

Run-On and Run-Off Control System Plan, Revision 1

Upstream Raise 92 CCR Surface Impoundment, Coal Creek Station

Submitted to:

Great River Energy

Coal Creek Station, 2875 Third Street SW, Underwood, North Dakota 58576

Submitted by:

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October 13, 2021

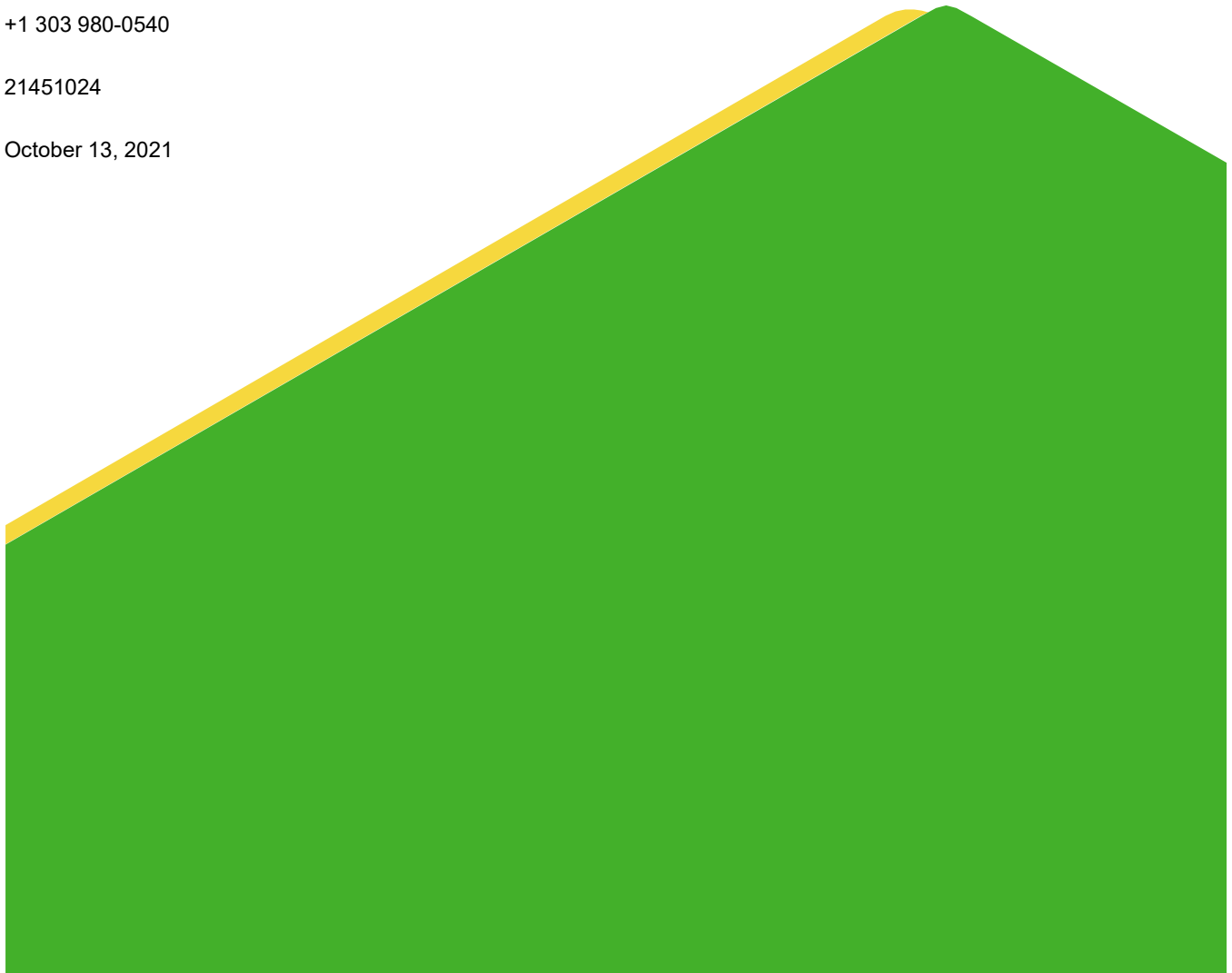


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1.0 INTRODUCTION

Golder Associates Inc. (Golder) has prepared this run-on and run-off control system plan for the Upstream Raise 92 Coal Combustion Residual (CCR) Surface Impoundment (Upstream Raise 92) at Great River Energy's (GRE's) Coal Creek Station (CCS). The United States Environmental Protection Agency's (USEPA's) Coal Combustion Residual Rule, 40 Code of Federal Regulations (CFR) Part 257 (USEPA 2015) requires a run-on and run-off control system plan be completed as specified in 40 CFR 257.81(c)(3) for all existing CCR landfills. Although Upstream Raise 92 is a surface impoundment and not a landfill, the facility is constructed with slopes extending above the original earthen embankments and will be closed with CCR in place above those original earthen embankments. Per 40 CFR 257.81(c)(4), run-on and run-off control system plans must be revisited every five years. This document serves as the current version of the run-on and run-off control system plan.

Upstream Raise 92 is also regulated by the North Dakota Department of Environmental Quality (NDDEQ) under Permit 0033. The NDDEQ requires a run-on and run-off control system plan as part of the application for a permit, as described in Section 33.1-20-08-05.2.c. of the North Dakota Administrative Code (NDAC 2020). This run-on and run-off control system plan satisfies the state-specific requirement.

2.0 REQUIREMENTS FOR RUN-ON AND RUN-OFF CONTROL SYSTEMS

In accordance with 40 CFR 257.81(c)(1) and NDAC Section 33.1-20-08-05.2.c.(1), the run-on and run-off control system plan must document how the run-on and run-off control 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 onto the active portion of the CCR unit during the peak discharge from a 24-hour, 25-year storm; and
- The run-off 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.

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

The owner or operator must design, construct, operate, and maintain the CCR landfill in such a way that any run-off 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.

The run-on and run-off control systems designed for and operated at Upstream Raise 92 are described below.

3.0 RUN-ON CONTROL

Run-on is defined as stormwater that may flow towards the active portions of the facility. The run-on control system for Upstream Raise 92 consists of the perimeter embankments, ditches, and grading, with slopes directing water away from the disposal area to prevent stormwater run-on.

Two other CCR facilities (Southeast Section 16 CCR Landfill [Southeast 16] and Upstream Raise 91 CCR Surface Impoundment [Upstream Raise 91]) buttress Upstream Raise 92 along the east and west sides of the facility. Water that may run-on from these facilities is handled in the same way that run-off is handled from Upstream

Raise 92 (Section 4.1). Contact water run-off controls for Southeast 16, Upstream Raise 91, and Upstream Raise 92 work in concert with each other.

An earthen embankment separates the facility on the north side from existing ground and Samuelson Slough. The embankment varies in height above the existing ground from 10 to 25 feet, and surrounding ground slopes north, directing stormwater away from Upstream Raise 92.

An earthen embankment separates the facility on the south side from a surface water drainage ditch. The embankment varies in height from 10 to 25 feet, and water collected and/or flowing through the surface water drainage ditch is directed east, away from the facility. The surface water drainage ditch is graded and maintained along the toe of the embankment of the facility.

4.0 RUN-OFF CONTROL

Run-off at Upstream Raise 92 consists of both contact water (namely water having directly contacted CCR within the active area of the facility), and non-contact stormwater (water that has contacted temporary or final cover).

A Notice of Intent to Close Upstream Raise 92 was submitted in June 2021 and closure of Upstream Raise 92 has commenced (Golder 2021). Closure activities include drainage and stabilization of CCRs, placement of beneficial use CCR (or other non-waste material) to achieve required crown slopes, regrading of final waste slopes, and placement of the final cover system.

4.1 Contact Water Run-Off Controls

Contact water run-off is contained and directed to one of three main areas described below:

- The pool within Upstream Raise 92. As indicated above, Upstream Raise 92 is currently undergoing closure and a minimal pool is anticipated to be present in the center of Upstream Raise 92 during the closure period. Only a small area will contribute contact water run-off to this pool. Water within this pool is allowed to percolate through the placed CCR, which ultimately will report to the collection systems at the base of the facility.
- The adjacent Upstream Raise 91 CCR Surface Impoundment.
- The contact water sump associated with Southeast 16.

Contact water run-off is directed using berms, channels, and culverts contained within the lined footprints of the facilities. Calculations supporting the design of the contact water controls are included in Appendix A (Golder 2012). The referenced calculations consider both Upstream Raise 92 and Southeast 16 as the contact water controls and routing are designed to work in concert with each other. Upstream Raise 91 is not included in these contact water controls as Upstream Raise 92 will be in the process of closing or closed for most of the active life of Upstream Raise 91. Contact water run-off calculations are based on a 24-hour, 25-year storm event for two different time periods over the life of the facility. Both phases are designed to contain and passively convey contact water to Upstream Raise 91 or the Southeast 16 contact water sump without ponding in the perimeter ditches above the Upstream Raise 92 composite liner.

4.2 Non-Contact Water Run-Off Controls

Non-contact run-off is collected in grass-lined terrace channels and is directed toward armored down-chute and outlet channels. Down-chute and outlet channels direct non-contact stormwater off the facility and into

surrounding drainage ditches or areas generally sloped away from the facility. Calculations supporting the design of non-contact surface water controls are included in Appendix B (Golder 2012; Golder 2015). The referenced calculations consider Upstream Raise 92, Southeast 16 and Upstream Raise 91 as the surface water controls and routing are designed to work in concert. Non-contact surface water run-off calculations are based on a 24-hour, 100-year storm event when the facility is developed to final grades.

These surface water calculations are based on the current permitted grades for Upstream Raise 92, Southeast 16 and Upstream Raise 91. Changes to 40 CFR Part 257 since original rule promulgation in 2015 (related to a liner demonstration specific to Coal Creek Station that requires review by the USEPA) will require that the final cover grades be updated for these facilities. Consequently, the run-off surface water controls and calculations will be required to be updated at that time.

5.0 REVISION HISTORY

A history of revisions to this document:

Revision 0 – Published October 13, 2016.

Revision 1 – 5-Year Update: Published October 13, 2021

- 1) New CCR unit naming convention (Upstream Raise to Upstream Raise 92)
- 2) Reflect that closure has commenced at Upstream Raise 92
- 3) Reflect that final grades (and surface water controls) are likely to change due to changes to 40 CFR Part 257 since original rule promulgation in 2015 (pending USEPA review)

6.0 CERTIFICATION

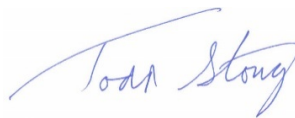
The undersigned attest to the completeness and accuracy of the above written run-on and run-off control plans, and certify that the plans meet the requirements detailed in 40 CFR 257.81(c) and Section 33.1-20-08-05.2.c. of the NDAC.

Signature Page

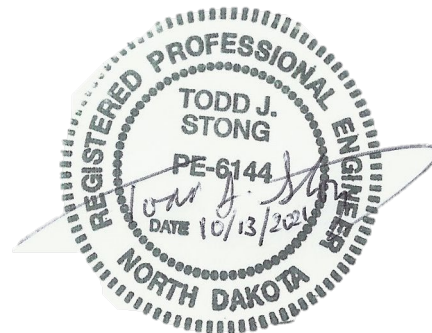
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[https://golderassociates.sharepoint.com/sites/140044/project files/6 deliverables/21451024/reports/7-r-ur92_roroplanrev1/7-r-0/21451024-7-r-0-ur92_roroplanrev1-13oct21.docx](https://golderassociates.sharepoint.com/sites/140044/project%20files/6%20deliverables/21451024/reports/7-r-ur92_roroplanrev1/7-r-0/21451024-7-r-0-ur92_roroplanrev1-13oct21.docx)

7.0 REFERENCES

Golder (Golder Associates Inc.). 2012. Permit Modification Document, Permit No. SP-033. December.

Golder (Golder Associates Inc.). 2015. Permit Modification Document, Permit No. SP-033. February.

Golder (Golder Associates Inc.). 2021. Notice of Intent to Close – Upstream Raise 92 CCR Surface Impoundment – Coal Creek Station. June 4, 2021.

NDAC (North Dakota Administrative Code). 2020. Chapter 33.1-20-08 – Disposal of Coal Combustion Residuals in Landfills and Surface Impoundments.

USEPA (United States Environmental Protection Agency). 2015. Code of Federal Regulations Title 40 Part 257: Hazardous and Solid Waste Management System; Disposal of Coal Combustion Residuals from Electric Utilities. April 17.

APPENDIX A

Contact Water Controls Calculations

APPENDIX A1

Contact Water Controls Part A Calculations



Subject
GRE – Coal Creek Station
Permit SP-033
Contact Water Controls Part A

Made by
LES LES
Checked by
SEA
Approved by
TJS

Job No.
113-81519
Date
12/3/2012
Sheet No.
1 of 4

1.0 OBJECTIVE

Evaluate the adequacy of contact water controls to contain/convey runoff from the Ash Pond 92 raise, SW Section 16 raise, and SE Section 16 landfill during the 25-year 24-hour design storm event.

2.0 METHOD

Golder Associates Inc. (Golder) delineated sub-basins for the proposed contact water control system based on planned and existing topography, shown in Figure 1. Times of concentration were calculated using the methodology described in TR-55 (U. S. Soil Conservation Service, 1986) for sheet and shallow concentrated flow and Manning's equation for channel flow. HEC-HMS modeling software (U.S. Army Corps of Engineers Hydrologic Engineering Center, 2010) was used to determine the routing of surface runoff from the raise/landfill slopes and the peak inflows that will report to the control ditches. The control ditches will be excavated into the coal combustion products (CCPs) and will be designed to contain the runoff from the raise/landfill, functioning as small reservoirs. Discharge from the control ditches will occur in one of two ways: 1) outflow through culverts, or 2) infiltration through the bottom ash lining of select control ditches and allow it to percolate down into the CCPs and/or through culverts. The sump to the north of SE Section 16 will be sized to contain all contributing inflow (SE Section 16 and portions of SW Section 16).

Analysis is performed in two parts – A and B, to reflect changes to the CCP disposal areas such as grades, pool areas, and final/temporary cover placement (Figure 1). Part A represents a maximum sludge pool height condition. The grades at Ash Pond 92 and SW Section 16 are up to elevation 2004, while SE Section 16 is graded to 1950 feet. No additional temporary or final cover is assumed (existing final cover on south side of Ash Pond 92 and SW Section 16 to elevation 1950), and contact water is managed through a combination of control ditches, channels, culverts, and a sump in the northeast corner of SE Section 16. Part B represents final CCP grades with final or temporary cover having been placed on most slopes depicted under Part A. Contact water is managed through channels created with berms along the edge of temporary/final covered slopes to the sump located in the northeast corner of SE Section 16. This calculation brief summarizes Part A of the contact water control calculations.

North Dakota Department of Environmental Quality

3.0 ASSUMPTIONS

- North Dakota Department of Health regulations require that "The landfill must be designed and operated to prevent the run-on and runoff of surface waters resulting from a maximum flow of a twenty-five year, twenty-four-hour storm." The 25-year, 24-hour, storm depth is 3.75 inches and was obtained from the "Rainfall Frequency Atlas of the United States" (Hershfield, 1961). The atlas section relevant to North Dakota is included in Attachment A.



Subject
GRE – Coal Creek Station
Permit SP-033
Contact Water Controls Part A

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12/3/2012
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- The 2-year, 24-hour storm depth, which is used in the TR-55 time of concentration method, is 1.9 inches (Hershfield, 1961). The relevant "Rainfall Frequency Atlas of the United States" section is included in Attachment A.
- The design storm is distributed in time as an SCS Type II synthetic distribution.
- Lag time is equal to 60% of the time of concentration.
- The minimum lag time is 3.6 minutes (a time of concentration of 6 minutes per TR-55).
- Maximum length of sheet flow is 300 feet.
- An SCS curve number of 94 was assumed for all sub-basins, reflecting hardened fly ash.
- An overland flow surface roughness of 0.011 was assumed for fly ash (Attachment B).
- A shallow concentrated flow coefficient of 20.33 was assumed for the surface of the raise (Attachment B) to reflect fly ash.
- Manning roughness coefficients of 0.012 (for capacity) and 0.011 (for velocity) were assumed for channels (Attachment C). This is the roughness for concrete and is assumed to be similar to that of fly ash.
- Outflow from the SW Section 16 South and East/North control ditches into the bottom ash occurs as gravity flow through the bottom ash-lined floor.
- Hydraulic conductivity for bottom ash of 0.03 cm/sec was used (from lab testing).
- Eight 12-inch HDPE culverts are modeled from the Ash Pond 92 control ditch into Ash Pond 91. The eight culverts are modeled as two sets of four identical culverts. The culverts have free discharge, minimal slope towards Ash Pond 91, and a Manning roughness of 0.011, and are approximately 100 feet long. The invert elevations of the culverts at Ash Pond 92 are approximately 1917.5 and 1916.8 feet for sets 1 and 2.
- One 24-inch HDPE culvert is modeled from the SE Section 16 upper control ditch to the SE Section 16 sump area. The culvert has free discharge, minimal slope, and a Manning roughness of 0.011, and is approximately 100 feet long. The invert elevation of the culvert at the SE Section 16 upper control ditch is approximately 1896 feet.
- One 24-inch HDPE culvert is modeled from the SE Section 16 central pond to the SE Section 16 sump area. The culvert has free discharge, a slope of approximately 4%, and a Manning roughness of 0.011, and is approximately 530 feet long. The invert elevation of the culvert at the SE Section 16 central pond is approximately 1922 feet.
- Outflow from the Ash Pond 92 and SE Section 16 control ditches through culverts is based on evaluation using the FHWA HY8 software.
- Control ditches are treated as "reservoir" elements in the HEC-HMS program. Elevation and area relationships for the control ditches are attached (Table 3).
- The composite liner for Ash Pond 92 ties into the embankment at an elevation of approximately 1920 feet.
- The composite liner for the SE Section 16 landfill control ditches ties into the South and East embankments at an elevation of approximately 1900 feet.
- The composite liner for the SE Section 16 landfill sump area ties into the North embankment at a low elevation of 1885 feet.
- The composite liner for the SW Section 16 raise South and East/North control ditches ties into the embankment at an elevation of approximately 1948 feet.



Subject GRE – Coal Creek Station
Permit SP-033
Contact Water Controls Part A

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Checked by <i>SCA</i>
Approved by <i>TJS</i>

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Date 12/3/2012
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4.0 CALCULATIONS

Flow through culverts was estimated using the HY8 software, which was used to evaluate both inlet and outlet control conditions. Outflow from each culvert was assessed for various head conditions at the inlet, which reflected ponding of water in the modeled control ditch or pond. Results of the culvert analysis are attached (Table 4), and were used to develop staged outflow curves for the control ditches (Figures 2-4).

Hydraulic parameters for the basins (Tables 1 and 2), and control ditches/ponds (Tables 3 and 4) were entered into the HEC-HMS modeling software and routed to calculate peak flows for each basin and ditch (Table 5). Peak flows were used to evaluate the capacity of each control ditch.

Channels were sized to accommodate peak flow (Table 6). Although only one basin (92-S) includes a formal channel, angled access roads were assumed to behave as channels during storm events. As such, access roads are included in the table, although they have not been sized based on flow capacity.

Output from the HEC-HMS modeling is attached (Table 7). The total required capacity of the SE Section 16 sump area was obtained from the HEC-HMS modeling results. The modeled value was compared to the sum of the runoff of all basins that drain to the sump area, calculated in Table 1.

5.0 RESULTS/CONCLUSIONS

The analysis examined control ditches around Ash Pond 92, SW Section 16 and SE Section 16, as well as the large pond in the center of the SE Section 16 raise. The estimated peak water elevations and the liner elevations for all control ditches and ponds are summarized in Table 8, below.

Table 8: Peak water elevations and liner elevations for control ditches and ponds

Ditch	Peak Elevation (ft)	Liner Elevation (ft)
Pond 92 Ditch	1919.9	1920
SW Section 16 Ditch (South)	1946.9	1948
SW Section 16 Ditch (East/North)	1947.8	1948
SE Section 16 Upper Ditch	1899.1	1900
SE Section 16 Central Pond	1925.2	-

Estimated peak water elevation is below the liner elevation for each control ditch and pond. These results indicate that the designed control ditches/ponds and culverts will be adequate to control the contact water from a 25-year, 24-hour storm event (will not overtop the liners).

Estimated velocities in the contact water channels range between 8 and 11 feet per second. Because the channels will be constructed out of hardened/cemented fly ash, these high velocities are not anticipated



Subject
GRE – Coal Creek Station
Permit SP-033
Contact Water Controls Part A

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to cause significant erosion. However, maintenance of the contact water channels should be done to maintain capacity and integrity.

The required capacity of the SE Section 16 sump area is 20.5 ac-ft. This result was obtained from both the HEC-HMS model constructed for this project and volumetric calculations based on total flow into the sump area (Table 1). To maintain the storm event capacity in the sump, contact water will be pumped to Ash Pond 91 whenever the elevation of accumulated water is greater than 2 feet in the sump. Therefore, the sump must be sized to accommodate the design event with 2 feet of existing water without overtopping the composite liner.

6.0 REFERENCES

Hershfield, D. M. (1961). *Rainfall Frequency Atlas of the United States for Durations from 30 Minutes to 24 Hours and Return Periods from 1 to 100 Years*. U.S. Department of Agriculture, Soil Conservation Service. Washington D. C.: U.S. Government Printing Office.

U. S. Soil Conservation Service. (1986). *Urban hydrology for small watersheds*. Washington D. C.: United States Department of Agriculture.

U.S. Army Corps of Engineers Hydrologic Engineering Center. (2010, August 10). Hydrologic Modeling System (HEC-HMS). (3.5). Davis, California, USA: U.S. Army Corps of Engineers.

TABLES

TABLE 1
SUBBASIN SUMMARY TABLE

GRE CCS Vertical Expansion
Contact Water Calculations - Part A
Project No.: 113-81519

Design Storm 25 -Year Recurrence Interval

Storm Duration (hours)	2-Year Depth (inches)	25 -Year Depth (inches)	Storm Distribution
24	1.9	3.8	II

Subbasin ID	Subbasin Area (ft ²)	Subbasin Area (acres)	Subbasin Area (sq mile)	CN = 94	Composite SCS Curve No.	S = $\frac{1000}{10 + \text{CN}}$	Unit Runoff Q (in)	Runoff Volume (ac-ft)	Runoff Volume (ft ³)
				Fair Coverage of Prairie Grasses					
92-NE	289,541	6.65	0.0104	6.65	CN = 94	0.64	3.08	1.71	74,308
92-NW	330,986	7.60	0.0119	7.60	CN = 94	0.64	3.08	1.95	84,944
92-S	320,687	7.36	0.0115	7.36	CN = 94	0.64	3.08	1.89	82,301
92-W	588,590	13.51	0.0211	13.51	CN = 94	0.64	3.08	3.47	151,055
SE-C	1,175,506	26.99	0.0422	26.99	CN = 94	0.64	3.08	6.93	301,681
SE-E	412,522	9.47	0.0148	9.47	CN = 94	0.64	3.08	2.43	105,869
SE-N	830,037	19.06	0.0298	19.06	CN = 94	0.64	3.08	4.89	213,020
SE-S	406,028	9.32	0.0146	9.32	CN = 94	0.64	3.08	2.39	104,203
SW-E1	139,290	3.20	0.0050	3.20	CN = 94	0.64	3.08	0.82	35,747
SW-E2	137,946	3.17	0.0049	3.17	CN = 94	0.64	3.08	0.81	35,402
SW-N	178,976	4.11	0.0064	4.11	CN = 94	0.64	3.08	1.05	45,932
SW-S	464,408	10.66	0.0167	10.66	CN = 94	0.64	3.08	2.74	119,185
SW-W	657,727	15.10	0.0236	15.10	CN = 94	0.64	3.08	3.88	168,798
Total:	5,932,244	136.19	0.21					34.95	1,522,445

TABLE 2
BASIN HYDRAULIC PARAMETER SUMMARY TABLE

GRE CCS Vertical Expansion
Contact Water Calculations - Part A
Project No.: 113-81519

Subbasin ID	Subbasin Area (sq mile)	Composite Curve Number	Total Lag (0.6*Tc) (min)	Total Travel Time (min)	Flow Segment 1						Flow Segment 2					
					Type of Flow	Length (ft)	Slope (ft/ft)	Roughness Condition ⁽¹⁾	Typical Hydraulic Radius (Channel Only) (ft)	Travel Time (min)	Type of Flow	Length (ft)	Slope (ft/ft)	Roughness Condition ⁽¹⁾	Typical Hydraulic Radius (Channel Only) (ft)	Travel Time (min)
92-NE	0.0104	94	3.6	2.4	Sheet	239	0.130	A Fly Ash		1.5	Sheet	61	0.250	A Fly Ash		0.4
92-NW	0.0119	94	3.6	2.2	Sheet	239	0.130	A Fly Ash		1.5	Sheet	61	0.250	A Fly Ash		0.4
92-S	0.0115	94	3.6	3.7	Sheet	239	0.130	A Fly Ash		1.5	Sheet	61	0.250	A Fly Ash		0.4
92-W	0.0211	94	3.6	2.2	Sheet	239	0.130	A Fly Ash		1.5	Sheet	61	0.250	A Fly Ash		0.4
SE-C	0.0422	94	3.6	0.8	Sheet	145	0.210	A Fly Ash		0.8						
SE-E	0.0148	94	3.6	1.9	Sheet	198	0.140	A Fly Ash		1.2	Sheet	102	0.210	A Fly Ash		0.6
SE-N	0.0298	94	3.6	2.1	Sheet	198	0.140	A Fly Ash		1.2	Sheet	102	0.190	A Fly Ash		0.6
SE-S	0.0146	94	3.6	1.7	Sheet	297	0.150	A Fly Ash		1.7						
SW-E1	0.0050	94	3.6	2.0	Sheet	239	0.130	A Fly Ash		1.5	Sheet	61	0.250	A Fly Ash		0.4
SW-E2	0.0049	94	3.6	1.9	Sheet	239	0.130	A Fly Ash		1.5	Sheet	61	0.250	A Fly Ash		0.4
SW-N	0.0064	94	3.6	1.9	Sheet	239	0.130	A Fly Ash		1.5	Sheet	61	0.250	A Fly Ash		0.4
SW-S	0.0167	94	3.6	1.9	Sheet	239	0.130	A Fly Ash		1.5	Sheet	61	0.250	A Fly Ash		0.4
SW-W	0.0236	94	3.6	2.7	Sheet	253	0.130	A Fly Ash		1.6	Sheet	47	0.250	A Fly Ash		0.3

TABLE 2
BASIN HYDRAULIC PARAMETER SUMMARY TABLE

GRE CCS Vertical Expansion
Contact Water Calculations - Part A
Project No.: 113-81519

Subbasin ID	Subbasin Area (sq mile)	Composite Curve Number	Flow Segment 3						Flow Segment 4						Typical Hydraulic Radius (Channel Only) (ft)	Travel Time (min)
			Type of Flow	Length (ft)	Slope (ft/ft)	Roughness Condition ⁽¹⁾			Type of Flow	Length (ft)	Slope (ft/ft)	Roughness Condition ⁽¹⁾				
92-NE	0.0104	94	Shallow	29	0.250	P	Paved		Channel	390	0.100	C	Concrete		0.23	0.4
92-NW	0.0119	94	Shallow	180	0.210	P	Paved									
92-S	0.0115	94	Shallow	35	0.250	P	Paved		Channel	1111	0.010	C	Concrete		0.75	1.8
92-W	0.0211	94	Shallow	177	0.220	P	Paved									
SE-C	0.0422	94														
SE-E	0.0148	94	Shallow	11	0.330	P	Paved									
SE-N	0.0298	94	Shallow	119	0.190	P	Paved									
SE-S	0.0146	94														
SW-E1	0.0050	94	Shallow	12	0.250	P	Paved		Channel	68	0.080	C	Concrete		0.22	0.1
SW-E2	0.0049	94	Shallow	35	0.250	P	Paved									
SW-N	0.0064	94	Shallow	41	0.250	P	Paved									
SW-S	0.0167	94	Shallow	35	0.250	P	Paved									
SW-W	0.0236	94	Shallow	406	0.180	P	Paved									

TABLE 3
CONTACT WATER CONTROL DITCH CAPACITY

GRE CCS Vertical Expansion
Contact Water Calculations - Part A
Project No.: 113-81519

Ash Pond 92 Contact Water Ditch - North and West Sides

Staged Capacity

Elevation	Area	Area
ft	ft ²	acres
1916.8	32,986	0.757
1917	35,355	0.812
1918	47,199	1.084
1919	58,761	1.349
1920	71,090	1.632
1921	83,419	1.915
1922	95,748	2.198
1923	108,077	2.481

SE Section 16 Upper Contact Water Ditch - South and East Sides

Staged Capacity

Elevation	Area	Area
ft	ft ²	acres
1896	33,685	0.773
1897	47,913	1.100
1898	62,347	1.431
1899	77,110	1.770
1900	91,684	2.105
1901	106,258	2.439

SW Section 16 Contact Water Ditch - South Side

Staged Capacity

Elevation	Area	Area
ft	ft ²	acres
1945	10,047	0.231
1946	17,455	0.401
1947	25,048	0.575
1948	32,829	0.754
1949	40,796	0.937
1950	48,945	1.124

SW Section 16 Contact Water Ditch - East/North Side

Staged Capacity

Elevation	Area	Area
ft	ft ²	acres
1945	6,540	0.150
1946	11,291	0.259
1947	16,111	0.370
1948	20,996	0.482
1949	26,004	0.597
1950	30,972	0.711

SE Section 16 Contact Water Pool - Central

Staged Capacity

Elevation	Area	Area
ft	ft ²	acres
1922	11,769	0.270
1924	47,075	1.081
1926	105,918	2.432
1928	188,298	4.323
1930	291,348	6.688

TABLE 4
CONTACT WATER CONTROL DITCH OUTFLOW

GRE CCS Vertical Expansion
Contact Water Calculations
Project No.: 113-81519

Ash Pond 92 Contact Water Ditch - Outflow through Culverts to Ash Pond 91

Elevation	Water in Ditch	Outflow (q)
ft	ft	cfs
1916.8	0.0	0.00
1917	0.2	1.00
1917.5	0.7	4.42
1918	1.2	11.20
1918.5	1.7	18.98
1919	2.2	25.05
1919.5	2.7	29.19
1920	3.2	32.70
1920.5	3.7	35.77
1921	4.2	38.64
1921.5	4.7	41.31
1922	5.2	43.85
1922.5	5.7	46.28
1923	6.2	48.60

- Outflow based on culvert analysis for two sets of four 12" HDPE pipes

SE Section 16 Upper Contact Water Ditch - Outflow through Culvert to Pond

Elevation	Water in Ditch	Outflow (q)
ft	ft	cfs
1896	0	0.00
1896.5	0.5	1.36
1897	1	3.41
1897.5	1.5	6.49
1898	2	9.59
1898.5	2.5	12.11
1899	3	14.22
1899.5	3.5	16.01
1900	4	17.60
1900.5	4.5	19.05
1901	5	20.33

- Outflow based on culvert analysis for one 24" HDPE pipe

SE Section 16 Central Pond - Outflow through Culvert to Pond

Elevation	Water in Central Pond	Outflow (q)
ft	ft	cfs
1922	0.0	0.00
1922.5	0.5	2.03
1923	1.0	4.07
1923.5	1.5	6.91
1924	2.0	9.75
1924.5	2.5	12.02
1925	3.0	14.29
1925.5	3.5	15.91
1926	4.0	17.53
1926.5	4.5	18.97
1927	5.0	20.41
1927.5	5.5	21.53
1928	6.0	22.66
1928.5	6.5	23.78
1929	7.0	24.91
1929.5	7.5	25.84
1930	8.0	26.77

- Outflow based on culvert analysis for one 24" HDPE pipe

TABLE 4
CONTACT WATER CONTROL DITCH OUTFLOW

GRE CCS Vertical Expansion
Contact Water Calculations
Project No.: 113-81519

SW Section 16 Contact Water Ditch (South Side) - Outflow through Bottom Ash Floor

Elevation	Gradient (i)	Outflow (q)
ft		cfs
1945	1.0	0.00
1945.1 to 1950	1.0	9.89

Area of ditch floor at elevation 1945 (A) = 10,047 ft²
 Hydraulic Conductivity of Bottom Ash (k) = 0.03 cm/sec
 Hydraulic Conductivity of Bottom Ash (k) = 9.84E-04 ft/sec

- Assume only outflow through ditch floor $Q = kiA$
- Assume gradient of 1 (vertical percolation) $i = \Delta h/L$

SW Section 16 Contact Water Ditch (East/North Sides) - Outflow through Bottom Ash Floor

Elevation	Gradient (i)	Outflow (q)
ft		cfs
1945	1.0	0.00
1945.1 to 1950	1.0	6.44

Area of ditch floor at elevation 1945 (A) = 6,540 ft²
 Hydraulic Conductivity of Bottom Ash (k) = 0.03 cm/sec
 Hydraulic Conductivity of Bottom Ash (k) = 9.84E-04 ft/sec

- Assume only outflow through ditch floor $Q = kiA$
- Assume gradient of 1 (vertical percolation) $i = \Delta h/L$

TABLE 5
FLOW RESULTS FROM HEC-HMS

GRE CCS Vertical Expansion
Contact Water Calculations - Part A
Project No.: 113-81519

HEC-HMS Basin Model:	GRE Landfill 1
HEC-HMS Met. Model:	USE 25yr 24hr
HEC-HMS Control Specs:	36hr 5min

Hydrologic Element	Drainage Area (sq mile)	Peak Discharge (cfs)	Time of Peak	Total Volume (ac-ft)
SE-C	0.0422	112.3	01Jan2050, 12:55	6.9
R-SE-C	0.0422	14.9	01Jan2050, 13:20	6.9
SE-E	0.0148	39.4	01Jan2050, 12:55	2.4
SE-S	0.0146	38.9	01Jan2050, 12:55	2.4
R-SE	0.0716	14.6	01Jan2050, 15:05	11.7
SE-N	0.0298	79.3	01Jan2050, 12:55	4.9
SW-W	0.0236	62.8	01Jan2050, 12:55	3.9
S-SE	0.125	151.1	01Jan2050, 12:55	20.5
92-W	0.0211	56.2	01Jan2050, 12:55	3.5
92-NW	0.0119	31.7	01Jan2050, 12:55	2
92-S	0.0115	30.6	01Jan2050, 12:55	1.9
92-NE	0.0104	27.7	01Jan2050, 12:55	1.7
R-92	0.0549	32.1	01Jan2050, 13:10	9
S-91	0.0549	32.1	01Jan2050, 13:10	9
SW-S	0.0167	44.5	01Jan2050, 12:55	2.7
R-SW-S	0.0167	9.9	01Jan2050, 12:45	2.7
S-SW-S	0.0167	9.9	01Jan2050, 12:45	2.7
SW-N	0.0064	17	01Jan2050, 12:55	1.1
SW-E1	0.005	13.3	01Jan2050, 12:55	0.8
SW-E2	0.0049	13	01Jan2050, 12:55	0.8
R-SW-E	0.0163	6.4	01Jan2050, 12:40	2.7
S-SW-E	0.0163	6.4	01Jan2050, 12:40	2.7

TABLE 6
CHANNEL HYDRAULIC CALCULATIONS

GRE CCS Vertical Expansion
Contact Water Calculations - Part A
Project No.: 113-81519

	Q25 from HEC-HMS (cfs)	HEC HMS Element ID for Q	Channel Design Geometry					Channel Roughness Parameters			Hydraulic Calculations							Channel Evaluation	
			Bed Slope (ft/ft)	Left Side Slope (H:1V)	Right Side Slope (H:1V)	Bottom Width (ft)	Minimum Channel Depth (ft)	Design Channel Lining	Mannings 'n' for Capacity (Depth Calculation)	Mannings 'n' for Stability (Velocity Calculation)	Maximum Velocity (ft/sec)	Maximum Normal Flow Depth (ft)	Froude Number	Normal Depth Shear Stress (lb/ft²)	Stream Power (W/m²)	Top Width of Flow (ft)	Top Width of Channel (ft)	Available Freeboard (ft)	
Channels/Roads																			
R-92NE (road)	27.7	92-NE	0.100	4.0	50.0	0	0.8	C	Concrete	0.012	0.011	11.1	0.30	5.04	1.89	306.13	16.4	40.5	0.4
R-92S	30.6	92-S	0.010	3.0	4.0	0	2.0	C	Concrete	0.012	0.011	7.9	1.05	1.91	0.66	75.15	7.4	14.0	0.9
R-SWE (road)	13.3	SW-E1	0.080	4.0	50.0	0	0.6	C	Concrete	0.012	0.011	8.5	0.24	4.34	1.20	148.48	13.0	33.5	0.4

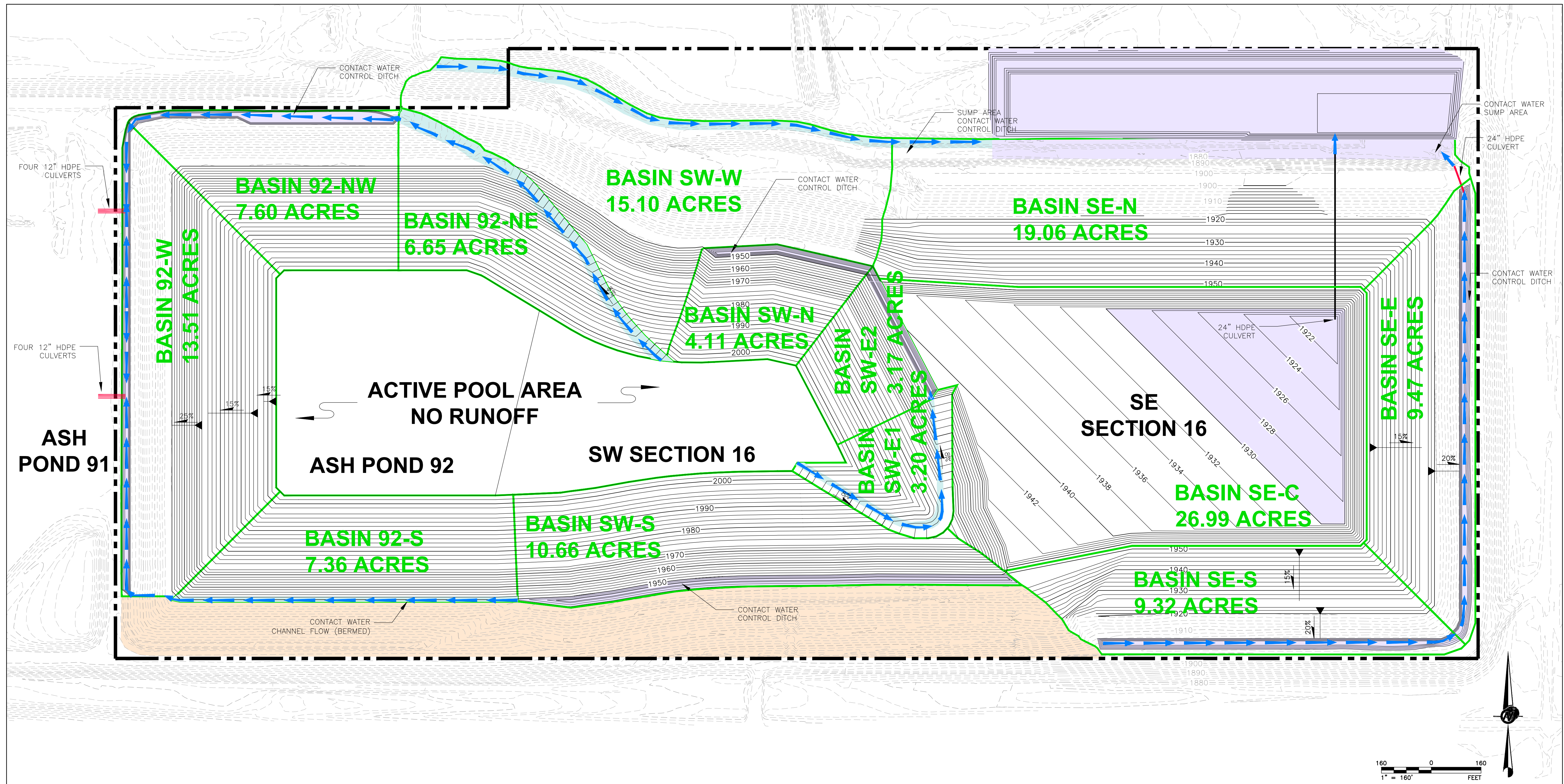
TABLE 7
HEC-HMS RESULTS

GRE CCS Vertical Expansion
Contact Water Calculations
Project No.: 113-81519

Ditch	Peak Elevation	Peak Inflow	Peak Outflow	Total Outflow/Volume
	ft	cfs	cfs	ac-ft
Pond 92 Ditch	1919.9	146.1	32.1	9
SW Section 16 Ditch (South)	1946.9	44.5	9.9	2.7
SW Section 16 Ditch (East/North)	1947.8	43.4	6.40	2.7
SE Section 16 Upper Ditch	1899.1	89.5	14.6	11.7
SE Section 16 Central Pond	1925.2	112.3	14.9	6.9

FIGURES

Drawing File: J:\110851\113-81519 GRE\WORK Permit Modification\Appendix C\9-Contact Water\Contact Water Part A\11381519_ContactWater_FINAL.dwg | Layout: CONTACT WATER A | Modified: Oct 26, 2012 09:04 | User: j | Plotted: 11/29/12 12:26pm | Sheet: 1 of 1



LEGEND

	EXISTING GROUND TOPOGRAPHY		CONTACT WATER CONTROL DITCH
	PROPOSED TOP OF COVER		CONTACT WATER CONTROL CHANNEL
	BASIN DELINEATION		TEMPORARY/FINAL COVER PLACED
	PERMITTED LIMIT OF CCP PLACEMENT (PERMIT MODIFICATION ISSUED 09/24/03)		
	CULVERTS		

GREAT RIVER ENERGY
COAL CREEK STATION
UNDERWOOD, NORTH DAKOTA

CONTACT WATER BASIN LAYOUT A

FIGURE 1



**Figure 2: Eight 12" HDPE Pipe Culverts (2 Sets of 4)
from Ash Pond 92 to Ash Pond 91**

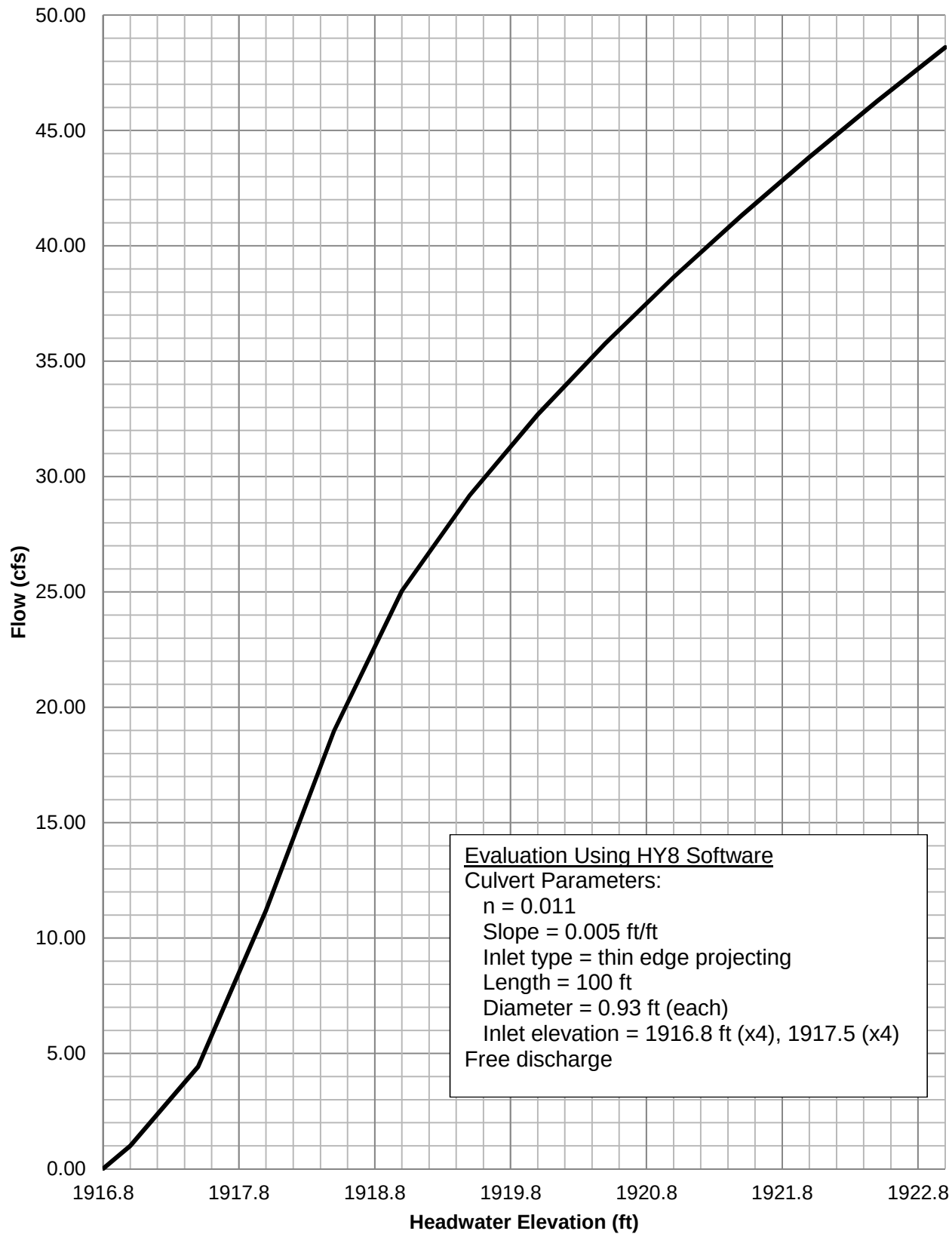
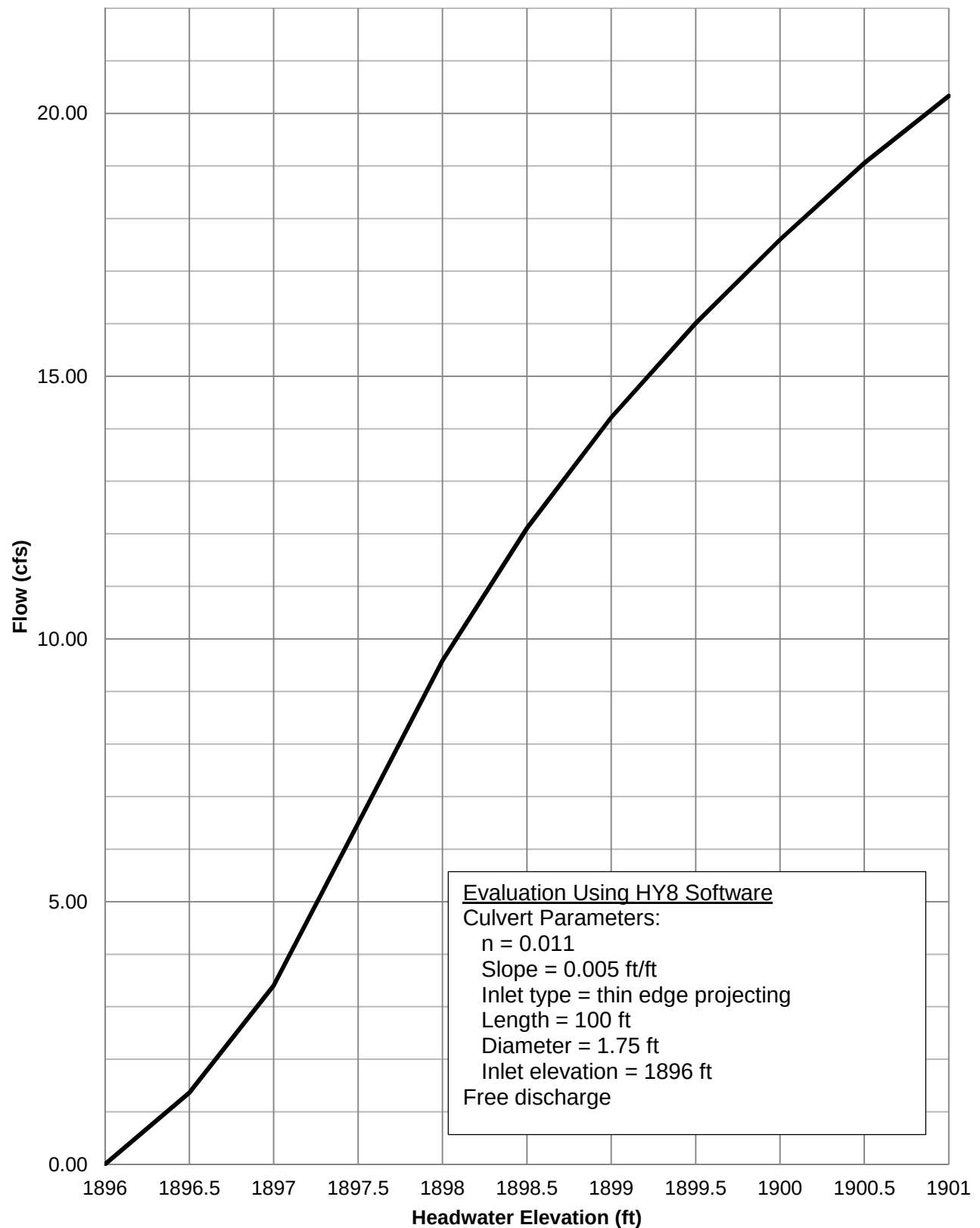
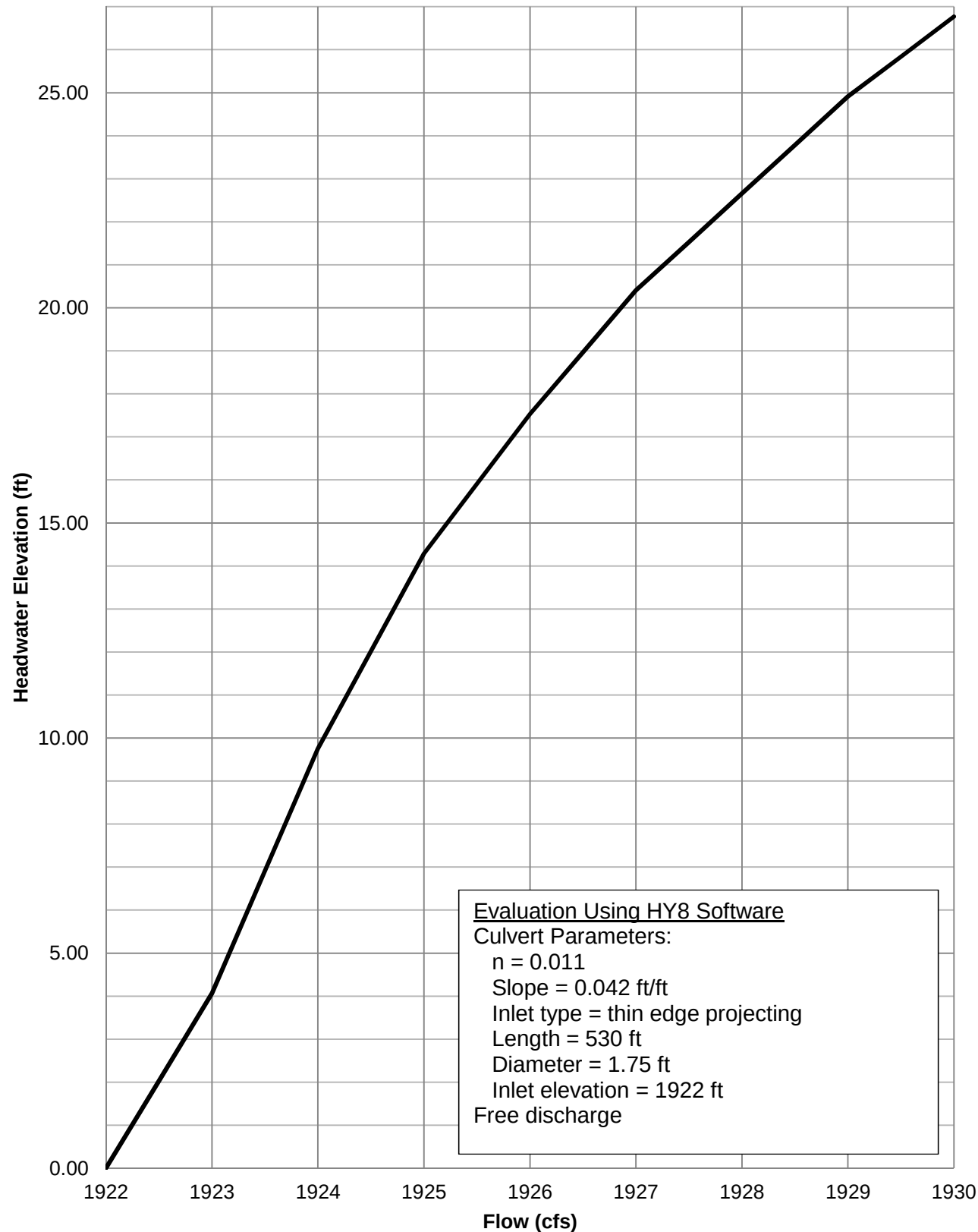


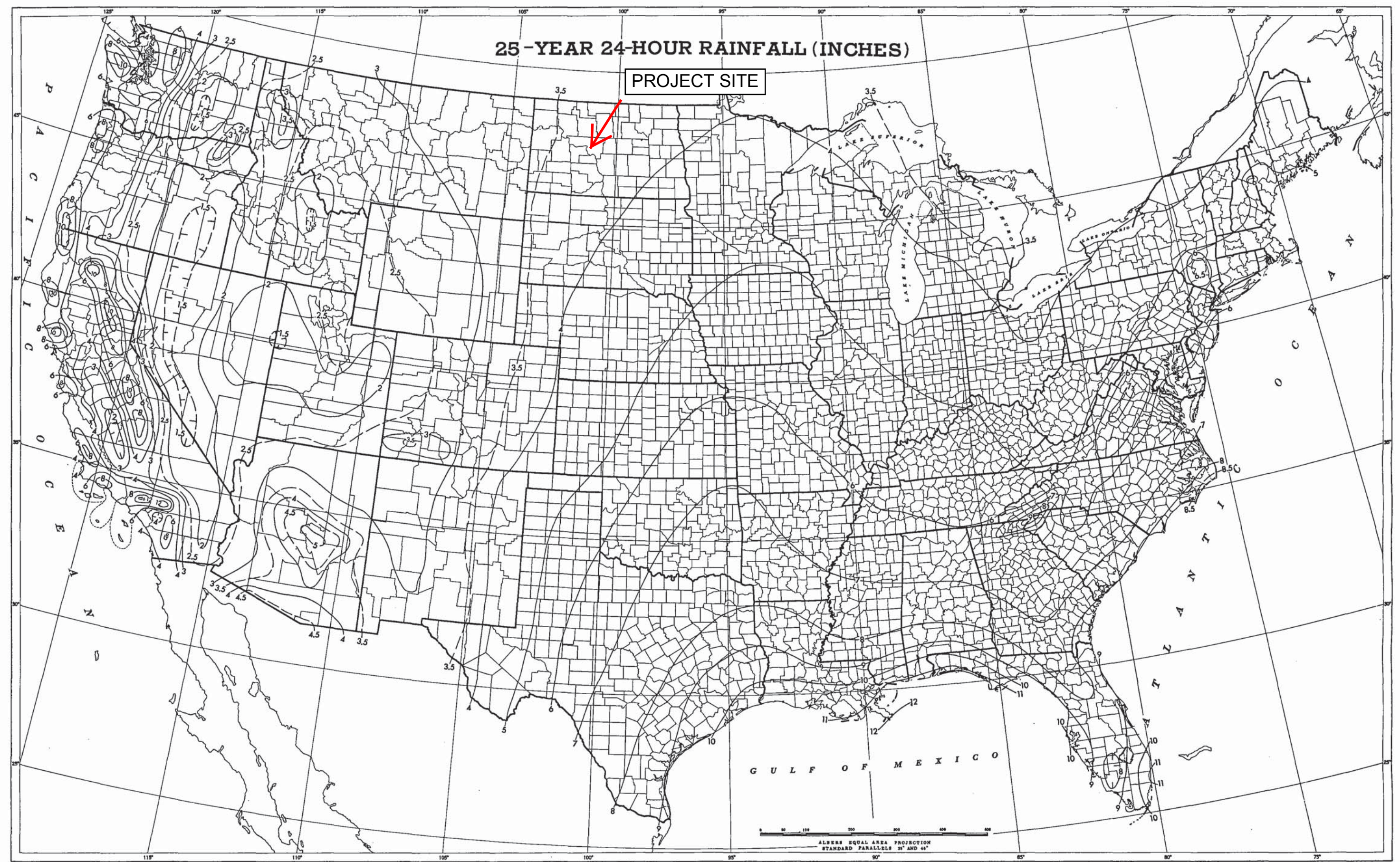
Figure 3: One 24" HDPE Pipe Culvert from SE Section 16 Upper Perimeter Ditch to Sump Area

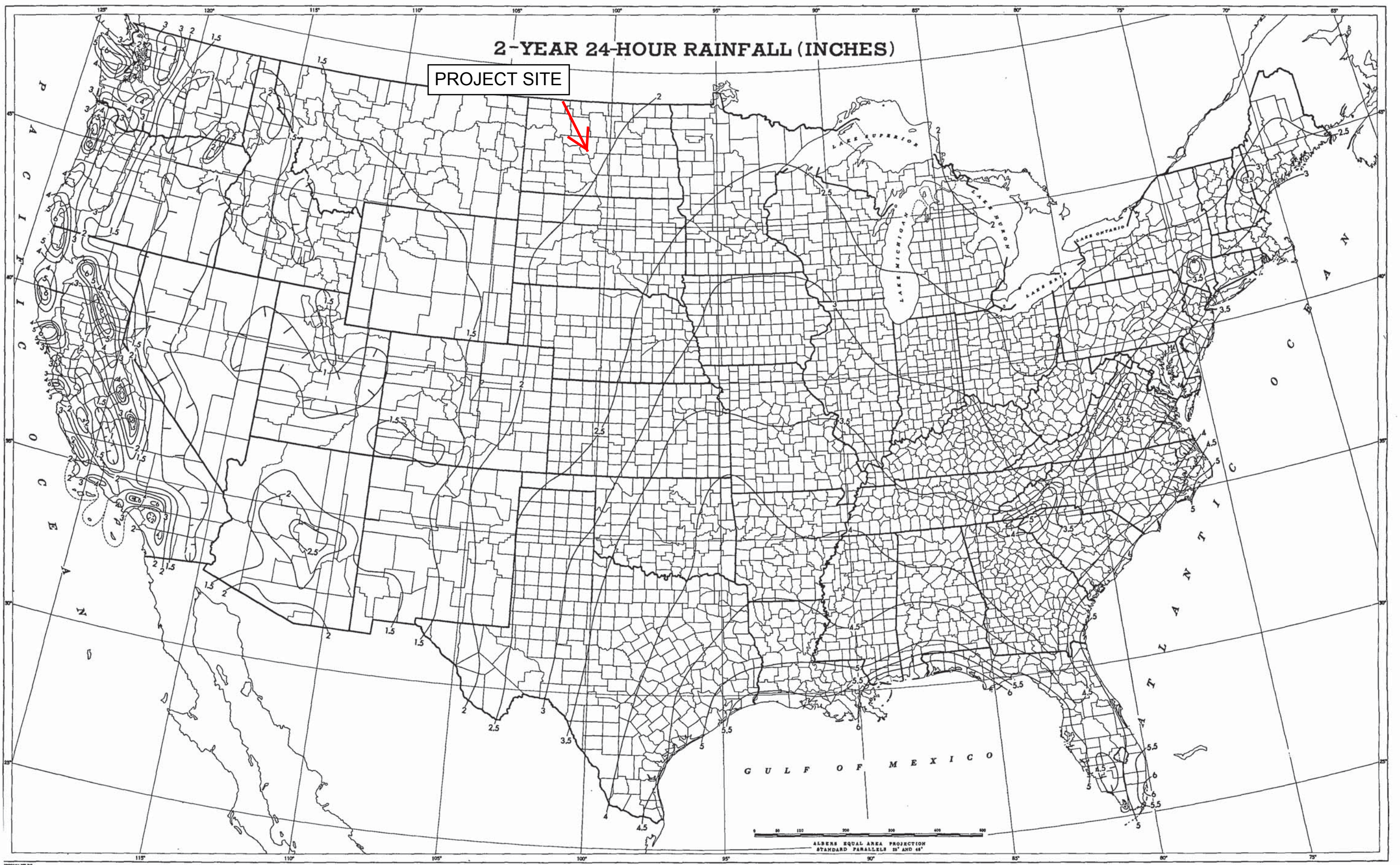


**Figure 4: One 24" HDPE Pipe Culvert from SE
Section 16 Central Pond to Sump Area**



ATTACHMENT A
RAINFALL FREQUENCY ATLAS (TP-40)
25-YEAR, 24-HOUR RAINFALL AND
2-YEAR, 24-HOUR RAINFALL





ATTACHMENT B
TIME OF CONCENTRATION CALCULATION EQUATIONS AND COEFFICIENTS

TR-55 (1986)**Sheet Flow Travel time (SCS Upland Method)**

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

Where: T_t = travel time (hr); 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 n	Surface Description	Short Description
Sheet/Overland Flow	A	0.011	Fly Ash	Fly Ash
	B	0.05	Fallow (no residue)	Fallow
	C	0.06	Cultivated soils: Residue cover <= 20%	Cover<20%
	D	0.17	Cultivated soils: Residue cover > 20%	Cover>20%
	E	0.15	Grass: Short grass prairie	Short Grass
	F	0.24	Grass: Dense grasses	Dense Grass
	G	0.41	Grass: Bermuda grass	Bermuda Grass
	H	0.13	Range (natural)	Range
	I	0.40	Woods: Light underbrush	Light woods
	J	0.80	Woods: Heavy underbrush	Heavy Woods

Shallow Concentrated Flow Velocity (SCS Upland Method)

$$v = mS^{0.5}$$

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

Flow Type	Surface Type	Roughness m	Surface Description	Short Description
Shallow Conc. Flow	P	20.3282	Paved Surfaces	Paved
	U	16.1345	Unpaved Surfaces	Unpaved

Channel Flow Velocity (Mannings Velocity)

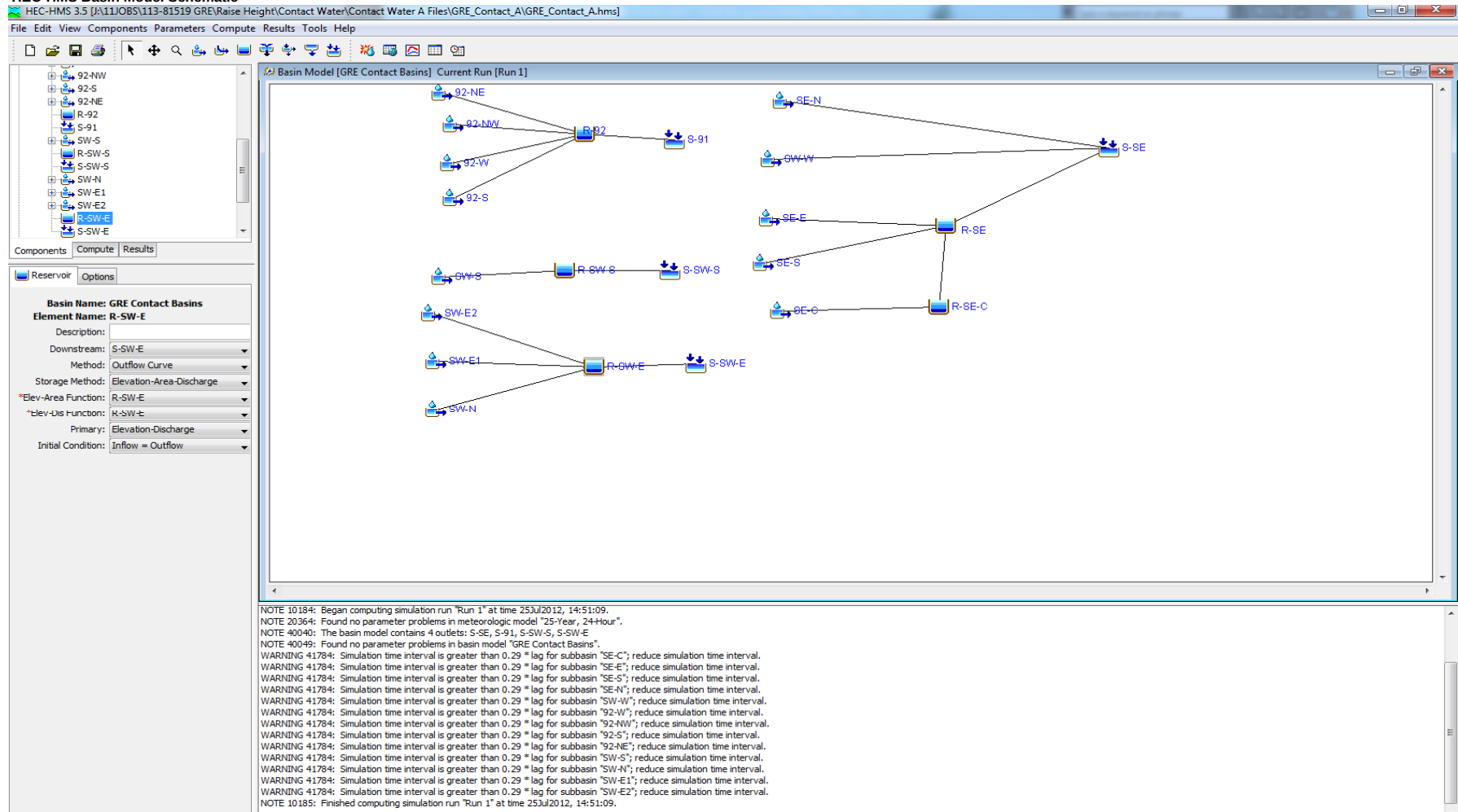
$$v = 1.49/n R_h^{2/3} S^{1/2}$$

Where: v = velocity (fps); n = roughness coefficient; R_h = Hydraulic Radius (ft), S = slope (ft/ft)

Lining Type	Mannings n for Depth	Mannings n for Velocity	Material	Maximum Velocity	Maximum Shear Stress
A	0.026	0.026	ACB	25	
C	0.012	0.011	Concrete	50	
E	0.025	0.022	Earth-lined	3	
G	0.035	0.030	Grass-lined	5	
I	0.017	0.013	Ductile Iron	50	
P	0.012	0.009	Plastic	25	
R	0.040	0.035	Riprap	16	
T	0.035	0.030	Turf Reinf.	10	1.5
Z	0.058	0.026	Flexamat	19	24

ATTACHMENT C
HEC-HMS SCREEN CAPTURES AND INPUTS

HEC-HMS Basin Model Schematic



Sub Basin Area	
Subbasin	Area (mi ²)
92-NE	0.0104
92-NW	0.0119
92-S	0.0115
92-W	0.0211
SE-C	0.0417
SE-E	0.0148
SE-N	0.0301
SE-S	0.0146
SW-E1	0.005
SW-E2	0.0049
SW-N	0.0065
SW-S	0.0167
SW-W	0.0232

Loss			
Subbasin	Initial Abstraction (in)	Curve Number	Impervious (%)
92-NE		94	0
92-NW		94	0
92-S		94	0
92-W		94	0
SE-C		94	0
SE-E		94	0
SE-N		94	0
SE-S		94	0
SW-E1		94	0
SW-E2		94	0
SW-N		94	0
SW-S		94	0
SW-W		94	0

Transform	
Subbasin	Lag Time (min)
92-NE	3.6
92-NW	3.6
92-S	3.6
92-W	3.6
SE-C	3.6
SE-E	3.6
SE-N	3.6
SE-S	3.6
SW-E1	3.6
SW-E2	3.6
SW-N	3.6
SW-S	3.6
SW-W	3.6

Ponds			
Pond	Elevation (ft)	Area (ac)	Discharge (cfs)
R-92	1916.8	0.757	0.00
	1917	0.812	1.00
	1918	1.084	11.20
	1919	1.349	25.05
	1920	1.632	32.70
	1921	1.915	38.64
	1922	2.183	43.85
	1923	2.458	48.60
R-SE	1896	0.773	0.00
	1897	1.100	3.35
	1898	1.431	9.58
	1899	1.770	14.19
	1900	2.105	17.64
R-SE-C	1922	0.270	0.00
	1924	1.081	17.53
	1926	2.432	26.77
	1928	4.323	33.52
	1930	6.688	39.12
R-SW-E	1945	0.150	0.00
	1946	0.259	6.44
	1947	0.370	6.44
	1948	0.482	6.44
	1949	0.597	6.44
	1950	0.711	6.44
R-SW-S	1945	0.231	0.00
	1946	0.401	9.89
	1947	0.575	9.89
	1948	0.754	9.89
	1949	0.937	9.89
	1950	1.124	9.89

ATTACHMENT D
HY8 CULVERT ANALYSIS OUTPUTS

SE16 Upper Control Ditch to Sump - Culvert 1

Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth (ft)	Outlet Control Depth (ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
0	0	1896	0	0.0*	0-NF	0	0	0	-10.5	0	0
2.1	2.1	1896.77	0.77	0.0*	1-S2n	0.46	0.52	0.47	-10.5	4	0
4.2	4.2	1897.14	1.14	0.0*	1-S2n	0.67	0.75	0.68	-10.5	4.9	0
6.3	6.3	1897.47	1.47	0.0*	1-S2n	0.85	0.92	0.85	-10.5	5.42	0
8.4	8.4	1897.8	1.8	0.0*	5-S2n	1.01	1.07	1.01	-10.5	5.82	0
10	10	1898.07	2.07	0.0*	5-S2n	1.14	1.17	1.14	-10.5	6.05	0
12.6	12.6	1898.6	2.6	2.52	2-M2c	1.37	1.32	1.32	-10.5	6.48	0
14.7	14.7	1899.12	3.12	2.79	2-M2c	1.75	1.42	1.42	-10.5	7.01	0
16.8	16.8	1899.73	3.73	3.38	7-M2c	1.75	1.49	1.5	-10.5	7.67	0
18.9	18.9	1900.44	4.44	4.01	7-M2c	1.75	1.57	1.57	-10.5	8.32	0
21	21	1901.26	5.26	4.72	7-M2c	1.75	1.64	1.62	-10.5	8.97	0

SE16 Central Pond to Sump - Culvert 1

Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth (ft)	Outlet Control Depth (ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
0	0	1922	0	0.0*	0-NF	0	0	0	5	0	0
5	5	1923.23	1.23	0.0*	1-S2n	0.42	0.82	0.43	5	10.95	0
10	10	1924.04	2.04	0.0*	5-S2n	0.61	1.17	0.61	5	13.26	0
15	15	1925.16	3.16	0.0*	5-S2n	0.76	1.43	0.76	5	14.92	0
20	20	1926.82	4.82	0.0*	5-S2n	0.9	1.61	0.9	5	16.08	0
25	25	1929.04	7.04	0.0*	6-FFc	1.03	1.75	1.75	5	10.39	0
30	30	1931.75	9.75	0.0*	6-FFc	1.17	1.75	1.75	5	12.47	0
35	35	1934.95	12.95	4.42	6-FFc	1.32	1.75	1.75	5	14.55	0
40	40	1938.65	16.65	11.98	6-FFc	1.54	1.75	1.75	5	16.63	0
45	45	1942.84	20.84	20.54	6-FFc	1.75	1.75	1.75	5	18.71	0
50	48.95	1950.01	24.5	28.01	6-FFc	1.75	1.75	1.75	5	20.35	0

Ash Pond 92 to Ash Pond 91**Culvert 1**

Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth (ft)	Outlet Control Depth (ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
0	0	1917.5	0	0.0*	0-NF	0	0	0	-1	0	0
2.5	2.5	1918	0.5	0.0*	1-S2n	0.32	0.33	0.32	-1	3.02	0
5	5	1918.26	0.76	0.0*	1-S2n	0.47	0.48	0.47	-1	3.63	0
7.5	7.5	1918.58	1.02	1.08	2-M2c	0.61	0.59	0.6	-1	4.08	0
10	10	1918.83	1.33	1.27	2-M2c	0.79	0.69	0.69	-1	4.61	0
12.5	12.5	1919.27	1.72	1.77	7-M2c	0.93	0.76	0.77	-1	5.22	0
15	15	1919.95	2.23	2.45	7-M2c	0.93	0.82	0.83	-1	5.88	0
17.5	17.5	1920.69	2.85	3.19	7-M2c	0.93	0.88	0.87	-1	6.63	0
20	20	1921.59	3.58	4.09	6-FFc	0.93	0.93	0.93	-1	7.36	0
22.5	22.5	1922.57	4.41	5.07	6-FFc	0.93	0.93	0.93	-1	8.28	0
25	25	1923.65	5.33	6.15	6-FFc	0.93	0.93	0.93	-1	9.2	0

Culvert 2

Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth (ft)	Outlet Control Depth (ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
0	0	1916.8	0	0.0*	0-NF	0	0	0	-0.3	0	0
2.5	2.5	1917.3	0.5	0.0*	1-S2n	0.32	0.33	0.32	-0.3	3.02	0
5	5	1917.56	0.76	0.0*	1-S2n	0.47	0.48	0.47	-0.3	3.63	0
7.5	7.5	1917.88	1.02	1.08	2-M2c	0.61	0.59	0.6	-0.3	4.08	0
10	10	1918.13	1.33	1.27	2-M2c	0.79	0.69	0.69	-0.3	4.61	0
12.5	12.5	1918.57	1.72	1.77	7-M2c	0.93	0.76	0.77	-0.3	5.22	0
15	15	1919.25	2.23	2.45	7-M2c	0.93	0.82	0.83	-0.3	5.88	0
17.5	17.5	1919.99	2.85	3.19	7-M2c	0.93	0.88	0.87	-0.3	6.63	0
20	20	1920.89	3.58	4.09	6-FFc	0.93	0.93	0.93	-0.3	7.36	0
22.5	22.5	1921.87	4.41	5.07	6-FFc	0.93	0.93	0.93	-0.3	8.28	0
25	25	1922.95	5.33	6.15	6-FFc	0.93	0.93	0.93	-0.3	9.2	0

APPENDIX A2

**Contact Water Controls Part B
Calculations**



Subject
GRE – Coal Creek Station
Permit SP-033
Contact Water Controls Part B

Made by
LES LES
Checked by
SEA
Approved by
TJ

Job No.
113-81519
Date
12/3/2012
Sheet No.
1 of 3

1.0 OBJECTIVE

Evaluate the adequacy of contact water controls to contain/convey runoff from the Ash Pond 92 raise, SW Section 16 raise and SE Section 16 landfill during the 25-year, 24-hour design storm event.

2.0 METHOD

Golder Associates Inc. (Golder) delineated sub-basins for the proposed contact water control system based on planned and existing topography, shown in Figure 1. Times of concentration were calculated using the methodology described in TR-55 (U. S. Soil Conservation Service, 1986) for sheet and shallow concentrated flow and Manning's equation for channel flow. HEC-HMS modeling software (U.S. Army Corps of Engineers Hydrologic Engineering Center, 2010) was used to determine the routing of surface runoff from the raise/landfill slopes and the peak inflows that will report to the sump area north of SE Section 16. Berms will be constructed along the boundaries of areas of the raise with temporary/final cover, creating perimeter channels. The perimeter channels will contain all contact water and convey it to the sump area. The sump area will be sized to contain all inflow.

Analysis is performed in two parts – A and B, to reflect changes to the CCP disposal areas such as grades, pool areas, and final/temporary cover placement (Figure 1). Part A represents a maximum sludge pool height condition. The grades at Ash Pond 92 and SW Section 16 are up to elevation 2004, while SE Section 16 is graded to 1950 feet. No additional temporary or final cover is assumed (existing final cover on south side of Ash Pond 92 and SW Section 16 to elevation 1950), and contact water is managed through a combination of control ditches, channels, culverts, and a sump in the northeast corner of SE Section 16. Part B represents final CCP grades with final or temporary cover having been placed on most slopes depicted under Part A. Contact water is managed through channels created with berms along the edge of temporary/final covered slopes to the sump located in the northeast corner of SE Section 16. This calculation brief summarizes Part B of the contact water control calculations.

North Dakota Department of Environmental Quality

3.0 ASSUMPTIONS

- North Dakota Department of Health regulations require that "The landfill must be designed and operated to prevent the run-on and runoff of surface waters resulting from a maximum flow of a twenty-five year, twenty-four-hour storm." The 25-year, 24-hour storm depth is 3.75 inches and was obtained from the "Rainfall Frequency Atlas of the United States" (Hershfield, 1961). The atlas section relevant to North Dakota is included in Attachment A.
- The 2-year, 24-hour storm depth, which is used in the TR-55 time of concentration method, is 1.9 inches (Hershfield, 1961). The relevant "Rainfall Frequency Atlas of the United States" section is included in Attachment A.
- The design storm is distributed in time as an SCS Type II synthetic distribution.
- Lag time is equal to 60% of the time of concentration.





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GRE – Coal Creek Station
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Contact Water Controls Part B

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- The minimum lag time is 3.6 minutes (a time of concentration of 6 minutes per TR-55).
- Maximum length of sheet flow is 300 feet.
- An SCS curve number of 94 was assumed for all sub-basins, reflecting fly ash.
- An overland flow surface roughness of 0.011 was assumed for fly ash (Attachment B).
- A shallow concentrated flow coefficient of 20.33 was assumed for the surface of the raise (Attachment B) to reflect fly ash.
- Manning roughness coefficients of 0.012 (for capacity) and 0.011 (for velocity) were assumed for channels (Attachment C). This is the roughness for concrete and is assumed to be similar to that of fly ash.
- All perimeter channels have minimal length-wise slope (1%) and an outer side slope of 3H:1V. The inner side slope of each channel is assumed to be equal to the slope of the raise surface.
- Channels that convey flow from two or more basins (the channels in Basin D and E) are modeled as reaches in HEC-HMS.

4.0 CALCULATIONS

Hydraulic parameters for the basins and reaches (Tables 1 and 2) were entered into the HEC-HMS modeling software and routed to calculate peak flows for each basin and ditch (Table 3). Channels were sized to accommodate peak flow (Table 4).

The total required capacity of the SE Section 16 sump area was obtained from the HEC-HMS modeling results. The modeled value was compared to the sum of the runoff of all basins that drain to the sump area, calculated in Table 1.

5.0 RESULTS/CONCLUSIONS

Individual channel reaches are summarized in Table 4, with peak flows, depths and velocities associated with the design storm event. The channels will be fly ash-lined v-notch channels with outside slopes of 3H:1V and inside slopes from 20H:1V to 6.7H:1V. The channels for Basins A and B will be 24 inches (2 feet) deep. The channels for Basins D and E, which must accommodate additional flow, will be 36 inches (3-feet) deep. Estimated velocities in the perimeter channels range between 3 and 16 feet per second. Because the channels will be constructed out of hardened/cemented fly ash, these high velocities are not anticipated to cause significant erosion. However, maintenance of the contact water channels should be done to maintain capacity and integrity.

The necessary capacity of the SE Section 16 sump area, based on Part B calculations, is 23.2 ac-ft. This result was obtained from both the HEC-HMS model constructed for this project and volumetric calculations based on total drainage into the sump area (Table 1). To maintain the storm event capacity in the sump, contact water will be pumped to Ash Pond 91 whenever the elevation of accumulated water



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Contact Water Controls Part B

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is greater than 2 feet in the sump. Therefore, the sump must be sized to accommodate the design event with 2 feet of existing water without overtopping the composite liner.

6.0 REFERENCES

Hershfield, D. M. (1961). Rainfall Frequency Atlas of the United States for Durations from 30 Minutes to 24 Hours and Return Periods from 1 to 100 Years. U.S. Department of Agriculture, Soil Conservation Service. Washington D. C.: U.S. Government Printing Office.

U. S. Soil Conservation Service. (1986). Urban hydrology for small watersheds. Washington D. C.: United States Department of Agriculture.

U.S. Army Corps of Engineers Hydrologic Engineering Center. (2010, August 10). Hydrologic Modeling System (HEC-HMS). (3.5). Davis, California, USA: U.S. Army Corps of Engineers.

TABLES

TABLE 1
SUBBASIN SUMMARY TABLE

GRE CCS Vertical Expansion
Contact Water Calculations - Part B
Project No.: 113-81519

Design Storm		25 -Year Recurrence Interval	
Storm Duration (hours)	2-Year Depth (inches)	25 -Year Depth (inches)	Storm Distribution
24	1.9	3.8	II

Subbasin ID	Subbasin Area (ft ²)	Subbasin Area (acres)	Subbasin Area (sq mile)	CN = 94	Composite SCS Curve No.	$S = \frac{1000}{10 - CN}$	Unit Runoff Q (in)	Runoff Volume (ac-ft)	Runoff Volume (ft ³)
				Fair Coverage of Prairie Grasses					
A	406,712	9.34	0.0146	9.34	CN = 94	0.64	3.08	2.40	104,378
B	485,552	11.15	0.0174	11.15	CN = 94	0.64	3.08	2.86	124,612
C	2,440,715	56.03	0.0875	56.03	CN = 94	0.64	3.08	14.38	626,383
D	173,689	3.99	0.0062	3.99	CN = 94	0.64	3.08	1.02	44,575
E	167,572	3.85	0.0060	3.85	CN = 94	0.64	3.08	0.99	43,006
F	268,171	6.16	0.0096	6.16	CN = 94	0.64	3.08	1.58	68,823
				0.00					
Total:	3,942,411	90.51	0.14					23.23	1,011,776

TABLE 2
BASIN HYDRAULIC PARAMETER SUMMARY TABLE

GRE CCS Vertical Expansion
Contact Water Calculations - Part B
Project Number: 113-81519

Subbasin ID	Subbasin Area (sq mile)	Composite Curve Number	Total Lag (0.6*Tc) (min)	Total Travel Time (min)	Flow Segment 1							Flow Segment 2						
					Type of Flow	Length (ft)	Slope (ft/ft)	Roughness Condition ⁽¹⁾		Typical Hydraulic Radius (Channel Only) (ft)	Travel Time (min)	Type of Flow	Length (ft)	Slope (ft/ft)	Roughness Condition ⁽¹⁾		Typical Hydraulic Radius (Channel Only) (ft)	Travel Time (min)
A	0.0146	94	8.4	13.9	Sheet	300	0.050	A	Fly Ash		2.6	Shallow	54	0.050	P	Paved		0.2
B	0.0174	94	10.2	17.0	Sheet	300	0.050	A	Fly Ash		2.6	Shallow	54	0.050	P	Paved		0.2
C	0.0875	94	3.6	3.9	Sheet	181	0.050	A	Fly Ash		1.8	Sheet	119	0.120	A	Fly Ash		0.9
D	0.0062	94	3.6	2.3	Sheet	300	0.090	A	Fly Ash		2.1	Channel	259	0.090	P	Plastic	0.39	0.2
E	0.0060	94	3.6	4.5	Sheet	210	0.050	A	Fly Ash		2.0	Sheet	90	0.150	A	Fly Ash		0.6
F	0.0096	94	3.6	5.9	Sheet	300	0.080	A	Fly Ash		2.2	Shallow	111	0.190	P	Paved		0.2

TABLE 2
BASIN HYDRAULIC PARAMETER SUMMARY TABLE

GRE CCS Vertical Expansion
Contact Water Calculations - Part B
Project Number: 113-81519

Subbasin ID	Subbasin Area (sq mile)	Composite Curve Number	Flow Segment 3							Flow Segment 4						
			Type of Flow	Length (ft)	Slope (ft/ft)	Roughness Condition ⁽¹⁾		Typical Hydraulic Radius (Channel Only) (ft)	Travel Time (min)	Type of Flow	Length (ft)	Slope (ft/ft)	Roughness Condition ⁽¹⁾		Typical Hydraulic Radius (Channel Only) (ft)	Travel Time (min)
A	0.0146	94	Channel	1694	0.001	C	Concrete	0.52	11.1							
B	0.0174	94	Channel	2209	0.001	C	Concrete	0.54	14.2							
C	0.0875	94	Shallow	606	0.160	P	Paved		1.2							
D	0.0062	94	Channel	6	0.001	C	Concrete	0.68	0.0							
E	0.0060	94	Shallow	101	0.150	P	Paved		0.2	Channel	395	0.001	C	Concrete	0.99	1.7
F	0.0096	94	Channel	797	0.001	C	Concrete	0.94	3.5							

TABLE 3
FLOW RESULTS FROM HEC-HMS

GRE CCS Vertical Expansion
Contact Water Calculations - Part B
Project No.: 113-81519

HEC-HMS Basin Model:	GRE Landfill 1		
HEC-HMS Met. Model:	USE 25yr 24hr		
HEC-HMS Control Specs:	36hr 5min		

Hydrologic Element	Drainage Area (sq mile)	Peak Discharge (cfs)	Time of Peak	Total Volume (ac-ft)
A	0.0146	32.6	01Jan2050, 13:00	2.4
B	0.0174	35.6	01Jan2050, 13:05	2.9
C	0.0875	232.9	01Jan2050, 12:55	14.4
D	0.0062	16.5	01Jan2050, 12:55	1
E	0.006	16	01Jan2050, 12:55	1
F	0.0096	25.6	01Jan2050, 12:55	1.6
J-AC	0.1021	258.1	01Jan2050, 12:55	16.8
J-BD	0.0236	49.4	01Jan2050, 13:00	3.9
J-DF	0.0332	68.3	01Jan2050, 13:00	5.4
J-EF	0.0392	78	01Jan2050, 13:00	6.4
R-B1	0.0174	35.6	01Jan2050, 13:05	2.9
R-D1	0.0236	46.5	01Jan2050, 13:05	3.9
R-F1	0.0332	63.7	01Jan2050, 13:00	5.4
Sink	0.1413	321.8	01Jan2050, 12:55	23.2

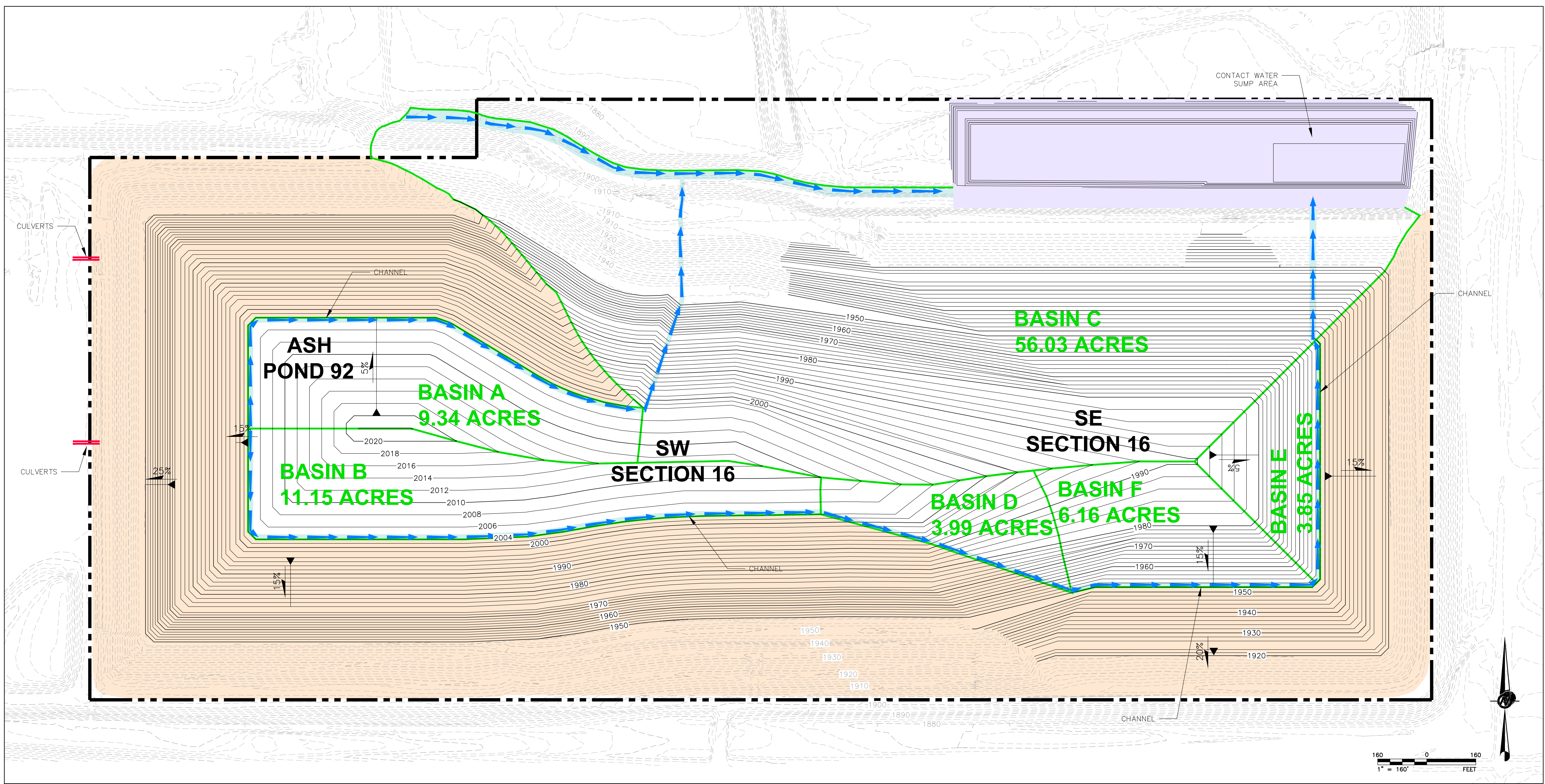
TABLE 4
CHANNEL HYDRAULIC CALCULATIONS

GRE CCS Vertical Expansion
Contact Water Calculations - Part B
Project No.: 113-81519

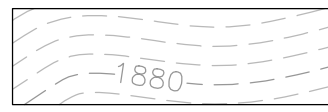
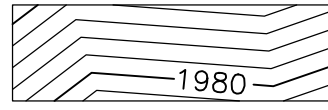
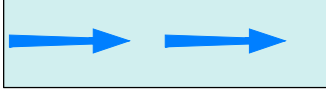
			Channel Design Geometry					Channel Roughness Parameters			Hydraulic Calculations							Channel Evaluation
Reach Designation	Q25 from HEC-HMS (cfs)	HEC HMS Element ID for Q	Bed Slope (ft/ft)	Left Side Slope (H:1V)	Right Side Slope (H:1V)	Bottom Width (ft)	Minimum Channel Depth (ft)	Design Channel Lining	Mannings 'n' for Capacity (Depth Calculation)	Mannings 'n' for Stability (Velocity Calculation)	Maximum Velocity (ft/sec)	Maximum Normal Flow Depth (ft)	Froude Number	Normal Depth Shear Stress (lb/ft ²)	Stream Power (W/m ²)	Top Width of Flow (ft)	Top Width of Channel (ft)	Available Freeboard (ft)
Perimeter Channels																		
R-A	32.6	A	0.001	3.0	20.0	0	2.0	C Concrete	0.012	0.011	2.5	1.05	0.62	0.07	2.43	24.3	46.0	0.9
R-B	35.6	B	0.001	20.0	3.0	0	2.0	C Concrete	0.012	0.011	2.6	1.09	0.62	0.07	2.57	25.1	46.0	0.9
R-D	49.4	J-BD	0.060	6.3	3.0	0	3.0	C Concrete	0.012	0.011	16.3	0.81	4.53	3.02	715.19	7.5	27.9	2.2
R-F	68.3	J-DF	0.001	6.7	3.0	0	3.0	C Concrete	0.012	0.011	3.8	1.93	0.68	0.12	6.60	18.7	29.1	1.1
R-E	78.0	J-EF	0.001	6.7	3.0	0	3.0	C Concrete	0.012	0.011	3.9	2.03	0.68	0.13	7.17	19.7	29.1	1.0

FIGURES

Drawing File: J:\11085\113-81519 GRE\WORK Permit Modification\Appendix C\3-Contact Water\Contact Water B Final.dwg | Layout: CONTACT WATER B | Final.dwg | Layout: CONTACT WATER B | Modified: Oct 26, 2012 09:11 | Lsberry | Plotted: 11/28/12 12:28pm | C:\shwettler

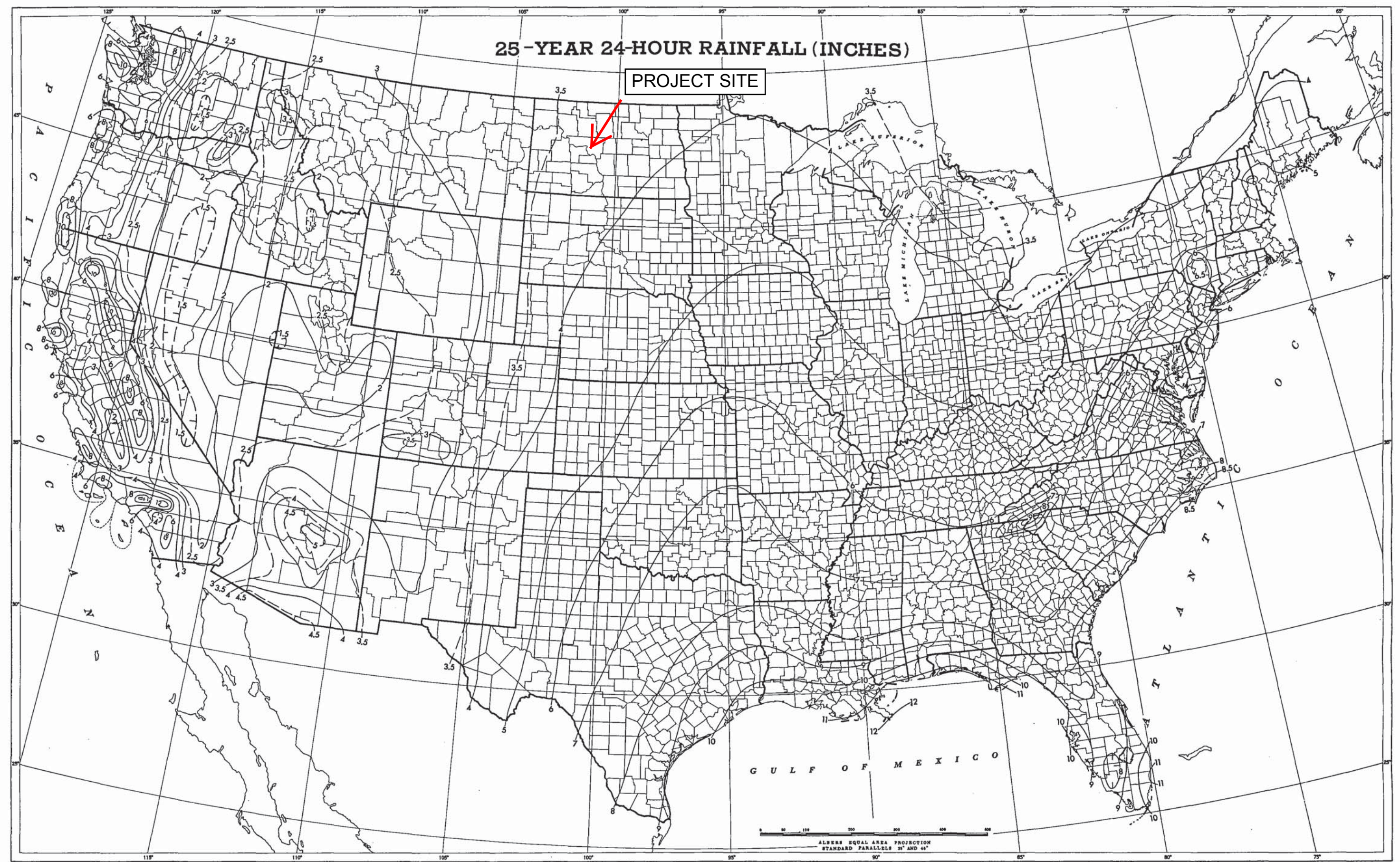


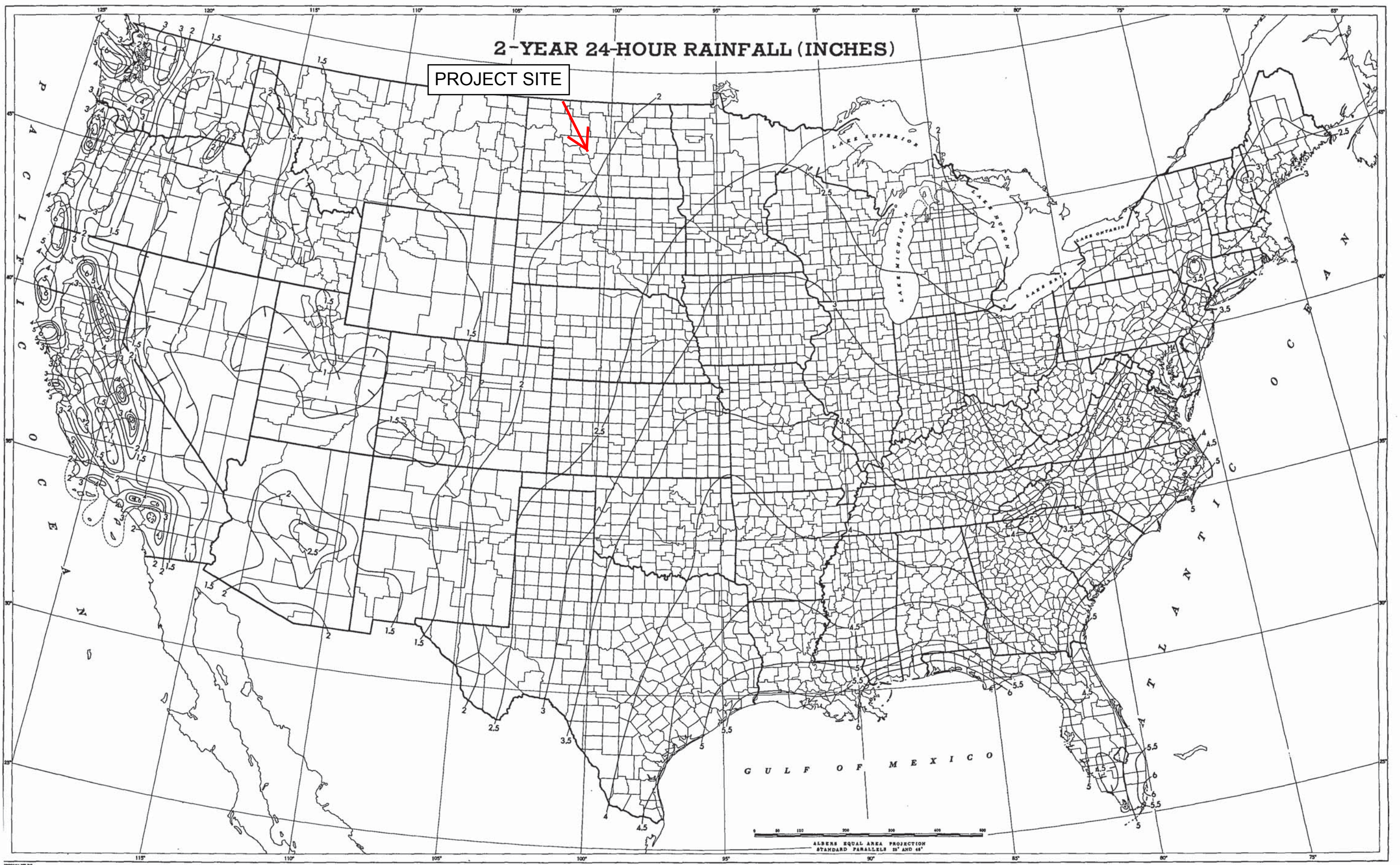
LEGEND

- | | | | |
|---|---|--|-------------------------------|
|  | EXISTING GROUND TOPOGRAPHY |  | CULVERTS |
|  | PROPOSED TOP OF COVER |  | CONTACT WATER CONTROL DITCH |
|  | BASIN DELINEATION |  | CONTACT WATER CONTROL CHANNEL |
|  | PERMITTED LIMIT OF CCP PLACEMENT
(PERMIT MODIFICATION ISSUED 09/24/03) |  | TEMPORARY/FINAL COVER PLACED |



ATTACHMENT A
RAINFALL FREQUENCY ATLAS (TP-40)
25-YEAR, 24-HOUR RAINFALL AND
2-YEAR, 24-HOUR RAINFALL





ATTACHMENT B
TIME OF CONCENTRATION CALCULATION EQUATIONS AND COEFFICIENTS

TR-55 (1986)**Sheet Flow Travel time (SCS Upland Method)**

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

Where: T_t = travel time (hr); 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 n	Surface Description	Short Description
Sheet/Overland Flow	A	0.011	Fly Ash	Fly Ash
	B	0.05	Fallow (no residue)	Fallow
	C	0.06	Cultivated soils: Residue cover <= 20%	Cover<20%
	D	0.17	Cultivated soils: Residue cover > 20%	Cover>20%
	E	0.15	Grass: Short grass prairie	Short Grass
	F	0.24	Grass: Dense grasses	Dense Grass
	G	0.41	Grass: Bermuda grass	Bermuda Grass
	H	0.13	Range (natural)	Range
	I	0.40	Woods: Light underbrush	Light woods
	J	0.80	Woods: Heavy underbrush	Heavy Woods

Shallow Concentrated Flow Velocity (SCS Upland Method)

$$v = mS^{0.5}$$

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

Flow Type	Surface Type	Roughness m	Surface Description	Short Description
Shallow Conc. Flow	P	20.3282	Paved Surfaces	Paved
	U	16.1345	Unpaved Surfaces	Unpaved

Channel Flow Velocity (Mannings Velocity)

$$v = 1.49/n R_h^{2/3} S^{1/2}$$

Where: v = velocity (fps); n = roughness coefficient; R_h = Hydraulic Radius (ft), S = slope (ft/ft)

Lining Type	Mannings n for Depth	Mannings n for Velocity	Material	Maximum Velocity	Maximum Shear Stress
A	0.026	0.026	ACB	25	
C	0.012	0.011	Concrete	50	
E	0.025	0.022	Earth-lined	3	
G	0.035	0.030	Grass-lined	5	
I	0.017	0.013	Ductile Iron	50	
P	0.012	0.009	Plastic	25	
R	0.040	0.035	Riprap	16	
T	0.035	0.030	Turf Reinf.	10	1.5
Z	0.058	0.026	Flexamat	19	24

ATTACHMENT C
HEC-HMS SCREEN CAPTURES AND INPUTS



Sub Basin Area	
Subbasin	Area (mi ²)
A	0.0146
B	0.0174
C	0.0875
D	0.0062
E	0.006
F	0.0096

Loss			
Subbasin	Initial Abstraction (in)	Curve Number	Impervious (%)
A		94	0
B		94	0
C		94	0
D		94	0
E		94	0
F		94	0

Transform	
Subbasin	Lag Time (min)
A	8.4
B	10.2
C	3.6
D	3.6
E	3.6
F	3.6

Reaches								
Reach	Length (ft)	Slope (ft/ft)	Manning's n	Subreaches	Shape	Diameter (ft)	Width (ft)	Side slope (xH:1V)
R-B1	265	0.060	0.01	2	Triangle			3
R-D1	797	0.001	0.01	2	Triangle			3
R-F1	790	0.001	0.01	2	Triangle			3

APPENDIX B

**Surface Water Controls
Calculations**

APPENDIX B1

**Upstream Raise 92 Surface Water
Controls Calculations**



Subject
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1.0 OBJECTIVE

Determine the size of terrace channels, down-chute channels and hydraulic jump basins needed to convey the design storm event.

2.0 METHOD

Golder delineated subbasins for the proposed surface water control system based on planned and existing topography, shown in Figure 1. Times of concentration were calculated using the methodology described in TR-55 (U. S. Soil Conservation Service, 1986) for sheet and shallow concentrated flow and Manning's equation for channel flow. Using the HEC-HMS modeling software (U.S. Army Corps of Engineers Hydrologic Engineering Center, 2010), determine the routing of surface runoff from the final cover system and the peak flows that will occur in each runoff channel. Peak flows are used to size the channels, assuming normal depths, as well as determine the required channel lining based on the maximum velocity in the channels.

North Dakota Department of Environmental Quality

3.0 ASSUMPTIONS

- North Dakota Department of Health regulations do not specify a design storm event for the evaluation of final cover surface water controls. A design storm event of 4.75 inches was used in this analysis. This event is the 24-hour, 100-year storm event from the "Rainfall Frequency Atlas of the United States" (Hershfield, 1961). The atlas section relevant to North Dakota is included in Attachment A.
- The 2-year, 24-hour storm depth, which is used in the TR-55 time of concentration method, is 1.9 inches (Hershfield, 1961). The relevant "Rainfall Frequency Atlas of the United States" section is included in Attachment A.
- The design storm is distributed in time as an SCS Type II synthetic distribution.
- Lag time is equal to 60% of the time of concentration.
- The minimum lag time is 3.6 minutes (a time of concentration of 6 minutes per TR-55).
- Calculation time interval is 5 minutes.
- Maximum length of sheet flow is 300 feet.
- An SCS curve number of 81 was assumed for all sub-basins, reflecting fair coverage of prairie grasses.
- An overland flow surface roughness of 0.15 was assumed for short grass prairie cover (Attachment B).
- A shallow concentrated flow coefficient of 16.13 was assumed for the unpaved surface of the raise (Attachment B) to reflect vegetative cover.
- A Manning roughness coefficient of 0.035 (for capacity) was assumed for grass lined channels and a Manning roughness coefficient of 0.026 was assumed for articulated concrete block lined channels (Attachment C).



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4.0 CALCULATIONS

Hydraulic parameters for the basins (Tables 1 and 2) were entered into the HEC-HMS modeling software and routed to calculate peak flows for each basin and channel (Table 3). Peak flows were used to size channels and determine the appropriate channel linings.

Output from the HEC-HMS modeling, channel sizing calculations (Table 4), and hydraulic jump basin sizing are attached (Table 5). Additionally, the HEC-HMS model and model inputs are included as Attachment C.

5.0 RESULTS/CONCLUSIONS

Individual terrace channel reaches are summarized in Table 4, with peak flows, depths and velocities associated with the design storm event. Terrace channels will be grass lined v-notch channels with outside slopes of 3H:1V, inside slopes from 20H:1V to 4H:1V and approximately 24 inches deep.

The down-chute and outlet channel reaches are also summarized in Table 4, with peak flows, depths and velocities associated with the design storm event. The down-chute and outlet channels are trapezoidal with 3H:1V side slopes, a 10 to 16-foot wide bottom and 2.0 foot depth. These channels will be lined with articulated concrete block such as Tri-lock. Special attention must be given to the installation of this lining to prevent the creation of erosion pathways at the interfaces between terrace channels and down-chute channels.

At the end of the outlet channels, the slope changes from 25 – 50% to 0% and hydraulic jump basin are required to dissipate energy. The minimum hydraulic jump length is summarized in Table 5 and ranges from approximately 5 to 14 feet. The length of the hydraulic jump basins will be set at approximately twice the minimum required length (10 to 25 feet). The hydraulic jump basin will be constructed of articulated concrete block or a concrete slab. After the hydraulic jump basin, the existing grass-lined channels will convey the water further from the site.

6.0 REFERENCES

- Hershfield, D. M. (1961). Rainfall Frequency Atlas of the United States for Durations from 30 Minutes to 24 Hours and Return Periods from 1 to 100 Years. U.S. Department of Agriculture, Soil Conservation Service. Washington D. C.: U.S. Government Printing Office.
- U. S. Soil Conservation Service. (1986). Urban hydrology for small watersheds. Washington D. C.: United States Department of Agriculture.
- U.S. Army Corps of Engineers Hydrologic Engineering Center. (2010, August 10). Hydrologic Modeling System (HEC-HMS). (3.5). Davis, California, USA: U.S. Army Corps of Engineers.

TABLES

TABLE 1
SUBBASIN SUMMARY TABLE

GRE CCS Vertical Expansion
Surface Water Calculations
Project No.: 113-81519

Design Storm				100 -Year Reccurence Interval							
Storm Duration (hours)	2-Year Depth (inches)	100 -Year Depth (inches)	Storm Distribution								
24	1.9	4.8	II								

Subbasin ID	Subbasin Area (ft ²)	Subbasin Area (acres)	Subbasin Area (sq mile)	CN = 81 Fair Coverage of Prairie Grasses	CN = 88 Crop Residue, Good cover, HSG C (acres)	CN = 98 Pond Area (acres)	Composite SCS Curve No.	$S = \frac{1000}{10 - CN}$	Unit Runoff Q (in)	Runoff Volume (ac-ft)	Runoff Volume (ft ³)
A1	73,654	1.69	0.0026	1.69			CN = 81	2.35	2.77	0.39	16,974
A2	77,949	1.79	0.0028	1.79			CN = 81	2.35	2.77	0.41	17,964
A3	76,991	1.77	0.0028	1.77			CN = 81	2.35	2.77	0.41	17,743
A4	95,118	2.18	0.0034	2.18			CN = 81	2.35	2.77	0.50	21,921
A5	49,243	1.13	0.0018	1.13			CN = 81	2.35	2.77	0.26	11,349
B1	73,616	1.69	0.0026	1.69			CN = 81	2.35	2.77	0.39	16,966
B2	77,951	1.79	0.0028	1.79			CN = 81	2.35	2.77	0.41	17,965
B3	76,992	1.77	0.0028	1.77			CN = 81	2.35	2.77	0.41	17,744
B4	95,119	2.18	0.0034	2.18			CN = 81	2.35	2.77	0.50	21,921
B5	53,850	1.24	0.0019	1.24			CN = 81	2.35	2.77	0.28	12,410
C1	182,215	4.18	0.0065	4.18			CN = 81	2.35	2.77	0.96	41,993
C2	131,242	3.01	0.0047	3.01			CN = 81	2.35	2.77	0.69	30,246
C3	117,779	2.70	0.0042	2.70			CN = 81	2.35	2.77	0.62	27,143
C4	139,243	3.20	0.0050	3.20			CN = 81	2.35	2.77	0.74	32,090
C5	73,559	1.69	0.0026	1.69			CN = 81	2.35	2.77	0.39	16,952
D1	197,768	4.54	0.0071	4.54			CN = 81	2.35	2.77	1.05	45,578
D2	139,385	3.20	0.0050	3.20			CN = 81	2.35	2.77	0.74	32,123
D3	120,288	2.76	0.0043	2.76			CN = 81	2.35	2.77	0.64	27,722
D4	153,861	3.53	0.0055	3.53			CN = 81	2.35	2.77	0.81	35,459
D5	79,981	1.84	0.0029	1.84			CN = 81	2.35	2.77	0.42	18,432
E1	179,071	4.11	0.0064	4.11			CN = 81	2.35	2.77	0.95	41,269
E2	196,107	4.50	0.0070	4.50			CN = 81	2.35	2.77	1.04	45,195
E3	152,086	3.49	0.0055	3.49			CN = 81	2.35	2.77	0.80	35,050
E4	134,461	3.09	0.0048	3.09			CN = 81	2.35	2.77	0.71	30,988
E5	118,786	2.73	0.0043	2.73			CN = 81	2.35	2.77	0.63	27,375
F1	160,860	3.69	0.0058	3.69			CN = 81	2.35	2.77	0.85	37,072
F2	181,429	4.17	0.0065	4.17			CN = 81	2.35	2.77	0.96	41,812
F3	140,421	3.22	0.0050	3.22			CN = 81	2.35	2.77	0.74	32,361
F4	97,316	2.23	0.0035	2.23			CN = 81	2.35	2.77	0.51	22,427
F5	58,391	1.34	0.0021	1.34			CN = 81	2.35	2.77	0.31	13,457
F6	43,963	1.01	0.0016	1.01			CN = 81	2.35	2.77	0.23	10,132

**GRE CCS Vertical Expansion
Surface Water Calculations
Project No.: 113-81519**

Design Storm		100 -Year Reccurence Interval	
Storm Duration (hours)	2-Year Depth (inches)	100 -Year Depth (inches)	Storm Distribution
24	1.9	4.8	II

Subbasin ID	Subbasin Area (ft ²)	Subbasin Area (acres)	Subbasin Area (sq mile)	CN = 81	CN = 88	CN = 98	Composite SCS Curve No.	S = $\frac{1000}{10 \text{ CN}}$	Unit Runoff Q (in)	Runoff Volume (ac-ft)	Runoff Volume (ft ³)
				Fair Coverage of Prairie Grasses	Crop Residue, Good cover, HSG C (acres)	Pond Area (acres)					
G1	66,969	1.54	0.0024	1.54			CN = 81	2.35	2.77	0.35	15,434
G2	235,626	5.41	0.0085	5.41			CN = 81	2.35	2.77	1.25	54,302
G3	143,838	3.30	0.0052	3.30			CN = 81	2.35	2.77	0.76	33,149
G4	150,092	3.45	0.0054	3.45			CN = 81	2.35	2.77	0.79	34,590
G5	157,941	3.63	0.0057	3.63			CN = 81	2.35	2.77	0.84	36,399
G6	98,131	2.25	0.0035	2.25			CN = 81	2.35	2.77	0.52	22,615
H1	64,133	1.47	0.0023	1.47			CN = 81	2.35	2.77	0.34	14,780
H2	171,029	3.93	0.0061	3.93			CN = 81	2.35	2.77	0.90	39,415
H3	133,219	3.06	0.0048	3.06			CN = 81	2.35	2.77	0.70	30,702
H4	92,478	2.12	0.0033	2.12			CN = 81	2.35	2.77	0.49	21,312
H5	64,360	1.48	0.0023	1.48			CN = 81	2.35	2.77	0.34	14,832
H6	55,162	1.27	0.0020	1.27			CN = 81	2.35	2.77	0.29	12,713
H7	31,091	0.71	0.0011	0.71			CN = 81	2.35	2.77	0.16	7,165
I1	262,635	6.03	0.0094	6.03			CN = 81	2.35	2.77	1.39	60,527
I2	152,406	3.50	0.0055	3.50			CN = 81	2.35	2.77	0.81	35,123
I3	148,178	3.40	0.0053	3.40			CN = 81	2.35	2.77	0.78	34,149
I4	106,119	2.44	0.0038	2.44			CN = 81	2.35	2.77	0.56	24,456
J1	262,206	6.02	0.0094	6.02			CN = 81	2.35	2.77	1.39	60,428
J2	178,010	4.09	0.0064	4.09			CN = 81	2.35	2.77	0.94	41,024
J3	181,816	4.17	0.0065	4.17			CN = 81	2.35	2.77	0.96	41,901
J4	95,133	2.18	0.0034	2.18			CN = 81	2.35	2.77	0.50	21,924
K1	76,589	1.76	0.0027	1.76			CN = 81	2.35	2.77	0.41	17,651
K2	80,950	1.86	0.0029	1.86			CN = 81	2.35	2.77	0.43	18,656
K3	89,770	2.06	0.0032	2.06			CN = 81	2.35	2.77	0.47	20,688
K4	40,066	0.92	0.0014	0.92			CN = 81	2.35	2.77	0.21	9,234
L1	76,596	1.76	0.0027	1.76			CN = 81	2.35	2.77	0.41	17,652
L2	80,943	1.86	0.0029	1.86			CN = 81	2.35	2.77	0.43	18,654
L3	92,312	2.12	0.0033	2.12			CN = 81	2.35	2.77	0.49	21,274
L4	39,195	0.90	0.0014	0.90			CN = 81	2.35	2.77	0.21	9,033
M1	123,663	2.84	0.0044	2.84			CN = 81	2.35	2.77	0.65	28,499
M2	215,237	4.94	0.0077	4.94			CN = 81	2.35	2.77	1.14	49,603
Total:	3,446,341	79.12	0.12							18.23	794,242

TABLE 2
SUBBASIN TIME OF CONCENTRATION CALCULATIONS

GRE CCS Vertical Expansion
Surface Water Calculations
Project No.: 113-81519

Subbasin ID	Subbasin Area (sq mile)	Composite Curve Number	Total Lag (0.6*Tc) (min)	Total Travel Time (min)	Flow Segment 1						Flow Segment 2						Flow Segment 3								
					Type of Flow	Length (ft)	Slope (ft/ft)	Roughness Condition ⁽¹⁾	Typical Hydraulic Radius (Channel Only) (ft)	Travel Time (min)	Type of Flow	Length (ft)	Slope (ft/ft)	Roughness Condition ⁽¹⁾	Typical Hydraulic Radius (Channel Only) (ft)	Travel Time (min)	Type of Flow	Length (ft)	Slope (ft/ft)	Roughness Condition ⁽¹⁾	Typical Hydraulic Radius (Channel Only) (ft)	Travel Time (min)			
A1	0.0026	81	14.8	24.6	Sheet	300	0.050	E	Short Grass		21.2	Shallow	46	0.050	U	Unpaved		0.2	Channel	135	0.010	G	Grass-lined	0.24	1.4
A2	0.0028	81	7.8	13.0	Sheet	18	0.050	E	Short Grass		2.2	Sheet	137	0.150	E	Short Grass		7.3	Channel	590	0.020	G	Grass-lined	0.32	3.5
A3	0.0028	81	6.8	11.4	Sheet	92	0.150	E	Short Grass		5.3	Sheet	42	0.250	E	Short Grass		2.3	Channel	701	0.020	G	Grass-lined	0.37	3.8
A4	0.0034	81	5.7	9.6	Sheet	119	0.250	E	Short Grass		5.3	Channel	835	0.020	G	Grass-lined	0.40	4.3							
A5	0.0018	81	5.9	9.9	Sheet	69	0.250	E	Short Grass		3.4	Channel	825	0.010	G	Grass-lined	0.36	6.4							
B1	0.0026	81	14.8	24.6	Sheet	300	0.050	E	Short Grass		21.2	Shallow	46	0.050	U	Unpaved		0.2	Channel	135	0.010	G	Grass-lined	0.24	1.4
B2	0.0028	81	7.8	13.0	Sheet	18	0.050	E	Short Grass		2.2	Sheet	137	0.150	E	Short Grass		7.3	Channel	590	0.020	G	Grass-lined	0.32	3.5
B3	0.0028	81	6.8	11.4	Sheet	92	0.150	E	Short Grass		5.3	Sheet	42	0.250	E	Short Grass		2.3	Channel	701	0.020	G	Grass-lined	0.37	3.8
B4	0.0034	81	5.7	9.6	Sheet	119	0.250	E	Short Grass		5.3	Channel	835	0.020	G	Grass-lined	0.40	4.3							
B5	0.0019	81	5.9	9.9	Sheet	69	0.250	E	Short Grass		3.4	Channel	840	0.010	G	Grass-lined	0.37	6.4							
C1	0.0065	81	15.1	25.2	Sheet	300	0.050	E	Short Grass		21.2	Shallow	12	0.050	U	Unpaved		0.1	Channel	305	0.010	G	Grass-lined	0.33	2.5
C2	0.0047	81	10.4	17.3	Sheet	78	0.050	E	Short Grass		7.2	Sheet	86	0.150	E	Short Grass		5.0	Channel	941	0.020	G	Grass-lined	0.38	5.0
C3	0.0042	81	7.7	12.9	Sheet	130	0.150	E	Short Grass		7.0	Sheet	16	0.250	E	Short Grass		1.1	Channel	972	0.020	G	Grass-lined	0.42	4.8
C4	0.0050	81	7.0	11.7	Sheet	132	0.220	E	Short Grass		6.1	Channel	1197	0.020	G	Grass-lined	0.46	5.6							
C5	0.0026	81	7.4	12.3	Sheet	91	0.250	E	Short Grass		4.3	Channel	1106	0.010	G	Grass-lined	0.40	8.0							
D1	0.0071	81	14.8	24.7	Sheet	300	0.050	E	Short Grass		21.2	Shallow	12	0.050	U	Unpaved		0.1	Channel	160	0.010	G	Grass-lined	0.34	1.3
D2	0.0050	81	11.1	18.5	Sheet	96	0.050	E	Short Grass		8.5	Sheet	85	0.150	E	Short Grass		5.0	Channel	949	0.020	G	Grass-lined	0.38	5.0
D3	0.0043	81	7.9	13.1	Sheet	130	0.150	E	Short Grass		7.0	Sheet	18	0.250	E	Short Grass		1.2	Channel	1002	0.020	G	Grass-lined	0.42	4.9
D4	0.0055	81	6.3	10.4	Sheet	93	0.250	E	Short Grass		4.4	Channel	1337	0.020	G	Grass-lined	0.48	6.1							
D5	0.0029	81	8.1	13.5	Sheet	95	0.250	E	Short Grass		4.4	Channel	1279	0.010	G	Grass-lined	0.42	9.0							
E1	0.0064	81	13.8	23.0	Sheet	232	0.050	E	Short Grass		17.3	Channel	438	0.010	G	Grass-lined	0.34	3.5	Channel	410	0.020	G	Grass-lined	0.38	2.2
E2	0.0070	81	11.7	19.5	Sheet	114	0.050	E	Short Grass		9.8	Sheet	109	0.150	E	Short Grass		6.1	Channel	743	0.020	G	Grass-lined	0.43	3.6
E3	0.0055	81	8.6	14.4	Sheet	134	0.145	E	Short Grass		7.3	Sheet	52	0.130	E	Short Grass		3.6	Channel	758	0.020	G	Grass-lined	0.46	3.5
E4	0.0048	81	7.2	12.0	Sheet	164	0.170	E	Short Grass		8.0	Channel	833	0.020	G	Grass-lined	0.45	4.0							
E5	0.0043	81	5.7	9.5	Sheet	98	0.250	E	Short Grass		4.6	Channel	1024	0.020	G	Grass-lined	0.44	4.9							
F1	0.0058	81	12.1	20.2	Sheet	186	0.050	E	Short Grass		14.5	Channel	443	0.010	G	Grass-lined	0.33	3.6	Channel	414	0.020	G	Grass-lined	0.40	2.1
F2	0.0065	81	11.6	19.4	Sheet	113	0.050	E	Short Grass		9.7	Sheet	96	0.150	E	Short Grass		5.5	Channel	846	0.020	G	Grass-lined	0.42	4.2
F3	0.0050	81	7.9	13.1	Sheet	140	0.150	E	Short Grass		7.4	Sheet	19	0.250	E	Short Grass		1.2	Channel	935	0.020	G	Grass-lined	0.45	4.4
F4	0.0035	81	5.5	9.2	Sheet	115	0.250	E	Short Grass		5.2	Channel	793	0.020	G	Grass-lined	0.41	4.0							
F5	0.0021	81	4.7	7.8	Sheet	63	0.250	E	Short Grass		3.2	Channel	801	0.020	G	Grass-lined	0.34	4.6							
F6	0.0016	81	5.5	9.2	Sheet	47	0.160	E	Short Grass		3.0	Channel	781	0.010	G	Grass-lined	0.35	6.2							
G1	0.0024	81	10.2	17.0	Sheet	163	0.050	E	Short Grass		13.0	Sheet	62	0.150	E	Short Grass		3.9	Channel	13	0.020	G	Grass-lined	0.28	0.1
G2	0.0085	81	13.3	22.2	Sheet	315	0.070	E	Short Grass		19.3	Shallow	15	0.150	U	Unpaved		0.0	Channel	598	0.020	G	Grass-lined	0.43	2.9
G3	0.0052	81	10.7	17.8	Sheet	172	0.100	E	Short Grass		10.3	Sheet	50	0.200	E	Short Grass		2.9	Channel	954	0.020	G	Grass-lined	0.44	4.6
G4	0.0054	81	7.9	13.1	Sheet	156	0.150	E	Short Grass		8.1	Channel	378	0.020	G	Grass-lined	0.41	1.9	Channel	666	0.020	G	Grass-lined	0.46	3.1
G5	0.0057	81	8.5	14.2	Sheet	148	0.150	E	Short Grass		7.8	Sheet	23	0.200	E	Short Grass		1.6	Channel	621	0.020	G	Grass-lined	0.44	3.0
G6	0.0035	81	7.8	13.0	Sheet	115	0.200	E	Short Grass		5.7	Channel	1094	0.010	G	Grass-lined	0.45	7.3							
H1	0.0023	81	9.6	15.9	Sheet	170	0.050	E	Short Grass		13.5	Sheet	35	0.150	E	Short Grass		2.5							
H2	0.0061	81	12.8	21.3	Sheet	185	0.060	E	Short Grass		13.4	Sheet	78	0.140	E	Short Grass		4.8	Channel	618	0.020	G	Grass-lined	0.40	3.1
H3	0.0048	81	10.5	17.5	Sheet	144	0.090	E	Short Grass		9.3	Sheet	61	0.180	E	Short Grass		3.6	Channel	295	0.020	G	Grass-lined	0.41	1.5
H4	0.0033	81	5.9	9.8	Sheet	124	0.200	E	Short Grass		6.0	Channel	729	0.020	G	Grass-lined	0.40	3.7							
H5	0.0023	81	6.0	9.9	Sheet	108	0.200	E	Short Grass		5.4	Channel	809	0.020	G	Grass-lined	0.35	4.6							
H6	0.0020	81	5.2	8.7	Sheet	64	0.180	E	Short Grass		3.7	Channel	856	0.020	G	Grass-lined	0.33	5.0							
H7	0.0011	81	9.0	14.9	Sheet	126	0.230	E	Short Grass		5.8	Channel	1005	0.010	G	Grass-lined	0.28	9.2							
I1	0.0094	81	13.3	22.1	Sheet	254	0.080	E	Short Grass		15.4	Sheet	46	0.150	E	Short Grass		3.1	Shallow	38	0.150	U	Unpaved		0.1
I2	0.0055	81	8.0	13.4	Sheet	156	0.150	E	Short Grass		8.1	Channel	1057	0.020	G	Grass-lined	0.42	5.3							
I3	0.0053	81	8.4	14.1	Sheet	137	0.150	E	Short Grass		7.3	Sheet	19	0.200	E	Short Grass		1.3	Channel	1118	0.020	G	Grass-lined	0.43	5.4
I4	0.0038	81	8.0	13.3	Sheet	115	0.200	E	Short Grass		5.7	Channel	1122	0.010	G	Grass-lined	0.44	7.6							
J1	0.0094	81	15.8	26.3	Sheet	108	0.050	E	Short Grass		9.4	Sheet	165	0.08											



GRE CCS Vertical Expansion
Surface Water Calculations
Project No.: 113-81519

TABLE 2
SUBBASIN TIME OF CONCENTRATION CALCULATIONS

Subbasin ID	Subbasin Area (sq mile)	Composite Curve Number	Flow Segment 4							Flow Segment 5						
			Type of Flow	Length (ft)	Slope (ft/ft)	Roughness Condition ⁽¹⁾		Typical Hydraulic Radius (Channel Only) (ft)	Travel Time (min)	Type of Flow	Length (ft)	Slope (ft/ft)	Roughness Condition ⁽¹⁾		Typical Hydraulic Radius (Channel Only) (ft)	Travel Time (min)
A1	0.0026	81	Channel	275	0.020	G	Grass-lined	0.28	1.8							
A2	0.0028	81														
A3	0.0028	81														
A4	0.0034	81														
A5	0.0018	81														
B1	0.0026	81	Channel	275	0.020	G	Grass-lined	0.28	1.8							
B2	0.0028	81														
B3	0.0028	81														
B4	0.0034	81														
B5	0.0019	81														
C1	0.0065	81	Channel	275	0.020	G	Grass-lined	0.40	1.4							
C2	0.0047	81														
C3	0.0042	81														
C4	0.0050	81														
C5	0.0026	81														
D1	0.0071	81	Channel	420	0.020	G	Grass-lined	0.41	2.1							
D2	0.0050	81														
D3	0.0043	81														
D4	0.0055	81														
D5	0.0029	81														
E1	0.0064	81														
E2	0.0070	81														
E3	0.0055	81														
E4	0.0048	81														
E5	0.0043	81														
F1	0.0058	81														
F2	0.0065	81														
F3	0.0050	81														
F4	0.0035	81														
F5	0.0021	81														
F6	0.0016	81														
G1	0.0024	81														
G2	0.0085	81														
G3	0.0052	81														
G4	0.0054	81														
G5	0.0057	81	Channel	410	0.020	G	Grass-lined	0.46	1.9							
G6	0.0035	81														
H1	0.0023	81														
H2	0.0061	81														
H3	0.0048	81	Channel	633	0.020	G	Grass-lined	0.42	3.1							
H4	0.0033	81														
H5	0.0023	81														
H6	0.0020	81														
H7	0.0011	81														
I1	0.0094	81	Channel	812	0.020	G	Grass-lined	0.50	3.6							
I2	0.0055	81														
I3	0.0053	81														
I4	0.0038	81														
J1	0.0094	81	Shallow	39	0.190	U	Unpaved		0.1	Channel	873.0	0.020	G	Grass-lined	0.46	4.1
J2	0.0064	81														
J3	0.0065	81														
J4	0.0034	81														
K1	0.0027	81	Channel	417	0.020	G	Grass-lined	0.29	2.6							
K2	0.0029	81														
K3	0.0032	81														
K4	0.0014	81														
L1	0.0027	81	Channel	417	0.020	G	Grass-lined	0.29	2.6							
L2	0.0029	81														
L3	0.0033	81														
L4	0.0014	81														
M1	0.0044	81														
M2	0.0077	81														



TABLE 3
FLOW RESULTS FROM HEC-HMS

GRE CCS Vertical Expansion
Surface Water Calculations
Project No.: 113-81519

HEC-HMS Basin Model:	GRE Landfill 1
HEC-HMS Met. Model:	USE 100yr 24hr
HEC-HMS Control Specs:	36hr 5min

Hydrologic Element	Drainage Area (sq mile)	Peak Discharge (cfs)	Time of Peak	Total Volume (ac-ft)
E1	0.0064	11	01Jan2050, 13:05	0.9
G1	0.0024	4.7	01Jan2050, 13:05	0.4
J-E1G1	0.0088	15.6	01Jan2050, 13:05	1.3
G2	0.0085	14.9	01Jan2050, 13:05	1.3
E2	0.007	13.1	01Jan2050, 13:05	1
J-E2G2J1	0.0243	43.7	01Jan2050, 13:05	3.6
E3	0.0055	11.4	01Jan2050, 13:00	0.8
G3	0.0052	10.1	01Jan2050, 13:05	0.8
J-E3G3J2	0.035	64.6	01Jan2050, 13:05	5.2
G4	0.0054	11.6	01Jan2050, 13:00	0.8
E4	0.0048	10.7	01Jan2050, 13:00	0.7
J-E4G4J3	0.0452	84.4	01Jan2050, 13:05	6.7
G5	0.0057	11.8	01Jan2050, 13:00	0.8
E5	0.0043	10.2	01Jan2050, 13:00	0.6
G6	0.0035	7.6	01Jan2050, 13:00	0.5
J-E5G5G6J4	0.0587	109.9	01Jan2050, 13:00	8.7
M1	0.0044	10.3	01Jan2050, 13:00	0.6
J-M1J5	0.0631	120.2	01Jan2050, 13:00	9.3
S-EGM	0.0631	120.2	01Jan2050, 13:00	9.3
F1	0.0058	10.7	01Jan2050, 13:05	0.9
H1	0.0023	4.5	01Jan2050, 13:05	0.3
J-F1H1	0.0081	15.3	01Jan2050, 13:05	1.2
F2	0.0065	12.2	01Jan2050, 13:05	1
H2	0.0061	10.9	01Jan2050, 13:05	0.9
J-F2H2J1	0.0207	38.4	01Jan2050, 13:05	3.1
F3	0.005	10.7	01Jan2050, 13:00	0.7
H3	0.0048	9.3	01Jan2050, 13:05	0.7
J-F3H3J2	0.0305	57.6	01Jan2050, 13:05	4.5
F4	0.0035	8.3	01Jan2050, 13:00	0.5
H4	0.0033	7.8	01Jan2050, 13:00	0.5
J-F4H4J3	0.0373	69.4	01Jan2050, 13:00	5.5
H5	0.0023	5.4	01Jan2050, 13:00	0.3
F5	0.0021	5	01Jan2050, 13:00	0.3
J-F5H5J4	0.0417	79.8	01Jan2050, 13:00	6.2
H6	0.002	4.8	01Jan2050, 13:00	0.3
F6	0.0016	3.8	01Jan2050, 13:00	0.2
H7	0.0011	2.2	01Jan2050, 13:00	0.2
J-F6H6J5	0.0464	90.6	01Jan2050, 13:00	6.8
S-FH	0.0464	90.6	01Jan2050, 13:00	6.8
D1	0.0071	11.6	01Jan2050, 13:10	1
B1	0.0026	4.3	01Jan2050, 13:10	0.4
J-B1D1	0.0097	15.9	01Jan2050, 13:10	1.4
D2	0.005	9.6	01Jan2050, 13:05	0.7
B2	0.0028	6.1	01Jan2050, 13:00	0.4
J-B2D2J1	0.0175	30.8	01Jan2050, 13:05	2.6
D3	0.0043	9.2	01Jan2050, 13:00	0.6
B3	0.0028	6.4	01Jan2050, 13:00	0.4
J-B3D3J2	0.0246	44.5	01Jan2050, 13:05	3.6
D4	0.0055	12.8	01Jan2050, 13:00	0.8
B4	0.0034	8	01Jan2050, 13:00	0.5
D5	0.0029	6.2	01Jan2050, 13:00	0.4
B5	0.0019	4.5	01Jan2050, 13:00	0.3
J-B5D5J4	0.0383	74.3	01Jan2050, 13:00	5.6
S-BD	0.0383	74.3	01Jan2050, 13:00	5.6
C1	0.0065	10.6	01Jan2050, 13:10	1
A1	0.0026	4.3	01Jan2050, 13:10	0.4
J-A1C1	0.0091	14.8	01Jan2050, 13:10	1.3
C2	0.0047	9.1	01Jan2050, 13:05	0.7
A2	0.0028	6.1	01Jan2050, 13:00	0.4
J-A2C2J1	0.0166	29.3	01Jan2050, 13:05	2.4

TABLE 3
FLOW RESULTS FROM HEC-HMS

GRE CCS Vertical Expansion
Surface Water Calculations
Project No.: 113-81519

HEC-HMS Basin Model:	GRE Landfill 1
HEC-HMS Met. Model:	USE 100yr 24hr
HEC-HMS Control Specs:	36hr 5min

Hydrologic Element	Drainage Area (sq mile)	Peak Discharge (cfs)	Time of Peak	Total Volume (ac-ft)
C3	0.0042	9.1	01Jan2050, 13:00	0.6
A3	0.0028	6.4	01Jan2050, 13:00	0.4
J-A3C3J2	0.0236	42.7	01Jan2050, 13:05	3.5
C4	0.005	11.2	01Jan2050, 13:00	0.7
A4	0.0034	8	01Jan2050, 13:00	0.5
C5	0.0026	5.7	01Jan2050, 13:00	0.4
A5	0.0018	4.2	01Jan2050, 13:00	0.3
J-A5C5J4	0.0364	70.9	01Jan2050, 13:00	5.4
S-AC	0.0364	70.9	01Jan2050, 13:00	5.4
J1	0.0094	15.1	01Jan2050, 13:10	1.4
L1	0.0027	4.5	01Jan2050, 13:05	0.4
J-J1L1	0.0121	19.5	01Jan2050, 13:10	1.8
J2	0.0064	14.3	01Jan2050, 13:00	0.9
L2	0.0029	6.6	01Jan2050, 13:00	0.4
J-J2L2J1	0.0214	36.6	01Jan2050, 13:05	3.2
J3	0.0065	14	01Jan2050, 13:00	1
J4	0.0034	7	01Jan2050, 13:00	0.5
L3	0.0033	7.3	01Jan2050, 13:00	0.5
L4	0.0014	3.3	01Jan2050, 13:00	0.2
J-J4L4J3	0.036	67.4	01Jan2050, 13:00	5.3
S-JL	0.036	67.4	01Jan2050, 13:00	5.3
I1	0.0094	16.5	01Jan2050, 13:05	1.4
K1	0.0027	4.5	01Jan2050, 13:05	0.4
J-I1K1	0.0121	21	01Jan2050, 13:05	1.8
I2	0.0055	11.8	01Jan2050, 13:00	0.8
K2	0.0029	6.6	01Jan2050, 13:00	0.4
J-I2K2J1	0.0205	37.2	01Jan2050, 13:05	3
I3	0.0053	11.1	01Jan2050, 13:00	0.8
I4	0.0038	8.1	01Jan2050, 13:00	0.6
K3	0.0032	7.1	01Jan2050, 13:00	0.5
K4	0.0014	3.3	01Jan2050, 13:00	0.2
J-I4K4J3	0.0342	65.2	01Jan2050, 13:00	5
S-IK	0.0342	65.2	01Jan2050, 13:00	5
M2	0.0077	15.1	01Jan2050, 13:05	1.1
S-M2	0.0077	15.1	01Jan2050, 13:05	1.1

TABLE 4
CHANNEL HYDRAULIC CALCULATIONS

GRE CCS Vertical Expansion
Surface Water Calculations
Project No.: 113-81519

Reach Designation	Q100 from HEC-HMS (cfs)	HEC HMS Element ID for Q	Channel Design Geometry					Channel Roughness Parameters			Hydraulic Calculations						Channel Evaluation	
			Bed Slope (ft/ft)	Left Side Slope (H:1V)	Right Side Slope (H:1V)	Bottom Width (ft)	Minimum Channel Depth (ft)	Design Channel Lining		Mannings 'n' for Capacity (Depth Calculation)	Mannings 'n' for Stability (Velocity Calculation)	Maximum Velocity (ft/sec)	Maximum Normal Flow Depth (ft)	Froude Number	Stream Power (W/m²)	Top Width of Flow (ft)	Top Width of Channel (ft)	Available Freeboard (ft)
Terrace Channels																		
RA1	4.3	A1	0.020	3.0	6.7	0	2.0	G	Grass-lined	0.035	0.030	2.6	0.58	0.85	27.52	5.7	19.4	1.4
RA1	4.3	A1	0.010	3.0	20.0	0	2.0	G	Grass-lined	0.035	0.030	1.6	0.48	0.59	7.07	11.0	46.0	1.5
RA2	6.1	A2	0.020	3.0	6.7	0	2.0	G	Grass-lined	0.035	0.030	2.8	0.67	0.87	34.24	6.5	19.4	1.3
RA3	6.4	A3	0.020	3.0	4.0	0	2.0	G	Grass-lined	0.035	0.030	3.1	0.77	0.88	43.09	5.4	14.0	1.2
RA4	8.0	A4	0.020	3.0	4.0	0	2.0	G	Grass-lined	0.035	0.030	3.3	0.84	0.89	49.54	5.8	14.0	1.2
RA5	4.2	A5	0.010	3.0	4.0	0	2.0	G	Grass-lined	0.035	0.030	2.2	0.75	0.62	14.54	5.2	14.0	1.3
RB1	4.3	B1	0.020	6.7	3.0	0	2.0	G	Grass-lined	0.035	0.030	2.6	0.58	0.85	27.52	5.7	19.4	1.4
RB1	4.3	B1	0.010	20.0	3.0	0	2.0	G	Grass-lined	0.035	0.030	1.6	0.48	0.59	7.07	11.0	46.0	1.5
RB2	6.1	B2	0.020	6.7	3.0	0	2.0	G	Grass-lined	0.035	0.030	2.8	0.67	0.87	34.24	6.5	19.4	1.3
RB3	6.4	B3	0.020	4.0	3.0	0	2.0	G	Grass-lined	0.035	0.030	3.1	0.77	0.88	43.09	5.4	14.0	1.2
RB4	8.0	B4	0.020	4.0	3.0	0	2.0	G	Grass-lined	0.035	0.030	3.3	0.84	0.89	49.54	5.8	14.0	1.2
RB5	4.5	B5	0.010	4.0	3.0	0	2.0	G	Grass-lined	0.035	0.030	2.2	0.77	0.62	15.18	5.4	14.0	1.2
RC1	10.6	C1	0.020	6.7	3.0	0	2.0	G	Grass-lined	0.035	0.030	3.3	0.82	0.90	48.36	7.9	19.4	1.2
RC1	10.6	C1	0.010	20.0	3.0	0	2.0	G	Grass-lined	0.035	0.030	2.0	0.67	0.62	12.43	15.4	46.0	1.3
RC2	9.1	C2	0.020	6.7	3.0	0	2.0	G	Grass-lined	0.035	0.030	3.1	0.77	0.89	43.96	7.5	19.4	1.2
RC3	9.1	C3	0.020	4.0	3.0	0	2.0	G	Grass-lined	0.035	0.030	3.4	0.88	0.90	53.69	6.1	14.0	1.1
RC4	11.2	C4	0.020	4.0	3.0	0	2.0	G	Grass-lined	0.035	0.030	3.6	0.95	0.91	61.13	6.6	14.0	1.1
RC5	5.7	C5	0.010	4.0	3.0	0	2.0	G	Grass-lined	0.035	0.030	2.3	0.84	0.63	17.60	5.9	14.0	1.2
RD1	11.6	D1	0.020	3.0	6.7	0	2.0	G	Grass-lined	0.035	0.030	3.3	0.85	0.90	51.16	8.2	19.4	1.2
RD1	11.6	D1	0.010	3.0	20.0	0	2.0	G	Grass-lined	0.035	0.030	2.1	0.69	0.63	13.15	16.0	46.0	1.3
RD2	9.6	D2	0.020	3.0	6.7	0	2.0	G	Grass-lined	0.035	0.030	3.2	0.79	0.89	45.45	7.6	19.4	1.2
RD3	9.2	D3	0.020	3.0	4.0	0	2.0	G	Grass-lined	0.035	0.030	3.4	0.88	0.90	54.06	6.2	14.0	1.1
RD4	12.8	D4	0.020	3.0	4.0	0	2.0	G	Grass-lined	0.035	0.030	3.7	1.00	0.92	66.45	7.0	14.0	1.0
RD5	6.2	D5	0.010	3.0	4.0	0	2.0	G	Grass-lined	0.035	0.030	2.4	0.86	0.64	18.55	6.1	14.0	1.1
RE1	11.0	E1	0.020	3.0	9.0	0	2.0	G	Grass-lined	0.035	0.030	3.1	0.76	0.89	43.39	9.2	24.0	1.2
RE1	11.0	E1	0.010	3.0	20.0	0	2.0	G	Grass-lined	0.035	0.030	2.1	0.68	0.62	12.72	15.7	46.0	1.3
RE2	13.1	E2	0.020	3.0	6.7	0	2.0	G	Grass-lined	0.035	0.030	3.4	0.89	0.91	55.20	8.6	19.4	1.1
RE3	11.4	E3	0.020	3.0	4.0	0	2.0	G	Grass-lined	0.035	0.030	3.6	0.95	0.91	61.81	6.7	14.0	1.0
RE4	10.7	E4	0.020	3.0	4.0	0	2.0	G	Grass-lined	0.035	0.030	3.5	0.93	0.91	59.41	6.5	14.0	1.1
RE5	10.2	E5	0.020	3.0	4.0	0	2.0	G	Grass-lined	0.035	0.030	3.5	0.92	0.91	57.66	6.4	14.0	1.1
RF1	10.7	F1	0.020	6.7	3.0	0	2.0	G	Grass-lined	0.035	0.030	3.3	0.82	0.90	48.64	8.0	19.4	1.2
RF1	10.7	F1	0.010	20.0	3.0	0	2.0	G	Grass-lined	0.035	0.030	2.0	0.67	0.62	12.50	15.5	46.0	1.3
RF2	12.2	F2	0.020	6.7	3.0	0	2.0	G	Grass-lined	0.035	0.030	3.4	0.86	0.91	52.80	8.4	19.4	1.1
RF3	10.7	F3	0.020	4.0	3.0	0	2.0	G	Grass-lined	0.035	0.030	3.5	0.93	0.91	59.41	6.5	14.0	1.1
RF4	8.3	F4	0.020	4.0	3.0	0	2.0	G	Grass-lined	0.035	0.030	3.3	0.85	0.90	50.69	5.9	14.0	1.2
RF5	5.0	F5	0.020	4.0	3.0	0	2.0	G	Grass-lined	0.035	0.030	2.9	0.70	0.87	36.93	4.9	14.0	1.3
RF6	3.8	F6	0.010	4.0	3.0	0	2.0	G	Grass-lined	0.035	0.030	2.1	0.72	0.62	13.66	5.0	14.0	1.3
RG1	4.7	G1	0.020	8.5	3.0	0	2.0	G	Grass-lined	0.035	0.030	2.6	0.57	0.85	26.19	6.5	23.0	1.4
RG1	4.7	G1	0.010	20.0	3.0	0	2.0	G	Grass-lined	0.035	0.030	1.7	0.49	0.59	7.48	11.4	46.0	1.5
RG2	14.9	G2	0.020	8.0	3.0	0	2.0	G	Grass-lined	0.035	0.030	3.5	0.89	0.91	55.36	9.7	22.0	1.1
RG3	10.1	G3	0.020	4.0	3.0	0	2.0	G	Grass-lined	0.035	0.030	3.5	0.91	0.91	57.30	6.4	14.0	1.1
RG4	11.6	G4	0.020	6.7	3.0	0	2.0	G	Grass-lined	0.035	0.030	3.3	0.85	0.90	51.16	8.2	19.4	1.2
RG4	11.6	G4	0.020	4.0	3.0	0	2.0	G	Grass-lined	0.035	0.030	3.6	0.96	0.91	62.48	6.7	14.0	1.0
RG5	11.8	G5	0.020	5.0	3.0	0	2.0	G	Grass-lined	0.035	0.030	3.5	0.92	0.91	58.21	7.3	16.0	1.1
RG5	11.8	G5	0.020	4.0	3.0	0	2.0	G	Grass-lined	0.035	0.030	3.6	0.97	0.92	63.16	6.8	14.0	1.0
RG6	7.6	G6	0.010	4.0	3.0	0	2.0	G	Grass-lined	0.035	0.030	2.5	0.93	0.64	21.06	6.5	14.0	1.1
RH1	4.5	H1	0.020	3.0	6.7	0	2.0	G	Grass-lined	0.035	0.030	2.6	0.59	0.85	28.31	5.8	19.4	1.4
RH1	4.5	H1	0.010	3.0	20.0	0	2.0	G	Grass-lined	0.035	0.030	1.7	0.49	0.59	7.27	11.2	46.0	1.5
RH2	10.9	H2	0.020	3.0	6.7	0	2.0	G	Grass-lined	0.035	0.030	3.3	0.83	0.90	49.21	8.0	19.4	1.2
RH3	9.3	H3	0.020	3.0	5.0	0	2.0	G	Grass-lined	0.035	0.030	3.3	0.84	0.90	50.16	6.7	16.0	1.2
RH3	9.3	H3	0.020	3.0	4.0	0	2.0	G	Grass-lined	0.035	0.030	3.4	0.88	0.90	54.42	6.2	14.0	1.1
RH4	7.8	H4	0.020	3.0	4.0	0	2.0	G	Grass-lined	0.035	0.030	3.3	0.83	0.89	48.76	5.8	14.0	1.2
RH5	5.4	H5	0.020	3.0	4.0	0	2.0	G	Grass-lined	0.035	0.030	3.0	0.72	0.87	38.75	5.0	14.0	1.3
RH6	4.8	H6	0.020	3.0	4.0	0	2.0	G	Grass-lined	0.035	0.030	2.9	0.69	0.87	36.00	4.8	14.0	1.3
RH7	2.2	H7	0.010	3.0	4.0	0	2.0	G	Grass-lined	0.035	0.030	1.8	0.59	0.60	9.71	4.1	14.0	1.4



TABLE 4
CHANNEL HYDRAULIC CALCULATIONS

GRE CCS Vertical Expansion
Surface Water Calculations
Project No.: 113-81519

Reach Designation	Q100 from HEC-HMS (cfs)	HEC HMS Element ID for Q	Channel Design Geometry					Channel Roughness Parameters				Hydraulic Calculations						Channel Evaluation
			Bed Slope (ft/ft)	Left Side Slope (H:1V)	Right Side Slope (H:1V)	Bottom Width (ft)	Minimum Channel Depth (ft)	Design Channel Lining		Mannings 'n' for Capacity (Depth Calculation)	Mannings 'n' for Stability (Velocity Calculation)	Maximum Velocity (ft/sec)	Maximum Normal Flow Depth (ft)	Froude Number	Stream Power (W/m²)	Top Width of Flow (ft)	Top Width of Channel (ft)	Available Freeboard (ft)
Terrace Channels																		
RI1	16.5	I1	0.020	3.0	6.7	0	2.0	G	Grass-lined	0.035	0.030	3.6	0.97	0.92	63.77	9.4	19.4	1.0
RI1	16.5	I1	0.020	3.0	5.0	0	2.0	G	Grass-lined	0.035	0.030	3.8	1.04	0.93	71.78	8.3	16.0	1.0
RI2	11.8	I2	0.020	3.0	6.7	0	2.0	G	Grass-lined	0.035	0.030	3.4	0.85	0.91	51.71	8.3	19.4	1.1
RI3	11.1	I3	0.020	3.0	5.0	0	2.0	G	Grass-lined	0.035	0.030	3.5	0.90	0.91	56.03	7.2	16.0	1.1
RI4	8.1	I4	0.010	3.0	5.0	0	2.0	G	Grass-lined	0.035	0.030	2.5	0.91	0.64	20.20	7.3	16.0	1.1
RJ1	15.1	J1	0.020	6.7	3.0	0	2.0	G	Grass-lined	0.035	0.030	3.6	0.93	0.92	60.33	9.1	19.4	1.1
RJ1	15.1	J1	0.020	5.0	3.0	0	2.0	G	Grass-lined	0.035	0.030	3.7	1.01	0.93	67.91	8.1	16.0	1.0
RJ2	14.3	J2	0.020	6.7	3.0	0	2.0	G	Grass-lined	0.035	0.030	3.5	0.92	0.92	58.31	8.9	19.4	1.1
RJ2	14.3	J2	0.020	5.0	3.0	0	2.0	G	Grass-lined	0.035	0.030	3.7	0.99	0.92	65.64	7.9	16.0	1.0
RJ3	14.0	J3	0.020	5.0	3.0	0	2.0	G	Grass-lined	0.035	0.030	3.7	0.98	0.92	64.78	7.8	16.0	1.0
RJ4	7.0	J4	0.010	5.0	3.0	0	2.0	G	Grass-lined	0.035	0.030	2.4	0.86	0.64	18.44	6.9	16.0	1.1
RK1	4.5	K1	0.020	6.7	3.0	0	2.0	G	Grass-lined	0.035	0.030	2.6	0.59	0.85	28.31	5.8	19.4	1.4
RK2	6.6	K2	0.020	6.7	3.0	0	2.0	G	Grass-lined	0.035	0.030	2.9	0.68	0.87	35.96	6.6	19.4	1.3
RK3	7.1	K3	0.020	5.0	3.0	0	2.0	G	Grass-lined	0.035	0.030	3.1	0.76	0.88	42.38	6.1	16.0	1.2
RK4	3.3	K4	0.010	5.0	3.0	0	2.0	G	Grass-lined	0.035	0.030	2.0	0.65	0.61	11.53	5.2	16.0	1.4
RL1	4.5	L1	0.020	3.0	6.7	0	2.0	G	Grass-lined	0.035	0.030	2.6	0.59	0.85	28.31	5.8	19.4	1.4
RL2	6.6	L2	0.020	3.0	6.7	0	2.0	G	Grass-lined	0.035	0.030	2.9	0.68	0.87	35.96	6.6	19.4	1.3
RL3	7.3	L3	0.020	3.0	5.0	0	2.0	G	Grass-lined	0.035	0.030	3.1	0.77	0.89	43.12	6.1	16.0	1.2
RL4	3.3	L4	0.010	3.0	5.0	0	2.0	G	Grass-lined	0.035	0.030	2.0	0.65	0.61	11.53	5.2	16.0	1.4
RM1	10.3	M1	0.010	3.0	4.0	0	2.0	G	Grass-lined	0.035	0.030	2.7	1.05	0.66	25.47	7.3	14.0	1.0
RM2	15.1	M2	0.010	3.0	3.0	0	2.0	G	Grass-lined	0.035	0.030	3.1	1.28	0.67	35.51	7.7	12.0	0.7
Downchute and Outlet Channels																		
AC DOWN 1	14.8	J-A1C1	0.110	4.0	4.0	10	2.0	A	ACB	0.026	0.026	6.4	0.21	2.55	135.82	11.7	26.0	1.8
AC DOWN 2	29.3	J-A2C2J1	0.180	4.0	4.0	10	2.0	A	ACB	0.026	0.026	9.6	0.27	3.39	430.13	12.2	26.0	1.7
AC DOWN 3	42.7	J-A3C3J2	0.180	4.0	4.0	10	2.0	A	ACB	0.026	0.026	11.0	0.34	3.50	611.96	12.7	26.0	1.7
AC OUT	70.9	J-A5C5J4	0.360	4.0	4.0	12	2.0	A	ACB	0.026	0.026	15.6	0.34	4.96	1729.53	14.7	28.0	1.7
BD DOWN 1	15.9	J-B1D1	0.110	4.0	4.0	10	2.0	A	ACB	0.026	0.026	6.6	0.22	2.56	145.42	11.8	26.0	1.8
BD DOWN 2	30.8	J-B2D2J1	0.180	4.0	4.0	10	2.0	A	ACB	0.026	0.026	9.8	0.28	3.40	450.83	12.3	26.0	1.7
BD DOWN 3	44.5	J-B3D3J2	0.180	4.0	4.0	12	2.0	A	ACB	0.026	0.026	10.6	0.32	3.47	546.51	14.5	28.0	1.7
BD OUT	74.3	J-B5D5J4	0.500	4.0	4.0	12	2.0	A	ACB	0.026	0.026	17.7	0.32	5.79	2534.44	14.5	28.0	1.7
EGM DOWN 1	15.6	J-E1G1	0.150	4.0	4.0	10	2.0	A	ACB	0.026	0.026	7.2	0.20	2.95	196.11	11.6	26.0	1.8
EGM DOWN 2	43.7	J-E2G2J1	0.250	4.0	4.0	10	2.0	A	ACB	0.026	0.026	12.3	0.32	4.08	878.19	12.5	26.0	1.7
EGM DOWN 3	64.6	J-E3G3J2	0.250	4.0	4.0	10	2.0	A	ACB	0.026	0.026	14.1	0.40	4.21	1262.20	13.2	26.0	1.6
EGM DOWN 4	84.4	J-E4G4J3	0.250	4.0	4.0	16	2.0	A	ACB	0.026	0.026	13.6	0.36	4.18	1096.17	18.8	32.0	1.6
EGM OUT 1	109.9	J-E5G5G6J4	0.250	4.0	4.0	16	2.0	A	ACB	0.026	0.026	15.0	0.42	4.28	1408.07	19.3	32.0	1.6
EGM OUT 2	120.2	J-M1J5	0.250	4.0	4.0	16	2.0	A	ACB	0.026	0.026	15.5	0.44	4.32	1532.27	19.5	32.0	1.6
FH DOWN 1	15.3	J-F1H1	0.150	4.0	4.0	10	2.0	A	ACB	0.026	0.026	7.2	0.20	2.94	192.50	11.6	26.0	1.8
FH DOWN 2	38.4	J-F2H2J1	0.250	4.0	4.0	10	2.0	A	ACB	0.026	0.026	11.8	0.29	4.03	778.01	12.3	26.0	1.7
FH DOWN 3	57.6	J-F3H3J2	0.250	4.0	4.0	16	2.0	A	ACB	0.026	0.026	11.8	0.28	4.04	760.64	18.3	32.0	1.7
FH DOWN 4	69.4	J-F4H4J3	0.250	4.0	4.0	16	2.0	A	ACB	0.026	0.026	12.7	0.32	4.11	909.45	18.5	32.0	1.7
FH DOWN 5	79.8	J-F5H5J4	0.250	4.0	4.0	16	2.0	A	ACB	0.026	0.026	13.3	0.34	4.16	1039.18	18.8	32.0	1.7
FH OUT	90.6	J-F6H6J5	0.310	4.0	4.0	16	2.0	A	ACB	0.026	0.026	15.0	0.35	4.64	1461.66	18.8	32.0	1.7
IK DOWN 1	21.0	J-I1K1	0.110	4.0	4.0	10	2.0	A	ACB	0.026	0.026	7.3	0.26	2.63	189.32	12.1	26.0	1.7
IK DOWN 2	37.2	J-I2K2J1	0.140	4.0	4.0	10	2.0	A	ACB	0.026	0.026	9.6	0.34	3.08	415.02	12.7	26.0	1.7
IK OUT	65.2	J-I4K4J3	0.350	4.0	4.0	12	2.0	A	ACB	0.026	0.026	15.0	0.33	4.86	1552.62	14.6	28.0	1.7
JL DOWN 1	19.5	J-J1L1	0.110	4.0	4.0	10	2.0	A	ACB	0.026	0.026	7.1	0.25	2.61	176.51	12.0	26.0	1.8
JL DOWN 2	36.6	J-J2L2J1	0.160	4.0	4.0	10	2.0	A	ACB	0.026	0.026	10.0	0.32	3.27	469.30	12.6	26.0	1.7
JL OUT	67.4	J-J4L4J3	0.320	4.0	4.0	12	2.0	A	ACB	0.026	0.026	14.8	0.34	4.68	1460.75	14.7	28.0	1.7
M OUT	15.1	M2	0.400	4.0	4.0	10	2.0	A	ACB	0.026	0.026	9.7	0.15	4.59	516.39	11.2	26.0	1.9



TABLE 5
HYDRAULIC JUMP (STILLING BASIN) CALCULATIONS

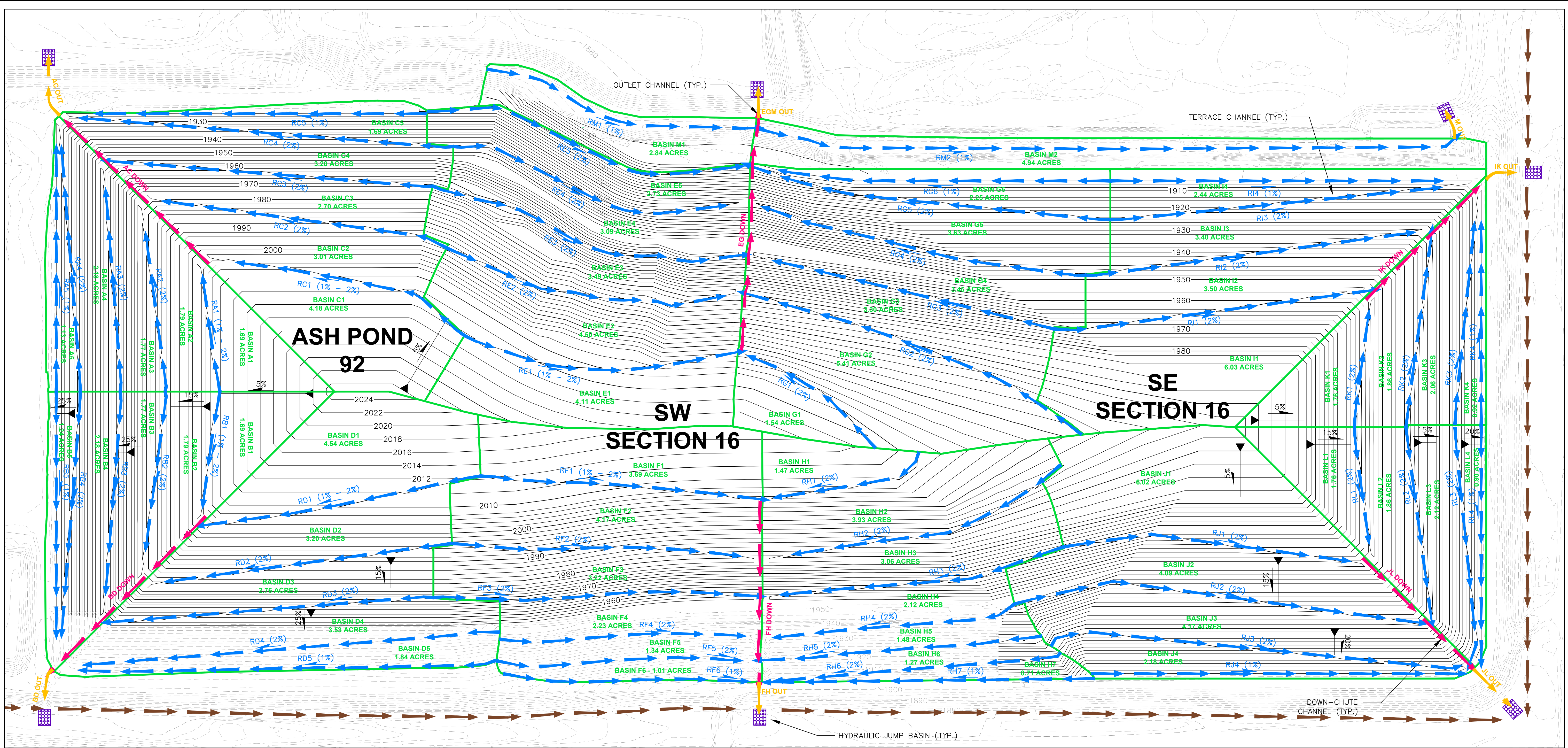
GRE CCS Vertical Expansion
Surface Water Calculations
Project No.: 113-81519

Reach Designation	Q100 from HEC-HMS (cfs)	HEC HMS Element ID for Q	Channel Configuration							Hydraulic Calculations						
			Bed Slope (ft/ft)	Left Side Slope (H:1V)	Right Side Slope (H:1V)	Bottom Width (ft)	Maximum Channel Depth (ft)	Mannings 'n' for Capacity (Depth Calculation)	Mannings 'n' for Stability (Velocity Calculation)	Maximum Velocity (ft/sec)	Maximum Normal Flow Depth (ft)	Normal Depth with Velocity 'n' (ft)	Froude Number	Conjugate Depth (ft)	L/d2 Ratio	Minimum Length of Jump (ft)
AC OUT	70.9	J-A5C5J4	0.36	4	4	12	2	0.026	0.026	15.6	0.34	0.34	4.96	2.11	6.03	12.71
BD OUT	74.3	J-B5D5J4	0.50	4	4	12	2	0.026	0.026	17.7	0.32	0.32	5.79	2.33	6.14	14.28
EGM OUT 2	120.2	J-M1J5	0.25	4	4	16	2	0.026	0.026	15.5	0.44	0.44	4.32	2.34	5.88	13.76
FH OUT	90.6	J-F6H6J5	0.31	4	4	16	2	0.026	0.026	15.0	0.35	0.35	4.64	2.03	5.97	12.13
IK OUT	65.2	J-I4K4J3	0.35	4	4	12	2	0.026	0.026	15.0	0.33	0.33	4.86	1.98	6.01	11.92
JL OUT	67.4	J-J4L4J3	0.32	4	4	12	2	0.026	0.026	14.8	0.34	0.34	4.68	1.99	5.98	11.88
M OUT	15.1	M2	0.40	4	4	10	2	0.026	0.026	9.7	0.15	0.15	4.59	0.86	5.95	5.10



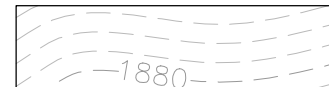
FIGURES

Drawing File: J:\11005\113-81519 GRE\WORK Permit Modification\Appendix C\8-Surface Water\ Raise_SurfaceWater_2011_Final_Drawing.dwg | Layout: 11381519SW02 | Modified: Aug 09, 2012 15:33 | User: j1128712 | 12:21 PM | 12/28/2011



Ash Pond 92 and SW Section 16 are now referred to as Upstream Raise 92,
SE Section 16 is now referred to as Southeast 16 (10/13/2011).

LEGEND

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

GREAT RIVER ENERGY
COAL CREEK STATION
UNDERWOOD, NORTH DAKOTA

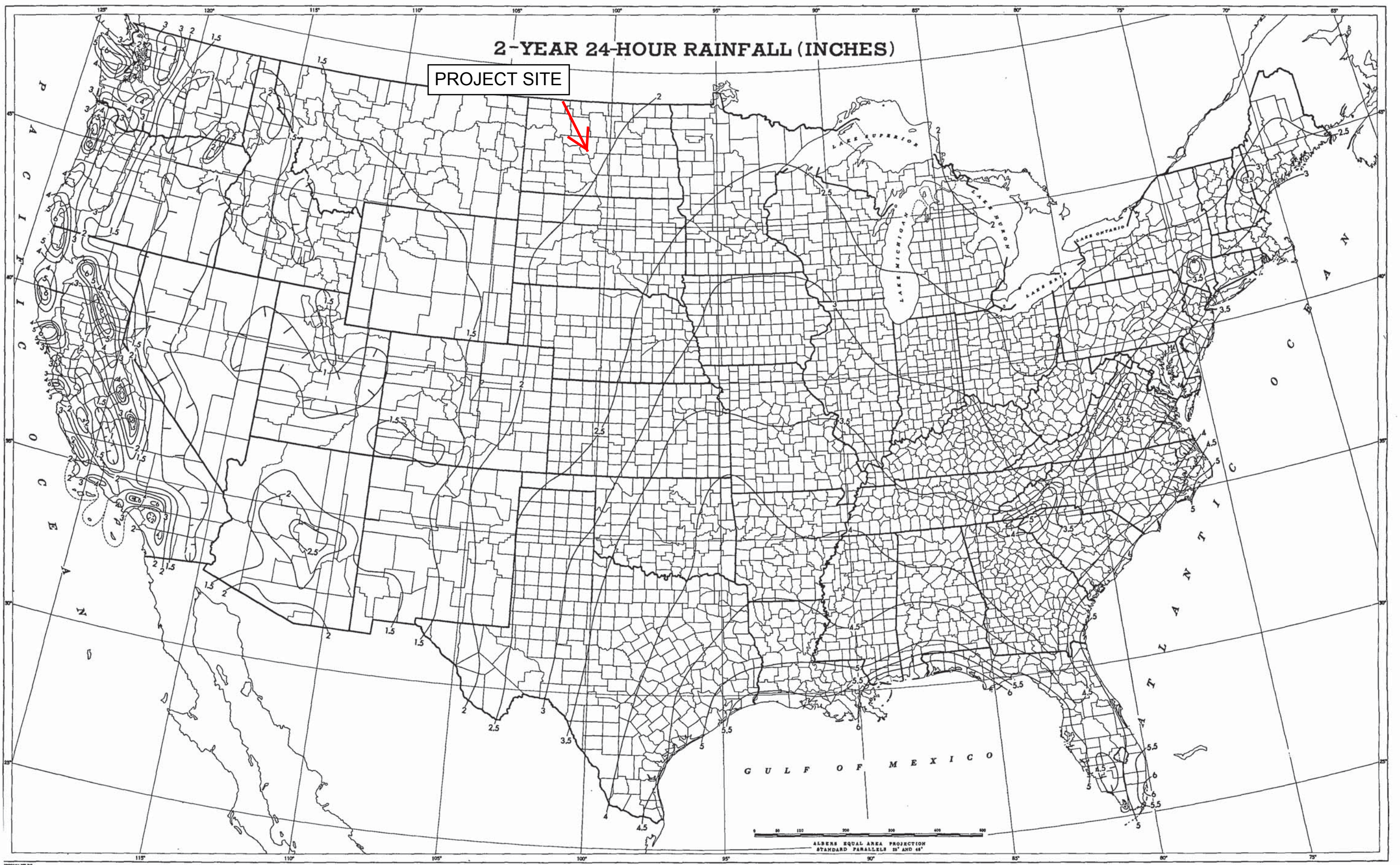
SURFACE WATER BASIN LAYOUT

FIGURE 1



ATTACHMENT A
RAINFALL FREQUENCY ATLAS (TP-40) –
100-YEAR, 24-HOUR RAINFALL AND
2-YEAR, 24-HOUR RAINFALL





ATTACHMENT B
TIME OF CONCENTRATION CALCULATION EQUATIONS AND COEFFICIENTS

TR-55 (1986)**Sheet Flow Travel time (SCS Upland Method)**

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

Where: T_t = travel time (hr); 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 n	Surface Description	Short Description
Sheet/Overland Flow	A	0.011	Fly Ash	Fly Ash
	B	0.05	Fallow (no residue)	Fallow
	C	0.06	Cultivated soils: Residue cover <= 20%	Cover<20%
	D	0.17	Cultivated soils: Residue cover > 20%	Cover>20%
	E	0.15	Grass: Short grass prairie	Short Grass
	F	0.24	Grass: Dense grasses	Dense Grass
	G	0.41	Grass: Bermuda grass	Bermuda Grass
	H	0.13	Range (natural)	Range
	I	0.40	Woods: Light underbrush	Light woods
	J	0.80	Woods: Heavy underbrush	Heavy Woods

Shallow Concentrated Flow Velocity (SCS Upland Method)

$$v = mS^{0.5}$$

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

Flow Type	Surface Type	Roughness m	Surface Description	Short Description
Shallow Conc. Flow	P	20.3282	Paved Surfaces	Paved
	U	16.1345	Unpaved Surfaces	Unpaved

Channel Flow Velocity (Mannings Velocity)

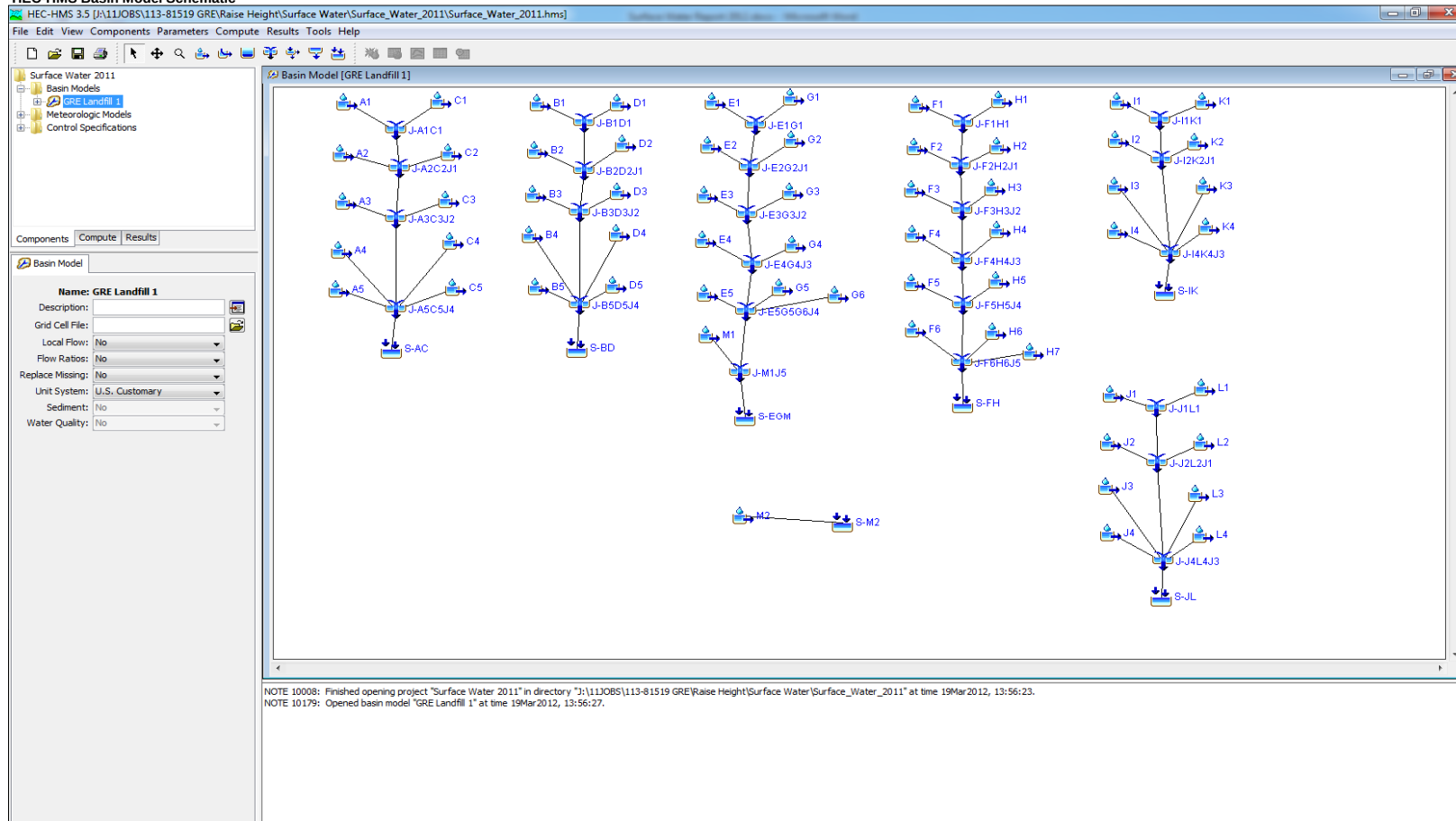
$$v = 1.49/n R_h^{2/3} S^{1/2}$$

Where: v = velocity (fps); n = roughness coefficient; R_h = Hydraulic Radius (ft), S = slope (ft/ft)

Lining Type	Mannings n for Depth	Mannings n for Velocity	Material	Maximum Velocity	Maximum Shear Stress
A	0.026	0.026	ACB	25	
C	0.024	0.022	CSP	50	
E	0.025	0.022	Earth-lined	3	
G	0.035	0.030	Grass-lined	5	
I	0.017	0.013	Ductile Iron	50	
P	0.012	0.009	Plastic	25	
R	0.040	0.035	Riprap	16	
T	0.035	0.030	Turf Reinf.	10	1.5
Z	0.058	0.026	Flexamat	19	24

ATTACHMENT C
HEC-HMS SCREEN CAPTURES AND INPUTS

HEC-HMS Basin Model Schematic



ATTACHMENT C
HEC-HMS SCREEN CAPTURES AND INPUTS

Sub Basin Area	
Subbasin	Area (mi ²)
A1	0.0026
A2	0.0028
A3	0.0028
A4	0.0034
A5	0.0018
B1	0.0026
B2	0.0028
B3	0.0028
B4	0.0034
B5	0.0019
C1	0.0065
C2	0.0047
C3	0.0042
C4	0.005
C5	0.0026
D1	0.0071
D2	0.005
D3	0.0043
D4	0.0055
D5	0.0029
E1	0.0064
E2	0.007
E3	0.0055
E4	0.0048
E5	0.0043
F1	0.0058
F2	0.0065
F3	0.005
F4	0.0035
F5	0.0021
F6	0.0016
G1	0.0024
G2	0.0085
G3	0.0052
G4	0.0054
G5	0.0057
G6	0.0035
H1	0.0023
H2	0.0061
H3	0.0048
H4	0.0033
H5	0.0023
H6	0.002
H7	0.0011
I1	0.0094
I2	0.0055
I3	0.0053
I4	0.0038
J1	0.0094
J2	0.0064
J3	0.0065
J4	0.0034
K1	0.0027
K2	0.0029
K3	0.0032
K4	0.0014
L1	0.0027
L2	0.0029
L3	0.0033
L4	0.0014
M1	0.0044
M2	0.0077

Loss			
Subbasin	Initial Abstraction (in)	Curve Number	Impervious (%)
A1		81	0
A2		81	0
A3		81	0
A4		81	0
A5		81	0
B1		81	0
B2		81	0
B3		81	0
B4		81	0
B5		81	0
C1		81	0
C2		81	0
C3		81	0
C4		81	0
C5		81	0
D1		81	0
D2		81	0
D3		81	0
D4		81	0
D5		81	0
E1		81	0
E2		81	0
E3		81	0
E4		81	0
E5		81	0
F1		81	0
F2		81	0
F3		81	0
F4		81	0
F5		81	0
F6		81	0
G1		81	0
G2		81	0
G3		81	0
G4		81	0
G5		81	0
G6		81	0
H1		81	0
H2		81	0
H3		81	0
H4		81	0
H5		81	0
H6		81	0
H7		81	0
I1		81	0
I2		81	0
I3		81	0
I4		81	0
J1		81	0
J2		81	0
J3		81	0
J4		81	0
K1		81	0
K2		81	0
K3		81	0
K4		81	0
L1		81	0
L2		81	0
L3		81	0
L4		81	0
M1		81	0
M2		81	0

Transform	
Subbasin	Lag Time (min)
A1	14.8
A2	7.8
A3	6.8
A4	5.7
A5	5.9
B1	14.8
B2	7.8
B3	6.8
B4	5.7
B5	5.9
C1	15.1
C2	10.4
C3	7.7
C4	7
C5	7.4
D1	14.8
D2	11.1
D3	7.9
D4	6.3
D5	8.1
E1	13.8
E2	11.7
E3	8.6
E4	7.2
E5	5.7
F1	12.1
F2	11.6
F3	7.9
F4	5.5
F5	4.7
F6	5.5
G1	10.2
G2	13.3
G3	10.7
G4	7.9
G5	8.5
G6	7.8
H1	9.6
H2	12.8
H3	10.5
H4	5.9
H5	6
H6	5.2
H7	9
I1	13.3
I2	8
I3	8.4
I4	8
J1	15.8
J2	7.1
J3	7.8
J4	8.7
K1	14.4
K2	6.9
K3	7.3
K4	6.2
L1	14.4
L2	6.9
L3	7.3
L4	6
M1	6
M2	10

APPENDIX B2

**Upstream Raise 91 Surface Water
Controls Calculations**



Subject GRE – Coal Creek Station
Permit SP-033
Final Cover Surface Water Controls

Made by SCA
Checked by CCS
Approved by TJS

Job No. 1400644
Date 2/17/2015
Sheet No. 1 of 3

1.0 OBJECTIVE

Determine the size of terrace channels, down-chute channels and hydraulic jump basins needed to convey the design storm event.

2.0 METHOD

Golder delineated subbasins for the proposed surface water control system based on the design grades shown in Figure 1. Times of concentration were calculated using the methodology described in TR-55 (U. S. Soil Conservation Service, 1986) for sheet and shallow concentrated flow and Manning's equation for channel flow. Using the HEC-HMS modeling software (U.S. Army Corps of Engineers Hydrologic Engineering Center, 2010), Golder determined the routing of surface runoff from the final cover system and the peak flows that will occur in each runoff channel. Peak flows are used to size the channels, assuming normal depths, as well as determine the required channel lining.

3.0 ASSUMPTIONS

North Dakota Department of Environmental Quality

- North Dakota Department of Health regulations do not specify a design storm event for the evaluation of final cover surface water controls. A design storm event of 4.75 inches was used in this analysis. This event is the 24-hour, 100-year storm event from the "Rainfall Frequency Atlas of the United States" (Hershfield, 1961). The atlas section relevant to North Dakota is included in Attachment A.
- The 2-year, 24-hour storm depth, which is used in the TR-55 time of concentration method, is 1.9 inches (Hershfield, 1961). The relevant "Rainfall Frequency Atlas of the United States" section is included in Attachment A.
- The design storm is distributed in time as an SCS Type II synthetic distribution.
- Lag time is equal to 60% of the time of concentration.
- The minimum lag time is 3.6 minutes (a time of concentration of 6 minutes per TR-55).
- Maximum length of sheet flow is 300 feet.
- An SCS curve number of 81 was assumed for all sub-basins, reflecting fair coverage of prairie grasses.
- An overland flow surface roughness of 0.15 was assumed for short grass prairie cover (Attachment B).
- A shallow concentrated flow coefficient of 16.13 was assumed for the unpaved surface of the raise (Attachment B) to reflect vegetative cover.
- A Manning roughness coefficient of 0.035 (for capacity) was assumed for grass lined channels and a Manning roughness coefficient of 0.026 was assumed for articulated concrete block lined channels (Attachment B).



Subject GRE – Coal Creek Station
Permit SP-033
Final Cover Surface Water Controls

Made by SCA
Checked by CCS
Approved by TJS

Job No. 1400644
Date 2/17/2015
Sheet No. 2 of 3

4.0 CALCULATIONS

Hydraulic parameters for the basins (Tables 1 and 2) were entered into the HEC-HMS modeling software and routed to calculate peak flows for each basin and channel (Table 3). Peak flows were used to size channels and determine the appropriate channel linings.

Output from the HEC-HMS modeling, channel sizing calculations (Table 4), and hydraulic jump basin sizing are attached (Table 5). Additionally, the HEC-HMS model schematic is included as Attachment C.

5.0 RESULTS/CONCLUSIONS

Individual terrace channel reaches are summarized in Table 4, with peak flows, depths and velocities associated with the design storm event. Terrace channels are designed as grass lined v-notch channels with outside slopes of 3H:1V, inside slopes from 20H:1V to 5H:1V, bed slopes of either 1% or 2%, and approximately 24 inches deep.

Perimeter channels are summarized in Table 4, with peak flows, depths and velocities associated with the design storm event. Perimeter channels are designed as grass lined v-notch channels with side slopes of 3H:1V, bed slopes of 1%, and 24 to 30 inches deep.

Channels along the landfill access road are summarized in Table 4, with peak flows, depths and velocities associated with the design storm event. Access road channels are designed as grass or turf-reinforcement mat lined v-notch channels with side slopes of 3H:1V, bed slopes of 7%, and 18 to 24 inches deep.

The down-chute and outlet channel reaches are also summarized in Table 4, with peak flows, depths and velocities associated with the design storm event. The down-chute and outlet channels are designed as trapezoidal with 3H:1V side slopes, a 10 - 12 foot wide bottom and 2.0 foot depth. These channels will be lined with articulated concrete block. Special attention must be given to the installation of this lining to prevent the creation of erosion pathways at the interfaces between terrace channels and down-chute channels.

At the end of the outlet channels, the slope changes from steep to 0% and hydraulic jump basins are required to dissipate energy. The minimum hydraulic jump length is summarized in Table 5 and ranges from approximately 12 to 17 feet. The hydraulic jump basin will be constructed of articulated concrete block or a concrete slab. After the hydraulic jump basin, the existing grass-lined channels will convey the water further from the site.



Subject GRE – Coal Creek Station
Permit SP-033
Final Cover Surface Water Controls

Made by SCA
Checked by CCS
Approved by TJS

Job No. 1400644
Date 2/17/2015
Sheet No. 3 of 3

6.0 REFERENCES

Hershfield, D. M. (1961). *Rainfall Frequency Atlas of the United States for Durations from 30 Minutes to 24 Hours and Return Periods from 1 to 100 Years*. U.S. Department of Agriculture, Soil Conservation Service. Washington D. C.: U.S. Government Printing Office.

U. S. Soil Conservation Service. (1986). *Urban hydrology for small watersheds*. Washington D. C.: United States Department of Agriculture.

U.S. Army Corps of Engineers Hydrologic Engineering Center. (2010, August 10). Hydrologic Modeling System (HEC-HMS). (3.5). Davis, California, USA: U.S. Army Corps of Engineers.

TABLES

**TABLE 1
SUBBASIN SUMMARY TABLE**

GRE CCS AP91

Surface Water Calculations

PROJECT NO.: 1400644

Date:	2/17/15
By:	SCA
Chkd:	CCS
Apprvd:	TJS

Design Storm 100 -Year Reccurence Interval

Storm Duration (hours)	2-Year Depth (inches)	100 -Year Depth (inches)	Storm Distribution
24	1.9	4.8	II

Subbasin ID	Subbasin Area (ft ²)	Subbasin Area (acres)	Subbasin Area (sq mile)	CN = 81	Composite SCS Curve No.	S = $\frac{1000}{10 + CN}$	Unit Runoff Q (in)	Runoff Volume (ac-ft)	Runoff Volume (ft ³)
				Fair Coverage of Prairie Grasses					
C1	258,519	5.93	0.0093	5.93	CN = 81	2.35	2.77	1.37	59,578
C2	131,242	3.01	0.0047	3.01	CN = 81	2.35	2.77	0.69	30,246
C3	117,779	2.70	0.0042	2.70	CN = 81	2.35	2.77	0.62	27,143
C4	139,243	3.20	0.0050	3.20	CN = 81	2.35	2.77	0.74	32,090
C5	73,559	1.69	0.0026	1.69	CN = 81	2.35	2.77	0.39	16,952
D1	271,247	6.23	0.0097	6.23	CN = 81	2.35	2.77	1.44	62,511
D2	139,385	3.20	0.0050	3.20	CN = 81	2.35	2.77	0.74	32,123
D3	120,288	2.76	0.0043	2.76	CN = 81	2.35	2.77	0.64	27,722
D4	153,861	3.53	0.0055	3.53	CN = 81	2.35	2.77	0.81	35,459
D5	79,981	1.84	0.0029	1.84	CN = 81	2.35	2.77	0.42	18,432
N1	286,419	6.58	0.0103	6.58	CN = 81	2.35	2.77	1.52	66,008
N2	228,752	5.25	0.0082	5.25	CN = 81	2.35	2.77	1.21	52,718
N3	169,769	3.90	0.0061	3.90	CN = 81	2.35	2.77	0.90	39,125
N4	191,281	4.39	0.0069	4.39	CN = 81	2.35	2.77	1.01	44,083
N5	71,728	1.65	0.0026	1.65	CN = 81	2.35	2.77	0.38	16,530
O1	167,213	3.84	0.0060	3.84	CN = 81	2.35	2.77	0.88	38,536
O2	136,066	3.12	0.0049	3.12	CN = 81	2.35	2.77	0.72	31,358
O3	131,102	3.01	0.0047	3.01	CN = 81	2.35	2.77	0.69	30,214
O4	132,593	3.04	0.0048	3.04	CN = 81	2.35	2.77	0.70	30,557
O5	83,929	1.93	0.0030	1.93	CN = 81	2.35	2.77	0.44	19,342
P1	100,141	2.30	0.0036	2.30	CN = 81	2.35	2.77	0.53	23,078
P2	118,547	2.72	0.0043	2.72	CN = 81	2.35	2.77	0.63	27,320
P3	98,003	2.25	0.0035	2.25	CN = 81	2.35	2.77	0.52	22,586
P4	50,788	1.17	0.0018	1.17	CN = 81	2.35	2.77	0.27	11,705
P5	21,176	0.49	0.0008	0.49	CN = 81	2.35	2.77	0.11	4,880
Q1	20,030	0.46	0.0007	0.46	CN = 81	2.35	2.77	0.11	4,616
Q2	36,553	0.84	0.0013	0.84	CN = 81	2.35	2.77	0.19	8,424
Q3	58,220	1.34	0.0021	1.34	CN = 81	2.35	2.77	0.31	13,417
Q4	9,875	0.23	0.0004	0.23	CN = 81	2.35	2.77	0.05	2,276
R1	42,789	0.98	0.0015	0.98	CN = 81	2.35	2.77	0.23	9,861
R2	82,703	1.90	0.0030	1.90	CN = 81	2.35	2.77	0.44	19,060
R3	166,849	3.83	0.0060	3.83	CN = 81	2.35	2.77	0.88	38,452
R4	157,044	3.61	0.0056	3.61	CN = 81	2.35	2.77	0.83	36,192
S1	201,021	4.61	0.0072	4.61	CN = 81	2.35	2.77	1.06	46,327
S2	127,294	2.92	0.0046	2.92	CN = 81	2.35	2.77	0.67	29,336
S3	95,455	2.19	0.0034	2.19	CN = 81	2.35	2.77	0.51	21,999
S4	93,785	2.15	0.0034	2.15	CN = 81	2.35	2.77	0.50	21,614
S5	29,555	0.68	0.0011	0.68	CN = 81	2.35	2.77	0.16	6,811
T1	233,770	5.37	0.0084	5.37	CN = 81	2.35	2.77	1.24	53,875
T2	173,480	3.98	0.0062	3.98	CN = 81	2.35	2.77	0.92	39,980
T3	115,429	2.65	0.0041	2.65	CN = 81	2.35	2.77	0.61	26,602
T4	116,073	2.66	0.0042	2.66	CN = 81	2.35	2.77	0.61	26,750
T5	29,295	0.67	0.0011	0.67	CN = 81	2.35	2.77	0.15	6,751

TABLE 2
SUBBASIN TIME OF CONCENTRATION CALCULATIONS

Date:	2/17/15
By:	SCA
Chkd:	CCS
Apprvd:	TJS

Subbasin ID	Subbasin Area (sq mile)	Composite Curve Number	Total Lag (0.6*Tc) (min)	Total Travel Time (min)	Flow Segment 1					Flow Segment 2						Flow Segment 3						Flow Segment 4					
					Type of Flow	Length (ft)	Slope (ft/ft)	Roughness Condition ⁽¹⁾	Travel Time (min)	Type of Flow	Length (ft)	Slope (ft/ft)	Roughness Condition ⁽¹⁾	Typical Hydraulic Radius (Channel Only) (ft)	Travel Time (min)	Type of Flow	Length (ft)	Slope (ft/ft)	Roughness Condition ⁽¹⁾	Typical Hydraulic Radius (Channel Only) (ft)	Travel Time (min)	Type of Flow	Length (ft)	Slope (ft/ft)	Roughness Condition ⁽¹⁾	Typical Hydraulic Radius (Channel Only) (ft)	Travel Time (min)
C1	0.0093	81	14.7	24.6	Sheet	300	0.050	E Short Grass	21.2	Shallow	20	0.050	P Paved		0.1	Channel	281	0.010	G Grass-lined	0.38	2.1	Channel	245	0.020	G Grass-lined	0.45	1.2
C2	0.0047	81	10.4	17.3	Sheet	78	0.050	E Short Grass	7.2	Sheet	86	0.150	E Short Grass		5.0	Channel	941	0.020	G Grass-lined	0.38	5.0						
C3	0.0042	81	7.7	12.9	Sheet	130	0.150	E Short Grass	7.0	Sheet	16	0.250	E Short Grass		1.1	Channel	972	0.020	G Grass-lined	0.42	4.8						
C4	0.0050	81	7.0	11.7	Sheet	132	0.220	E Short Grass	6.1	Channel	1197	0.020	G Grass-lined	0.46	5.6												
C5	0.0026	81	7.4	12.3	Sheet	91	0.250	E Short Grass	4.3	Channel	1106	0.010	G Grass-lined	0.40	8.0												
D1	0.0097	81	14.7	24.6	Sheet	300	0.050	E Short Grass	21.2	Shallow	16	0.050	P Paved		0.1	Channel	279	0.010	G Grass-lined	0.39	2.1	Channel	266	0.020	G Grass-lined	0.46	1.2
D2	0.0050	81	11.1	18.5	Sheet	96	0.050	E Short Grass	8.5	Sheet	85	0.150	E Short Grass		5.0	Channel	949	0.020	G Grass-lined	0.38	5.0						
D3	0.0043	81	7.9	13.1	Sheet	130	0.150	E Short Grass	7.0	Sheet	18	0.250	E Short Grass		1.2	Channel	1002	0.020	G Grass-lined	0.42	4.9						
D4	0.0055	81	6.3	10.4	Sheet	93	0.250	E Short Grass	4.4	Channel	1337	0.020	G Grass-lined	0.48	6.1												
D5	0.0029	81	8.1	13.5	Sheet	95	0.250	E Short Grass	4.4	Channel	1279	0.010	G Grass-lined	0.42	9.0												
N1	0.0103	81	14.2	23.7	Sheet	300	0.050	E Short Grass	21.2	Channel	166	0.010	G Grass-lined	0.40	1.2	Channel	289	0.020	G Grass-lined	0.48	1.3						
N2	0.0082	81	12.3	20.5	Sheet	111	0.050	E Short Grass	9.6	Sheet	125	0.150	E Short Grass		6.8	Channel	884	0.020	G Grass-lined	0.45	4.2						
N3	0.0061	81	7.6	12.7	Sheet	202	0.200	E Short Grass	8.9	Channel	848	0.020	G Grass-lined	0.48	3.8												
N4	0.0069	81	6.8	11.3	Sheet	173	0.200	E Short Grass	7.8	Channel	791	0.020	G Grass-lined	0.51	3.4												
N5	0.0026	81	7.8	13.0	Sheet	122	0.200	E Short Grass	5.9	Channel	971	0.010	G Grass-lined	0.40	7.0												
O1	0.0060	81	12.9	21.6	Sheet	262	0.050	E Short Grass	19.0	Channel	147	0.010	G Grass-lined	0.33	1.2	Channel	257	0.020	G Grass-lined	0.40	1.3						
O2	0.0049	81	10.9	18.2	Sheet	90	0.050	E Short Grass	8.1	Sheet	93	0.150	E Short Grass		5.4	Channel	900	0.020	G Grass-lined	0.38	4.8						
O3	0.0047	81	7.7	12.9	Sheet	189	0.200	E Short Grass	8.4	Channel	934	0.020	G Grass-lined	0.44	4.5												
O4	0.0048	81	6.6	10.9	Sheet	144	0.200	E Short Grass	6.8	Channel	880	0.020	G Grass-lined	0.45	4.2												
O5	0.0030	81	7.6	12.7	Sheet	122	0.200	E Short Grass	5.9	Channel	963	0.010	G Grass-lined	0.42	6.7												
P1	0.0036	81	12.6	21.0	Sheet	267	0.050	E Short Grass	19.3	Channel	313	0.020	G Grass-lined	0.37	1.7												
P2	0.0043	81	8.1	13.5	Sheet	142	0.150	E Short Grass	7.5	Channel	896	0.020	G Grass-lined	0.27	6.0												
P3	0.0035	81	6.9	11.5	Sheet	135	0.150	E Short Grass	7.2	Channel	773	0.020	G Grass-lined	0.36	4.2												
P4	0.0018	81	5.3	8.9	Sheet	135	0.200	E Short Grass	6.4	Channel	415	0.020	G Grass-lined	0.32	2.5												
P5	0.0008	81	4.0	6.7	Sheet	73	0.200	E Short Grass	3.9	Channel	298	0.010	G Grass-lined	0.27	2.8												
Q1	0.0007	81	5.4	9.0	Sheet	146	0.100	E Short Grass	9.0																		
Q2	0.0013	81	4.6	7.7	Sheet	147	0.150	E Short Grass	7.7																		
Q3	0.0021	81	4.1	6.8	Sheet	144	0.200	E Short Grass	6.8																		
Q4	0.0004	81	3.6	2.7	Sheet	46	0.200	E Short Grass	2.7																		
R1	0.0015	81	6.1	10.1	Sheet	199	0.150	E Short Grass	9.8	Channel	44	0.020	G Grass-lined	0.30	0.3												
R2	0.0030	81	5.5	9.1	Sheet	133	0.200	E Short Grass	6.4	Channel	509	0.020	G Grass-lined	0.37	2.7												
R3	0.0060	81	6.8	11.3	Sheet	136	0.200	E Short Grass	6.5	Channel	1046	0.020	G Grass-lined	0.47	4.8												
R4	0.0056	81	9.8	16.3	Sheet	147	0.200	E Short Grass	6.9	Channel	1497	0.010	G Grass-lined	0.49	9.5												
S1	0.0072	81	13.2	22.0	Sheet	300	0.050	E Short Grass	21.2	Shallow	8	0.150	P Paved		0.0	Channel	152	0.020	G Grass-lined	0.42	0.8						
S2	0.0046	81	10.7	17.8	Sheet	83	0.050	E Short Grass	7.6	Sheet	118	0.150	E Short Grass		6.5	Channel	684	0.020	G Grass-lined	0.37	3.7						
S3	0.0034	81	6.9	11.5	Sheet	153	0.150	E Short Grass	8.0	Channel	635	0.020	G Grass-lined	0.35	3.5												
S4	0.0034	81	6.2	10.3	Sheet	159	0.200	E Short Grass	7.3	Channel	568	0.020	G Grass-lined	0.38	3.0												
S5	0.0011	81	5.6	9.3	Sheet	81	0.200	E Short Grass	4.3	Channel	566	0.010	G Grass-lined	0.29	5.1												
T1	0.0084	81	13.6	22.6	Sheet	298	0.050	E Short Grass	21.1	Channel	308	0.020	G Grass-lined	0.44	1.5												
T2	0.0062	81	11.3	18.9	Sheet	101	0.050	E Short Grass	8.9	Sheet	126	0.150	E Short Grass		6.8	Channel	630	0.020	G Grass-lined	0.41	3.2						
T3	0.0041	81	6.9	11.6	Sheet	163	0.150	E Short Grass	8.4	Channel	599	0.020	G Grass-lined	0.38	3.2												
T4	0.0042	81	6.1	10.2	Sheet	172	0.200	E Short Grass	7.8	Channel	481	0.020	G Grass-lined	0.41	2.4												
T5	0.0011	81	5.4	9.0	Sheet	81	0.200	E Short Grass	4.3	Channel	530	0.010	G Grass-lined	0.29	4.7												

TABLE 3 **FLOW RESULTS FROM HEC-HMS**

GRE CCS AP91
Surface Water Calculations
PROJECT NO.: 1400644

Date:	2/17/15
By:	SCA
Chkd:	CCS
Apprvd:	TJS

HEC-HMS Basin Model:	AP91finalcover
HEC-HMS Met. Model:	100 Year, 24 Hour
HEC-HMS Control Specs:	36 Hour, 5 Minute

Hydrologic Element	Drainage Area (sq mile)	Peak Discharge (cfs)	Time of Peak	Total Volume (ac-ft)
N1	0.0103	17.3	01Jan2050, 13:05	1.5
C1	0.0093	15.2	01Jan2050, 13:10	1.4
J-N1C1	0.0196	32.5	01Jan2050, 13:05	2.9
N2	0.0082	15	01Jan2050, 13:05	1.2
C2	0.0047	9.1	01Jan2050, 13:05	0.7
J-N2C2J1	0.0325	56.7	01Jan2050, 13:05	4.8
N3	0.0061	13.3	01Jan2050, 13:00	0.9
C3	0.0042	9.1	01Jan2050, 13:00	0.6
J-N3C3J2	0.0428	76.8	01Jan2050, 13:05	6.3
N4	0.0069	15.7	01Jan2050, 13:00	1
C4	0.005	11.2	01Jan2050, 13:00	0.7
C5	0.0026	5.7	01Jan2050, 13:00	0.4
N5	0.0026	5.6	01Jan2050, 13:00	0.4
J-N5C5J4	0.0599	109.2	01Jan2050, 13:05	8.8
S-NC	0.0599	109.2	01Jan2050, 13:05	8.8
D1	0.0097	15.9	01Jan2050, 13:10	1.4
T1	0.0084	14.5	01Jan2050, 13:05	1.2
J-T1D1	0.0181	30.4	01Jan2050, 13:05	2.7
T2	0.0062	11.8	01Jan2050, 13:05	0.9
D2	0.005	9.6	01Jan2050, 13:05	0.7
J-T2D2J1	0.0293	51.7	01Jan2050, 13:05	4.3
D3	0.0043	9.2	01Jan2050, 13:00	0.6
T3	0.0041	9.3	01Jan2050, 13:00	0.6
J-T3D3J2	0.0377	67.9	01Jan2050, 13:05	5.6
D4	0.0055	12.8	01Jan2050, 13:00	0.8
T4	0.0042	9.8	01Jan2050, 13:00	0.6
D5	0.0029	6.2	01Jan2050, 13:00	0.4
T5	0.0011	2.6	01Jan2050, 13:00	0.2
J-T5D5J4	0.0514	93.7	01Jan2050, 13:00	7.6
S-TD	0.0514	93.7	01Jan2050, 13:00	7.6
O1	0.006	10.7	01Jan2050, 13:05	0.9
P1	0.0036	6.5	01Jan2050, 13:05	0.5
J-O1P1	0.0096	17.2	01Jan2050, 13:05	1.4
O2	0.0049	9.4	01Jan2050, 13:05	0.7
P2	0.0043	9.1	01Jan2050, 13:00	0.6
J-O2P2	0.0188	35.1	01Jan2050, 13:05	2.8

TABLE 3 FLOW RESULTS FROM HEC-HMS

GRE CCS AP91
Surface Water Calculations
PROJECT NO.: 1400644

Date:	2/17/15
By:	SCA
Chkd:	CCS
Apprvd:	TJS

HEC-HMS Basin Model:	AP91finalcover
HEC-HMS Met. Model:	100 Year, 24 Hour
HEC-HMS Control Specs:	36 Hour, 5 Minute

Hydrologic Element	Drainage Area (sq mile)	Peak Discharge (cfs)	Time of Peak	Total Volume (ac-ft)
O3	0.0047	10.2	01Jan2050, 13:00	0.7
P3	0.0035	7.9	01Jan2050, 13:00	0.5
J-O3P3	0.027	50.9	01Jan2050, 13:05	4
O4	0.0048	11	01Jan2050, 13:00	0.7
O5	0.003	6.6	01Jan2050, 13:00	0.4
P4	0.0018	4.3	01Jan2050, 13:00	0.3
J-O5P5	0.0366	72.3	01Jan2050, 13:00	5.4
Q3	0.0021	5	01Jan2050, 13:00	0.3
Q2	0.0013	3.1	01Jan2050, 13:00	0.2
Q1	0.0007	1.7	01Jan2050, 13:00	0.1
J-Q2	0.002	4.8	01Jan2050, 13:00	0.3
J-Q3	0.0041	9.8	01Jan2050, 13:00	0.6
Q4	0.0004	1	01Jan2050, 12:55	0.1
J-Q4	0.0045	10.7	01Jan2050, 13:00	0.7
P5	0.0008	1.9	01Jan2050, 12:55	0.1
J-QP	0.0053	12.6	01Jan2050, 13:00	0.8
J-QOP	0.0419	85	01Jan2050, 13:00	6.2
S-OP	0.0419	85	01Jan2050, 13:00	6.2
S1	0.0072	12.7	01Jan2050, 13:05	1.1
S2	0.0046	8.9	01Jan2050, 13:05	0.7
R1	0.0015	3.5	01Jan2050, 13:00	0.2
J-S1R1S2	0.0133	24.2	01Jan2050, 13:05	2
S3	0.0034	7.7	01Jan2050, 13:00	0.5
R2	0.003	7.1	01Jan2050, 13:00	0.4
J-R2S3	0.0197	37.1	01Jan2050, 13:00	2.9
R3	0.006	13.6	01Jan2050, 13:00	0.9
R4	0.0056	11	01Jan2050, 13:05	0.8
S4	0.0034	7.9	01Jan2050, 13:00	0.5
S5	0.0011	2.6	01Jan2050, 13:00	0.2
J-R4S5	0.0358	71.9	01Jan2050, 13:00	5.3
S-RS	0.0358	71.9	01Jan2050, 13:00	5.3

TABLE 4
CHANNEL HYDRAULIC CALCULATIONS

Date:	2/17/15
By:	SCA
Chkd:	CCS
Apprvd:	TJS

Reach Designation	Q100 from HEC-HMS (cfs)	HEC HMS Element ID for Q	Channel Design Geometry					Channel Roughness Parameters				Hydraulic Calculations					
			Bed Slope (ft/ft)	Left Side Slope (H:1V)	Right Side Slope (H:1V)	Bottom Width (ft)	Minimum Channel Depth (ft)	Design Channel Lining		Mannings 'n' for Capacity (Depth Calculation)	Mannings 'n' for Stability (Velocity Calculation)	Maximum Velocity (ft/sec)	Maximum Normal Flow Depth (ft)	Froude Number	Top Width of Flow (ft)	Top Width of Channel (ft)	Available Freeboard (ft)
Terrace Channels																	
RC1	15.2	C1	0.020	6.7	3.0	0	2.0	G	Grass-lined	0.035	0.030	3.6	0.94	0.92	9.1	19.4	1.1
RC1	15.2	C1	0.010	20.0	3.0	0	2.0	G	Grass-lined	0.035	0.030	2.2	0.77	0.64	17.7	46.0	1.2
RC2	9.1	C2	0.020	6.7	3.0	0	2.0	G	Grass-lined	0.035	0.030	3.1	0.77	0.89	7.5	19.4	1.2
RC3	9.1	C3	0.020	4.0	3.0	0	2.0	G	Grass-lined	0.035	0.030	3.4	0.88	0.90	6.1	14.0	1.1
RC4	11.2	C4	0.020	4.0	3.0	0	2.0	G	Grass-lined	0.035	0.030	3.6	0.95	0.91	6.6	14.0	1.1
RC5	5.7	C5	0.010	4.0	3.0	0	2.0	G	Grass-lined	0.035	0.030	2.3	0.84	0.63	5.9	14.0	1.2
RD1	15.9	D1	0.020	3.0	6.7	0	2.0	G	Grass-lined	0.035	0.030	3.6	0.95	0.92	9.2	19.4	1.0
RD1	15.9	D1	0.010	3.0	20.0	0	2.0	G	Grass-lined	0.035	0.030	2.3	0.78	0.64	18.0	46.0	1.2
RD2	9.6	D2	0.020	3.0	6.7	0	2.0	G	Grass-lined	0.035	0.030	3.2	0.79	0.89	7.6	19.4	1.2
RD3	9.2	D3	0.020	3.0	4.0	0	2.0	G	Grass-lined	0.035	0.030	3.4	0.88	0.90	6.2	14.0	1.1
RD4	12.8	D4	0.020	3.0	4.0	0	2.0	G	Grass-lined	0.035	0.030	3.7	1.00	0.92	7.0	14.0	1.0
RD5	6.2	D5	0.010	3.0	4.0	0	2.0	G	Grass-lined	0.035	0.030	2.4	0.86	0.64	6.1	14.0	1.1
RN1	17.3	N1	0.020	3.0	6.7	0	2.0	G	Grass-lined	0.035	0.030	3.7	0.98	0.93	9.5	19.4	1.0
RN1	17.3	N1	0.010	3.0	20.0	0	2.0	G	Grass-lined	0.035	0.030	2.3	0.81	0.64	18.6	46.0	1.2
RN2	15.0	N2	0.020	3.0	6.7	0	2.0	G	Grass-lined	0.035	0.030	3.6	0.93	0.92	9.0	19.4	1.1
RN3	13.3	N3	0.020	3.0	5.0	0	2.0	G	Grass-lined	0.035	0.030	3.6	0.96	0.92	7.7	16.0	1.0
RN4	15.7	N4	0.020	3.0	5.0	0	2.0	G	Grass-lined	0.035	0.030	3.8	1.02	0.93	8.2	16.0	1.0
RO1	10.7	O1	0.020	6.7	3.0	0	2.0	G	Grass-lined	0.035	0.030	3.3	0.82	0.90	8.0	19.4	1.2
RO1	10.7	O1	0.010	20.0	3.0	0	2.0	G	Grass-lined	0.035	0.030	2.0	0.67	0.62	15.5	46.0	1.3
RO2	9.4	O2	0.020	6.7	3.0	0	2.0	G	Grass-lined	0.035	0.030	3.2	0.78	0.89	7.6	19.4	1.2
RO3	10.2	O3	0.020	5.0	3.0	0	2.0	G	Grass-lined	0.035	0.030	3.4	0.87	0.90	6.9	16.0	1.1
RO4	11.0	O4	0.020	5.0	3.0	0	2.0	G	Grass-lined	0.035	0.030	3.4	0.89	0.91	7.1	16.0	1.1
RP1	6.5	P1	0.020	3.0	6.7	0	2.0	G	Grass-lined	0.035	0.030	2.9	0.68	0.87	6.6	19.4	1.3
RP1	6.5	P1	0.010	3.0	20.0	0	2.0	G	Grass-lined	0.035	0.030	1.8	0.56	0.60	12.9	46.0	1.4
RP2	9.1	P2	0.020	3.0	6.7	0	2.0	G	Grass-lined	0.035	0.030	3.1	0.77	0.89	7.5	19.4	1.2
RP3	7.9	P3	0.020	3.0	5.0	0	2.0	G	Grass-lined	0.035	0.030	3.2	0.79	0.89	6.3	16.0	1.2
RP4	4.3	P4	0.020	3.0	5.0	0	2.0	G	Grass-lined	0.035	0.030	2.7	0.63	0.86	5.0	16.0	1.4
RR1	3.5	R1	0.020	6.7	3.0	0	2.0	G	Grass-lined	0.035	0.030	2.5	0.54	0.84	5.2	19.4	1.5
RR2	7.1	R2	0.020	5.0	3.0	0	2.0	G	Grass-lined	0.035	0.030	3.1	0.76	0.88	6.1	16.0	1.2
RR3	13.6	R3	0.020	5.0	3.0	0	2.0	G	Grass-lined	0.035	0.030	3.6	0.97	0.92	7.7	16.0	1.0
RS1	12.7	S1	0.020	3.0	6.7	0	2.0	G	Grass-lined	0.035	0.030	3.4	0.88	0.91	8.5	19.4	1.1
RS1	12.7	S1	0.010	3.0	20.0	0	2.0	G	Grass-lined	0.035	0.030	2.1	0.72	0.63	16.5	46.0	1.3
RS2	8.9	S2	0.020	3.0	6.7	0	2.0	G	Grass-lined	0.035	0.030	3.1	0.77	0.89	7.4	19.4	1.2
RS3	7.7	S3	0.020	3.0	5.0	0	2.0	G	Grass-lined	0.035	0.030	3.2	0.78	0.89	6.3	16.0	1.2
RS4	7.9	S4	0.020	3.0	5.0	0	2.0	G	Grass-lined	0.035	0.030	3.2	0.79	0.89	6.3	16.0	1.2
RT1	14.5	T1	0.020	6.7	3.0	0	2.0	G	Grass-lined	0.035	0.030	3.5	0.92	0.92	8.9	19.4	1.1
RT1	14.5	T1	0.010	20.0	3.0	0	2.0	G	Grass-lined	0.035	0.030	2.2	0.76	0.63	17.4	46.0	1.2
RT2	11.8	T2	0.020	6.7	3.0	0	2.0	G	Grass-lined	0.035	0.030	3.4	0.85	0.91	8.3	19.4	1.1
RT3	9.3	T3	0.020	5.0	3.0	0	2.0	G	Grass-lined	0.035	0.030	3.3	0.84	0.90	6.7	16.0	1.2
RT4	9.8	T4	0.020	5.0	3.0	0	2.0	G	Grass-lined	0.035	0.030	3.3	0.86	0.90	6.8	16.0	1.1

Note: Side slopes for downchutes measured in line with flow.

TABLE 4
CHANNEL HYDRAULIC CALCULATIONS

Date:	2/17/15
By:	SCA
Chkd:	CCS
Apprvd:	TJS

Reach Designation	Q100 from HEC-HMS (cfs)	HEC HMS Element ID for Q	Channel Design Geometry					Channel Roughness Parameters				Hydraulic Calculations					
			Bed Slope (ft/ft)	Left Side Slope (H:1V)	Right Side Slope (H:1V)	Bottom Width (ft)	Minimum Channel Depth (ft)	Design Channel Lining	Mannings 'n' for Capacity (Depth Calculation)	Mannings 'n' for Stability (Velocity Calculation)	Maximum Velocity (ft/sec)	Maximum Normal Flow Depth (ft)	Froude Number	Top Width of Flow (ft)	Top Width of Channel (ft)	Available Freeboard (ft)	
Downchute and Outlet Channels																	
NC DOWN 1	32.5	J-N1C1	0.110	4.0	4.0	10	2.0	A	ACB	0.026	0.026	8.5	0.34	2.73	12.7	26.0	1.7
NC DOWN 2	56.7	J-N2C2J1	0.180	4.0	4.0	10	2.0	A	ACB	0.026	0.026	12.1	0.40	3.59	13.2	26.0	1.6
NC DOWN 3	76.8	J-N3C3J2	0.180	4.0	4.0	10	2.0	A	ACB	0.026	0.026	13.4	0.48	3.68	13.8	26.0	1.5
NC OUT	109.2	J-N5C5J4	0.360	4.0	4.0	12	2.0	A	ACB	0.026	0.026	18.2	0.44	5.15	15.5	28.0	1.6
OP DOWN 1	17.2	J-O1P1	0.110	4.0	4.0	10	2.0	A	ACB	0.026	0.026	6.8	0.23	2.58	11.9	26.0	1.8
OP DOWN 2	35.1	J-O2P2	0.140	4.0	4.0	10	2.0	A	ACB	0.026	0.026	9.4	0.33	3.07	12.6	26.0	1.7
OP DOWN 3	50.9	J-O3P3	0.140	4.0	4.0	10	2.0	A	ACB	0.026	0.026	10.7	0.41	3.17	13.3	26.0	1.6
OP OUT	85.0	S-OP	0.320	4.0	4.0	12	2.0	A	ACB	0.026	0.026	16.0	0.39	4.78	15.1	28.0	1.6
RS DOWN 1	12.7	S1	0.150	4.0	4.0	10	2.0	A	ACB	0.026	0.026	6.7	0.18	2.89	11.4	26.0	1.8
RS DOWN 2	24.2	J-S1R1S2	0.200	4.0	4.0	10	2.0	A	ACB	0.026	0.026	9.3	0.24	3.50	11.9	26.0	1.8
RS DOWN 3	37.1	J-R2S3	0.200	4.0	4.0	10	2.0	A	ACB	0.026	0.026	10.8	0.31	3.63	12.4	26.0	1.7
RS OUT	71.9	J-R4S5	0.310	4.0	4.0	12	2.0	A	ACB	0.026	0.026	15.0	0.36	4.64	14.9	28.0	1.6
TD DOWN 1	30.4	J-T1D1	0.110	4.0	4.0	10	2.0	A	ACB	0.026	0.026	8.3	0.32	2.71	12.6	26.0	1.7
TD DOWN 2	51.7	J-T2D2J1	0.180	4.0	4.0	10	2.0	A	ACB	0.026	0.026	11.7	0.38	3.56	13.1	26.0	1.6
TD DOWN 3	67.9	J-T3D3J2	0.180	4.0	4.0	12	2.0	A	ACB	0.026	0.026	12.3	0.41	3.60	15.2	28.0	1.6
TD OUT	93.7	J-T5D5J4	0.400	4.0	4.0	12	2.0	A	ACB	0.026	0.026	17.8	0.39	5.33	15.1	28.0	1.6
Perimeter Channels																	
RN5	5.6	N5	0.010	3.0	5.0	0	2.0	G	Grass-lined	0.035	0.030	2.5	0.79	0.73	6.3	16.0	1.2
RO5	6.6	O5	0.010	5.0	3.0	0	2.0	G	Grass-lined	0.035	0.030	2.6	0.84	0.73	6.7	16.0	1.2
RP5	12.6	J-QP	0.010	3.0	5.0	0	2.5	G	Grass-lined	0.035	0.030	3.1	1.07	0.76	8.6	20.0	1.4
RR4	11.0	R4	0.010	5.0	3.0	0	2.5	G	Grass-lined	0.035	0.030	3.0	1.02	0.76	8.1	20.0	1.5
RS5	2.6	S5	0.010	3.0	5.0	0	2.0	G	Grass-lined	0.035	0.030	2.1	0.59	0.69	4.7	16.0	1.4
RT5	2.6	T5	0.010	5.0	3.0	0	2.0	G	Grass-lined	0.035	0.030	2.1	0.59	0.69	4.7	16.0	1.4
Access Road Channels																	
RQ1	1.7	Q1	0.070	3.0	3.0	0	1.5	G	Grass-lined	0.035	0.030	4.1	0.39	1.69	2.4	9.0	1.1
RQ2	4.8	J-Q2	0.070	3.0	3.0	0	2.0	T	Turf Reinf.	0.035	0.030	5.3	0.58	1.80	3.5	12.0	1.4
RQ3	9.8	J-Q3	0.070	3.0	3.0	0	2.0	T	Turf Reinf.	0.035	0.030	6.4	0.76	1.88	4.5	12.0	1.2
RQ4	10.7	J-Q4	0.070	3.0	3.0	0	2.0	T	Turf Reinf.	0.035	0.030	6.5	0.78	1.89	4.7	12.0	1.2

Note: Side slopes for downchutes measured in line with flow.

TABLE 5
HYDRAULIC JUMP (STILLING BASIN) CALCULATIONS

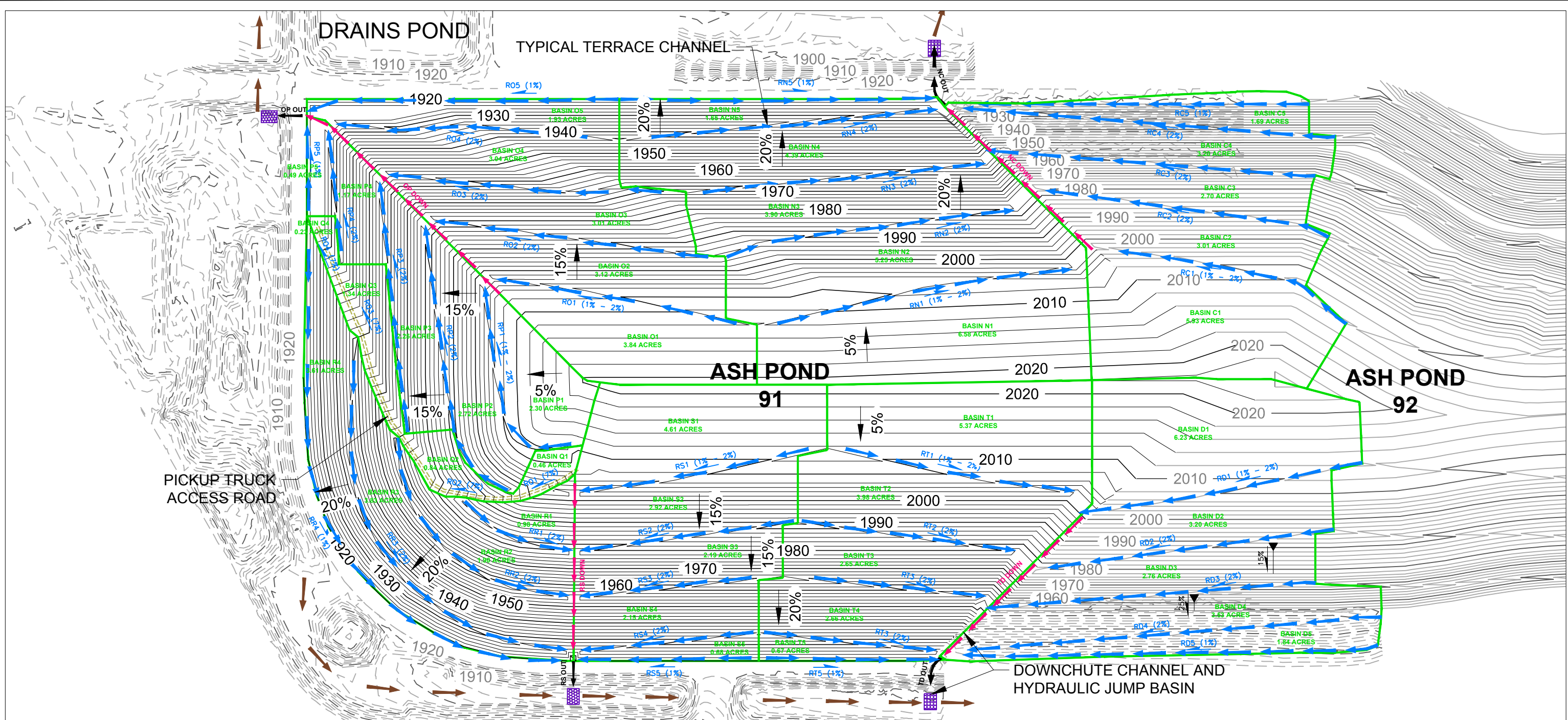
GRE CCS AP91
Surface Water Calculations
PROJECT NO.: 1400644

Date:	2/17/15
By:	SCA
Chkd:	CCS
Apprvd:	TJS

			Channel Configuration							Hydraulic Calculations						
Reach Designation	Q100 from HEC-HMS (cfs)	HEC HMS Element ID for Q	Bed Slope (ft/ft)	Left Side Slope (H:1V)	Right Side Slope (H:1V)	Bottom Width (ft)	Maximum Channel Depth (ft)	Mannings 'n' for Capacity (Depth Calculation)	Mannings 'n' for Stability (Velocity Calculation)	Maximum Velocity (ft/sec)	Maximum Normal Flow Depth (ft)	Normal Depth with Velocity 'n' (ft)	Froude Number	Conjugate Depth (ft)	L/d2 Ratio	Minimum Length of Jump (ft)
NC OUT	109.2	J-N5C5J4	0.36	4	4	12	2	0.026	0.026	18.2	0.44	0.44	5.15	2.79	6.07	16.9
TD OUT	93.7	J-T5D5J4	0.40	4	4	12	2	0.026	0.026	17.8	0.39	0.39	5.33	2.58	6.09	15.7
OP OUT	85	S-OP	0.32	4	4	12	2	0.026	0.026	16.0	0.39	0.39	4.78	2.31	6.00	13.9
RS OUT	71.9	J-R4S5	0.31	4	4	12	2	0.026	0.026	15.0	0.36	0.36	4.64	2.06	5.97	12.3

Note: Side slopes for downchutes measured in line with flow.

FIGURES



LEGEND



EXISTING GROUND TOPOGRAPHY
(SEE REFERENCE 2)



DESIGN TOP OF FINAL COVER GRADES
(ASH POND 92 AND SW SECTION 16
UPSTREAM RAISE)



PROPOSED TOP OF FINAL COVER GRADES
(ASH POND 91 UPSTREAM RAISE)



PICKUP TRUCK ACCESS ROAD



HYDRAULIC JUMP BASIN

BASIN DELINEATION

TERRACE CHANNELS

DOWNCHUTE CHANNELS

OUTLET CHANNELS

EXISTING OFF-SITE DRAINAGE

Ash Pond 91 is now referred to as Upstream Raise 91,
Ash Pond 92 is now referred to as Upstream Raise 92 (10/13/2021).



0 300 600 Feet

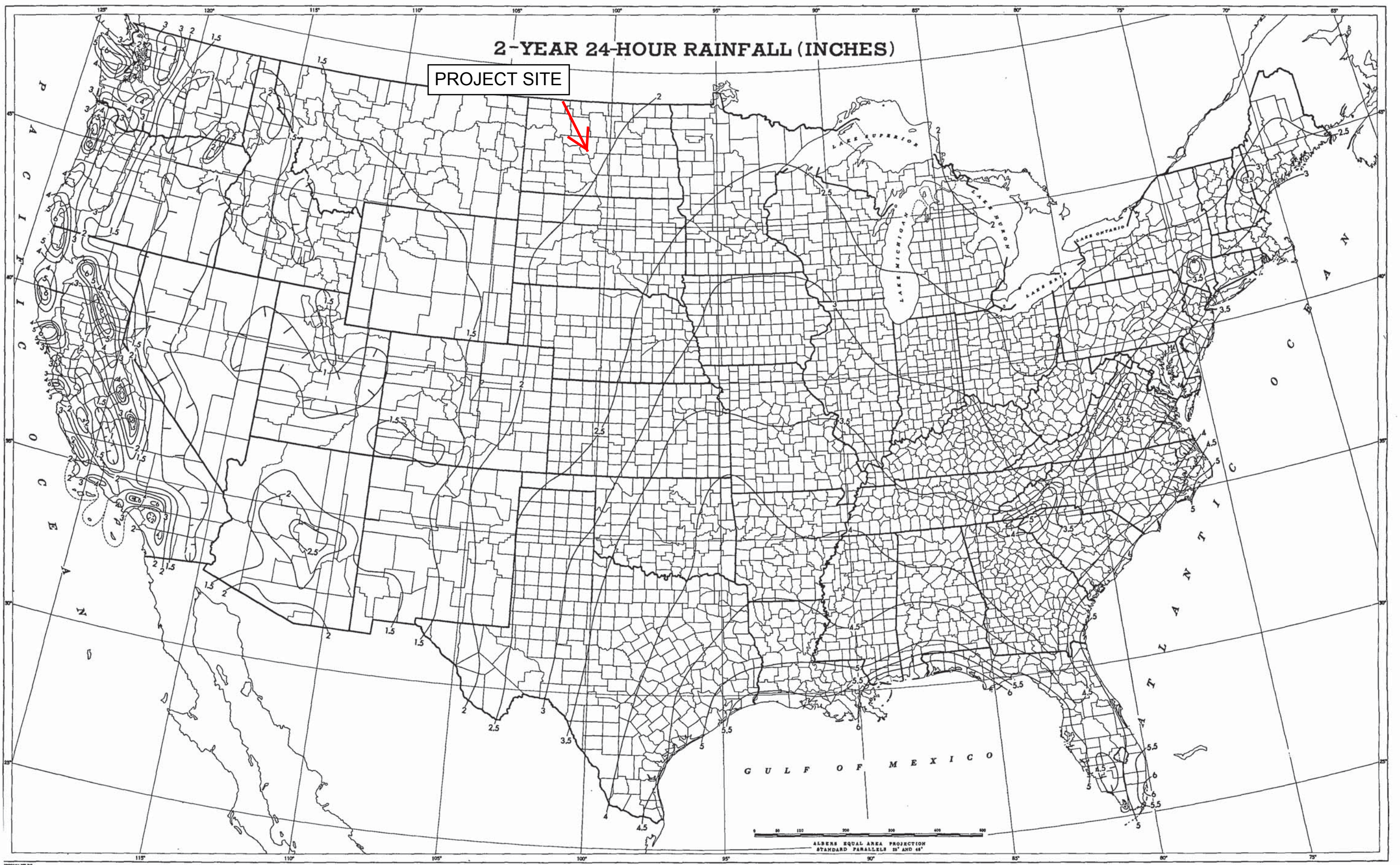
GREAT RIVER ENERGY
COAL CREEK STATION
UNDERWOOD, NORTH DAKOTA

SURFACE WATER BASIN LAYOUT

FIGURE 1

ATTACHMENT A

**RAINFALL FREQUENCY ATLAS (TP-40) –
100-YEAR, 24-HOUR RAINFALL AND
2-YEAR, 24-HOUR RAINFALL**





ATTACHMENT B
TIME OF CONCENTRATION CALCULATION EQUATIONS AND COEFFICIENTS

ATTACHMENT B

TIME OF CONCENTRATION AND MANNING'S FLOW COEFFICIENTS

TR-55 (1986)

Sheet Flow Travel time (SCS Upland Method)

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

Where: T_t = travel time (hr); 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 n	Surface Description	Short Description
Sheet/Overland Flow	A	0.011	Fly Ash	Fly Ash
	B	0.05	Fallow (no residue)	Fallow
	C	0.06	Cultivated soils: Residue cover <= 20%	Cover<20%
	D	0.17	Cultivated soils: Residue cover > 20%	Cover>20%
	E	0.15	Grass: Short grass prairie	Short Grass
	F	0.24	Grass: Dense grasses	Dense Grass
	G	0.41	Grass: Bermuda grass	Bermuda Grass
	H	0.13	Range (natural)	Range
	I	0.40	Woods: Light underbrush	Light woods
	J	0.80	Woods: Heavy underbrush	Heavy Woods

Shallow Concentrated Flow Velocity (SCS Upland Method)

$$v = mS^{0.5}$$

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

Flow Type	Surface Type	Roughness m	Surface Description	Short Description
Shallow Conc. Flow	P	20.3282	Paved Surfaces	Paved
	U	16.1345	Unpaved Surfaces	Unpaved

Channel Flow Velocity (Mannings Velocity)

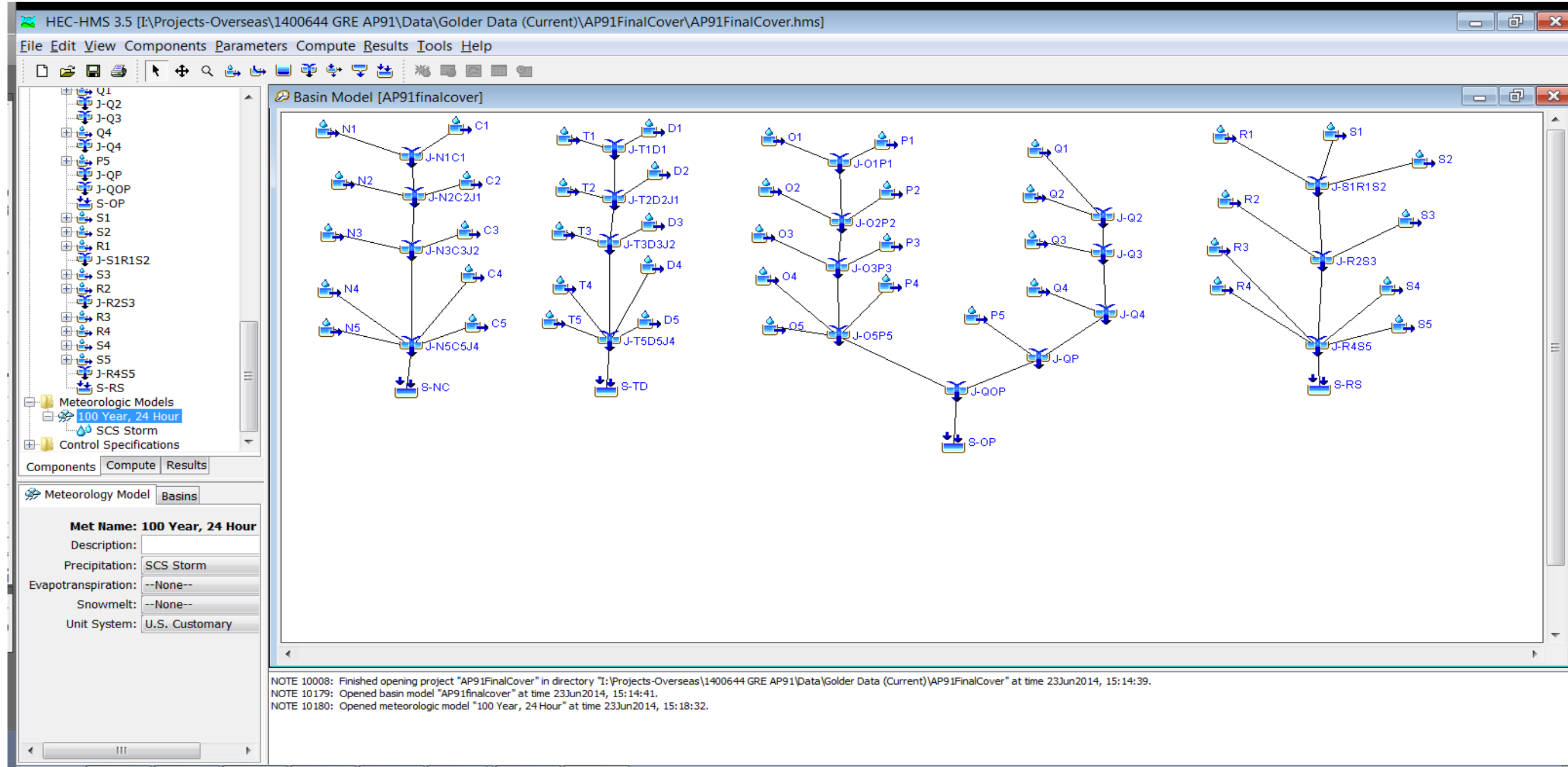
$$v = 1.49/n R_h^{2/3} S^{1/2}$$

Where: v = velocity (fps); n = roughness coefficient; R_h = Hydraulic Radius (ft), S = slope (ft/ft)

Lining Type	Mannings n for Depth	Mannings n for Velocity	Material	Maximum Velocity	Maximum Shear Stress
A	0.026	0.026	ACB	25	
C	0.024	0.022	CSP	50	
E	0.025	0.022	Earth-lined	3	
G	0.035	0.030	Grass-lined	5	
I	0.017	0.013	Ductile Iron	50	
P	0.012	0.009	Plastic	25	
R	0.040	0.035	Riprap	16	
T	0.035	0.030	Turf Reinf.	10	1.5
Z	0.058	0.026	Flexamat	19	24

ATTACHMENT C
HEC-HMS SCREEN CAPTURES AND INPUTS

HEC-HMS Basin Model Schematic





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