP OF LAYER 3	0.003	(0.001)		
LATERAL DRAINAGE COLLECTED FROM LAYER 4	3.85756	(1.64410)	14002.948	9.07139
PERCOLATION/LEAKAGE THROUGH FROM LAYER 6	0.00105	(0.00029)	3.828	0.00248
AVERAGE HEAD ACROSS TOP OF LAYER 6	6.481	(1.766)		
CHANGE IN WATER STORAGE	0.070	(2.1395)	255.43	0.165

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PEAK DAILY VALUES FOR YEARS 1 THROUGH 20

	(INCHES)	(CU. FT.)
PRECIPITATION	3.76	13648.800
RUNOFF	2.650	9620.7734
PERCOLATION/LEAKAGE THROUGH LAYER 3	0.180711	655.97986
AVERAGE HEAD ACROSS LAYER 3	0.060	
DRAINAGE COLLECTED FROM LAYER 4	0.02565	93.12045
PERCOLATION/LEAKAGE THROUGH LAYER 6	0.000005	0.01968
AVERAGE HEAD ACROSS LAYER 6	12.000	
SNOW WATER	2.87	10419.2432

MAXIMUM VEG. SOIL WATER (VOL/VOL)	0.3302
MINIMUM VEG. SOIL WATER (VOL/VOL)	0.1007

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FINAL WATER STORAGE AT END OF YEAR 20

LAYER	(INCHES)	(VOL/VOL)
1	3.2526	0.2710
2	35.3215	0.2943
3	5.0280	0.4190
4	3.8547	0.3212
5	0.0000	0.0000
6	10.2480	0.4270
SNOW WATER	0.000	

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PROJECT	HDR- GBORO. LF	SHEET 1 OF 2	
SUBJECT	Leachate Quantity Estimates	JOB NO. HDRGN-2	
		DATE 11/22/95	
		COMPUTED BY PKS	
		CHECKED BY	

- Objective: To estimate leachate quantities generated under the following "normal operating conditions" for the landfill cell:

  1. Surge Event Generation (1 yr 24 hr Storm)
  2. Normal Daily Generation

- Assumptions:

  A. Assume largest subcell for surge event

  B. Assume full cell area developed for long term generation rate.

  C. For surge event consider subcell with little or no refuse in place. Assume that entire rain event reaches LCS within 8 hrs. of end of design storm. (Conservative)

  D. For rates of removal, neglect any leachate that is removed from the LCS or storage tank(s) during the storm event.

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DRAWN	JOB NO.	APPROVED	DATE	REVISED DATE

G.N. Richardson & Associates

ENGINEERING AND GEOLOGICAL SERVICES

SHEET: 2/2
JOB #: HDRGN-2
DATE: 11/22/95
BY: PKS
CHKD BY:

City of Greensboro
Leachate Quantity Estimates

Case 1: Surge Event:

1 Year, 24 Hr. Design Storm Depth = 3.0 inches

Size of Largest Subcell = 5.6 acres

Quantity of Leachate Produced = 456160 gallons

Maximum Tank Capacity = 341000 gallons (62' Diam. 15' High Tank)

Available Tank Capacity (gallons)	Volume Retained in Landfill Cell (gallons)	Maximum Detention Time in Cell (days)	
		Pumping Rate = 15,000 gpd	Pumping Rate = 30,000 gpd
300000	156160	10.4	5.2
250000	206160	13.7	6.9
200000	256160	17.1	8.5
190000	266160	17.7	8.9
180000	276160	18.4	9.2
170000	286160	19.1	9.5
160000	296160	19.7	9.9
150000	306160	20.4	10.2
140000	316160	21.1	10.5
130000	326160	21.7	10.9
120000	336160	22.4	11.2
110000	346160	23.1	11.5
100000	356160	23.7	11.9
90000	366160	24.4	12.2
80000	376160	25.1	12.5
70000	386160	25.7	12.9
60000	396160	26.4	13.2
50000	406160	27.1	13.5
40000	416160	27.7	13.9
30000	426160	28.4	14.2
20000	436160	29.1	14.5
10000	446160	29.7	14.9
0	456160	30.4	15.2

Case 2: Normal Daily Generation:

Daily Leachate Generation Rate = 1200 gallons/acre/day

Size of Landfill Cell = 20 acres

Days of Capacity for Specified Tank = 14.2 days

LCHOUAN.WB1

PROJECT HDR – GBORO, LF

SUBJECT Leachate Collection Pipe Spacing

SHEET 1 OF 2
JOB NO. HDR GN-2
DATE 11/21/95
COMPUTED BY DKS
CHECKED BY

— Objective: Evaluate the leachate collection pipe spacing which will maintain at most 1 Foot of head on the geomembrane under Normal Operating Conditions.

— Analysis: The US EPA mounding equation found in SW 869 will be used to calculate the required spacings. The equation is:

$$h_{max} = \frac{L\sqrt{c}}{2}\left[\frac{\tan^2\alpha}{c} + 1 - \frac{\tan\alpha}{c}\sqrt{\tan^2\alpha + c}\right]$$

where: h_{max} = Max. Allowable Head (Ft)

L = Pipe Spacing (Ft)

$c = q/k$

q = Infiltration Rate (cm/sec)
k = Drainage Layer Perm (cm/sec)

Note: The infiltration rate, q, is assumed to be either the rainfall intensity or the operational cover permeability, whichever is smaller. For the long-term duration rainfall events of interest here, the operational cover permeability controls.

α = Bottom Slope Angle (degrees)

— Determine L based on the following graph where h_{max} = 1 Ft (constant).

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DRAWN	JOB NO.	APPROVED	DATE	REVISED DATE

G.N. Richardson & Associates

ENGINEERING AND GEOLOGICAL SERVICES

SHEET: 2/2
JOB #: HDRGN-2
DATE: 11/21/95
BY: PKS
CHKD BY:

City of Greensboro
Analysis of Leachate Collection System
Leachate Collection Pipe Spacing

c	Slope (%)	Slope (Deg.)	(c^.5)/2	tan a	(tan a)^2	(tan a)/c	((tan a)^2+c)^.5	( )	L
0.005	1	0.57	0.0354	0.0099	0.0001	1.9897	0.0714	0.8777	32.22
0.005	2	1.15	0.0354	0.0201	0.0004	4.0148	0.0735	0.7855	36.01
0.005	4	2.29	0.0354	0.0400	0.0016	7.9979	0.0812	0.6701	42.21
0.005	6	3.43	0.0354	0.0599	0.0036	11.9873	0.0927	0.6073	46.57
0.005	8	4.57	0.0354	0.0799	0.0064	15.9862	0.1067	0.5718	49.47
0.005	10	5.71	0.0354	0.1000	0.0100	19.9979	0.1225	0.5505	51.38
0.0025	1	0.57	0.0250	0.0099	0.0001	3.9795	0.0510	0.8367	47.81
0.0025	2	1.15	0.0250	0.0201	0.0004	8.0296	0.0539	0.7286	54.90
0.0025	4	2.29	0.0250	0.0400	0.0016	15.9957	0.0640	0.6155	64.98
0.0025	6	3.43	0.0250	0.0599	0.0036	23.9746	0.0781	0.5656	70.72
0.0025	8	4.57	0.0250	0.0799	0.0064	31.9724	0.0943	0.5412	73.91
0.0025	10	5.71	0.0250	0.1000	0.0100	39.9958	0.1118	0.5279	75.78
0.001	1	0.57	0.0158	0.0099	0.0001	9.9487	0.0332	0.7692	82.23
0.001	2	1.15	0.0158	0.0201	0.0004	20.0740	0.0375	0.6511	97.14
0.001	4	2.29	0.0158	0.0400	0.0016	39.9893	0.0510	0.5604	112.85
0.001	6	3.43	0.0158	0.0599	0.0036	59.9364	0.0678	0.5307	119.18
0.001	8	4.57	0.0158	0.0799	0.0064	79.9311	0.0860	0.5182	122.06
0.001	10	5.71	0.0158	0.1000	0.0100	99.9895	0.1049	0.5119	123.55
0.00075	1	0.57	0.0137	0.0099	0.0001	13.2649	0.0291	0.7455	97.97
0.00075	2	1.15	0.0137	0.0201	0.0004	26.7653	0.0340	0.6285	116.20
0.00075	4	2.29	0.0137	0.0400	0.0016	53.3191	0.0485	0.5479	133.28
0.00075	6	3.43	0.0137	0.0599	0.0036	79.9152	0.0659	0.5237	139.45
0.00075	8	4.57	0.0137	0.0799	0.0064	106.5748	0.0845	0.5139	142.12
0.00075	10	5.71	0.0137	0.1000	0.0100	133.3194	0.1037	0.5090	143.47
0.0005	1	0.57	0.0112	0.0099	0.0001	19.8974	0.0245	0.7110	125.80
0.0005	2	1.15	0.0112	0.0201	0.0004	40.1480	0.0300	0.5995	149.19
0.0005	4	2.29	0.0112	0.0400	0.0016	79.9787	0.0458	0.5340	167.51
0.0005	6	3.43	0.0112	0.0599	0.0036	119.8728	0.0640	0.5163	173.24
0.0005	8	4.57	0.0112	0.0799	0.0064	159.8622	0.0830	0.5094	175.58
0.0005	10	5.71	0.0112	0.1000	0.0100	199.9791	0.1025	0.5061	176.73
0.00025	1	0.57	0.0079	0.0099	0.0001	39.7948	0.0187	0.6525	193.86
0.00025	2	1.15	0.0079	0.0201	0.0004	80.2959	0.0256	0.5600	225.86
0.00025	4	2.29	0.0079	0.0400	0.0016	159.9573	0.0430	0.5181	244.12
0.00025	6	3.43	0.0079	0.0599	0.0036	239.7456	0.0620	0.5084	248.80
0.00025	8	4.57	0.0079	0.0799	0.0064	319.7245	0.0815	0.5048	250.58
0.00025	10	5.71	0.0079	0.1000	0.0100	399.9582	0.1012	0.5031	251.43
0.00010	1	0.57	0.0050	0.0099	0.0001	99.4870	0.0141	0.5864	341.06
0.00010	2	1.15	0.0050	0.0201	0.0004	200.7398	0.0224	0.5277	379.02
0.00010	4	2.29	0.0050	0.0400	0.0016	399.8934	0.0412	0.5076	394.03
0.00010	6	3.43	0.0050	0.0599	0.0036	599.3641	0.0608	0.5034	397.27
0.00010	8	4.57	0.0050	0.0799	0.0064	799.3112	0.0806	0.5019	398.45
0.00010	10	5.71	0.0050	0.1000	0.0100	999.8954	0.1005	0.5012	399.01

$$c = t/k = \frac{1\times10^{-5}\,cm/sec \leftarrow \text{Op. Cover}}{1\times10^{-2}\,cm/sec \leftarrow \text{SAND Drainage Layer}}$$

$$= \underline{0.001}$$

SLOPE ≅ 2% ALONG PIPE

PIPSPACE.WB1

$L_{MAX} \cong 100'$

PROJECT HDR – GBORO, LF

SUBJECT Leachate Collection Pipe Sizing

SHEET 1 OF 2
JOB NO. HDRGN-2
DATE 11/21/95
COMPUTED BY PKS
CHECKED BY

– Objective: Evaluate the required size of leachate collector, header, & outlet pipes based on the 25 yr, 24 hr storm.

– Assumptions:

1. Assume entire storm acts on system at one time. (Very Conservative)
2. Neglect influence of waste. (Conservative)
3. Drain rainfall from cell in at most 24 hrs. from end of rainfall event, neglecting removal during the storm. (Conservative)
4. All runoff is retained within the cell.

– Analysis:

1. Calculate volumes to be drained by each pipe.
2. Calculate required flow volumes to drain cell in 24 hrs.
3. Size each pipe.
4. Equations:

Volume = Depth of Storm (Ft) × Area (Ft^2)

Q_{Req} = Required Flow Volume To Drain in 24 hrs. (cfs)

= Volume / 86400 sec/24hrs.

Reqd. Pipe Diameter (D_{Req}) = $16 \left[\frac{Q_{Req} \cdot n}{N \cdot s}\right]^{.375}$ – Manning's Eq'n. For Circ. Pipes Flowing Just Full

n = Manning's Coef. s = slope of pipe

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DRAWN	JOB NO.	APPROVED	DATE	REVISED DATE

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ENGINEERING AND GEOLOGICAL SERVICES

SHEET: 2/2
JOB #: HDRGN-2
DATE: 11/21/95
BY: PKS
CHKD BY:

City of Greensboro
Analysis of Leachate Collection System
Leachate Collection Pipe Sizing

25 Year, 24 Hour Design Storm Depth = 6 inches

Cell #1 & #2:

Outlet Pipe Sizing:

Max. Area Drained = 22.5 Ac. (1)
Slope of Pipe = 4 %
Manning's Coefficient (n) = 0.01

Volume (cf)	Qreq (cfs)	Dreq (in)	Dact (in)
490050	5.67	9.97	10

Header Pipe Sizing:

Max. Area Drained = 19.1 Ac (2)
Slope of Pipe = 2.5 %
Manning's Coefficient (n) = 0.01

Volume (cf)	Qreq (cfs)	Dreq (in)	Dact (in)
415998	4.81	10.24	12

Primary Collection Pipe Sizing:

Subcells 1A & 2A:

Max. Area Drained = 7.00 Ac (3)
Slope of Pipe = 0.5 %
Manning's Coefficient (n) = 0.01

Volume (cf)	Qreq (cfs)	Dreq (in)	Dact (in)
152460	1.76	9.51	10

Remaining Subcells: (4)

Max. Area Drained = 9.50 Ac.
Slope of Pipe = 1.0 %
Manning's Coefficient (n) = 0.01

Volume (cf)	Qreq (cfs)	Dreq (in)	Dact (in)
206910	2.39	9.36	10

Secondary Collection Pipe Sizing:

Max. Area Drained = 0.60 Ac. (5)
Slope of Pipe = 2.0 %
Manning's Coefficient (n) = 0.01

Volume (cf)	Qreq (cfs)	Dreq (in)	Dact (in)
13068	0.15	2.92	4

Cell #3:

Primary Collection Pipe Sizing:

Max. Area Drained = 6.70 Ac. (6)
Slope of Pipe = 1.5 %
Manning's Coefficient (n) = 0.01

Volume (cf)	Qreq (cfs)	Dreq (in)	Dact (in)
145926	1.69	7.61	8

Secondary Collection Pipe Sizing:

Max. Area Drained = 0.60 Ac. (5)
Slope of Pipe = 2.0 %
Manning's Coefficient (n) = 0.01

Volume (cf)	Qreq (cfs)	Dreq (in)	Dact (in)
13068	0.15	2.92	4

PPSIZE.WB1

(1) = Max. Subcell (3A = 6.7 Ac) + 35% Remaining Area (51.9 Ac - 6.7 Ac

(2) = Max. Subcell (6.7 Ac) + 35% Remaining Area with Subcells 1A & 2A Not Included (51.9 - 6.7 - 5.4 - 4.5)

(3) = Subcell 1A (5.4 Ac) + 35% Cell 2A (4.5 Ac)

(4) = Subcell 1C (5.6 Ac) + 35% Subcell 2C (3.9 Ac)

(5) = 100' Spacing x 250' Length (Max.)

(6) = Max Subcell Cell 3 (6.7 Ac)

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SHEET: 4/4
JOB #: HDRGN-2
DATE: 11/21/95
BY: PKS
CHKD BY:

City of Greensboro
Analysis of Leachate Collection Pipe Stresses

Case 1: Maximum Static Loading

Leachate Collection Sand:
Thickness (ft) = 0.5
Unit Weight (pcf) = 120

Compacted Soil Cover:
Thickness (ft) = 2
Unit Weight (pcf) = 120

Operational Cover:
Thickness (ft) = 2
Unit Weight (pcf) = 120

Agricultural Cover:
Thickness (ft) = 2
Unit Weight (pcf) = 120

Waste & Daily Cover:
Thickness (ft) = 150
Unit Weight (pcf) = 60

Max. Vertical Stress (Pt) (psi) = 89

Calculate Safety Factors Against Crushing and Buckling:

SDR	SA (psi)	E (psi)	Pc (psi)	Pcb (psi)	FS crush	FS buckle	Comment
19	724	17500	5.92	75.38	2.07	0.94	No Good
17	643	19000	6.97	92.81	2.33	1.15	Marginal
15.5	583	20000	12.46	109.37	2.67	1.36	Marginal
11	402	24000	41.83	200.40	3.73	2.49	O.K.

Case 2: Dynamic (Equipment) Loading

SDR (Determine From Static Loading Analysis) = 11

Line Loads:

Equipment	Weight* (lbs)	Track Length (ft)	Dynamic Line Loads (psi) 6" Cover	12" cover	18" Cover	SA 6" Cover	12" cover	18" Cover	FS 6" Cover	12" cover	18" Cover
D4 Bulldozer (D4C-II)	19485	6.74	19	10	6	98	48	32	15.6	31.3	46.9
D6 Bulldozer (D6H-II)	46505	8.63	36	18	12	178	89	59	8.4	16.9	25.3
D8 Bulldozer (D8L)	95898	10.5	61	30	20	303	151	101	5.0	9.9	14.8
953 Track Loader	37560	7.5	33	17	11	166	83	55	9.0	18.1	27.1
963 Track Loader	48914	8.08	40	20	13	201	100	67	7.5	14.9	22.4

* Includes Blades, Loaded Buckets, etc.

Point Loads:

Equipment	Weight* (lbs)	Number of Tires	Dynamic Point Loads (psi) 6" Cover	12" cover	18" Cover	SA 6" Cover	12" cover	18" Cover	FS 6" Cover	12" cover	18" Cover
950 Wheel Loader	48828	4	242	60	27	1209	302	134	1.2	5.0	11.2
615 Scraper	91000	4	453	113	50	2263	566	251	0.7	2.7	6.0
621 Scraper	115195	4	573	143	64	2865	716	318	0.5	2.1	4.7
816B Compactor	45477	4	226	57	25	1131	283	126	1.3	5.3	11.9
826C Compactor	69733	4	347	87	39	1734	434	193	0.9	3.5	7.8

* Includes Blades, Loaded Buckets, etc.

SDR 11 Pipe O.K. – As an alternative to smooth wall HDPE, corrugated HDPE such as Advanced Drainage Systems N12 or equivalent may be used.

PROJECT: HDR-GBORO. LF
SUBJECT: Leachate Collection Pipe Stresses (HDPE PIPE)

SHEET 1 OF 4
JOB NO. HDRGN-2
DATE 11/28/95
COMPUTED BY PKS
CHECKED BY

— Objective: Evaluate leachate collection pipe stresses due to static (overburden) and dynamic (equipment) loads. Check both crushing and buckling failure modes.

Cases To Be Evaluated:

1. Maximum Static Loading
2. Equipment Loads as Follows:
   A. Construction
   B. Operation

— Analysis: Follow Driscoplpe Systems Design Manual

Minimum F.S. ⟹ Static = 1.8
Dynamic = 1.4

— Equations:

— Crushing Stress:

$$S_A = \left[\frac{SDR-1}{2}\right] P_T$$ (Driscoplpe p.36)

where: S_A = Stress in Pipe Wall (psi)
SDR = Standard Dimension Ratio
= Outside Diam./Wall Thickness
P_T = External Pressure (psi)

$$F.S._{crushing} = \sigma_{yield}\ (HDPE = 1500\,psi) / S_A$$

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DRAWN	JOB NO.	APPROVED	DATE	REVISED DATE

PROJECT: HDR- GBORO. L.F.
SUBJECT: Leachate Collection Pipe Stresses

SHEET 2 OF 4
JOB NO. HDRGN-2
DATE 11/28/95
COMPUTED BY PKS
CHECKED BY

— Wall Buckling:

$$P_{cb} = 0.8\sqrt{E'(P_c)}$$ (Driscopipe p.37)

where: P_{cb} = Critical Buckling Soil Pressure @ Top of Pipe (psi)

E' = Base Soil Modulus (psi)

$$E' = \frac{P_T}{\epsilon_s} = \frac{\text{Vertical Soil Pressure}}{\text{Vertical Soil Strain}}$$

* Use $E' = 1500$ psi for Compacted soil/liner

P_c = Hydrostatic Critical Collapse Differential Pressure (psi)

$$P_c = \frac{2.32E}{(SDR)^3}$$

E = Stress/Time Dependent Tensile Modulus of Elasticity (psi)

$$F.S._{buckling} = P_{cb}/P_T$$

— Equipment Loading:

Point Loads: ①

$$P_T = P_P = \frac{3Wz^3}{2\pi z^5}$$

Line Loads: ②

$$P_T = P_L = \frac{2Wz^3}{\pi z^4}$$

where: W = Dynamic Equipment Load (1.5 times weight of machine) (lbs or lbs/Ft)

z = Vertical Distance From The Point Load To Top of Pipe (ft)

① Driscopipe p.44

② Holtz & Kovacs, An Intro. To Geotech. Eng., p.348

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DRAWN	JOB NO.	APPROVED	DATE	REVISED DATE

PROJECT: HDR- GBORO, LF.

SUBJECT: Leachate Collection Pipe Stresses

SHEET 3 OF 4
JOB NO. HDRGN-2
DATE 11/28/95
COMPUTED BY PKS
CHECKED BY

Values of E':

A.

TABLE 3.4 Average Values of Modulus of Soil Reaction, E' (For Initial Flexible Pipe Deflection)

Soil type-pipe bedding material (Unified Classification System*)	E' for degree of compaction of bedding, lb/in² Dumped	Slight, < 85% proctor, < 40% relative density	Moderate, 85%–95% proctor, 40%–70% relative density	High, > 95% proctor, > 70% relative density
Fine-grained soils (LL > 50†) Soils with medium to high plasticity CH, MH, CH-MH	No data available; consult a competent soils engineer; Otherwise use E' = 0			
Fine-grained soils (LL < 50) Soils with medium to no plasticity CL, ML, ML-CL, with less than 25% coarse-grained particles	50	200	400	1000
Fine-grained soils (LL < 50) Soils with medium to no plasticity CL, ML, ML-CL, with more than 25% coarse-grained particles Coarse-grained soils with fines GM, GC, SM, SC contains more than 12% fines	100	400	1000	2000
Coarse-grained soils with little or no fines GW, GP, SW, SP‡ contains less than 12% fines	200	1000	2000	3000
Crushed rock	1000	3000	3000	3000
Accuracy in terms of percentage deflection§	± 2	± 2	± 1	± 0.5

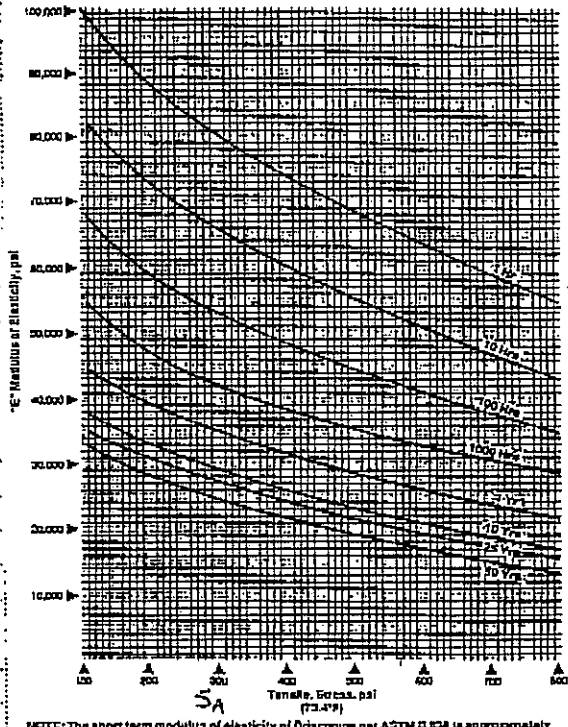
*ASTM Designation D2487, USBR Designation E-3
†LL = liquid Limit
‡Or any borderline soil beginning with one of these symbols (i.e., GM-GC, GC-SC)
§For ± 1% accuracy and predicted deflection of 3%, actual deflection would be between 2% and 4%.

NOTE: Values applicable only for fills less than 50 ft (15 m). Table does not include any safety factor. For use in predicting initial deflections only, appropriate deflection lag factor must be applied for long-term deflections. If bedding falls on the borderline between two compaction categories, select lower E' value or average the two values. Percentage proctor based on laboratory maximum dry density from test standards using about 12,500 ft-lb/ft³ (598,000 J/m³) (ASTM D698, AASHO T-99, USBR Designation E-11). 1 lb/in² = 6.9 kN/m².

SOURCE: Amster K. Howard, "Soil Reaction for Buried Flexible Pipe," U.S. Bureau of Reclamation, Denver, Colo. Reprinted with Permission from American Society of Civil Engineers *J. Geotech. Eng. Div.*, January 1977, pp. 83–93.

B.

Chart 25
Time Dependent Modulus of Elasticity for Polyethylene Pipe vs. Stress Intensity (73.4°F)



NOTE: The short term modulus of elasticity of Driscopipe per ASTM D 638 is approximately 100,000 psi. Due to the cold flow (creep) characteristic of the pipe material, this modulus is dependent upon the stress intensity and the time duration of the applied stress.

C.

TABLE 19.5 TYPICAL RANGE OF VALUES FOR MODULUS OF ELASTICITY.

Type of Soil	Modulus of Elasticity psi	Modulus of Elasticity kp/cm²
Very soft clay	50–400	3.5–30
Soft clay	250–800	20–50
*Medium clay	600–1,200	40–80
Hard clay	1,000–2,500	70–180
Sandy clay	4,000–8,000	300–400
Silty sand	1,000–2,000	70–200
Loose sand	1,500–3,500	100–250
Dense sand	7,000–12,000	500–800
Dense sand and gravel	14,000–28,000	1,000–2,000
Wood	1,200,000–1,500,000	80,000–100,000
Concrete	2,800,000–4,000,000	200,000–300,000
Steel	30,000,000	2,150,000

References:

A. Moser, Buried Pipe Design
B. Winterkorn & Fang, Foundation Engineering Handbook
C. Driscopipe Design Manual

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DRAWN	JOB NO.	APPROVED	DATE	REVISED DATE

PROJECT HDR-GBORO. LF

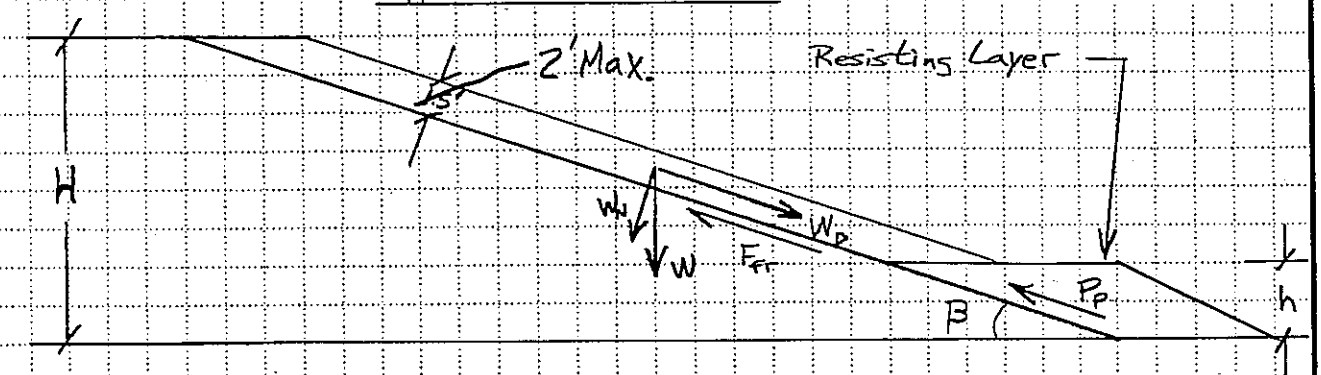
SUBJECT Operational Cover Stability

SHEET 1 OF 3
JOB NO. HDRGN-2
DATE 11/21/95
COMPUTED BY PKS
CHECKED BY

— Objective: Evaluate the stability of the operational cover veneer against sliding. Utilize the gravel toe drain (if applicable) as a toe buttress. Analyze the maximum slope height.

— Analysis: Use the sliding block method to derive the driving and resisting forces in the slope. Use a procedure in NAVFAC 7.2 to evaluate the passive pressure generated from the gravel toe drain (where applicable) or from the leachate collection & op. cover layers on the landfill bottom. Ignore adhesion (conservative).

Typical Cross-Section:



Soil Data: Op. Cover: $\phi_1, c_1, \gamma_1, t_1$
Gravel: ϕ_2, c_2, γ_2

Friction Angle (Op. Cover to Geonet): Analyze 10°-25°

Sideslope Forces:

$W = L\gamma t = (H/\sin\beta)\gamma_1 t_1$

$W_N = W\cos\beta$

$W_D = W\sin\beta$

$F_{FT} = W_N \tan\delta \quad (\delta = 10°-25°)$

$P_P = (K_P \gamma_2 h^2)/2$

($K_P \Rightarrow$ From NAVFAC 7.2 p.7.2-67)

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DRAWN	JOB NO.	APPROVED	DATE	REVISED DATE

PROJECT HDR-GBORO. LF

SUBJECT Operational Cover Stability

SHEET 2 OF 3
JOB NO. HDRGN-2
DATE 11/21/95
COMPUTED BY PKS
CHECKED BY

REDUCTION FACTOR (R) OF Kp FOR VARIOUS RATIOS OF $-\delta/\phi$

ϕ \ δ/ϕ	-0.7	-0.6	-0.5	-0.4	-0.3	-0.2	-0.1	0.0
10	.978	.962	.946	.929	.912	.898	.881	.864
15	.961	.934	.907	.881	.854	.830	.803	.775
20	.939	.901	.862	.824	.787	.752	.716	.678
25	.912	.860	.808	.759	.711	.666	.620	.574
30	.878	.811	.746	.686	.627	.574	.520	.467
35	.836	.752	.674	.603	.536	.475	.417	.362
40	.783	.682	.592	.512	.439	.375	.316	.262
45	.718	.600	.500	.414	.339	.276	.221	.174

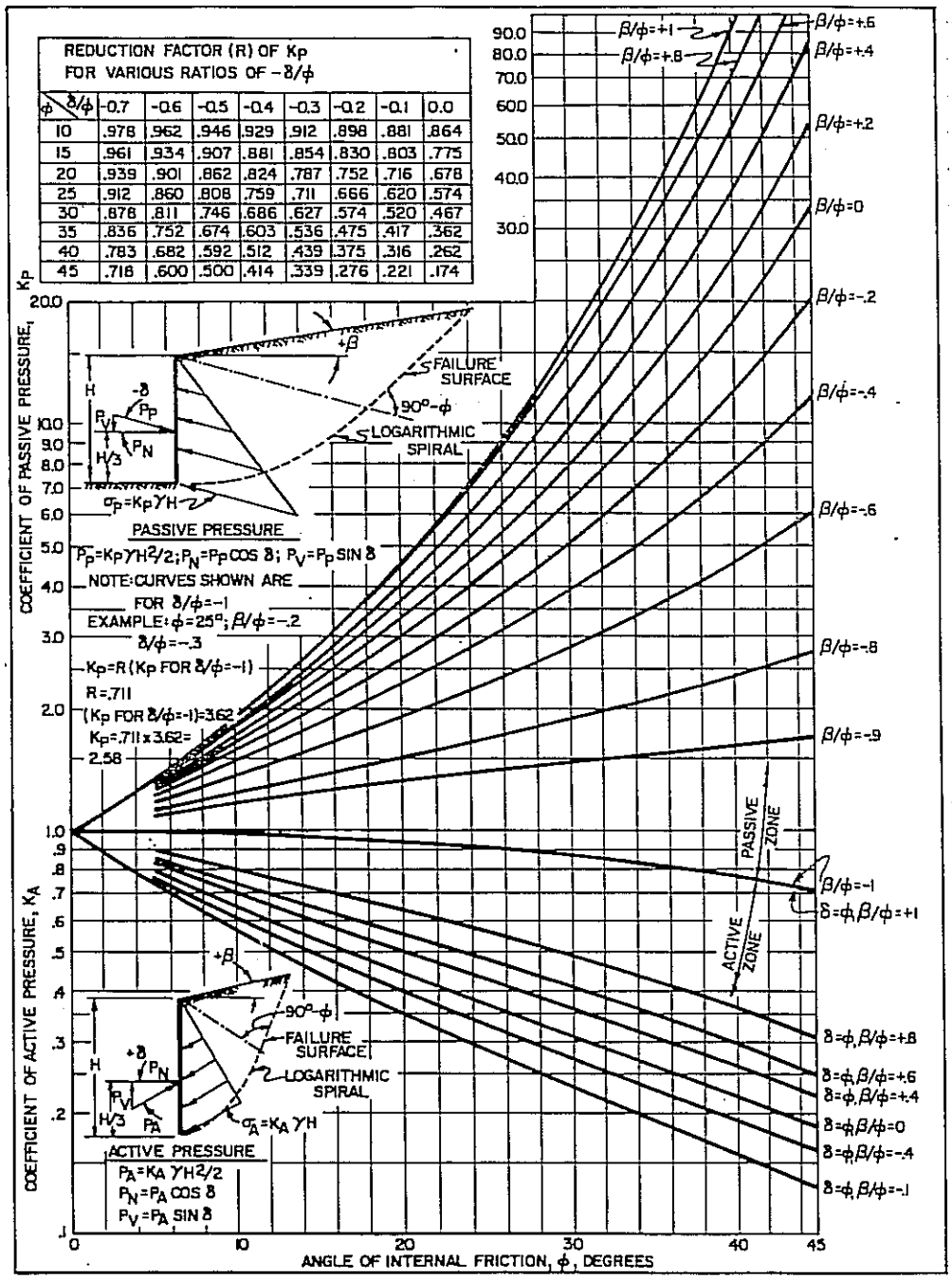

FIGURE 6
Active and Passive Coefficients with Wall Friction
(Sloping Backfill)
7.2-67

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DRAWN	JOB NO.	APPROVED	DATE	REVISED DATE

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ENGINEERING AND GEOLOGICAL SERVICES

SHEET: ~~3/4~~ 3/3
JOB #: HDRGN-2
DATE: 11/21/95
BY: PKS
CHKD BY:

City of Greensboro
Analysis of Operational Cover Stability

Input Parameters: (User Input)

Sideslope Angle (Beta):		18.4	degrees
Max. Slope Height (H):		16	ft
Operational Cover:	Thickness:	1.5	ft
	Unit Weight:	110	pcf
Resisting Layer:	Height (h):	3	ft
(Gravel Column)	Unit Weight:	140	pcf
	Phi:	40	degrees
	Beta/Phi:	-0.46	

Passive Pressure Coefficient = 6.6 (from NAVFAC Chart)

Calculate FS Against Sliding:

Interface Fric. Angle	W	WN	WD	Ffr	Pp	Resisting Force	Driving Force	FS slide
10	8364	7936	2640	1399	4158	5557	2640	2.11
15	8364	7936	2640	2126	4158	6284	2640	2.38
20	8364	7936	2640	2889	4158	7047	2640	2.67
25	8364	7936	2640	3701	4158	7859	2640	2.98

PROJECT	HDR-GBORO, LF	SHEET 1 OF 10	
SUBJECT	Geomembrane Stresses	JOB NO. HDRGN-2	
		DATE 11/21/95	
		COMPUTED BY PKS	
		CHECKED BY	

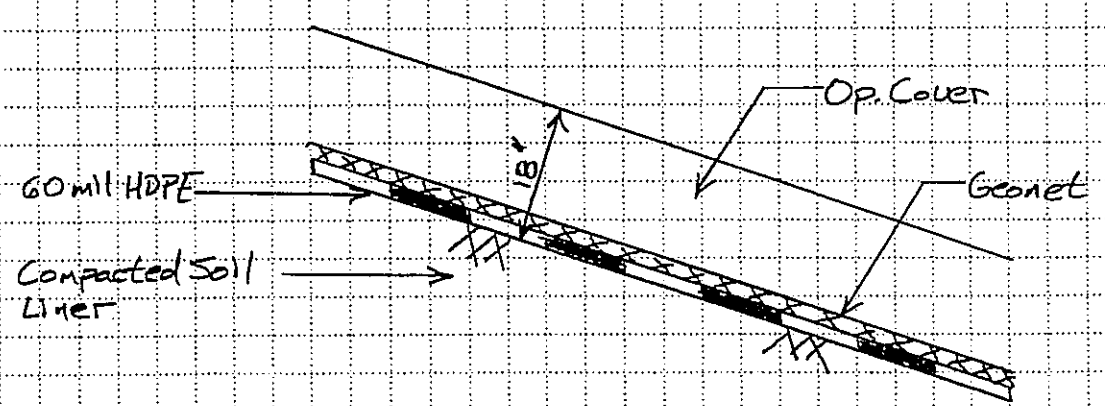
— Objective: Calculate the stresses in the geomembrane due to the following cases:

1. Stress Due To Self-Weight
2. Stress Due To Operational Cover Sliding
3. Stress Due To Waste Subsidence

— Analysis: Use methods outlined in "Geosynthetic Design Guidance For Hazardous Waste Landfill Cells and Surface Impoundments" to calculate stresses in the geomembrane.

— Assumptions:

1. 3H : 1V (β = 18.4°)
2. Max Height of Slope = 16 Ft
3. Geomembrane is 60 mil HDPE w/ σ_y = 2000 psi
4. Sideslope Cross-Section (Typ.):



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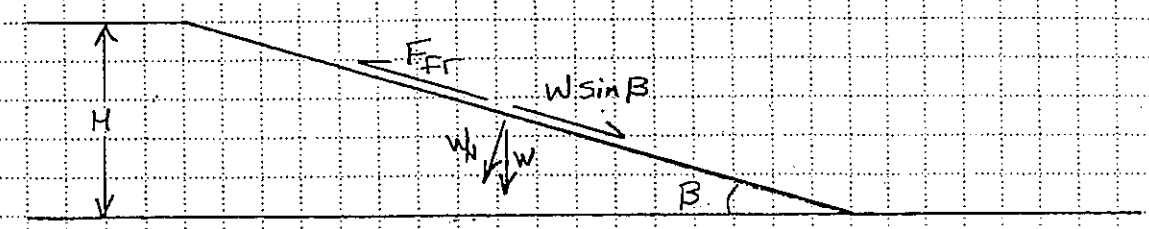
DRAWN	JOB NO.	APPROVED	DATE	REVISED DATE

Case 1 : Stress Due To Self Weight :



- $W = W_1 + W_2 + W_3$ (lb/ft)

  where: W_1 = Liner Wt.

  W_2 = Weight of Geonet

  W_3 = Weight of Geotextile (Assume Saturated)

- $W_1 = (G_s \gamma t)(1' \text{ Unit Width} \times H/\sin\beta)$

  where G_s = Specific Gravity of HDPE = 0.95

  t = Liner Thickness = .06" (60 mil)

  $L = H/\sin\beta$

- $W_2 = 50 \text{ oz/yd}^2$ Geonet $\times L$

$$\frac{50 \text{ oz/yd}^2}{16 \text{ oz/lb}} = 0.31 \text{ lb/yd}^2 \cdot \frac{1 \text{ yd}^2}{9 \text{ ft}^2} = 0.035 \text{ lb/ft}^2/\text{ft}$$

$W_2 = .035 (H/\sin\beta)$

- $W_3 = [8\ oz/yd^2\ \text{Geotextile} + \text{Wt. Water}] \times L$

$$\frac{8\ oz/yd^2}{16\ oz/lb} = 0.50\ lb/yd^2 \cdot \frac{1\ yd^2}{9\ ft^2} = 0.056\ lb/ft^2/ft$$

Wt. Water: Thickness $= .07''/12''/ft = .006'$
Porosity $= .35$

$$.35(.006' \times 1' \times 1')(62.4\ lb/ft^3) = 0.13\ lb\ H_2O/ft$$

$$W_3 = [0.056 + 0.13](H/\sin\beta)$$

- Frictional Resistance (F_{Fr}):

Frictional resistance is a function of friction between geomembrane and compacted soil liner.

$$F_{Fr} = W\cos\beta\tan\delta_L$$

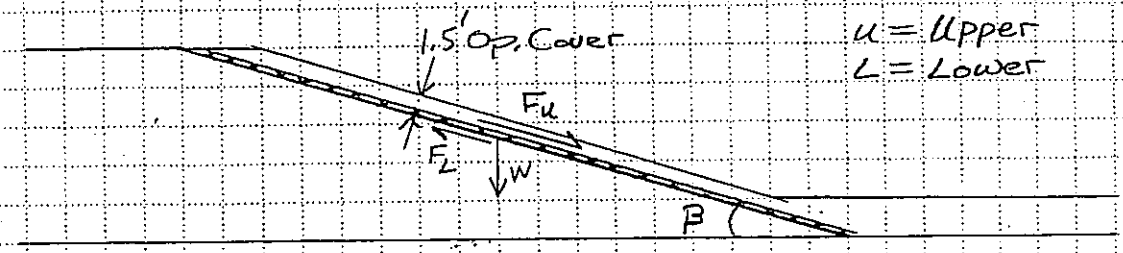
where δ_L ranges from 5 to 20°

- Total Force (T) $= W\sin\beta - F_{Fr}$
- Max. Stress $= T_{max}/A$

A = Thickness of Geomembrane over Unit Width

- Factor of Safety (F.S.) $= \dfrac{T_y(\text{geomembrane})}{\text{Max. Stress}}$

- Case 2: Stress Due To Operational Cover Sliding:



- Tension in the Geotextile (T_{GT}) = $F_u - F_L$

$$F_u = W \cos\beta \tan\delta_u$$

$$F_L = W \cos\beta \tan\delta_L$$

W = Wt. of Op. Cover, Geomembrane, Geonet, & G-textile

δ_u = Friction Angle Between GT & Op. Cover (Range: 20° - 35°)

δ_L = Friction Angle Between GT & Geonet (Range: 18°-28°)

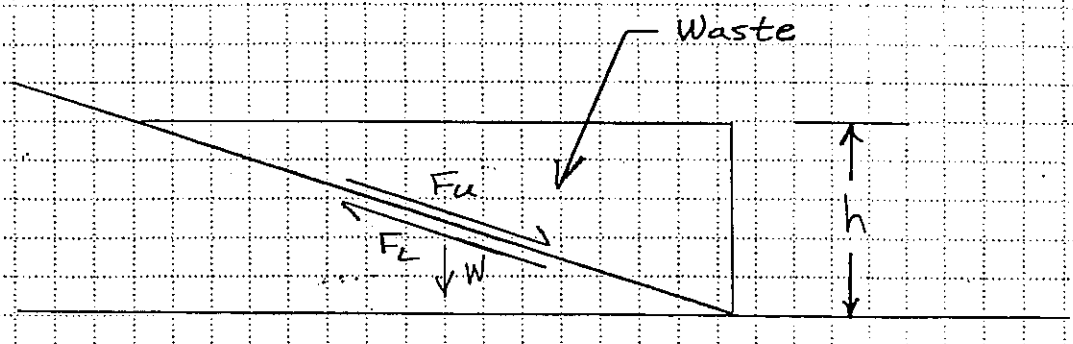
If $\delta_L > \delta_u$, then No Net Downdrag

- Follow Same Procedure For Tension in Geonet & Geomembrane:

- For Geonet: (GN)
  - W = T_{GT} (max.)
  - δ_u = Friction Bet. GT & GN (18°-28°)
  - δ_L = Friction Bet. GN & GM (10°-12°)

- For Geomembrane: (GM)
  - W = T_{GN} (max.)
  - δ_u = Friction Bet. GN & GM (10°-12°)
  - δ_L = Friction Bet. GM & Clay Liner (5°-15°)

- Case 3: Stress Due To Waste Subsidence:



- Tension in the Geotextile (T_{GT}) = $F_u - F_L$

$F_u = W \cos\beta \tan\delta_u$
$F_L = W \cos\beta \tan\delta_L$

W = Wt. of Waste, Op. Cover, GT, GN, GM

δ_u = Friction Angle Bet. GT & Op. Cover (Range: 20°–35°)
δ_L = Friction Angle Bet. GT & GN (Range: 18°–28°)

If $\delta_L > \delta_u$, then No Downdrag

- Follow Same Procedure For Tension in Geonet & Geomembrane:

- For Geonet: (GN) $W = T_{GT}$ (max.)
  δ_u = 18°–28°
  δ_L = 10°–12°

- For Geomembrane: (GM) $W = T_{GN}$ (max.)
  δ_u = 10°–12°
  δ_L = 5°–15°

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ENGINEERING AND GEOLOGICAL SERVICES

SHEET:	6/10
JOB #:	HDRGN-2
DATE:	11/21/95
BY:	PKS
CHKD BY:	

City of Greensboro
Analysis of Geosynthetics
Geomembrane Stresses

Input Parameters:

Sideslope Angle:		18.4	degrees
Max. Slope Height:		16	ft
Geomembrane:	Yield Stress:	2000	psi
	Thickness:	0.06	in
Operational Cover:	Thickness:	18	in
	Unit Weight:	110	lbs/cf
Waste Parameters:	Max. Lift Ht:	10	ft
	Unit Weight:	65	pcf

Case 1: Stress Due To Self Weight

W1 =	15.02	lb/ft
W2 =	1.77	lb/ft
W3 =	9.43	lb/ft
W =	26.23	lb/ft

DELL	tan (DELL)	Ffr (lb/ft)	T (lb/ft)
5	0.087	2.18	6.10
10	0.176	4.39	3.89
15	0.268	6.67	1.61
20	0.364	9.06	

Maximum Stress = ********** psf = 8.5 psi

Factor of Safety = 236

STRESSES.WB1

Case 2: Stress Due To Operational Cover Sliding SHEET: 7/10

Tension in Geotextile:

W = 8390 lbs/ft
FU = 7961 tan (DELU)
FL = 7961 tan (DELL)
T = 7961 (tan(DELU)-tan(DELL))
Stress = T/(A=.09/12)/144 psi

Sensitivity Analysis:

DELU	DELL	tan(DELU)-tan(DELL)	T (lb/ft)	Stress (psi)
20	18	0.0391	311	288
25	18	0.1414	1126	1042
25	20	0.1023	815	754
25	22	0.0623	496	459
30	18	0.2524	2010	1861
30	20	0.2134	1699	1573
30	22	0.1733	1380	1278
30	24	0.1321	1052	974
30	26	0.0896	713	661
30	28	0.0456	363	336
35	18	0.3753	2988	2766
35	20	0.3362	2677	2479
35	22	0.2962	2358	2183
35	24	0.2550	2030	1880
35	26	0.2125	1692	1566
35	28	0.1685	1341	1242
35	30	0.1229	978	906
35	32	0.0753	600	555
35	34	0.0257	205	189

T(max.) = 2988

Case 2 Continued: Stress Due To Operational Cover Sliding SHEET: 8/10

Tension in Geonet:

W = 2988 lbs/ft
FU = 2988 tan (DELU)
FL = 2988 tan (DELL)
T = 2988 (tan(DELU)-tan(DELL))
Stress = T/(A=.2/12)/144 psi

Sensitivity Analysis:

DELU	DELL	tan(DELU)-tan(DELL)	T (lb/ft)	Stress (psi)
18	10	0.1486	444	185
18	12	0.1124	336	140
20	10	0.1876	561	234
20	12	0.1514	452	188
22	10	0.2277	680	283
22	12	0.1915	572	238
24	10	0.2689	803	335
24	12	0.2327	695	290
26	10	0.3114	930	388
26	12	0.2752	822	343
28	10	0.3554	1062	442
28	12	0.3192	954	397

T(max.) = 1062

Case 2 Continued: Stress Due To Operational Cover Sliding

Tension in Geomembrane:

W = 1062 lbs/ft
FU = 1062 tan (DELU)
FL = 1062 tan (DELL)
T = 1062 (tan(DELU)-tan(DELL))
Stress = T/(A=.06/12)/144 psi

Sensitivity Analysis:

DELU	DELL	tan(DELU)-tan(DELL)	T (lb/ft)	Stress (psi)
10	5	0.0888	94	131
10	6	0.0712	76	105
10	7	0.0535	57	79
10	8	0.0358	38	53
10	9	0.0179	19	26
12	5	0.1251	133	184
12	6	0.1075	114	158
12	7	0.0898	95	132
12	8	0.0720	76	106
12	9	0.0542	58	80
12	10	0.0362	38	53
12	11	0.0182	19	27

T(max.) = 133

Factor of Safety = 15.1

Case 3 Continued: Stress Due To Waste Subsidence SHEET: 10/10

Tension In Geonet:

W = 5534 lbs/ft
FU = 5534 tan (DELU)
FL = 5534 tan (DELL)
T = 5534 (tan(DELU)-tan(DELL))
Stress = T/(A=.2/12)/144 psi

Sensitivity Analysis:

DELU	DELL	tan(DELU)-tan(DELL)	T (lb/ft)	Stress (psi)
18	10	0.1486	822	343
18	12	0.1124	622	259
20	10	0.1876	1038	433
20	12	0.1514	838	349
22	10	0.2277	1260	525
22	12	0.1915	1060	441
24	10	0.2689	1488	620
24	12	0.2327	1288	536
26	10	0.3114	1723	718
26	12	0.2752	1523	634
28	10	0.3554	1967	819
28	12	0.3192	1766	736

T(max.) = 1967

Case 3 Continued: Stress Due To Waste Subsidence

Tension in Geomembrane:

W = 1967 lbs/ft
FU = 1967 tan (DELU)
FL = 1967 tan (DELL)
T = 1967 (tan(DELU)-tan(DELL))
Stress = T/(A=.06/12)/144 psi

Sensitivity Analysis:

DELU	DELL	tan(DELU)-tan(DELL)	T (lb/ft)	Stress (psi)
10	5	0.0888	175	243
10	6	0.0712	140	195
10	7	0.0535	105	146
10	8	0.0358	70	98
10	9	0.0179	35	49
12	5	0.1251	246	342
12	6	0.1075	211	293
12	7	0.0898	177	245
12	8	0.0720	142	197
12	9	0.0542	107	148
12	10	0.0362	71	99
12	11	0.0182	36	50

T(max.) = 246

Factor of Safety = 8.1

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December 7, 1995

Joseph C. Readling, P.E.
HDR Engineering, Inc.
128 South Tryon Street, Suite 1400
Charlotte, NC 28202-5001

RE: Seismic and Slope Stability Analysis
White Street Landfill
Greensboro, North Carolina

Dear Joe:

This report was prepared in response to your request. The report is consistent with our letter proposal dated November 3, 1995 and meets 40 CFR 258 requirements as expressed in the EPA guidance document EPA/600/R-95/051.

Site Specific Seismic Considerations

On October 9, 1993, RCRA Subtitle D regulations (40 CFR Part 258) governing landfills receiving municipal solid waste (MSW) went into effect. These regulations require that

- Section 258.13 : landfills cannot be sited within 200-feet of a fault that has been active during the Holocene Epoch (past 11,000 years) unless it can be demonstrated that a lesser set back is safe.

- Section 258.14 : landfills must be designed for seismic conditions if they are within a seismic impact zone defined as having a peak bedrock acceleration exceeding 0.1 g based on a 90% probability of non-exceedance over a 250 year time period.

The recent EPA guidance for seismic design guidance for municipal solid waste landfills (EPA/600/R-95/051) clearly indicates that only two faults east of the Rocky Mountains have been shown to be active. The region of capable faults is shown on Figure 1 and extends eastward only to the Meers fault in Oklahoma. Thus the Greensboro site satisfies the requirements of 258.13.

The peak bedrock acceleration at the Greensboro site is obtained from USGS MF-2120 which is partially reproduced on Figure 2. This indicates that a peak bedrock acceleration of 0.10g can be assigned to the Greensboro site. This peak acceleration represents a 90% probability of not being exceeded in 250 years. This corresponds to a site earthquake having a return period exceeding 2400 years.

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The peak bedrock acceleration must be modified for site conditions to predict the peak ground surface acceleration at the site. The site amplification or attenuation of the peak bedrock acceleration can be evaluated using one-dimensional wave propagation analysis either specifically performed for the site or based on parametric studies. Since the Greensboro site is only marginally associated with a seismic impact zone, the site amplification or attenuation is estimated using the parametric relationships shown on Figure 3. Soil borings performed by Engineering Tectonics under the direction of GNRA personnel indicate that much of the Greensboro site is underlain by primarily dense to stiff sandy silts (ML or MH) to silty sands (SM). Due to the limited overburden at the site after borrow activities, the ground surface acceleration is taken from Figure 3 as equal to the peak bedrock acceleration of 0.10g.

Liquefaction Evaluation

The first step in any liquefaction evaluation is to assess whether the potential for liquefaction of cohesionless soils exists at a site. A variety of screening techniques exists to distinguish sites that are clearly safe with respect to liquefaction from those sites that require more detailed study (EPA/600/R-95/051). The following five screening criteria are most commonly used to make this assessment:

- Geologic age and origin. Liquefaction potential decreases with increasing age of a soil deposit. Pre-Holocene age soil deposits generally do not liquefy, though liquefaction has occasionally been observed in Pleistocene-age deposits.

  The deposits beneath the Greensboro site are of the Late Precambrian to Cambrian period and greatly predate the Pleistocene.

- Fines content and plasticity index. Liquefaction potential decreases with increasing fines content and increasing plasticity index, PI. Soils having greater than 15 percent (by weight) finer than 0.005 mm, a liquid limit greater than 35 percent, and an in-situ water content less than 0.9 times the liquid limit generally do not liquefy (Seed and Idriss, 1982).

  Grain size distributions performed by Geotechnologies and Trigon indicate that most of the soil layers have in excess of 20% fines.

- Saturation. Although partially saturated soils have been reported to liquefy, at least 80 to 85 percent saturation is generally deemed to be a necessary condition for soil liquefaction. In many locations, the water table is subject to seasonal oscillation. In general, it is prudent that the highest anticipated seasonal water table elevation be considered for initial screening.

- Depth below ground surface. While failures due to liquefaction of end-bearing

piles resting on sand layers up to 100 ft (30 m) below the ground surface have been reported, surface effects from liquefaction is generally not likely to occur more than 50 ft (15 m) below the ground surface.

- Soil Penetration Resistance. According to the data presented in Seed and Idriss (1985), liquefaction has not been observed in soil deposits having normalized Standard Penetration Test (SPT) blowcount larger than 22. Marcuson, et al. (1990) suggest a normalized SPT value of 30 as the threshold value above which liquefaction will not occur. However, Chinese experience, as quoted in Seed et al. (1983), suggests that in extreme conditions liquefaction is possible in soils having normalized SPT blowcounts as high as 40.

  Based on the work performed by Engineering Tectonics, normalized blowcounts in the soils underlying the landfill are generally in excess of 30. Soils where normalized blowcounts were less than 30 were found to be above the water table.

If three or more of the above criteria indicate that liquefaction is not likely, the potential for liquefaction may be considered to be small. If, however, based on the above initial screening criteria, the potential for liquefaction of a cohesionless soil layer beneath the site of a planned landfill (new construction or lateral expansion) cannot be dismissed, more rigorous analysis of liquefaction potential is needed.

Based on the above screening criteria it is apparent that liquefaction is not likely at the White Street Landfill and a more rigorous analysis of this potential is not necessary.

Slope Stability Evaluation

EPA guidance, EPA/600/R-95/051, requires that the completed landfill have minimum factors of safety against slope failures of 1.5 statically and 1.0 dynamically. The slope stability evaluations for the Greensboro Landfill were obtained using the computer program STABL5. A block failure was assumed for the analysis such that the liner formed a major portion of the block. The STABL5 search algorithm looked for the lowest factor of safety for a failure block defined by the geomembrane surface and a plane up through the refuse. Additional slope stability analyses were performed assuming circular failure surfaces through the refuse.

Slope stability evaluations were performed at three sections through the final proposed refuse contours. The sections were selected at locations of maximum steepness of final cover combined with liner slopes to produce minimum slope factors of safety. The locations of the slope stability cuts are shown on Figure 4.

Computer output for the STABL5 studies is presented in Attachment 1 for static and dynamic

loadings. The minimum factors of safety are 1.4 for static conditions and 1.1 for dynamic loading conditions (see Table 1). Note that the minimum static factor of safety was not met (1.4<1.5). However, a second analysis of the same failure surface with a slightly increased cohesion value for the waste (c = 300 psf versus c = 200 psf) produced an adequate factor of safety of 1.5. The waste parameters used in the second analysis are still considered to be quite conservative for municipal solid waste.

The slope stability analyses were performed assuming the minimum interface friction angle of the liner system is 10 degrees. This low friction angle is representative of smooth HDPE and rounded sands or a nonwoven geotextile. This assumption is conservative for the proposed liner system (geomembrane over 2 feet of compacted clay liner). The project specifications should indicate that the minimum interface friction angle of the liner system shall be 10 degrees and require contractor verification. This would require direct shear testing of the geomembrane/geosynthetic material interface.

A veneer stability analysis of the final cover was performed assuming a minimum interface friction angle of 25 degrees and is included in Attachment 2. This interface friction angle is appropriate for geotextile/soil or geotextile/textured geomembrane interfaces. The minimum seismic veneer slope stability factor of safety using this assumption is 1.26. This exceeds EPA guidelines.

Summary

This seismic impact evaluation clearly demonstrates that the lined landfill proposed in Greensboro will satisfy all of the criteria expressed in 40 CFR 258. No site liquefaction or interface friction failures are anticipated for this project.

Cordially,
G.N. Richardson & Associates

Pieter K. Scheer, EIT
Staff Engineer

NORTH CAROLINA PROFESSIONAL SEAL 8895 ENGINEER GREGORY N. RICHARDSON

Gregory N. Richardson, Ph.D., P.E.
President

References

Algermissen, S.T., Perkins, D.M., P.C. Thenhaus, S.L. Hanson, and B.L. Bender (1990), "Probabilistic Earthquake Acceleration and Velocity Maps for the United States and Puerto Rico," U.S. Geological Survey Map MF-2120.

Krinitzsky, E.L., Gould, J.P., and P.H. Edinger (1993), Fundamentals of Earthquake-Resistant Construction, John Wiley & Sons, New York.

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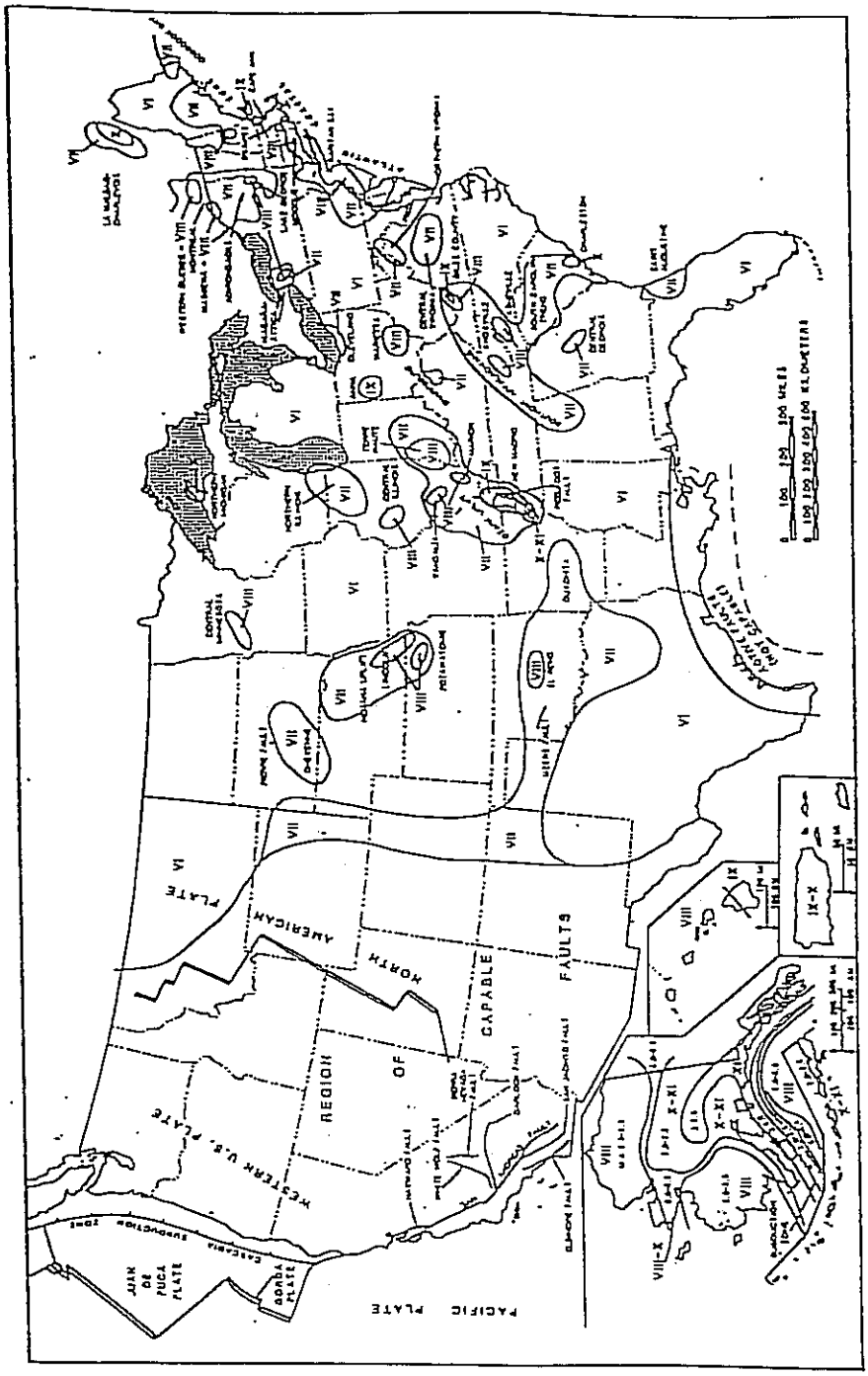
Seed, H.B. and Idriss, I.M. (1982), "Ground Motions and Soil Liquefaction During Earthquakes," Monograph No. 5, Earthquake Engineering Research Institute, Berkeley, California.



CAPABLE FAULTS MAP
(KRINITZSKY et al., 1993)

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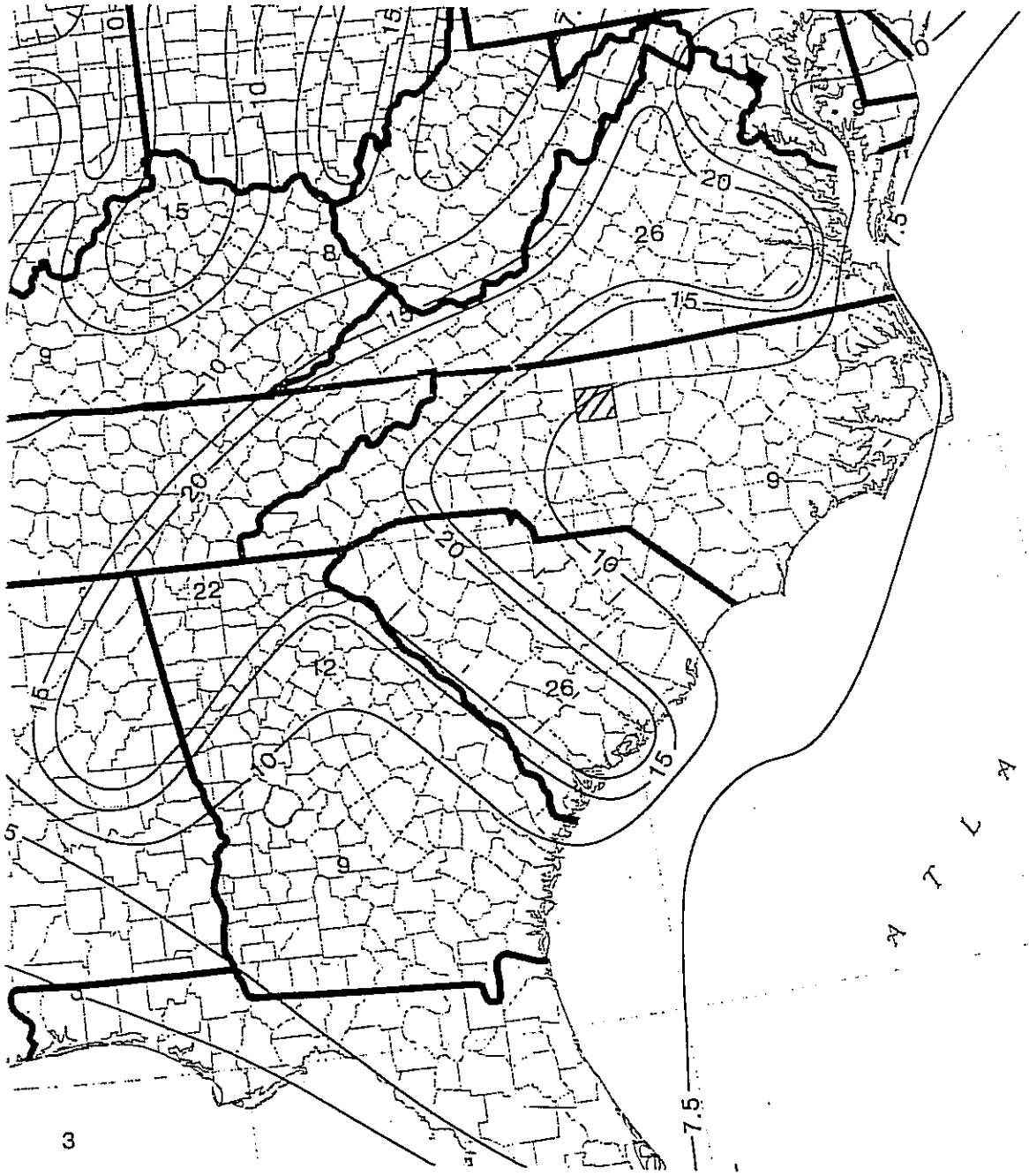
SCALE:	DRAWN BY:	CHECKED BY:	DATE:	PROJECT NO.	FIGURE NO.
AS SHOWN		PKS	12/6/95	HDRGN-2	1



USGS MF-2120
PEAK BEDROCK ACCELERATIONS AS A PERCENT OF GRAVITY (90% PROBABILITY OF NOT BEING EXCEEDED IN 250 YEARS)

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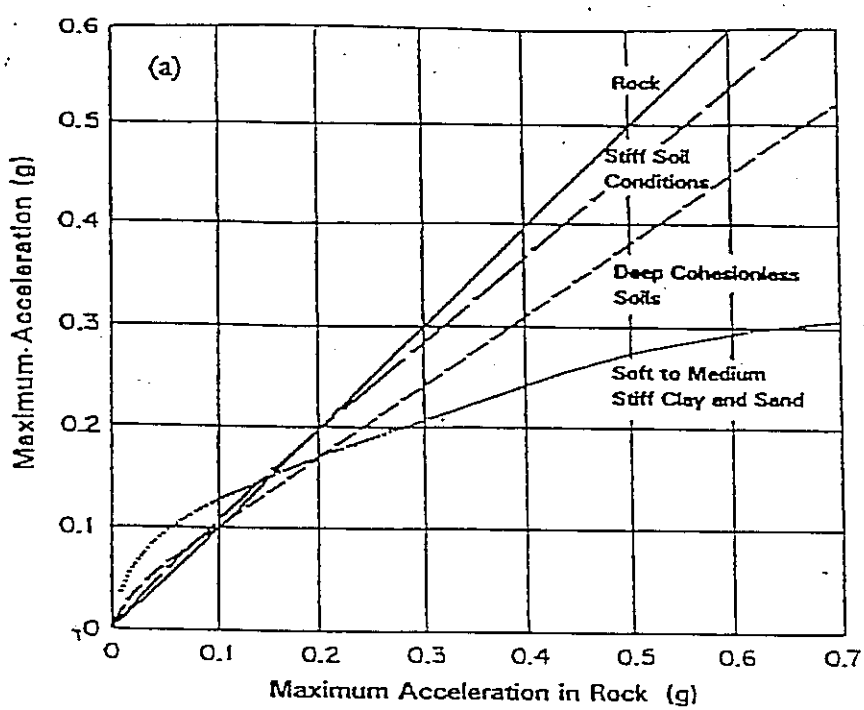
SCALE:	DRAWN BY:	CHECKED BY:	DATE:	PROJECT NO.	FIGURE NO.
1"=625,000 FT		PKS	12/6/95	HDRGN-2	2



SITE AMPLIFICATION/ATTENUATION RELATIONSHIPS
(SEED & IDRISS, 1982)

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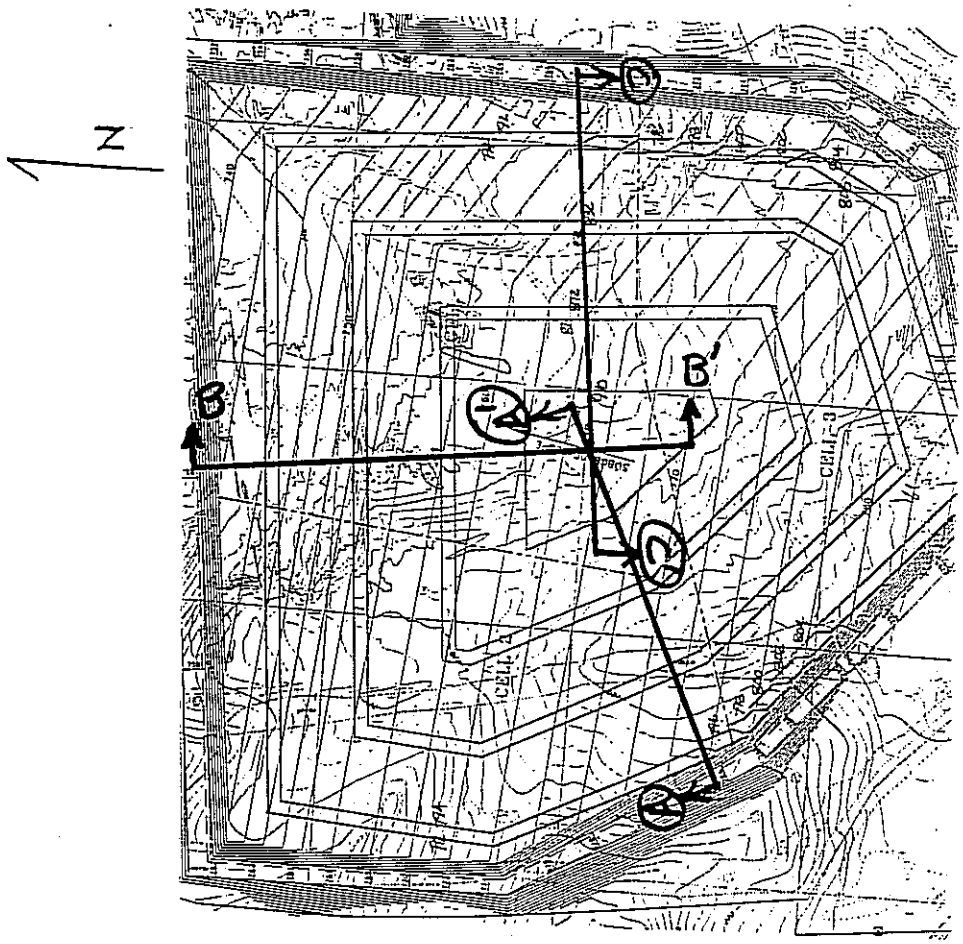
SCALE:	DRAWN BY:	CHECKED BY:	DATE:	PROJECT NO.	FIGURE NO.
N/A		PKS	12/6/95	HDRGN-2	3



LOCATION OF SLOPE STABILITY
CROSS SECTIONS

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SCALE:	DRAWN BY:	CHECKED BY:	DATE:	PROJECT NO.	FIGURE NO.
1"=400'		PKS	12/6/95	HDRGN-2	4

Table 1 Results of Slope Stability Analyses
White Street Landfill
Greensboro, NC

		Failure Type	
Cross Section	Failure Type	Static	Dynamic*
A	Block	1.9	1.4
	Circular	2.0	1.6
B	Block	1.5	1.2
	Circular	2.0	1.6
C	Block	1.4	1.1
	Block #	1.5	-----
	Circular	2.0	1.6
Cover Veneer	Infinite Slope**	1.87	1.26

* Horizontal and Vertical Coefficients = +0.05g (= ½ Peak Ground Surface Acceleration)

** Interface Friction Angle = 25°

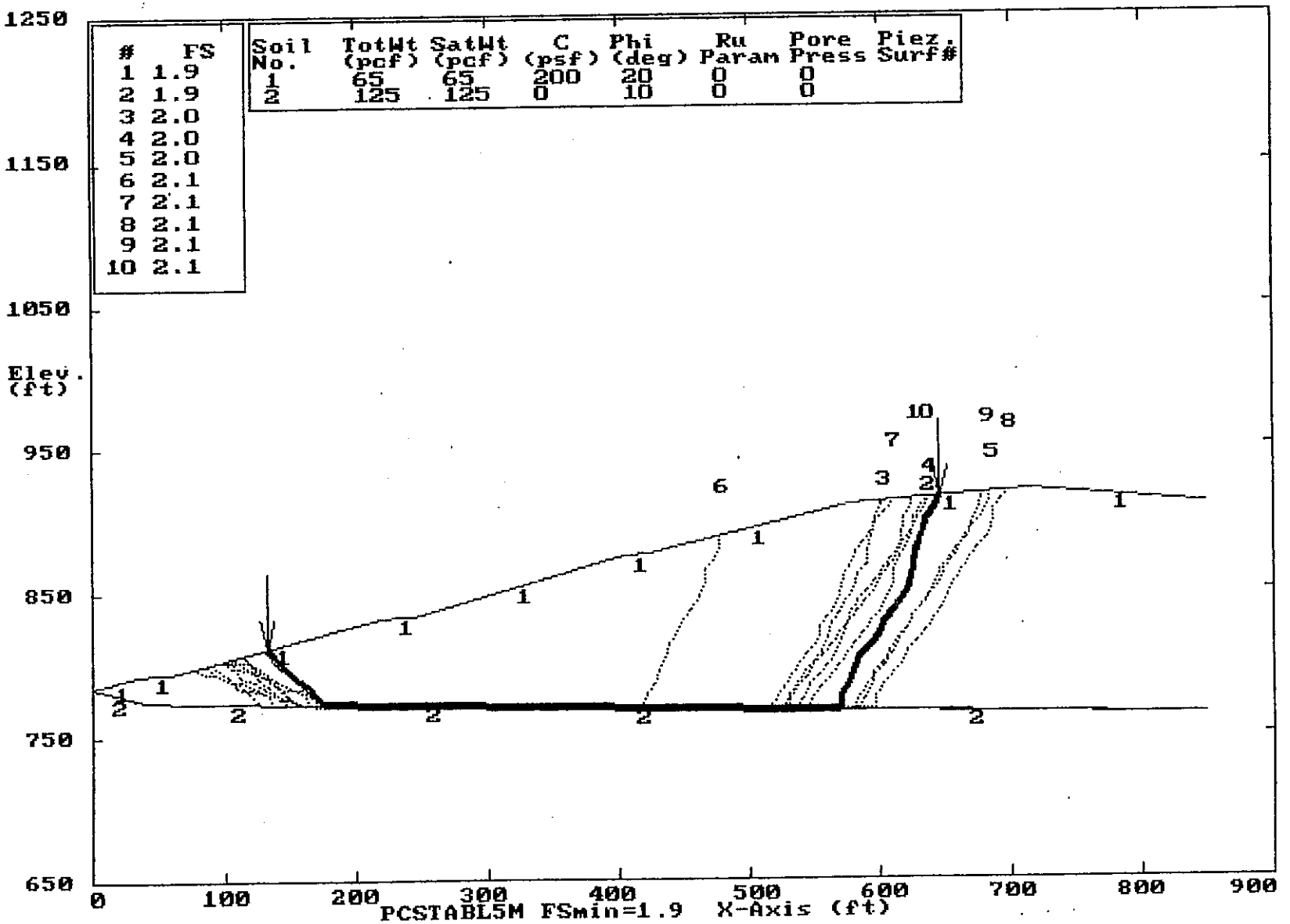
\# c (MSW) = 300 psf

Attachment 1

Computer Output

Static and Dynamic Loadings

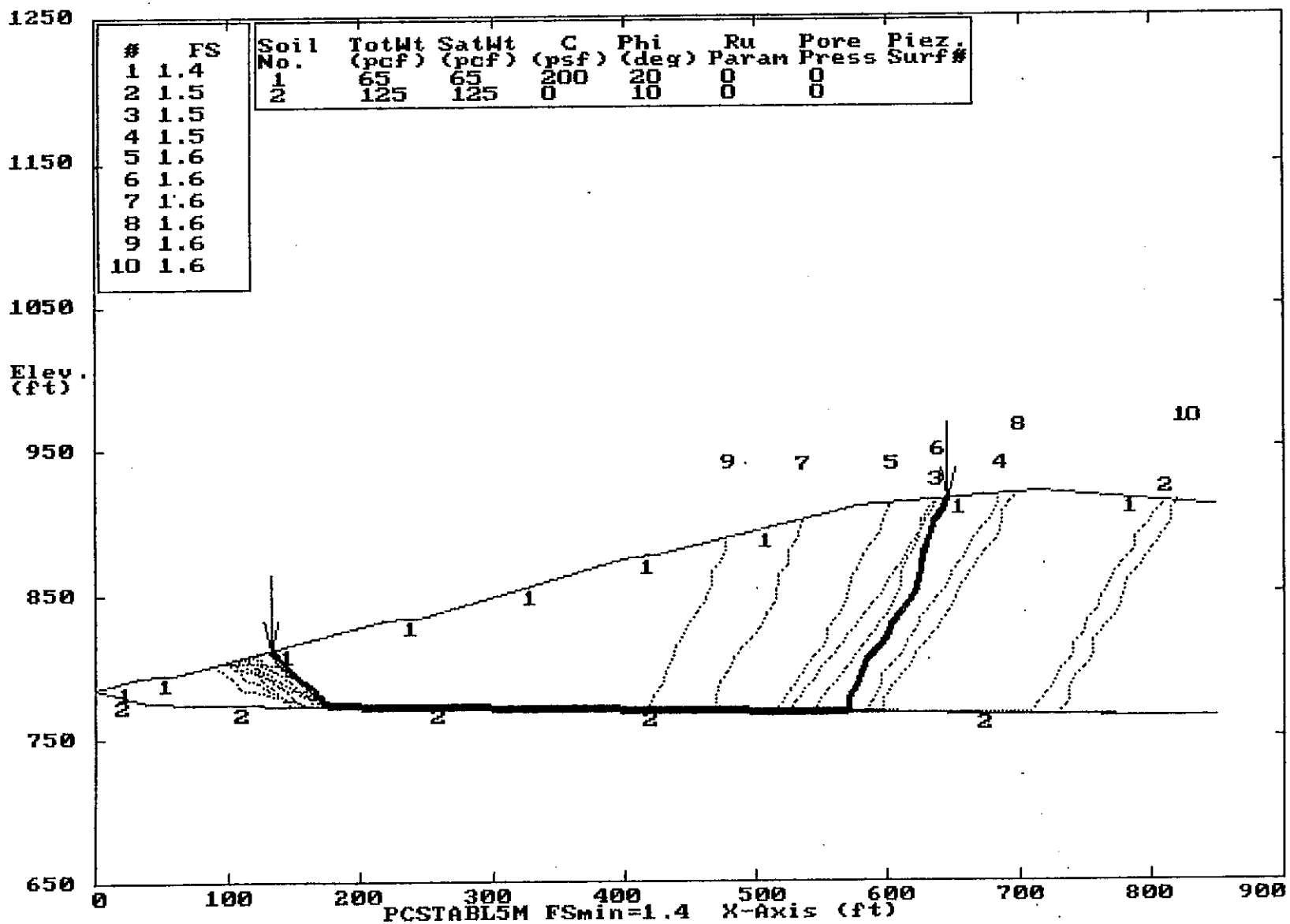
Greensboro Landfill - Section A-A' Block Stability Along Liner - STATIC
Ten Most Critical. A:GNAA.PLT By: PKS 12-07-95 1:28pm



#	FS
1	1.9
2	1.9
3	2.0
4	2.0
5	2.0
6	2.1
7	2.1
8	2.1
9	2.1
10	2.1

Soil No.	TotWt (pcf)	SatWt (pcf)	C (psf)	Phi (deg)	Ru Param	Pore Press	Piez. Surf#
1	65	65	200	20	0	0	
2	125	125	0	10	0	0	

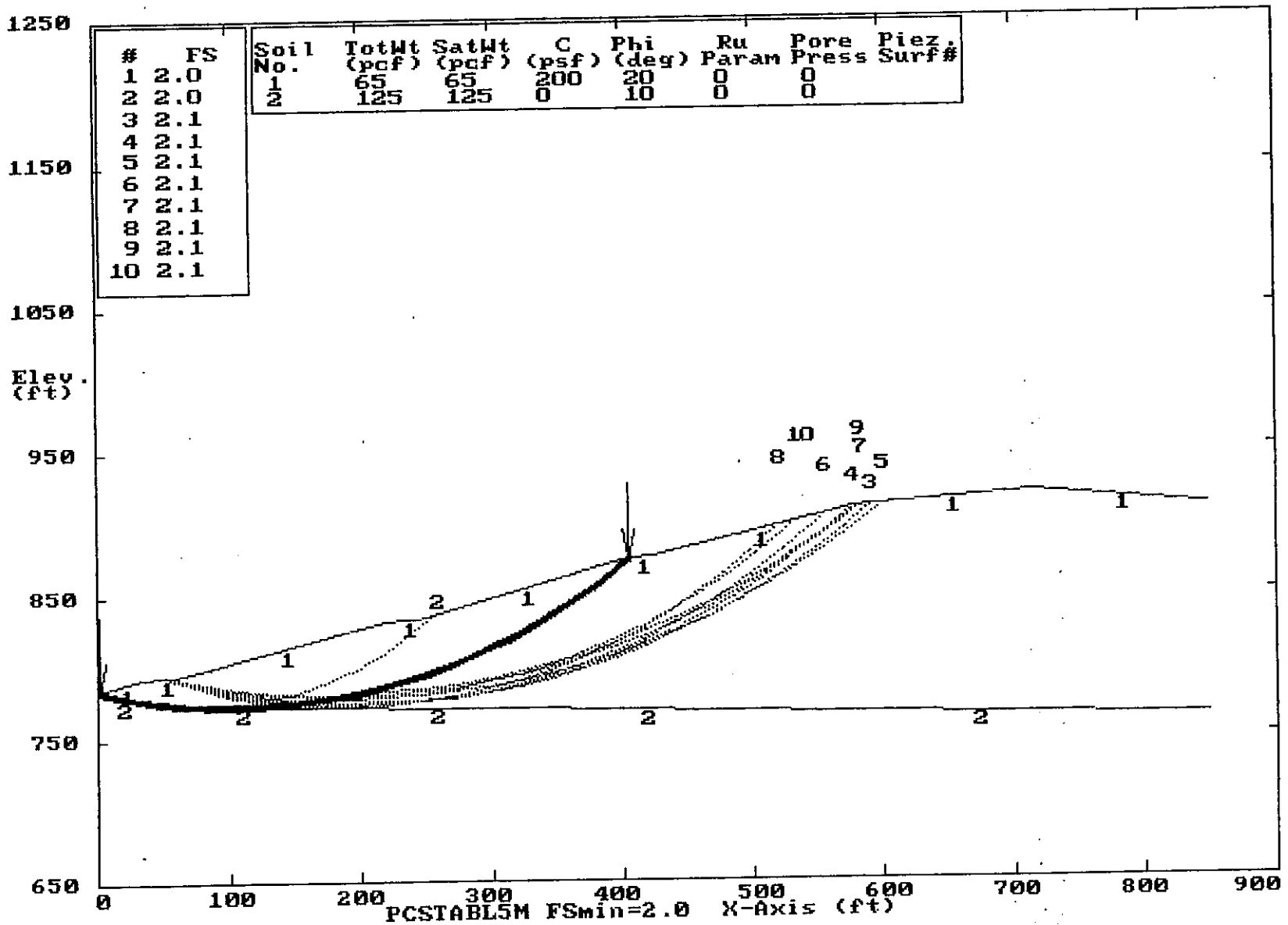
Greensboro Landfill - Section A-A' Block Stability Along Liner - EQUAKE
Ten Most Critical. A:GNAAE.PLT By: PKS 12-07-95 1:31pm



#	FS
1	1.4
2	1.5
3	1.5
4	1.5
5	1.6
6	1.6
7	1.6
8	1.6
9	1.6
10	1.6

Soil No.	TotWt (pcf)	SatWt (pcf)	C (psf)	Phi (deg)	Ru Param	Pore Press	Piez. Surf#
1	65	65	200	20	0	0	
2	125	125	0	10	0	0	

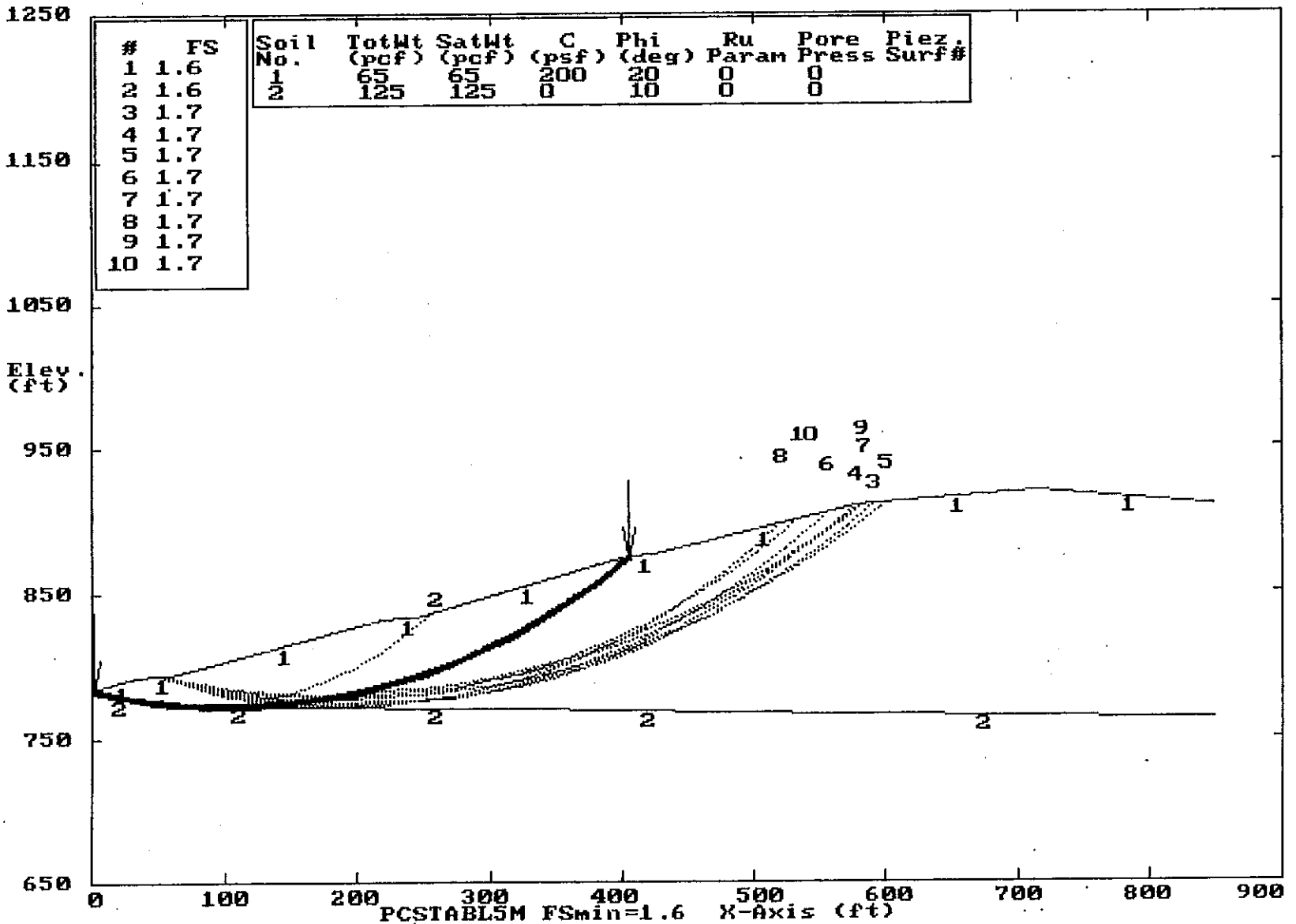
Greensboro Landfill - Section A-A' Circular Stability - STATIC
Ten Most Critical. A:GNAAC.PLT By: PKS 12-07-95 1:37pm



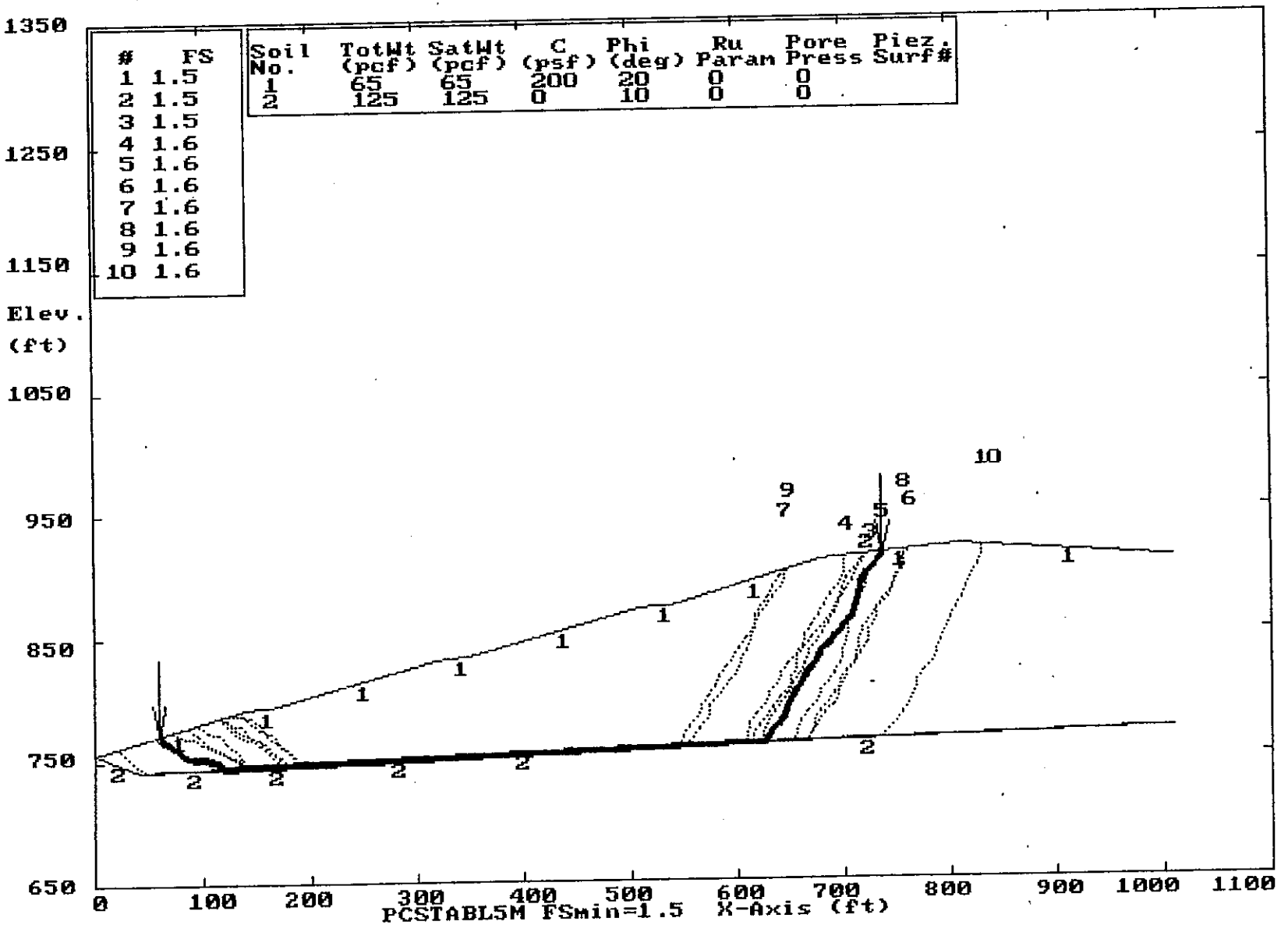
#	FS
1	2.0
2	2.0
3	2.1
4	2.1
5	2.1
6	2.1
7	2.1
8	2.1
9	2.1
10	2.1

Soil No.	TotWt (pcf)	SatWt (pcf)	C (psf)	Phi (deg)	Ru Param	Pore Press	Piez. Surf#
1	65	65	200	20	0	0	
2	125	125	0	10	0	0	

Greensboro Landfill - Section A-A' Circular Stability - EQUAKE
Ten Most Critical. A:GNAACE.PLT By: PKS 12-07-95 1:42pm



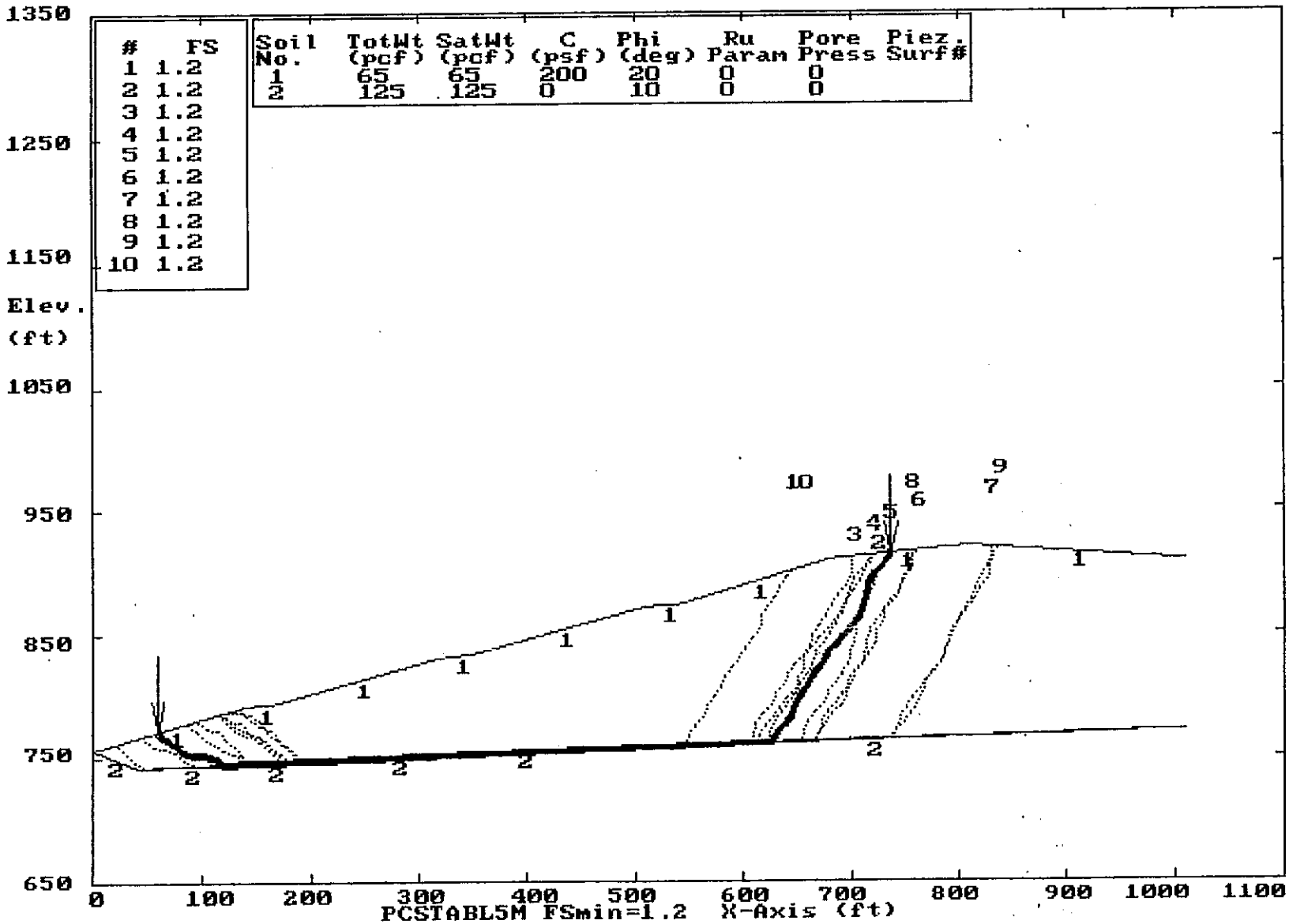
Greensboro Landfill - Section B-B' Block Stability Along Liner - STATIC
Ten Most Critical. A:GNBB.PLT By: PKS 12-07-95 2:06pm



#	FS
1	1.5
2	1.5
3	1.5
4	1.6
5	1.6
6	1.6
7	1.6
8	1.6
9	1.6
10	1.6

Soil No.	TotWt (pcf)	SatWt (pcf)	C (psf)	Phi (deg)	Ru Param	Pore Press	Piez. Surf#
1	65	65	200	20	0	0	
2	125	125	0	10	0	0	

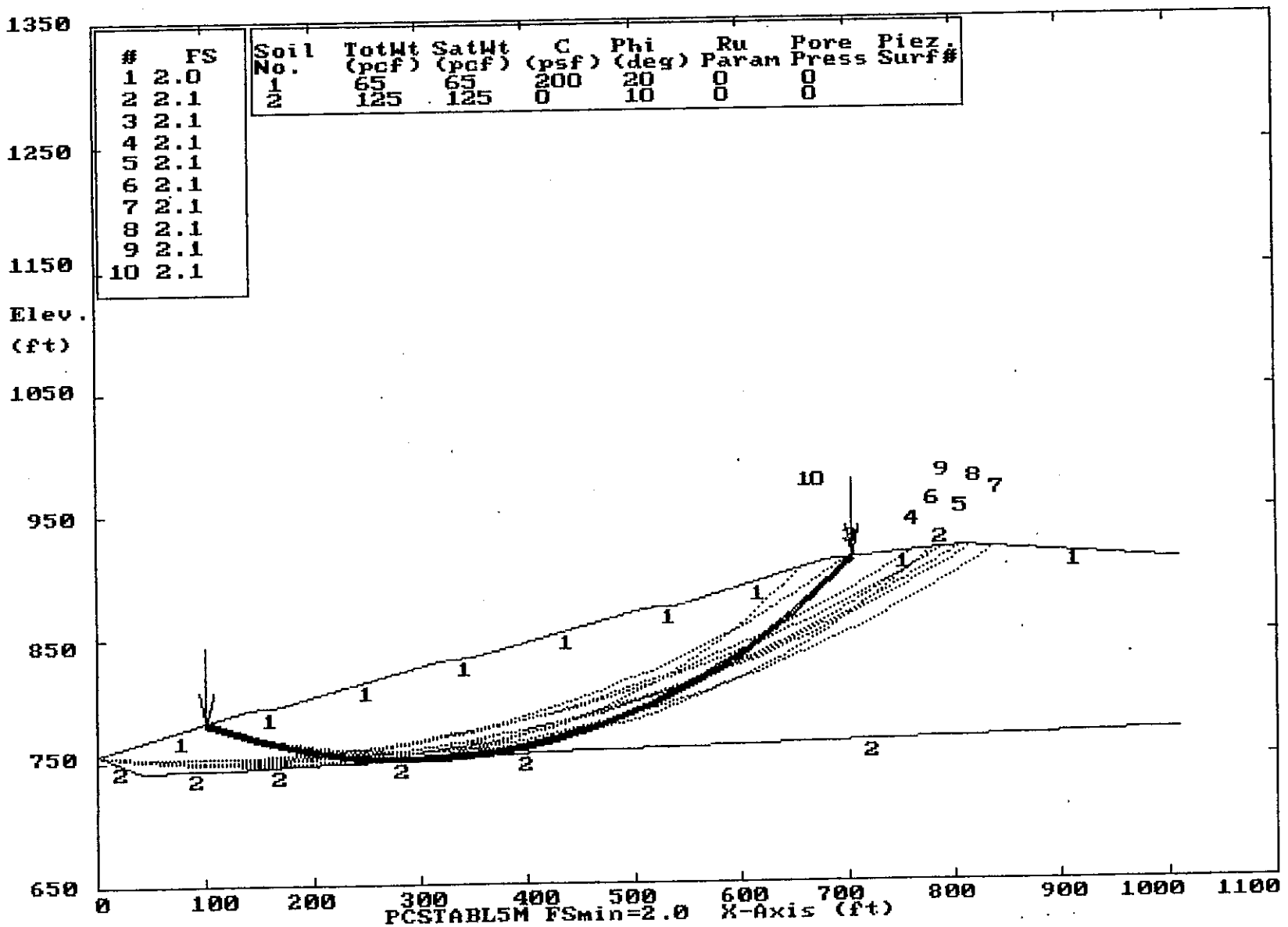
Greensboro Landfill - Section B-B' Block Stability Along Liner - EQUAKE
Ten Most Critical. A:GNBBE.PLT By: PKS 12-07-95 2:09pm



#	FS
1	1.2
2	1.2
3	1.2
4	1.2
5	1.2
6	1.2
7	1.2
8	1.2
9	1.2
10	1.2

Soil No.	TotWt (pcf)	SatWt (pcf)	C (psf)	Phi (deg)	Ru Param	Pore Press	Piez. Surf#
1	65	65	200	20	0	0	
2	125	125	0	10	0	0	

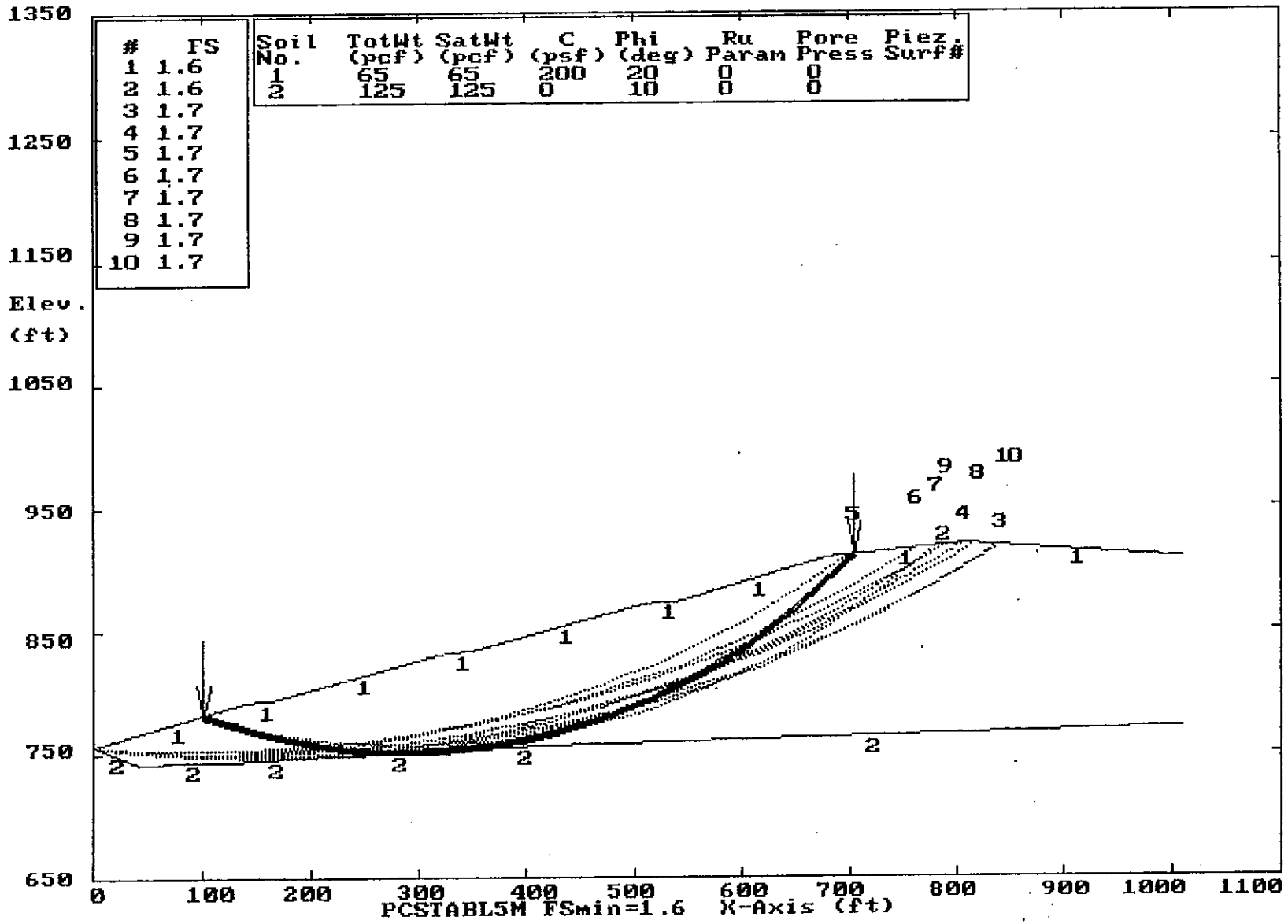
Greensboro Landfill - Section B-B' Circular Stability - STATIC
Ten Most Critical. A:GNBBC.PLT By: PKS 12-07-95 2:02pm



#	FS
1	2.0
2	2.1
3	2.1
4	2.1
5	2.1
6	2.1
7	2.1
8	2.1
9	2.1
10	2.1

Soil No.	TotWt (pcf)	SatWt (pcf)	C (psf)	Phi (deg)	Ru Param	Pore Press	Piez. Surf#
1	65	65	200	20	0	0	
2	125	125	0	10	0	0	

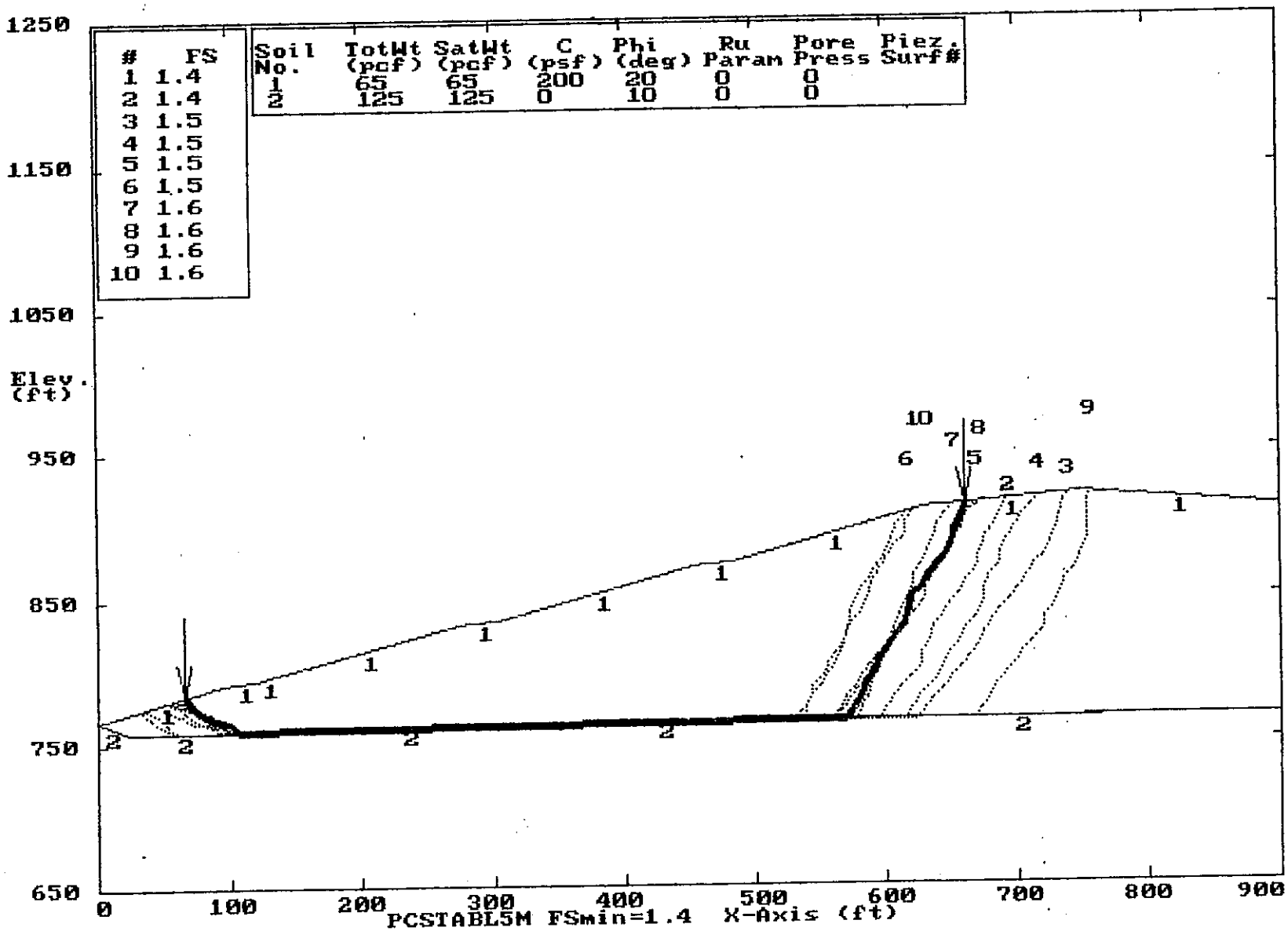
Greensboro Landfill - Section B-B' Circular Stability - EQUAKE
Ten Most Critical. A:GNBBCE.PLT By: PKS 12-07-95 2:00pm



#	FS
1	1.6
2	1.6
3	1.7
4	1.7
5	1.7
6	1.7
7	1.7
8	1.7
9	1.7
10	1.7

Soil No.	TotWt (pcf)	SatWt (pcf)	C (psf)	Phi (deg)	Ru Param	Pore Press	Piez. Surf#
1	65	65	200	20	0	0	
2	125	125	0	10	0	0	

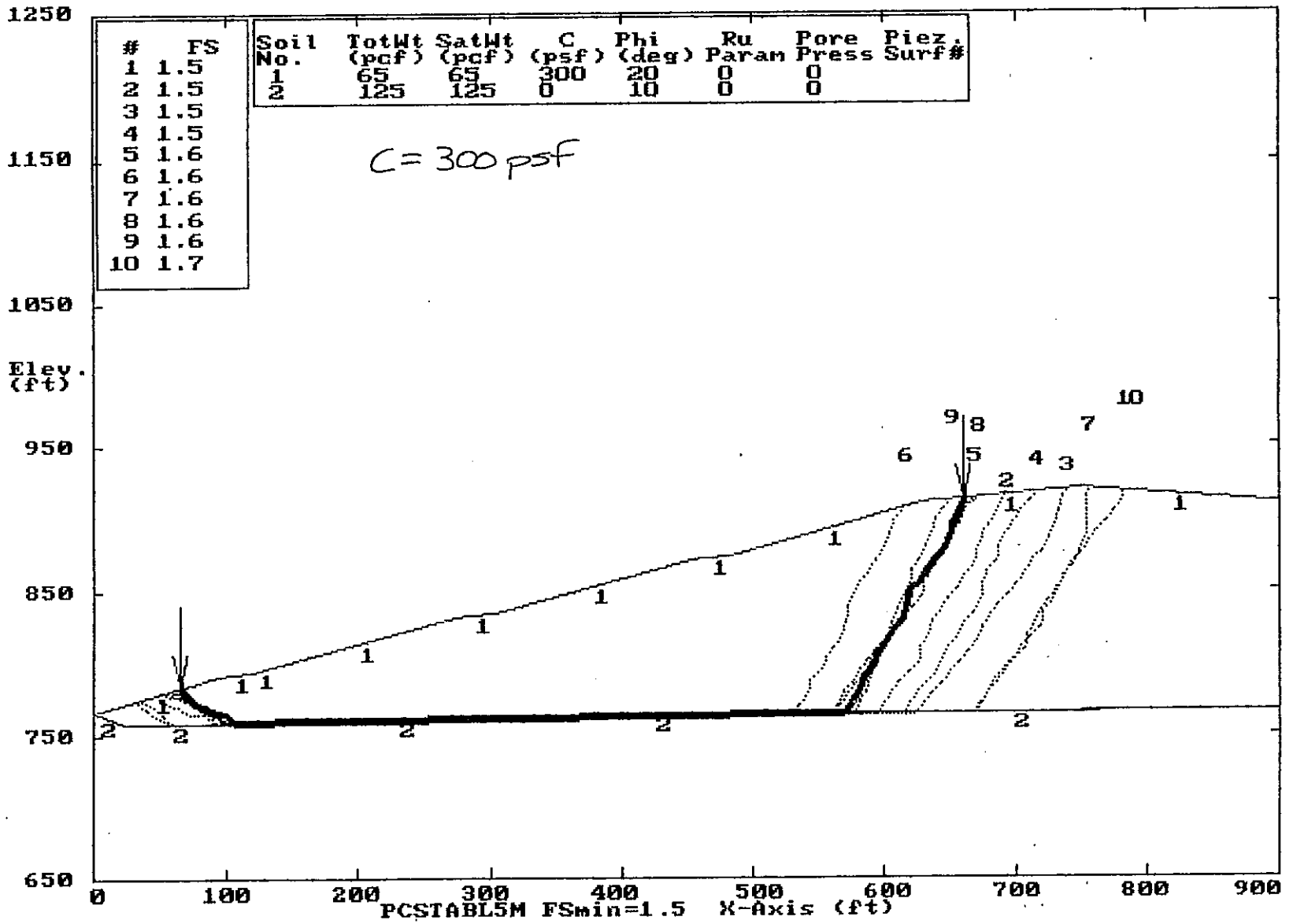
Greensboro Landfill - Section C-C' Block Stability Along Liner - STATIC
Ten Most Critical. A:GNCC.PLT By: PKS 12-07-95 2:27pm



#	FS
1	1.4
2	1.4
3	1.5
4	1.5
5	1.5
6	1.5
7	1.6
8	1.6
9	1.6
10	1.6

Soil No.	TotWt (pcf)	SatWt (pcf)	C (psf)	Phi (deg)	Ru Param	Pore Press	Piez. Surf#
1	65	65	200	20	0	0	
2	125	125	0	10	0	0	

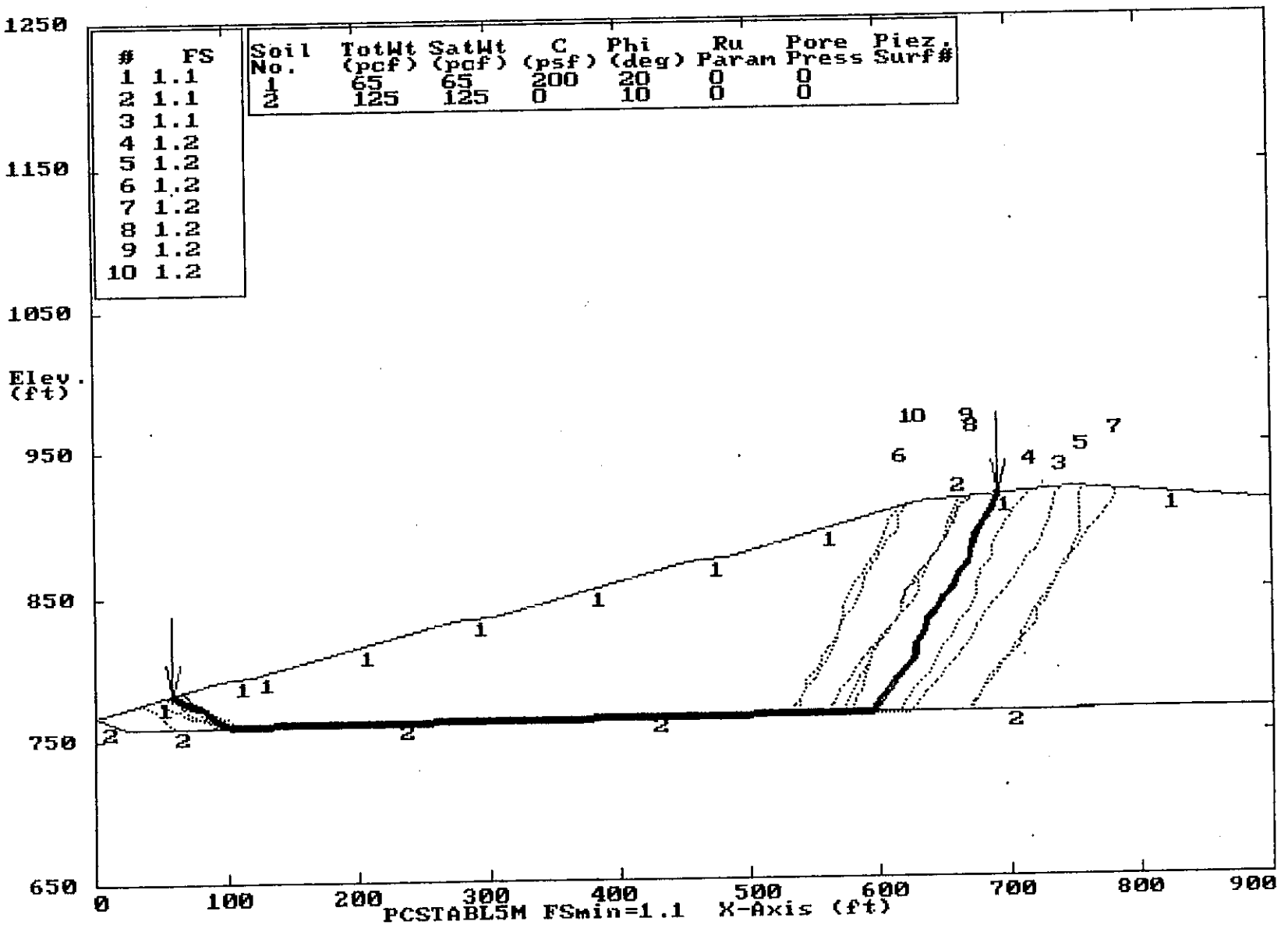
Greensboro Landfill - Section C-C' Block Stability Along Liner - STATIC
Ten Most Critical. A:GNCC1.PLT By: PKS 12-07-95 4:17pm



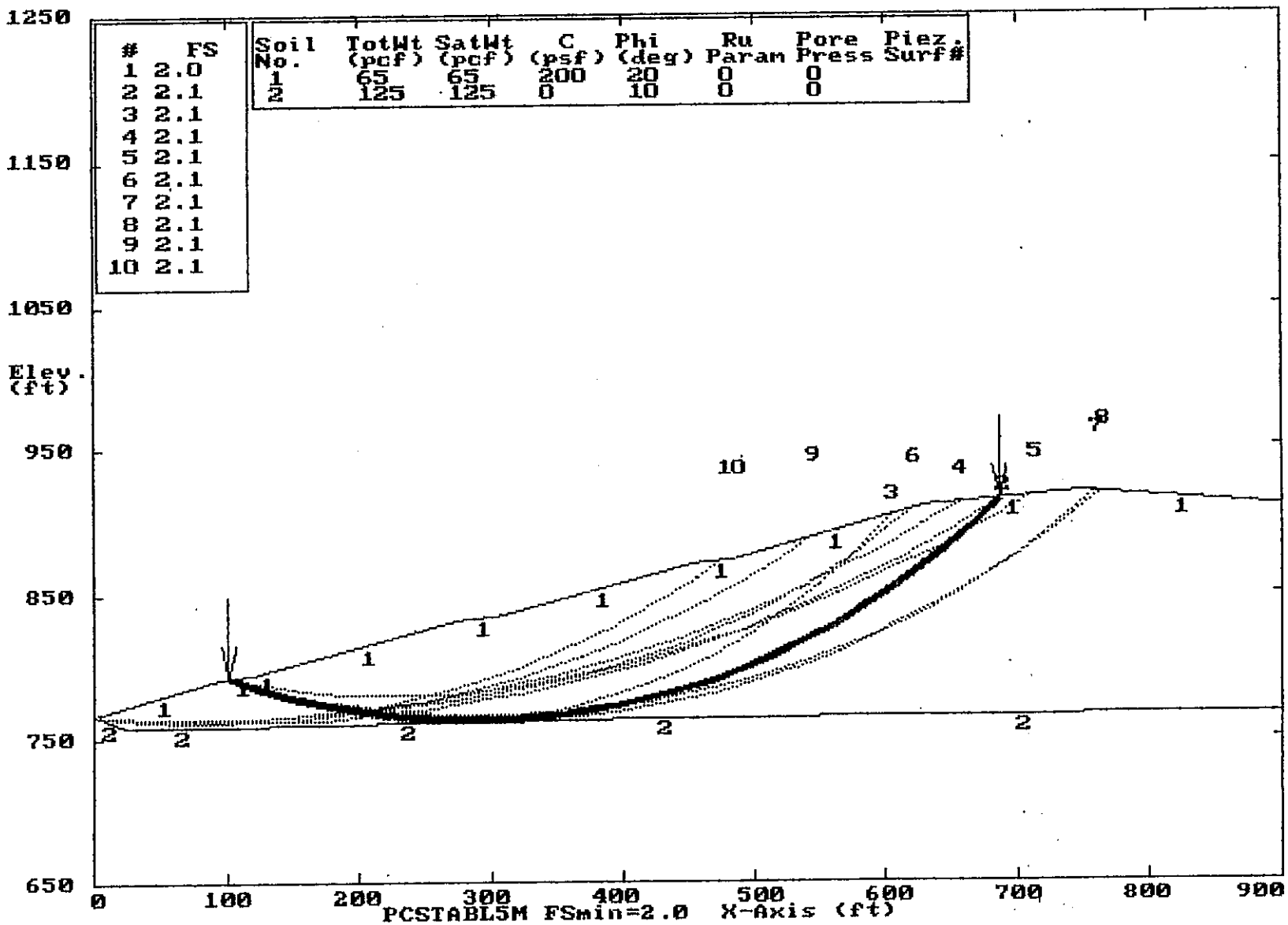
#	FS
1	1.5
2	1.5
3	1.5
4	1.5
5	1.6
6	1.6
7	1.6
8	1.6
9	1.6
10	1.7

Soil No.	TotWt (pcf)	SatWt (pcf)	C (psf)	Phi (deg)	Ru Param	Pore Press	Piez. Surf#
1	65	65	300	20	0	0	
2	125	125	0	10	0	0	

Greensboro Landfill - Section C-C' Block Stability Along Liner - EQUAKE
Ten Most Critical, A:GNCCE.PLT By: PKS 12-07-95 2:16pm



Greensboro Landfill - Section C-C' Circular Stability - STATIC
Ten Most Critical. A:GNCCC.PLT By: PKS 12-07-95 2:34pm



Greensboro Landfill - Section C-C' Circular Stability - EQUAKE
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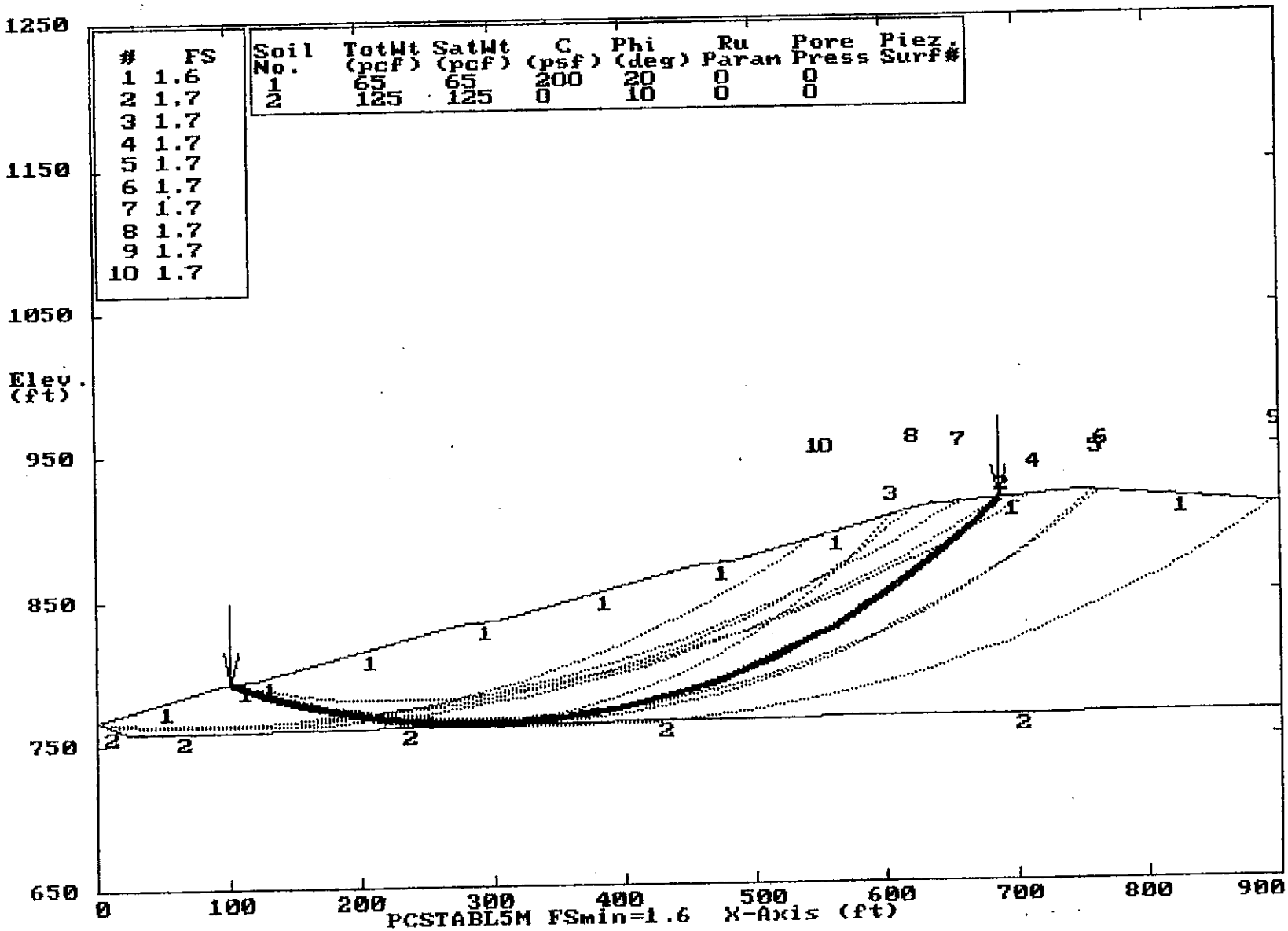

Attachment 2

Veneer Stability Analysis of
Final Cover

PROJECT HDR-GBORO LF

SUBJECT Final Cover Stability Evaluation

SHEET 1 OF 2
JOB NO. HDRGN-2
DATE 12/6/95
COMPUTED BY PKS
CHECKED BY

— Objective: To evaluate the stability of the Final cover veneer against sliding.

— Analysis: Treat the Final cover as an infinite slope and use the following equation (Matasović, 1991):

$$FS = \frac{[c/(\gamma \cdot z \cdot \cos^2\beta) + \tan\phi[1 - \gamma_w(z - d_w)/(\gamma \cdot z)] - k_s \cdot \tan\beta]}{k_s + \tan\beta}$$

where:
- FS = Factor of Safety
- k_s = Seismic Coefficient (= 0 for Static Stability)
- γ = Unit Weight of Slope Material(s)
- γ_w = Unit Weight of Water
- c = Cohesion
- ϕ = Interface Friction Angle of Assumed Failure Surface
- z = Depth To Failure Surface
- d_w = Depth To Seepage Surface (= z if slope is Dry)
- β = Slope Angle of Cover

— Reference: Matasović, N, (1991), "Selection of Method for Seismic Slope Stability Analysis," Proc. 2nd International Conference on Recent Advances in Geotechnical Earthquake Engineering and Soil Dynamics, St. Louis, Vol. 2, pp. 1057-1062.

— Requirements: FS_{min}(Static) = 1.5

FS_{min}(Dynamic) = 1.0 (If Applicable)

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G.N. Richardson & Associates

ENGINEERING AND GEOLOGICAL SERVICES

SHEET: 2/2
JOB #: HDRGN-2
DATE: 12/7/95
BY: PKS
CHKD BY:

HDR - Greensboro Landfill
Analysis of Final Cover Stability

Input Parameters: (User Input)

Sideslope Angle (Beta): 14 degrees

Final Cover:
- Thickness (z): 2 ft
- Unit Weight: 110 pcf
- Cohesion: 0 psf
- Water Depth: 2 ft (= z if Slope is Dry)

Seismic Coefficient (ks):
- 0 Static FS
- 0.10 Dynamic FS (= Peak Ground Acceleration For The Site)

Calculate Static FS Against Sliding:

Interface Fric. Angle	Resisting Force	Driving Force	FS slide	Comment
10	0.18	0.25	0.71	NO GOOD
15	0.27	0.25	1.07	NO GOOD
20	0.36	0.25	1.46	NO GOOD
25	0.47	0.25	1.87	OK

Calculate Dynamic FS Against Sliding:

Interface Fric. Angle	Resisting Force	Driving Force	FS slide	Comment
10	0.15	0.35	0.43	NO GOOD
15	0.24	0.35	0.70	NO GOOD
20	0.34	0.35	0.97	NO GOOD
25	0.44	0.35	1.26	OK