REPORT

Run-On and Runoff Control System Plan

Gerald Gentleman Station, Nebraska Public Power District

Submitted to:

Nebraska Public Power District

Gerald Gentleman Station

6089 South Highway 25, Sutherland, Nebraska 69165

Submitted by:

Golder Associates Inc.

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1.0 INTRODUCTION

Golder Associates Inc. (Golder) has prepared the following plan to address the Environmental Protection Agency's (EPA's) Coal Combustion Residual (CCR) Rule at the Nebraska Public Power District's (NPPD's) Gerald Gentleman Station (GGS). The CCR Rule, 40 Code of Federal Regulations (CFR) Part 257 (EPA 2015), requires the creation and maintenance of an initial Run-On and Run-Off Control Plan, as specified in § 257.81, no later than October 17, 2016, for all existing or new CCR landfills or lateral expansions, with renewal every five years thereafter.

2.0 REQUIREMENTS FOR RUN-ON AND RUNOFF CONTROL SYSTEMS (40 CFR §257.81)

In accordance with § 257.81(b)(1), the plan must document how the run-on and run-off systems have been designed and constructed to meet the following criteria, as supported by appropriate engineering calculations, for CCR landfills:

- The run-on control system must be designed to prevent flow on the active portion of the CCR unit during the peak discharge from a 24-hour, 25-year storm; and
- The runoff control system from the active portion of the CCR unit must be designed to collect and control at least the water volume resulting from a 24-hour, 25-year storm, in accordance with § 257.3-3, detailing discharges to surface waters.

Further clarification on the intent of the rule is provided in the text of the Preamble for the CCR Rule:

The owner or operator must design, construct, operate, and maintain the CCR landfill is such a way that any runoff generated from at least a 24-hour, 25-year storm must be collected through hydraulic structures, such as drainage ditches, toe drains, swales, or other means, and controlled so as to not adversely affect the condition of the CCR landfill. EPA has promulgated these requirements to minimize the detention time of run-off on the CCR landfill and minimize infiltration into the CCR landfill, to dissipate storm water run-off velocity, and to minimize erosion of CCR landfill slopes. An additional concern with run-off from CCR landfills is the water quality of the run-off, which may collect suspended solids from the landfill slopes.

Descriptions of the run-on and runoff control systems designed for and operated at GGS follow within the following sections.

3.0 RUN-ON CONTROL

Run-on is defined as stormwater that may flow towards the active portions of a landfill. Topographically, the landfill at GGS sits higher than the surrounding features. There is a significant elevation drop from the ash disposal area to the agricultural fields to the south of the landfill, Nebraska State Highway 25 on the west of the landfill, the process water evaporation pond east of the landfill, and the historic closed ash disposal areas to the north of the landfill. Consequently, the potential for run-on to the landfill is considered to be negligible, and run-on calculations were not warranted for this site. The landfill has been designed and operated with berms and drainage features to manage contact water within the lined landfill footprint and to shed clean stormwater runoff from closed areas. These features were designed based on a 24-hour, 25-year storm, and will also reduce the risk of run-on into the landfill. The design of these surface water runoff control features is described in the following sections of this plan.

4.0 RUNOFF CONTROL

Runoff at GGS consists of both contact water (water having directly contacted CCR within the active area of the landfill) and non-contact stormwater. Contact water runoff is contained and directed to evaporation ponds within the composite-lined landfill footprint. Calculations supporting the design of the contact water controls (channel dimensions, layout, spacing, etc.) are included in Appendix A. Calculations supporting the sizing of the evaporation ponds during the phased operation are provided in Appendix B. The final cover stormwater controls are based on calculations included in Appendix C. The calculations for the contact and non-contact stormwater controls are based on a 24-hour, 25-year storm event.

Non-contact water is kept separate from contact water by a series of earthen berms. Non-contact water is directed to perimeter surface water channels and managed under the site wide surface water control plan. Contact water is minimized by closing the facility in phases, placing partial final cover as ash reaches final grades. Contact water is handled through multiple means at the landfill, consisting of channels and phased use of evaporation ponds for storing contact water run-off. Water from the contact water evaporation ponds may be used for dust control within the landfill area. NPPD operations staff routinely monitor the landfill, including after significant storm events. Potential erosion or surface water management issues are documented and corrected as necessary to ensure the landfill operates as designed.

5.0 CERTIFICATION

Jacob Sauer (PE E-15119) attests to the completeness and accuracy of the written Run-on and Runoff Control Plan and certifies that the plan meets the requirements detailed in 40 CFR §257.81. Notification of the completion of the plan will be provided to the appropriate regulatory agencies, as the plan will be placed in the operating records and available on NPPD's publicly accessible website.

Golder Associates Inc.

Jacob Sauer, PE
Associate, Senior Engineer

Jason Obermeyer, PE
Associate, Senior Consultant

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https://golderassociates.sharepoint.com/sites/131840/project files/6 deliverables/reports/3-r-ggs_ro_ro_plan/3-r-0/20149028-3-r-0-_2021_ggs_roro_rpt_20sep21.docx

6.0 REFERENCES

EPA 2015. Environmental Protection Agency, Code of Federal Regulations Title 40 Part 257: Hazardous and Solid Waste Management System; *Disposal of Coal Combustion Residuals from Electric Utilities*. April 17, 2015, amended July 30, 2018.

APPENDIX A

Contact Water Controls

Golder Associates	Subject NPPD - GGS	Made by SCA	Job No 033-2167
	Ash Pits	Checked by TJJ	Date 10/13/2004
	Contact Water Controls	Approved by	Sheet No 1 of 2

OBJECTIVE:

Determine the size of water channels needed to convey the design storm event at ash pits 1-4 at the Gerald Gentleman Station operated by the Nebraska Public Power District.

METHOD:

Use the HEC-HMS modeling software (USACE) to route surface runoff from each phase of ash pit construction and estimate the peak flows that will occur in each contact water channel. Peak flows are used to size the channels using Manning's equation assuming normal depths.

ASSUMPTIONS:

- Refer to the Contact Water Basin and Channel Layout figures (Figures 1 and 2) for basin delineations, channel locations and flow routing.
- An SCS curve number of 94 was assumed for all basins, reflecting fly ash coverage.
- A Manning roughness coefficient of 0.016 for stability and 0.020 for capacity was assumed for fly ash channels and a Manning roughness coefficient of 0.011 was assumed for sheet flow.
- A design storm event of 4.25 inches was used in this analysis. This event is the 24-hour, 25-year storm event from the "Rainfall Frequency Atlas of the United States." (SCS 1961).
- The areas, lengths, and slopes used to calculate the total lag time were estimated from Permit drawings.
- Shallow concentrated flow was assumed for slope lengths greater than 300 ft.

CALCULATIONS:

Hydrologic parameters for the basins (Tables 1A and 1B) were entered into the HEC-HMS modeling software and routed to calculate peak flows for each basin and channel. Peak flows were used to size contact water channels and determine the appropriate channel linings.

Output from the HEC-HMS modeling (Attachment C) and channel sizing calculations (Table 2) are attached.

RESULTS/CONCLUSIONS:

Individual channel reaches are summarized in Table 2, showing peak flows, channel geometries, and velocities associated with the design storm event. Most of the contact water channels will be fly ash-lined, V-notch channels with side slopes of 3H:1V on the outside, 4H:1V on the inside, and a depth of 2 feet. The exceptions are Channel R-2-A (outside side slope of 2H:1V, inside side slope of 4H:1V, and depth of 3 feet), Channel R-2-B-1 (outside side slope of 3H:1V, inside side slope of 10H:1V, and depth of 2 feet), and Channel R-7-B (outside side slope of 3H:1V, inside side slope of 4H:1V, and depth of 2.5 feet).

It should be noted that several of the velocities listed in Table 2 (4 – 8 fps) exceed the preferred channel velocity of 5 fps. However, due to the nature of fly ash-lined channels and the relatively short lifespan of the channels, all velocities listed in Table 2 are considered acceptable. The contact water channels are expected to properly convey the design storm event to the evaporation ponds, but some maintenance may be required after large storm events.

REFERENCES:

HEC-HMS Hydrologic Modeling System [computer software], May 2003 US Army Corps of Engineers Version 2.2.2.

"Rainfall Frequency Atlas of The United States", May 1961 Soil Conservation Service, Technical Paper No. 40.

Table 1A
Basin Summary

Job No.: 033-2167
By: SCA
Date: 10/13/2004

2yr-24hr 2.25 in 25yr-24hr 4.25 in

				Sheet Flow				Shallow Concentrated Flow				Channel Flow					Total	Total	Basin	Storm
Basin	Area (ft^2)	Area (acres)	Area (mi^2)	Length (ft)	Slope (ft/ft)	Surface n	tc (min)	Length (ft)	Slope (ft/ft)	Paved/ Unpaved	tc (min)	Length (ft)	Slope (ft/ft)	Mannings n	Avg Rh	Tc (ft)	Tc (min)	Lag (min)	Curve Number	Depth (in)
1-B-1	61,084	1.40	0.00219	196	25.0%	0.011	0.90					500	1.0%	0.016	0.40	2.46	3.36	3.6	94	4.25
1-B-2	363,194	8.34	0.01303	300	10.0%	0.011	1.83	200	10.0%	Unpaved	0.65	800	1.0%	0.016	0.86	2.36	4.84	3.6	94	4.25
1-C-1	90,850	2.09	0.00326	237	25.0%	0.011	1.05					395	1.0%	0.016	0.40	1.94	2.99	3.6	94	4.25
1-C-2	205,930	4.73	0.00739	300	25.0%	0.011	1.27					730	1.0%	0.016	0.86	2.15	3.42	3.6	94	4.25
2-A-1	53,707	1.23	0.00193	165	25.0%	0.011	0.79					450	1.00%	0.016	0.33	2.51	3.30	3.6	94	4.25
2-A-2	276,673	6.35	0.00992	300	10.0%	0.011	1.83	150	10.0%	Unpaved	0.49	720	1.0%	0.016	0.60	2.70	5.02	3.6	94	4.25
2-A-3	194,950	4.48	0.00699	300	25.0%	0.011	1.27	10	25.0%	Unpaved	0.02	720	1.0%	0.016	0.86	2.12	3.41	3.6	94	4.25
2-B-1	481,469	11.05	0.01727	300	10.0%	0.011	1.83	170	10.0%	Unpaved	0.56	800	1.0%	0.016	0.60	3.00	5.38	3.6	94	4.25
2-B-2	204,939	4.70	0.00735	300	25.0%	0.011	1.27	10	25.0%	Unpaved	0.02	720	1.0%	0.016	0.86	2.12	3.41	3.6	94	4.25
2-C-1	270,398	6.21	0.00970	300	10.0%	0.011	1.83	400	10.0%	Unpaved	1.31	70	1.0%	0.016	0.60	0.26	3.40	3.6	94	4.25
2-C-2	194,950	4.48	0.00699	300	25.0%	0.011	1.27	10	25.0%	Unpaved	0.02	720	1.0%	0.016	0.86	2.12	3.41	3.6	94	4.25
2-D	194,950	4.48	0.00699	300	25.0%	0.011	1.27	10	25.0%	Unpaved	0.02	720	1.0%	0.016	0.86	2.12	3.41	3.6	94	4.25

- Basin areas, slopes and lengths from basin layout figures
- Basin curve number is 94 reflecting fly ash coverage
- Sheet and shallow concentrated flow calculations by TR-55
- Shallow concentrated flow is assumed for slopes longer than 300 feet
-Manning's n value of 0.011 used to represent land covered by fly ash
- Unpaved conditions assumed for shallow concentrated flow to reflect fly ash cover
-Manning's n value of 0.016 used to represent fly ash channels

- Lag time is equal to 60 percent of the time of concentration (tc)
- Minimum lag time of 3.6 minutes (minimum Tc of 6 minutes per TR-55)
- Channel flow by Manning's Equation
- Avg Rh is an estimated value and should be compared to actual calculated values
- The design storm event is the 25yr-24hr event from rainfall frequency atlas

Table 1B
Basin Summary

Job No.: 033-2167
By: SCA
Date: 10/13/2004

2yr-24hr 2.25 in 25yr-24hr 4.25 in

Basin	Area (ft^2)	Area (acres)	Area (mi^2)	Sheet Flow Length (ft)	Sheet Flow Slope (ft/ft)	Sheet Flow Surface n	Sheet Flow tc (min)	Shallow Concentrated Flow Length (ft)	Shallow Concentrated Flow Slope (ft/ft)	Shallow Concentrated Flow Paved/ Unpaved	Shallow Concentrated Flow tc (min)	Channel Flow Length (ft)	Channel Flow Slope (ft/ft)	Channel Flow Mannings n	Channel Flow Avg Rh	Channel Flow Tc (ft)	Total Tc (min)	Total Lag (min)	Basin Curve Number	Storm Depth (in)
4A	204,181	4.69	0.00732	150	5.0%	0.011	1.39	150	25.0%	Unpaved	0.31	1180	2.0%	0.016	0.47	3.68	6.10	3.7	94	4.25
				150	25.0%	0.011	0.73													
4B	252,951	5.81	0.00907	115	5.0%	0.011	1.12	140	25.0%	Unpaved	0.29	550	1.0%	0.016	0.58	2.11	4.38	3.6	94	4.25
				185	25.0%	0.011	0.86													
5A	419,503	9.63	0.01505	300	5.0%	0.011	2.41	100	5.0%	Unpaved	0.46	250	1.0%	0.016	0.70	0.85	4.44	3.6	94	4.25
								350	25.0%	Unpaved	0.72									
5B	157,935	3.63	0.00567	300	5.0%	0.011	2.41	100	5.0%	Unpaved	0.46	375	0.6%	0.016	0.54	1.95	5.60	3.6	94	4.25
								375	25.0%	Unpaved	0.77									
6A	317,599	7.29	0.01139	300	25.0%	0.011	1.27	200	25.0%	Unpaved	0.41	250	1.0%	0.016	0.63	0.91	2.59	3.6	94	4.25
6B	399,476	9.17	0.01433	300	5.0%	0.011	2.41	225	5.0%	Unpaved	1.04	600	1.3%	0.016	0.66	1.85	6.03	3.6	94	4.25
								350	25.0%	Unpaved	0.72									
6C	125,723	2.89	0.00451	200	5.0%	0.011	1.74	350	25.0%	Unpaved	0.72	350	0.6%	0.016	0.49	1.94	4.93	3.6	94	4.25
				100	25.0%	0.011	0.53													
7A	260,408	5.98	0.00934	300	5.0%	0.011	2.41	100	5.0%	Unpaved	0.46	1725	1.5%	0.016	0.53	5.74	9.33	5.6	94	4.25
								350	25.0%	Unpaved	0.72									
7B	476,194	10.93	0.01708	300	5.0%	0.011	2.41	100	5.0%	Unpaved	0.46	500	1.0%	0.016	0.84	1.50	5.28	3.6	94	4.25
								440	25.0%	Unpaved	0.91									

- Basin areas, slopes and lengths from basin layout figures
- Basin curve number is 94 reflecting fly ash coverage
- Sheet and shallow concentrated flow calculations by TR-55
- Shallow concentrated flow is assumed for slopes longer than 300 feet
-Manning's n value of 0.011 used to represent land covered by fly ash
- Unpaved conditions assumed for shallow concentrated flow to reflect fly ash cover
-Manning's n value of 0.016 used to represent fly ash channels

- Lag time is equal to 60 percent of the time of concentration (tc)
- Minimum lag time of 3.6 minutes (minimum Tc of 6 minutes per TR-55)
- Channel flow by Manning's Equation
- Avg Rh is an estimated value and should be compared to actual calculated values
- The design storm event is the 25yr-24hr event from rainfall frequency atlas

Job No.: 033-2167
By: SCA
Date: 10/13/2004

Table 2

Channel Summary

Channel Designation	Bottom Width (ft)	Outside Slopes H:1V	Inside Slope H:1V	Channel Slope (ft/ft)	Channel Lining Material	Stability Mannings 'n' for Velocity	Capacity Mannings 'n' for Depth	Q from HEC-HMS (cfs)	Designed Channel Depth (ft)	Max Normal Flow Depth (ft)	Hydraulic Radius Rh (ft)	Max Flow Velocity (ft/s)	Shear Stress (psf)	Velocity Head for Freeboard (ft)	Required Channel Depth (ft)	Top Width of Flow (ft)
R-2-A	0	2	4	1.00%	Fly Ash	0.0160	0.0200	67.6	3.00	1.83	0.86	7.96	1.14	0.98	2.4	14.4
R-2-B-1	0	3	10	1.00%	Fly Ash	0.0160	0.0200	50.6	2.00	1.22	0.60	6.23	0.76	0.60	1.8	0.0
R-1-C-1	0	3	4	1.00%	Fly Ash	0.0160	0.0200	9.6	2.00	0.83	0.40	4.74	0.51	0.35	1.4	9.8
R-2-A-1	0	3	4	1.00%	Fly Ash	0.0160	0.0200	5.7	2.00	0.68	0.33	4.16	0.42	0.27	1.2	8.4
R-2-C-1	0	3	4	1.00%	Fly Ash	0.0160	0.0200	28.4	2.00	1.24	0.60	6.23	0.77	0.60	1.8	0.0
R-4-A	0	3	4	2.00%	Fly Ash	0.0160	0.0200	21.3	2.00	0.98	0.47	7.51	1.22	0.88	1.5	10.5
R-4-B	0	3	4	1.00%	Fly Ash	0.0160	0.0200	26.6	2.00	1.21	0.58	6.12	0.76	0.58	1.8	12.6
R-5-A	0	3	4	1.00%	Fly Ash	0.0160	0.0200	44.1	2.00	1.46	0.70	6.95	0.91	0.75	2.0	14.0
R-5-B	0	3	4	0.60%	Fly Ash	0.0160	0.0200	16.6	2.00	1.12	0.54	4.49	0.42	0.31	1.7	11.9
R-6-A	0	3	4	1.00%	Fly Ash	0.0160	0.0200	33.4	2.00	1.32	0.63	6.48	0.82	0.65	1.9	13.3
R-6-B	0	3	4	1.30%	Fly Ash	0.0160	0.0200	42.0	2.00	1.37	0.66	7.57	1.11	0.89	1.9	13.3
R-6-C	0	3	4	0.60%	Fly Ash	0.0160	0.0200	13.2	2.00	1.03	0.49	4.24	0.38	0.28	1.6	0.0
R-7-A	0	3	4	1.50%	Fly Ash	0.0160	0.0200	25.7	2.00	1.11	0.53	7.07	1.04	0.78	1.7	11.9
R-7-B	0	3	4	1.00%	Fly Ash	0.0160	0.0200	70.7	2.50	1.75	0.84	7.82	1.09	0.95	2.3	16.1

- Normal flow depth by Manning's Equation

ATTACHMENT A
TIME OF CONCENTRATION CALCULATION COEFFICIENTS

TR-55 (1986)

Sheet Flow Travel time

$$T_t = \frac{0.007\,(n'\,L)^{0.8}}{(P_2)^{0.5}\,s^{0.4}}$$

Where: T_t = travel time (hrs); n' = roughness coefficient; L = flow length (ft);

P_2 = 2-yr storm depth (inches); s = slope (ft/ft)

flow velocity = $L/(60T_t)$

Flow Type	**Surface Type**	**roughness coefficient n':**	**Surface Description**
Sheet/Overland Flow	A	0.011	Smooth surfaces (concrete, asphalt, gravel, bare soil)
	B	0.05	Fallow (no residue)
	C	0.06	Cultivated soils: Residue cover <= 20%
	D	0.17	Cultivated soils: Residue cover > 20%
	E	0.15	Grass: Short grass prairie
	F	0.24	Grass: Dense grasses
	G	0.41	Grass: Bermuda grass
	H	0.13	Range (natural)
	I	0.40	Woods: Light underbrush
	J	0.80	Woods: Heavy underbrush

Shallow Concentrated Flow Velocity

$v = mS^{0.5}$

Where: v = velocity (fps); m = roughness coeffient; S = slope (ft/ft)

Flow Type	**Surface Type**	**roughness coefficient m:**	**Surface Description**
Shallow Conc. Flow	P	20.3282	Paved
	U	16.1345	Unpaved

ATTACHMENT B
REFERENCE VALUES

Mannings n Values

Channel Lining Material	Mannings n Value for Velocity	Mannings n Value for Depth
Fly Ash	0.016	0.020
None	0.025	0.030
Dirt	0.025	0.030
Grass	0.030	0.035
Riprap	0.035	0.040
Trilock	0.026	0.026
Concrete	0.015	0.015

Freeboard in Channel requirements

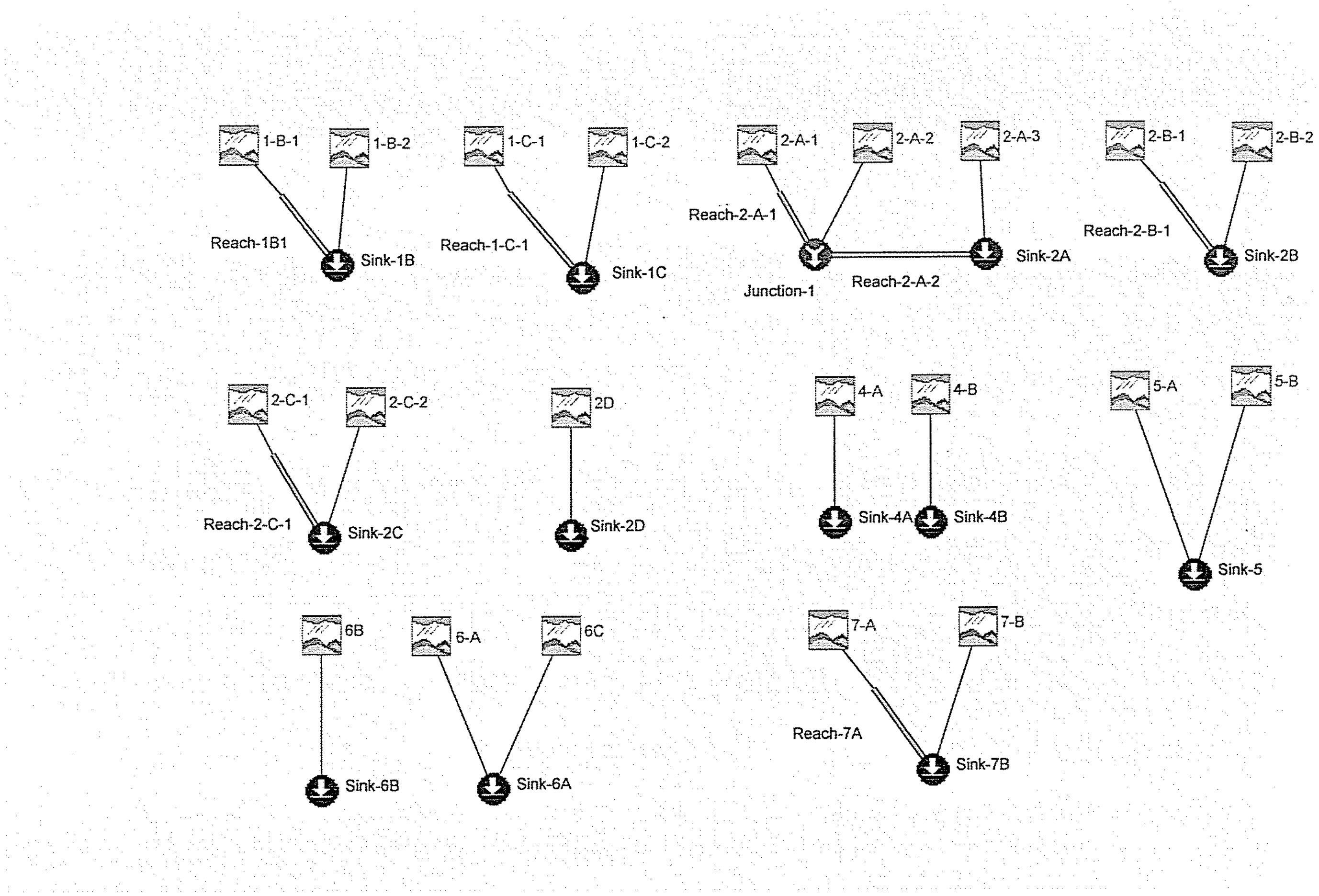
Minumum Freeboard in channel of 0.5 ft

or

50% Percent of Velocity head ($V^2/2g$)

whichever is greater

ATTACHMENT C:
HEC-HMS OUTPUT



1-B-1
1-B-2
Reach-1B1
Sink-1B
1-C-1
1-C-2
Reach-1-C-1
Sink-1C
2-A-1
2-A-2
2-A-3
Reach-2-A-1
Sink-2A
Junction-1
Reach-2-A-2
2-B-1
2-B-2
Reach-2-B-1
Sink-2B
2-C-1
2-C-2
Reach-2-C-1
Sink-2C
2D
Sink-2D
4-A
4-B
Sink-4A
Sink-4B
5-A
5-B
Sink-5
6B
6-A
6C
Sink-6B
Sink-6A
7-A
7-B
Reach-7A
Sink-7B

HMS * Summary of Results

Project : NPPD_SCA_8-25-04 Run Name : Run 12

Start of Run : 01Jan04 0000 Basin Model : Contact Water
End of Run : 02Jan04 1200 Met. Model : 25 year 24 hour
Execution Time : 13Oct04 1109 Control Specs : 6-minute

Hydrologic Element	Discharge Peak (cfs)	Time of Peak	Volume (ac ft)	Drainage Area (sq mi)
1-B-1	6.4186	01 Jan 04 1154	0.41693	0.002
Reach-1B1	6.1303	01 Jan 04 1200	0.41700	0.002
1-B-2	38.189	01 Jan 04 1154	2.4807	0.013
Sink-1B	43.337	01 Jan 04 1154	2.8977	0.015
1-C-1	9.5547	01 Jan 04 1154	0.62064	0.003
Reach-1-C-1	9.0983	01 Jan 04 1200	0.62102	0.003
1-C-2	21.659	01 Jan 04 1154	1.4069	0.007
Sink-1C	29.514	01 Jan 04 1154	2.0279	0.011
2-A-1	5.6566	01 Jan 04 1154	0.36743	0.002
Reach-2-A-1	5.3266	01 Jan 04 1200	0.36799	0.002
2-A-2	29.074	01 Jan 04 1154	1.8886	0.010
Junction-1	34.103	01 Jan 04 1154	2.2566	0.012
Reach-2-A-2	32.703	01 Jan 04 1200	2.2599	0.012
2-A-3	20.487	01 Jan 04 1154	1.3308	0.007
Sink-2A	51.617	01 Jan 04 1200	3.5906	0.019
2-B-1	50.616	01 Jan 04 1154	3.2879	0.017
Reach-2-B-1	47.695	01 Jan 04 1200	3.2929	0.017
2-B-2	21.542	01 Jan 04 1154	1.3993	0.007
Sink-2B	67.583	01 Jan 04 1200	4.6922	0.025
2-C-1	28.430	01 Jan 04 1154	1.8467	0.010
Reach-2-C-1	26.874	01 Jan 04 1200	1.8492	0.010
2-C-2	20.487	01 Jan 04 1154	1.3308	0.007
Sink-2C	45.787	01 Jan 04 1200	3.1799	0.017
2D	20.487	01 Jan 04 1154	1.3308	0.007
Sink-2D	20.487	01 Jan 04 1154	1.3308	0.007
4-A	21.276	01 Jan 04 1154	1.3936	0.007
Sink-4A	21.276	01 Jan 04 1154	1.3936	0.007
4-B	26.583	01 Jan 04 1154	1.7267	0.009
Sink-4B	26.583	01 Jan 04 1154	1.7267	0.009
5-A	44.110	01 Jan 04 1154	2.8652	0.015
5-B	16.618	01 Jan 04 1154	1.0795	0.006
Sink-5	60.728	01 Jan 04 1154	3.9447	0.021
6-A	33.383	01 Jan 04 1154	2.1684	0.011
6C	13.218	01 Jan 04 1154	0.85861	0.005
Sink-6A	46.601	01 Jan 04 1154	3.0270	0.016
6B	42.000	01 Jan 04 1154	2.7281	0.014
Sink-6B	42.000	01 Jan 04 1154	2.7281	0.014
7-A	25.690	01 Jan 04 1200	1.7781	0.009
Reach-7A	24.492	01 Jan 04 1200	1.7791	0.009
7-B	50.059	01 Jan 04 1154	3.2517	0.017
Sink-7B	70.707	01 Jan 04 1200	5.0308	0.026

LEGEND

3165 / 3170	EXISTING GROUND TOPOGRAPHY
3205 / 3195	TOP OF ASH TOPOGRAPHY
	CONTACT WATER BASINS
	CONTACT WATER CHANNELS

200 0 200
1" = 200 FEET

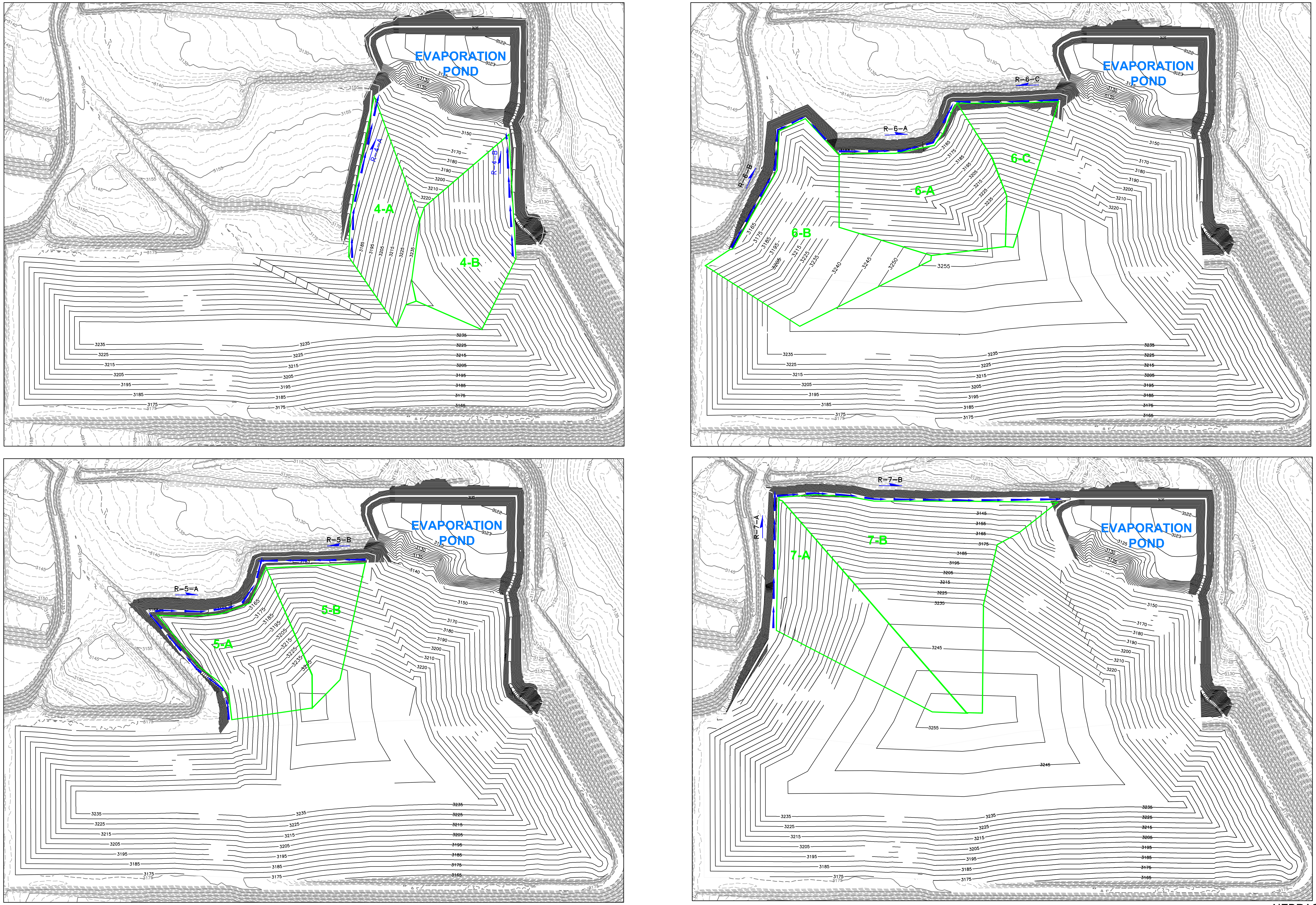
NEBRASKA PUBLIC POWER DISTRICT
GERALD GENTLEMAN STATION
LINCOLN COUNTY, NEBRASKA

PHASES 1 AND 2 CONTACT WATER BASIN AND CHANNEL LAYOUT

FIGURE 1

Golder Associates
Denver, Colorado

PROJECT No. 033-2167 CADD SCA DATE 9/7/04 FILE No. 0332167A036.dwg



LEGEND

EXISTING GROUND TOPOGRAPHY

TOP OF ASH TOPOGRAPHY

CONTACT WATER BASINS

CONTACT WATER CHANNELS

200 0 200
1" = 200 FEET

NEBRASKA PUBLIC POWER DISTRICT
GERALD GENTLEMAN STATION
LINCOLN COUNTY, NEBRASKA

PHASES 4-7
CONTACT WATER BASIN AND CHANNEL LAYOUT

FIGURE 2

Golder Associates
Denver, Colorado

PROJECT No. 033-2167 CADD SCA DATE 9/7/04 FILE No. 0332167A037.dwg

APPENDIX B

Evaporation Pond Sizing

Golder Associates	Subject NPPD – GGS	Made by TJS	Job No 033-2167
	Ash Pits Nos. 1 - 4	Checked by JEO	Date 9/23/2004
	Phases 1-3 Evaporation Pond	Approved by	Sheet No 1 of 3

OBJECTIVE:

To determine the adequacy of the Ash Pit No. 4 evaporation pond to contain contact water during Phases 1 to 3 of the ash pits operations. Phase 3 consists of filling in the area that makes up the evaporation pond. The pond size and location will change as Phase 3 is filled and reclaimed. Analysis will focus on the pond adequacy during Phases 1 to 2.

METHOD:

The modeling software GoldSim was used to model the evaporation pond water balance due to precipitation, run-on, evaporation, and dust suppression use of ponded water. Run-on to the evaporation pond is based on an approximate contact water basin footprint and the routing of water to the evaporation pond. Run-on is calculated using the SCS curve number method. Evaporation is calculated based on pond area, a pan factor, and historical pan evaporation data.

ASSUMPTIONS:

The size of the evaporation pond and staged storage curve was taken from the operations drawings (Phase 1a) and is provided in Table 1.

Table 1: Phases 1 to 3 Evaporation Pond – Staged Storage

Elevation	Area	Cum. Volume
ft	ft^2	gal
3158	0	0
3159	40,119	184,655
3160	88,156	664,413
3161	153,635	1,568,731
3162	224,148	2,981,670
3163	295,253	4,924,268
3164	367,280	7,402,191
3165	396,314	10,258,091
3166	402,786	13,246,785
3167	409,298	16,284,044
3168	415,861	19,370,201
3169	422,470	22,505,623
3170	429,128	25,690,663
3171	435,823	28,925,646
3172	442,579	32,210,936
3173	449,373	35,546,904
3174	458,210	38,941,334

Phases 1 to 2 of the ash pits will take approximately 11 years to complete.

The size of the contact water basin contributing run-on is based on the idea of sequential closure/construction. The contact water basin area was estimated for each phase and an approximate relationship with time is given in Table 2.

Table 2: Phases 1 to 2 Contact Water Basin

Phase	Cumulative Time (yrs)	Contact Water Basin (acres)
1A Start	0.0	14.2
1A End	1.8	14.2
1B End	4.6	10.2
1C End	5.8	8.7
2A Start	5.8	16.4
2A End	7.7	14.2
2B Start	7.7	21.0
2B End	9.5	17.5
2C End	10.3	12.8
2D End	11.3	3.2

Approximately 15,000 gallons of water per day are used for dust suppression Monday through Friday during the months of May to October.

A pan factor of 0.7 is used to convert pan evaporation into pond evaporation.

A curve number of 94 is used for the contact water basin to reflect fly ash slopes.

Precipitation and evaporation data are from the North Platte EXP Farm weather station (station 6075), and were obtained from the NOAA Hydrologic Data Systems Group web site (http://dipper.nws.noaa.gov/hdsb/data/archived/).

Latitude = 41.05 Longitude = 100.75 Elevation = 3025 feet

Precipitation and evaporation data used are from years 1976 to 1986 (consecutive 11 years with complete precipitation and evaporation data).

CALCULATIONS:

Results of the GoldSim modeling evaluation are attached (Figures 1 and 2).

CONCLUSIONS/RESULTS:

The design grades allow for the creation of an evaporation pond in the southeast corner of Ash Pit No. 4 to collect contact water resulting during Phases 1 to 3. The maximum water level expected within the evaporation pond is approximately 3165 feet, which is below the top of dike elevation of 3174 feet. Therefore, the design grades for the evaporation pond are adequate to contain the contact water during the life of Phases 1 to 2. If water within the evaporation pond reduces the freeboard to two feet or less, water shall be actively evaporated or pumped to the large existing evaporation pond located east of the ash pits.

Figure 1: Phases 1-3 Evaporation Pond Cumulative Inflows/Outflows

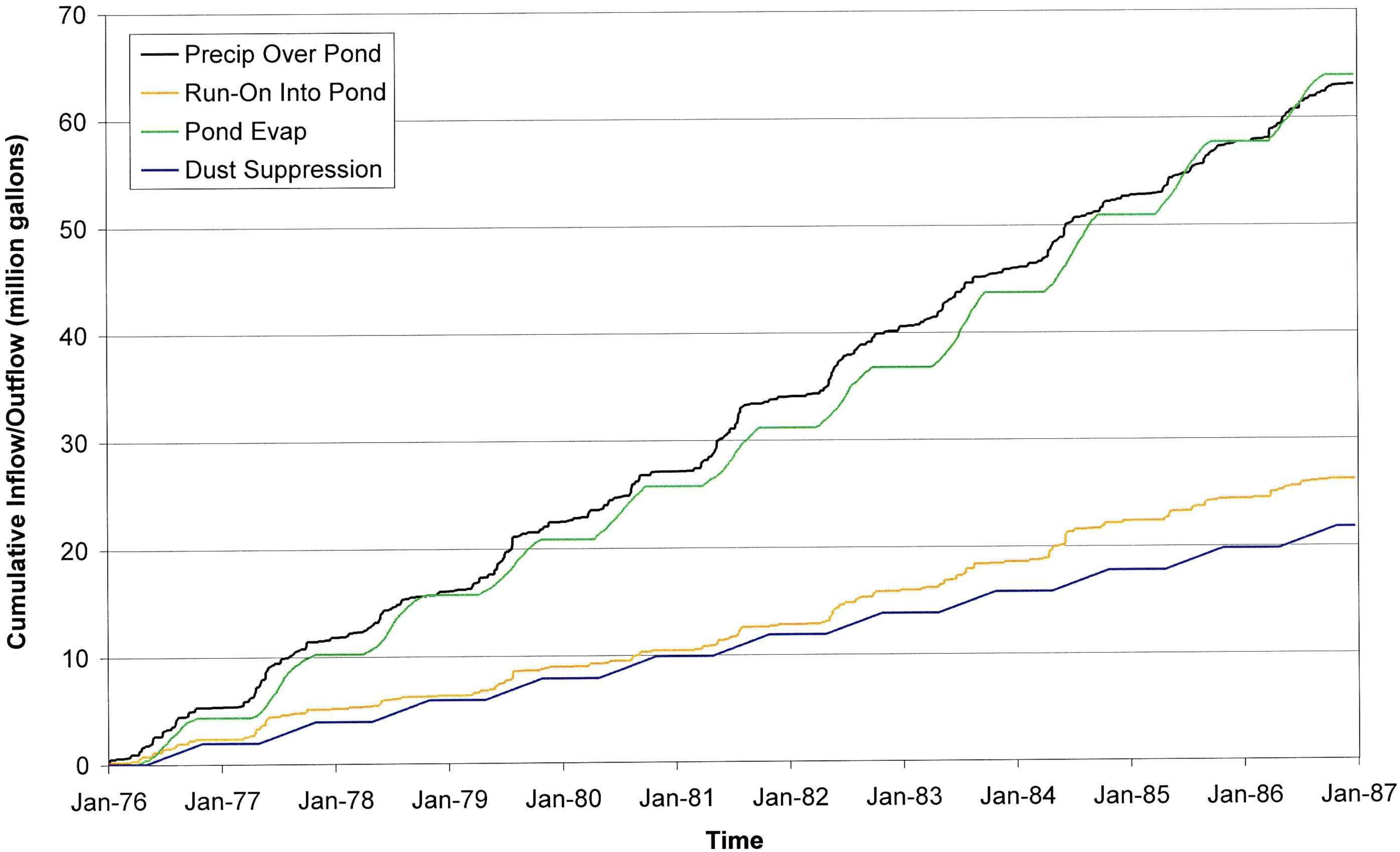
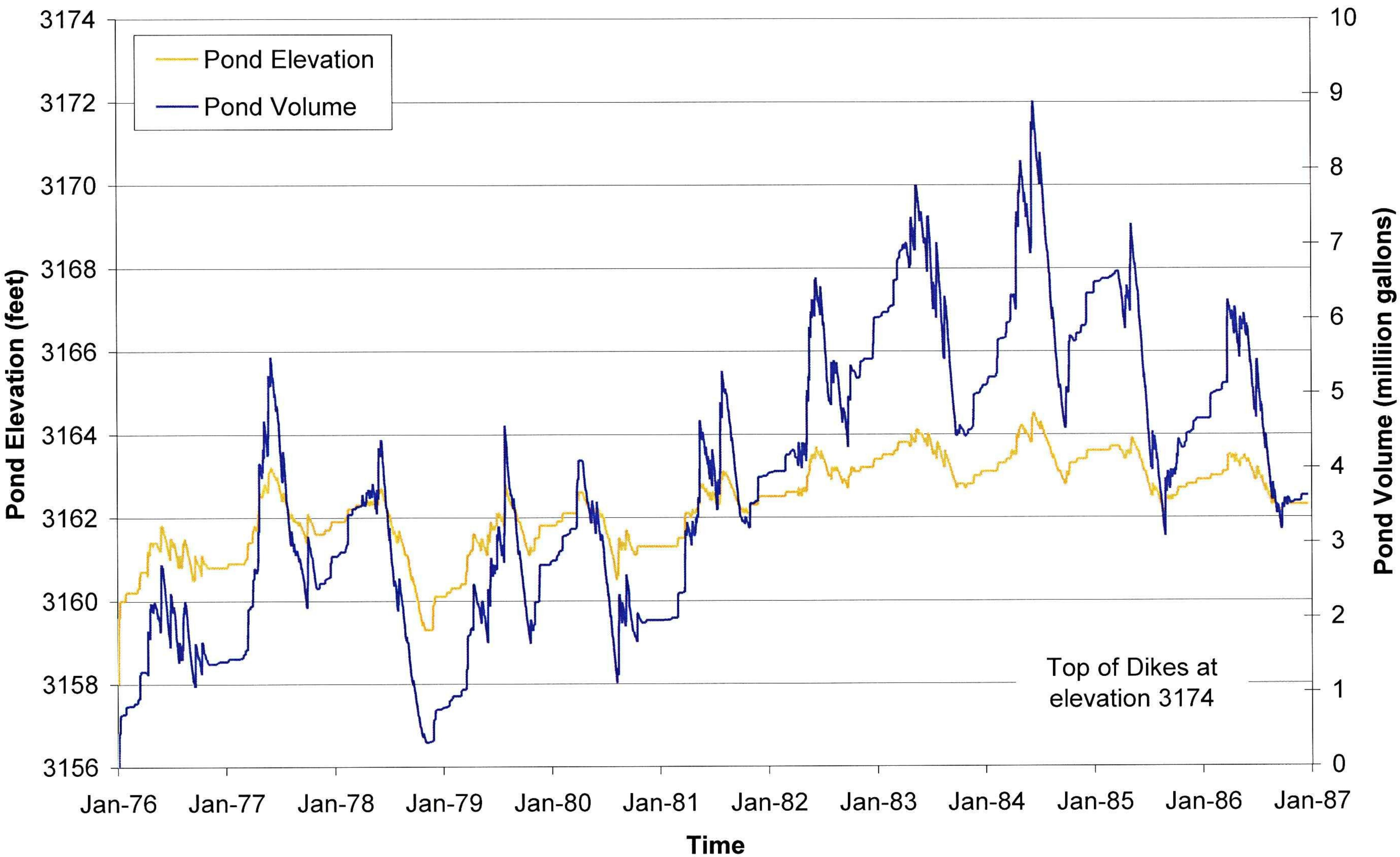


Figure 2: Phases 1-3 Evaporation Pond Elevation/Volume



	Subject NPPD – GGS	Made by TJS	Job No 033-2167
Golder Associates	Ash Pits Nos. 1 - 4	Checked by JEO	Date 9/23/2004
	Phases 4-8 Evaporation Pond	Approved by	Sheet No 1 of 3

OBJECTIVE:

To determine the adequacy of the future evaporation pond to contain contact water resulting during Phases 4 to 8 of the ash pits operations. Phase 8 consists of filling in the area that makes up the evaporation pond. The pond size and location will change as Phase 8 is filled and reclaimed. Analysis will focus on the pond adequacy during Phases 4 to 7.

METHOD:

The modeling software GoldSim was used to model the future evaporation pond water balance due to precipitation, run-on, evaporation, and dust suppression use of ponded water. Run-on to the evaporation pond is based on an approximate contact water basin footprint and the routing of water to the evaporation pond. Run-on is calculated using the SCS curve number method. Evaporation is calculated based on pond area, a pan factor, and historical pan evaporation data.

ASSUMPTIONS:

The size of the evaporation pond and staged storage curve was taken from the permit drawings (Phase 4) and is provided in Table 1.

Table 1: Phases 4 to 8 Evaporation Pond – Staged Storage

Elevation	Area	Cum. Volume
ft	ft^2	gal
3122	0	0
3123	22,196	90,190
3124	53,020	371,518
3125	95,098	925,520
3126	113,590	1,706,066
3127	130,812	2,620,192
3128	146,801	3,658,539
3129	155,612	4,789,642
3130	163,975	5,984,981
3131	171,744	7,240,658
3132	179,286	8,553,604
3133	186,820	9,922,938
3134	194,426	11,348,899
3135	202,312	12,832,800

Phases 4 to 7 of the ash pits will take approximately 24 years to complete.

The size of the contact water basin contributing run-on is based on the idea of sequential closure/construction. The contact water basin area was estimated for each phase and an approximate relationship with time is given in Table 2.

Table 2: Phases 4 to 7 Contact Water Basin

Phase	Cumulative Time (yrs)	Contact Water Basin (acres)
4 Start	0.0	15.2
4 End	4.6	8.6
5 Start	4.6	21.8
5 End	11.1	15.9
6 Start	11.1	28.4
6 End	16.7	16.5
7 Start	16.7	28.1
7 End	24.3	9.8

Approximately 15,000 gallons of water per day are used for dust suppression Monday through Friday during the months of May to October.

If the evaporation pond comes within 2 feet of the top of dikes (El. 3135), water will be pumped from the ash pits evaporation pond to the large site evaporation pond at a rate of 96,000 gallons per day.

A pan factor of 0.7 is used to convert pan evaporation into pond evaporation.

A curve number of 94 is used for the contact water basin to reflect fly ash slopes.

Precipitation and evaporation data are from the North Platte EXP Farm weather station (station 6075), and were obtained from the NOAA Hydrologic Data Systems Group web site (http://dipper.nws.noaa.gov/hdsb/data/archived/).

Latitude = 41.05 Longitude = 100.75 Elevation = 3025 feet

Precipitation and evaporation data used are from years 1966 to 1994 (consecutive 24 years with complete precipitation and evaporation data).

CALCULATIONS:

Results of the GoldSim modeling evaluation are attached (Figures 1 and 2).

CONCLUSIONS/RESULTS:

The design grades allow for the creation of an evaporation pond in the northeast corner of the entire ash pit facility during Phase 4 to collect contact water during Phases 4 to 8. The maximum water level expected within the evaporation pond is approximately 3134 feet which is below the top of dike elevation of 3135 feet. Water levels in the evaporation pond are maintained through active placement of final cover, use of dust suppression water, and pumping to the large site evaporation pond. In the model evaluated, approximately 2.7 million gallons of water were pumped from the ash pits evaporation pond to the large site evaporation pond. In actual management, active placement of final cover and use of water for dust suppression may reduce the pumping requirements. Based on the modeling, the design grades for the evaporation pond are adequate to contain the contact water during the life of Phases 4 to 7. If water within the evaporation pond reduces the freeboard to two feet or less, water shall be actively evaporated or pumped to the large existing evaporation pond located east of the ash pits.

Figure 1: Phases 4-8 Evaporation Pond Cumulative Inflows/Outflows

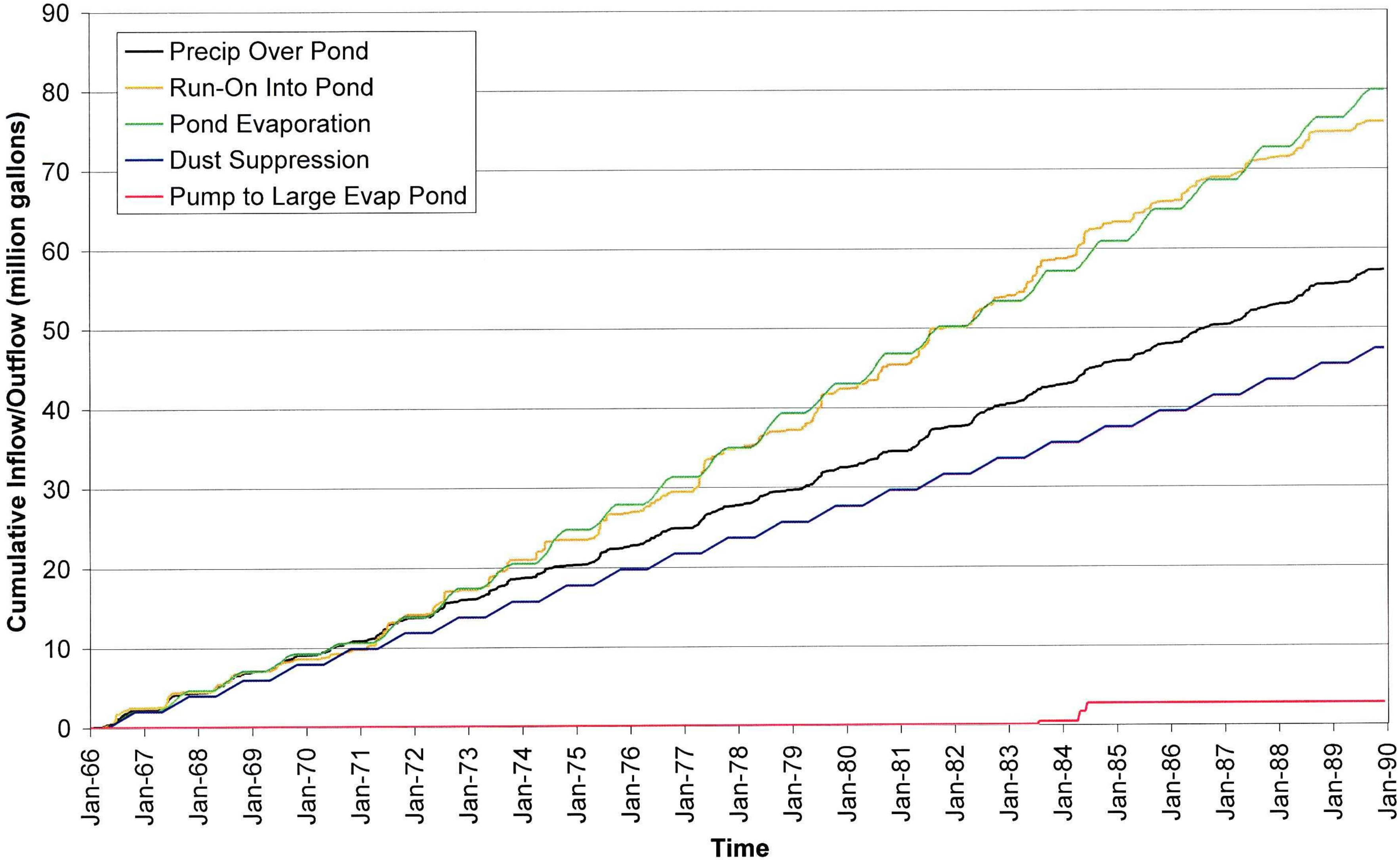
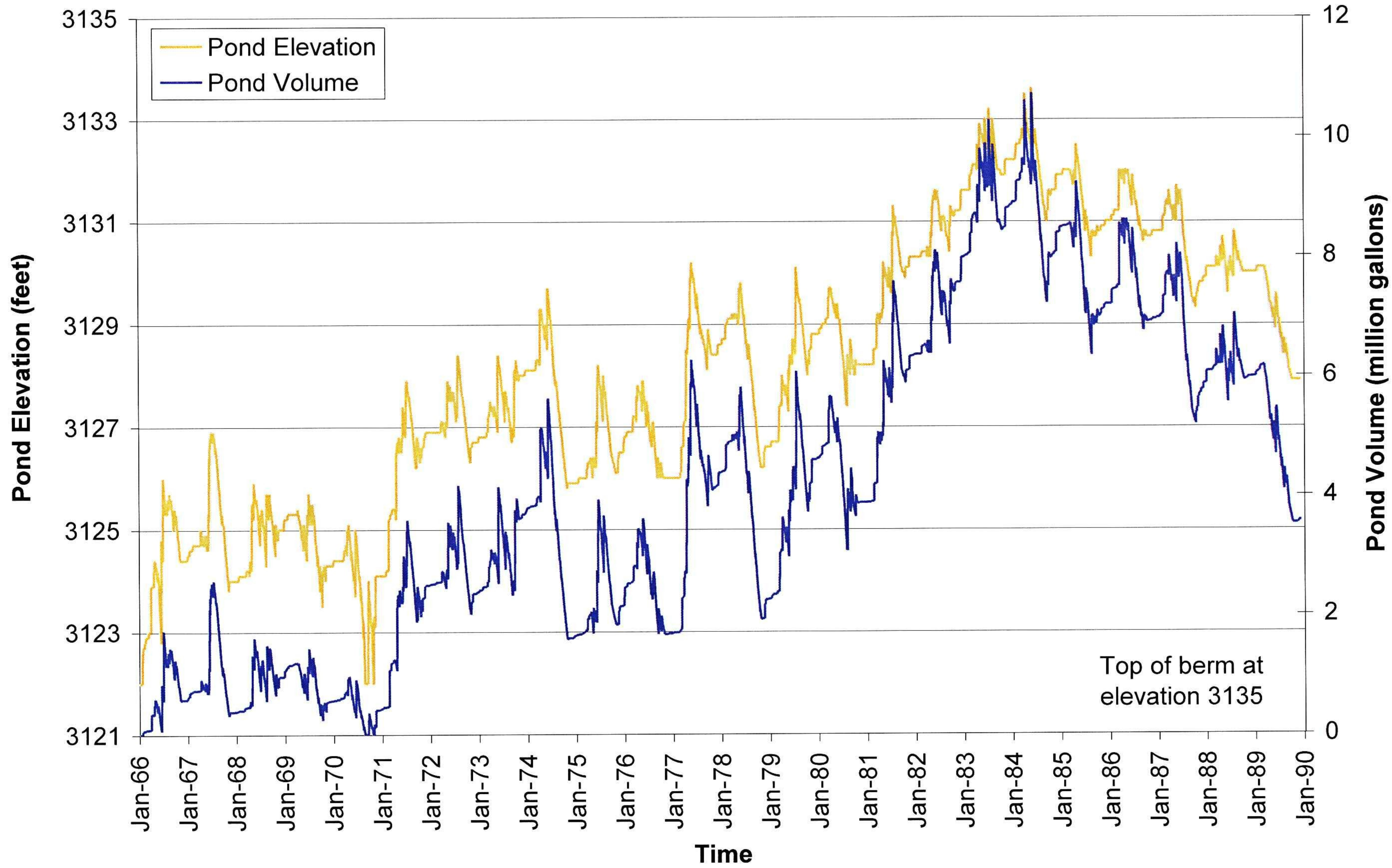


Figure 2: Phases 4-8 Evaporation Pond Elevation/Volume



APPENDIX C

Surface Water Controls

OBJECTIVE:

Determine the size of terrace channels, downslope channels, outlet channels, and hydraulic jump basins needed to convey the design storm event.

METHOD:

Use the HEC-HMS modeling software (USACE) to route surface runoff from the final cover system and estimate the peak flows that will occur in each runoff channel. Peak flows are used to size the channels using Manning's equation assuming normal depths, as well as determine the required channel lining based on the maximum velocity in the channels. Peak flows at the end of downslope channels are used to determine Froude numbers for evaluation of hydraulic jump basins.

ASSUMPTIONS:

- Refer to the Surface Water Channel and Basin Layout (Figure 1) for basin delineations, channel locations, and flow routing.
- An SCS curve number of 81 was assumed for all basins, reflecting fair coverage of prairie grasses.
- A Manning roughness coefficient of 0.030 for stability and 0.035 for capacity was assumed for grass-lined channels and vegetated channels with turf reinforcement mat (TRM).
- A Manning roughness coefficient of 0.035 for stability and 0.040 for capacity was assumed for riprap-lined channels.
- A Manning roughness coefficient of 0.026 for both stability and capacity was assumed for articulated concrete block-lined channels.
- A design storm event of 4.3 inches was used in this analysis. This event is the 25-year, 24-hour storm event from the "Rainfall Frequency Atlas of the United States." (SCS 1961).

CALCULATIONS:

Hydrologic parameters for the basins (Tables 1A to 1C) were entered into the HEC-HMS modeling software and routed to calculate peak flows for each basin and channel. Peak flows were used to size channels and determine the appropriate channel linings.

Output from the HEC-HMS modeling, channel sizing calculations (Tables 2A to 2D), riprap sizing calculations (Table 3), and hydraulic jump basin sizing (Tables 4A to 4C) are attached.

RESULTS/CONCLUSIONS:

Individual terrace channel reaches are summarized in Tables 2A & 2B, with peak flows, depths, and velocities associated with the design storm event. Terrace channels will be grass-lined V-notch channels with side slopes of approximately 2H:1V and 3H:1V, and approximately 24 inches deep.

The downslope channel reaches and outlet channel reaches are summarized in Tables 2C & 2D, with peak flows, depths, and velocities associated with the design storm event. The downslope channels convey water off the ash facility's final slopes, and the outlet channels convey water away from the facility to existing drainage pathways. Both the downslope and outlet channels will be trapezoidal with 3H:1V side slopes, 10-foot wide bottoms, and 2.0-foot depths. Velocities and shear forces in these channels will require erosion protection lining. Three lining options were evaluated: riprap constructed from broken concrete, turf reinforcement mat, and articulated concrete block. Table 3 provides riprap gradation requirements for the downslope and outlet channels. Riprap with a D_{50} of 6" to 12" will be required for downslope channels and outlet channels. Broken concrete riprap shall have steel reinforcement cut to the edge of concrete blocks and removed. The concrete blocks shall also have breadth and thickness no less than 1/3 the length and shall have a visual gradation meeting the riprap gradation specified on Table 3. Turf reinforcement mat and articulated concrete block shall be selected and installed per manufacturer recommendations to reduce the potential of erosion pathways forming.

At the end of the downslope and outlet channels, where the slope becomes significantly flatter, a hydraulic jump basin is required to dissipate energy. The minimum hydraulic jump lengths are summarized in Tables 4A to 4C for different channel linings and range from approximately 2 to 12 feet. The hydraulic jump basin will be constructed of articulated concrete block or a concrete slab. Hydraulic jump basins required at the end of downslope channels will tie-in with the downslope channel and the outlet channel. Hydraulic jump basins required at the end of outlet channels will convey water away from the hydraulic jump basin to existing grass-lined channels to convey water further from the site. Additional channel protection (10-20') upstream and downstream of hydraulic jump basins will be provided to prevent damage to the existing drainage pathways.

REFERENCES:

United States Army Corps of Engineers, HEC-HMS Hydrologic Modeling System [computer software], Version 2.2.2, May 2003.

United States Department of Agriculture, Natural Resources Conservation Service, Conservation Engineering Division, "Urban Hydrology for Small Watersheds," Technical Release 55 (TR-55), June 1986.

United States Department of Agriculture, Soil Conservation Service, "Rainfall Frequency Atlas of the United States," Technical Paper No. 40, May 1961.

2yr-24hr	1.8	in
100yr-24hr	5.4	in
25yr-24hr	4.3	in

Table 1A
Basin Summary

Job No.: 033-2167
By: TJS
Date: 10/13/2004

Basin	Area (ft^2)	Area (acres)	Area (mi^2)	Sheet Flow Length (ft)	Sheet Flow Slope (ft/ft)	Sheet Flow Surface n	Sheet Flow tc (min)	Shallow Concentrated Flow Length (ft)	Shallow Concentrated Flow Slope (ft/ft)	Shallow Concentrated Flow Paved/ Unpaved	Shallow Concentrated Flow tc (min)	Channel Flow Length (ft)	Channel Flow Slope (ft/ft)	Channel Flow Mannings n	Channel Flow Avg Rh	Channel Flow Tc (ft)	Total Tc (min)	Total Lag (min)	Basin Curve Number	Storm Depth (in)
A-1	30,429	0.70	0.00109	172	5.0%	0.150	13.97					171	2.0%	0.030	0.23	1.61	20.19	12.1	81	4.3
				96	25.0%	0.150	4.60													
A-2	40,928	0.94	0.00147	147	25.0%	0.150	6.47					309	2.0%	0.030	0.29	2.49	8.97	5.4	81	4.3
A-3	10,032	0.23	0.00036	44	25.0%	0.150	2.47					328	1.0%	0.030	0.20	4.80	7.26	4.4	81	4.3
B-1	19,629	0.45	0.00070	111	5.0%	0.150	9.84					206	2.0%	0.030	0.20	2.13	16.46	9.9	81	4.3
				93	25.0%	0.150	4.49													
B-2	37,103	0.85	0.00133	142	25.0%	0.150	6.30					339	2.0%	0.030	0.27	2.87	9.17	5.5	81	4.3
B-3	9,855	0.23	0.00035	44	25.0%	0.150	2.47					316	1.0%	0.030	0.20	4.62	7.09	4.3	81	4.3
C-1	124,503	2.86	0.00447	296	5.0%	0.150	21.57	60	25.0%	unpaved	0.12	594	2.0%	0.030	0.38	4.00	26.06	15.6	81	4.3
				4	25.0%	0.150	0.36													
C-2	87,565	2.01	0.00314	141	25.0%	0.150	6.26					693	2.0%	0.030	0.37	4.75	11.02	6.6	81	4.3
C-3	36,835	0.85	0.00132	82	25.0%	0.150	4.06					695	1.0%	0.030	0.32	7.43	11.49	6.9	81	4.3
D-1	265,295	6.09	0.00952	296	5.0%	0.150	21.57					575	2.0%	0.030	0.50	3.23	25.16	15.1	81	4.3
				4	25.0%	0.150	0.36													
D-2	97,149	2.23	0.00348	141	25.0%	0.150	6.26					638	2.0%	0.030	0.39	4.23	10.49	6.3	81	4.3
D-3	34,833	0.80	0.00125	82	25.0%	0.150	4.06					636	1.0%	0.030	0.32	6.80	10.86	6.5	81	4.3
E-1	211,089	4.85	0.00757	300	5.0%	0.150	21.81	137	5.0%	unpaved	0.63	93	2.0%	0.030	0.47	0.54	23.20	13.9	81	4.3
								105	25.0%	unpaved	0.22									
E-2	100,227	2.30	0.00360	130	25.0%	0.150	5.87					651	2.0%	0.030	0.40	4.24	10.11	6.1	81	4.3
E-3	64,847	1.49	0.00233	140	25.0%	0.150	6.23					640	1.0%	0.030	0.39	5.99	12.22	7.3	81	4.3

- Basin areas, slopes and lengths from basin layout figure
- Basin curve number is 81 reflecting fair coverage of prairie grasses
- Sheet and shallow concentrated flow calculations by TR-55
- Sheet flow surface roughness is 0.15 reflecting short prairie grass (Attachment A)
- Shallow concentrated flow is assumed for slopes longer than 300 feet
- Unpaved conditions assumed for shallow concentrated flow to reflect vegetative cover

- Lag time is equal to 60 percent of the time of concentration (tc)
- Minimum lag time of 3.6 minutes (minimum Tc of 6 minutes per TR-55)
- Channel flow by Manning's Equation
- Roughness coefficient for Channel Flow based on grass lining from Attachment B
- Avg Rh is an estimated value and should be compared to actual calculated values
- The design storm event is the 25yr-24hr event from rainfall frequency atlas

2yr-24hr 1.8 in

100yr-24hr 5.4 in

25yr-24hr 4.3 in

Table 1B
Basin Summary

Job No.: 033-2167

By: TJS

Date: 10/13/2004

Basin	Area (ft^2)	Area (acres)	Area (mi^2)	Sheet Flow Length (ft)	Sheet Flow Slope (ft/ft)	Sheet Flow Surface n	Sheet Flow tc (min)	Shallow Concentrated Flow Length (ft)	Shallow Concentrated Flow Slope (ft/ft)	Shallow Concentrated Flow Paved/ Unpaved	Shallow Concentrated Flow tc (min)	Channel Flow Length (ft)	Channel Flow Slope (ft/ft)	Channel Flow Mannings n	Channel Flow Avg Rh	Channel Flow Tc (ft)	Total Tc (min)	Total Lag (min)	Basin Curve Number	Storm Depth (in)
F-1	58,883	1.35	0.00211	135	5.0%	0.150	11.51					522	2.0%	0.030	0.30	4.12	19.12	11.5	81	4.3
				68	25.0%	0.150	3.49													
F-2	68,723	1.58	0.00247	130	25.0%	0.150	5.87					635	2.0%	0.030	0.34	4.61	10.48	6.3	81	4.3
F-3	74,149	1.70	0.00266	140	25.0%	0.150	6.23					702	1.0%	0.030	0.41	6.36	12.59	7.6	81	4.3
G-1	26,002	0.60	0.00093	33	5.0%	0.150	3.73					350	2.0%	0.030	0.24	3.20	11.07	6.6	81	4.3
				84	25.0%	0.150	4.14													
G-2	76,763	1.76	0.00275	136	25.0%	0.150	6.08					710	2.0%	0.030	0.36	4.96	11.04	6.6	81	4.3
G-3	99,550	2.29	0.00357	60	25.0%	0.150	3.16					945	1.0%	0.030	0.47	7.82	10.98	6.6	81	4.3
H-1	225,918	5.19	0.00810	300	5.0%	0.150	21.81	177	5.0%	unpaved	0.82	179	2.0%	0.030	0.48	1.03	23.82	14.3	81	4.3
								78	25.0%	unpaved	0.16									
H-2	82,341	1.89	0.00295	163	25.0%	0.150	7.03					447	2.0%	0.030	0.37	3.07	10.10	6.1	81	4.3
H-3	53,440	1.23	0.00192	60	25.0%	0.150	3.16					277	1.0%	0.030	0.36	2.74	5.90	3.6	81	4.3
I-1	56,269	1.29	0.00202	188	5.0%	0.150	15.00					77	2.0%	0.030	0.29	0.62	19.72	11.8	81	4.3
				83	25.0%	0.150	4.10													
I-2	58,957	1.35	0.00211	157	25.0%	0.150	6.82					331	2.0%	0.030	0.33	2.45	9.27	5.6	81	4.3
I-3	69,783	1.60	0.00250	137	25.0%	0.150	6.12					462	2.0%	0.030	0.35	3.29	9.41	5.6	81	4.3
J-1	203,321	4.67	0.00729	300	5.0%	0.150	21.81	71	5.0%	unpaved	0.33	203	2.0%	0.030	0.46	1.20	23.53	14.1	81	4.3
								93	25.0%	unpaved	0.19									
J-2	101,587	2.33	0.00364	168	25.0%	0.150	7.20					570	2.0%	0.030	0.40	3.71	10.92	6.5	81	4.3
J-3	121,539	2.79	0.00436	155	25.0%	0.150	6.75					716	2.0%	0.030	0.42	4.51	11.27	6.8	81	4.3

- Basin areas, slopes and lengths from basin layout figure
- Basin curve number is 81 reflecting fair coverage of prairie grasses
- Sheet and shallow concentrated flow calculations by TR-55
- Sheet flow surface roughness is 0.15 reflecting short prairie grass (Attachment A)
- Shallow concentrated flow is assumed for slopes longer than 300 feet
- Unpaved conditions assumed for shallow concentrated flow to reflect vegetative cover
- Lag time is equal to 60 percent of the time of concentration (tc)
- Minimum lag time of 3.6 minutes (minimum Tc of 6 minutes per TR-55)
- Channel flow by Manning's Equation
- Roughness coefficient for Channel Flow based on grass lining from Attachment B
- Avg Rh is an estimated value and should be compared to actual calculated values
- The design storm event is the 25yr-24hr event from rainfall frequency atlas

Table 1C
Basin Summary

Job No.: 033-2167
By: TJS
Date: 10/13/2004

2yr-24hr	1.8	in	
100yr-24hr	5.4	in	
25yr-24hr	4.3	in	

				Sheet Flow				Shallow Concentrated Flow				Channel Flow					Total	Total	Basin	Storm
Basin	Area (ft^2)	Area (acres)	Area (mi^2)	Length (ft)	Slope (ft/ft)	Surface n	tc (min)	Length (ft)	Slope (ft/ft)	Paved/ Unpaved	tc (min)	Length (ft)	Slope (ft/ft)	Mannings n	Avg Rh	Tc (ft)	Tc (min)	Lag (min)	Curve Number	Depth (in)
K-1	60,254	1.38	0.00216	0	0.0%	0.150	0.00					722	3.0%	0.030	0.31	4.55	4.55	3.6	81	4.3
K-2	78,092	1.79	0.00280	0	0.0%	0.150	0.00					985	1.5%	0.030	0.38	7.67	7.67	4.6	81	4.3
L-1	184,039	4.22	0.00660	300	5.0%	0.150	21.81	71	5.0%	unpaved	0.33	203	2.0%	0.030	0.45	1.22	23.55	14.1	81	4.3
								93	25.0%	unpaved	0.19									
L-2	102,150	2.35	0.00366	170	25.0%	0.150	7.27					531	2.0%	0.030	0.40	3.46	10.73	6.4	81	4.3
L-3	123,024	2.82	0.00441	157	25.0%	0.150	6.82					704	2.0%	0.030	0.42	4.44	11.26	6.8	81	4.3
L-4	38,554	0.89	0.00138	50	25.0%	0.150	2.73					900	1.5%	0.030	0.29	8.39	11.12	6.7	81	4.3
M-1	184,453	4.23	0.00662	300	5.0%	0.150	21.81	77	5.0%	unpaved	0.36	148	2.0%	0.030	0.45	0.89	23.26	14.0	81	4.3
								98	25.0%	unpaved	0.20									
M-2	79,928	1.83	0.00287	184	25.0%	0.150	7.75					342	2.0%	0.030	0.36	2.39	10.14	6.1	81	4.3
N-1	77,364	1.78	0.00278	75	25.0%	0.150	3.78					630	2.0%	0.030	0.36	4.40	8.18	4.9	81	4.3
O-1	115,501	2.65	0.00414	257	5.0%	0.150	19.27	44	25.0%	unpaved	0.09	267	2.0%	0.030	0.37	1.83	23.61	14.2	81	4.3
				43	25.0%	0.150	2.42													
O-2	41,644	0.96	0.00149	156	25.0%	0.150	6.79					263	2.0%	0.030	0.29	2.12	8.91	5.3	81	4.3
O-3	31,736	0.73	0.00114			0.150	0.00					510	3.0%	0.030	0.24	3.81	3.81	3.6	81	4.3
P-1	72,233	1.66	0.00259	257	5.0%	0.150	19.27	44	25.0%	unpaved	0.09	267	2.0%	0.030	0.31	2.06	23.84	14.3	81	4.3
				43	25.0%	0.150	2.42													
P-2	40,960	0.94	0.00147	156	25.0%	0.150	6.79					261	2.0%	0.030	0.29	2.11	8.90	5.3	81	4.3

- Basin areas, slopes and lengths from basin layout figure
- Basin cur 64846.7
- Sheet and shallow concentrated flow calculations by TR-55
- Sheet flow surface roughness is 0.15 reflecting short prairie grass (Attachment A)
- Shallow concentrated flow is assumed for slopes longer than 300 feet
- Unpaved conditions assumed for shallow concentrated flow to reflect vegetative cover
- Lag time is equal to 60 percent of the time of concentration (tc)
- Minimum lag time of 3.6 minutes (minimum Tc of 6 minutes per TR-55)
- Channel flow by Manning's Equation
- Roughness coefficient for Channel Flow based on grass lining from Attachment B
- Avg Rh is an estimated value and should be compared to actual calculated values
- The design storm event is the 25yr-24hr event from rainfall frequency atlas

Table 2A

Job No.: 033-2167
By: TJS
Date: 10/13/2004

Channel Summary

Channel Designation	Bottom Width (ft)	Outside Slopes H:1V	Inside Slope H:1V	Channel Slope (ft/ft)	Channel Lining Material	Stability Mannings 'n' for Velocity	Capacity Mannings 'n' for Depth	Q from HEC-HMS (cfs)	Designed Channel Depth (ft)	Max Normal Flow Depth (ft)	Hydraulic Radius Rh (ft)	Max Flow Velocity (ft/s)	Shear Stress (psf)	Velocity Head for Freeboard (ft)	Required Channel Depth (ft)	Top Width of Flow (ft)
Basin A																
R-A1	0	4	3.00	2.00%	Grass	0.030	0.035	1.87	2.00	0.48	0.23	2.6	0.61	0.1	1.0	7.0
R-A2	0	4	3.00	2.00%	Grass	0.030	0.035	3.21	2.00	0.59	0.29	2.9	0.74	0.1	1.1	7.7
R-A3	0	4	2.00	1.00%	Grass	0.030	0.035	0.79	2.00	0.42	0.20	1.6	0.27	0.0	1.0	6.0
Basin B																
R-B1	0	4	3.00	2.00%	Grass	0.030	0.035	1.24	2.00	0.42	0.20	2.3	0.52	0.1	1.0	7.0
R-B2	0	4	3.00	2.00%	Grass	0.030	0.035	2.90	2.00	0.57	0.27	2.8	0.71	0.1	1.1	7.7
R-B3	0	4	2.00	1.00%	Grass	0.030	0.035	0.77	2.00	0.42	0.20	1.6	0.26	0.0	1.0	6.0
Basin C																
R-C1	0	4	3.00	2.00%	Grass	0.030	0.035	6.71	2.00	0.78	0.38	3.5	0.98	0.2	1.3	9.1
R-C2	0	4	3.00	2.00%	Grass	0.030	0.035	6.64	2.00	0.78	0.37	3.5	0.97	0.2	1.3	9.1
R-C3	0	4	2.00	1.00%	Grass	0.030	0.035	2.76	2.00	0.68	0.32	2.2	0.42	0.1	1.2	7.2
Basin D																
R-D1	0	4	3.00	2.00%	Grass	0.030	0.035	14.63	2.00	1.05	0.50	4.3	1.31	0.3	1.6	11.2
R-D2	0	4	3.00	2.00%	Grass	0.030	0.035	7.44	2.00	0.81	0.39	3.6	1.02	0.2	1.4	9.8
R-D3	0	4	2.00	1.00%	Grass	0.030	0.035	2.65	2.00	0.67	0.32	2.2	0.42	0.1	1.2	7.2
Basin E																
R-E1	0	4	3.00	2.00%	Grass	0.030	0.035	12.23	2.00	0.98	0.47	4.1	1.22	0.3	1.5	10.5
R-E2	0	4	3.00	2.00%	Grass	0.030	0.035	7.74	2.00	0.83	0.40	3.6	1.03	0.2	1.4	9.8
R-E3	0	4	2.00	1.00%	Grass	0.030	0.035	4.79	2.00	0.84	0.39	2.6	0.52	0.1	1.4	8.4
Basin F																
R-F1	0	4	3.00	2.00%	Grass	0.030	0.035	3.66	2.00	0.62	0.30	3.0	0.78	0.1	1.2	8.4
R-F2	0	4	3.00	2.00%	Grass	0.030	0.035	5.28	2.00	0.72	0.34	3.3	0.89	0.2	1.3	9.1
R-F3	0	4	2.00	1.00%	Grass	0.030	0.035	5.40	2.00	0.87	0.41	2.6	0.55	0.1	1.4	8.4
Basin G																
R-G1	0	4	3.00	2.00%	Grass	0.030	0.035	1.97	2.00	0.49	0.24	2.6	0.62	0.1	1.0	7.0
R-G2	0	4	3.00	2.00%	Grass	0.030	0.035	5.82	2.00	0.74	0.36	3.4	0.93	0.2	1.3	9.1
R-G3	0	4	2.00	1.00%	Grass	0.030	0.035	7.55	2.00	0.99	0.47	2.9	0.62	0.1	1.5	9.0

- Normal flow depth by Manning's Equation

Table 2B

Job No.: 033-2167
By: TJS
Date: 10/13/2004

Channel Summary

Channel Designation	Bottom Width (ft)	Outside Slopes H:1V	Inside Slope H:1V	Channel Slope (ft/ft)	Channel Lining Material	Stability Mannings 'n' for Velocity	Capacity Mannings 'n' for Depth	Q from HEC-HMS (cfs)	Designed Channel Depth (ft)	Max Normal Flow Depth (ft)	Hydraulic Radius Rh (ft)	Max Flow Velocity (ft/s)	Shear Stress (psf)	Velocity Head for Freeboard (ft)	Required Channel Depth (ft)	Top Width of Flow (ft)
Basin H																
R-H1	0	4	3.00	2.00%	Grass	0.030	0.035	12.88	2.00	1.00	0.48	4.1	1.25	0.3	1.5	10.5
R-H2	0	4	3.00	2.00%	Grass	0.030	0.035	6.34	2.00	0.77	0.37	3.5	0.96	0.2	1.3	9.1
R-H3	0	4	3.00	1.00%	Grass	0.030	0.035	4.34	2.00	0.76	0.36	2.4	0.47	0.1	1.3	9.1
Basin I																
R-I1	0	4	3.00	2.00%	Grass	0.030	0.035	3.49	2.00	0.61	0.29	3.0	0.76	0.1	1.2	8.4
R-I2	0	4	3.00	2.00%	Grass	0.030	0.035	4.59	2.00	0.68	0.33	3.2	0.85	0.2	1.2	8.4
R-I3	0	4	3.00	2.00%	Grass	0.030	0.035	5.44	2.00	0.72	0.35	3.3	0.90	0.2	1.3	9.1
Basin J																
R-J.1	0	4	3.00	2.00%	Grass	0.030	0.035	11.68	2.00	0.96	0.46	4.0	1.20	0.3	1.5	10.5
R-J2	0	4	3.00	2.00%	Grass	0.030	0.035	7.73	2.00	0.83	0.40	3.6	1.03	0.2	1.4	9.8
R-J3	0	4	3.00	2.00%	Grass	0.030	0.035	9.16	2.00	0.88	0.42	3.8	1.10	0.2	1.4	9.8
Basin K																
R-K.1	0	4	3.00	3.00%	Grass	0.030	0.035	4.88	2.00	0.64	0.31	3.8	1.21	0.2	1.2	8.4
R-K.2	0	4	3.00	1.50%	Grass	0.030	0.035	6.13	2.00	0.80	0.38	3.1	0.75	0.1	1.3	9.1
Basin L																
R-L.1	0	4	3.00	2.00%	Grass	0.030	0.035	10.58	2.00	0.93	0.45	3.9	1.16	0.2	1.5	10.5
R-L.2	0	4	3.00	2.00%	Grass	0.030	0.035	7.80	2.00	0.83	0.40	3.6	1.03	0.2	1.4	9.8
R-L.3	0	4	3.00	2.00%	Grass	0.030	0.035	9.26	2.00	0.88	0.42	3.8	1.10	0.2	1.4	9.8
R-L.4	0	4	3.00	1.50%	Grass	0.030	0.035	2.91	2.00	0.60	0.29	2.6	0.57	0.1	1.2	8.4
Basin M																
R-M.1	0	4	3.00	2.00%	Grass	0.030	0.035	10.65	2.00	0.93	0.45	3.9	1.16	0.2	1.5	10.5
R-M.2	0	4	3.00	2.00%	Grass	0.030	0.035	6.17	2.00	0.76	0.36	3.4	0.95	0.2	1.3	9.1
Basin N																
R-N.1	0	4	3.00	2.00%	Grass	0.030	0.035	6.10	2.00	0.76	0.36	3.4	0.94	0.2	1.3	9.1
Basin O																
R-O.1	0	4	3.00	2.00%	Grass	0.030	0.035	6.61	2.00	0.78	0.37	3.5	0.97	0.2	1.3	9.1
R-O.2	0	4	3.00	2.00%	Grass	0.030	0.035	3.26	2.00	0.60	0.29	2.9	0.74	0.1	1.1	7.7
R-O.3	0	4	3.00	3.00%	Grass	0.030	0.035	2.58	2.00	0.51	0.24	3.2	0.95	0.2	1.1	7.7
Basin P																
R-P.1	0	4	3.00	2.00%	Grass	0.030	0.035	4.12	2.00	0.65	0.31	3.1	0.81	0.2	1.2	8.4
R-P.2	0	4	3.00	2.00%	Grass	0.030	0.035	3.21	2.00	0.59	0.29	2.9	0.74	0.1	1.1	7.7

- Normal flow depth by Manning's Equation

Table 2C

Channel Summary

Job No.: 033-2167
By: TJS
Date: 10/13/2004

Channel Designation	Bottom Width (ft)	Outside Slopes H:1V	Inside Slope H:1V	Channel Slope (ft/ft)	Channel Lining Material	Stability Mannings 'n' for Velocity	Capacity Mannings 'n' for Depth	Q from HEC-HMS (cfs)	Designed Channel Depth (ft)	Max Normal Flow Depth (ft)	Hydraulic Radius Rh (ft)	Max Flow Velocity (ft/s)	Shear Stress (psf)	Velocity Head for Freeboard (ft)	Required Channel Depth (ft)	Top Width of Flow (ft)
Down-Chutes (broken concrete riprap)																
D-BC	10	4	4	18.0%	Riprap	0.035	0.040	16.09	2.00	0.25	0.23	6.4	2.80	0.6	0.8	16.4
D-DE	10	4	4	25.0%	Riprap	0.035	0.040	37.47	2.00	0.37	0.33	9.6	5.78	1.4	1.1	18.8
D-FG	10	4	4	18.0%	Riprap	0.035	0.040	16.44	2.00	0.25	0.23	6.4	2.83	0.6	0.8	16.4
D-HI	10	4	4	25.0%	Riprap	0.035	0.040	24.68	2.00	0.29	0.26	8.3	4.54	1.1	0.9	17.2
D-LJ	10	4	4	25.0%	Riprap	0.035	0.040	52.37	2.00	0.45	0.39	10.8	7.02	1.8	1.4	21.2
D-MO	10	4	4	25.0%	Riprap	0.035	0.040	23.71	2.00	0.28	0.26	8.2	4.43	1.0	0.9	17.2
D-PA	10	4	4	18.0%	Riprap	0.035	0.040	11.48	2.00	0.20	0.19	5.7	2.29	0.5	0.8	16.4
Down-Chutes (turf reinforcement mat with vegetation)																
D-BC	10	4	4	18.0%	TRM	0.030	0.035	16.09	2.00	0.23	0.21	7.1	2.59	0.8	0.8	16.4
D-DE	10	4	4	25.0%	TRM	0.030	0.035	37.47	2.00	0.34	0.30	10.6	5.35	1.7	1.3	20.4
D-FG	10	4	4	18.0%	TRM	0.030	0.035	16.44	2.00	0.23	0.21	7.1	2.62	0.8	0.8	16.4
D-HI	10	4	4	25.0%	TRM	0.030	0.035	24.68	2.00	0.27	0.24	9.1	4.20	1.3	1.0	18.0
D-LJ	10	4	4	25.0%	TRM	0.030	0.035	52.37	2.00	0.42	0.36	11.9	6.50	2.2	1.6	22.8
D-MO	10	4	4	25.0%	TRM	0.030	0.035	23.71	2.00	0.26	0.24	9.0	4.10	1.3	0.9	17.2
D-PA	10	4	4	18.0%	TRM	0.030	0.035	11.48	2.00	0.19	0.18	6.2	2.12	0.6	0.7	15.6
Down-Chutes (articulated concrete block)																
D-BC	10	4	4	18.0%	Trilock	0.026	0.026	16.09	2.00	0.19	0.18	7.7	2.17	0.9	0.7	15.6
D-DE	10	4	4	25.0%	Trilock	0.026	0.026	37.47	2.00	0.29	0.26	11.6	4.50	2.1	1.4	21.2
D-FG	10	4	4	18.0%	Trilock	0.026	0.026	16.44	2.00	0.20	0.18	7.8	2.20	0.9	0.7	15.6
D-HI	10	4	4	25.0%	Trilock	0.026	0.026	24.68	2.00	0.23	0.21	10.0	3.52	1.6	1.1	18.8
D-LJ	10	4	4	25.0%	Trilock	0.026	0.026	52.37	2.00	0.35	0.31	13.1	5.47	2.7	1.7	23.6
D-MO	10	4	4	25.0%	Trilock	0.026	0.026	23.71	2.00	0.22	0.20	9.9	3.44	1.5	1.0	18.0
D-PA	10	4	4	18.0%	Trilock	0.026	0.026	11.48	2.00	0.16	0.15	6.8	1.78	0.7	0.7	15.6

- Normal flow depth by Manning's Equation
- Down-chute channels have 3:1 side slopes perpendicular to the channel and approximately 4:1 in line with flow

Table 2D

Channel Summary

Job No.: 033-2167
By: TJS
Date: 10/13/2004

Channel Designation	Bottom Width (ft)	Outside Slopes H:1V	Inside Slope H:1V	Channel Slope (ft/ft)	Channel Lining Material	Stability Mannings 'n' for Velocity	Capacity Mannings 'n' for Depth	Q from HEC-HMS (cfs)	Designed Channel Depth (ft)	Max Normal Flow Depth (ft)	Hydraulic Radius Rh (ft)	Max Flow Velocity (ft/s)	Shear Stress (psf)	Velocity Head for Freeboard (ft)	Required Channel Depth (ft)	Top Width of Flow (ft)
Outlet Channels (broken concrete riprap)																
Out-BC	10	4	4	10.0%	Riprap	0.035	0.040	19.61	2.00	0.33	0.30	5.7	2.07	0.5	0.9	17.2
Out-DE	10	4	4	36.0%	Riprap	0.035	0.040	44.53	2.00	0.37	0.32	11.5	8.28	2.0	1.4	21.2
Out-FG	10	4	4	33.0%	Riprap	0.035	0.040	29.39	2.00	0.30	0.27	9.6	6.12	1.4	1.1	18.8
Out-HI	10	4	4	12.0%	Riprap	0.035	0.040	34.29	2.00	0.44	0.38	7.3	3.26	0.8	1.0	18.0
Out-K	10	4	4	40.0%	Riprap	0.035	0.040	10.83	2.00	0.16	0.15	7.1	3.89	0.8	0.7	15.6
Out-LJ	10	4	4	33.0%	Riprap	0.035	0.040	55.28	2.00	0.43	0.37	12.0	8.82	2.2	1.6	22.8
Out-N	10	4	4	33.0%	Riprap	0.035	0.040	6.10	2.00	0.12	0.11	5.4	2.42	0.5	0.7	15.6
Out-MO	10	4	4	33.0%	Riprap	0.035	0.040	26.19	2.00	0.28	0.25	9.3	5.72	1.3	1.0	18.0
Out-PA	10	4	4	36.0%	Riprap	0.035	0.040	12.26	2.00	0.17	0.16	7.2	3.89	0.8	0.7	15.6
Outlet Channels (turf reinforcement mat with vegetation)																
Out-BC	10	4	4	10.0%	TRM	0.030	0.035	19.61	2.00	0.31	0.28	6.3	1.92	0.6	0.9	17.2
Out-DE	10	4	4	36.0%	TRM	0.030	0.035	44.53	2.00	0.34	0.30	12.7	7.67	2.5	1.6	22.8
Out-FG	10	4	4	33.0%	TRM	0.030	0.035	29.39	2.00	0.27	0.25	10.6	5.66	1.8	1.2	19.6
Out-HI	10	4	4	12.0%	TRM	0.030	0.035	34.29	2.00	0.40	0.35	8.1	3.02	1.0	1.0	18.0
Out-K	10	4	4	40.0%	TRM	0.030	0.035	10.83	2.00	0.14	0.14	7.8	3.60	1.0	0.7	15.6
Out-LJ	10	4	4	33.0%	TRM	0.030	0.035	55.28	2.00	0.40	0.35	13.3	8.17	2.7	1.8	24.4
Out-N	10	4	4	33.0%	TRM	0.030	0.035	6.10	2.00	0.11	0.10	5.9	2.23	0.5	0.7	15.6
Out-MO	10	4	4	33.0%	TRM	0.030	0.035	26.19	2.00	0.26	0.23	10.2	5.29	1.6	1.1	18.8
Out-PA	10	4	4	36.0%	TRM	0.030	0.035	12.26	2.00	0.16	0.15	7.9	3.59	1.0	0.7	15.6
Outlet Channels (articualted concrete block)																
Out-BC	10	4	4	10.0%	Trilock	0.026	0.026	19.61	2.00	0.26	0.23	6.9	1.61	0.7	0.8	16.4
Out-DE	10	4	4	36.0%	Trilock	0.026	0.026	44.53	2.00	0.29	0.26	13.9	6.45	3.0	1.8	24.4
Out-FG	10	4	4	33.0%	Trilock	0.026	0.026	29.39	2.00	0.23	0.21	11.7	4.75	2.1	1.3	20.4
Out-HI	10	4	4	12.0%	Trilock	0.026	0.026	34.29	2.00	0.34	0.30	8.9	2.54	1.2	1.0	18.0
Out-K	10	4	4	40.0%	Trilock	0.026	0.026	10.83	2.00	0.12	0.12	8.6	3.01	1.1	0.7	15.6
Out-LJ	10	4	4	33.0%	Trilock	0.026	0.026	55.28	2.00	0.33	0.30	14.6	6.87	3.3	2.0	26.0
Out-N	10	4	4	33.0%	Trilock	0.026	0.026	6.10	2.00	0.09	0.09	6.5	1.87	0.7	0.6	14.8
Out-MO	10	4	4	33.0%	Trilock	0.026	0.026	26.19	2.00	0.22	0.20	11.2	4.44	1.9	1.2	19.6
Out-PA	10	4	4	36.0%	Trilock	0.026	0.026	12.26	2.00	0.13	0.13	8.7	3.01	1.2	0.8	16.4

- Normal flow depth by Manning's Equation
- Outlet channels have 3:1 side slopes perpendicular to the channel and approximately 4:1 in line with flow

Table 3

Job No.: 033-2167
By: TJS
Date: 10/13/2004

Erosion Protection Design

Channel Section	Bed Slope S (ft/ft)	Bottom Width W (ft)	Discharge Q (ft^3/s)	Total Unit Discharge q_t (ft^2/s)	Median Riprap Size D_{50}[1] (in)	Horizontal Runout Length[2] (ft)
Down-chutes						
D-BC	18.00%	10.0	16.09	1.61	4.8	6.0
D-DE	25.00%	10.0	37.47	3.75	*8.2*	10.3
D-FG	18.00%	10.0	16.44	1.64	4.8	6.0
D-HI	25.00%	10.0	24.68	2.47	6.6	8.2
D-LJ	25.00%	10.0	52.37	5.24	*9.9*	12.4
D-MO	25.00%	10.0	23.71	2.37	6.4	8.0
D-PA	18.00%	10.0	11.48	1.15	4.0	5.0
Outlets						
Out-BC	10.00%	10.0	19.61	1.96	4.1	5.2
Out-DE	36.00%	10.0	44.53	4.45	*9.8*	12.2
Out-FG	33.00%	10.0	29.39	2.94	*7.6*	9.5
Out-HI	12.00%	10.0	34.29	3.43	6.0	7.5
Out-K	40.00%	10.0	10.83	1.08	4.4	5.5
Out-LJ	33.00%	10.0	55.28	5.53	*10.9*	13.6
Out-N	33.00%	10.0	6.10	0.61	3.1	3.9
Out-MO	33.00%	10.0	26.19	2.62	7.1	8.9
Out-PA	36.00%	10.0	12.26	1.23	4.7	5.9

(1) From Robinson, K.M, Rice, C.E., Kadavy, K.C. "Design of Rock Chutes" Presented at 1997 ASAE Annual International Meeting,Paper No. 972062. ASAE, 2950 Niles Road, St. Joseph, MI 49085-9659 USA

(2) Horizontal Length at end of downslope = 15 x D_{50} per Robinson, Rice and Kadavy

RIPRAP TYPE

Riprap Designation	Percent Smaller Than Given Size by Weight	Intermediate Rock Dimension (inches)	D50 Dia. (inches)
Type VL	70 - 100	12	
	50 - 70	9	
	35 - 50	6	6
	2 - 10	2	
Type L	70 - 100	15	
	50 - 70	12	
	35 - 50	9	9
	2 - 10	3	
Type M	70 - 100	21	
	50 - 70	18	
	35 - 50	12	12
	2 - 10	4	
Type H	70 - 100	30	
	50 - 70	24	
	35 - 50	18	18
	2 - 10	6	
Type VH	70 - 100	42	
	50 - 70	33	
	35 - 50	24	24
	2 - 10	9	

Hydraulic Jump (A)

Table 4A - Riprap Erosion Protection

Hydraulic Jump Lengths

Job No.: 033-2167
By: TJS
Date: 10/13/2004

	CHANNEL DESIGN						
REACH	Q (cfs)	CHANNEL MATERIAL	SLOPE (ft/ft)	LEFT SIDE SLOPE (H:1V)	RIGHT SIDE SLOPE (H:1V)	CHANNEL DEPTH (ft)	BOTTOM WIDTH (ft)
D-BC	16.09	Riprap	0.180	4.0	4.0	2.0	10.0
D-DE	37.47	Riprap	0.250	4.0	4.0	2.0	10.0
D-FG	16.44	Riprap	0.180	4.0	4.0	2.0	10.0
D-HI	24.68	Riprap	0.250	4.0	4.0	2.0	10.0
D-LJ	52.37	Riprap	0.250	4.0	4.0	2.0	10.0
D-MO	23.71	Riprap	0.250	4.0	4.0	2.0	10.0
D-PA	11.48	Riprap	0.180	4.0	4.0	2.0	10.0
Out-BC	19.6	Riprap	0.100	4.0	4.0	2.0	10.0
Out-DE	44.5	Riprap	0.360	4.0	4.0	2.0	10.0
Out-FG	29.4	Riprap	0.330	4.0	4.0	2.0	10.0
Out-HI	34.3	Riprap	0.120	4.0	4.0	2.0	10.0
Out-K	10.8	Riprap	0.400	4.0	4.0	2.0	10.0
Out-LJ	55.3	Riprap	0.330	4.0	4.0	2.0	10.0
Out-N	6.1	Riprap	0.330	4.0	4.0	2.0	10.0
Out-MO	26.2	Riprap	0.330	4.0	4.0	2.0	10.0
Out-PA	12.3	Riprap	0.360	4.0	4.0	2.0	10.0

	HYDRAULIC PARAMETERS							
REACH	MANNING n FOR CAPACITY	MANNING n FOR STABILITY	MAX VELOCITY (fps)	MAX NORMAL FLOW DEPTH (ft)	SHEAR STRESS (lb/ft^2)	AVAILABLE FREEBOARD (ft)	TOP WIDTH OF FLOW (ft)	velocity head (ft)
D-BC	0.040	0.035	6.4	0.25	2.8	1.8	12.0	0.64
D-DE	0.040	0.035	9.6	0.37	5.8	1.6	13.0	1.44
D-FG	0.040	0.035	6.5	0.25	2.8	1.7	12.0	0.65
D-HI	0.040	0.035	8.3	0.29	4.5	1.7	12.3	1.07
D-LJ	0.040	0.035	10.8	0.45	7.0	vel head > 1.6	13.6	1.81
D-MO	0.040	0.035	8.2	0.28	4.4	1.7	12.3	1.04
D-PA	0.040	0.035	5.7	0.20	2.3	1.8	11.6	0.50
Out-BC	0.040	0.035	5.7	0.33	2.1	1.7	12.7	0.50
Out-DE	0.040	0.035	11.5	0.37	8.3	vel head > 1.6	12.9	2.05
Out-FG	0.040	0.035	9.7	0.30	6.1	1.7	12.4	1.45
Out-HI	0.040	0.035	7.3	0.43	3.3	1.6	13.5	0.84
Out-K	0.040	0.035	7.1	0.16	3.9	1.8	11.2	0.79
Out-LJ	0.040	0.035	12.0	0.43	8.8	vel head > 1.6	13.4	2.25
Out-N	0.040	0.035	5.4	0.12	2.4	1.9	10.9	0.45
Out-MO	0.040	0.035	9.3	0.28	5.7	1.7	12.2	1.33
Out-PA	0.040	0.035	7.2	0.17	3.9	1.8	11.4	0.81

	HYDRAULIC JUMP CALCULATIONS							
REACH	STABILITY NORMAL FLOW DEPTH (ft)	SHEAR STRESS (lb/ft^2)	STABILITY DEPTH (ft)	HYDRAULIC DEPTH (ft)	FROUDE #	Conjugate Depth (ft)	L/d2	Length of Jump (ft)
D-BC	0.23	2.6	0.23	0.21	2.5	0.66	4.8	3.1
D-DE	0.34	5.3	0.34	0.31	3.1	1.24	5.3	6.6
D-FG	0.23	2.6	0.23	0.21	2.5	0.67	4.8	3.2
D-HI	0.27	4.2	0.27	0.24	3.0	0.95	5.3	5.0
D-LJ	0.42	6.5	0.42	0.36	3.2	1.54	5.4	8.3
D-MO	0.26	4.1	0.26	0.24	2.9	0.92	5.2	4.8
D-PA	0.19	2.1	0.19	0.18	2.4	0.53	4.7	2.5
Out-BC	0.31	1.9	0.31	0.28	1.9	0.65	4.2	2.7
Out-DE	0.34	7.7	0.34	0.30	3.7	1.51	5.6	8.5
Out-FG	0.27	5.6	0.27	0.25	3.4	1.13	5.5	6.2
Out-HI	0.40	3.0	0.40	0.35	2.2	0.98	4.5	4.4
Out-K	0.14	3.6	0.14	0.14	3.4	0.61	5.5	3.3
Out-LJ	0.40	8.2	0.40	0.35	3.6	1.70	5.6	9.5
Out-N	0.11	2.2	0.11	0.10	3.0	0.39	5.3	2.1
Out-MO	0.26	5.3	0.26	0.23	3.4	1.05	5.5	5.8
Out-PA	0.16	3.6	0.16	0.15	3.3	0.64	5.4	3.5

Gravity **32.2** ft/s^2

Hydraulic Jump (B)

Table 4B - TRM Erosion Protection

Hydraulic Jump Lengths

Job No.: 033-2167
By: TJS
Date: 10/13/2004

	CHANNEL DESIGN						
REACH	Q (cfs)	CHANNEL MATERIAL	SLOPE (ft/ft)	LEFT SIDE SLOPE (H:1V)	RIGHT SIDE SLOPE (H:1V)	CHANNEL DEPTH (ft)	BOTTOM WIDTH (ft)
D-BC	16.09	Grass	0.180	4.0	4.0	2.0	10.0
D-DE	37.47	Grass	0.250	4.0	4.0	2.0	10.0
D-FG	16.44	Grass	0.180	4.0	4.0	2.0	10.0
D-HI	24.68	Grass	0.250	4.0	4.0	2.0	10.0
D-LJ	52.37	Grass	0.250	4.0	4.0	2.0	10.0
D-MO	23.71	Grass	0.250	4.0	4.0	2.0	10.0
D-PA	11.48	Grass	0.180	4.0	4.0	2.0	10.0
Out-BC	19.6	Grass	0.100	4.0	4.0	2.0	10.0
Out-DE	44.5	Grass	0.360	4.0	4.0	2.0	10.0
Out-FG	29.4	Grass	0.330	4.0	4.0	2.0	10.0
Out-HI	34.3	Grass	0.120	4.0	4.0	2.0	10.0
Out-K	10.8	Grass	0.400	4.0	4.0	2.0	10.0
Out-LJ	55.3	Grass	0.330	4.0	4.0	2.0	10.0
Out-N	6.1	Grass	0.330	4.0	4.0	2.0	10.0
Out-MO	26.2	Grass	0.330	4.0	4.0	2.0	10.0
Out-PA	12.3	Grass	0.360	4.0	4.0	2.0	10.0

	HYDRAULIC PARAMETERS							
REACH	MANNING n FOR CAPACITY	MANNING n FOR STABILITY	MAX VELOCITY (fps)	MAX NORMAL FLOW DEPTH (ft)	SHEAR STRESS (lb/ft^2)	AVAILABLE FREEBOARD (ft)	TOP WIDTH OF FLOW (ft)	velocity head (ft)
D-BC	0.035	0.030	7.1	0.23	2.6	1.8	11.8	0.77
D-DE	0.035	0.030	10.6	0.34	5.3	1.7	12.7	1.76
D-FG	0.035	0.030	7.1	0.23	2.6	1.8	11.9	0.79
D-HI	0.035	0.030	9.2	0.27	4.2	1.7	12.1	1.30
D-LJ	0.035	0.030	11.9	0.42	6.5	1.6	13.3	2.22
D-MO	0.035	0.030	9.0	0.26	4.1	1.7	12.1	1.27
D-PA	0.035	0.030	6.2	0.19	2.1	1.8	11.5	0.60
Out-BC	0.035	0.030	6.3	0.31	1.9	1.7	12.5	0.61
Out-DE	0.035	0.030	12.7	0.34	7.7	1.7	12.7	2.51
Out-FG	0.035	0.030	10.7	0.27	5.6	1.7	12.2	1.77
Out-HI	0.035	0.030	8.1	0.40	3.0	1.6	13.2	1.02
Out-K	0.035	0.030	7.8	0.14	3.6	1.9	11.2	0.95
Out-LJ	0.035	0.030	13.3	0.40	8.2	1.6	13.2	2.76
Out-N	0.035	0.030	5.9	0.11	2.2	1.9	10.9	0.55
Out-MO	0.035	0.030	10.2	0.26	5.3	1.7	12.1	1.62
Out-PA	0.035	0.030	7.9	0.16	3.6	1.8	11.3	0.98

	HYDRAULIC JUMP CALCULATIONS							
REACH	STABILITY NORMAL FLOW DEPTH (ft)	SHEAR STRESS (lb/ft^2)	STABILITY DEPTH (ft)	HYDRAULIC DEPTH (ft)	FROUDE #	Conjugate Depth (ft)	L/d2	Length of Jump (ft)
D-BC	0.21	2.4	0.21	0.19	2.8	0.71	5.1	3.6
D-DE	0.31	4.9	0.31	0.28	3.5	1.33	5.6	7.4
D-FG	0.21	2.4	0.21	0.20	2.8	0.72	5.1	3.7
D-HI	0.25	3.8	0.25	0.23	3.4	1.01	5.5	5.6
D-LJ	0.38	5.9	0.38	0.34	3.6	1.66	5.6	9.3
D-MO	0.24	3.7	0.24	0.22	3.4	0.99	5.5	5.4
D-PA	0.17	1.9	0.17	0.16	2.7	0.56	5.0	2.8
Out-BC	0.28	1.7	0.28	0.25	2.2	0.70	4.5	3.2
Out-DE	0.31	7.0	0.31	0.28	4.2	1.62	5.8	9.5
Out-FG	0.25	5.2	0.25	0.23	3.9	1.21	5.8	7.0
Out-HI	0.37	2.8	0.37	0.33	2.5	1.06	4.8	5.1
Out-K	0.13	3.3	0.13	0.13	3.9	0.65	5.8	3.7
Out-LJ	0.36	7.5	0.36	0.32	4.1	1.83	5.8	10.6
Out-N	0.10	2.0	0.10	0.10	3.4	0.42	5.5	2.3
Out-MO	0.23	4.8	0.23	0.22	3.9	1.12	5.7	6.4
Out-PA	0.15	3.3	0.15	0.14	3.8	0.69	5.7	3.9

Gravity **32.2** ft/s^2

Hydraulic Jump (C)

Table 4C - Trilock Erosion Protection

Hydraulic Jump Lengths

Job No.: 033-2167
By: TJS
Date: 10/13/2004

	CHANNEL DESIGN						
REACH	Q (cfs)	CHANNEL MATERIAL	SLOPE (ft/ft)	LEFT SIDE SLOPE (H:1V)	RIGHT SIDE SLOPE (H:1V)	CHANNEL DEPTH (ft)	BOTTOM WIDTH (ft)
D-BC	16.09	Trilock	0.180	4.0	4.0	2.0	10.0
D-DE	37.47	Trilock	0.250	4.0	4.0	2.0	10.0
D-FG	16.44	Trilock	0.180	4.0	4.0	2.0	10.0
D-HI	24.68	Trilock	0.250	4.0	4.0	2.0	10.0
D-LJ	52.37	Trilock	0.250	4.0	4.0	2.0	10.0
D-MO	23.71	Trilock	0.250	4.0	4.0	2.0	10.0
D-PA	11.48	Trilock	0.180	4.0	4.0	2.0	10.0
Out-BC	19.6	Trilock	0.100	4.0	4.0	2.0	10.0
Out-DE	44.5	Trilock	0.360	4.0	4.0	2.0	10.0
Out-FG	29.4	Trilock	0.330	4.0	4.0	2.0	10.0
Out-HI	34.3	Trilock	0.120	4.0	4.0	2.0	10.0
Out-K	10.8	Trilock	0.400	4.0	4.0	2.0	10.0
Out-LJ	55.3	Trilock	0.330	4.0	4.0	2.0	10.0
Out-N	6.1	Trilock	0.330	4.0	4.0	2.0	10.0
Out-MO	26.2	Trilock	0.330	4.0	4.0	2.0	10.0
Out-PA	12.3	Trilock	0.360	4.0	4.0	2.0	10.0

	HYDRAULIC PARAMETERS							
REACH	MANNING n FOR CAPACITY	MANNING n FOR STABILITY	MAX VELOCITY (fps)	MAX NORMAL FLOW DEPTH (ft)	SHEAR STRESS (lb/ft^2)	AVAILABLE FREEBOARD (ft)	TOP WIDTH OF FLOW (ft)	velocity head (ft)
D-BC	0.026	0.026	7.7	0.19	2.2	1.8	11.5	0.93
D-DE	0.026	0.026	11.7	0.29	4.5	1.7	12.3	2.11
D-FG	0.026	0.026	7.8	0.20	2.2	1.8	11.6	0.94
D-HI	0.026	0.026	10.0	0.23	3.5	1.8	11.8	1.56
D-LJ	0.026	0.026	13.1	0.35	5.5	1.6	12.8	2.67
D-MO	0.026	0.026	9.9	0.22	3.4	1.8	11.8	1.52
D-PA	0.026	0.026	6.8	0.16	1.8	1.8	11.3	0.72
Out-BC	0.026	0.026	6.9	0.26	1.6	1.7	12.1	0.74
Out-DE	0.026	0.026	13.9	0.29	6.4	1.7	12.3	3.02
Out-FG	0.026	0.026	11.7	0.23	4.7	1.8	11.8	2.12
Out-HI	0.026	0.026	8.9	0.34	2.5	1.7	12.7	1.23
Out-K	0.026	0.026	8.6	0.12	3.0	1.9	11.0	1.14
Out-LJ	0.026	0.026	14.6	0.33	6.9	1.7	12.7	3.32
Out-N	0.026	0.026	6.5	0.09	1.9	1.9	10.7	0.65
Out-MO	0.026	0.026	11.2	0.22	4.4	1.8	11.7	1.95
Out-PA	0.026	0.026	8.7	0.13	3.0	1.9	11.1	1.17

	HYDRAULIC JUMP CALCULATIONS							
REACH	STABILITY NORMAL FLOW DEPTH (ft)	SHEAR STRESS (lb/ft^2)	STABILITY DEPTH (ft)	HYDRAULIC DEPTH (ft)	FROUDE #	Conjugate Depth (ft)	L/d2	Length of Jump (ft)
D-BC	0.19	2.2	0.19	0.18	3.2	0.76	5.4	4.1
D-DE	0.29	4.5	0.29	0.26	4.0	1.42	5.8	8.3
D-FG	0.20	2.2	0.20	0.18	3.2	0.77	5.4	4.1
D-HI	0.23	3.5	0.23	0.21	3.9	1.08	5.7	6.2
D-LJ	0.35	5.5	0.35	0.31	4.1	1.77	5.8	10.3
D-MO	0.22	3.4	0.22	0.20	3.9	1.05	5.7	6.0
D-PA	0.16	1.8	0.16	0.15	3.1	0.60	5.4	3.2
Out-BC	0.26	1.6	0.26	0.24	2.5	0.75	4.8	3.6
Out-DE	0.29	6.4	0.29	0.26	4.8	1.72	6.0	10.3
Out-FG	0.23	4.7	0.23	0.21	4.5	1.29	5.9	7.6
Out-HI	0.34	2.5	0.34	0.30	2.9	1.13	5.2	5.8
Out-K	0.12	3.0	0.12	0.12	4.4	0.68	5.9	4.0
Out-LJ	0.33	6.9	0.33	0.30	4.7	1.95	6.0	11.6
Out-N	0.09	1.9	0.09	0.09	3.9	0.44	5.7	2.5
Out-MO	0.22	4.4	0.22	0.20	4.4	1.19	5.9	7.0
Out-PA	0.13	3.0	0.13	0.13	4.3	0.73	5.9	4.3

Gravity **32.2** ft/s^2

ATTACHMENT A
TIME OF CONCENTRATION CALCULATION COEFFICIENTS

TR-55 (1986)

Sheet Flow Travel time

$$T_t = \frac{0.007\,(n'\,L)^{0.8}}{(P_2)^{0.5}\,S^{0.4}}$$

Where: T_t = travel time (hrs); n' = roughness coefficient; L = flow length (ft);
P_2 = 2-yr storm depth (inches); s = slope (ft/ft)
flow velocity = $L/(60T_t)$

Flow Type	Surface Type	roughness coefficient n':	Surface Description
Sheet/Overland Flow	A	0.011	Smooth surfaces (concrete, asphalt, gravel, bare soil)
	B	0.05	Fallow (no residue)
	C	0.06	Cultivated soils: Residue cover <= 20%
	D	0.17	Cultivated soils: Residue cover > 20%
	E	0.15	Grass: Short grass prairie
	F	0.24	Grass: Dense grasses
	G	0.41	Grass: Bermuda grass
	H	0.13	Range (natural)
	I	0.40	Woods: Light underbrush
	J	0.80	Woods: Heavy underbrush

Shallow Concentrated Flow Velocity

$v = mS^{0.5}$

Where: v = velocity (fps); m = roughness coeffient; S = slope (ft/ft)

Flow Type	Surface Type	roughness coefficient m:	Surface Description
Shallow Conc. Flow	P	20.3282	Paved
	U	16.1345	Unpaved

ATTACHMENT B
REFERENCE VALUES

Mannings n Values

Channel Lining Material	Mannings n Value for Velocity	Mannings n Value for Depth
None	0.025	0.030
Dirt	0.025	0.030
Grass	0.030	0.035
TRM	0.030	0.035
Riprap	0.035	0.040
Trilock	0.026	0.026
Concrete	0.015	0.015

Freeboard in Channel requirements

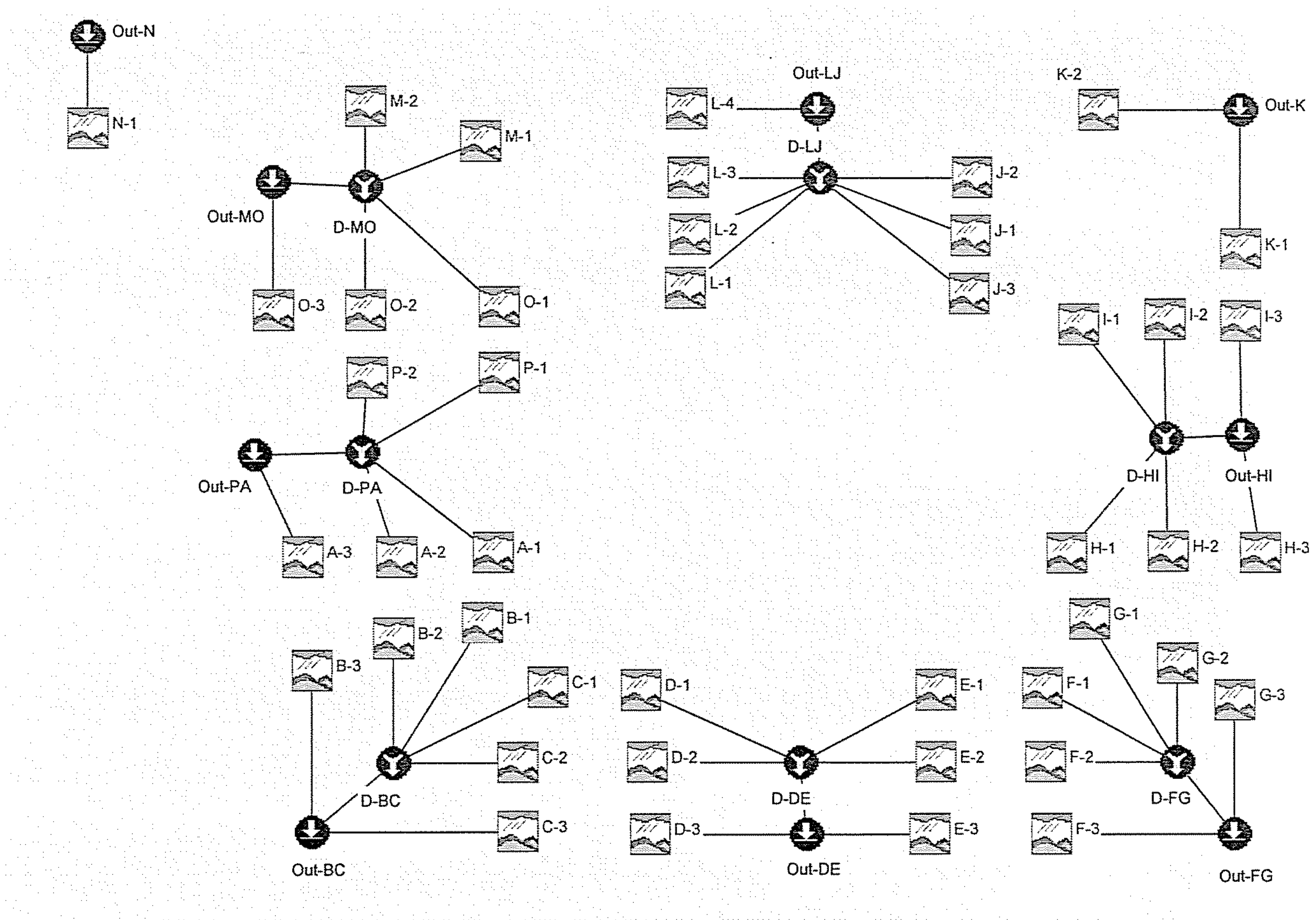
Minumum Freeboard in channel of 0.5 ft

or

50% Percent of Velocity head ($V^2/2g$)

whichever is greater

HEC-HMS **Project: NPPD-GGS-Pits1-4** **Basin Model: Final Cover**



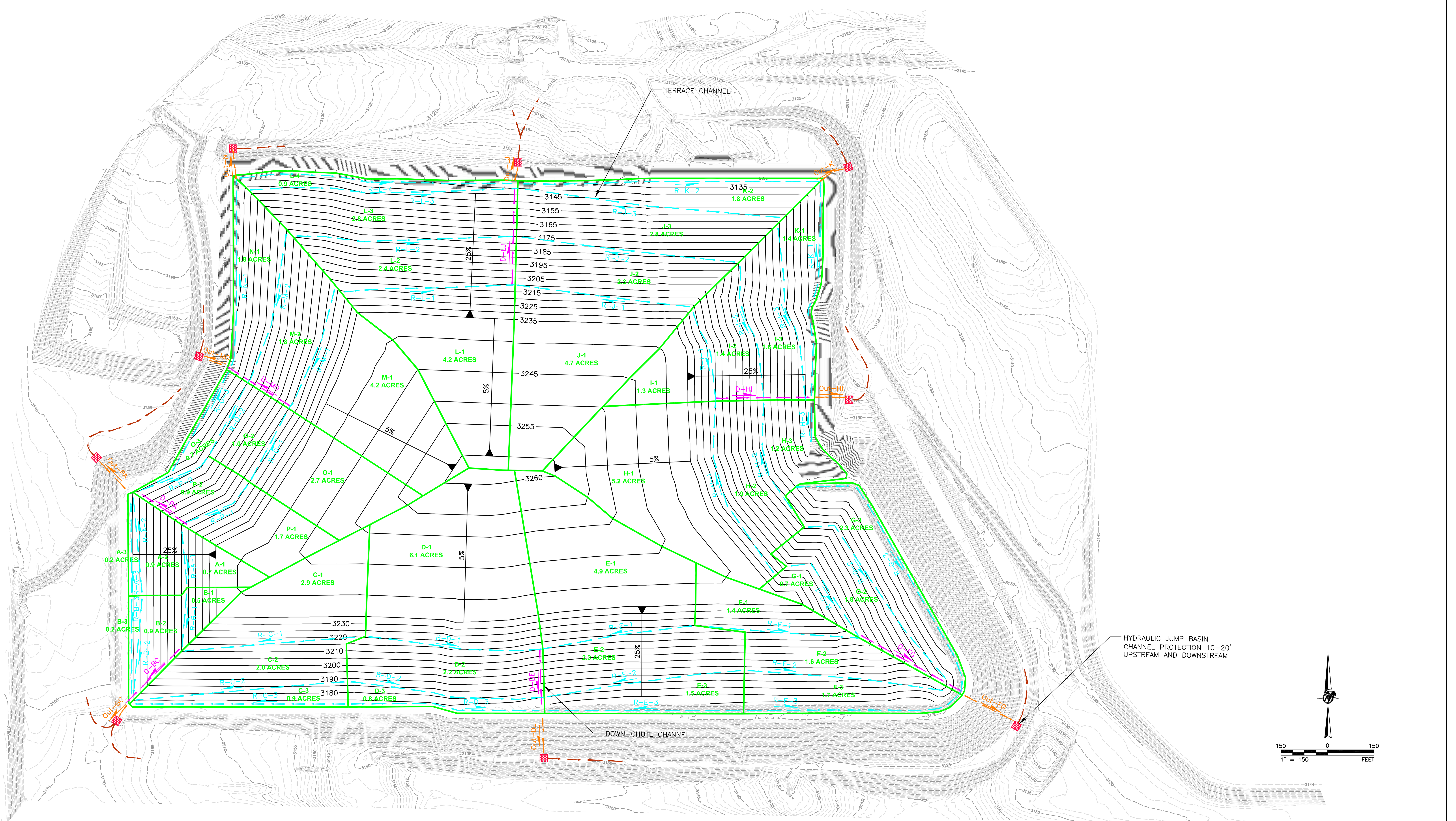
HMS * Summary of Results

Project : NPPD-GGS-Pits1-4 Run Name : 25-Year

Start of Run : 01Jan04 1200 Basin Model : Final Cover
End of Run : 02Jan04 2400 Met. Model : 24-hour,25-year
Execution Time : 13Oct04 0904 Control Specs : 6-Minute

Hydrologic Element	Discharge Peak (cfs)	Time of Peak	Volume (ac ft)	Drainage Area (sq mi)
B-2	2.8980	01 Jan 04 2400	0.19735	0.001
B-1	1.2410	01 Jan 04 2400	0.10387	0.001
C-2	6.6448	01 Jan 04 2400	0.46594	0.003
C-1	6.7110	02 Jan 04 0006	0.66329	0.004
D-BC	16.085	01 Jan 04 2400	1.4305	0.010
B-3	0.76560	01 Jan 04 2400	0.051935	0.000
C-3	2.7632	01 Jan 04 2400	0.19587	0.001
Out-BC	19.613	01 Jan 04 2400	1.6783	0.011
D-1	14.633	02 Jan 04 0006	1.4126	0.010
D-2	7.4403	01 Jan 04 2400	0.51639	0.003
E-2	7.7408	01 Jan 04 2400	0.53419	0.004
E-1	12.226	02 Jan 04 0006	1.1233	0.008
D-DE	37.472	02 Jan 04 0006	3.5865	0.024
D-3	2.6549	01 Jan 04 2400	0.18548	0.001
E-3	4.7928	01 Jan 04 2400	0.34574	0.002
Out-DE	44.529	01 Jan 04 2400	4.1177	0.028
F-1	3.6644	02 Jan 04 0006	0.31310	0.002
F-2	5.2809	01 Jan 04 2400	0.36652	0.002
G-1	1.9680	01 Jan 04 2400	0.13800	0.001
G-2	5.8195	01 Jan 04 2400	0.40806	0.003
D-FG	16.436	01 Jan 04 2400	1.2257	0.008
F-3	5.4007	01 Jan 04 2400	0.39471	0.003
G-3	7.5548	01 Jan 04 2400	0.52974	0.004
Out-FG	29.391	01 Jan 04 2400	2.1501	0.014
H-1	12.880	02 Jan 04 0006	1.2019	0.008
I-1	3.4890	02 Jan 04 0006	0.29974	0.002
I-2	4.5896	01 Jan 04 2400	0.31310	0.002
H-2	6.3431	01 Jan 04 2400	0.43774	0.003
D-HI	24.679	01 Jan 04 2400	2.2525	0.015
I-3	5.4379	01 Jan 04 2400	0.37097	0.003
H-3	4.3375	01 Jan 04 2354	0.28490	0.002
Out-HI	34.294	01 Jan 04 2400	2.9084	0.020
K-2	6.1347	01 Jan 04 2400	0.41548	0.003
K-1	4.8797	01 Jan 04 2354	0.32052	0.002
Out-K	10.834	01 Jan 04 2400	0.73600	0.005
L-1	10.578	02 Jan 04 0006	0.97936	0.007
L-3	9.2638	01 Jan 04 2400	0.65439	0.004
L-2	7.8002	01 Jan 04 2400	0.54310	0.004
J-3	9.1588	01 Jan 04 2400	0.64697	0.004
J-1	11.683	02 Jan 04 0006	1.0817	0.007
J-2	7.7311	01 Jan 04 2400	0.54013	0.004

Hydrologic Element	Discharge Peak (cfs)	Time of Peak	Volume (ac ft)	Drainage Area (sq mi)
D-LJ	52.366	01 Jan 04 2400	4.4457	0.030
L-4	2.9094	01 Jan 04 2400	0.20477	0.001
Out-LJ	55.276	01 Jan 04 2400	4.6505	0.031
N-1	6.0952	01 Jan 04 2400	0.41252	0.003
Out-N	6.0952	01 Jan 04 2400	0.41252	0.003
P-2	3.2124	01 Jan 04 2400	0.21813	0.001
A-2	3.2082	01 Jan 04 2400	0.21813	0.001
A-1	1.8699	02 Jan 04 0006	0.16174	0.001
P-1	4.1185	02 Jan 04 0006	0.38432	0.003
D-PA	11.475	01 Jan 04 2400	0.98232	0.007
A-3	0.78802	01 Jan 04 2400	0.053419	0.000
Out-PA	12.263	01 Jan 04 2400	1.0357	0.007
O-2	3.2561	01 Jan 04 2400	0.22110	0.001
M-2	6.1711	01 Jan 04 2400	0.42587	0.003
M-1	10.650	02 Jan 04 0006	0.98232	0.007
O-1	6.6092	02 Jan 04 0006	0.61432	0.004
D-MO	23.712	01 Jan 04 2400	2.2436	0.015
O-3	2.5754	01 Jan 04 2354	0.16916	0.001
Out-MO	26.192	01 Jan 04 2400	2.4128	0.016



LEGEND

EXISTING GROUND TOPOGRAPHY	DOWN CHUTE CHANNELS
PROPOSED TOP OF FINAL COVER TOPOGRAPHY	OUTLET CHANNELS
BASIN DELINEATION	HYDRAULIC JUMP BASIN
TERRACE CHANNELS	EXISTING OFF-SITE DRAINAGE

Golder Associates
Denver, Colorado

NEBRASKA PUBLIC POWER DISTRICT
GERALD GENTLEMAN STATION

SURFACE WATER CHANNEL AND BASIN LAYOUT

FIGURE 1

PROJECT No. 033–2167 CADD TJS DATE 08/31/04 FILE No. 0332167A035.dwg

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