Xcel Energy[SM]

13999 Industrial Boulevard
Becker, Minnesota 55308-9611

August 19, 2002

Patty Fowler
Division of Waters
Minnesota Department of Natural Resources
940 Industrial Drive, Suite 103
Sauk Rapids, Minnesota 56379

Re: Application for Dam Safety Permit for Northern States Power Company Sherburne County Generating Plant.

Enclosed a copy of the Construction Documents Report for the proposed Sherco Scrubber Solids Pond 3. The Construction Documents includes the Engineering Report; Construction Quality Assurance Plan; Technical Specifications; and Drawings. This pond, as with the previously permitted Ponds 1 and 2, will be used for storage of fly ash and other coal combustion by-products from the Northern States Power Company's (d/b/a Xcel Energy) Sherco Power Plant as well as coal combustion by-products from other NSP power plants. Also enclosed is a completed copy of the Minnesota Local/State/Federal Application Form for Water/Wetland Projects and a check to cover the $75.00 application fee.

Pond 3 will be constructed adjoining the east side of Pond 2 sharing the eastern embankment of Pond 2. The approximately 115 acre Pond 3 will be constructed in two phases beginning with the northern section, Pond 3N, followed after several years by Pond 3S. The pond will operate for a period of 30 years, providing 25 years of additional ash storage. For the first five years Pond 3 will serve in a water management capacity to control water chemistry and by providing additional water storage for storm water runoff from the site. The embankments will be constructed starting with a small starter dike followed by vertical expansion using "upstream construction" methods. These upstream dikes will include a 4.5 foot thick clay barrier for seepage containment. These methods involve constructing subsequent pond embankments interior to the previous set and placing them over previously place ash products. After the final embankment height is reached a system of interior dikes will be used to place ash to elevations above the perimeter embankment to achieve the final interior elevation required to create the crown required for closure.

Pond 3 will employ a composite liner on the entire base and along the west side slope. The composite liner consists of a geosynthetic clay liner under a 60-mil high-density polyethylene geomembrane. A drainage layer composed of bottom ash or sand and a system of dewatering pipes will be placed over the liner to accommodate post-closure dewatering. Pond closure will include construction of a geomembrane and vegetated soil cap over the crowned surface and installation of storm water runoff control structures.

Pond 3 is designed to keep seepage from the pond to a minimal level. No seepage is projected to occur for the first 16 years of pond operation. Seepage is estimated to be less than 1 gallon/acre/day (GAD) in year 17 and peak at 22 GAD in year 30. Seepage will decrease to near zero following closure and initiation of the dewatering system. By comparison Pond 2 is designed for a maximum seepage rate of 500 GAD.

We are submitting these documents for your review and approval. We have also submitted a copy to the MPCA for NPDES review. At the current rate of filling, we will need to start Pond 3 construction in 2003. Therefore we need final approval by the end of 2002 so we can proceed with detailed engineering and procurement. If you have any questions or would like additional information please call either Dan Orr at 763-261-3155 or Steve Bluhm at 763-261-3133.

Sincerely,

Daniel J Orr
Senior Environmental Analyst
Northern States Power Company
d/b/a Xcel Energy

Steve Bluhm
Senior Plant Engineer
Northern States Power Company
d/b/a Xcel Energy

enclosures: 1

cc: Manny Castillo (w/o enclosures)
Terry Coss (w/o enclosures)
Environmental Services File
Sherco Plant File

Xcel Energy[SM]

13999 Industrial Boulevard
Becker, Minnesota 55308-9611

July 3, 2002

Don Kriens
Metro Division / Major Facilities
Minnesota Pollution Control Agency
520 Lafayette Road North
St. Paul, Minnesota 55155

Re: Submittal of Pond 3 Construction Documents for Northern States Power Company Sherburne County Generating Plant, NPDES Permit # MN0002186.

Enclosed is two complete copies each of the Construction Documents Report and Hydrogeologic Report for the proposed Sherco Scrubber Solids Pond 3. The Construction Documents includes the Engineering Report; Construction Quality Assurance Plan; Technical Specifications; and Drawings. This pond, as with the previously permitted Ponds 1 and 2, will be used for storage of fly ash and other coal combustion by-products from the Northern States Power Company's (d/b/a Xcel Energy) Sherco Power Plant as well as coal combustion by-products from other NSP power plants.

Pond 3 will be constructed adjoining the east side of Pond 2 sharing the eastern embankment of Pond 2. The approximately 115 acre Pond 3 will be constructed in two phases beginning with the northern section, Pond 3N, followed after several years by Pond 3S. The pond will operate for a period of 30 years, providing 25 years of additional ash storage. For the first five years Pond 3 will serve in a water management capacity to control water chemistry and by providing additional water storage for storm water runoff from the site. The embankments will be constructed starting with a small starter dike followed by vertical expansion using "upstream construction" methods. These upstream dikes will include a 4.5 foot thick clay barrier for seepage containment. These methods involve constructing subsequent pond embankments interior to the previous set and placing them over previously place ash products. After the final embankment height is reached a system of interior dikes will be used to place ash to elevations above the perimeter embankment to achieve the final interior elevation required to create the crown required for closure.

Pond 3 will employ a composite liner on the entire base and along the west side slope. The composite liner consists of a geosynthetic clay liner under a 60-mil high-density polyethylene geomembrane. A drainage layer composed of bottom ash or sand and a system of dewatering pipes will be placed over the liner to accommodate post-closure dewatering. Pond closure will include construction of a geomembrane and vegetated soil cap over the crowned surface and installation of storm water runoff control structures.

Pond 3 is designed to keep seepage from the pond to a minimal level. No seepage is projected to occur for the first 16 years of pond operation. Seepage is estimated to be less than 1 gallon/acre/day (GAD) in year 17 and peak at 22 GAD in year 30. Seepage will decrease to near zero following closure and initiation of the dewatering system. By comparison Pond 2 is designed for a maximum seepage rate of 500 GAD.

Pursuant to Section III.C.3. of NPDES Permit MN 0002186 we are submitting these documents for your review and approval. We are also submitting the Construction Documentation Report to the DNR as part of the Dam Safety Permit application. At the current rate of filling, we will need to start Pond 3 construction in 2003. Therefore we need final approval by the end of 2002 so we can proceed with detailed engineering and procurement. If you have any questions or would like additional information please call either Dan Orr at 763-261-3155 or Steve Bluhm at 763-261-3133.

Sincerely,

Daniel J Orr
Senior Environmental Analyst
Northern States Power Company
d/b/a Xcel Energy

Steve Bluhm

Steve Bluhm
Senior Plant Engineer
Northern States Power Company
d/b/a Xcel Energy

enclosures: 2

cc: Manny Castillo (w/o enclosures)
Terry Coss (w/o enclosures)
Environmental Services File
Sherco Plant File

Construction Documents
Scrubber Solids Pond No. 3

NPDES Permit No. 0002186
Sherburne County Generating Plant
Northern States Power Company

(dba Xcel Energy, Inc.)

Pond 3 Documents Include:

- Engineering Report
- Construction Quality Assurance Plan
- Technical Specifications
- Permit Application Drawings

Prepared for

Xcel Energy

June 2002

Prepared by

McCain
and Associates, Inc.

434 2nd Street
Excelsior, MN 55331
ph 952-881-0347
fx 952-470-0728

Executive Summary
Scrubber Solids Pond No. 3
NPDES Permit No. 0002186
Sherburne County Generating Plant
Northern States Power Company
(dba Xcel Energy, Inc.)

This document and the accompanying drawings, specifications, construction quality assurance plan, and hydrogeologic evaluation constitute an application for repermitting of NPDES Permit No. 0002186 for construction of Scrubber Solids Pond No. 3 at Xcel Energy's Sherco Generating Plant. Pond No. 3 will operate for approximately 30 years and provide 25 years of disposal capacity (approx. 10 million cubic yards) for scrubber solids from Units 1 and 2, bottom ash from all three units, and bottom and fly ash from Xcel Energy metro-area plants. Pond No. 3 will also serve a water management function in controlling water chemistry and providing surge capacity for storm water runoff from the plant site. The first 5 years of operation are solely for the water management function during phase-out and closure of existing Pond No. 2.

Pond No. 3 will be located east of and adjacent to existing Pond No. 2, sharing the existing east embankment of Pond No. 2, and will occupy an approximate 115-acre footprint. Initial pond development consists of construction of the north half of the pond with a small "starter" dike (for the water management function mentioned above), followed several years later by construction of the south half of the pond also with a small starter dike. The remainder of Pond No. 3 will be developed in phases using "upstream construction" whereby the pond is raised by constructing embankment sections toward the pond interior over previously-placed ash materials. After the final embankment height is reached, a system of interior dikes will be constructed to allow slurry-placement of scrubber solids to elevations above the perimeter embankment in order to create a sloped "crown" for post-closure drainage purposes.

Pond No. 3 design features include a composite liner on the base and west side slope consisting of a geosynthetic clay liner (GCL) overlain by a 60-mil high-density polyethylene geomembrane. A bottom ash or sand drainage layer and system of dewatering pipes will be placed over the liner to accommodate post-closure dewatering of the pond to reduce the potential for long-term seepage. Upstream dikes on the north, east, and south sides of the pond include a 4.5-foot thick clay barrier for seepage containment. A series of discharge structures will be constructed on the west side slope to return pond water to the plant for re-use in plant operations. Pond closure will consist of constructing a geomembrane with a vegetated soil cap over the crowned surface and installing storm water control structures and piping.

Pond No. 3 design features restrict seepage from the pond (discharge of pond water to the environment) to a minimal level. No seepage is estimated to occur during the first 16 years of pond operation. Seepage is estimated to begin in year 17 at a rate of less than 1 gallon per acre per day (GAD, total seepage distributed across the 100-acre lined area) and peak at a maximum of 22 GAD in year 30. Seepage will then decline to zero within a few years following startup of the dewatering system. For comparison, Pond No. 2 is designed for a maximum seepage rate of 500 GAD.

Engineering Report
Scrubber Solids Pond No. 3
NPDES Permit No. 0002186
Sherburne County Generating Plant
Northern States Power Company
(dba Xcel Energy, Inc.)

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Certification

I hereby certify that this report was prepared by me or under my direct supervision and that I am a duly licensed Professional Engineer under the laws of the State of Minnesota.

John R. McCain

Date: 06/28/02 License No. 21835

Engineering Report
Scrubber Solids Pond No. 3
NPDES Permit No. 0002186
Sherburne County Generating Plant
Northern States Power Company
(dba Xcel Energy, Inc.)

Prepared for

Xcel Energy

June 2002

Prepared by

McCain and Associates, Inc.
434 2nd Street
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fx 952-470-0728

Section 1—Introduction

This Engineering Report presents design information for proposed Scrubber Solids Pond No. 3 at Northern States Power Company's (dba Xcel Energy, Inc.) Sherburne County Generating Plant (Sherco) in Becker, Minnesota. This report is submitted as part of an application for repermitting of NPDES Permit No. 0002186. Other Pond 3 documents include:

- Permit Application Drawings (McCain and Associates, June 2002)
- Technical Specifications for Liner, Dike, and Final Cover Construction (McCain and Associates, June 2002)
- Construction QA/QC Plan (McCain and Associates, June 2002)
- Hydrogeologic Evaluation (Xcel Energy, May 2002)

Pond No. 3 will augment and ultimately replace existing Pond No. 2 when Pond No. 2 reaches capacity. Pond No. 3 will serve the same functions:

- Receive scrubber solids from Sherco Units 1 and 2, bottom ash from the Sherco Bottom Ash Pond, and bottom ash and fly ash from other Xcel Energy metro-area plants.
- Hold water for temporary storage prior to return of the water to the plant scrubber systems and Unit 3 ash conditioning system. Sufficient water storage must be maintained to control pond water chemistry.
- Provide surge capacity for management of storm water runoff from the Sherco plant site.

Subsequent sections of this report present the following information for proposed Pond No. 3:

- Section 2—Existing Site Conditions
- Section 3—Pond Development Plan
- Section 4—Pond Design and Construction
- Section 5—Final Cover Design and Construction
- Section 6—Surface Water Control System

Section 2—Existing Site Conditions

Pond No. 3 is located east of and immediately adjacent to existing Pond No. 2 as shown in Figure 1. Existing features on the site include perimeter fencing for the Sherco Plant, overhead electrical lines, and gravel-surfaced roads for access to the south end of Pond No. 2 and the NRG Becker RDF Ash Landfill. Approximately 10 acres of land is currently in agricultural production at the north end of the Pond No. 3 footprint. The remainder of the site currently has no agricultural or other uses.

Section 3—Proposed Pond Development Plan

This section describes general features of Pond No. 3, the planned development sequence, and general pond operations.

3.1 General Pond Features

The Pond No. 3 disposal footprint covers 101.5 acres, including the existing east dike of Pond No. 2. The disposal footprint is defined as the horizontal limits of scrubber solids and ash placed in the pond. An additional 13.5 acres is covered by exterior pond dikes, for a total land area of 115 acres for Pond No. 3. The base of the pond will be constructed in two cells, identified as Pond 3N and 3S. Pond No. 3 will be constructed in vertical phases to a final dike elevation of 1012. Upon closure, a sloped final cover system will be constructed to elevation 1025. A schematic cross section of Pond No. 3 is shown in Figure 2.

The Pond No. 3 disposal footprint will be lined with a composite liner consisting of a geosynthetic clay liner (GCL) overlain by a 60-mil HDPE geomembrane, except for the upper portion of the west sideslope which will use the existing Pond No. 2 clay liner. The composite liner extends to elevation 960 on the north, east, and south sides, and to elevation 994 on the west side. On the north, east, and south sides, waste containment above elevation 960 is provided by a clay barrier which slopes inward over the composite liner to Elevation 1010. This orientation of the clay barrier in the perimeter dikes ("upstream" construction) provides an additional 3.7 million cubic yards of disposal volume within the pond footprint versus conventional soil-embankment dikes. The existing Pond No. 2 clay liner extends to elevation 1010 on the west side.

A discharge structure system will be constructed to decant water from the pond and return it to the plant for use in plant operations. The system consists of 5 precast concrete box structures constructed at increasing elevations on the west slope of Pond No. 3. Each structure will be in service through a range of pond water surface levels, then be abandoned. Water will be returned to the plant through an extension of the existing 24-inch diameter steel pipe currently serving Pond No. 2.

A 12-inch diameter steel pipe will be extended from the Pond No. 2 discharge structure to the Pond No. 3 discharge structure system. This pipe is used to provide freeze protection for the discharge structure by pumping water from the recycle basin, and also provides a means of transferring water between the scrubber solids ponds and the recycle basin for water management purposes.

Pond No. 3 is designed with a dewatering system so that free water may be removed from the pond. Pond dewatering will commence when the pond is closed. The dewatering system includes a drainage layer covering the pond base and west slope; perforated collection pipes in gravel drains on the pond base; and a wet well and pumpout system located outside the pond footprint (separate systems for Ponds 3N and 3S). Water removed from the pond will be used in plant operations should the plant continue to operate past Pond No. 3 closure, or will be treated either on or off site.

The Pond No. 3 final cover system consists of a geomembrane barrier layer overlain by a drainage layer, rooting soil, and topsoil layers. Diversion berms, ditches, subsurface drains, and catch basins will collect rainfall from the final cover surface. Collected water will flow through drop pipes and energy dissipation structures to existing ground level at the dike perimeter, then be discharged to sedimentation/infiltration ponds.

3.2 Development Sequence and Operation

Pond No. 3 will be developed and operated in six phases as described below.

3.2.1 Phase 1 Development and Operation

Phase 1 consists of constructing the north cell of Pond No. 3 (Pond 3N). Phase 1A construction includes the composite base liner to Elevation 960 on the north and east sides and to Elevation 972 on the south side, and the composite-lined west side slope to Elevation 972 (with additional soil fill to Elevation 976). Phase 1B construction includes upstream dikes to Elevation 974 on the north and east sides. The dewatering system and discharge structure system will also be constructed.

When put into service, Pond 3N will receive water decanted from Pond No. 2 and will serve the water management function described in Section 1. Pond 3N will not directly receive scrubber solids or ash during operations until Phase 2 (Pond 3S) construction is completed (some bypass ash materials carried by decant water from Pond No. 2 may be deposited in Pond 3N prior to construction of Pond 3S). Disposal of scrubber solids and other ash streams will continue in Pond No. 2 for an estimated five years after Pond 3N is constructed. Additional disposal volume is made available in Pond No. 2 when the water management function currently provided by Pond No. 2 is transferred to Pond 3N.

A normal Pond 3N water level at approximate Elevation 959 will be maintained, providing the 1,000,000 NOW volume required to maintain water chemistry (currently approximately 800,000 cubic yards and on an increasing trend). The pond level will fluctuate between Elevation 959 and 968 to accommodate storm water runoff from the plant site (an additional 700,000 cubic yards of capacity), with 4 feet of freeboard to the top-of-liner Elevation 972 and a total of 6 feet of freeboard to the dike crest at Elevation 974.

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3.2.2 Phase 2 Development and Operation

Phase 2 consists of constructing the south cell of Pond No. 3 (Pond 3S). The construction will occur approximately five years after Pond 3N construction. Phase 2A construction includes the composite base liner to Elevation 960 on the south and east sides and to Elevation 972 on the north side (forming an interior dike between Ponds 3N and 3S), and the composite-lined west side slope to Elevation 972. Phase 2B construction includes the upstream dikes to Elevation 974 on the south and east sides. The dewatering system will also be constructed in Pond 3S.

When put into service, Pond 3S will receive scrubber solids (via slurry) and other ash streams for disposal. At the start of this phase, scrubber solids will be deposited primarily in Pond 3S, and slurry water will move through a weir in the interior dike to Pond 3N. Dry ash (bottom ash and metro-plant ash) will be placed around the perimeter of both Ponds 3N and 3S as a foundation for Phase 3 upstream dike construction. Together, Ponds 3N and 3S provide approximately 2.3 million cubic yards of disposal capacity, reserving 1.5 million cubic yards for water management (water chemistry and storm water). At the anticipated average disposal rate of 390,000 cubic yards per year, the available capacity will be consumed in six years.

3.2.3 Phase 3 Development and Operation

Phase 3 consists of raising the perimeter dikes on the north, east, and south sides of Pond No. 3 to Elevation 986 and constructing additional side slope liner on the west side to Elevation 994. The west side slope liner connects to the existing Pond No. 2 clay liner at elevation 990. The construction is anticipated to occur approximately five years after construction of Pond 3S, but is dependent upon the actual ash disposal rate.

Slurry discharge will continue primarily in the south end of the pond to promote formation of the scrubber solids delta in that end, leaving clear water in the north end, particularly in the vicinity of the discharge structures. Dry ash will again be placed around the perimeter of the pond as a foundation for Phase 4 upstream dike construction. Phase 3 adds approximately 1.75 million cubic yards of disposal capacity, providing four to five years of disposal at 390,000 cubic yards per year.

3.2.4 Phases 4 and 5 Development and Operation

Phases 4 and 5 consist of raising the perimeter dikes on the north, east, and south sides of Pond No. 3 to Elevations 998 and 1012 (final elevation), respectively. Construction is anticipated to occur four to five years after the previous construction phase, but could be more or less depending upon actual ash disposal rates. Each phase adds approximately 1.75 million cubic yards of disposal capacity, providing approximately four to five years of disposal at 390,000 cubic yards per year.

3.2.5 Interior Diking Development and Operation

An interior diking system, similar to that currently being implemented in Pond No. 2, will be constructed in Pond No. 3 when the scrubber solids elevation in Pond No. 3 approaches the dike crest. Figure 3 shows a schematic/conceptual cross-section of the interior diking system. Actual dike locations and sequence will be determined following Phase 5 development. Construction of the interior diking system will allow placement of scrubber solids in Pond No. 3 to elevations above the top elevation of the perimeter embankment, in order to construct a crown on the pond to facilitate storm water drainage after pond closure. Up to 3 million cubic yards of scrubber solids may be placed within the interior diking system, consuming the freeboard space between the normal maximum water level at Elevation 1008 and the perimeter embankment crest at Elevation 1012 and creating a crown on the pond with a 2-percent slope. Placement of scrubber solids at elevations above the normal maximum water level will be accomplished by slurrying scrubber solids into interior "cells" created by construction of bottom ash dikes within Pond No. 3. In general, the interior diking plan consists of:

- **Maintaining a clear-water zone in the northwest corner of Pond No. 3.** Scrubber solids will be excluded from this zone during operation of the interior diking system. The clear-water zone will be used to maintain required water chemistry for plant operations, and provide freeboard for the surge volume resulting from plant-area runoff.
- **Using bottom ash as a construction material for interior dikes.** Bottom ash dikes will be constructed to form interior cells in the pond. The dikes are generally configured with a 20-foot top width, 2H:1V slopes, and approximate 12-foot maximum height.
- **Directing the scrubber solids slurry into the current operational cell.** Deposition of scrubber solids within the current operational cell will be controlled by selectively positioning the slurry discharge location and by using culverts to control the water level within the cell.
- **Constructing interior dikes sequentially to create a crown.** Interior cells will be constructed sequentially beginning with a cell in the center of the pond, then progressing

outward toward the perimeter. After the first "lift" of interior diking and filling is complete, the sequence will be repeated on top of the first lift to create a series of dike steps approximating the sloped crown required for final cover construction.

3.2.6 Phase 6 Development and Operation

Phase 6 consists of preparing base grades, constructing final cover and surface water controls, and activating the dewatering system when final cover construction is complete. Several options will be considered for management of water produced by the dewatering system, including discharge to future Pond No. 4, use in plant operations, discharge to the Becker POTW, and on-site treatment.

Section 4—Pond Design, Construction, and Performance

Primary components of Pond No.3 include a composite liner (GCL/geomembrane) on the disposal footprint (defined as the horizontal extents of scrubber solids and ash placed in the pond), upstream dike construction for vertical pond development (including a clay barrier), a discharge structure system to fulfill plant process water requirements, and a dewatering system to remove free water after pond closure. Description of the construction and performance of each of these components is provided in the following subsections:

- 4.1—Base and West Side Slope Liner
- 4.2—Upstream Dikes/Upper West Slope
- 4.3—Discharge Structure System
- 4.4—Dewatering System
- 4.5—Erosion Control

Description of the performance of each pond component includes analysis and discussion of estimated seepage (release of pond water to the environment) during pond operations and dewatering. Table 1 summarizes the results of the seepage analyses. No seepage (complete penetration of pond water through the clay barrier) is estimated to occur for the first 16 years of pond operation. Seepage is estimated to begin in year 17 at a rate of less that 1 gallon per acre per day (GAD, total seepage distributed across the 100-acre pond footprint), and peak at a maximum of 22 GAD in year 30 (immediately before dewatering begins). Seepage declines to zero within a few years following startup of the pond dewatering system.,

Figure 4 shows the results of pond seepage and dewatering analyses for the life of the facility. Dewatering is anticipated to begin when final cover is constructed, approximately 30 years after the start of pond operation. Seepage is shown in terms of GAD over the pond footprint. The corresponding pond water level (or elevation of saturated scrubber solids after dewatering begins) is also shown, scaled against the axis on the right side of the graph.

4.1 Base and West Side Slope Liner

A composite liner will be constructed on the base area and west side slope of the pond during Phases 1A, 2A, 3 as shown in Figure 2 and on Sheets 7, 9, and 11 of the Permit Application Drawings. Descriptions of the construction and performance of the base and west side slope liner are presented below.

4.1.1 Composite Liner System

The base and west side slope of Pond No. 3 will be lined with a composite liner consisting of a geosynthetic clay liner (GCL) overlain by a high-density polyethylene geomembrane. The primary liner component is the geomembrane. Geomembranes are virtually impervious, and are subject to leaking only as a result of manufacturing and installation defects, or damage caused by construction equipment while placing cover materials over the liner. The secondary liner component is a GCL. A GCL will function in the same fashion as would a conventional clay liner in providing a secondary barrier to leakage below the geomembrane.

A GCL is a manufactured product consisting of a layer of natural bentonite clay sandwiched between two geotextiles. GCLs are manufactured with high levels of quality control, producing a uniform product with consistent properties. Bentonite clay has low permeability (the coefficient of permeability of a GCL is approximately 5×10^{-9} cm/s, 20 times lower than conventional clay liner material), and high swell potential (which results in self-healing, self-sealing characteristics).

Xcel Energy proposes to implement a rigorous construction quality control (CQA) plan for Pond No. 3 which exceeds the basic requirements of the MPCA for waste containment facilities. The CQA plan (attached to this permit application as a separate document) includes strict requirements for and verification of manufacturing quality control, installation and seaming oversight and testing, and post-construction leak location testing using electrical detection methods per ASTM D6747-02. Damage to a geomembrane can be detected after placement of materials is completed using electrical leak location systems. The principle behind the leak location method is to place a voltage across a geomembrane and then locate areas where electrical current flows through discontinuities in the liner. Leak location systems were developed in the early 1980's and have been commercially available since 1985. The proposed electrical leak location system can detect holes in the geomembrane as small as 1/8" in diameter when testing though a 2-foot thick layer of cover material.

Implementation of the CQA plan, and in particular the electrical leak location survey, will reveal any damage that may have occurred to the geomembrane and GCL during construction, and provide opportunity to repair both the GCL and the geomembrane prior to placing the pond in service. The results of CQA Plan implementation will demonstrate that both the geomembrane and GCL are intact upon completion of construction and that the liner system will perform in accordance with the assumptions upon which pond seepage analyses presented in Section 4.1.8 are based.

4.1.2 Site Preparation

Prior to beginning liner construction, vegetation and topsoil will be cleared from the area required for liner, perimeter berm, and access road construction. The demonstration road located east of Pond No. 2, constructed using Unit 3 AQCS ash landfill solids, will be excavated and placed in the pond if it has not been previously removed.

Subgrade for liner construction will be prepared by excavating existing soils and placing and compacting random fill to the elevations and grades shown on Sheets 7 and 9 of the Permit Application Drawings. Sheets 7 and 9 show top of liner contours.

4.1.3 Water Table Separation

Base grades are designed to provide a minimum of 5 feet of separation between the finished liner elevation and the historic high water table elevation at the site. The low liner elevation is 939.5 in Pond 3N and 938.0 in Pond 3S. The minimum separation distance occurs at the northeast corner of each pond. The historic high water table is shown on the site cross sections on Sheets 5 and 6 of the Permit Application Drawings. Liner and water table elevations and minimum separation distance are given in the table below.

Pond	Low Liner Elevation (ft MSL)	Historic High Water Table Elevation (ft MSL)	Minimum Separation Distance (ft)
3N	939.5	934.4	5.1
3S	938.0	932.8	5.2

4.1.4 Geosynthetic Clay Liner (GCL) Construction

A geosynthetic clay liner (GCL) will be constructed on the base and west side slope of Pond 3N and 3S during Phases lA, 2A, and 3. The base area of Ponds 3N and 3S are designed with a 2 percent crown to provide for drainage during construction. Slope areas are designed with a 3H:1V slope. The existing Pond No. 2 clay liner will be used for containment above Elevation 990 on the west side of Pond No. 3, and no GCL will be installed above this elevation. Design details for the GCL are shown on Sheets 15 through 18 of the Permit Application Drawings.

GCL installation will be performed in accordance with manufacturers recommendations, and as specified in the Technical Specifications and the Construction Quality Assurance (CQA) Plan. During construction, Xcel Energy will provide qualified construction inspectors for full-time oversight of the GCL installation. An adequate number of inspectors will be provided for continuous observation at all times during installation. Results of all CQA efforts will be summarized and presented in a Documentation Report at the completion of construction.

4.1.5 Geomembrane Liner Construction

A 60 mil HDPE geomembrane liner will be installed over the GCL. Smooth geomembrane will be used on the base areas and textured geomembrane on the slope areas. Geomembrane anchorages will be constructed at Elevation 960 on the north, east and south sides of Pond No. 3, at Elevation 972 at the interior dike (between Pond 3N and 3S) and west side slope, and again at Elevation 994 on the west side slope.

Geomembrane liner installation will be performed in accordance with MPCA requirements for subgrade condition, material type, panel placement, seaming, and testing, as specified in the Technical Specifications and the CQA Plan. During construction, Xcel Energy will provide qualified construction inspectors for full-time oversight of the geomembrane installation. An adequate number of inspectors will be provided for continuous observation at all times during installation. Results of all CQA efforts will be summarized and presented in a Documentation Report at the completion of construction.

4.1.6 Drainage Layer Construction

A 2-foot thick drainage layer will placed over the geomembrane as part of the dewatering system, and to protect the composite liner system during pond start-up and operations. Bottom ash or sand will be used as the drainage layer material, and will be installed in accordance with the Technical Specifications. As with construction of the composite liner system, Xcel Energy will provide qualified construction inspectors for full-time oversight of the drainage layer construction. An adequate number of inspectors will be provided for continuous observation at all times during installation. Results of all CQA efforts will be summarized and presented in a Documentation Report at the completion of construction.

4.1.7 Post-Construction Liner Integrity Testing

After placement of the drainage layer is completed, an electrical leak location method will be used to survey the integrity of the geomembrane liner. Since leak detection testing will occur after construction of the drainage layer, the potential for an undetected hole or tear in the liner system due to installation is negligible.

4.1.8 Composite Liner Performance

The purpose of the composite geomembrane/GCL liner is to provide a barrier against pond water seepage. The proposed composite liner system combines a virtually impervious geomembrane with the low-permeability, self sealing characteristics of GCL. When constructed properly, the liner system will provide a high degree of protection against seepage of pond water. If a defect-free liner installation is achieved, there will be no seepage from the base and side slope areas of the pond. It is reasonable to assume that some liner defects would exist following construction. For purposes of evaluating potential seepage from the composite liner, it is assumed there will be a one-half-inch diameter hole in the geomembrane per acre of liner. It is assumed that the GCL is intact beneath the hole, and serves as the barrier layer for seepage analysis. This defect rate is consistent with guidelines used by the MPCA for evaluating the performance of landfill liners.

The seepage from the assumed liner defect is calculated using Darcy's Law. Darcy's Law states that volume of flow per unit of time through soil is equal to the product of the hydraulic conductivity of the soil, the hydraulic gradient, and the cross-sectional area of flow, expressed by the formula:

$$Q = kiA$$

where Q = flow volume per unit time

k = coefficient of permeability

i = hydraulic gradient

A = cross sectional area of flow

The coefficient of permeability for a GCL is 5×10^{-9} cm/s. When the pond is at the maximum water level, the head on the liner will be approximately 68 feet. This head in combination with the GCL thickness produces an hydraulic gradient of 3,238 ft/ft. A one-half-inch diameter hole under these conditions will produce seepage a rate of 0.00046 gallons per day. Using the assumed defect rate of one hole per acre, seepage expressed in terms of gallons per acre day (GAD) is 0.00046 GAD. Details of the analysis and example calculations are presented in Appendix A.

4.2 Upstream Dikes/Upper West Slope

Upstream dikes will be constructed during Phases 1B, 2B, 3, 4, and 5 on the north, east, and south sides of Pond No.3. Upstream dike configuration is shown in Figure 2 and on Sheets 17, 18, and 19 of the Permit Application Drawings. In preparation for upstream construction, Sherco bottom ash and other dry ash streams (metro-plant ash) will be placed around the pond perimeter during routine operations as foundation material for the upstream dikes.

The west side slope composite liner will be constructed from the pond bottom up to Elevation 990 as discussed in previous sections. Above Elevation 990, the existing Pond No. 2 clay liner will be used for containment. The west side slope configuration is shown in Figure 2 and on Sheets 17 and 18 of the Permit Application Drawings.

4.2.1 Ash Fill Placement

Ash fill will be placed and compacted around the pond interior as shown on the Drawings to serve as a foundation for upstream clay barrier construction. Ash placement and compaction will follow the requirements of the Technical Specifications.

4.2.2 Clay Barrier Construction

A 4.5-foot thick clay barrier (measured normal to the slope) will be constructed over the ash fill foundation, as shown on the Drawings. Prior to beginning clay barrier construction, the clay surface from the previous phase will be exposed and scarified to a depth of 4 inches to promote bonding with the next clay lift. The scarified clay will be re compacted with the first lift of new clay barrier material. The clay barrier will be constructed in horizontal lifts. Clay barrier construction will be performed in accordance with MPCA requirements for material type, moisture content during placement and compaction, lift thickness, compacted density, and permeability, as specified in the Technical Specifications.

4.2.3 Dike Construction

The upstream dike will be completed by placing random fill on the exterior side of the clay barrier to the lines and grades shown on the Drawings. The depth of fill over the clay barrier is designed to prevent uplift from hydraulic pressure at the ultimate pond height. Exterior slopes will be topsoiled and vegetated.

4.2.4 Clay Barrier Performance

Perimeter dikes on the north, south, and east sides of Pond No.3 are constructed over ash fill from Elevation 960 to Elevation 1012. The clay barrier is constructed above a compacted ash foundation and extends to a maximum elevation of 1010 at a slope of 1.5H:1V. The clay barrier thickness is approximately 4.5 feet.

The performance of the clay barrier was evaluated using Darcy's Law applied to vertical increments of clay barrier in one-year time increments to calculate the seepage rate through the barrier. The pond water elevation was adjusted year-by-year to match the planned pond operation. After 30 years of pond operation, it is assumed that the dewatering system will remove free water from the ash foundation upon which the inclined barrier is constructed, thus depressurizing the barrier and halting seepage.

The seepage rate and depth of penetration into the clay barrier was calculated for each increment of barrier for each year of pond operation. The result produces an approximation of a wetting front moving through the clay barrier. Seepage is assumed to begin when the wetting front has passed completely through the 4.5-foot-thick barrier. A seepage volume is calculated by multiplying the seepage rate by the height increment and total length of barrier. The total seepage volume is calculated by summing the seepage volume exiting each barrier increment during a year's operation. The total seepage voume is then expressed in terms of gallons per acre of pond area per day (GAD) by dividing the total seepage volume by the pond footprint (100 acres).

Results of this analysis indicate that zero seepage occurs during the first 16 years of pond operation. Seepage begins during year 17 at a rate of less that 1 GAD and increases steadily to 22 GAD in year 30. Seepage then declines to zero in years 31 and 32 when the dewatering system depressurizes the clay barrier. Pond seepage is summarized in Table 1 and shown on Figure 3. Details of the analysis are presented in Appendix B.

4.2.5 Existing Pond 2 Clay Liner Performance

Seepage calculations were performed for the existing Pond No. 2 clay liner located at the top of the west side slope above Elevation 990. The existing Pond No. 2 clay liner above Elevation 990 consists of two components: the original Pond No. 2 side slope liner and the inclined clay barrier within the Pond No. 2 vertical dike extension. Testing performed during construction showed that the original clay liner is approximately 2.4 feet thick with an average permeability of 1.6×10^{-8} cm/s. The inclined clay barrier is 4.5 feet thick (measured perpendicular to the slope) with a permeability of 3.0×10^{-8} cm/s.

In a similar manner as described above for the clay barrier, an approximation of the wetting front was calculated for Pond No. 3 seepage into the Pond No. 2 liner. Using this data in the incremental analysis as described above, it was determined that the wetting front penetrated approximately 1.6 feet into the clay liner but that no pond seepage was discharged through the liner. Seepage calculations are provided in Appendix B.

4.2.6 Stability Analysis

The construction of dikes which impound water requires an evaluation of stability to ensure that the impoundment is safe. Since the Pond No.3 dikes are constructed above ponded wastes, stability with respect to uplift pressure must also be assessed. The following subsections describe the stability evaluations. Details of the analyses are presented in Appendix D.

Uplift Stability

Since the upstream clay barrier will be built over pre-existing pond deposits, uplift pressure will exist beneath the upstream clay barrier as the pond level is raised. To be certain that stability is maintained at all points along the liner, a safety factor with respect to uplift is used, determined by:

$FS = \sigma_v U$

where: σ_v = Vertical effective overburden pressure

U = Uplift pressure

Generally, a factor of safety above 1.0 is necessary to maintain stability. For design, a factor of safety above 1.3 is recommended. The inclined clay liner has been designed at all locations in Pond No. 3 so that the factor of safety is 1.3 or greater for uplift stability.

Slope Stability

The stability of north, south, and east perimeter dikes was determined for wedge-shaped and circular slip surfaces extending from the crest to the exterior side of the perimeter dike. Evaluations were completed for potential failure along the clay barrier, through the base of the dike, and through the foundation. Both static and seismic loading conditions were evaluated. For purposes of this analysis, a safety factor of 1.5 is considered acceptable for static conditions. A factor of safety of 1.2 is required for seismic conditions which simulate earthquake loading using a seismic coefficient of 0.025. Results indicate that the perimeter dikes have a sufficient factor of safety for both static and seismic conditions at the maximum planned elevation. The calculated minimum factor of safety for static conditions is 1.92 , determined for a circular surface extending through the base of the dike. For seismic conditions, the calculated factor of safety is 1.75.

4.3 Discharge Structure System

The Pond No.3 discharge structure returns pond water to the plant for use in the scrubber systems. The discharge structure layout, sections, and details are shown on sheets 21 through 24 of the Permit Application Drawings.

4.3.1 System Description

The discharge structure for Pond No.3 consists of a series of intake structures constructed sequentially on the west slope, and connected to a 24-inch steel discharge pipe. The steel pipe is an extension of the existing discharge pipe serving existing Pond No. 2, and is the suction pipe from the pump house. The steel pipe penetrates the composite liner at the northwest corner of Pond 3N. The penetration will be booted.

Each individual structure is assembled from 8-foot by 8-foot precast concrete box sections and box culvert end sections. The structures will be constructed at increasing elevations on the west side slope. A prefabricated truss bridge will connect each structure to the perimeter road. Generally, two structures will be in service at any given time to accommodate fluctuations in pond level. A downslope structure will be abandoned-in-place when the normal pond level is near the top of that structure and the next up slope structure is in service.

4.3.2 Structural Design

The discharge structure system is constructed primarily from prefabricated components. Appendix E presents design computations for structural stability (bearing, sliding, uplift), stoplog and grating spans, and strength of supports and connections.

4.3.3 Stability Analysis

Since the west dike of Pond No.3 bears on the existing Pond No.2 dike, the exterior stability is not of concern. However, construction of the discharge structures along the side slopes above the liners requires that interior stability be evaluated. The potential for sliding along or above the liner is determined for critical loading cases during operation of the pond. These issues are discussed in detail in the following subsections. Details of the stability analysis are presented in Appendix C.

Bearing Capacity Analysis

The bearing capacity of the discharge structures is determined as part of the structural design, as discussed in Section 4.3.2. The standard bearing capacity computation generally assumes that the ground is horizontal and that sloping interfaces are not encountered within the zone of influence of the structure. Structural bearing capacity evaluations simply assure that the load of the structure is spread over a sufficient area to prevent failure of the soil. The potential zone of influence for each structure was determined in order to assure that (1) concentrated loading does not occur along the geomembrane interface, and (2) concentrated loading does not occur on the backside of a discharge structure due to loading from the one higher on the slope. Also, stability with respect to bearing capacity was evaluated for slope construction.

The zone of influence for each structure does not extend to the structure immediately downslope, nor to the adjacent structure, but does extend below the liner in some cases. The factor of safety with respect to bearing capacity is greater than 3 for the discharge structures which is considered acceptable. Bearing capacity is also acceptable when ballast is used to abandon structures and the drainage layer friction angle is reduced to 25 degrees due to saturation. Details of the analysis are presented in Appendix C.

Slope Stability Analysis

The potential for sliding of soil and structures along the geomembrane was evaluated using SLOPE/W, a limit equilibrium program for analyzing the stability of slopes. Spencer's method of force and moment equilibrium was used for potential sliding surfaces which extend along the geomembrane beneath the structures. Several slip surfaces were considered assuming that the geomembrane interface friction angle is 24 degrees. Also, the potential for failure beneath structures was evaluated, assuming maximum and minimum water levels in the pond. For purposes of this analysis, a safety factor of 1.5 is considered acceptable for design.

Analyses showed a minimum safety factor of 1.51 for potential slip along the geomembrane for Phase 2 construction, which is acceptable. Results also indicate that placement of ballast within the Phase 1 discharge structure results in a safety factor of 1.82 which is also acceptable. The minimum factor of safety for the maximum surge level for Phases 1 and 2 is 1.51. All other conditions during operation of the discharge structures in Pond No.3 are considered less critical.

than the cases evaluated for Phases 1 and 2. Details of the analysis are presented in Appendix C.

4.4 Dewatering System

The Pond No. 3 dewatering system consists of a drainage layer, lateral drains, and perimeter drains/collectors. The drains consist of perforated collection pipes covered by two-stage aggregate filter drains. There are separate dewatering systems for Ponds 3N and 3S. The location of lateral drains and perimeter drains/collectors is shown on Sheets 7 and 9 of the Permit Application Drawings.

The perimeter drains/collectors exit Pond 3N and Pond 3S at the north and south ends of the pond, respectively. Non-perforated polyethylene pipes exit the ponds through double-booted penetrations of the composite liner. The pipes then gravity-drain to wet wells equipped with duplex pumping systems for discharge to a future pond, to other plant uses, or to an on- or off-site treatment plant.

The dewatering system will be activated when Pond No. 3 has been closed to remove available water from scrubber solids and ash placed in the pond. The dewatering system will be operated until the piezometric head inside the pond is below elevation 960 (top of the composite liner). Dewatering system sections and details are shown on Sheet 20 of the Permit Application Drawings.

4.4.1 Drainage Layer

A 2-foot thick drainage layer will be constructed over the base and side slope area of Pond No. 3. The drainage layer will be screened to remove particles larger than 3/4 inches prior to placement, to minimize potential puncture damage to the geomembrane. The drainage layer material will be placed in a single two-foot lift (rather than the typical 1-foot lift), which will reduce bearing pressure from earthmoving equipment and correspondingly reduce geomembrane puncture potential.

4.4.2 Dewatering Drains and Collection Pipes

Dewatering drains are located at quarter-points on the Pond 3N and 3S base areas, running in an east-west direction. The drains are connected to the drains/collectors located along the east and west edges of the base area. The drains and drains/collectors include a 6-inch diameter perforated PVC pipe, coarse and fine aggregates, and are underlain by a non-woven filter fabric cushion. The coarse aggregate and perforated pipe serve as conveyance media to move water from the pond perimeter to the liner exit point and wet well.

The fine filter aggregate has been designed as part of a graded filter system and will be placed between the coarse aggregate and drainage layer. The graded filter system considers the grain size distributions of the scrubber solids, drainage layer, fine filter aggregate, and coarse aggregate, and is designed to maintain separation of materials and prevent siltation of the dewatering system.

Calculations for pipe strength and graded filters are presented in Appendix F.

4.4.3 Dewatering Manholes

Dewatering manholes are located at the pond corners to collect and pump dewatering system discharge. The manholes are equipped with duplex pumping systems, float controls and alarms, and head monitoring pressure transducers. The dewatering discharge piping, manholes, and pressure transducers will be constructed as part of Phases 1 and 2 construction. Construction of the pumps and pump discharge piping will be coordinated with operation of the interior diking system and final cover construction. The dewatering manholes are shown on Sheet 20 of the Permit Application Drawings.

4.4.4 Dewatering System Performance

The Pond No.3 dewatering system is designed to remove available water from the waste and thus minimize the potential long-term impact the pond may have on groundwater quality. Dewatering will commence approximately 4 years after reaching the maximum planned elevation. Pumping will occur at an initial rate of 100 gpm, 50 gpm from both north and south cells, and be reduced over time as the rate of gravity drainage from the waste decreases.

The first part of the analysis assumes that ash fill material placed around the pond perimeter will drain faster than the recharge rate from the adjacent scrubber solids, because the ash fill is at least one order of magnitude more permeable than the scrubber solids. When pumping begins, water will be removed primarily from the ash fill and the head in the ash fill will drop below Elevation 960 (the top elevation of the composite base liner) within approximately 1 year. At this point, pond leakage through the upstream clay barrier will essentially cease because the clay barrier has been depressurized.

The second part of the analysis evaluates dewatering of the scrubber solids, which will drain under transient flow conditions. Water will drain from the scrubber solids in two ways:

- Downward flow to the drainage layer at the base of the pond then lateral flow toward dewatering drains and drains/collectors.
- Lateral flow into the dewatered ash fill around the pond perimeter, then downward flow to the dewatering drains/collectors.

The analysis for vertical and lateral drainage from the scrubber solids was performed using Darcy's Law for saturated flow. A water balance approach was used to compute the dewatering rate and to track head in the waste based on the volume of water removed by pumping versus the available water volume in the scrubber solids.

Dewatering of the scrubber solids is estimated to occur over a period of 15 years. The pumping rate will be adjusted to match the drainage rate over this time period, ranging from 100 gpm initially to approximately 35 gpm at the conclusion of dewatering. Details of the dewatering analysis are presented in Appendix G.

4.4.5 Disposition of Water Removed from Pond

One of several options will be implemented for disposal of pumped water when dewatering begins. The primary plan is to pump the water to future Pond No. 4. If Pond No. 4 is not constructed, the water will be used in plant processes. If the water cannot be used by the plant, the water will be discharge to the City of Becker publicly-owned treatment works (POTW). Finally, if other options are not available, a treatment plant will be constructed at the site to treat and discharge the water.

4.5 Erosion Control

Vegetation will be established on the exterior slopes of the pond embankment for erosion control. Erosion control will also be provided for the interior slopes of the pond (bottom ash or sand, used as foundation material for the clay barrier on the north, east, and south sides, and as geomembrane cover material on the west slope). Several options for interior-slope erosion control are being evaluated, including a geotextile layer, riprap, and roller-compacted concrete. A final selection of erosion control methods for interior slopes will be made after testing for effectiveness in existing Pond No. 2.

Section 5—Final Cover Design and Construction

5.1 Ash Fill Placement

The entire pond will be covered with a final cover system consisting of an ash or soil subgrade layer, geomembrane barrier layer, drainage layer, rooting soil, and vegetated topsoil. A surface water control system will be constructed as part of final cover construction, and is discussed separately in Section 6. The final cover system plan, sections, and details are shown on Sheets 14 and 25 through 27 of the Permit Application Drawings, and are described below.

5.2 Base Grade Preparation

Base grades will be prepared to 2 feet below the final cover lines and grades shown on Sheet 14 of the Permit Application Drawings. The crown will be developed using the interior diking plan described in Section 3. Final grading will be performed to shape the surface to the design grades.

5.3 Geomembrane Barrier Layer

A 40-mil geomembrane will be installed over the prepared base grades. The geomembrane will have elongation characteristics to accommodate pond consolidation and settlement which may occur after final cover construction. The geomembrane liner will be constructed in accordance with MPCA requirements for subgrade condition, material type, panel placement, seaming, and testing, as specified in the Technical Specifications for Final Cover Construction.

5.4 Granular Drainage Layer

The geomembrane barrier layer will be covered by a granular drainage layer. The drainage layer serves two functions. First, the drainage layer provides a buffer against physical damage to the geomembrane from construction equipment during final cover construction. The specified drainage layer gradation has no particles larger than 3/8 inch in order to protect the geomembrane against puncture. The second function of the granular drainage layer is to convey surface water which infiltrates the final cover soils across the geomembrane surface. Subsurface water is collected by perforated drain tubing and is conveyed through drop pipes to sedimentation ponds. The specified drainage layer gradation has not more than 5 percent of material passing the #200 sieve and a minimum hydraulic conductivity of 1×10^{-3} cm/s.

5.5 Rooting Soil and Topsoil

The 6-inch thick rooting soil and topsoil layers will be placed over the drainage layer to promote and sustain vegetative growth on the final cover surface. The rooting soil is a finer-grained mineral soil to promote moisture retention and to provides a medium for root growth. The topsoil layer contains organic material and provides nutrients for plant growth. Material requirements for rooting soil and topsoil are described in the Technical Specifications.

5.6 Turf Establishment

Vegetative cover will be established on all topsoiled areas of the final cover system to encourage evapotranspiration of precipitation which infiltrates the final cover soils and to minimize erosion. Requirements for seed type and application rate, fertilizer, and mulch are described in the Technical Specifications.

5.7 Post-Closure Consolidation/Settlement Analysis

The potential post-closure settlement of the waste is determined to evaluate differential settlement of the cover which might cause adverse slopes (resulting in ponding on the cover) or excessive tensile strain in the geomembrane. Generally, the cover is designed such that final slope of the surface after settlement is 2 percent or greater to facilitate adequate drainage of surface water .

Because the waste is comprised primarily of solids which range in size from silt to sand, consolidation is not expected to be significant after placement of the cover. Compression of the waste is likely to occur during pond development, and the resulting settlement of the upstream clay barrier may be estimated assuming elastic deformation. Dewatering of the waste will cause additional compression, which may be estimated as an elastic volume change. Since dewatering will begin after capping has been completed, the deformation of the waste resulting from dewatering is determined to indicate the potential cover settlement.

The potential settlement was determined using a finite element model and assuming that all materials behave as linear elastic solids. The analysis was performed for completely saturated wastes to allow the determination of dewatering effects on the waste. Results indicate that the clay liner may sustain tensile strains up to 0.1 percent, which are easily tolerable by the material. Since the construction of the upstream dikes will occur in phases, adjustments will be made during each increment of construction to accommodate settlement which may have occurred during the previous phase.

Complete dewatering of the waste may result in a maximum settlement of 0.3 feet for the cover, causing as much as 0.1 percent tensile strain in the membrane. This amount of deformation is easily tolerable and should not affect the integrity of the membrane. Also, since this amount of settlement is included in the design of the cover, dewatering is not expected to significantly impact drainage of the surface. Details of the analysis are presented in Appendix H.

Section 6— Surface Water Control System

Surface water runoff from Pond No.3 will be controlled in order to minimize erosion of the final cover system and minimize sediment transport off-site. The surface water control features consist of a series of diversion ditches, catch basins, drainage pipes and sedimentation ponds. Subsurface drain tubing placed above the geomembrane barrier layer captures subsurface water which has infiltrated the cover soils.

Surface water runoff controls for the final cover system for Pond No. 3 are shown on Sheets 14 and 25 through 27 of the Permit Application Drawings. Materials and construction requirements for the surface water controls are described in the Technical Specifications. Design computations for the surface water runoff controls are included in Appendix I.

6.1 Surface Water Hydrology

6.1.1 Drainage Areas and System Layout

There are seven separate drainage systems that are part of the final cover surface water controls. Each system consists of a series of ditches, catch basins, manholes, and pipes to convey runoff from the cover down the slopes. The north and south ends of the site each have one system, the east side has three systems, and the area between Pond No. 2 and Pond No. 3 has two systems. Each drainage system drains to a sedimentation pond.

The Pond No. 3 drainage systems on the west side will be connected to the surface water pipe system located between Pond Nos. 2 and 3, to be installed during Pond No. 2 final cover construction. That pipe system was designed to accommodate the flows from both Pond Nos. 2 and 3.

Surface water ditches are located to allow a maximum uncontrolled flow length down the 2 percent final cover slope of approximately 400 feet. Surface water ditches are also located as close to the inside of the perimeter road as possible in order to reduce the amount of flow down the 3H:1V slopes.

Subsurface drainage is provided at all low points of the geomembrane, all outside edges of the geomembrane, and along the centerlines of all the surface water ditches to provide interception of subsurface flows at approximately every 400 feet. The subsurface drainage consists of perforated drain tubing wrapped with filter fabric. The drain tubing outlets into the nearest catch basin or manhole. Outletting the drain tubing in a structure allows visual inspection to determine whether or not the drain tubing is functioning, and provides cleanout access.

Sheet 14 shows the final cover contours and the overall layout of the diversion dikes, catch basins, manholes, surface water pipes, and subsurface drain tubing.

6.1.2 Hydrology

The Barr Hydrograph Method was used to determine surface water runoff hydrographs for the design of the surface water control features for the final cover of Pond No. 3. The Barr Hydrograph Method generates peak discharges and volumes within a watershed for various storm frequencies and durations. Discharges and volumes were determined for the 25-year frequency, 1/2-hour through 24-hour duration storms and the 50-year frequency, 1/2-hour through 2-hour duration storms. The sizing of diversion dikes, catch basins, and pipes was based on peak discharges and volumes from the 50-year frequency critical duration storm for each design feature. It was found that for nearly all cases, the 1-hour duration storm was critical for these design features. A detailed discussion of the methodology of the Barr Hydrograph Method is included in Appendix I.

6.1.3 Hydrologic/Hydraulic Routing

In order to determine the flood elevation at each catch basin and determine the maximum flows in each segment of pipe, storage routing was performed at all the catch basins using the Barr Model. For routing purposes, elevation-storage-discharge tables were required. These were computed using concepts discussed in the following paragraphs.

Four routing models were run; one for each different drainage system configuration. The drainage systems on the north and south ends are nearly identical in terms of drainage area and pipe layout and the three pipe systems on the east side are also nearly identical. Therefore, one model was run for the north and one for the center pipe system on the east side. The results of each model were used for the design of the other similar drainage systems. Page 1 shows the surface water pipe layout. The routing results start on page 7. The results summarize the depth of flow in the ditches, the headwater at the catch basins, the head water at the outlet pipes, the pipe capacities, and the velocities and depth of flow in the pipes for the peak flows.

6.2 Surface Water Control Features

6.2.1 Surface Water Diversion Ditches

The capacity of the surface water ditches were based on the Manning equation. Manning's "n" was determined for two conditions: bare soil where channel velocity is critical and turfed areas where depth of flow is critical. For ditches with bare soil, the typical channel velocities are less than 2 fps which is low enough to minimize erosion. For ditches with established vegetation, Manning's "n" was determined assuming a retardance "B" channel and using a graph indicating how "n" varies with the product of the hydraulic radius and velocity. The vegetated ditches provide at least 1 foot of freeboard at peak flows. The size and shape of the surface water dikes and ditches were determined mainly by the ability to construct them with large earth moving equipment. The dikes could have been smaller but they would be difficult to construct. Also, additional height is beneficial in the event settlement occurs during dewatering. Computations for ditch capacities are included in Appendix I.

6.2.2 Pipes and Catch Basins

Catch basin and pipe inlet capacities were determined using nomographs based on weir and orifice equations. Pipe capacities were calculated using the FlowMaster computer program. The program performs pipe flow computations based on Manning's equation: Pipe flow velocities for the design storm exceed 7 fps in all cases. These velocities are sufficient to remove accumulated sediment in the pipes that may reduce their flow capacity. Pipe velocities for flows equal to one half the design flows still exceed 6 fps. Therefore, flows from storms that occur more frequent than the design storm will also carry sediment out of the pipes. The computations for pipe and catch basin capacity are included in Appendix I.

6.2.3 Energy Dissipation

Energy dissipation manholes are located at the outlets of each drop pipe (located at the base of the Pond No. 3 dike). The inlet pipes of these manholes are approximately 6 feet higher than the outlet pipe invert. Inlet flows impact on the wall of the manhole and drop vertically before entering the outlet pipe. This change in direction effectively reduces the velocities through the manhole. The outlet pipe is laid at a shallow slope and sized to flow full with velocities less than 7 fps. An apron and riprap is placed at the outlet to dissipate the energy of the outlet flows in accordance with Mn/DOT guidelines.

6.2.4 Sedimentation/Infiltration Ponds

The sedimentation/infiltration ponds shown on Sheet 14 of the Permit Application Drawings are sized to provide effective sedimentation by holding the entire runoff volume from the critical 25-year storm event. The runoff volumes were determined by the Barr Model. There are no outlet pipes proposed for the ponds. Discharge from the sedimentation ponds will be by infiltration into the sandy native soils and evaporation. Any overflow from the ponds would either infiltrate as it flowed overland, pond in a downstream depression, or drain overland to the Mississippi River . The size, depth, and location of the sedimentation ponds is shown conceptually on Sheet 14. The actual location may vary from that shown on the Permit Application Drawings, but will provide the required required storage volume.

Table

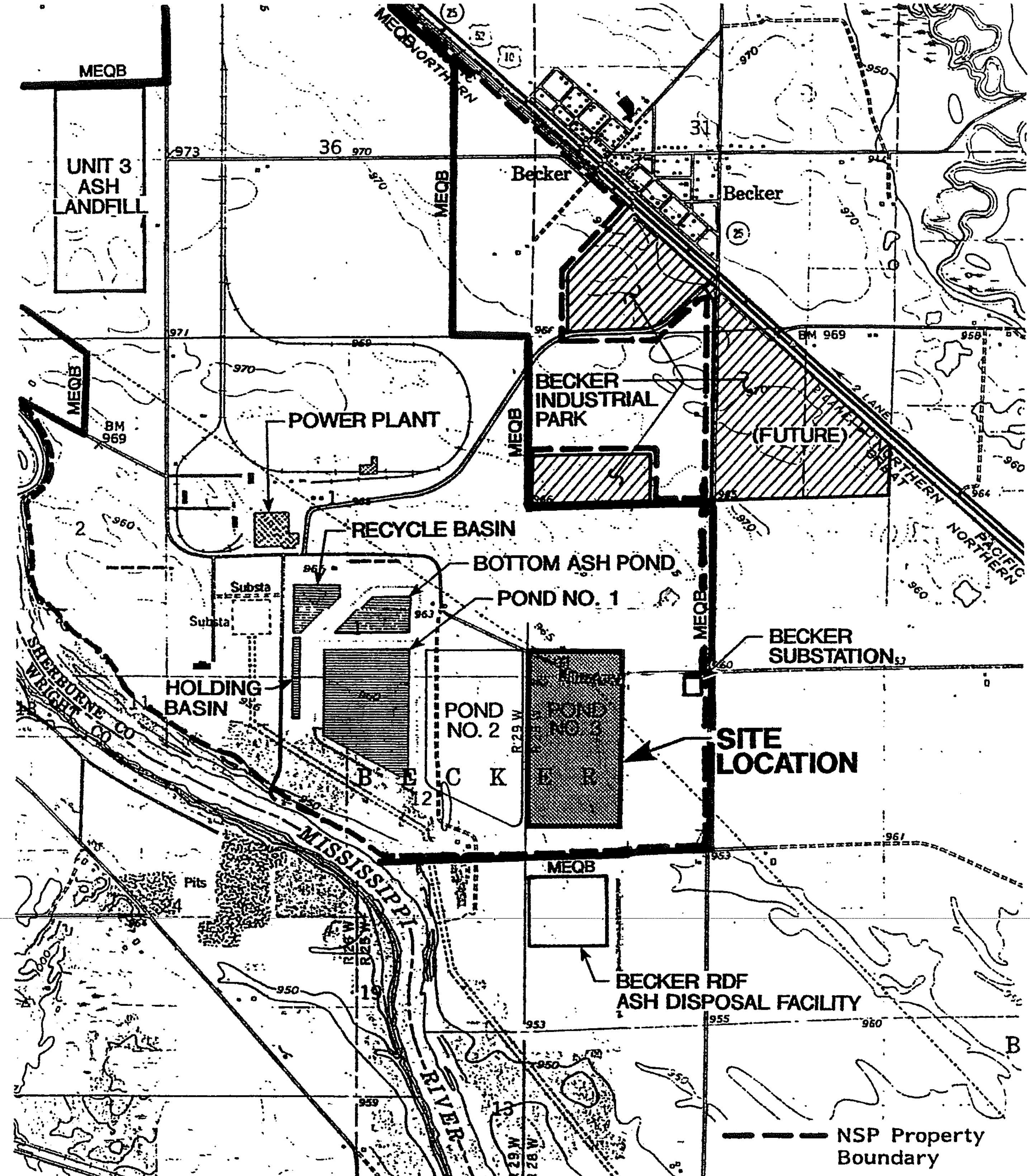
Table 1

Summary of Pond No. 3 Seepage

YEAR	POND ELEVATION (ft MSL)	SEEPAGE (GAD)
1	959	0
2	959	0
3	959	0
4	959	0
5	959	0
6	970	0
7	970	0
8	970	0
9	970	0
10	970	0
11	982	0
12	982	0
13	982	0
14	982	0
15	982	0
16	994	0
17	994	0.9
18	994	2.7
19	994	4.2
20	994	5.3
21	1008	10.0
22	1008	12.2
23	1008	14.5
24	1008	16.0
25	1008	17.2
26	1008	18.4
27	1008	19.6
28	1008	20.5
29	1008	21.1
30	1008	21.9
31	984	6.4
32	960	0

Notes:
1) Calculations for composite liner seepage are contained in Appendix A
2) Calculations for upstream clay barrier seepage are contained in Appendix B
3) Refer to Figure 4 for a graphical representation of seepage data

Figures



Source: Clear Lake, Becker, Silver Creek and Monticello, Minnesota Quadrangles, 7.5 Minute Series, 1980.

0 2000 4000
Scale in Feet

Figure 1

SITE LOCATION MAP
Sherco Generating Plant
Northern States Power Company

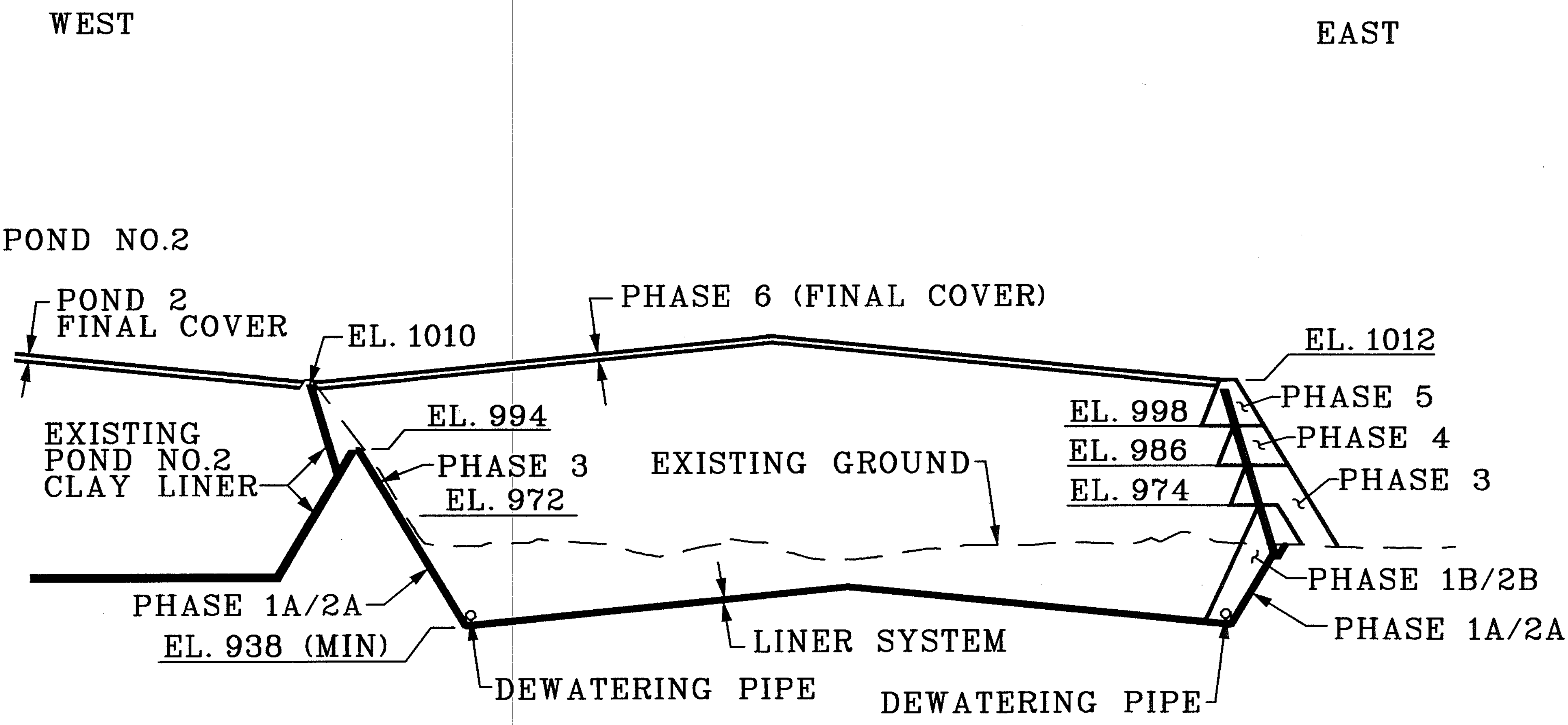


Figure 2

SCHEMATIC CROSS SECTION
POND 3
PHASING DEVELOPMENT

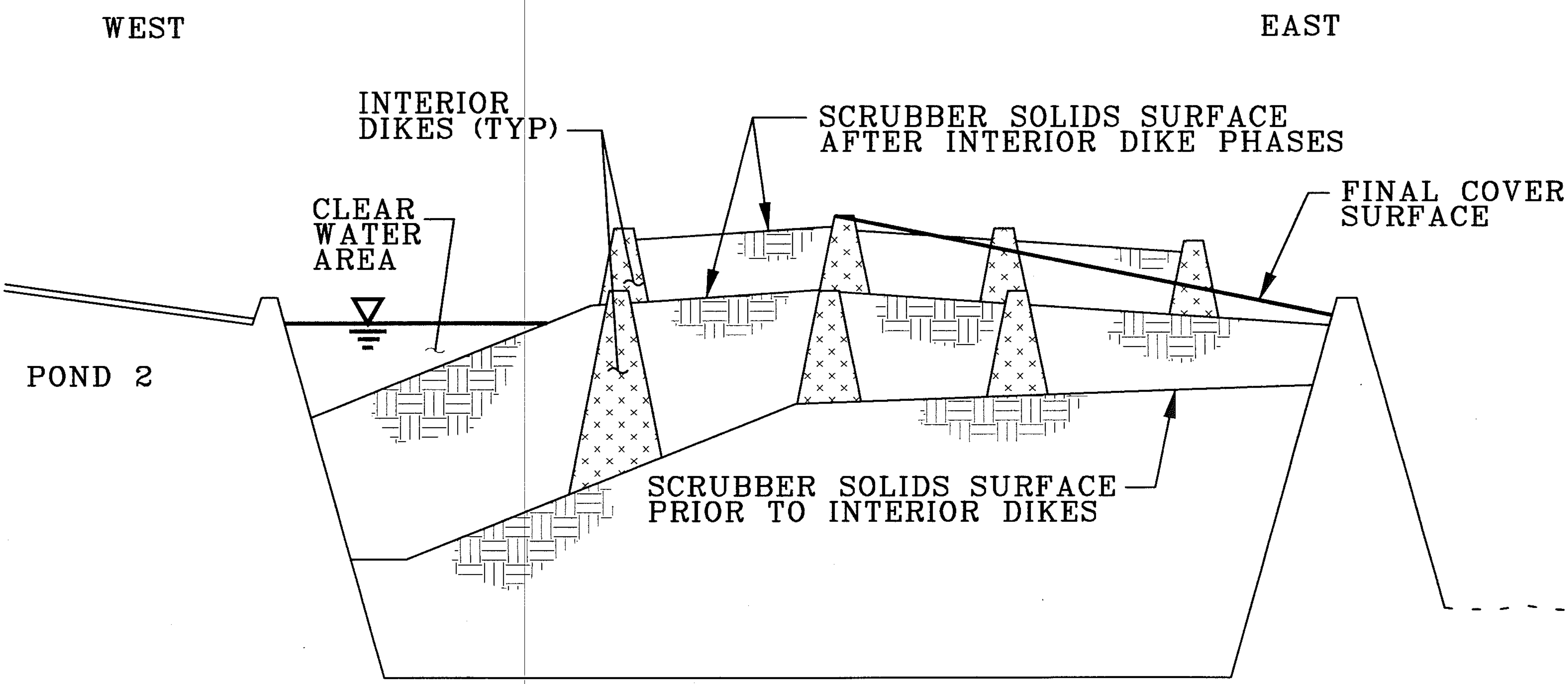


Figure 3

SCHEMATIC CROSS SECTION
POND 3
INTERIOR DIKING PLAN

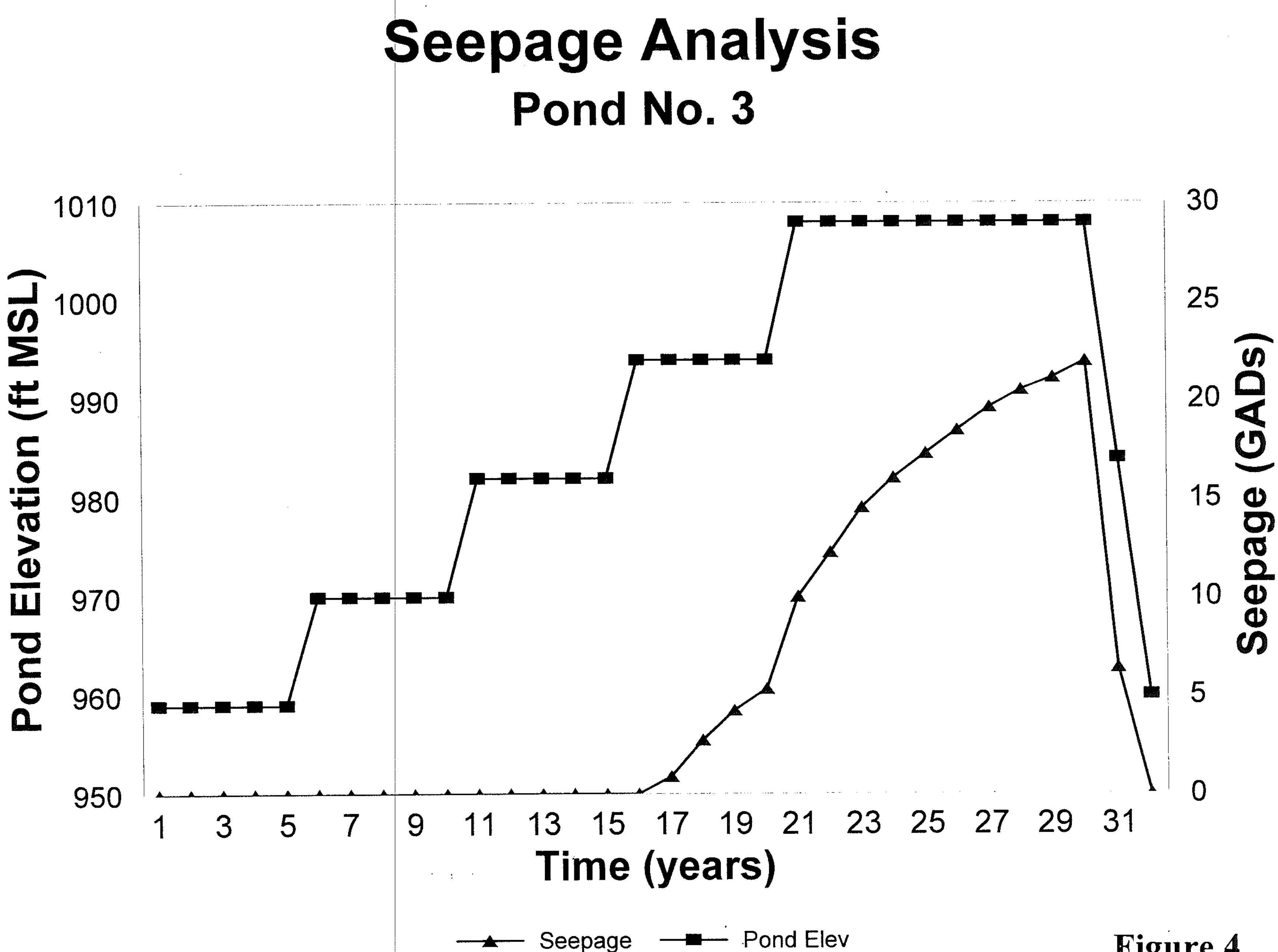


Figure 4
SEEPAGE ANALYSIS
POND 3

Appendix A

Performance Analysis - Composite Liner

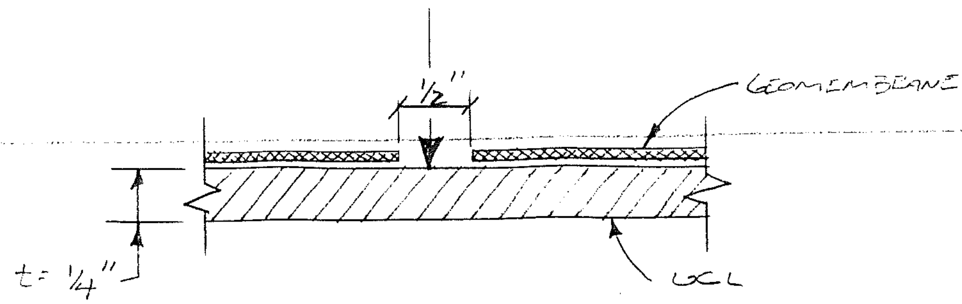
POLARIS·GROUP

Name: DSS Date: 06/17/02
Project: SHERCO P3 No. ____
Desc. SEEPAGE CALC.
Checked By: ____ Sheet ____ of ____

LINER SEEPAGE ANALYSIS

ASSUME GEOMEMBRANE LINER DEFECT RATE OF ONE ONE-HALF INCH HOLE / ACRE

CALCULATE SEEPAGE THROUGH GCL



USING DARCY'S LAW:

$$Q = KiA$$

$$k_{GCL} = 5 \times 10^{-9}\ \text{cm/s} = 1.42 \times 10^{-5}\ \text{FT/DAY}$$

$$\left.\begin{array}{l}\text{MAX W.L.} = 1005 \\ \text{MIN LINER EL} = 935\end{array}\right\} H = 70\ \text{FT}$$

$$i = \frac{H}{t}\quad \frac{70}{0.25/12} = 3360$$

$$A = \frac{\pi}{4}\left(0.5/12\right)^2 = 0.00136\ \text{FT}^2$$

$$\Longrightarrow Q = (1.42 \times 10^{-5}\ \text{FT/D})(3360)(0.00136\ \text{FT}^3)$$

$$Q = 6.49 \times 10^{-5}\ \text{CF/D}$$

$$Q = 0.00049\ \text{GAL/D} =$$

$$Q = 0.00049\ \text{GAD @ MAX HEAD}$$

Appendix B

Performance Analysis - Upstream Dikes Clay Barrier and Existing Pond No. 2 Clay Liner

SHERCO POND 3 SEEPAGE ANALYSIS

Upstream Barrier Data
k= 1E-07 cm/s 0.103465 ft/yr
t= 4.5 ft barrier thickness
L= 4700 ft of barrier length
Interval 2 ft of incremental barrier height

q=seepage rate
d=penetration into clay barrier
S=seepage out of clay barrier

Existing Pond No. 2 Clay Liner Data
k= 1.80E-08 cm/s 0.018624
t= 2.4 ft of liner thickness
L= 2850 ft of liner length
W= 20 ft of liner width

Area= 100 acres of pond footprint

Year	Pond Elev (ft MSL)	(Upstream Barrier Elev 960 to 962) 961			(Upstream Barrier Elev 962 to 964) 963			(Upstream Barrier Elev 964 to 966) 965			(Upstream Barrier Elev 966 to 968) 967			(Upstream Barrier Elev 968 to 970) 969			(Upstream Barrier Elev 970 to 972) 971			(Upstream Barrier Elev 972 to 974) 973		
		q (ft/yr)	d (ft)	S (gal/day)	q (ft/yr)	d (ft)	S (gal/day)	q (ft/yr)	d (ft)	S (gal/day)	q (ft/yr)	d (ft)	S (gal/day)	q (ft/yr)	d (ft)	S (gal/day)	q (ft/yr)	d (ft)	S (gal/day)	q (ft/yr)	d (ft)	S (gal/day)
1	959	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	959	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	959	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	959	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	959	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	970	0.21	0.21	0.00	0.16	0.16	0.00	0.11	0.11	0.00	0.07	0.07	0.00	0.02	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	970	0.21	0.41	0.00	0.16	0.32	0.00	0.11	0.23	0.00	0.07	0.14	0.00	0.02	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	970	0.21	0.62	0.00	0.16	0.48	0.00	0.11	0.34	0.00	0.07	0.21	0.00	0.02	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9	970	0.21	0.83	0.00	0.16	0.64	0.00	0.11	0.46	0.00	0.07	0.28	0.00	0.02	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	970	0.21	1.03	0.00	0.16	0.80	0.00	0.11	0.57	0.00	0.07	0.34	0.00	0.02	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11	982	0.48	1.52	0.00	0.44	1.24	0.00	0.39	0.97	0.00	0.34	0.69	0.00	0.30	0.41	0.00	0.25	0.25	0.00	0.21	0.21	0.00
12	982	0.48	2.00	0.00	0.44	1.68	0.00	0.39	1.36	0.00	0.34	1.03	0.00	0.30	0.71	0.00	0.25	0.51	0.00	0.21	0.41	0.00
13	982	0.48	2.48	0.00	0.44	2.12	0.00	0.39	1.75	0.00	0.34	1.38	0.00	0.30	1.01	0.00	0.25	0.76	0.00	0.21	0.62	0.00
14	982	0.48	2.97	0.00	0.44	2.55	0.00	0.39	2.14	0.00	0.34	1.72	0.00	0.30	1.31	0.00	0.25	1.01	0.00	0.21	0.83	0.00
15	982	0.48	3.45	0.00	0.44	2.99	0.00	0.39	2.53	0.00	0.34	2.07	0.00	0.30	1.61	0.00	0.25	1.26	0.00	0.21	1.03	0.00
16	994	0 76	4.21	0.00	0.71	3.70	0.00	0.67	3.20	0.00	0.62	2.69	0.00	0.57	2.18	0.00	0.53	1.79	0.00	0.48	1.52	0.00
17	994	0.76	4.97	89.83	0.71	4.41	0.00	0.67	3.86	0.00	0.62	3.31	0.00	0.57	2.76	0.00	0.53	2.32	0.00	0.48	2.00	0.00
18	994	0.76	5.73	146 16	0.71	5.13	120.83	0.67	4.53	5.67	0.62	3.93	0.00	0.57	3.33	0.00	0.53	2.85	0.00	0.48	2.48	0.00
19	994	0 76	6.48	146.16	0.71	5.84	137.30	0.67	5.20	128.44	0.62	4.55	10.10	0.57	3.91	0.00	0.53	3.38	0.00	0.48	2.97	0.00
20	994	0.76	7.24	146.16	0.71	6.55	137 30	0.67	5.86	128.44	0.62	5.17	119.59	0.57	4.48	0.00	0.53	3.91	0.00	0.48	3.45	0.00
21	1008	1.08	8.32	208.17	1.03	7.59	199.31	0.99	6.85	190.45	0.94	6.12	181.59	0.90	5.38	169.55	0.85	4.76	49.96	0.80	4.25	0.00
22	1008	1.08	9.40	208.17	1.03	8.62	199.31	0.99	7.84	190.45	0.94	7.06	181.59	0.90	6.28	172.73	0.85	5.61	163.88	0.80	5.06	107.54
23	1008	1 08	10.48	208.17	1.03	9.66	199 31	0.99	8.83	190.45	0.94	8.00	181.59	0.90	7.17	172.73	0.85	6.46	163.88	0.80	5.86	155.02
24	1008	1.08	11.57	208.17	1.03	10.69	199.31	0.99	9.82	190.45	0.94	8.94	181.59	0.90	8.07	172.73	0.85	7.31	163.88	0.80	6.67	155.02
25	1008	1.08	12.65	208.17	1.03	11.73	199.31	0.99	10.81	190.45	0.94	9.89	181.59	0.90	8.97	172.73	0.85	8.16	163.88	0.80	7.47	155.02
26	1008	1.08	13 73	208.17	1.03	12.76	199 31	0.99	11.79	190.45	0.94	10.83	181.59	0.90	9.86	172.73	0.85	9.01	163.88	0.80	8.28	155.02
27	1008	1.08	14.81	208.17	1.03	13.80	199 31	0.99	12.78	190.45	0.94	11.77	181.59	0.90	10.76	172.73	0.85	9.86	163.88	0.80	9.08	155.02
28	1008	1.08	15.89	208.17	1.03	14.83	199.31	0.99	13.77	190.45	0.94	12.71	181.59	0.90	11.66	172.73	0.85	10.71	163.88	0.80	9.89	155.02
29	1008	1.08	16.97	208 17	1.03	15.86	199.31	0.99	14.76	190.45	0.94	13.66	181.59	0.90	12.55	172.73	0.85	11.57	163.88	0.80	10.69	155.02
30	1008	1.08	18.05	208.17	1.03	16 90	199.31	0.99	15.75	190.45	0.94	14.60	181.59	0.90	13.45	172.73	0.85	12.42	163.88	0.80	11.50	155.02
31	984	0 53	18.58	101.87	0.48	17 38	93.01	0.44	16.19	84.15	0.39	14.99	75.29	0.34	13.80	66.44	0.30	12.71	57.58	0.25	11.75	48.72
32	960	0.00	18.58	0 00	0 00	17 38	0.00	0.00	16.19	0.00	0.00	14.99	0.00	0.00	13.80	0.00	0.00	12.71	0.00	0.00	11.75	0.00

SHERCO POND 3 SEEPAGE ANALYSIS

		(Upstream Barrier Elev 974 to 976)			(Upstream Barrier Elev 976 to 978)			(Upstream Barrier Elev 978 to 980)			(Upstream Barrier Elev 980 to 982)			(Upstream Barrier Elev 982 to 984)			(Upstream Barrier Elev 984 to 986)			(Upstream Barrier Elev 986 to 988)		
	Pond Elev		975			977			979			981			983			985			987	
Year	(ft MSL)	q	d	S	q	d	S	q	d	S	q	d	S	q	d	S	q	d	S	q	d	S
		(ft/yr)	(ft)	(gal/day)	(ft/yr)	(ft)	(gal/day)	(ft/yr)	(ft)	(gal/day)	(ft/yr)	(ft)	(gal/day)	(ft/yr)	(ft)	(gal/day)	(ft/yr)	(ft)	(gal/day)	(ft/yr)	(ft)	(gal/day)
1	959	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	959	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	959	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	959	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	959	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	970	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	970	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	970	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9	970	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	970	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11	982	0.16	0.16	0.00	0.11	0.11	0.00	0.07	0.07	0.00	0.02	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12	982	0.16	0.32	0.00	0.11	0.23	0.00	0.07	0.14	0.00	0.02	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
13	982	0.16	0.48	0.00	0.11	0.34	0.00	0.07	0.21	0.00	0.02	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
14	982	0.16	0.64	0.00	0.11	0.46	0.00	0.07	0.28	0.00	0.02	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15	982	0.16	0.80	0.00	0.11	0.57	0.00	0.07	0.34	0.00	0.02	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
16	994	0.44	1.24	0.00	0.39	0.97	0.00	0.34	0.69	0.00	0.30	0.41	0.00	0.25	0.25	0.00	0.21	0.21	0.00	0.16	0.16	0.00
17	994	0.44	1.68	0.00	0.39	1.36	0.00	0.34	1.03	0.00	0.30	0.71	0.00	0.25	0.51	0.00	0.21	0.41	0.00	0.16	0.32	0.00
18	994	0.44	2.12	0.00	0.39	1.75	0.00	0.34	1.38	0.00	0.30	1.01	0.00	0.25	0.76	0.00	0.21	0.62	0.00	0.16	0.48	0.00
19	994	0.44	2.55	0.00	0.39	2.14	0.00	0.34	1.72	0.00	0.30	1.31	0.00	0.25	1.01	0.00	0.21	0.83	0.00	0.16	0.64	0.00
20	994	0.44	2.99	0.00	0.39	2.53	0.00	0.34	2.07	0.00	0.30	1.61	0.00	0.25	1.26	0.00	0.21	1.03	0.00	0.16	0.80	0.00
21	1008	0.76	3.75	0.00	0.71	3.24	0.00	0.67	2.74	0.00	0.62	2.23	0.00	0.57	1.84	0.00	0.53	1.56	0.00	0.48	1.29	0.00
22	1008	0.76	4.51	1.24	0.71	3.95	0.00	0.67	3.40	0.00	0.62	2.85	0.00	0.57	2.41	0.00	0.53	2.09	0.00	0.48	1.77	0.00
23	1008	0.76	5.27	146.16	0.71	4.67	32.25	0.67	4.07	0.00	0.62	3.47	0.00	0.57	2.99	0.00	0.53	2.62	0.00	0.48	2.25	0.00
24	1008	0.76	6.02	146.16	0.71	5.38	137.30	0.67	4.74	45.53	0.62	4.09	0.00	0.57	3.56	0.00	0.53	3.15	0.00	0.48	2.74	0.00
25	1008	0.76	6.78	146.16	0.71	6.09	137.30	0.67	5.40	128.44	0.62	4.71	41.11	0.57	4.14	0.00	0.53	3.68	0.00	0.48	3.22	0.00
26	1008	0.76	7.54	146.16	0.71	6.81	137.30	0.67	6.07	128.44	0.62	5.33	119.59	0.57	4.71	41.11	0.53	4.21	0.00	0.48	3.70	0.00
27	1008	0.76	8.30	146.16	0.71	7.52	137.30	0.67	6.74	128.44	0.62	5.95	119.59	0.57	5.29	110.73	0.53	4.74	45.53	0.48	4.18	0.00
28	1008	0.76	9.06	146.16	0.71	8.23	137.30	0.67	7.40	128.44	0.62	6.58	119.59	0.57	5.86	110.73	0.53	5.27	101.87	0.48	4.67	32.25
29	1008	0.76	9.82	146.16	0.71	8.94	137.30	0.67	8.07	128.44	0.62	7.20	119.59	0.57	6.44	110.73	0.53	5.79	101.87	0.48	5.15	93.01
30	1008	0.76	10.58	146.16	0.71	9.66	137.30	0.67	8.74	128.44	0.62	7.82	119.59	0.57	7.01	110.73	0.53	6.32	101.87	0.48	5.63	93.01
31	984	0.21	10.78	39.86	0.16	9.82	31.00	0.11	8.85	22.15	0.07	7.89	13.29	0.02	7.04	4.43	0.00	6.32	0.00	0.00	5.63	0.00
32	960	0.00	10.78	0.00	0.00	9.82	0.00	0.00	8.85	0.00	0.00	7.89	0.00	0.00	7.04	0.00	0.00	6.32	0.00	0.00	5.63	0.00

SHERCO POND 3 SEEPAGE ANALYSIS

Year	Pond Elev (ft MSL)	(Upstream Barrier Elev 988 to 990) 989 q (ft/yr)	d (ft)	S (gal/day)	(Upstream Barrier Elev 990 to 992) 991 q (ft/yr)	d (ft)	S (gal/day)	(Upstream Barrier Elev 992 to 994) 993 q (ft/yr)	d (ft)	S (gal/day)	(Upstream Barrier Elev 994 to 996) 995 q (ft/yr)	d (ft)	S (gal/day)	(Upstream Barrier Elev 996 to 998) 997 q (ft/yr)	d (ft)	S (gal/day)	(Upstream Barrier Elev 998 to 1000) 999 q (ft/yr)	d (ft)	S (gal/day)	(Upstream Barrier Elev 1000 to 1002) 1001 q (ft/yr)	d (ft)	S (gal/day)
1	959	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	959	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	959	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	959	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	959	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	970	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	970	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	970	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9	970	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	970	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11	982	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12	982	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
13	982	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
14	982	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15	982	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
16	994	0.11	0.11	0.00	0.07	0.07	0.00	0.02	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
17	994	0.11	0.23	0.00	0.07	0.14	0.00	0.02	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
18	994	0.11	0.34	0.00	0.07	0.21	0.00	0.02	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
19	994	0.11	0.46	0.00	0.07	0.28	0.00	0.02	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	994	0.11	0.57	0.00	0.07	0.34	0.00	0.02	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21	1008	0.44	1.01	0.00	0.39	0.74	0.00	0.34	0.46	0.00	0.30	0.30	0.00	0.25	0.25	0.00	0.21	0.21	0.00	0.16	0.16	0.00
22	1008	0.44	1.45	0.00	0.39	1.13	0.00	0.34	0.80	0.00	0.30	0.60	0.00	0.25	0.51	0.00	0.21	0.41	0.00	0.16	0.32	0.00
23	1008	0.44	1.89	0.00	0.39	1.52	0.00	0.34	1.15	0.00	0.30	0.90	0.00	0.25	0.76	0.00	0.21	0.62	0.00	0.16	0.48	0.00
24	1008	0.44	2.32	0.00	0.39	1.91	0.00	0.34	1.49	0.00	0.30	1.20	0.00	0.25	1.01	0.00	0.21	0.83	0.00	0.16	0.64	0.00
25	1008	0.44	2.76	0.00	0.39	2.30	0.00	0.34	1.84	0.00	0.30	1.49	0.00	0.25	1.26	0.00	0.21	1.03	0.00	0.16	0.80	0.00
26	1008	0.44	3.20	0.00	0.39	2.69	0.00	0.34	2.18	0.00	0.30	1.79	0.00	0.25	1.52	0.00	0.21	1.24	0.00	0.16	0.97	0.00
27	1008	0.44	3.63	0.00	0.39	3.08	0.00	0.34	2.53	0.00	0.30	2.09	0.00	0.25	1.77	0.00	0.21	1.45	0.00	0.16	1.13	0.00
28	1008	0.44	4.07	0.00	0.39	3.47	0.00	0.34	2.87	0.00	0.30	2.39	0.00	0.25	2.02	0.00	0.21	1.66	0.00	0.16	1.29	0.00
29	1008	0.44	4.51	1.24	0.39	3.86	0.00	0.34	3.22	0.00	0.30	2.69	0.00	0.25	2.28	0.00	0.21	1.86	0.00	0.16	1.45	0.00
30	1008	0.44	4.94	84.15	0.39	4.25	0.00	0.34	3.56	0.00	0.30	2.99	0.00	0.25	2.53	0.00	0.21	2.07	0.00	0.16	1.61	0.00
31	984	0.00	4.94	0.00	0.00	4.25	0.00	0.00	3.56	0.00	0.00	2.99	0.00	0.00	2.53	0.00	0.00	2.07	0.00	0.00	1.61	0.00
32	960	0.00	4.94	0.00	0.00	4.25	0.00	0.00	3.56	0.00	0.00	2.99	0.00	0.00	2.53	0.00	0.00	2.07	0.00	0.00	1.61	0.00

SHERCO POND 3 SEEPAGE ANALYSIS

		(Upstream Barrier Elev 1002 to 1004) 1003			(Upstream Barrier Elev 1004 to 1006) 1005			(Upstream Barrier Elev 1006 to 1008) 1007			Existing Pond No. 2 Clay Liner 990			Cumulative
Year	Pond Elev (ft MSL)	q (ft/yr)	d (ft)	S (gal/day)	q (ft/yr)	d (ft)	S (gal/day)	q (ft/yr)	d (ft)	S (gal/day)	q (ft/yr)	d (ft)	S (gal/day)	Seepage (gal/ac/day) (GADs)
1	959	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
2	959	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
3	959	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
4	959	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
5	959	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
6	970	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
7	970	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
8	970	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
9	970	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
10	970	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
11	982	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
12	982	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
13	982	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
14	982	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
15	982	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
16	994	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.03	0.00	0.0
17	994	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.06	0.00	0.9
18	984	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.09	0.00	2.7
19	994	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.12	0.00	4.2
20	994	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.16	0.00	5.3
21	1008	0.11	0.11	0.00	0.07	0.07	0.00	0.02	0.02	0.00	0.14	0.29	0.00	10.0
22	1008	0.11	0.23	0.00	0.07	0.14	0.00	0.02	0.05	0.00	0.14	0.43	0.00	12.2
23	1008	0.11	0.34	0.00	0.07	0.21	0.00	0.02	0.07	0.00	0.14	0.57	0.00	14.5
24	1008	0.11	0.46	0.00	0.07	0.28	0.00	0.02	0.09	0.00	0.14	0.71	0.00	16.0
25	1008	0.11	0.57	0.00	0.07	0.34	0.00	0.02	0.11	0.00	0.14	0.85	0.00	17.2
26	1008	0.11	0.69	0.00	0.07	0.41	0.00	0.02	0.14	0.00	0.14	0.99	0.00	18.4
27	1008	0.11	0.80	0.00	0.07	0.48	0.00	0.02	0.16	0.00	0.14	1.13	0.00	19.6
28	1008	0.11	0.92	0.00	0.07	0.55	0.00	0.02	0.18	0.00	0.14	1.27	0.00	20.5
29	1008	0.11	1.03	0.00	0.07	0.62	0.00	0.02	0.21	0.00	0.14	1.41	0.00	21.1
30	1008	0.11	1.15	0.00	0.07	0.69	0.00	0.02	0.23	0.00	0.14	1.55	0.00	21.9
31	984	0.00	1.15	0.00	0.00	0.69	0.00	0.00	0.23	0.00	0.00	1.55	0.00	6.4
32	960	0.00	1.15	0.00	0.00	0.69	0.00	0.00	0.23	0.00	0.00	1.55	0.00	0.0

Appendix C

Stability Analysis - West Sideslope

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STABILITY OF DISCHARGE STRUCTURES

Soil and Waste Properties (see Reference)

Material	γ (pcf)	c (psf)	ϕ (deg)
Structure	40	10,000	45 [1]
Gran. Fill	120	0	30
Bottom Ash	103	0	30
Clay/Membrane	127	0	24
Alluvium	120	0	30

[1] Effective Unit wt. of structure determined from:

$$\gamma_E = \frac{W}{U} = \frac{73 \text{ Kip} \quad \text{[previous comp.]}}{(17)(9.4)(9.4) - \frac{1}{2}(6.6+1.0)(9.4)(12) + (6.67)(22.6)(9.4)}$$

$= 35.2$ pcf $\Rightarrow$ Assume 40 pcf

When abandoned, $\gamma_{struc.} = 150$ pcf

Water Levels

Phase	Normal Max.	Surge Max.
1	960	970
2	965	970
3	977	982
4	989	994
5	1003	1008

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Results (see following figures)

File	FS	Conditions
P3PH1N	1.564	$\phi_{B.A.} = 30°$, $\phi_{liner} = 24°$
P3PH2N	1.506	
P3PH3N	1.598	
P3PH4N	1.536	
P3PH5N	1.723	
P3PH2N	1.479	$\phi_{B.A.} = 25°$ due to wetting
P3PH2NA	1.817	assuming previous structures are abandoned by filling w/ concrete
P3PH3NA	1.959	
P3PH1I	1.942	initial conditions - no water
P3PH2L	1.592	minimum water level 954
P3PH2S	1.644	surge level 970
P3PH1S	1.506	surge level 970

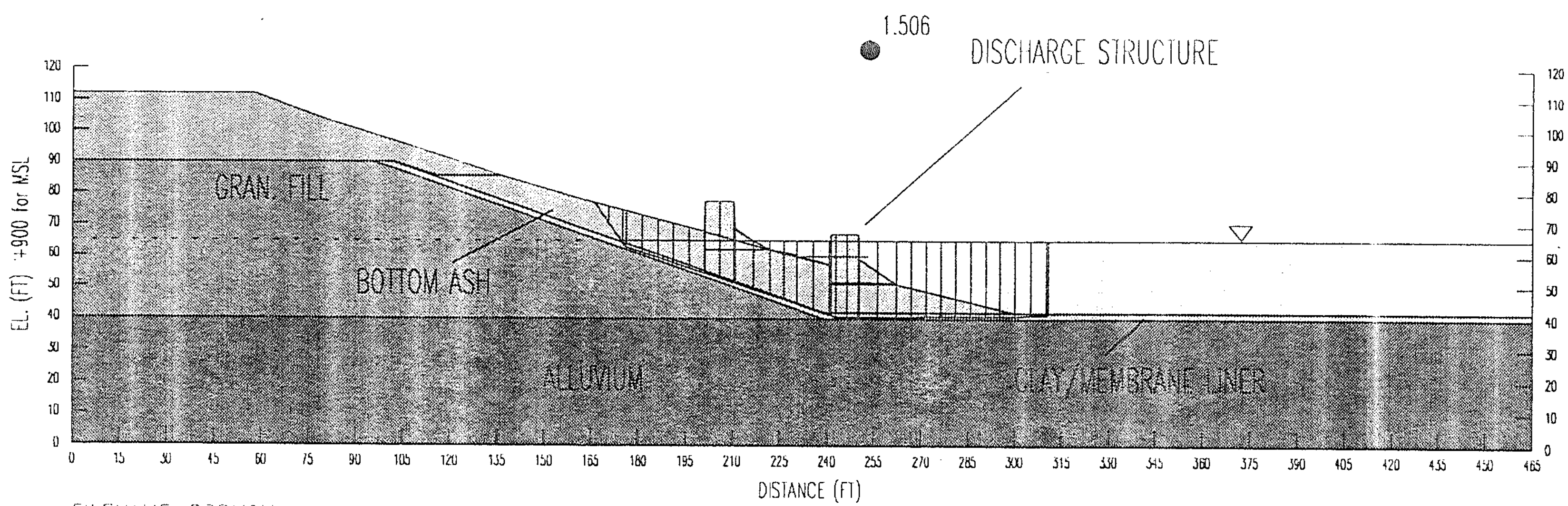
Conclusions

1. Each phase has sufficient factor of safety (>1.5) for sliding on membrane for normal max. water level and surge water level.
2. If bottom ash/membrane friction angle is reduced to 25° by wetting, stability is still acceptable.
3. Filling lower structures with concrete results in higher factors of safety.

Reference Application for Amendment of NPDES Permit No. 0002186, Barr, Jan., 1995

NSP--SHERCO POND NO. 3
DISCHARGE STRUCTURES
23-71-027-TJR

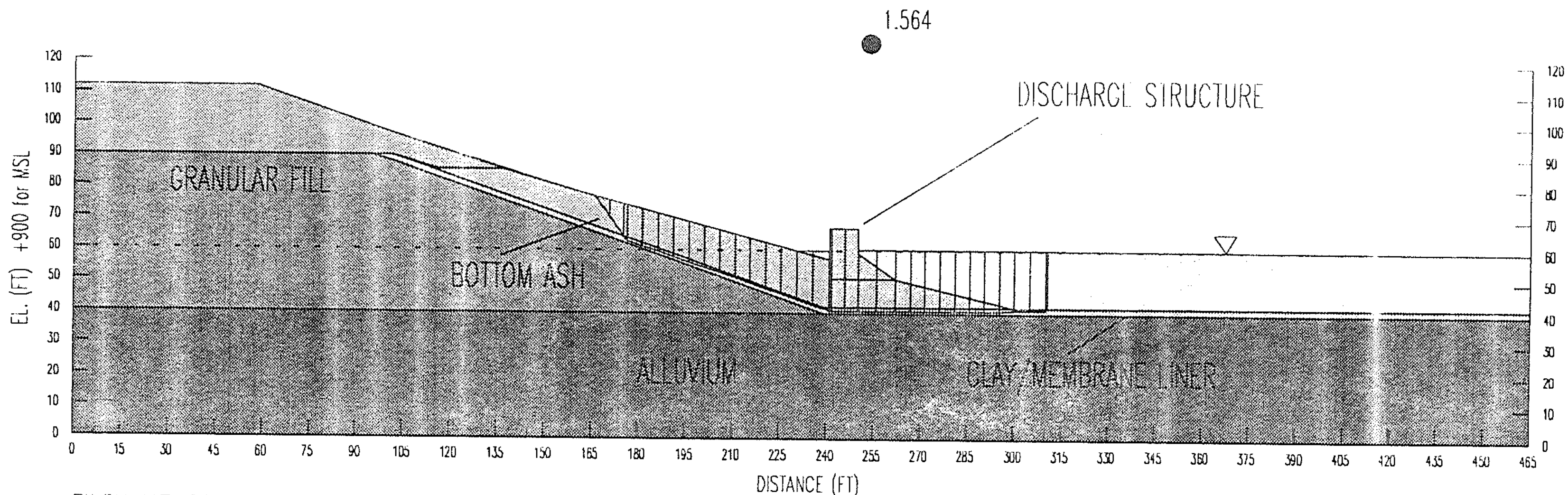
PHASE 2
NORMAL MAX. WATER LEVEL: 965



FILENAME: P3PH2N

NSP-SHERCO POND NO. 3
DISCHARGE STRUCTURES
23-71-027-TJR

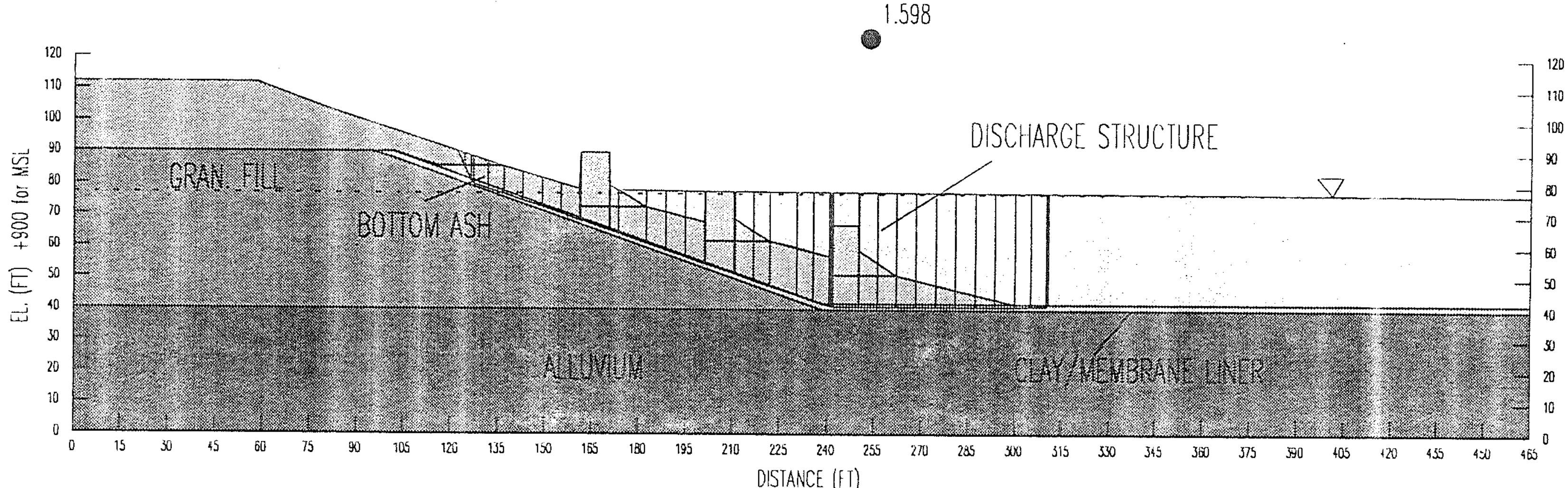
PHASE 1
NORMAL MIN. WATER LEVEL: 960



FILENAME: P3PH1N

NSP-SHERCO POND NO. 3
DISCHARGE STRUCTURES
23-71-027-TJR

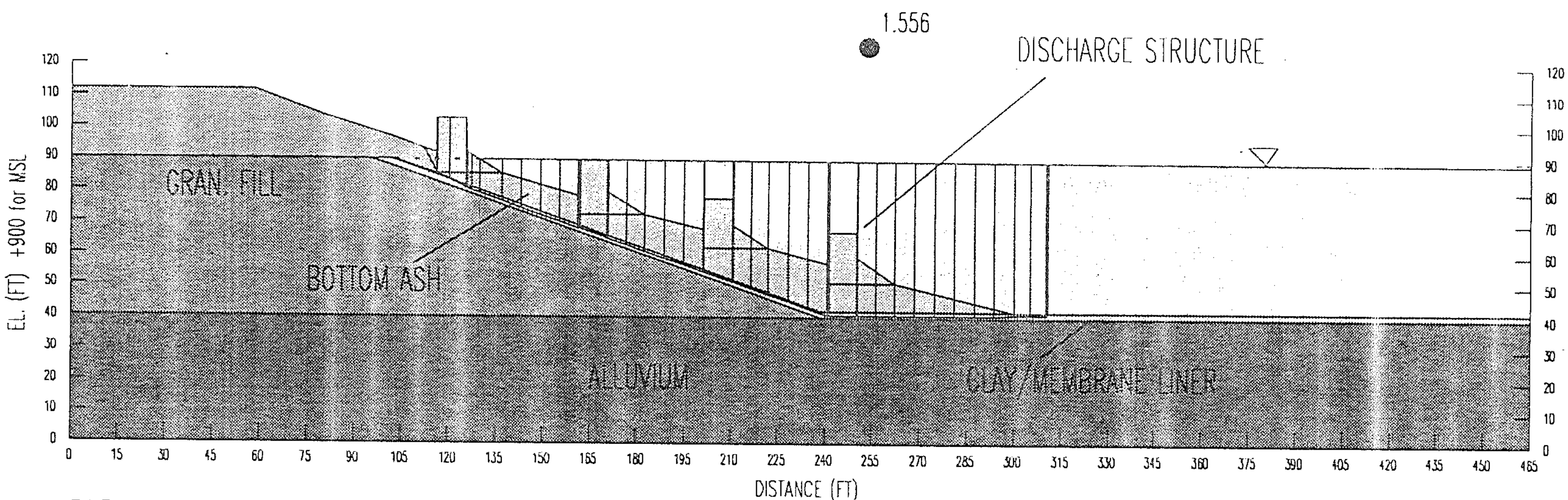
PHASE 3
NORMAL MAX. WATER LEVEL: 977



FILENAME: P3PH3N

NSP-SHERCO POND NO. 3
DISCHARGE STRUCTURES
23-71-027-TJR

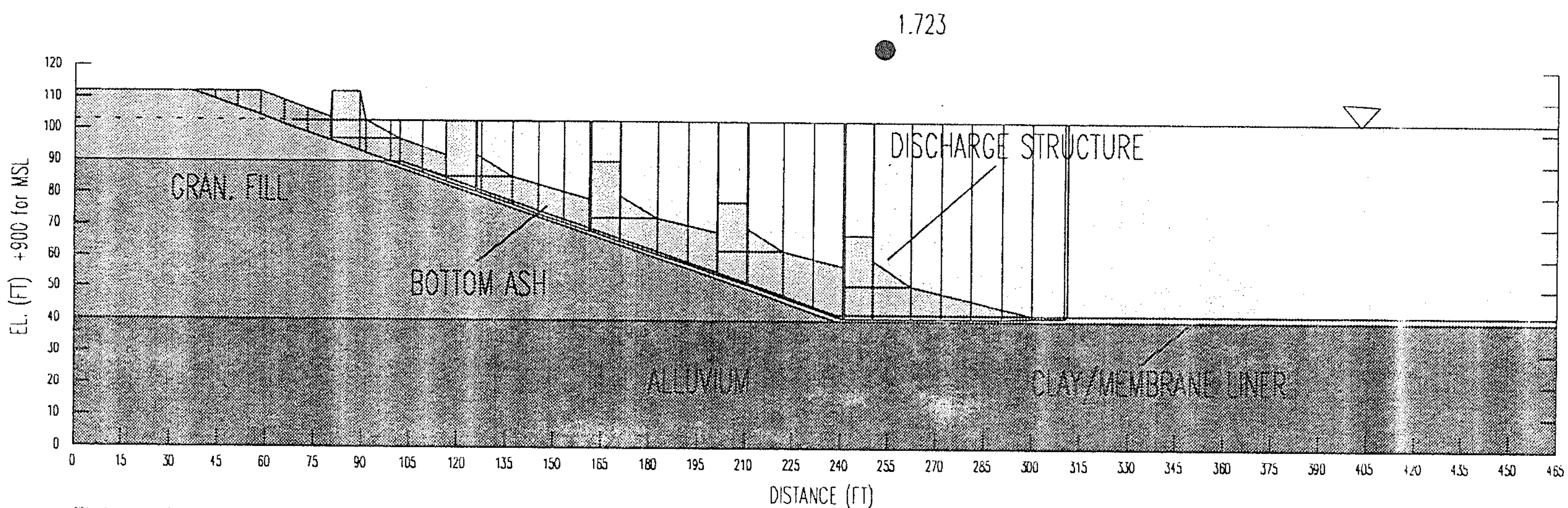
PHASE 4
NORMAL MAX. WATER LEVEL: 989



FILENAME: P3PH4N

NSP-SHERCO POND NO. 3
DISCHARGE STRUCTURES
23-71-027-TJR

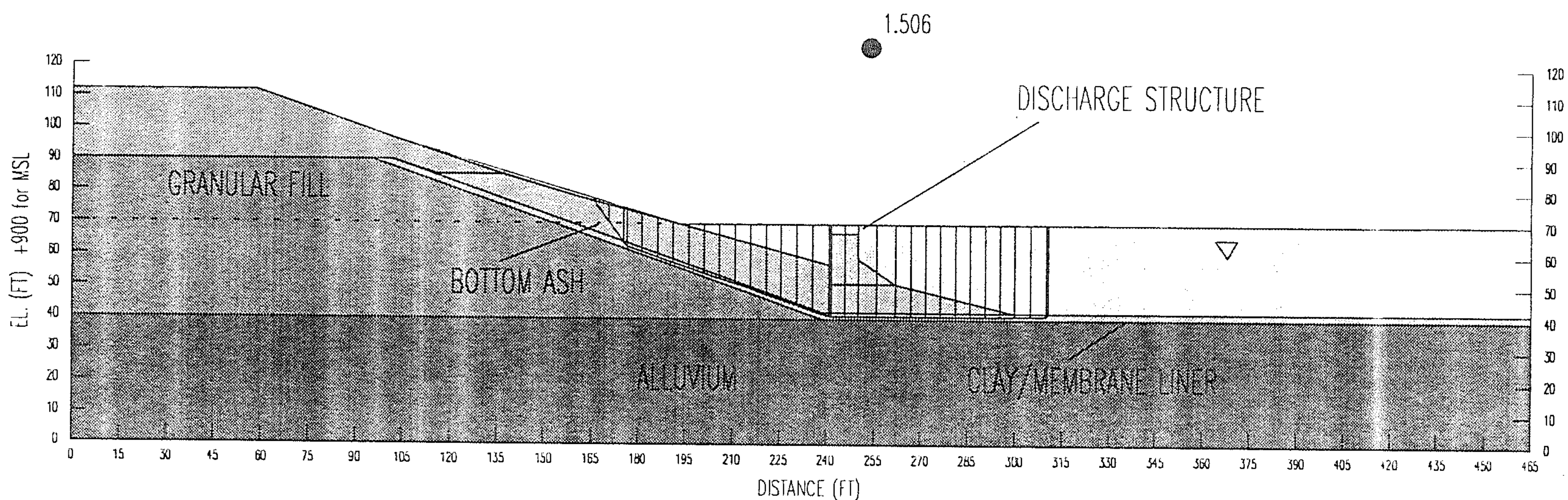
PHASE 5
NORMAL MAX. WATER LEVEL: 1003



FILE NAME: P3PH5N

NSP-SHERCO POND NO. 3
DISCHARGE STRUCTURES
23-71-027-TJR

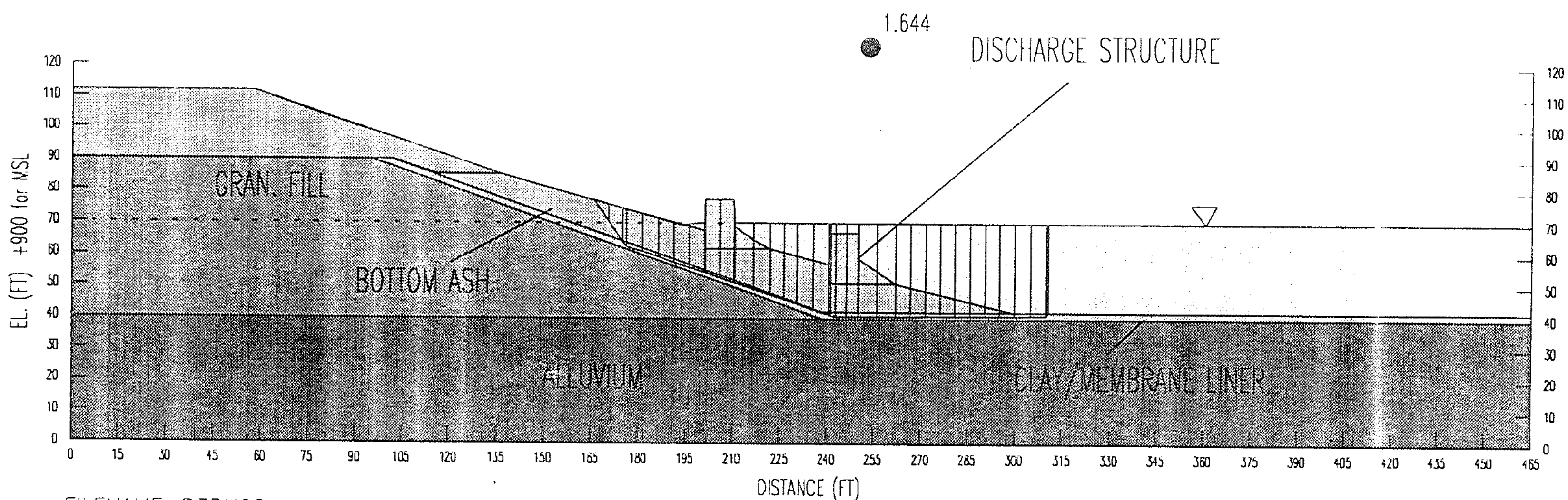
PHASE 1
SURGE WATER LEVEL: 970



P3PH1S

NSP-SHERCO POND NO. 3
DISCHARGE STRUCTURES
23-71-027-TJR

PHASE 2
SURGE WATER LEVEL: 970



FILENAME: P3PH2S

NSP- Sherco Intake Structure
BARR ENGINEERING CO.

23/71-027 TJR 160

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Reference: Bowles "Foundation Analysis and Design", 1988.

Figure 4-6 (Bowles)

Structure	slope	Soil Bottom Ash	
$D = 3.0'$	$\beta = 14° = \theta$	$\phi = 30°$	$\gamma = 103\,pcf$
$B = 9.33' = L$			

$\boxed{\text{Method \#1}}$ $\alpha = 45 + \phi/2 = 60°$

(1) Find r_o

$$\frac{\sin\alpha}{B} = \frac{\sin 45 + \phi/2}{r_o}$$

$r_o = 9.33'$

(2) Find r

$r = r_o e^{\theta \tan\phi}$

$r = 10.75'$

(3) Find $\overline{E_g}$ (Distance downslope that the failure plane exits.)

$$\overline{E_g} \approx \frac{r + D}{\sin(45 - \phi/2)} = 27.5'$$

$\boxed{\text{Method \#2}}$ $\alpha = 45 + \phi/2 = 60°$

$\overline{gE} = B\tan^2\alpha$

$\overline{gE} = 28'$

$\phi = 25°$ $\alpha = 45 + \phi/2 = 57.5$

$\boxed{\text{Method \#2}}$ $\overline{gE} = B\tan^2\alpha$

$\overline{gE} = 23'$

$\boxed{\text{Method \#1}}$ $\alpha = 65°$

$r_o = 8.68$ $r = 9.73$

$$\overline{E_g} = \frac{r + D}{\sin(45 - \phi/2)} = 23.7'$$

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NSP Sherco Intake Structure

Soil Bearing Capacity

eference: (Bowles ....)

$$q_{ult} = \bar{q} N_q' s_q d_q g_q + \frac{1}{2} \gamma B N_\gamma s_\gamma g_\gamma d_\gamma$$

$s_q = 1 + \frac{B}{L} \tan \phi = 1.58$

$d_q = 1+2 \tan \phi (1-\sin \phi)^2 \frac{D}{B} = 1.09$

$g_q = (1 - \tan \beta)^2 = 0.56$

$s_\gamma = 1 - 0.4 \, B/L = 0.6$

$d_\gamma = 1$

$g_\gamma = (1 - \tan \beta)^2 = 0.56$

$\bar{q} = \gamma D = 309 \, psf$

Table 4-7 (Bowles)

Find N_q'

	$D/B = 0$		$D/B = 0.75$
$\beta = 0°$	18.40	(13.31)	11.16
		14.92	
$\beta = 20°$	18.40	(14.75)	9.84

interpolate for $D/B = 0.32$ and $\beta = 14°$

$N_q' = 14.92$

$N_\gamma' = 1.5 (N_q - 1) \tan \phi$

(Hansen equation)

$N_q = e^{\pi \tan \phi} \tan^2 (45 + \phi/2)$

$N_q = 18.40$

$N_\gamma = 1.5 (17.40) \tan \phi$

$N_\gamma = 15.07$

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NSP Sherco Intake Structure

Soil Bearing Capacity (cont.)

$$q_{ult} = \underset{\bar{q}}{(309\,psf)}\underset{N_q'}{(14.92)}\underset{s_q}{(1.58)}\underset{d_q}{(1.09)}\underset{g_q}{(0.56)} + \frac{1}{2}\underset{\gamma_{soil}}{(103\,pcf)}\underset{B}{(9.33')}\underset{N_\gamma}{(15.07)}\underset{s_\gamma}{(0.6)}(0.56)$$

$q_{ult} = 4446 + 2434$

$q_{ult} = 6880\ psf$

@ $\phi = 25°$

$$q_{ult} = \bar{q}\, N_q' \, s_q\, d_q\, g_q + \tfrac{1}{2}\gamma B N_\gamma s_\gamma g_\gamma d_\gamma$$

$s_q = 1 + \frac{B}{L}\tan\phi = 1.47$

$d_q = 1 + 2\tan\phi(1-\sin\phi)^2\frac{D}{B} = 1.10$

$g_q = (1-\tan\beta)^2 = 0.56$

$s_\gamma = 0.6$

$d_\gamma = 1$

$g_\gamma = 0.56$

$\bar{q} = \gamma D = 309\ psf$

$N_q' = 14.92$

$N_\gamma' = 1.5(N_q - 1)\tan\phi$

$N_q = e^{\pi\tan\phi}\tan^2(45 + \phi/2)$

$N_q = 10.66$

$N_\gamma = 1.5(9.66)\tan\phi$

$N_\gamma = 6.76$

$$q_{ult} = \underset{\bar{q}}{(309\,psf)}\underset{N_q'}{(14.92)}\underset{s_q}{(1.47)}\underset{d_q}{(1.10)}\underset{g_q}{(0.56)} + \frac{1}{2}\underset{\gamma_{soil}}{(103\,pcf)}\underset{B}{(9.33)}\underset{N_\gamma}{(6.76)}\underset{s_\gamma}{(0.6)}\underset{g_\gamma}{(0.56)}$$

$q_{ult} = 4175 + 1091$

$q_{ult} = 5266\ psf$

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NSP - Sherco
Intake Structure

Load Calculations   Factor Safety = 3.0

Total Weight of Structure ≈ 73 kips = P
(assume concrete @ 150 pcf)

Assume P acts on square base only - $B = 9.33'$

$$q = \frac{P}{B^2} = \frac{73 \text{ kips}}{(9.33)^2 \text{ ft}^2} = 838 \text{ lbs/ft}^2$$

add ballast @ 120 pcf

Volume of ballast = $8' \times 8' \times 17' = 1088 \text{ ft}^3$

$1088 \times 120 = 131$ kips

$$\boxed{q = \frac{73 + 131}{(9.33)^2} = 2344 \text{ lbs/ft}^2}$$

@ $\phi = 30°$ $\frac{q_{ult}}{F.S.} = q_{allow} = \frac{6880}{3} = 2293 \text{ lbs/ft}^2 \approx 2344$ psf

@ $\phi = 25°$ $q_{allow} = \frac{5266}{3} = 1755 \text{ lbs/ft}^2 < 2344$ psf

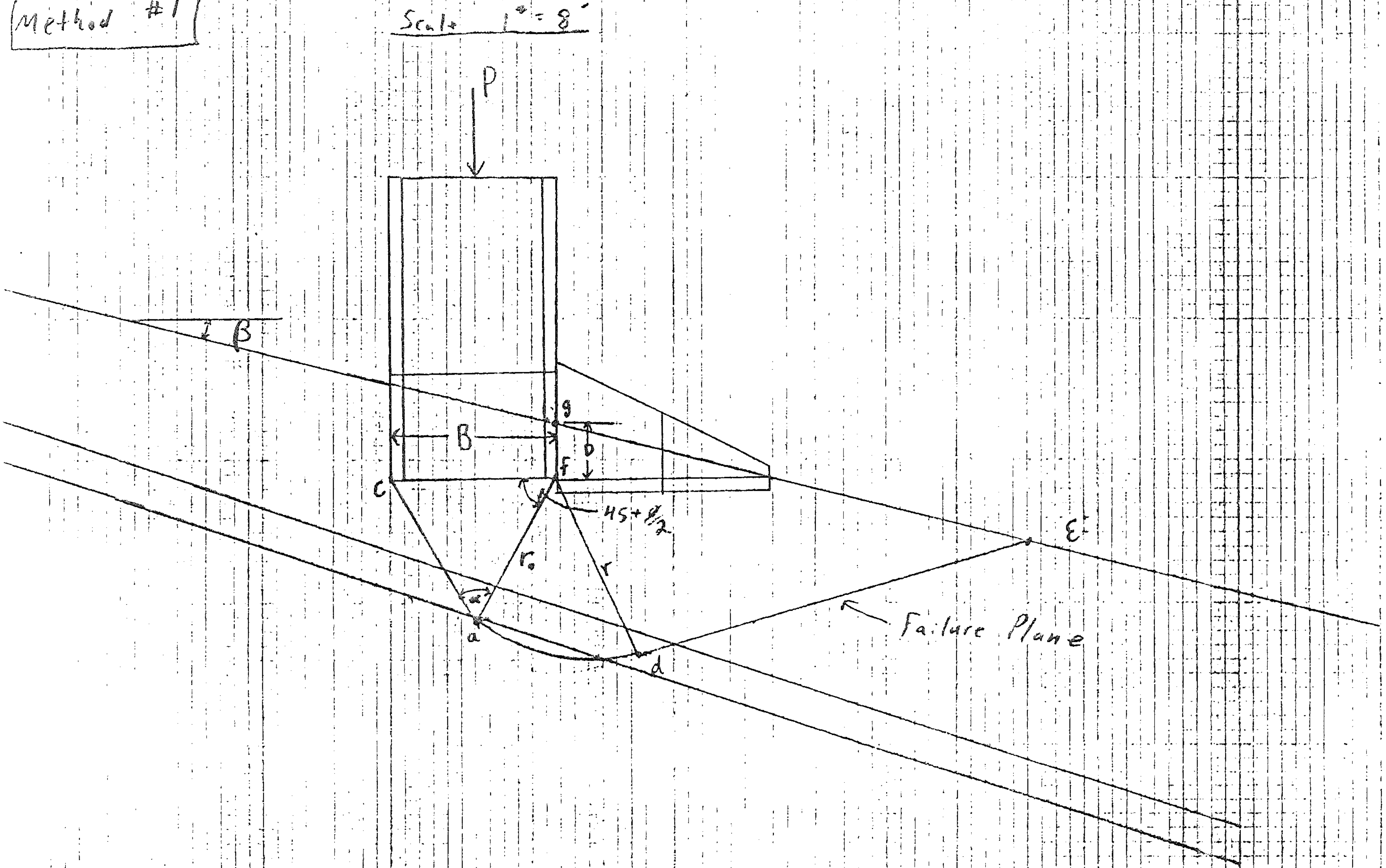
For fully effective base: $q = \frac{73 \text{ kip}}{(9.33)(22.6) \text{ ft}^2} = 346$ psf

with ballast: $q = \frac{73+131}{(9.33)(22.6)} = 967$ psf

$q_{allow} = 1755$ psf > 967 psf OK

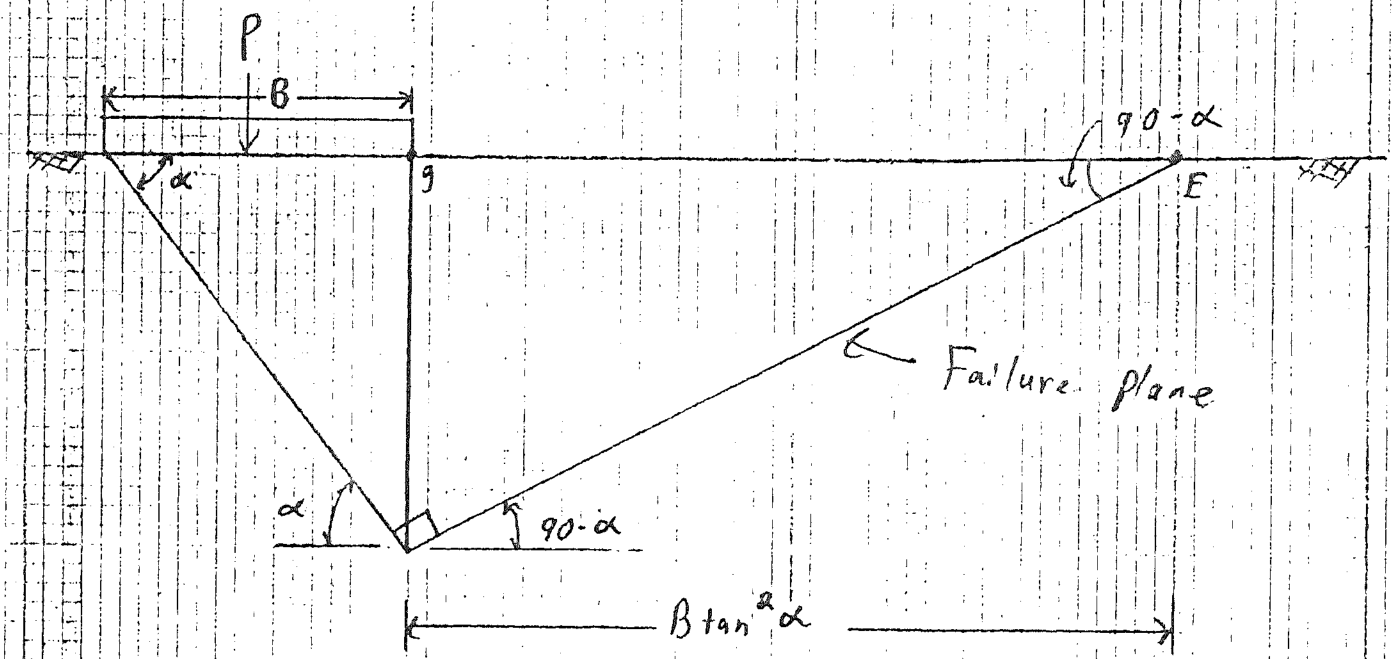
Method #1

2-17-95



Method

Not to Scale



Appendix D

Stability Analysis - Upstream Dikes

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STABILITY OF PERIMETER DIKES

Soil and Waste Properties (See Reference)

Material	γ (pcf)	c (psf)	ϕ (deg.)
Gran. Fill	120	0	30
Clay	127	0	30
Bottom Ash	103	0	30
Scr. Solids	107	0	35
Alluvium	120	0	30

Results (See following figures)

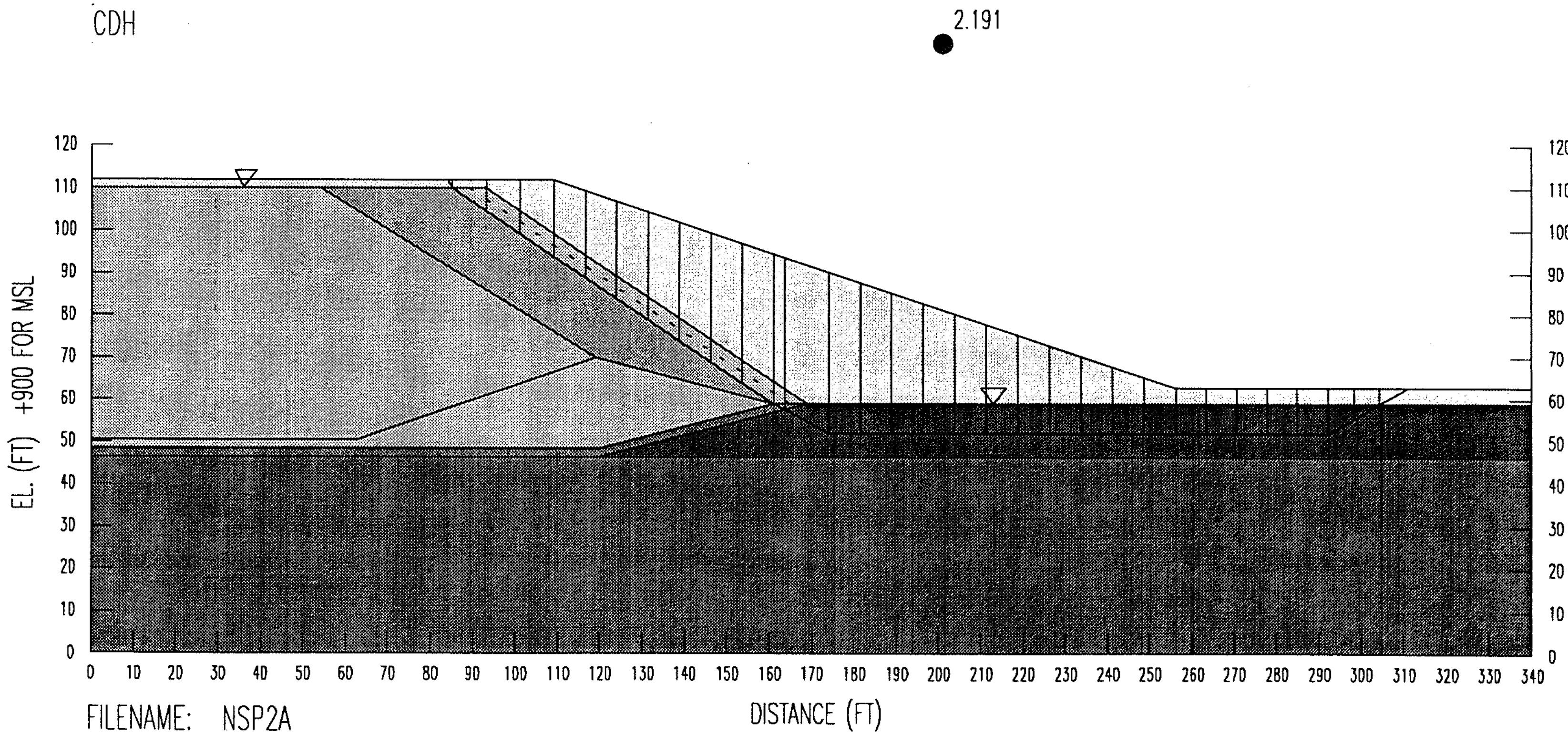
File	FS	Conditions
NSP2A	2.191	Max. water
NSP3A	1.916	↓
NSP4A	2.503	↓
NSP3AS	1.752	C_s = 0.025 [seismic loading]

Conclusions

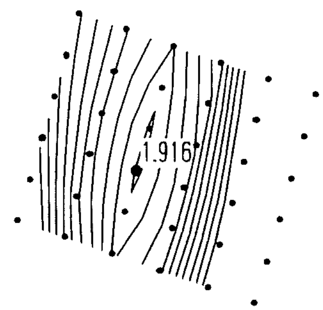
Sufficient FS for seismic and static conditions.

Reference Application for Amendment of NPDES Permit No. 0002186, Barr, Jan. 1995

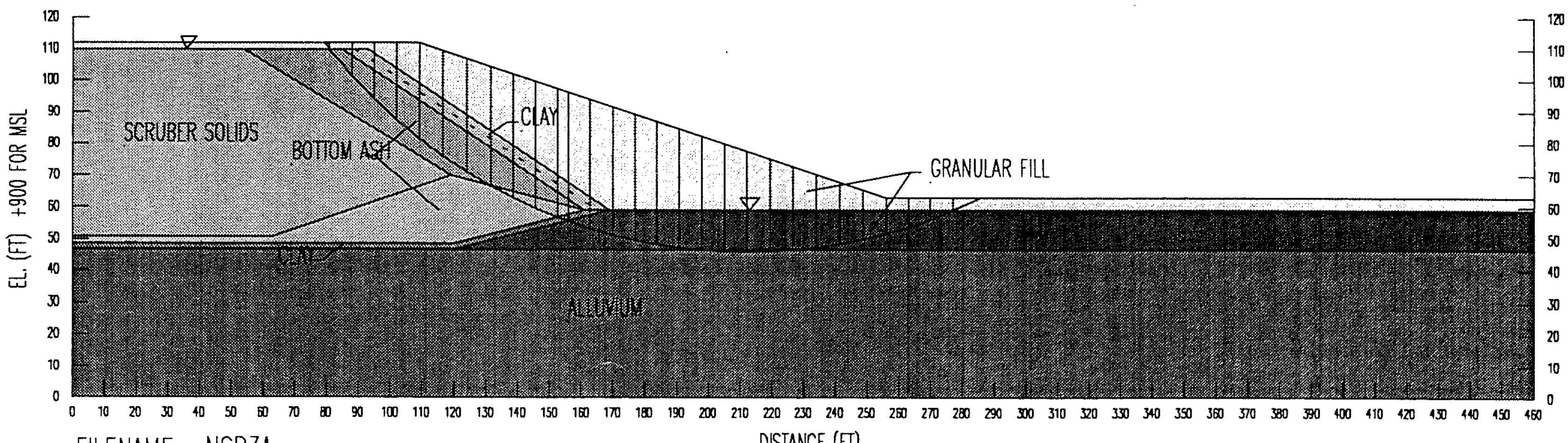
NSP SHERCO
23-71-027-TJR-160
2-16-95
CDH



FILENAME: NSP2A

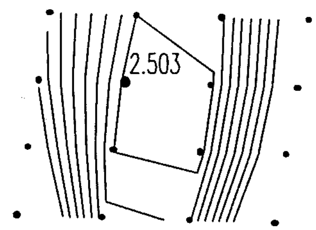


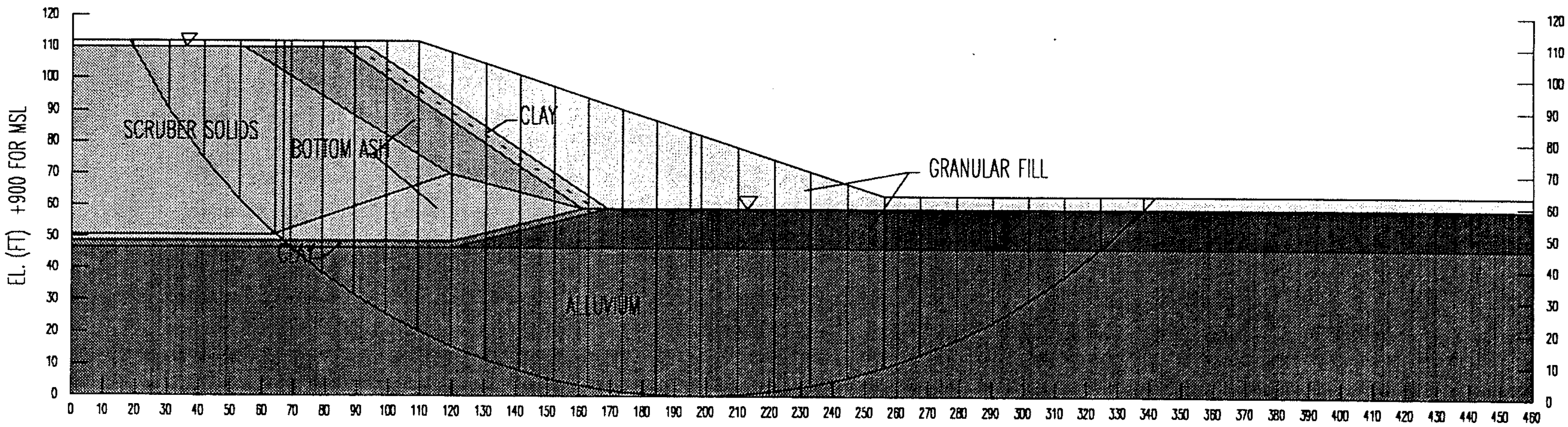
NSP SHERCO
23-71-027-TJR-160
CDH
2-16-95



FILENAME: NSP3A

NSP SHERCO
23-71-027-TJR-160
CDH
2-16-95





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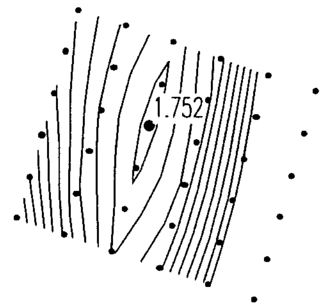
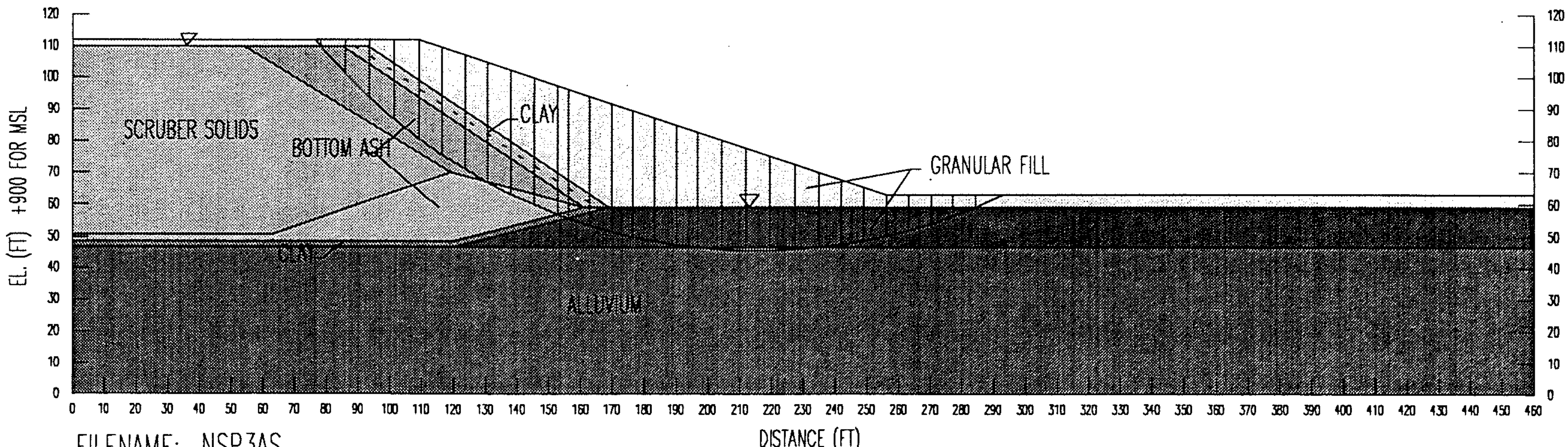


NSP SHERCO
23-71-027-TJR-160
CDH
2-16-95

Seismic Coeff, C_s = 0.025



FILENAME: NSP3AS

Appendix E

Structural Analysis - Discharge Structures

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DISCHARGE STRUCTURE

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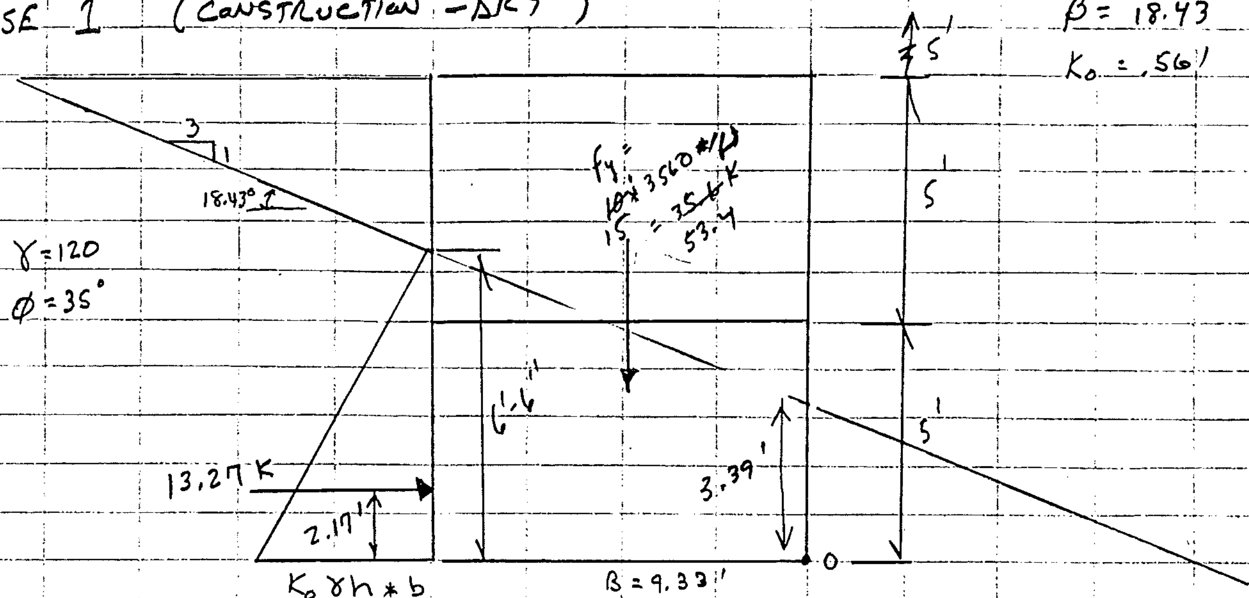
WT 8 x 8 ≈ 3560 #/ft
6 x 6 ≈ 2460 #/ft

$K_o = (1 - \sin\phi)(1 + \sin\beta)$
$\phi = 35°$
$\beta = 18.43$
$K_o = .561$

CASE 1 (CONSTRUCTION - DRY)



$K_o \gamma h * b$
$= .561 * 120 * 6.5 * 9.33'$
$= 4.082$ KSF

F_y	F_x	ARM	ΣM_{OT}	ΣM_R
~~35.6~~ 53.4		4.67		~~166.07~~ 249.4 K
	13.27	2.17	28.8 K	

$F.S = \frac{\Sigma M_R}{\Sigma M_{OT}} = \cancel{5.76}\ 8.64$

$X_R = \frac{\Sigma M_{net}}{\Sigma F_y} = \cancel{3.86}\ 4.13$ ft

$e = \frac{B}{2} - X_R = \cancel{.805}\ .53 < \frac{B}{6} = 1.56$

∴ w/in Kern

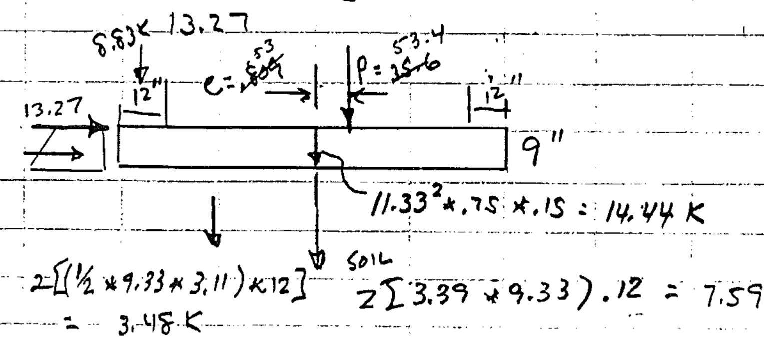
SLIDING

$F.S = \frac{\Sigma F_y \tan\phi \ \mu}{\Sigma F_H}$

$\mu_s =$ CONC - CONC ≈ .8 * .75 (wet) ≈ .6

$F.S = \frac{\cancel{35.6}\ 53.4 * .6}{13.27} = \cancel{1.61}\ 2.41 > 1.5$ O.K NO Dowels REQ'D

BEARING



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	F_y		F_x	arm	M_{OT}	M_R	
Box	~~35.6~~ 53.4			4.856		~~172.87~~ 274.2	
FTG	14.44			5.67		67.36	
Soil	8.83	19.9		10.33		91.21	159.37
Soil	7.59			5.67		43.03	
Soil	3.48			7.22		25.13	
~~Soil~~	~~4.67~~			~~5~~			
			13.27	.75	9.95	-	
			3.06	.375	1.14		
	~~69.94~~ 87.74		16.33		11.09	~~399.6~~ 500.94	

$X_R = \frac{\Sigma M_{net}}{\Sigma F_y} = \cancel{5.55}\ 5.58$ $\qquad e = \frac{B}{2} - X_R = \cancel{.11}\ .08$

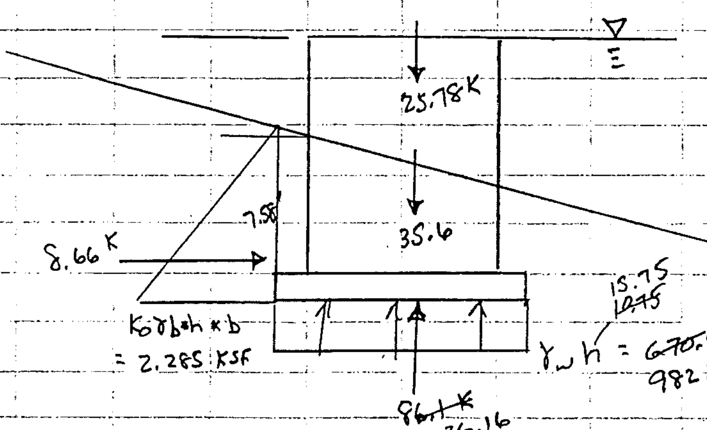
$$f_b = \frac{P}{BL}\left(1 \pm \frac{6e}{L}\right)$$

$$= \frac{\cancel{69.94}\ 87.74}{11.33 \times 11.33}\left(1 \pm \frac{6 \times \cancel{.11}\ .08}{11.33}\right) = \cancel{.576}\ .713 \text{ KSF}$$

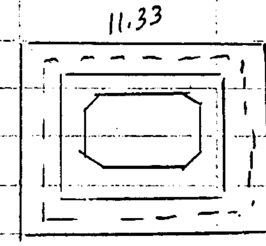
~~.513~~ .653 KSF

CASE 2 (MAX UPLIFT, DEWATERED)

FOR 10' SECTION



11.33



AREA
$11.33^2 - 9.33^2 = 41.32 \text{ ft}^2$
$h = \cancel{10}\ 15$
$P = \gamma h = \cancel{624}\ 936$ PSF
$F = PA = \cancel{25.78}\ 38.68$ K

	F_y	F_x	ARM	M_{OT}	M_R
Box	~~35.6~~ 53.4		4.856		~~172.87~~ 259.3
FTG	14.44		5.67		67.36
γ_b Soil	$19.9 \times \frac{57.6}{120} = 9.55$		8.008		76.49
H_2O FTG	~~25.78~~ 38.68		5.67		~~146.17~~ 219.3
uplift	<~~86.1~~> <126.16>		5.67	~~488.2~~ 715.3	- - -
		8.66	2.53	21.88	
	<~~.73~~> <10.09>			~~510.08~~ 737.2	~~462.89~~ 622.5

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∴ Add Ballast

$A_{I.S.} = (8' \times 8') - 2$ # fillets $= 62\ ft^2$

leave ~~4~~ 6 feet for Bounce

$Wt = (\cancel{18'}\,15' - \cancel{4'}\,6')\ 62\ ft^2 \times 145\ pcf = \cancel{53.94}\ 80.91\ K \downarrow$

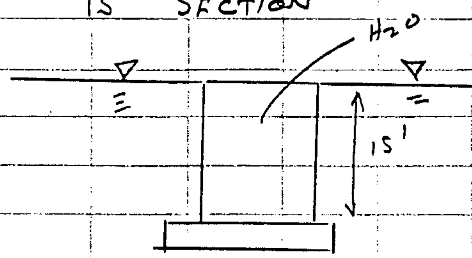
$\Sigma F_y = \cancel{53.21}\ 70.82 \downarrow$ $\qquad M_R = \cancel{768.72}\ 1015.4\ K$ $\qquad F.S._{OT} = \dfrac{1015.4}{737.2} = 1.37$

$\Sigma F_x = 8.66 \rightarrow$ $\qquad M_{OT} = \cancel{510.08}\ 737.2$

$X_R = \dfrac{\Sigma M_{net}}{\Sigma F_y} = \dfrac{\cancel{255.65}\ 278.2}{\cancel{53.21}\ 70.82} = \cancel{4.86}\ 3.93$ $\qquad e = \cancel{.804'}\ 1.74 < \dfrac{B}{6}$

Base Sliding $= \dfrac{\Sigma F_y \tan\phi}{\Sigma F_H} = \dfrac{\cancel{53.21}\ 70.82 \tan 35^\circ}{8.66} = \cancel{4.30}\ 5.72 > 1.5$ O.K

CASE 2A 15' SECTION NO FILL, NOT DEWATE.



	F_y	f_x	arm	M_{OT}	M_R
Box	53.4		4.67		249.4
FTG	14.44		5.67		67.36
γ_b, soil	9.55		8.008		76.49
O.S. H_2O	25.78 * 15/10 = 38.67		5.67		219.26
I.S. H_2O	62 * 15 * .0624 = 58		5.67		329.04
uplift	<126.16>		5.67	715.3	
		8.66	2.53	21.88	
	47.90	8.66		737.2	941.55

$X_R = \dfrac{\Sigma M_{net}}{\Sigma F_y} = 4.27$ $\qquad e = \dfrac{B}{2} - X_R = 1.40' < 1.88$ w/in Kern

$f_p = \dfrac{P}{A}\left(1 \pm \dfrac{6e}{L}\right) = \dfrac{47.9}{(11.33)^2}\left(1 \pm \dfrac{6(1.40)}{11.33}\right) = $ .65 KSF, .10 KSF

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SLIDING

Base $F.S. = \frac{\Sigma F_V \tan\phi}{\Sigma F_H} = \frac{47.90 \tan 35}{8.66} = 3.87 > 1.5$ o.k.

O.T.

$F.S. = \frac{\Sigma M_R}{\Sigma M_{OT}} = \frac{941.55}{737.2} = 1.27$

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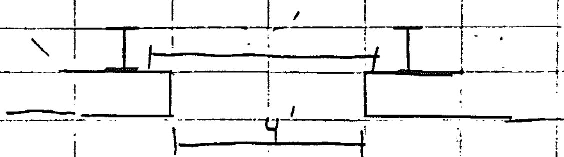
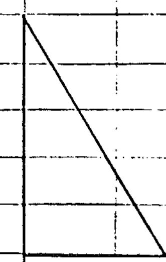
STOP LOGS





$p = \gamma h$

h	p	$M = \frac{1}{8} w l^2$ (4.5 ft)	$V = \frac{1}{2} w l$	d REQ'd
6'	374.4 PSF	.949	.84	2.41
8'	499.2	1.265	1.13	2.79
10'	624	1.58	1.41	3.11
12'	748.8	1.895	1.69	3.41
15'	936	2.37 K-ft/ft	2.11	3.82

Slenderness factor

$C_s = \sqrt{\frac{l_e d}{b^2}}$

$l_e = 1.63\, l_u + 3d$

$= 1.63(30) + 3(6) = 66.9$

DURATION $C_D = 1.25$ (7 DAYS)

5"+ B&S OR P.T. MOISTURE C_M = $F_b, F_t, F_v, E = 1.0$; $F_{c\perp} = .67$, $F_c = .91$

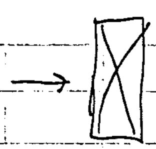
FORM $C_F = 1.0$

SOUTHERN YELLOW PINE / USED ANY CONDITION, SURFACE GREEN, NO. 2 SP

	F_b	F_t	F_v	$F_{c\perp}$	F_c	E
NO. 2 SR, 5" & THICKER	1100	725	45	375	625	1,400,000
2½"-4" Thick NO. 2, 5" & WIDER	975	500	85	375	675	1,400,000

$S_x = \frac{bd^2}{6}$ (per ft) $= \frac{12\, d^2}{6}$ $\qquad f_b = \frac{M}{S_x}$ (K-in) $\Rightarrow d = \sqrt{\frac{6M}{b F_b}} = \sqrt{\frac{6M}{12 \cdot 975}}$

TRY 4 × 12 ROUGH



$S_y = \frac{bd^2}{6} = \frac{12 \cdot 4^2}{6} = 32\ in^3/ft$

$f_b = \frac{M}{S_y} = 888$ PSI (@ h = 15') < 975 PSI

use 4×12 or 4×6

$C_s = \sqrt{\frac{66.9 \times 6}{12^2}} = 1.66 < 10 \therefore$ Short Beam $F_b' = F_b''$

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TRY SPAN $L = 5.25'$

@ $h = 15'$ $M = \frac{1}{8}(936)(5.25)^2 = 3{,}225 \ \frac{\#\text{-}ft}{ft}$

$d = \sqrt{\frac{6M}{12 \times .975}} \Rightarrow d = 4.45 \text{ in}$

FOR No. 2

No. 1 $F_b = 1200$ PSI

$d = 4.01$ in O.K.

Use 4 x 12 ROUGH
No. 2

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SHELF ANGLE

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1) @ GRATING

SPAN = 8'

GRATING CAPACITY $w = 343$ PSF $* \frac{8}{2}' = 1372$ #/ft

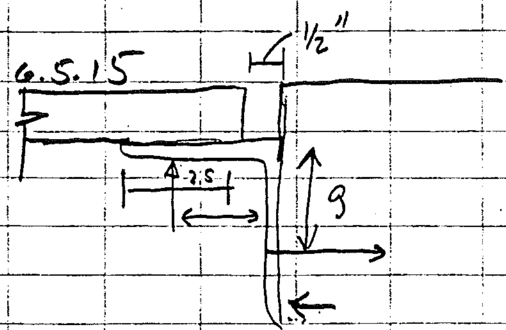
or $C = 1375$ #

BOLT SPACING : TRY 3'

$P_{max} = 1372 * 3 = 4,116$ #

PCI FIG. 6.5.15

TRY L 3x4



$e_v = 2.5/2 + .5 = 1.75$ in

$g = 1.5$

$l_1 - g = 2.5$

$\frac{l_1 - g}{6} = .417$ in

$e_i = 2.08$ in

$\frac{e_v}{e_i} = \frac{1.75}{2.08} \leq 1$

$$t = \sqrt{\frac{4 V_u e_v}{\phi f_y b}}$$

$V_u = 1.7 * 4,116 = 7$ K

$$t = \sqrt{\frac{4 * 7 * 1.75}{.9 (36)(48)}} = .177 \text{ in} \approx \frac{3}{16}$$

or ACI $f_b = \frac{M}{S} = \frac{6M}{bd^2}$

$$d = \sqrt{\frac{6M}{b f_b}} = \sqrt{\frac{6 * 4.116 * 1.75}{48 * 22}}$$

Pe @ fillet

$d = .202$

$\boxed{\text{use } L\ 4 \times 3 \times 1/4}$

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$$P_u = V_u \frac{e_v}{e_n} = 7 * \frac{1.75}{2.08} = 5.9\ K$$

HILTI HAS SS (304 SS)

5/8" Ø x 5" Tensile = 7530 # Bond 5070 ($F_c' = 4{,}000$)

Shear = 5050 #

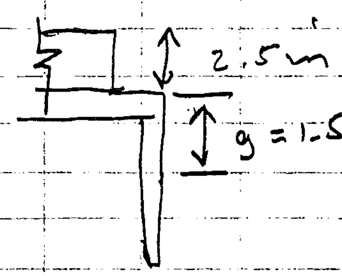
FORCES T = 5.9 / 1.7 = 3.47 K

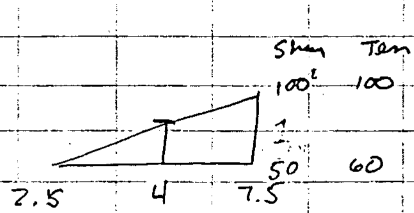
V = 4.12 K

ED = 7.5 in

ED_{MIN} = 2.5 in

actual ED = 4 in





Shear Capacity = 68.75% * 5050 = 3.47 K

Tensile " = 72% * 5070 = 3.65 K < 4.12 N.G.

→ Actual allowable Grating Loading 100 PSF

V = 100 * 4' * 3' = 1200

$F_{s\,applied}$ = 1.2 K

V_u = 1.7 * 1200 = 2.04 K

$$P_u = 2.04 * \frac{1.75}{2.08} = 1.72\ K$$

$F_{T\,applied}$ = 1.01 K

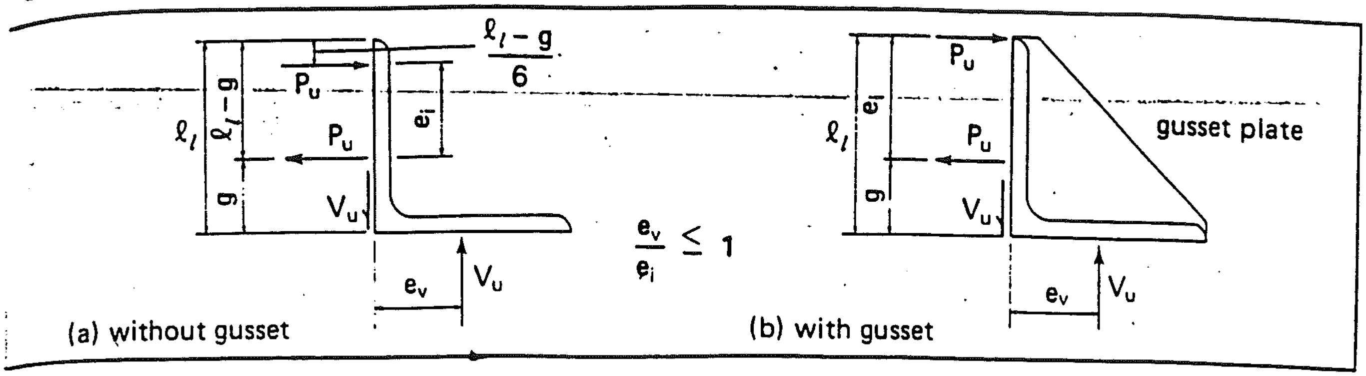
<u>Combined Loading</u>

Working Stress

$$\frac{F_{s}\ applied}{F_{s}\ allow} + \frac{F_{T}\ applied}{F_{T}\ allow} \le 1$$

$$\frac{1.2}{3.47} + \frac{1.01}{3.65} = .62 < 1 \quad O.K.$$

Fig. 6.5.14 Design relationships for connection angles



6.5.9 Connection Angles

Angles used to support precast members can be designed by statics as shown in Fig. 6.5.14. In addition to the applied vertical and horizontal loads, the design should include all loads induced by restraint of relative movement between the precast member and the supporting member. The minimum thickness of non-gusseted angles loaded in shear as shown in Fig. 6.5.15 can be determined by:

$$t = \sqrt{\frac{4\,V_u\,e_v}{\phi\,f_y b}} \qquad \text{(Eq. 6.5.11)}$$

where

ϕ = 0.90

b = length of the angle

design e_v = specified e_v + ½ in.

The tension on the bolt can be calculated by:

$$P_u = V_u \frac{e_v}{e_i} \qquad \text{(Eq. 6.5.12)}$$

For angles loaded axially, Fig. 6.5.16, either in tension or compression, the minimum thickness of non-gusseted angles can be calculated by:

$$t = \sqrt{\frac{4\,N_u g}{\phi\,f_y b}} \qquad \text{(Eq. 6.5.13)}$$

where

ϕ = 0.90

g = gage of the angle (see Fig. 6.5.16)

b = length of the angle

Fig. 6.5.15 Vertical loads on connection angle

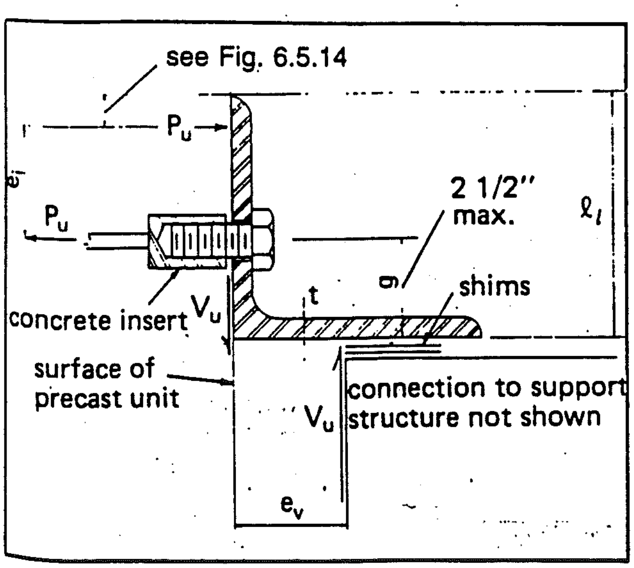
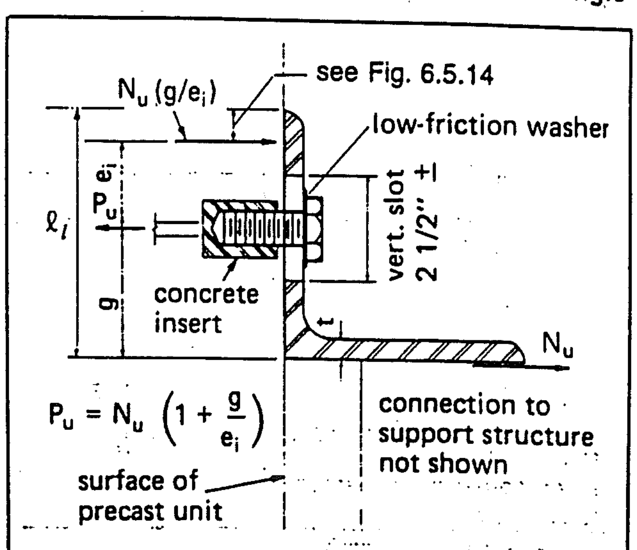
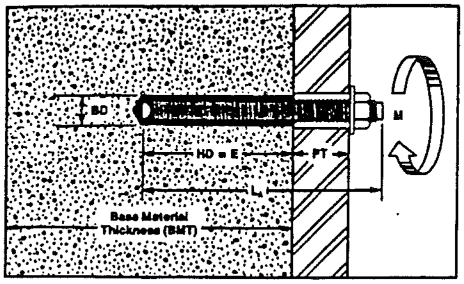


Fig. 6.5.16 Horizontal loads on connection angle



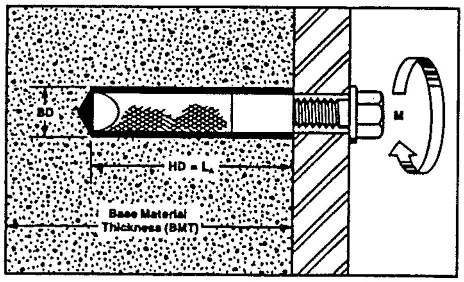
Specification Table

HAS Anchor Rod



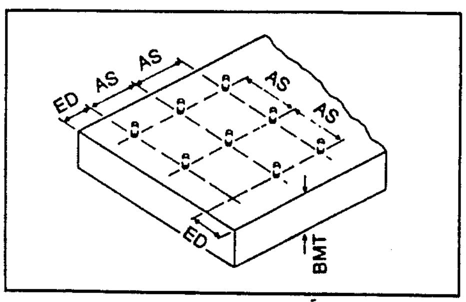
Details \ Anchor size			HAS 3/8"	HAS 1/2"	HAS 5/8"	HAS 3/4"	HAS 7/8"	HAS 1"	HAS 1 1/4"
BD	bit diameter (inches)		15/32	9/16	11/16	7/8	1	1 1/8	1 1/2
HD = E	min. depth of embedment = capsule length		3 1/2	4 1/4	5	6 5/8	6 5/8	8 1/4	12
PT	max. thickness fastened (inches)		1	1 1/2	1 3/4	2	2 1/4	2 1/2	2 3/4
L_A	anchor length (inches)		5 1/8	6 1/2	7 5/8	9 5/8	10	12	16
Tensile Stress Area (in^2)			0.078	0.142	0.226	0.334	0.462	0.606	0.969
M	max. tightening torque (ft. lbs.)	HAS S.S.	18	30	75	150	175	235	400
		HAS Std. HAS-Super	18	35	80	160	200	330	550
Drill bit size			TE-C-15/32-12	TE-C-9/16-12	TE-C-11/16-12	TE-F-7/8-13	TE-F-1-13	TE-F-1 1/8-17	TE-G-1 1/2-23
BMT	min. base material thickness (inches)		5 1/2	6 1/4	7 1/8	8 1/2	8 1/2	10 1/2	15

HFA Insert



Details \ Anchor size		HFA 3/8"	HFA 1/2"	HFA 5/8"	HFA 3/4"
BD	bit diameter (inches)	5/8	11/16	1	1 1/8
HD = L_A	min depth of embedment = capsule length (inches)	3 1/2	4 1/4	5	6 5/8
Useable Thread Length (inches)		1 1/2	1 1/2	2 1/16	2 1/2
M =	max. tightening torque (ft. lbs.)	18	35	80	160
Drill bit size		TE-C 5/8-12	TE-C 11/16-12	TE-F 1-13	TE-F 1 1/8-17
BMT	min. base material thickness (inches)	5 1/2	6 1/4	7 1/8	8 1/2

Anchor Spacing and Edge Distance Guidelines (HAS Rod and HFA Insert)



Details \ Anchor size		HVA 3/8"	HVA 1/2"	HVA 5/8"	HVA 3/4"	HVA 7/8"	HVA 1"	HVA 1 1/4"
AS	spacing required to obtain maximum working load (inches)	3 1/2	4 1/4	5	6 5/8	6 5/8	8 1/4	12
AS_{min}	Minimum allowable spacing between anchors (inches) Refer to note 1	1 3/4	2 1/8	2 1/2	3 1/4	3 1/4	4 1/8	6
ED	Edge distance required to obtain maximum working load (inches)	5 1/4	6 3/8	7 1/2	10	10	12 3/8	18
ED_{min}	Minimum allowable edge distance (inches) Refer to notes 2 and 3	1 3/4	2 1/8	2 1/2	3 1/4	3 1/4	4 1/8	6

NOTES:
1. When using AS_{min} reduce the working load by 30%.
2. When using ED_{min} and the load is a shear load, reduce the working load by 50%.
3. When using ED_{min} and the load is a tensile load, reduce the working load by 40%.

The HVA Anchor Spacings and Edge Distances are calculated using the following information:

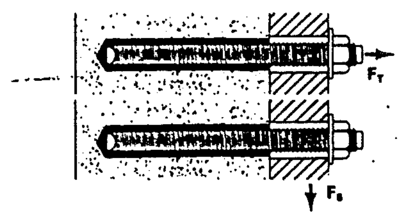
	Anchor Spacing			Edge Distance Shear Load Only			Edge Distance Tensile Load Only		
	AS	AS_{min}	f_{AS}	ED	ED_{min}	f_{ED}	ED	ED_{min}	f_{ED}
HVA	1.0E	0.5E	0.7	1.5E	0.5E	0.5	1.5E	0.5E	0.6

. Embedment (E) is based on the min. depth of embedment as stated in the Specification Table.
2. Use linear interpolation between max. and min. AS or ED to determine load factor.

HVA Allowable Bond Strength and Steel Strength for HAS Rods and HFA Inserts

Anchor Diameter (in.)	Embed. Depth (in.)	Adhesive Capsule(s) Required	[1]Bond Strength Allowable Tensile Loads (lbs) 2000 psi Conc.	3000 psi Conc.	4000 psi Conc.	6000 psi Conc.	Anchor Rod Allowable Loads (lbs) HAS Std. [1]Tensile	HAS Std. Shear	HAS Super (SAE 4140) [1]Tensile	HAS Super (SAE 4140) Shear	HAS SS (304 SS) Tensile	HAS SS (304 SS) Shear	HFA [6]Tensile	HFA [6]Shear
	3 1/2	1 - 3/8 x 3 1/2	2010	2210	2420	2830								
3/8	5 1/4	2 - 3/8 x 3 1/2	3010	3320	3630	4250	1560	1070	3250	1900	2600	1850	[4]2880	1820
	7	2 - 3/8 x 3 1/2	4010	4425	4840	5665								
	4 1/4	1 - 1/2 x 4 1/4	2660	2990	3330	3990								
1/2	6 3/8	1 - 1/2 x 4 1/4 & 1 - 3/8 x 3 1/2	4000	4490	4990	5980	2840	2090	5920	3270	4730	3600	3690	2635
	8 1/2	2 - 1/2 x 4 1/4	5330	5990	6650	7970								
	5	1 - 5/8 x 5	4120	4590	5070	6020								
5/8	7 1/2	1 - 5/8 x 5 & 1 - 1/2 x 4 1/4	6180	6890	7600	9030	4520	3000	9420	5632	7530	5050	[4]7295	5055
	10	2 - 5/8 x 5	8240	9190	10140	12040								
	6 5/8	1 - 3/4 x 6 5/8	5750	6510	7260	8770								
3/4	10	1 - 3/4 x 6 5/8 & 1 - 1/2 x 4 1/4	8630	9760	10890	13150	6680	4800	13920	7650	9460	7270	9750	7315
	13 1/4	2 - 3/4 x 6 5/8	11510	13020	14520	17530								
	6 5/8	1 - 7/8 x 6 5/8	6770	7660	8550	10320								
7/8	10	2 - 3/4 x 6 5/8	10160	11490	12820	15490	9240	6350	19250	10780	[3]—	[3]—	[5]—	[5]—
	13 1/4	2 - 7/8 x 6 5/8	13540	15320	17090	20650								
	8 1/4	1 - 1 x 8 1/4	9640	10960	12290	14930								
1	12 3/8	2 - 7/8 x 6 5/8	14460	16450	18430	22390	12120	7630	25250	13760	[3]—	[3]—	[5]—	[5]—
	16 1/2	2 - 1 x 8 1/4	19280	21930	24570	29860								
	12	1 - 1 1/4 x 12	20510	23220	25940	31370								
1 1/4	15	1 - 1 1/4 x 12 & 1 - 1 x 8 1/4	24935	27535	30140	35340	19380	13070	40375	21530	[3]—	[3]—	[5]—	[5]—
	18	1 - 1 1/4 x 12 & 2 - 1 x 8 1/4	29360	31850	34340	39310								

1. Allowable tensile load for anchor rods is based upon allowable stress = .33 Fu Acting upon the tensile stress area of the rods. Per AISC Section 1.5
2. Use lower value of either bond or steel strength!
3. 7/8-1 1/4 HAS SS only available through special order, no test data available.
4. HEA adhesive capsule will not fill the drilled hole completely.
5. Standard HFA's not available in these thread sizes, contact Specials for availability.
6. Values obtained using a SAE Grade 5 bolt.



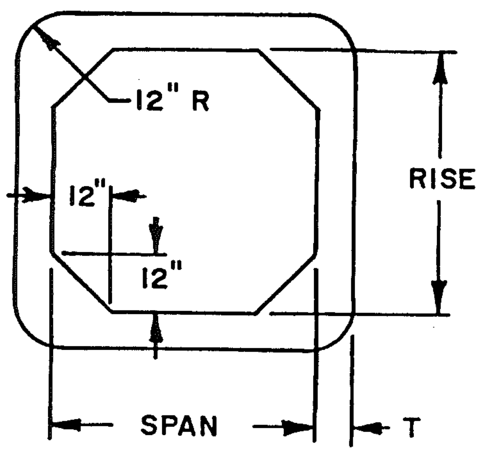
HVA Ultimate Bond Strength and Steel Strength for HAS Rods and HFA Inserts

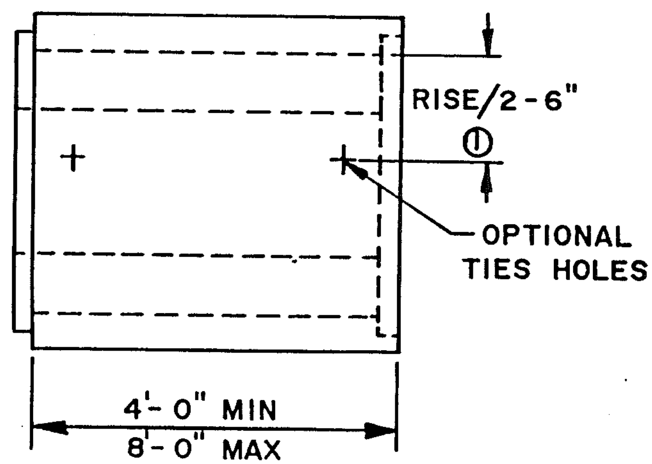
Anchor Diameter (in.)	Embed. Depth (in.)	Adhesive Capsule(s) Required	HEA ULTIMATE Bond Strength (lbs) Concrete Strength 2000 psi	3000 psi	4000 psi	6000 psi	Steel Strength (lbs)[1] HAS Std. Yield Strength	HAS Std. Tensile Strength	HAS Std. Shear Strength	HAS Super (SAE 4140) Yield Strength	HAS Super Tensile Strength	HAS Super Shear Strength	HAS SS (304 SS) Yield Strength	HAS SS Tensile Strength	HAS SS Shear Strength	HFA (lbs) [6]Tensile Strength	HFA [6]Shear Strength
	3 1/2	1 - 3/8 x 3 1/2	7530	8300	9070	10620											
3/8	5 1/4	2 - 3/8 x 3 1/2	11290	12450	13610	15930	2810	4680	4015	8190	9750	7120	5070	7800	6930	[4]10810	6827
	7	2 - 3/8 x 3 1/2	15050	16600	18140	21240											
	4 1/4	1 - 1/2 x 4 1/4	9990	11230	12470	14950											
1/2	6 3/8	1 - 1/2 x 4 1/4 & 1 - 3/8 x 3 1/2	14980	16840	18700	22420	5110	8520	7850	14910	17750	12280	9230	14200	13490	13830	9890
	8 1/2	2 - 1/2 x 4 1/4	19980	22460	24930	29890											
	5	1 - 5/8 x 5	15440	17220	19010	22570											
5/8	7 1/2	1 - 5/8 x 5 & 1 - 1/2 x 4 1/4	23160	25840	28510	33860	8140	13560	11240	23730	28250	21120	14690	22600	18950	[4]27365	18965
	10	2 - 5/8 x 5	30890	34450	38010	45140											
	6 5/8	1 - 3/4 x 6 5/8	21580	24400	27230	32870											
3/4	10	1 - 3/4 x 6 5/8 & 1 - 1/2 x 4 1/4	32370	36600	40840	49310	12020	20040	18010	35070	41750	28700	15030	28390	27250	36560	27405
	13 1/4	2 - 3/4 x 6 5/8	43160	48810	54450	65740											
	6 5/8	1 - 7/8 x 6 5/8	25390	28720	32050	38710											
7/8	10	2 - 3/4 x 6 5/8	38090	43080	48080	58070	16630	27720	23805	48510	57750	40410	[3]—	[3]—	[3]—	[5]—	[5]—
	13 1/4	2 - 7/8 x 6 5/8	50780	57440	64100	77420											
	8 1/4	1 - 1 x 8 1/4	36160	41110	46070	55980											
1	12 3/8	2 - 7/8 x 6 5/8	54230	61670	69100	83970	21820	36360	28615	63630	75750	51590	[3]—	[3]—	[3]—	[5]—	[5]—
	16 1/2	2 - 1 x 8 1/4	72310	82230	92140	111970											
	12	1 - 1 1/4 x 12	76910	87080	97260	117620											
1 1/4	15	1 - 1 1/4 x 12 & 1 - 1 x 8 1/4	93505	103255	113025	132525	34880	58140	49000	101745	121125	80740	[3]—	[3]—	[3]—	[5]—	[5]—
	18	1 - 1 1/4 x 12 & 2 - 1 x 8 1/4	110100	119430	128760	147420											

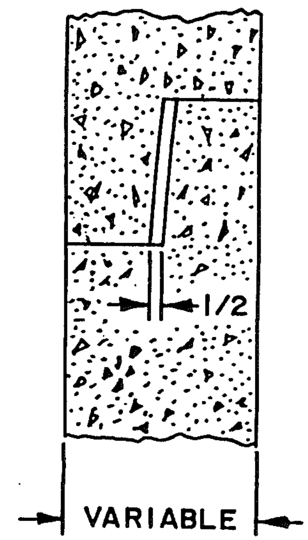
1. Steel strength based on tensile stress area of standard UNC thread.
2. Use lower value of either bond or steel strength!
3. 7/8-1 1/4 HAS SS only available through special order, no test data available.
4. HEA adhesive capsule will not fill the drilled hole completely.
5. Standard HFA's not available in these thread sizes, contact Specials for Availability.
6. Values obtained using a SAE Grade 5 bolt.

		RISE								
		3'	4'	6'	7'	8'	9'	10'	11'	12'
SPAN	6'	X	X	X						
	7'									
	8'					X				
	9'					X	X			
	10'					X	X	X		
	11'									
	12'					X	X	X		

8'' 9''







TYPICAL JOINT

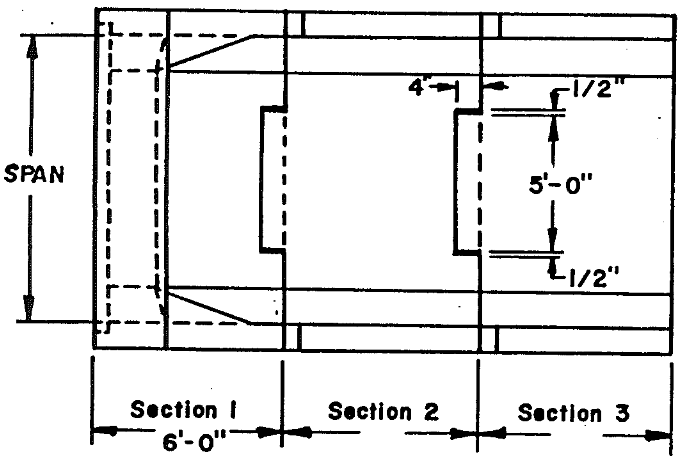
NOTE:

1. Culvert ties are to be 1" dia rods.
2. Optional tie holes - Locate at Rise / 2 - 6" from inside top of barrel.
3. Thickness T varies with span and rise dimensions

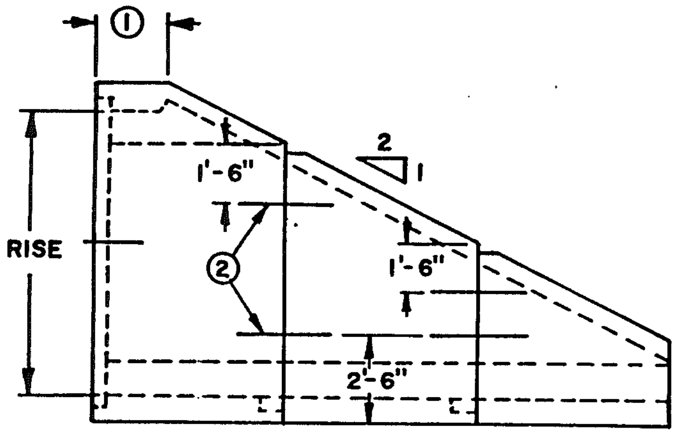
REVISIONS		
NO.	DATE	BY
1		
2		
3		
4		
5		

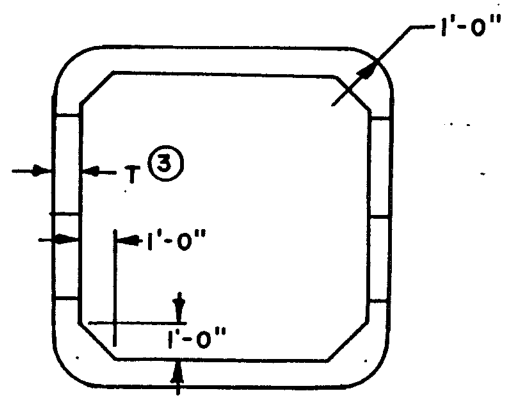
PRECAST CONCRETE
BOX CULVERT

DRAWN BY C. B	SCALE NONE	MATERIAL
CHK'D	DATE 12-23-80	DRAWING NO. A-7
TRACED	APP'D	



		RISE					
		7'	8'	9'	10'	11'	12'
SPAN	7'						
	8'		X				
	9'		X	X			
	10'		X	X	X		
	11'						
	12'		X	X	X		





NOTE:

① 2'-0" for groove end and 2'-7" for tongue end.

② Culvert ties are to be 1" dia rods.

③ Wall thickness varies with span and rise dimensions

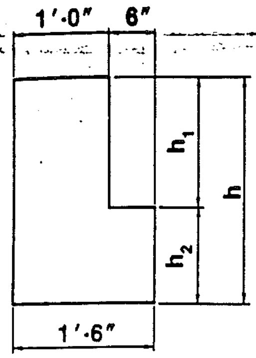
REVISIONS		
NO.	DATE	BY
1		
2		
3		
4		
5		

PRECAST END SECTION FOR BOX CULVERT

DRAWN BY C.B.	SCALE NONE	MATERIAL
CHK'D	DATE 12-21-80	DRAWING NO.
TRACED	APP'D	A-

L-SHAPED BEAMS

Normal Weight Concrete



f'_c = 5000 psi

f_{pu} = 270,000 psi

Section Properties								
Designation	h (in.)	h_1/h_2 (in.)	A (in.^{2})	I (in.^{4})	y_b (in.)	Z_b (in.^{3})	Z_t (in.^{3})	wt (plf)
18LB20	20	12/8	288	9696	9.00	1077	882	300
18LB24	24	12/12	360	16,762	10.80	1552	1270	375
18LB28	28	16/12	408	26,611	12.59	2114	1727	425
18LB32	32	20/12	456	39,695	14.42	2753	2258	475
18LB36	36	24/12	504	56,407	16.29	3463	2862	525
18LB40	40	24/16	576	77,568	18.00	4309	3526	600
18LB44	44	28/16	624	103,153	19.85	5197	4271	650
18LB48	48	32/16	672	133,705	21.71	6159	5086	700
18LB52	52	36/16	720	169,613	23.60	7187	5972	750
18LB56	56	40/16	768	211,264	25.50	8285	6927	800
18LB60	60	44/16	816	259,046	27.41	9451	7949	850

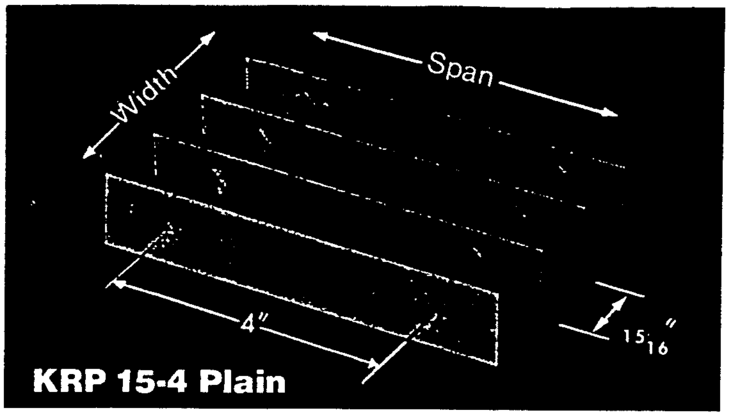
Key
6486 — Safe superimposed service load, plf
0.3 — Estimated camber at erection, in.
0.1 — Estimated long-time camber, in.

Safe loads shown include 50% dead load and 50% live load. 800 psi top tension has been allowed, therefore additional top reinforcement is required.

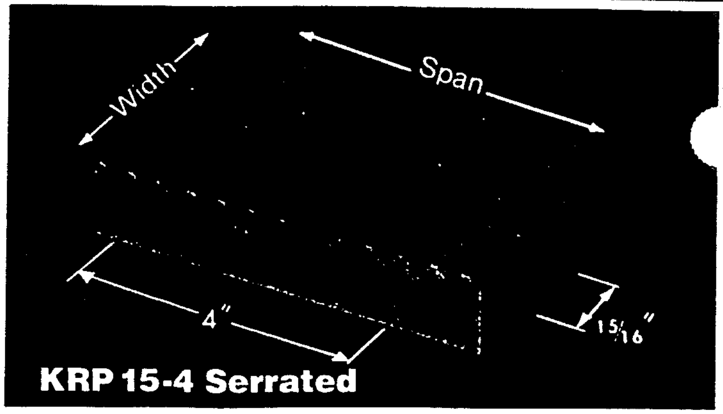
Table of safe superimposed service load (plf) and cambers

Designation	No. Strand	e	Span, ft. 16	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50
18LB20	9	6.26	6486 0.3 0.1	5068 0.4 0.1	4053 0.5 0.1	3303 0.6 0.2	2732 0.7 0.2	2288 0.8 0.2	1935 0.9 0.2	1650 0.9 0.2	1414 1.0 0.2	1218 1.1 0.2								
18LB24	10	7.67	9179 0.3 0.1	7182 0.3 0.1	5753 0.4 0.1	4696 0.5 0.1	3891 0.5 0.1	3266 0.6 0.1	2769 0.7 0.1	2369 0.8 0.1	2041 0.8 0.1	1769 0.9 0.1	1541 1.0 0.1	1349 1.0 0.0	1184 1.1 0.0					
18LB28	12	8.93			8039 0.3 0.1	6578 0.4 0.1	5466 0.5 0.1	4600 0.6 0.1	3914 0.6 0.2	3360 0.7 0.2	2906 0.8 0.2	2531 0.8 0.2	2216 0.9 0.1	1949 1.0 0.1	1722 1.0 0.1	1524 1.1 0.1	1351 1.1 0.0	1200 1.2 0.0		
18LB32	14	10.22				8814 0.4 0.1	7331 0.4 0.1	6176 0.5 0.1	5260 0.6 0.2	4521 0.7 0.2	3916 0.7 0.2	3414 0.8 0.2	2994 0.9 0.2	2639 0.9 0.2	2335 1.0 0.2	2074 1.1 0.2	1847 1.1 0.1	1650 1.2 0.1	1476 1.2 0.1	1323 1.3 0.0
18LB36	16	11.52					9358 0.4 0.1	7903 0.5 0.1	6744 0.5 0.1	5807 0.6 0.1	5040 0.7 0.2	4405 0.7 0.2	3872 0.8 0.2	3422 0.9 0.2	3037 0.9 0.2	2706 1.0 0.2	2419 1.1 0.2	2168 1.1 0.1	1948 1.2 0.1	1755 1.2 0.1
18LB40	18	12.52						9693 0.4 0.1	8284 0.5 0.1	7146 0.5 0.2	6215 0.6 0.2	5443 0.7 0.2	4797 0.7 0.2	4250 0.8 0.2	3783 0.9 0.2	3380 0.9 0.2	3026 1.0 0.2	2718 1.0 0.2	2447 1.1 0.2	2208 1.1 0.2
18LB44	19	14.19								8729 0.5 0.1	7601 0.6 0.2	6666 0.6 0.2	5883 0.7 0.2	5219 0.7 0.2	4653 0.8 0.2	4166 0.9 0.2	3743 0.9 0.2	3370 1.0 0.2	3042 1.0 0.2	2752 1.1 0.2
18LB48	21	15.48									9166 0.5 0.1	8048 0.6 0.1	7110 0.6 0.1	6313 0.7 0.2	5629 0.8 0.2	5041 0.8 0.2	4531 0.9 0.2	4086 0.9 0.2	3695 1.0 0.2	3351 1.0 0.2
18LB52	23	16.78										9538 0.5 0.2	8427 0.6 0.2	7486 0.7 0.2	6683 0.7 0.2	5992 0.8 0.2	5393 0.8 0.2	4871 0.9 0.2	4412 0.9 0.2	4007 1.0 0.2
18LB56	25	18.07											9842 0.6 0.2	8752 0.6 0.2	7820 0.7 0.2	7019 0.7 0.2	6324 0.8 0.2	5718 0.8 0.2	5186 0.9 0.2	4717 1.0 0.2
18LB60	27	19.36													9026 0.6 0.2	8116 0.7 0.2	7326 0.7 0.2	6630 0.8 0.2	6020 0.9 0.2	5481 0.9 0.2

Rectangular Bar Aluminum Grating



KRP 15-4 Plain



KRP 15-4 Serrated

TABLE OF SAFE SPANS

SPAN

3/4" x 3/16"	15-4-33	2.49	.2285	U	495	316	-220	161	97								
				D	.192	.299	.432	.587	.768								
				C	495	396	330	283	193								
				D	.154	.240	.346	.470	.614								
1" x 1/8"	15-4-42	2.26	.2708	U	586	375	261	192	147								
				D	.144	.225	.324	.442	.578								
				C	586	470	392	335	294								
				D	.115	.180	.260	.353	.460								
1" x 3/16"	15-4-43	3.21	.4063	U	881	563	392	287	220	174							
				D	.144	.225	.324	.440	.576	.730							
				C	881	704	586	503	440	392							
				D	.115	.180	.259	.353	.461	.584							
1-1/4" x 1/8"	15-4-52	2.74	.4232	U	916	586	407	300	229	180							
				D	.115	.180	.259	.353	.461	.581							
				C	916	733	611	524	458	407							
				D	.092	.144	.207	.282	.369	.466							
1-1/4" x 3/16"	15-4-53	3.92	.6348	U	1375	879	611	449	344	271	220	182					
				D	.115	.180	.259	.353	.462	.583	.721	.871					
				C	1375	1100	916	786	687	611	550	500					
				D	.092	.144	.207	.282	.296	.466	.576	.698					
1-1/2" x 1/8"	15-4-62	3.21	.6094	U	1320	845	586	431	330	261	211	174					
				D	.096	.150	.216	.294	.384	.487	.600	.724					
				C	1320	1056	881	754	660	586	529	480					
				D	.077	.120	.173	.235	.307	.389	.481	.581					
1-1/2" x 3/16"	15-4-63	4.64	13K .0703 .9141	U	1980	1267	881	846	495	392	317	262	220	187			
				D	.096	.150	.216	.294	.384	.487	.601	.728	.865	1.011			
				C	1980	1585	1320	1132	989	681	792	721	661	609			
				D	.077	.120	.173	.235	.307	.389	.480	.581	.692	.811			
1-3/4" x 3/16"	15-4-73	5.35	1.2441	U	2694	1724	1198	879	673	532	431	356	300	255	220	169	
				D	.082	.129	.185	.252	.329	.417	.514	.621	.741	.868	1.009	1.321	
				C	2694	2156	1797	1540	1348	1198	1078	980	899	829	771	673	
				D	.066	.103	.148	.202	.263	.333	.411	.498	.593	.695	.807	1.053	
2" x 3/16"	15-4-83	6.08	1.6250	U	3520	2253	1564	1149	881	695	563	466	392	333	287	220	174
				D	.072	.113	.162	.221	.288	.364	.450	.545	.649	.759	.880	1.153	1.460
				C	3520	2816	2346	2011	1760	1564	1408	1280	1174	1083	1006	881	782
				D	.058	.090	.130	.176	.230	.292	.360	.436	.519	.608	.706	.922	1.166
2-1/4" x 3/16"	15-4-93	6.78	2.0566	U	4454	2851	1980	1454	1114	879	713	589	495	.422	364	279	220
				D	.064	.100	.144	.196	.256	.324	.400	.484	.576	.677	.784	1.026	1.297
				C	4454	3564	2970	2546	2227	1980	1782	1620	1485	1371	1273	1114	989
				D	.051	.080	.115	.157	.205	.259	.320	.397	.461	.541	.627	.819	1.036
2-1/2" x 3/16"	15-4-103	7.51	2.5391	U	5500	3520	2445	1796	1375	1086	879	727	611	521	449	343	212
				D	.058	.090	.130	.176	.230	.292	.360	.436	.518	.609	.706	.920	1.166
				C	5500	4399	3666	3142	2749	2445	2200	1999	1833	1692	1572	1375	955
				D	.046	.072	.104	.141	.184	.233	.288	.348	.415	.487	.565	.737	.933

SPECIFICATIONS:

DESCRIPTION: Panel shall consist of equally spaced extruded aluminum bearing bars, positioned and locked by swaged cross rods to provide a permanent lock.

Bearing bars shall be on 15/16" centers, and the cross rods shall be on 4" centers.

MATERIALS: Bearing bars, shall be aluminum alloy 6061-T6. Cross rods, shall be aluminum alloy 6063-T1.

FINISH: Panels shall be supplied with a mill finish unless otherwise specified.

NOTE: Spans and loads to the right of the heavy line exceeds a deflection of ¼" for uniform loads of 100#/sq. ft. which provide safe pedestrian comfort, but can be exceeded for other types of loads at the discretion of the engineer.

U—Safe Uniform Load, in lbs. per sq. ft.

C—Safe Concentrated Load in lbs. per foot of grating width.

D—Deflection in inches.

Loads and deflections given in this table are theoretical and based on a fibre stress of 12,000 PSI.

PANEL WIDTH CHART IN INCHES — DIMENSIONS SHOWN ARE OUT TO OUT OF BEARING BARS*

1/8 Bar	1 1/4	2 3/16	3 1/8	4 1/16	5	5 15/16	6 7/8	7 13/16	8 3/4	9 11/16	10 5/8	11 9/16	12 1/2	13 7/16	14 3/8	15 5/16	16 1/4	17 3/16	18 1/8
3/16 Bar	1 5/16	2 1/4	3 3/16	4 1/8	5 1/16	6	6 15/16	7 7/8	8 13/16	9 3/4	10 11/16	11 5/8	12 9/16	13 1/2	14 7/16	15 3/8	16 3/16	17 1/4	18 3/16

1/8 Bar	19 1/16	20	20 15/16	21 7/8	22 13/16	23 3/4	24 11/16	25 5/8	26 9/16	27 1/2	28 7/16	29 3/8	30 5/16	31 1/4	32 3/16	33 1/8	34 1/16	35	35 15/16
3/16 Bar	19 1/8	20 1/16	21	21 15/16	22 7/8	23 13/16	24 3/4	25 11/16	26 5/8	27 9/16	28 1/2	29 7/16	30 3/8	31 5/16	32 1/4	33 3/16	34 1/8	35 1/16	36

*Includes 3/16" for Extended Crossrods

I-Bar Aluminum Grating Design Data

[illegible]	[illegible]	Area In^2	Weight lbs. per ft.	I In^4	S In^3
1 x 1/4	1 x 3/16	0.120	0.144	0.0158	0.0312
1 1/4 x 1/4	1 1/4 x 3/16	0.150	0.180	0.0306	0.0489
1 1/2 x 1/4	1 1/2 x 3/16	0.180	0.216	0.0528	0.0703
1 3/4 x 1/4	1 3/4 x 3/16	0.210	0.252	0.0839	0.1015
2 x 1/4	2 x 3/16	0.240	0.288	0.1252	0.1252
2 1/4 x 1/4	2 1/4 x 3/16	0.270	0.324	0.1788	0.1588
2 1/2 x 1/4	2 1/2 x 3/16	0.300	0.360	0.2435	0.1948
1 x 3/16	1 x 1/8	0.080	0.096	0.0104	0.0208
1 1/4 x 3/16	1 1/4 x 1/8	0.100	0.120	0.0204	0.0326
1 1/2 x 3/16	1 1/2 x 1/8	0.120	0.144	0.0352	0.0470

Sample Calculation—Klemp I-Bar Aluminum Grating and Rectangular Aluminum Grating

Size of I-Bar = 1 1/2" x 1/4"

Size of I-Bar for calculation purposes = 1 1/2" x 3/16"

Span = 3'-0"

Fibre Stress = 12,000 psi

Section Modulus of one bearing bar $= \frac{bd^2}{6} = \frac{3/16 \times (1\,1/2)^2}{6} = .0703 \text{ in}^3$

Section Modulus per foot of grating $= .0703 \times 11 = .773 \text{ in}^2 = S$

Moment of inertia of one bearing bar $= \frac{bd^3}{12} = \frac{3/16 \times (1\,1/2)^3}{12} = .0526 \text{ in}^4$

Moment of inertia per foot of grating $= .0528 \times 11 = .5708 \text{ in}^4 = I$

Ratio

$$\frac{1}{L/D} = \frac{1}{36/212} = \frac{1}{170}$$

$\frac{1}{170}$ Deflection of Span

Uniform Load

Maximum moment (M) = fs = 12,000 x .773

= 9310 in. lbs.

= 776 ft. lbs.

$$M = \frac{UL^2}{8}$$

$$U = \frac{8M}{L^2} = \frac{8 \times 776}{3^2} = 688 \text{ lbs./ft.}^2$$

Deflection, Uniform Load

$$D = \frac{5 \times UL \times (L \times 12)^3}{384 \times E \times I} = \frac{5 \times 688 \times 3 \times (3 \times 12)^3}{384 \times 10^7 \times 0.5708} = .212''$$

Concentrated Load

$$M = \frac{CL}{4}$$

$$C = \frac{4M}{L}\ \frac{4 \times 776}{3} = 1032 \text{ lbs./ft. of width}$$

Deflection, Concentrated Load

$$D = \frac{C \times (L \times 12)^3}{48 \times E \times I} = \frac{1032 \times (3 \times 12)^3}{48 \times 10^7 \times .5708} = .174''$$

Rectangular Bar Aluminum Grating Design Data

BAR SIZE	AREA — IN^2	WEIGHT LBS./FT.	I = IN^4	S = IN^3
3/4 x 3/16	0.141	0.166	0.0066	0.0176
1 x 1/8	0.125	0.147	0.0104	0.0208
1 x 3/16	0.188	0.221	0.0156	0.0313
1 1/4 x 1/8	0.156	0.184	0.0203	0.0326
1 1/4 x 3/16	0.234	0.276	0.0305	0.0488
1 1/2 x 1/8	0.188	0.220	0.0352	0.0469
1 1/2 x 3/16	0.281	0.331	0.0527	0.0703
1 3/4 x 3/16	0.328	0.386	0.0837	0.0957
2 x 3/16	0.375	0.441	0.1250	0.1250
2 1/4 x 3/16	0.422	0.496	0.1780	0.1582
2 1/2 x 3/16	0.469	0.551	0.2441	0.1953

Appendix F

Pipe Strength Analysis - Dewatering System

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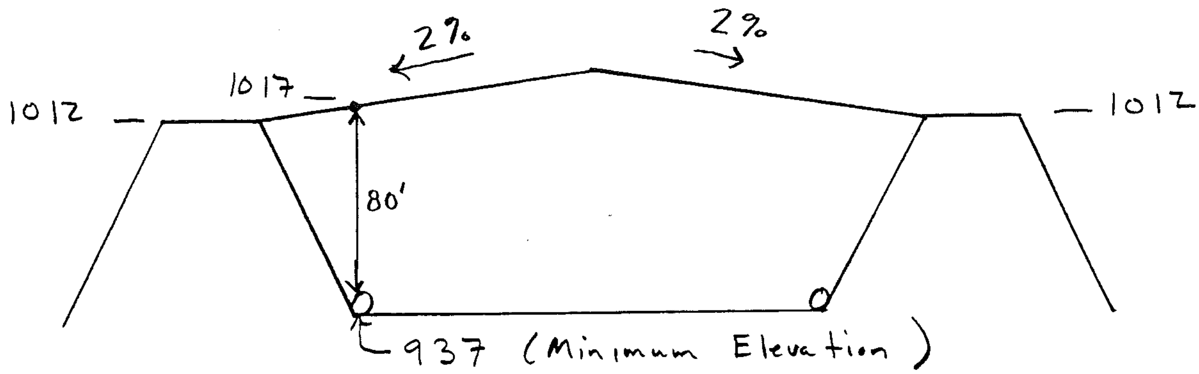
Dewating Pipe Strength Calculations

6" Dia SCH 80 PVC Pipe



Ⓐ Load on Pipe

Material	Density (PCF)	Thickness (Ft)	Load Psf
Cover Soil	120	2	240
FGD Sludge	107	76	8,132
Drainage Layer	120	2	240

P_T = External Pressure = 8,612 PCF

P_T = 59.8 psi

Ⓑ *Pipe Bedding Material

Use MN|DOT Coarse Filter Aggregate 3149.2 H

Sieve Size	Percent Passing
1"	100
3/4"	85-100
3/8"	30-60
No. 4	0-10

(C) Soil Classification (From Soil Classification Chart)

$$C_u = \frac{12\,mm}{5\,mm} = 2.4 < 4$$

Soil = GP Poorly Graded Gravel

(D) Size Perforations:

$$\frac{(D_{85})\ 85\%\ \text{size of filter Material}}{(H\phi)\ \text{hole Diameter}} > 1.0$$

$D_{85} = 16\,mm$
(Upper limit)

$$\frac{16\,mm}{H\phi} > 1.0$$

$$H\phi < \frac{16.0}{1.0} = 16\,mm = 1.6\,cm$$

$$1.6\,cm * \frac{1\,in}{2.54\,cm} = 0.63'' \text{ (Maximum Hole Dia)}$$
$$\approx 5/8''$$

Use 1/2" Perforations

(E) Equivalent load on Perforated Pipe:

Perforations : 1/2" dia ; 2 holes / ft

$$\text{Equivalent Pipe length} = \frac{12-(2)(1/2)}{12} = 0.92\ ft/ft$$

$$\text{Equivalent load on Pipe} = \frac{59.8\,psi}{0.92} = 65\,psi = P_T'$$

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(F) Pipe Deflection:

REF: Handbook of PVC Pipe - Uni-Bell Plastic Pipe Association: Third Edition

$$\left(\begin{array}{l}\text{Modified Iowa} \\ \text{Formula}\end{array}\right) = \% \frac{\Delta Y}{D} = \frac{D_L K P (100)}{[2E/(3(DR-1)^3)] + 0.061 E'}$$

D_L = Deflection Lag factor = 1.5 (page 208)

K = Bedding Constant = 0.1 (page 207)

E = Elastic Modulus of pipe (psi) = 400,000 PSI

DR = Dimension Ratio = $\frac{6.625''}{0.432}$ = 15.3 for 6" SCH 80

E' = Bedding Elastic Modulus (psi) = 1000 psi for slight compaction

P = P_T' = 65 psi

$$\% \frac{\Delta}{D} = \frac{(1.5)(0.1)(65)(100)}{\left[\frac{2(400{,}000)}{3(15.3-1)^3}\right] + 0.061(1000)} = 6.4\% < 7.5\% \checkmark$$

Deflection allowable = 7.5% (ASTM D3034-88)

(E) Critical Buckling Pressure (P_{cr}):

$$P_{cr} = \frac{2E}{(DR-1)^3}$$ page 223

$$P_{cr} = \frac{2(400{,}000)}{(15.3-1)^3} = 274 \text{ psi}$$

(E) (Continued)

$$S.F. = \frac{P_{cr}}{P_T{}'} = \frac{274}{65} = 4.2 > 1.0 \checkmark \text{ ok}$$

(F) WALL CRUSHING:

$$P_y = \frac{\sigma_c\, 2\, A}{D_o} \qquad \text{(page 227)}$$

P_y = Vertical soil pressure, psi
D_o = Outside Diam., in = 6.625 in
σ_c = Hoop tensile = 4,000 psi
A = Area of Pipe wall; in^2
⇒ P_y = 65 psi – check allowable P_y

O.D. = 6.625 in
I.D. = 5.761 in

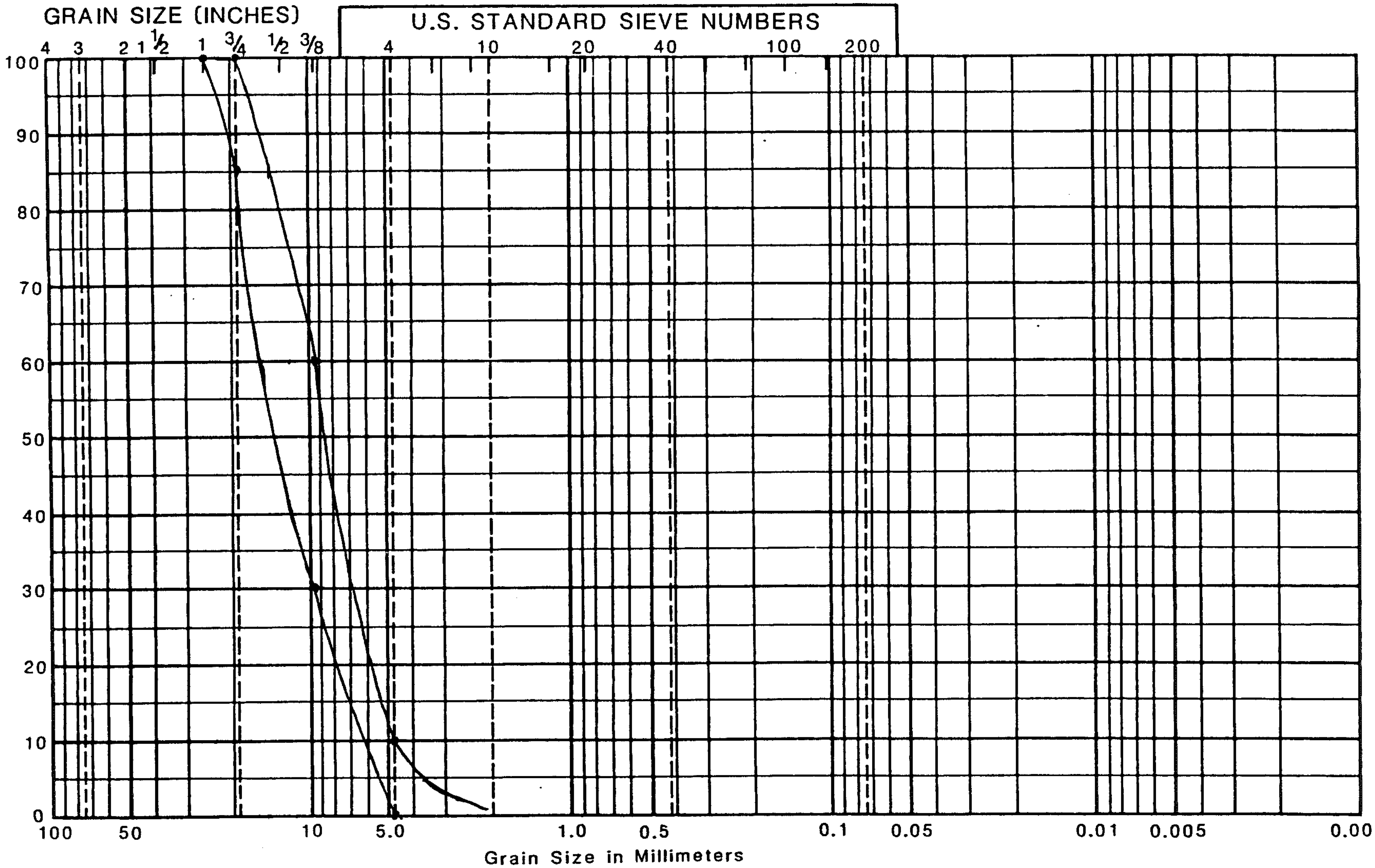
$$Area_{OD} = \pi\left(\frac{6.625}{2}\right)^2 = 34.45\ in^2$$

$$Area_{ID} = \pi\left(\frac{5.761}{2}\right)^2 = 26.05\ in^2$$

$$A = 34.45 - 26.05 = 8.4\ in^2$$

$$P_{y\ allowable} = \frac{(4000)(2)(8.4)}{6.625} = 10{,}143\ psi < 65 \checkmark \text{ ok}$$

GRAIN SIZE DISTRIBUTION DIAGRAM



Unified Soil Classification System	GRAVEL		SAND			FINES
	COARSE	FINE	COARSE	MEDIUM	FINE	

Boring Number	Sample Number	Depth (ft)	Soil Classification

Job No. 23/71/027TJR112 Date 2-20-95

Project NSP - Pond 3

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Table A.5 Average Values of Modulus of Soil Reaction E' (for Initial Flexible-Pipe Average Deflection*)

Soil Type—Primary Pipe-Zone Backfill Material (Unified Classification System)†	E' for Degree of Compaction of Pipe-Zone Backfill Material *psi (MPa)* Dumped	Slight <85% Proctor <40% relative density	Moderate 85–95%Proctor 40–70% relative density	High >95% Proctor >70% relative density
Fine-grained soils (LL>50)‡ Soils with medium to high plasticity (CH, MH, CH–MH)	Soils in this category require special engineering analysis to determine required density, moisture content, and compactive effort.			
Fine-grained soils (LL<50) Soils with medium to no plasticity (CL, ML, ML–CL, CL–CH, or ML–MH) with less than 25% coarse-grained particles	50 (0.34)	200 (1.4)	400 (2.8)	1000 (6.9)
Fine-grained soils (LL<50) Soils with medium to no plasticity (CL, ML, ML–CL, CL–CH, ML–MH) with more than 25% coarse-grained particles	100 (0.69)	400 (2.8)	1000 (6.9)	2000 (13.8)
Coarse-grained soils with fines (GM, GC, SM, SC, GM–GC, GC–SC, and so forth) containing more than 12% fines	100 (0.69)	400 (2.8)	1000 (6.9)	2000 (13.8)
Coarse-grained soils with little or no fines, (GW, GP, SW, SP, GM–GC, GC–SC, and so forth) containing less than 12% fines	200 (1.4)	1000 (6.9)	2000 (13.8)	3000 (20.7)
Crushed rock	1000 (6.9)	3000 (20.7)	3000 (20.7)	3000 (20.7)
Accuracy in terms of difference between predicted and actual average percent deflection	± 2%	± 2%	± 1%	± 0.5%

NOTES: Values applicable only for fill less than 50 ft (15 m).

For use in predicting initial deflections only, appropriate deflection lag factor D_L must be applied for long-term deflections.

Percent Proctor based on laboratory maximum dry density from test standards using about 12,500 ft-lb/ft^3 (598,000 J/m^3) (Method D698, AASHO T-99, Moisture-Density Relations of Soils Using a 5.5-lb (2.5-kg) Rammer and a 12-in. (305-mm) Drop. Available from American Association of State Highway and Transportation Officials, 444 N. Capitol St., N.W., Suite 225, Washington, DC 20001.

*Values in table are as determined by the US Bureau of Reclamation. Refer to Sec. A.3.4.2.6 when calculating pipe deflections using tabulated values of E'.

†ASTM Classification D2487.

‡LL = Liquid limit.

Table A.6 Soil Classification Chart

Criteria for Assigning Group Symbols and Group Names Using Laboratory Tests[a]				Soil Classification: Group Symbol	Soil Classification: Group Name[b]
Coarse-grained soils More than 50% retained on No. 200 sieve	Gravels More than 50% of coarse fraction retained on No. 4 sieve	Clean gravels Less than 5% fines[c]	$Cu \geq 4$ and $1 \leq Cc \leq 3$[e]	GW	Well-graded gravel[f]
			$Cu < 4$ and/or $1 > Cc > 3$[e]	GP	Poorly graded gravel[f]
		Gravels with fines More than 12% fines[c]	Fines classify as ML or MH	GM	Silty gravel[f, g, h]
			Fines classify as CL or CH	GC	Clayey gravel[f, g, h]
	Sands 50% or more of coarse fraction passes No. 4 sieve	Clean sands Less than 5% fines[d]	$Cu \geq 6$ and $1 \leq Cc \leq 3$[e]	SW	Well-graded sand[i]
			$Cu < 6$ and/or $1 > Cc > 3$[e]	SP	Poorly graded sand[i]
		Sands with fines More than 12% fines[d]	Fines classify as ML or MH	SM	Silty sand[g, h, i]
			Fines classify as CL or CH	SC	Clayey sand[g, h, i]
Fine-grained soils 50% or more passes the No. 200 sieve	Silts and Clays Liquid limit less than 50	Inorganic	PI > 7 and plots on or above "A" line[j]	CL	Lean clay[k, l, m]
			PI < 4 or plots below "A" line[j]	ML	Silt[k, l, m]
		Organic	$\frac{\text{Liquid limit—oven dried}}{\text{Liquid limit—not dried}} < 0.75$	OL	Organic clay[k, l, m, n]
					Organic silt[k, l, m, o]
	Silts and Clays Liquid limit 50 or more	Inorganic	PI plots on or above "A" line	CH	Fat clay[k, l, m]
			PI plots below "A" line	MH	Elastic silt[k, l, m]
		Organic	$\frac{\text{Liquid limit—oven dried}}{\text{Liquid limit—not dried}} < 0.75$	OH	Organic clay[k, l, m, p]
					Organic silt[k, l, m, q]
Highly organic soils		Primarily organic matter, dark in color, and organic odor		PT	Peat

a Based on the material passing the 3-in. (75-mm) sieve.

b If field sample contained cobbles and/or boulders, add "with cobbles and/or boulders" to group name.

c Gravels with 5 to 12% fines require dual symbols:
GW–GM well-graded gravel with silt
GW–GC well-graded gravel with clay
GP–GM poorly graded gravel with silt
GP–GC poorly graded gravel with clay

d Sands with 5 to 12% fines require dual symbols:
SW–SM well-graded sand with silt
SW–SC well-graded sand with clay
SP–SM poorly graded sand with silt
SP–SC poorly graded sand with clay

e $Cu = D_{60}/D_{10}$

$$Cc = \frac{(D_{30})^2}{D_{10} \times D_{60}}$$

f If soil contains ≥ 15% sand, add "with sand" to group name.

g If fines classify as CL–ML, use dual symbol GC–GM or SC–SM.

h If fines are organic, add "with organic fines" to group name.

i If soil contains ≥ 15% gravel, add "with gravel" to group name.

j If the Atterberg limits (liquid limit and plasticity index) plot in hatched area on plasticity chart, soil is a CL–ML, silty clay.

k If soil contains 15 to 29% plus No. 200, add "with sand" or "with gravel," whichever is predominant.

l If soil contains ≥ 30% plus No. 200, predominantly sand, add "sandy" to group name.

m If soil contains ≥ 30% plus No. 200, predominantly gravel, add "gravelly" to group name.

n PI ≥ 4 and plots on or above "A" line.

o PI ≤ 4 or plots below "A" line.

p PI plots on or above "A" line.

q PI plots below "A" line.

Appendix G

Performance Analysis - Dewatering System

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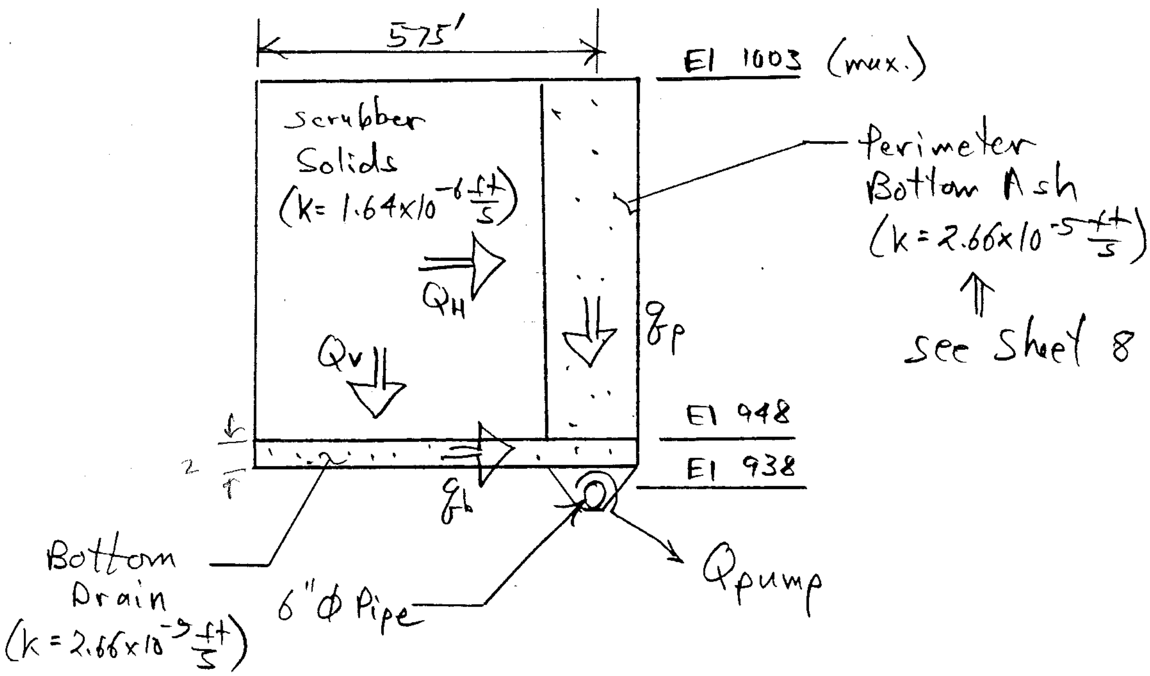
DEWATERING PERFORMANCE AT A VARIABLE PUMPING RATE

MODEL



Assume:
1) Cell dimensions: 1150' (E-W) × 1500' (N-S)
2) Max. pumping rate per cell is 50 gpm.
3) Specific yield of scrubber solids (SS) is 0.3
4) Average thickness of perim. drain is 15'.
5) Flow from SS is into bottom and 4 sides.
6) Bottom Ash perimeter is completely dewatered first.
(7) 2' thickness B.A. perimeter

Method:
1) Avail. Discharge = $Q_H + q_b$ since $Q_V \gg q_b$ and $Q_H \ll q_p$
If this is > 50 gpm, limit Qpump to 50 gpm
2) Determine time to change head from:
time = Avail Water / Qpump
3) Capacity of pipe is based on Polypipe Industries handbook: $q_{pipe} = 2.449 V d^3$ [gpm]
where: V is velocity (use 1 fps)
d is pipe diameter (use 6 in)

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If available discharge > 50gpm for entire dewatering

Avail. Water ⇒ $AW = S_y * V_T = 0.3 V_T$

$AW = 0.3(1500 \times 1150 \times (1003 - 948)) = 28{,}463{,}000$ cf

Pumping Rate ⇒ $PR = 50\text{gpm} = 9620 \frac{\text{cfd}}{\text{cell}}$

$\text{Time} = \frac{AW}{PR} = \frac{28{,}463{,}000 \text{ cf}}{9620 \text{ cfd/cell}} = \boxed{8 \text{ years}}$

Water Balance at Max. Water Level

Flow in Scrubber Solids:

$Q_H = KiA = (1.64 \times 10^{-6} \frac{ft}{s})(\frac{65}{575})(65 \times 5300 \; ft^2) = 5520$ cfd

$Q_V = kiA = (1.64 \times 10^{-6} \frac{ft}{s})(1)(1150ft \times 1500ft) = 244{,}430$ cfd

$Q_{SS} = 249{,}950$ cfd

Flow in Bottom Ash:

$q_{P(vert)} = KiA = (2.66 \times 10^{-5} \frac{ft}{s})(1)(15ft \times 5300ft) = 182{,}710$ cfd

$q_{B(horiz.)} = KiA = (2.66 \times 10^{-5} \frac{ft}{s})(\frac{65}{575})(2ft \times 5300ft) = 2330$ cfd

$q_{BA} = 185{,}040$ cfd

Horizontal Flow: $Q_H << q_P$ so drain can handle all hor. flow

Vertical Flow: $Q_V >> q_B$ so drain limits flow

Available Discharge $= Q_H + q_b = 7850$ [< 9620 cfd]

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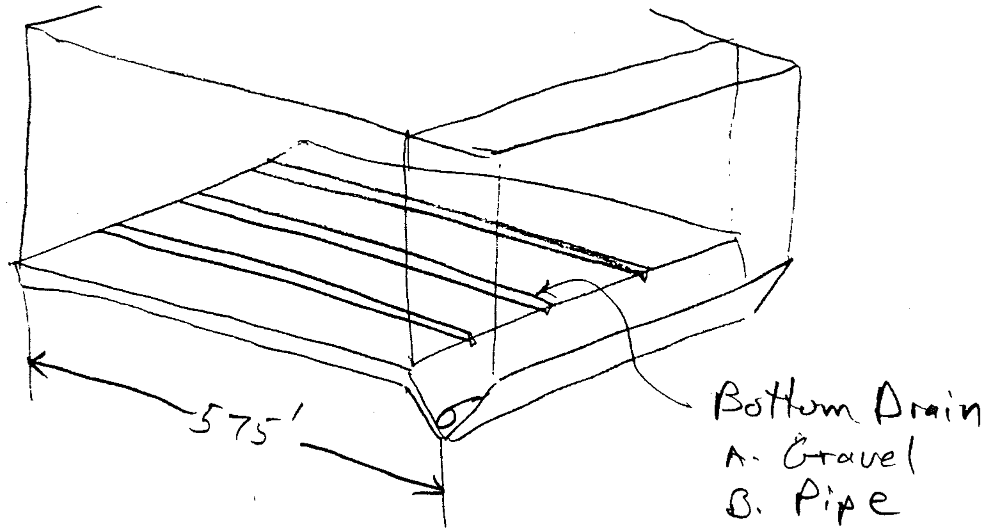
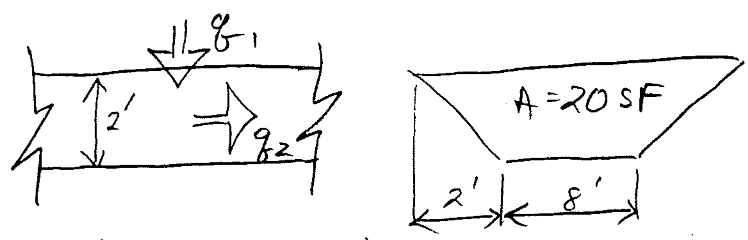
Consider addition of bottom drains:



(A.) Gravel

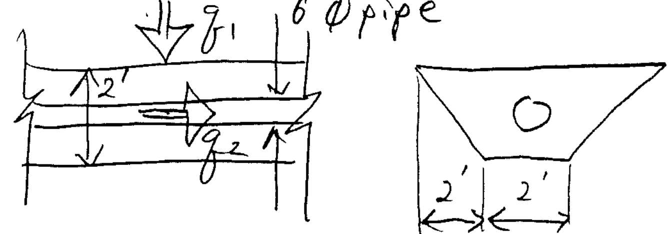


$q_1 = kiA = \left(0.142 \frac{ft}{day}\right)(1)(12' \times 1150')(3) = 5879$ cfd for 3 drains

$q_2 = kiA = \left(283.5 \frac{ft}{day}\right)\left(\frac{65}{575}\right)(20SF)(3) = 1923$ cfd for 3 drains

∴ gravel drain capacity limits flow

(B.) Pipe



$q_1 = \left(0.142 \frac{ft}{day}\right)(1)(6' \times 1150')(3) = 2939$ cfd for 3 drains

$q_2 = 2.449\, V d^2 (3) = 2.449(1)(6)^2(3) = 50{,}780$ cfd for 3 drains

∴ scrubber solids limit flow

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DEWATERING WORKSHEET (See Sheets 6 & 7)

Time	Inc. H	Flow in SS		Flow in BA		Pump. Rate	Gravel Drain			Pipe Drain		
		q_H	q_V	q_P	q_B		3	4	5	3	4	5

$$q_H = kiA = \left(1.64\times10^{-6}\tfrac{ft}{s}\right)\left(\frac{H-93.8}{575}\right)(H-948)(5300)$$

$$q_v = kiA = \left(1.64\times10^{-6}\right)(1)(1150\times1500)$$

$$q_P = kiA = \left(2.66\times10^{-5}\right)(1)(15\times5300)$$

$$q_B = kiA = \left(2.66\times10^{-5}\right)\left(\frac{H-938}{575}\right)(2\times5300)$$

Pumping Rate

If $q_v > q_B$ THEN $PR = q_H + q_B$

ELSE $PR = 50$ gpm (9620 cfd)

Assuming a decline in head ΔH, available water is:

$$AW = S_y V_T = (0.3)(1500\times1150\times\Delta H)$$

The new head is: $H = H_{orig} - \Delta H = 55 - \Delta H$

the time to pump ΔH is: $t = AW/PR$

For gravel drains:

$$q_{BG} = q_B + kiA = q_B + \left(3.28\times10^{-3}\tfrac{ft}{s}\right)\left(\frac{H-938}{575}\right)(20)(N)$$

where: N = # of drains

Then: $PR = q_H + q_{BG}$ if $q_v > q_{BG}$
and $PR = 50$ gpm if $q_v < q_{BG}$

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For pipe drains:

$$q_{BP} = q_B + (2.449)(v)(d^2) = q_B + (16,927)(N)$$

where: N = # of drains

then: $PR = q_H + q_{BP}$ if $q_v > q_{BP}$
and $PR = 50$ gpm if $q_v < q_{BP}$

Time for gravel + pipe drains is the same

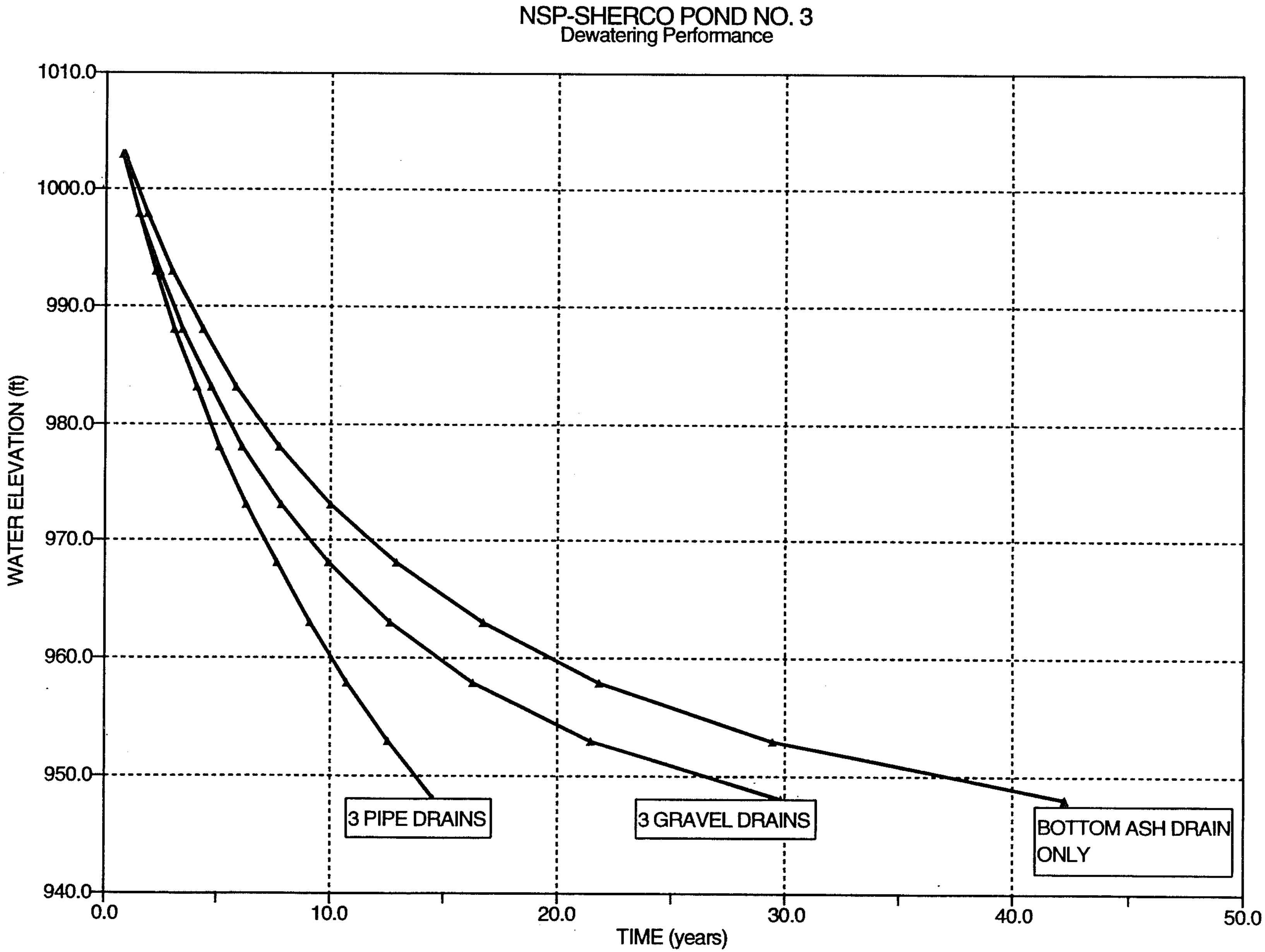
Re-arranging the spreadsheet:

H	ΔH	Flow in SS	Flow in BA	PR	AW	t	Gravel	Pipes
		q_H q_V	q_P q_B				N, q_{BG}, PR, t	N, q_{BP}, PR, t

Constants:

Orig H: 1003
Ave. Bot. Elev: 938
K_{SS}: 1.64×10^{-6}
K_{BA}: 2.66×10^{-5}
K_{grav}: 3.28×10^{-3}

Specific Yield: 0.3
Length: 1500
Width: 1150
Orig. Pumping Rate/Cell: 50 gpm (9620 cfd)



NSP-SHERCO POND NO. 3
Dewatering Performance
1010.0
1000.0
990.0
980.0
970.0
960.0
950.0
940.0
WATER ELEVATION (ft)
0.0
10.0
20.0
30.0
40.0
50.0
TIME (years)
3 PIPE DRAINS
3 GRAVEL DRAINS
BOTTOM ASH DRAIN ONLY

Sheet 6

NSP-SHERCO POND EXPANSION
Pond 3 Dewatering Performance

Max. Water Elev. (ft):	1003	Permeability of Scr. Sol. (ft/day):	0.142
Ave. Bottom Elev. (ft):	938	Permeability of Bot. Ash (ft/day):	2.298
Cell Length (ft):	1500	Permeability of Gravel (ft/day):	283.39
Cell Width (ft):	1150	Orig. Pumping Rate (cfd):	9620
Specific Yield of Scr. Sol.:	0.3	Number of Drains:	3

		<Flow in SS	>	<Flow in BA	>					< 3 Gravel Drains			><	3 Pipe Drains			>
H (ft)	delta H (ft)	Qh (cfd)	Qv (cfd)	Qp (cfd)	Qb (cfd)	PR (cfd)	AW (cf)	delta Time (days)	Time (yrs)	Qbg (cfd)	PR (cfd)	delta Time (days)	Time (yrs)	Qbp (cfd)	PR (cfd)	delta Time (days)	Time (yrs)
1003	5	5529.97	244950.00	182691.00	2753.60	8283.58	2587500.00	312.37	0.86	4675.73	9620.00	268.97	0.74	5693.00	9620.00	268.97	0.74
998	5	4711.93	244950.00	182691.00	2541.79	7253.72	2587500.00	356.71	1.83	4316.06	9027.99	286.61	1.52	5481.19	9620.00	268.97	1.47
993	5	3959.33	244950.00	182691.00	2329.97	6289.30	2587500.00	411.41	2.96	3956.38	7915.71	326.88	2.42	5269.37	9228.70	280.38	2.24
988	5	3272.17	244950.00	182691.00	2118.16	5390.33	2587500.00	480.03	4.28	3596.71	6868.89	376.70	3.45	5057.56	8329.73	310.63	3.09
983	5	2650.46	244950.00	182691.00	1906.34	4556.80	2587500.00	567.83	5.83	3237.04	5887.50	439.49	4.65	4845.74	7496.20	345.17	4.04
978	5	2094.19	244950.00	182691.00	1694.53	3788.72	2587500.00	682.95	7.70	2877.37	4971.56	520.46	6.08	4633.93	6728.12	384.58	5.09
973	5	1603.37	244950.00	182691.00	1482.71	3086.07	2587500.00	838.44	10.00	2517.70	4121.06	627.87	7.80	4422.11	6025.47	429.43	6.27
968	5	1177.98	244950.00	182691.00	1270.89	2448.88	2587500.00	1056.61	12.89	2158.03	3336.01	775.63	9.92	4210.29	5388.28	480.21	7.58
963	5	818.04	244950.00	182691.00	1059.08	1877.12	2587500.00	1378.44	16.67	1798.36	2616.40	988.95	12.63	3998.48	4816.52	537.21	9.06
958	5	523.55	244950.00	182691.00	847.26	1370.81	2587500.00	1887.57	21.84	1438.69	1962.23	1318.65	16.25	3786.66	4310.21	600.32	10.70
953	5	294.50	244950.00	182691.00	635.45	929.94	2587500.00	2782.43	29.47	1079.01	1373.51	1883.86	21.41	3574.85	3869.34	668.72	12.53
948	5	130.89	244950.00	182691.00	423.63	554.52	2587500.00	4666.21	42.25	719.34	850.23	3043.30	29.75	3363.03	3493.92	740.57	14.56
943	5	32.72	244950.00	182691.00	211.82	244.54	2587500.00	10581.20	71.24	359.67	392.39	6594.15	47.81	3151.22	3183.94	812.67	16.79
938	5	0.00	244950.00	182691.00	0.00	0.00	2587500.00	ERR	ERR	0.00	0.00	ERR	ERR	2939.40	2939.40	880.28	19.20

Sht 2

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Bottom Ash Dewatering

Since the perimeter has a much higher permeability than the scrubber solids, a sustained pumping rate of 50 gpm may be possible.

Permeability of bottom ash based on measurements of screened bottom ash used for recycle basin:

Permeability (cm/s)

$$\left.\begin{array}{l} 8.5\times10^{-4} \\ 5.3\times10^{-4} \\ 3.7\times10^{-4} \\ 1.0\times10^{-4} \\ 2.2\times10^{-3} \end{array}\right\} \text{Ave} = 8.1\times10^{-4}\ \text{cm/s} \ (2.66\times10^{-5}\ \text{ft/s})$$

Note: these perms. were determined for R.C. ≥ 95% and screened (> 3/8") bot. ash. It is likely that unscreened bottom ash will have perm. ≥ 8.1×10^{-4} cm/s.

Determine Rate of Dewatering from:

Avail. Water, $AW = (\Delta H)(L)(W)(S_y) = \Delta H(1)(15)(0.3)$ $\left[\frac{CF}{ft}\right]$

$Q_{bottom} = KiA = (2.66\times10^{-5}\ ft/s)(\Delta H/575)(2'\times1')$ [CFD/ft]

$Q_{perim.} = KiA = (1.64\times10^{-6}\ ft/s)(\Delta H/575)(65'\times1')$ [CFD/ft]

Inflow volume $= S_y * \frac{1}{2}(\Delta H/2)^2$ [CF/ft] see Sheet 9

Pumping Rate = 9620 CFD/cell = 1.815 CFD/ft

$$\text{Time} = \frac{\left[t_{previous} * (Q_{bottom} + Q_{perim}) + AW + \text{Inflow}\right]}{1.815}$$

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Bottom Ash Dewatering Spreadsheet (See Sheets 10 & 11)

Use spreadsheet to estimate incremental drop in head in the bottom ash for 100 gpm pumping rate (25 gpm per side per cell).

For 5′ increment:

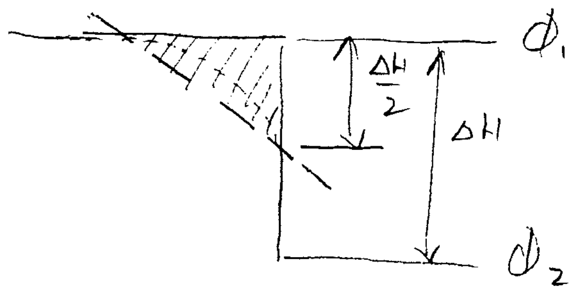
$$AW = (5')(15')(1')(0.3) = 22.5 \text{ cf/ft} \Rightarrow \text{avail. to drain by gravity}$$
$$= (\Delta H)(W)(L)(S_y)$$

$$Q_1 = k\,i\,A = k\,\frac{\Delta H}{\Delta L}\,(L \times W)$$
$$= \left(2.66 \times 10^{-5}\,\tfrac{ft}{s}\right)\left(\frac{5}{575}\right)(2 \times 1) = 0.04 \text{ cfd/ft}$$

$$Q_2 = (1.64 \times 10^{-6})\left(\frac{5}{575}\right)(66) = 0.08 \text{ cfd/ft}$$

$$Q_T = Q_1 + Q_2 = 0.12 \text{ cfd/ft}$$

Inflow = Volume released from scrubber solids



Assume volume is ½ of drawdown (shaded area)

$$\text{Vol.} = S_y * \tfrac{1}{2}\left(\frac{\Delta H}{2}\right)^2$$

$$= (0.3)(0.5)\left(\frac{5}{2}\right)^2 = 0.94 \text{ CF/ft}$$

$$\text{Time} = \frac{\text{Volume}}{\text{Pumping Rate}} = \frac{22.5 \text{ CF/ft}}{(4810 \text{ CFD})/2650 \text{ ft}} = \frac{22.5 \text{ cf/ft}}{1.815 \text{ cfd/ft}}$$

$$= 12.4 \text{ days}$$

For successive days:

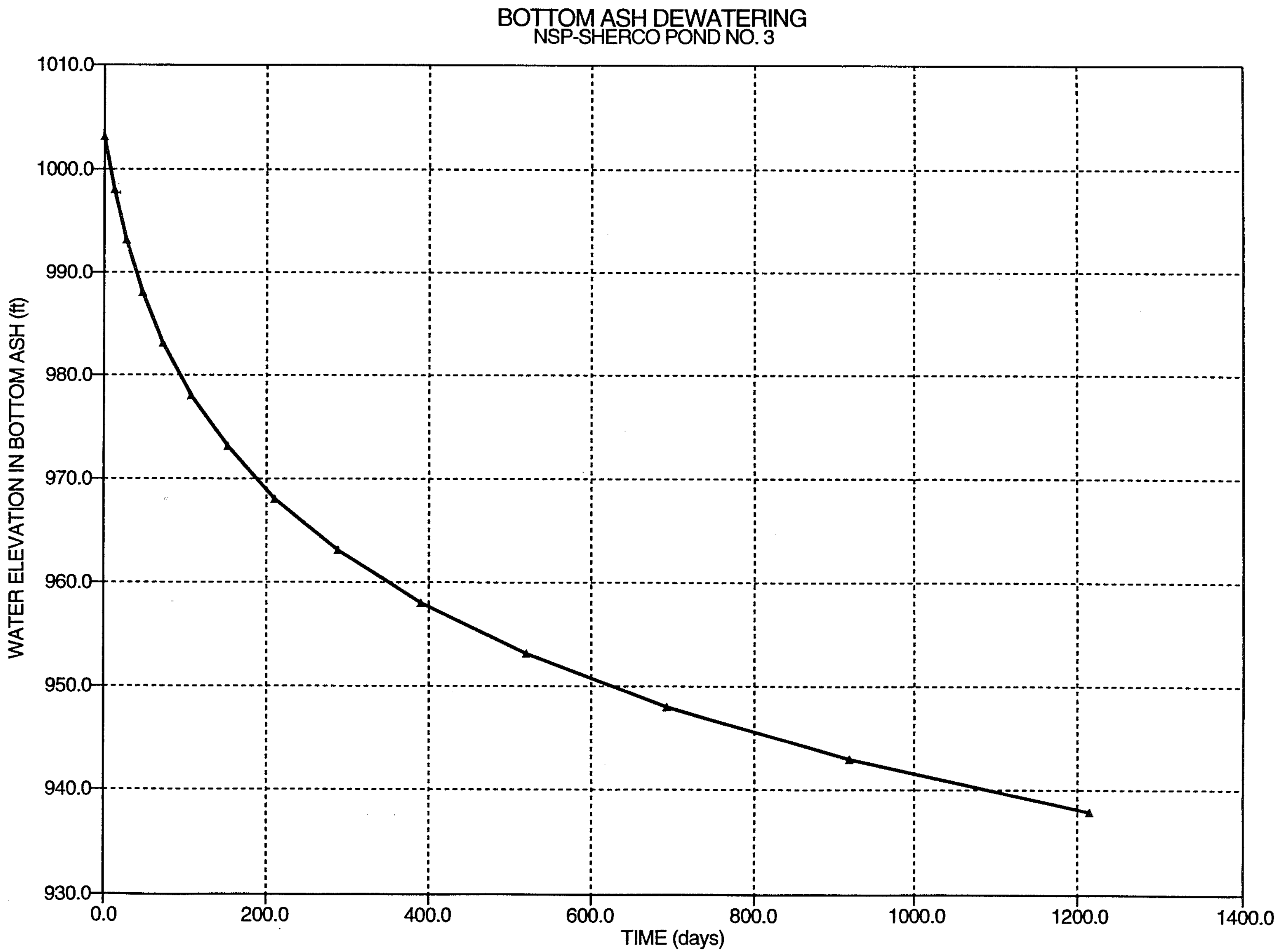
$$\text{Time} = \left[\text{Previous Time}\,(Q_1 + Q_2) + AW + \text{Inflow}\right] / 1.815$$

Sheet 10

NSP-SHERCO POND NO. 3
DEWATERING PERFORMANCE, RATE OF BOTTOM ASH DEWATERING

Specific yield of bottom ash	0.3
Permeability of bottom ash	2.298
Permeability of Scrubber Solids	0.142

Head (ft)	Increment (ft)	Volume (CF/ft)	Q1 (CFD/ft)	Q2 (CFD/ft)	Total Q (CFD/ft)	Time (day)	Total Time (day)	Inflow (CF/ft)
1003	0	0	0.00	0.00	0.00	0.00	0.00	0.00
998	5	22.5	0.04	0.08	0.12	12.40	12.40	0.94
993	5	22.5	0.08	0.16	0.24	16.12	28.52	3.75
988	5	22.5	0.12	0.24	0.36	20.28	48.80	8.44
983	5	22.5	0.16	0.33	0.49	26.09	74.89	15.00
978	5	22.5	0.20	0.41	0.61	34.04	108.93	23.44
973	5	22.5	0.24	0.49	0.73	44.66	153.59	33.75
968	5	22.5	0.28	0.57	0.85	58.63	212.22	45.94
963	5	22.5	0.32	0.65	0.97	76.84	289.06	60.00
958	5	22.5	0.36	0.73	1.09	100.52	389.58	75.94
953	5	22.5	0.40	0.81	1.21	131.32	520.89	93.75
948	5	22.5	0.44	0.90	1.34	171.56	692.45	113.44
943	5	22.5	0.48	0.98	1.46	224.55	917.00	135.00
938	5	22.5	0.52	1.06	1.58	295.04	1212.04	158.44



BOTTOM ASH DEWATERING
NSP-SHERCO POND NO. 3
WATER ELEVATION IN BOTTOM ASH (ft)
1010.0
1000.0
990.0
980.0
970.0
960.0
950.0
940.0
930.0
0.0
200.0
400.0
600.0
800.0
1000.0
1200.0
1400.0
TIME (days)

Sheet 11

Appendix H

Consolidation/Settlement Analysis

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SETTLEMENT ANALYSIS

Soil and Waste Properties

Material	Unit Wt. (pcf)	Modulus (psf)	Poisson's Ratio
Scrubber Sol.	107	500,000	0.35
Compacted Bot. Ash	103	500,000	0.35
Dike	120	1,000,000	0.35
Clay Liner	127	500,000	0.35
Alluvium	120	1,000,000	0.35

Method of Analysis

- Finite element program SIGMA/W
- linear elastic materials
- total-undrained analysis for load/deformation
- drained analysis for dewatering
- assume
  1) entire load placed at once
  2) complete dewatering occurs

References

- Scrubber Solids Pond No. 2 design report
  Application for Amendment of NPDES Permit No. 0002186
  January 1995
  Barr Eng. Co.

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Results (see following figures for mesh & analysis)

File	Conditions	Liner Settlement (ft)	Liner Settlement (% strain)	Cover Settlement (ft) Max/Min	Cover Settlement (ft) Dist.
P3SET-L	E_{ss} = 100,000 psf	1.10	0.07	1.34/0.78	58.8
P3SET-V		1.76	0	2.20/1.30	72.0
P3SET-L1	E_{ss} = 500,000 psf	0.48	0.10	0.46/0.40	55.5
P3SET-V1		0.75	0.02	0.73/0.63	41.1

File	Cover Settlement (ft)	Cover Strain (%)
P3SET-V	0.89	0.6
P3SET-V1	0.26	0.08

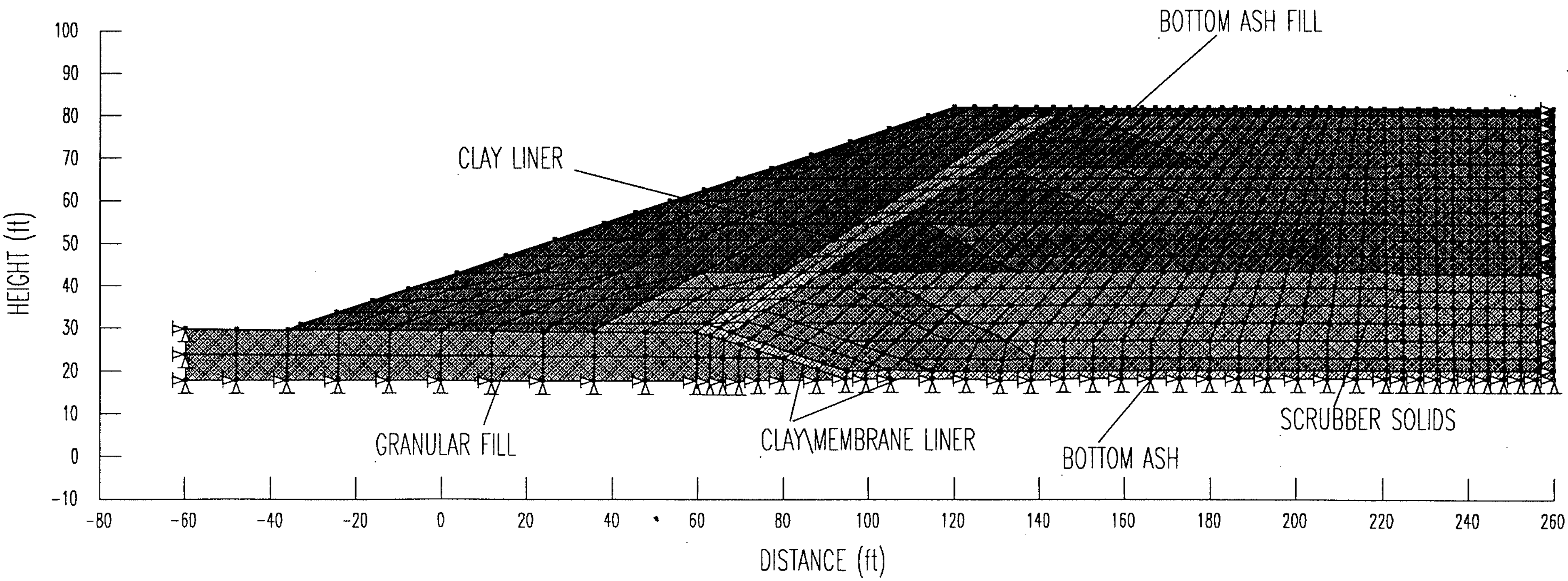
Conclusions

1. The maximum tensile liner strain during construction is less than 0.10 %, much less than what would be required for failure of the liner. This assumes that during operation, scrubber solids have a lower modulus (100,000 psf) than at final conditions.

2. The maximum tensile cover strain is less than 0.1 % which is much less than the tensile strength of the cover materials. This assumes that the cover must withsand the effects of complete dewatering.

NSP-SHERCO POND NO. 3
SETTLEMENT ANALYSIS
23-71-027-TJR

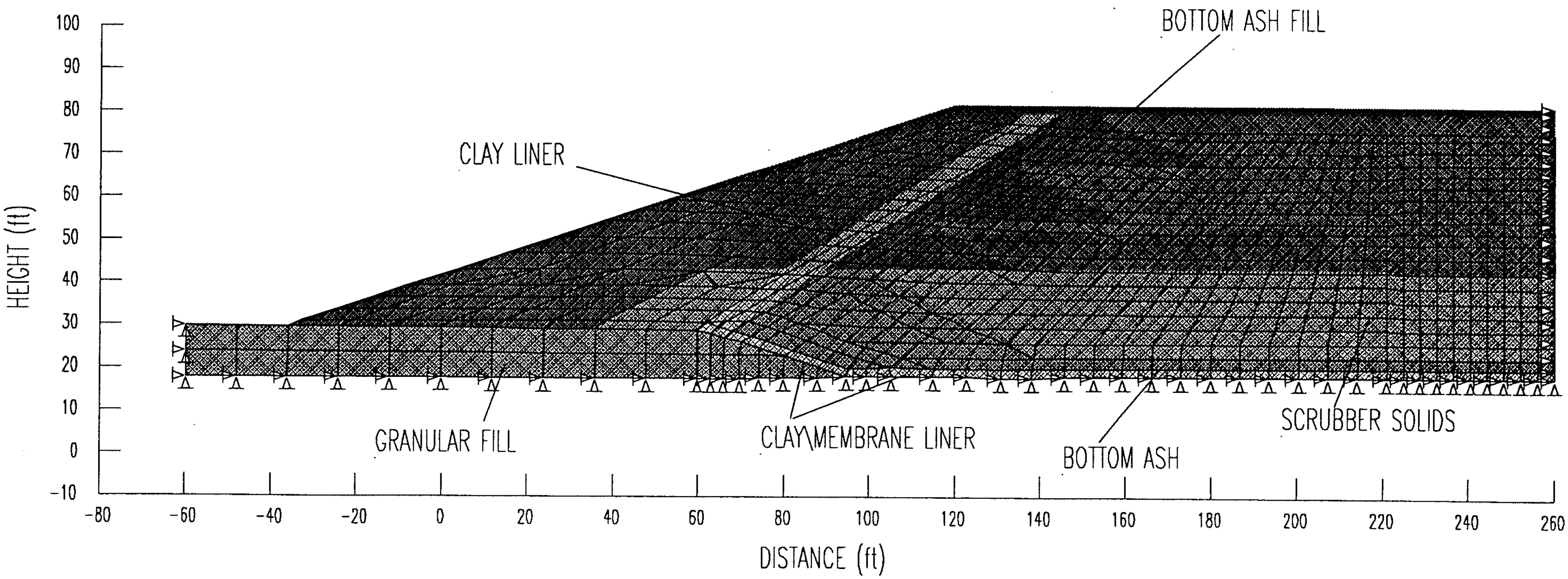
PHASE 5
CONDITIONS BEFORE CLOSURE
FINITE ELEMENT MESH



FILENAME: P3SET-L

NSP-SHERCO POND NO. 3
SETTLEMENT ANALYSIS
23-71-027-TJR

PHASE 5
CONDITIONS BEFORE CLOSURE
MAGNIFICATION: 5X



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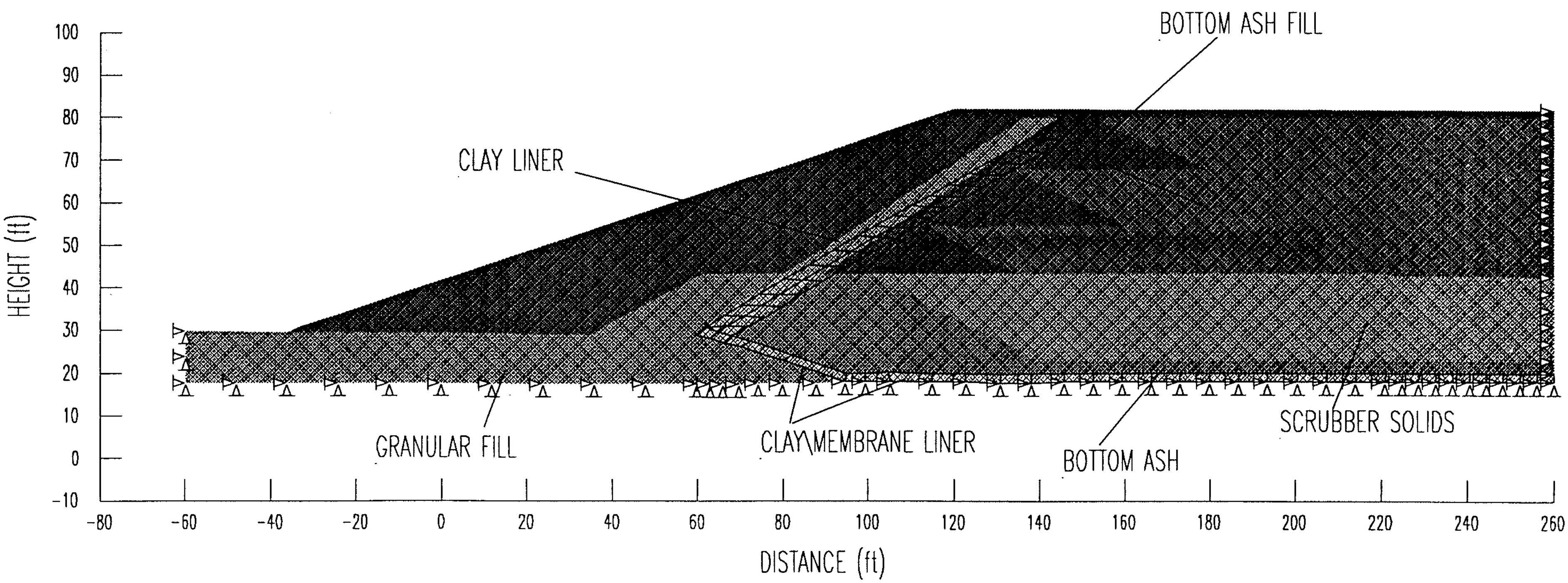
NSP–SHERCO POND NO. 3
SETTLEMENT ANALYSIS
23–71–027–TJR

PHASE 5
CONDITIONS BEFORE CLOSURE
FINITE ELEMENT MESH



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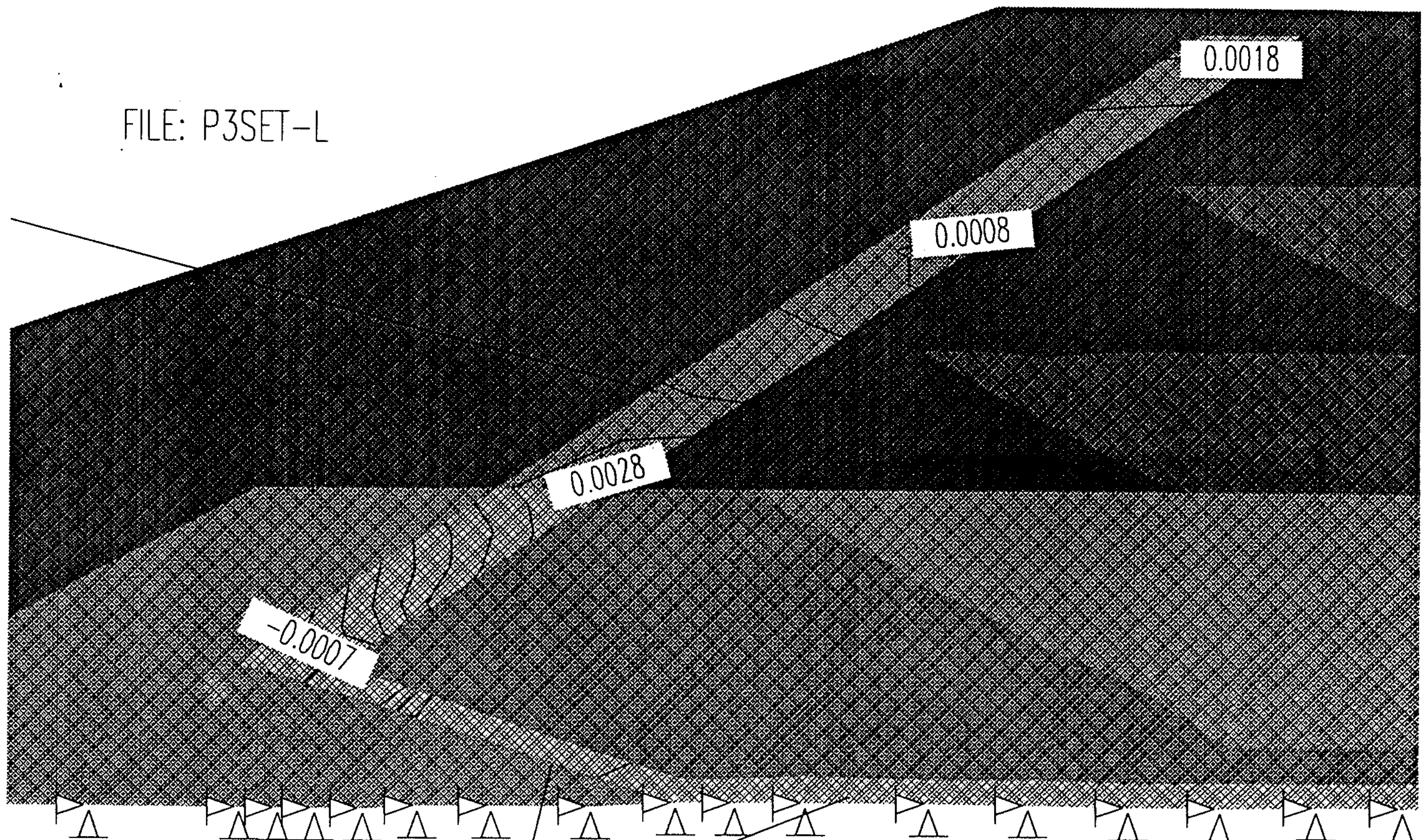
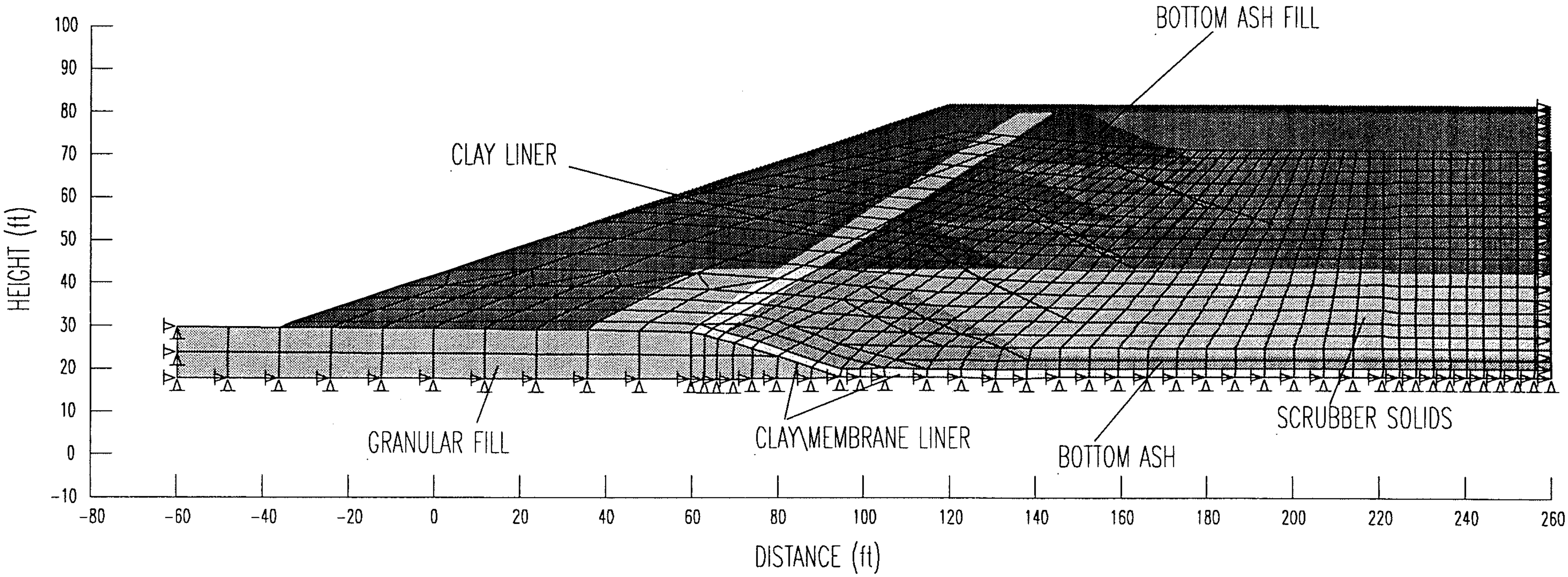


Contours of x-direction strain

NSP-SHERCO POND NO. 3
SETTLEMENT ANALYSIS
23-71-027-TJR

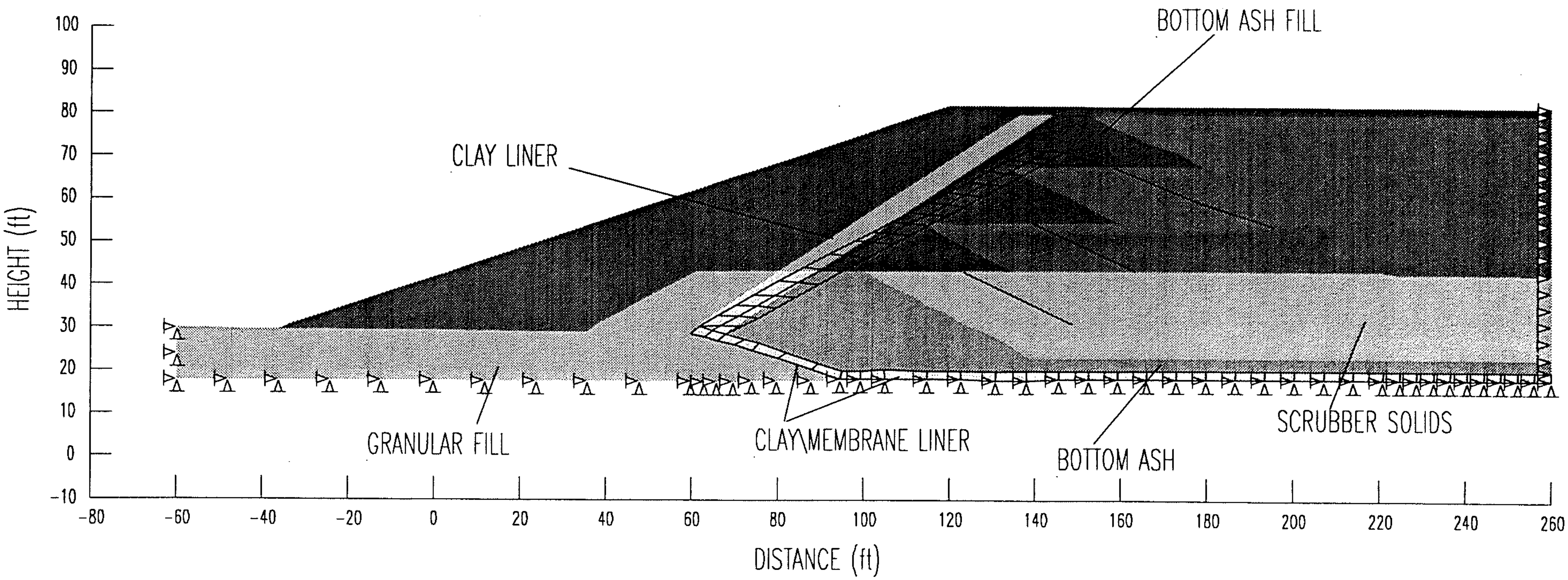
PHASE 5
CONDITIONS AFTER DEWATERING
MAGNIFICATION: 5X



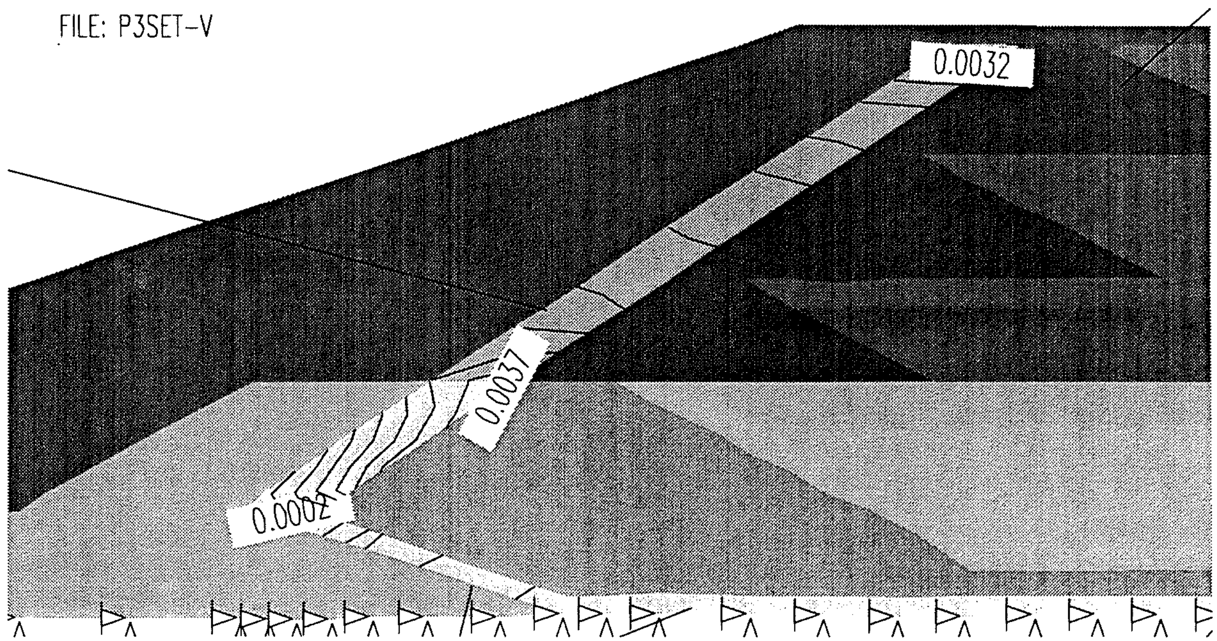
FILENAME: P3SET-V

NSP-SHERCO POND NO. 3
SETTLEMENT ANALYSIS
23-71-027-TJR

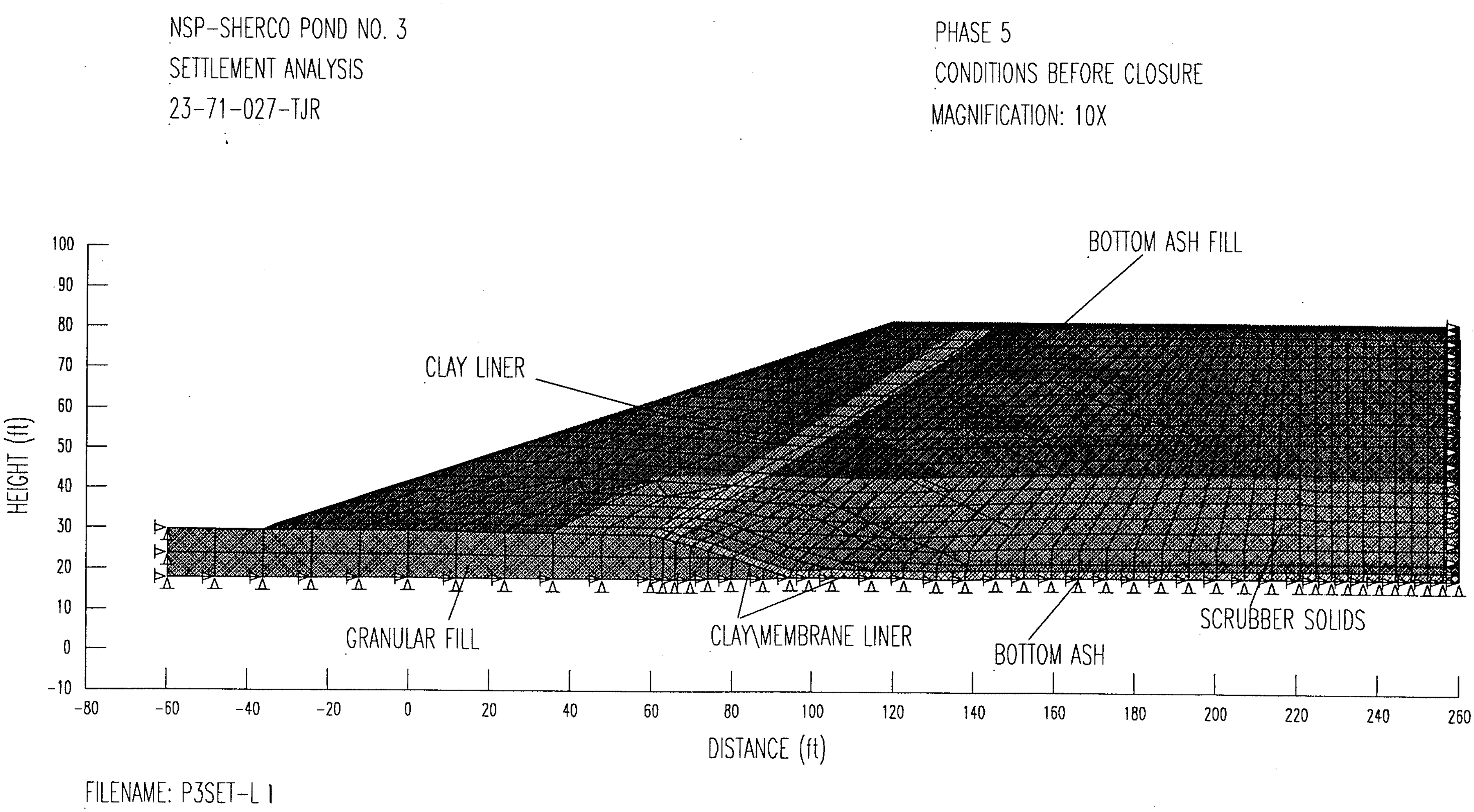
PHASE 5
CONDITIONS AFTER DEWATERING
MAGNIFICATION: 5X



FILENAME: P3SET-V

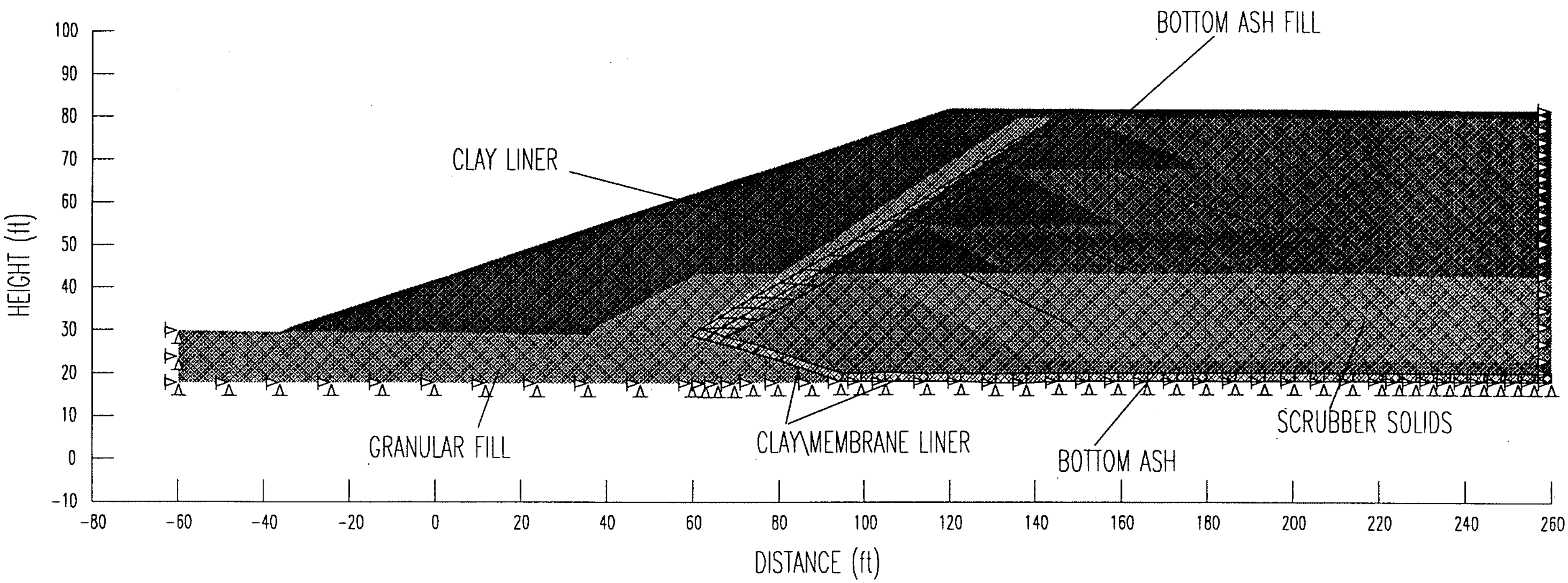


Contours of x-direction strain

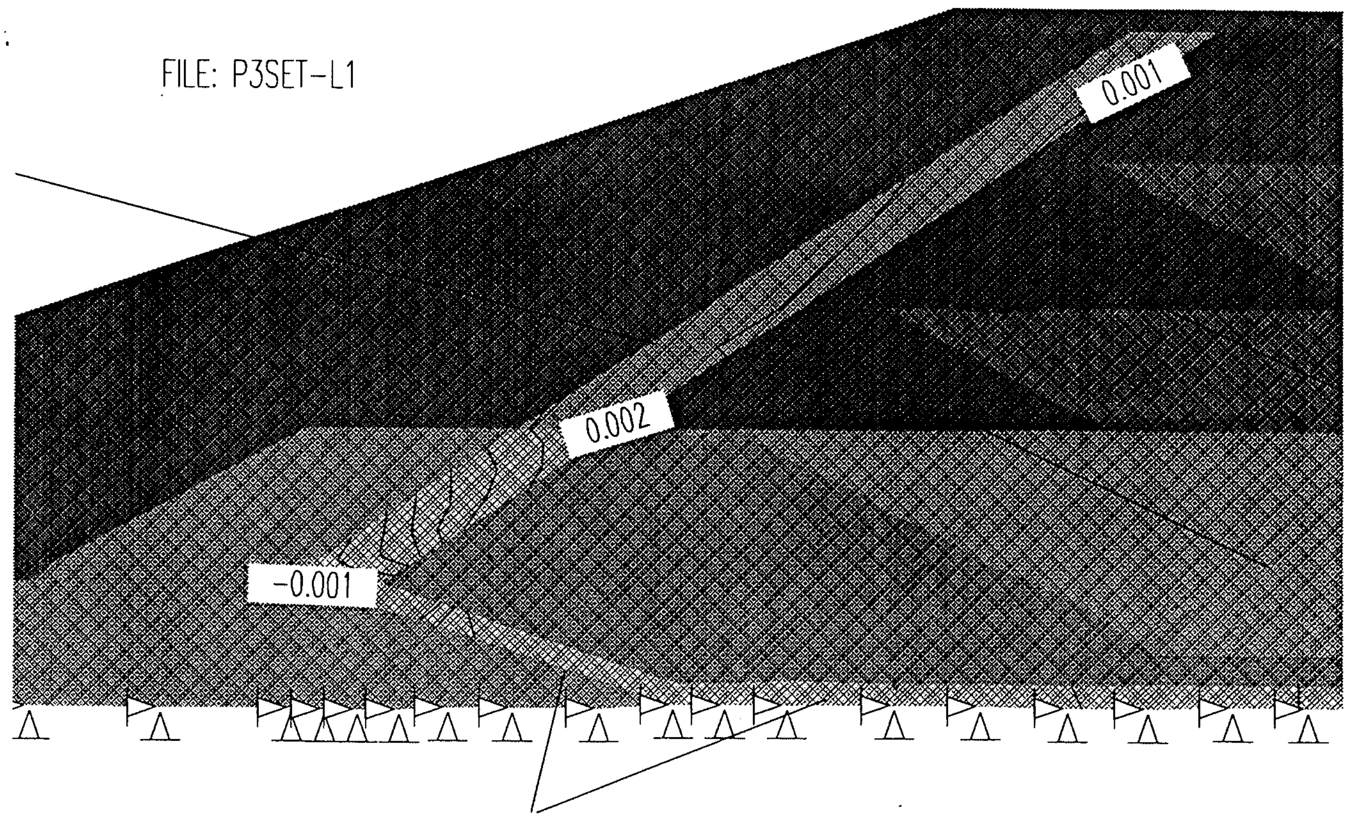

NSP-SHERCO POND NO. 3
SETTLEMENT ANALYSIS
23-71-027-TJR
PHASE 5
CONDITIONS BEFORE CLOSURE
MAGNIFICATION: 10X
BOTTOM ASH FILL
CLAY LINER
GRANULAR FILL
CLAY\MEMBRANE LINER
BOTTOM ASH
SCRUBBER SOLIDS
HEIGHT (ft)
DISTANCE (ft)
100
90
80
70
60
50
40
30
20
10
0
-10
-80
-60
-40
-20
0
20
40
60
80
100
120
140
160
180
200
220
240
260
FILENAME: P3SET-L I

NSP-SHERCO POND NO. 3
SETTLEMENT ANALYSIS
23-71-027-TJR

PHASE 5
CONDITIONS BEFORE CLOSURE
MAGNIFICATION: 10X



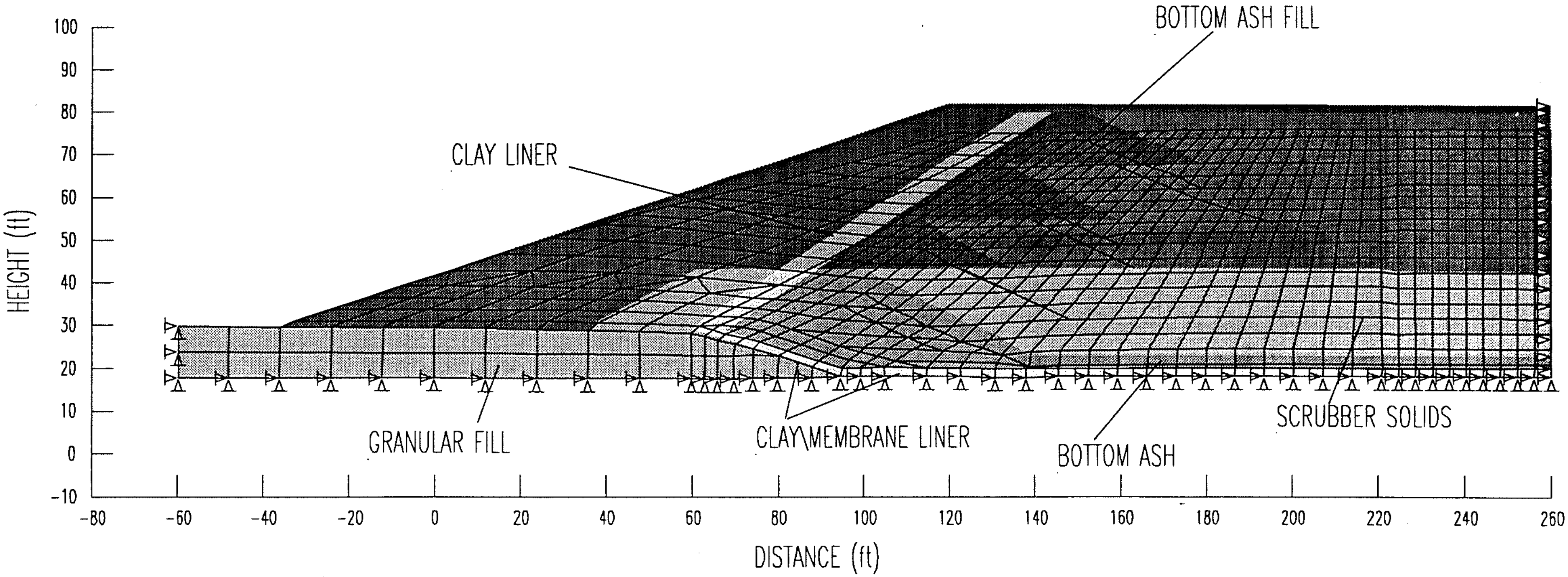
FILENAME: P3SET-L1



Contours of x-direction strain

NSP-SHERCO POND NO. 3
SETTLEMENT ANALYSIS
23-71-027-TJR

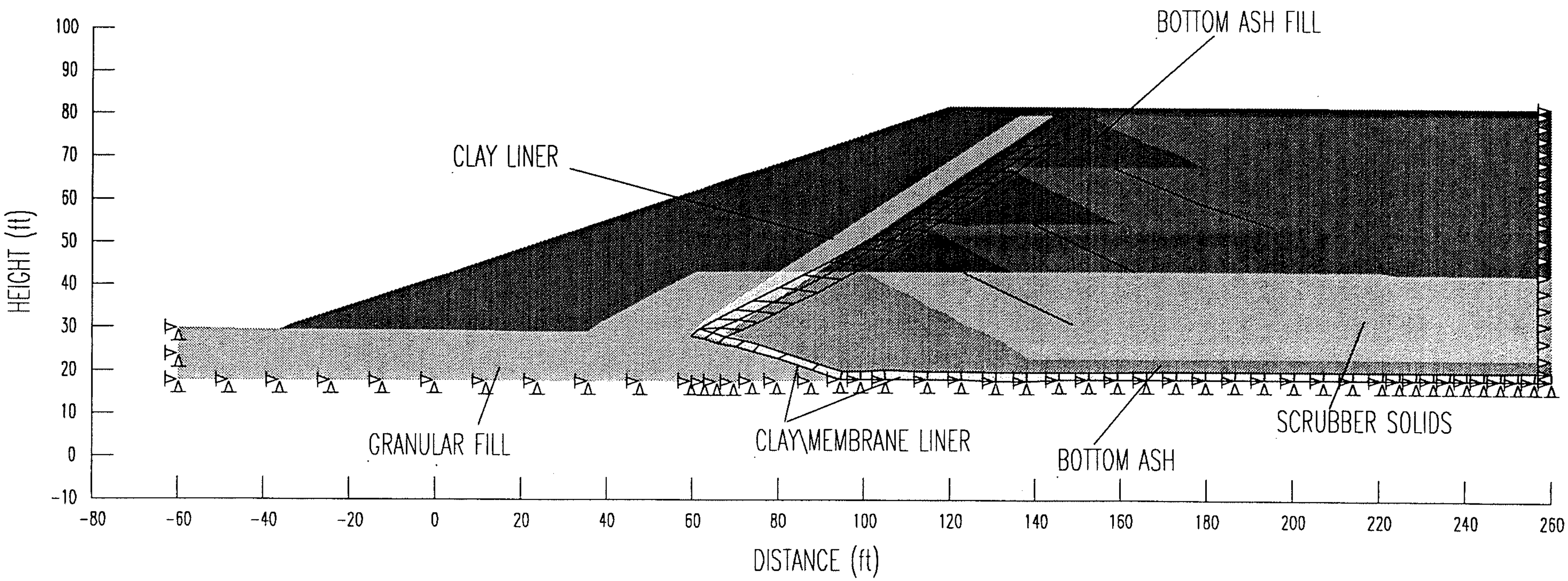
PHASE 5
CONDITIONS BEFORE CLOSURE
MAGNIFICATION: 10X



FILENAME: P3SET-VI

NSP–SHERCO POND NO. 3
SETTLEMENT ANALYSIS
23–71–027–TJR

PHASE 5
CONDITIONS BEFORE CLOSURE
MAGNIFICATION: 10X



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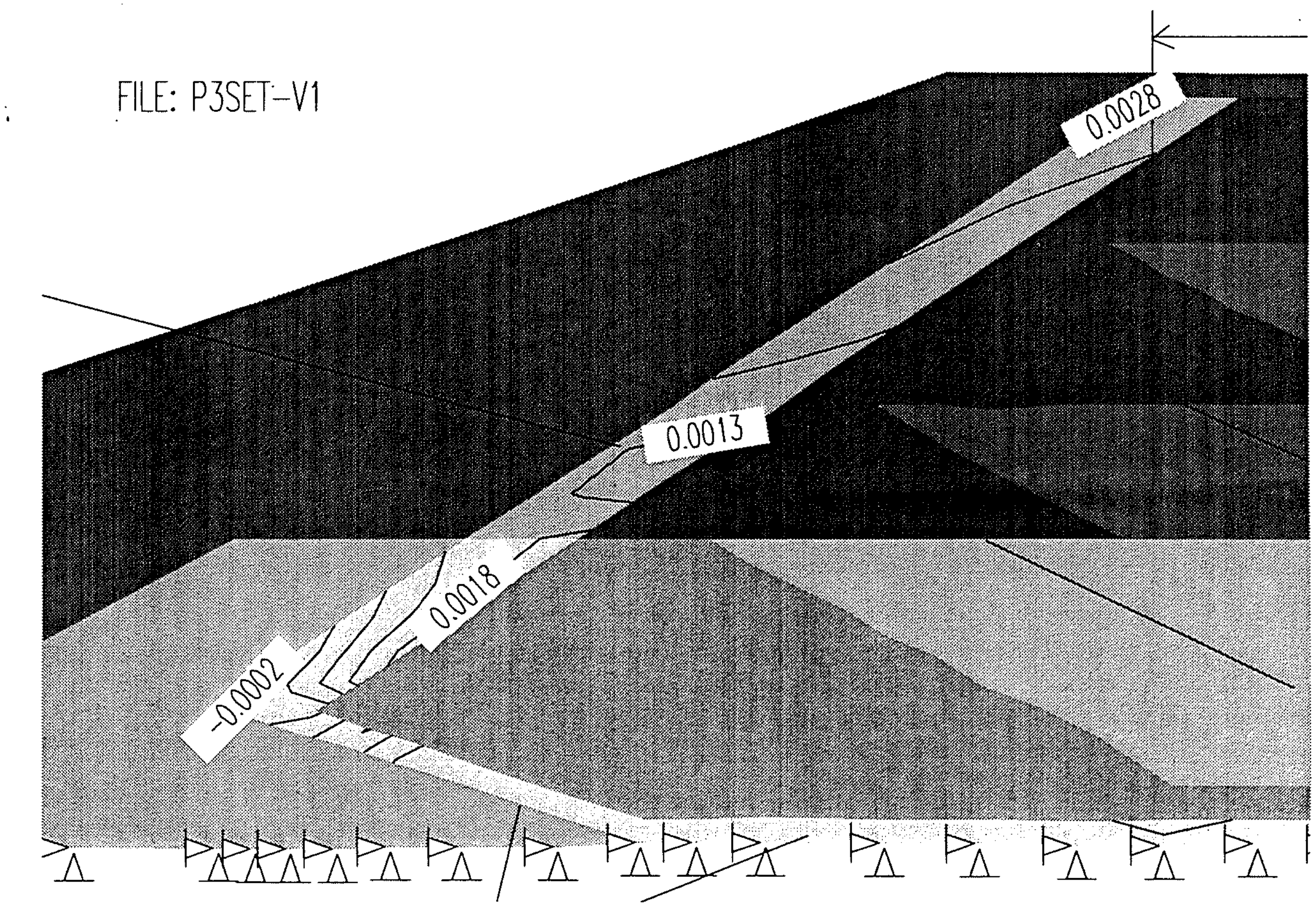

Contours of X-direction strain

Appendix I

Surface Water Hydrology Analysis

BARR ENGINEERING CO.

NSP Storm Pond #3

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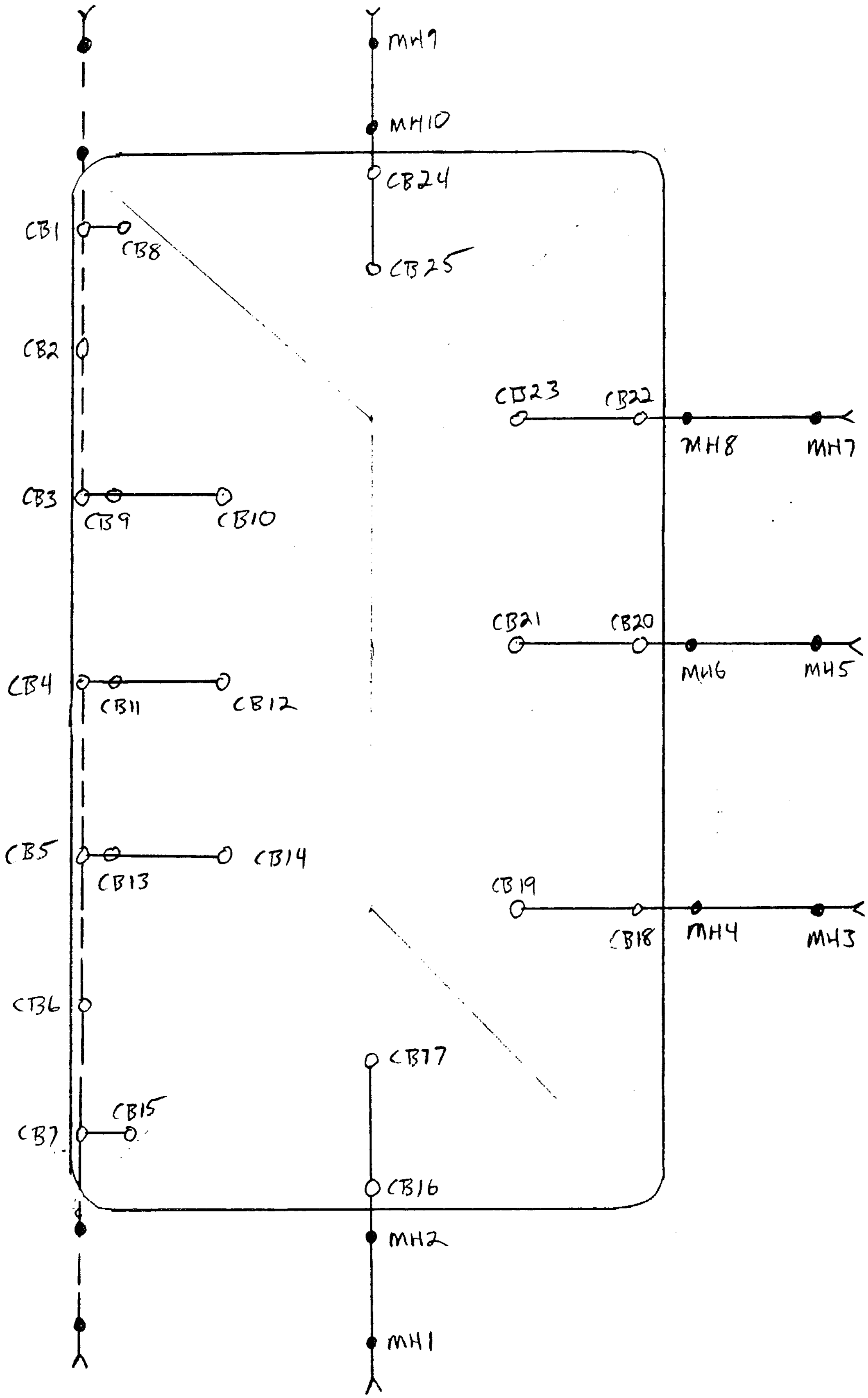

INTRODUCTION

The following describes the Barr Hydrograph Method, which was used in the hydrologic/hydraulic analysis.

BARR HYDROGRAPH METHOD

The Barr Hydrograph Method was developed in the late 1950's. The model has been modified and computerized through its years of use in urban watershed management. The Barr Hydrograph Method is an example of a practical urban runoff model. It works with each part of the rainfall-runoff process to estimate stormwater discharges and volumes. The procedures focus on simulating the storage effects occurring throughout the process of runoff.

The model has four basic components: 1) the hyetograph; 2) the abstractions from the hyetograph - interception, infiltration, and depression losses; 3) overland flow routing; and 4) routing to account for flow through swales or ditches and surface water pipes to the subwatershed outlet.

Rainfall Distribution and Duration

The first step in the Hydrograph Method is to determine the characteristics of the design storm. This requires determining both the amount of precipitation and the intensity distribution of the precipitation. Technical Papers No. 40 and 49, published by the National Weather Service, were used to determine the amount of precipitation. A synthetic hyetograph is developed to represent the intensity of rainfall versus time. Three synthetic hyetographs were used in this study.

For short duration storms (3 hours or less), a synthetic hyetograph is developed from data in a paper entitled, "Relation of Hourly Mean Rainfall to Actual Intensities," published in Civil Engineering in May, 1940. This hyetograph is shaped similar to the storm pattern shown by C.J. Keifer and H.H. Chu in a paper entitled, "Synthetic Storm Pattern for Drainage Design," published in the Proceedings of American Society of American Engineers, August, 1957. The hyetograph is also very similar to the second quartile hyetograph discussed in a paper by F.A. Huff entitled, "Time Distribution of Rainfall in Heavy Storms," published in Water Resources Research, Fourth Quarter, 1967.

The rainfall intensity distribution developed for longer duration storms was developed from Huff's third and fourth quartile, 50 percent probability hyetographs for the 12-hour and 4-day storms, respectively. These hyetographs are also discussed in Huff's paper.

The storm duration that is critical for a subwatershed is dependent on the subwatershed size and slope, the volume of storage available in the system, and the outlet capacity. The critical duration is determined by routing several different duration storms of a given frequency and determining which duration produces the greatest peak discharge or ponding elevation. A small subwatershed with little available storage will have a critical storm of smaller duration than a large subwatershed with abundant storage.

Estimation of Losses

After the hyetograph is developed, the various losses that occur after the rain reaches the ground are estimate. The three major losses are interception, infiltration, and depression storage.

Interception is the portion of the rainfall captured and held on leaves, blades of grass, and other similar objects. This water is returned to the atmosphere by evaporation. The interception loss was estimated to be 0.05 inches to 0.25 inches depending on the storm duration and land use type.

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Information and data concerning interception losses can be found in the textbook, Hydrology for Engineers, by Linsley, Kohler, and Paulhus, published in 1982.

The next loss considered is the infiltration of water into the soil. The method used to determine the infiltration is outlined in Technical Manual of Engineering Practice No. 28, published by the American Society of Civil Engineers in 1949. This procedure uses a standard infiltration curve which depends on soil types and ground cover. The standard infiltration curve is adjusted to account for low intensity rainfall in the early parts of a storm.

Once interception and infiltration losses are removed from the hyetograph, the remaining water is runoff. However, part of this runoff is often collected by depressions along the drainage route and never reaches the primary collection system (e.g., gutters and swales). The amount of water held in depression storage is dependent on the slope and the grading of the area. It is estimated that the total depression storage ranges from approximately 0.1 to 0.7 inches depending on the storm duration and land use type. This estimate was partially based on data in the book Hydrology for Engineers. After all three types of losses have been deducted, the average point runoff is known.

Development of Unit Hydrograph

The next step in the initial-runoff process is the conversion of the remaining hyetograph to a unit hydrograh. This consists of routing runoff from the point on which it lands as rainfall to the primary collection system. The overland flow process has the effect of attenuating and lagging the point runoff due to detention of the water on the land surface. The overland flow distance and the slope of the land affect the rate that water from a given area reaches a collection system.

The method outlined by W.W. Horner and S.W. Jens in a paper entitled, "Surface Runoff Determination from Rainfall Without Using Coefficients," published in the Transactions of the American Society of Civil Engineers, Volume 107, is used as a basis for the overland flow routing. Synthetic unit hydrographs are developed for impervious and pervious areas as well as water surfaces from the outflows of the overland flow routing.

The computations up to this point in the Barr Hydrograph Method generate five runoff hydrographs: one for impervious areas, one for water surfaces, and three for pervious areas which account for three separate choices in the general range of slope and flow lengths in the overland flow process. Given the percent of the total subwatershed included in each of these areas, these hydrographs are multiplied by this percentage and summed to give a composite runoff hydrograph.

Routing Through Primary Drainage System

The composite runoff hydrograph is routed through the subwatershed's conveyance system to develop the outflow runoff hydrograph for the downstream end of the subwatershed. This system is made up of swales, ditches, and surface water pipes. The average velocity and the longest flow length of the primary conveyance system are used in a storage routing procedure to generate the hydrograph at the outlet of the subwatershed. The method used for channel routing is outlined in Technical Manual of Engineering Practice No. 28, published by the American Society of Civil Engineers. An option of not routing the water surface hydrographs through the conveyance system is provided by the Barr Hydrograph Method. This option is used if the water surface is at the outlet of the subwatershed, which is commonly the case in urban watershed analysis.

Outflow Hydrograph

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The output of the Barr Hydrograph Method gives the outflow hydrograph of the subwatershed, the peak flow, the time of peak, and the volume of runoff. These data are then input to a separate routing program which sums hydrographs from adjacent subwatersheds and routes them through detention ponds and conveyance systems to downstream watersheds.

HYROLOGIC/HYDRAULIC ROUTING RESULTS

BARR ENGINEERING CO.

NSP Sherco Pond #3

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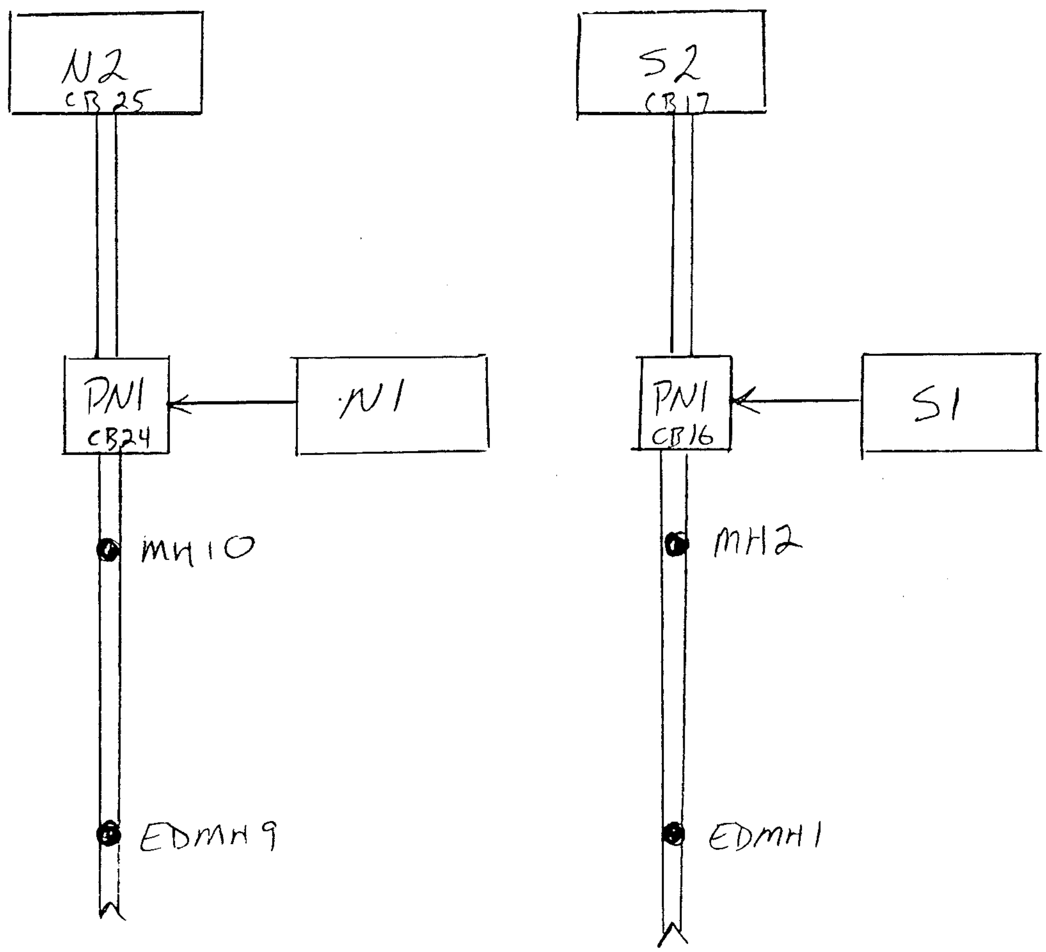
N + S AREA

The North and South Areas are essentially identical
∴ Only one routing model was completed



BARR ENGINEERING CO.

NSP Sherco Pond #3

CHECKED BY ________________
DATE ________________

NAME KAL
DATE 2-13-95
SHEET ________ IN SET
PAGE 9/96 IN FILE

N. AND S. AREA

SUMMARY

ALL Q'S DETERMINED FROM "BARR WATERSHED MODEL" - SEE OUTPUT
DESIGN STORM: 50 YR

* THE PIPE SYSTEMS ON THE NORTH AND SOUTH ENDS OF THE SITE ARE ESSENTIALLY THE SAME. THEREFORE COMPUTATIONS FOR BOTH SYSTEMS WERE NOT COMPLETED.

SUBWATERSHED	STRUCTURE	DITCH Q max	DITCH CAPACITY ①		HW @ CB	(See Barr Model Output)
N2	CB25	2.6 cfs	24 cfs @ 1%	OK	0.8'	OK
N1	CB24	4.6 cfs	16 cfs @ 1/2%	OK	1.0'	OK

① ASSUMED DEPTH OF FLOW = 1.5', SEE FLOWMASTER® OUTPUT

PIPE BTWN	PIPE Q max	PIPE SIZE & TYPE	INLET CONTROL HW		PIPE SLOPE	Q FULL ② PIPE CAPACITY		V @ Q max	d @ Q max
CB25 ⇒ CB24	4.7 cfs	12" PE	2.1'	OK	2%	6.6 cfs	OK	9 f/s	0.6'
CB24 ⇒ MH10	11.0 cfs	18" RC	2.5'	OK	7%	30 cfs	OK	16 f/s	0.6'
MH10 ⇒ MH9	11.0 cfs	18"	2.5'	OK	~25%		OK	25 f/s	0.5'
MH9 ⇒ END	11.0 cfs	18" RC	2.5'	OK	0.33%	6.5 cfs	OK	6.2 f/s	full

② SEE FLOWMASTER® OUTPUT

10/96

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**********************************************************************************
              *** BARR WATERSHED MODEL PROGRAM RESULTS SUMMARY ***
                              Version  6/07/91
**********************************************************************************

              ****************************************************
              *   Program Developed By:                          *
              *                                                  *
              *                      Barr Engineering Co.        *
              *                      7803 Glenroy Road           *
              *                      Minneapolis, MN  55439      *
              *                                                  *
              *                      Phone:  (612) 830-0555      *
              *                      Fax  :  (612) 835-0186      *
              *                                                  *
              ****************************************************

Run Date:    2/11/95
Time:        9:00:26

NSPOND#3.DAT = Input data file
NULL         = Output file
NSPOND#3.SUM = Summary file
NULL         = Input external hydrograph file
NULL         = Output external hydrograph file

NSP SHERCO POND #3 VERT. EXPANSION*N & S AREA *25YR & 50YR STORMS**FINAL COVER S

Number of storms modeled       = 10
Number of external hydrographs =  0
Number of Pipe Nodes           =  1
Pipe Nodes Included:
PN1

**********************************************************************************
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BARR HYDROGRAPH INPUT DATA

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UNIT HYETOGRAPHS

Storm frequency and duration = 25 YR-0.5 HR
Standard Short Duration Unit Hyetograph
Time Increment = .50 minutes, Rainfall = 1.90 inches

.11	.18	.23	.26	.29	.32	.37	.41	.46	.52
.62	.68	.78	.93	1.10	1.27	1.49	1.78	2.19	2.62
2.92	3.07	3.06	2.92	2.69	2.42	2.19	1.99	1.81	1.64
1.51	1.41	1.30	1.19	1.10	1.01	.93	.86	.80	.75
.69	.63	.59	.55	.52	.50	.46	.43	.41	.39
.37	.35	.34	.32	.31	.30	.27	.23	.17	.00

Storm frequency and duration = 25 YR-1.0 HR
Standard Short Duration Unit Hyetograph
Time Increment = 1.00 minutes, Rainfall = 2.40 inches

.11	.18	.23	.26	.29	.32	.37	.41	.46	.52
.62	.68	.78	.93	1.10	1.27	1.49	1.78	2.19	2.62
2.92	3.07	3.06	2.92	2.69	2.42	2.19	1.99	1.81	1.64
1.51	1.41	1.30	1.19	1.10	1.01	.93	.86	.80	.75
.69	.63	.59	.55	.52	.50	.46	.43	.41	.39
.37	.35	.34	.32	.31	.30	.27	.23	.17	.00

Storm frequency and duration = 25 YR-2.0 HR
Standard Short Duration Unit Hyetograph
Time Increment = 2.00 minutes, Rainfall = 2.80 inches

.11	.18	.23	.26	.29	.32	.37	.41	.46	.52
.62	.68	.78	.93	1.10	1.27	1.49	1.78	2.19	2.62
2.92	3.07	3.06	2.92	2.69	2.42	2.19	1.99	1.81	1.64
1.51	1.41	1.30	1.19	1.10	1.01	.93	.86	.80	.75
.69	.63	.59	.55	.52	.50	.46	.43	.41	.39
.37	.35	.34	.32	.31	.30	.27	.23	.17	.00

Storm frequency and duration = 25 YR-3.0 HR
Standard Short Duration Unit Hyetograph
Time Increment = 3.00 minutes, Rainfall = 3.00 inches

.11	.18	.23	.26	.29	.32	.37	.41	.46	.52
.62	.68	.78	.93	1.10	1.27	1.49	1.78	2.19	2.62
2.92	3.07	3.06	2.92	2.69	2.42	2.19	1.99	1.81	1.64
1.51	1.41	1.30	1.19	1.10	1.01	.93	.86	.80	.75
.69	.63	.59	.55	.52	.50	.46	.43	.41	.39
.37	.35	.34	.32	.31	.30	.27	.23	.17	.00

Storm frequency and duration = 25 YR-6.0 HR
User Input Unit Hyetograph
Time Increment = 6.00 minutes, Rainfall = 3.50 inches

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.24	.24	.30	.42	.42	.48	.54	.66	.72	.66
.66	.60	.48	.48	.42	.36	.36	.30	.18	.24
.36	.42	.48	.60	.72	.72	1.08	1.08	1.26	1.62
1.80	2.34	2.58	2.58	2.64	2.94	3.54	3.00	2.58	2.16
1.92	1.92	1.68	1.62	1.38	1.32	1.26	1.14	.96	.84
.66	.48	.36	.30	.30	.24	.12	.12	.06	.06

Storm frequency and duration = 25 YR-12 HR
User Input Unit Hyetograph
Time Increment = 12.00 minutes, Rainfall = 4.10 inches

.24	.24	.30	.42	.42	.48	.54	.66	.72	.66
.66	.60	.48	.48	.42	.36	.36	.30	.18	.24
.36	.42	.48	.60	.72	.72	1.08	1.08	1.26	1.62
1.80	2.34	2.58	2.58	2.64	2.94	3.54	3.00	2.58	2.16
1.92	1.92	1.68	1.62	1.38	1.32	1.26	1.14	.96	.84
.66	.48	.36	.30	.30	.24	.12	.12	.06	.06

Storm frequency and duration = 25 YR-24 HR
User Input Unit Hyetograph
Time Increment = 24.00 minutes, Rainfall = 4.60 inches

.24	.24	.30	.42	.42	.48	.54	.66	.72	.66
.66	.60	.48	.48	.42	.36	.36	.30	.18	.24
.36	.42	.48	.60	.72	.72	1.08	1.08	1.26	1.62
1.80	2.34	2.58	2.58	2.64	2.94	3.54	3.00	2.58	2.16
1.92	1.92	1.68	1.62	1.38	1.32	1.26	1.14	.96	.84
.66	.48	.36	.30	.30	.24	.12	.12	.06	.06

Storm frequency and duration = 50 YR-0.5 HR
Standard Short Duration Unit Hyetograph
Time Increment = .50 minutes, Rainfall = 2.15 inches

.11	.18	.23	.26	.29	.32	.37	.41	.46	.52
.62	.68	.78	.93	1.10	1.27	1.49	1.78	2.19	2.62
2.92	3.07	3.06	2.92	2.69	2.42	2.19	1.99	1.81	1.64
1.51	1.41	1.30	1.19	1.10	1.01	.93	.86	.80	.75
.69	.63	.59	.55	.52	.50	.46	.43	.41	.39
.37	.35	.34	.32	.31	.30	.27	.23	.17	.00

Storm frequency and duration = 50 YR-1.0 HR
Standard Short Duration Unit Hyetograph
Time Increment = 1.00 minutes, Rainfall = 2.75 inches

.11	.18	.23	.26	.29	.32	.37	.41	.46	.52
.62	.68	.78	.93	1.10	1.27	1.49	1.78	2.19	2.62
2.92	3.07	3.06	2.92	2.69	2.42	2.19	1.99	1.81	1.64
1.51	1.41	1.30	1.19	1.10	1.01	.93	.86	.80	.75
.69	.63	.59	.55	.52	.50	.46	.43	.41	.39
.37	.35	.34	.32	.31	.30	.27	.23	.17	.00

Storm frequency and duration = 50 YR-2.0 HR
Standard Short Duration Unit Hyetograph
Time Increment = 2.00 minutes, Rainfall = 3.25 inches

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.11	.18	.23	.26	.29	.32	.37	.41	.46	.52
.62	.68	.78	.93	1.10	1.27	1.49	1.78	2.19	2.62
2.92	3.07	3.06	2.92	2.69	2.42	2.19	1.99	1.81	1.64
1.51	1.41	1.30	1.19	1.10	1.01	.93	.86	.80	.75
.69	.63	.59	.55	.52	.50	.46	.43	.41	.39
.37	.35	.34	.32	.31	.30	.27	.23	.17	.00

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HYETOGRAPH LOSSES (inches)

STORM DURATION	INTERCEPTION imperv.	INTERCEPTION perv.	DEPRESSION imperv.	DEPRESSION perv.	INFILTRATION(in/hr) initial	infinity	..at	time=(min)
25 YR-0.5 HR	.05	.15	.10	.00	2.50	.30	1.70	15.00
25 YR-1.0 HR	.05	.15	.10	.00	2.50	.30	1.70	15.00
25 YR-2.0 HR	.05	.15	.10	.00	2.50	.30	1.70	15.00
25 YR-3.0 HR	.05	.15	.10	.00	2.50	.30	1.70	15.00
25 YR-6.0 HR	.05	.15	.10	.00	2.50	.30	1.70	15.00
25 YR-12 HR	.05	.15	.10	.00	2.50	.30	1.70	15.00
25 YR-24 HR	.05	.15	.10	.00	2.50	.30	1.70	15.00
50 YR-0.5 HR	.05	.15	.10	.00	2.50	.30	1.70	15.00
50 YR-1.0 HR	.05	.15	.10	.00	2.50	.30	1.70	15.00
50 YR-2.0 HR	.05	.15	.10	.00	2.50	.30	1.70	15.00

WATERSHED FEATURES SUMMARY TABLE

WATERSHED	total	Water	AREA Impervious (acres)	.001	.003	.005	AVERAGE VELOCITY (fps)	LONGEST FLOW LENGTH (feet)	TOC (min)
N1	5.2	.0	.0	5.2	.0	.0	.5	600.	20.00
N2	2.5	.0	.0	2.5	.0	.0	.5	400.	13.33
S1	5.0	.0	.0	5.0	.0	.0	.5	600.	20.00
S2	2.5	.0	.0	2.5	.0	.0	.5	400.	13.33

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BARR HYDROGRAPH OUTPUT STATISTICS

WATERSHED	STORM DURATION	PEAK DISCHARGE (cfs)	TIME OF PEAK (minutes)	HYDROGRAPH VOLUME (acft)
N1	25 YR-0.5 HR	6.85	26.50	.33
N1	25 YR-1.0 HR	6.81	42.00	.40
N1	25 YR-2.0 HR	5.26	72.00	.42
N1	25 YR-3.0 HR	4.46	102.00	.44
N1	25 YR-6.0 HR	4.74	252.00	.58
N1	25 YR-12 HR	3.17	480.00	.54
N1	25 YR-24 HR	1.41	936.00	.28
N1	50 YR-0.5 HR	8.74	26.00	.42
N1	50 YR-1.0 HR	9.05	42.00	.54 DITCH Qmax = 9.1 ÷ 2 = 4.6 cfs
N1	50 YR-2.0 HR	7.16	72.00	.57
N2	25 YR-0.5 HR	4.07	24.50	.15
N2	25 YR-1.0 HR	3.90	40.00	.19
N2	25 YR-2.0 HR	2.88	68.00	.19
N2	25 YR-3.0 HR	2.38	96.00	.20

N2	25 YR-6.0 HR	2.47	246.00	.27
N2	25 YR-12 HR	1.61	468.00	.25
N2	25 YR-24 HR	.68	912.00	.13
N2	50 YR-0.5 HR	5.19	24.00	.20
N2	50 YR-1.0 HR	5.20	39.00	.25 Ditch Q_{max} = 5.2 ÷ 2 = 2.6 cfs
N2	50 YR-2.0 HR	3.93	68.00	.27
S1	25 YR-0.5 HR	6.56	26.50	.31
S1	25 YR-1.0 HR	6.53	42.00	.38
S1	25 YR-2.0 HR	5.04	72.00	.40
S1	25 YR-3.0 HR	4.27	102.00	.42
S1	25 YR-6.0 HR	4.54	252.00	.56
S1	25 YR-12 HR	3.04	480.00	.52
S1	25 YR-24 HR	1.35	936.00	.27
S1	50 YR-0.5 HR	8.37	26.00	.40
S1	50 YR-1.0 HR	8.67	42.00	.52
S1	50 YR-2.0 HR	6.86	72.00	.55
S2	25 YR-0.5 HR	4.07	24.50	.15
S2	25 YR-1.0 HR	3.90	40.00	.19
S2	25 YR-2.0 HR	2.88	68.00	.19
S2	25 YR-3.0 HR	2.38	96.00	.20
S2	25 YR-6.0 HR	2.47	246.00	.27
S2	25 YR-12 HR	1.61	468.00	.25
S2	25 YR-24 HR	.68	912.00	.13
S2	50 YR-0.5 HR	5.19	24.00	.20
S2	50 YR-1.0 HR	5.20	39.00	.25
S2	50 YR-2.0 HR	3.93	68.00	.27

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WATERSHED ROUTING OUTPUT

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Storage routing performed through pond at outlet of Watershed N2

STORAGE ROUTING DATA FOR WATERSHED: N2

Input Elevation-Storage-Discharge Curve

ELEVATION (feet)	STORAGE (ac-ft)	DISCHARGE (CFS)
1017.40	.00	.00
1018.40	.05	6.30
1019.40	.45	8.40
1020.40	1.55	9.20

Starting water elevation = 1017.40 feet

STORAGE ROUTING STATISTICS

STORM EVENT	PEAK DISCHARGE Inflow (cfs)	Time (min)	Outflow (cfs)	Time (min)	VOLUME Inflow (acft)	Outflow (acft)	PEAK ELEV (feet)	STORAGE VOLUME (acft)
25 YR-0.5 HR	4.06	24.0	3.54	31.0	.15	.15	1017.96	.03
25 YR-1.0 HR	3.90	40.0	3.56	46.0	.19	.19	1017.96	.03
25 YR-2.0 HR	2.88	68.0	2.73	76.0	.19	.19	1017.83	.02
25 YR-3.0 HR	2.38	96.0	2.30	102.0	.20	.20	1017.76	.02
25 YR-6.0 HR	2.47	246.0	2.41	252.0	.27	.27	1017.78	.02
25 YR-12 HR	1.61	468.0	1.57	480.0	.25	.25	1017.65	.01
25 YR-24 HR	.68	912.0	.69	936.0	.13	.13	1017.51	.01
50 YR-0.5 HR	5.19	24.0	4.52	31.0	.20	.20	1018.12	.04
50 YR-1.0 HR	5.19	38.0	4.73	46.0	.25	.25	1018.15	.04
50 YR-2.0 HR	3.93	68.0	3.71	72.0	.27	.27	1017.99	.03

Pipe Q_{max} HW@CB25 = 0.8'

****

No routing perfomed for Watershed POND hydrograph to Pipe Node PN1

HYDROGRAPH STATISTICS

STORM EVENT	PEAK DISCHARGE Inflow (cfs)	Time (min)	Outflow (cfs)	Time (min)	VOLUME Inflow (acft)	Outflow (acft)
25 YR-0.5 HR	3.54	31.0	3.54	31.0	.15	.15
25 YR-1.0 HR	3.56	46.0	3.56	46.0	.19	.19
25 YR-2.0 HR	2.73	76.0	2.73	76.0	.19	.19
25 YR-3.0 HR	2.30	102.0	2.30	102.0	.20	.20
25 YR-6.0 HR	2.41	252.0	2.41	252.0	.27	.27
25 YR-12 HR	1.57	480.0	1.57	480.0	.25	.25

25 YR-24 HR	.69	936.0	.69	936.0	.13	.13
50 YR-0.5 HR	4.52	31.0	4.52	31.0	.20	.20
50 YR-1.0 HR	4.73	46.0	4.73	46.0	.25	.25
50 YR-2.0 HR	3.71	72.0	3.71	72.0	.27	.27

Outflow hydrograph decision: STORE1

****
Storage routing performed through pond at outlet of Watershed N1

STORAGE ROUTING DATA FOR WATERSHED: N1

Input Elevation-Storage-Discharge Curve

ELEVATION (feet)	STORAGE (ac-ft)	DISCHARGE (CFS)
1012.40	.00	.00
1013.40	.11	6.30
1014.40	.92	8.90

Starting water elevation = 1012.40 feet

STORAGE ROUTING STATISTICS

STORM EVENT	PEAK DISCHARGE Inflow (cfs)	Time (min)	Outflow (cfs)	Time (min)	VOLUME Inflow (acft)	Outflow	PEAK ELEV (feet)	STORAGE VOLUME (acft)
25 YR-0.5 HR	6.84	26.0	5.01	38.0	.33	.33	1013.20	.09
25 YR-1.0 HR	6.81	42.0	5.43	56.0	.40	.40	1013.26	.09
25 YR-2.0 HR	5.26	72.0	4.53	88.0	.42	.42	1013.12	.08
25 YR-3.0 HR	4.46	102.0	4.01	114.0	.44	.44	1013.04	.07
25 YR-6.0 HR	4.74	252.0	4.41	264.0	.58	.58	1013.10	.08
25 YR-12 HR	3.17	480.0	3.02	492.0	.54	.54	1012.88	.05
25 YR-24 HR	1.41	936.0	1.36	936.0	.28	.28	1012.62	.02
50 YR-0.5 HR	8.74	26.0	6.31	38.0	.42	.42	1013.40	.11
50 YR-1.0 HR	9.05	42.0	6.39	58.0	.54	.54	1013.43	.14
50 YR-2.0 HR	7.16	72.0	6.18	84.0	.57	.57	$\boxed{1013.38}$	.11

HW@CB24 = 1.0'

****
No routing perfomed for Watershed POND   hydrograph to Pipe Node PN1

HYDROGRAPH STATISTICS

STORM EVENT	PEAK DISCHARGE Inflow (cfs)	Time (min)	Outflow (cfs)	Time (min)	VOLUME Inflow (acft)	Outflow
25 YR-0.5 HR	5.01	38.0	5.01	38.0	.33	.33
25 YR-1.0 HR	5.43	56.0	5.43	56.0	.40	.40
25 YR-2.0 HR	4.53	88.0	4.53	88.0	.42	.42
25 YR-3.0 HR	4.01	114.0	4.01	114.0	.44	.44
25 YR-6.0 HR	4.41	264.0	4.41	264.0	.58	.58
25 YR-12 HR	3.02	492.0	3.02	492.0	.54	.54

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25 YR-24 HR	1.36	936.0	1.36	936.0	.28	.28
50 YR-0.5 HR	6.31	38.0	6.31	38.0	.42	.42
50 YR-1.0 HR	6.39	58.0	6.39	58.0	.54	.54
50 YR-2.0 HR	6.18	84.0	6.18	84.0	.57	.57

Outflow hydrograph decision: SUM

****

No routing perfomed for Pipe Node PN1 hydrograph to Watershed END

HYDROGRAPH STATISTICS

STORM EVENT	PEAK DISCHARGE Inflow (cfs)	Time (min)	Outflow (cfs)	Time (min)	VOLUME Inflow (acft)	Outflow (acft)
25 YR-0.5 HR	8.29	34.0	8.29	34.0	.48	.48
25 YR-1.0 HR	8.71	50.0	8.71	50.0	.59	.59
25 YR-2.0 HR	7.06	80.0	7.06	80.0	.61	.61
25 YR-3.0 HR	6.14	108.0	6.14	108.0	.64	.64
25 YR-6.0 HR	6.67	258.0	6.67	258.0	.85	.85
25 YR-12 HR	4.54	480.0	4.54	480.0	.79	.79
25 YR-24 HR	2.05	936.0	2.05	936.0	.41	.41
50 YR-0.5 HR	10.60	34.0	10.60	34.0	.61	.61
50 YR-1.0 HR	11.04	46.0	11.04	46.0	.79	.79
50 YR-2.0 HR	9.64	80.0	9.64	80.0	.84	.84

Outflow hydrograph decision: STOP

PIPE Qmax

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FINAL OUTFLOW HYDROGRAPH STATISTICS

STORM DURATION	PEAK DISCHARGE (cfs)	TIME OF PEAK (minutes)	HYDROGRAPH VOLUME (acft)	ACCUMULATED HYD. VOLUME (acft)
25 YR-0.5 HR	8.29	34.00	.48	.48
25 YR-1.0 HR	8.71	50.00	.59	.59
25 YR-2.0 HR	7.06	80.00	.61	.61
25 YR-3.0 HR	6.14	108.00	.64	.64
25 YR-6.0 HR	6.67	258.00	.85	.85
25 YR-12 HR	4.54	480.00	.79	.79
25 YR-24 HR	2.05	936.00	.41	.41
50 YR-0.5 HR	10.60	34.00	.61	.62
50 YR-1.0 HR	11.04	46.00	.79	.79
50 YR-2.0 HR	9.64	80.00	.84	.84

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BARR ENGINEERING CO.

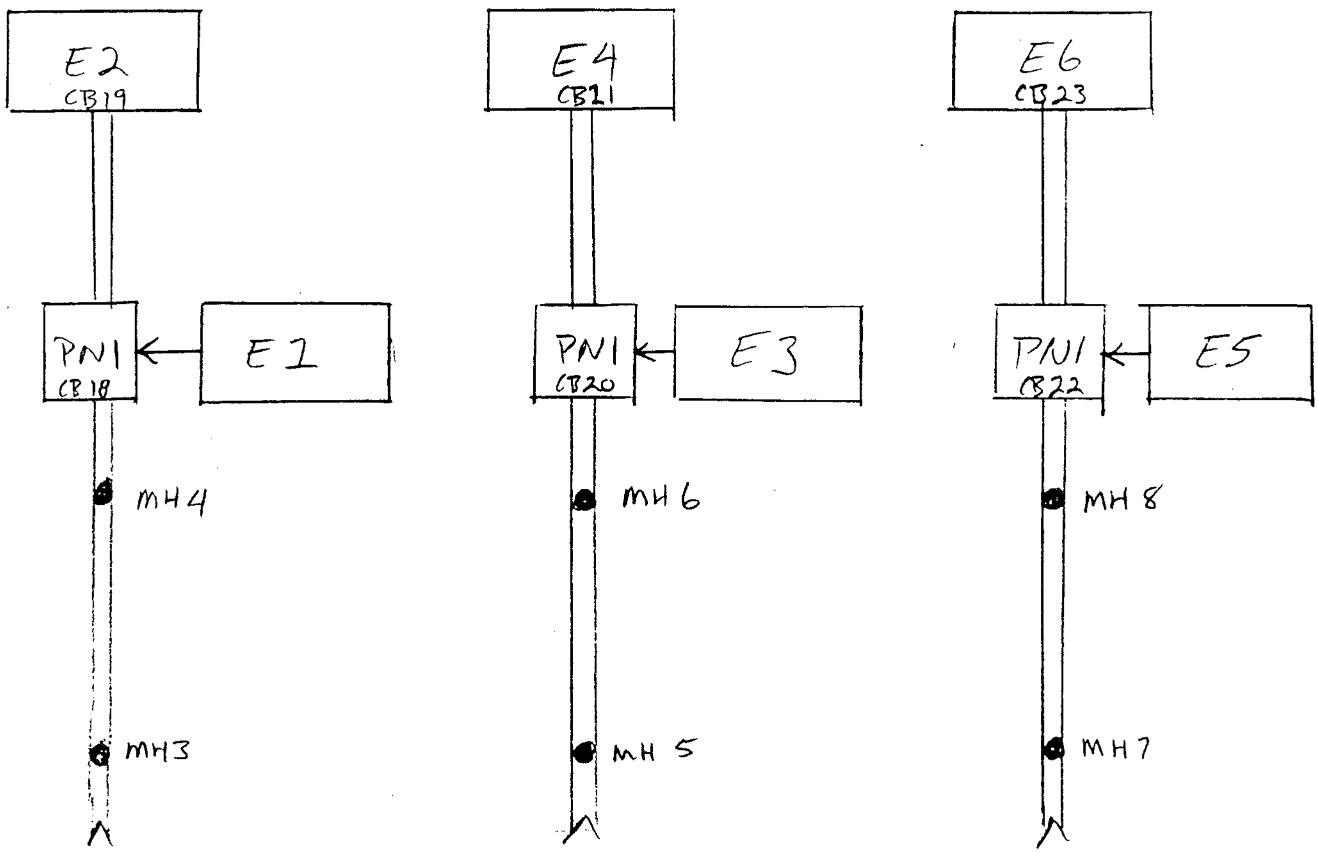
NSP Sherco Pond #3

CHECKED BY ______
DATE ______

NAME KAL
DATE 2-11-95
SHEET ______ IN SET
PAGE 18/96 IN FILE

E AREA

The three pipe systems on the East slope are essentially the same. ∴ Only one routing model was completed.



BARR ENGINEERING CO.

NSP Sherco Pond #3

CHECKED BY ______ DATE ______

NAME KAL
DATE 2-13-95
SHEET ______ IN SET
PAGE 19/96 IN FILE

E AREA

SUMMARY

ALL Q's DETERMINED FROM "BARR WATERSHED MODEL" - SEE OUTPUT
DESIGN STORM: 50 YR

* THE PIPE SYSTEMS INCLUDING AREAS E1+E2 AND E5+E6 ARE ESSENTIALLY THE SAME AS E3+E4 AND THEREFORE COMPUTATIONS FOR THESE SYSTEMS ARE NOT INCLUDED.

SUBWATERSHED	STRUCTURE	DITCH Qmax	DITCH CAPACITY (1)		HW @ CB (See Barr Model Output)	
E4	CB21	4.5 cfs	24 cfs@1%	OK	1.1'	OK
E3	CB20	5.1 cfs	16 cfs@0.5%	OK	1.1'	OK

(1) ASSUMED DEPTH OF FLOW = 1.5', See FLOWMASTER® OUTPUT

PIPE BTWN	PIPE Qmax	PIPE SIZE & TYPE	INLET CONTROL HW		PIPE SLOPE	Qfull (2) PIPE CAPACITY		V @ Qmax	d @ Qmax
CB21 ⇒ CB20	6.5 cfs	12" PE	3.4'	OK	2%	6.6 cfs	OK	9.5 f/s	0.8'
CB20 ⇒ MH6	13.0	18" RC	3.3'	OK	7%	30 cfs	OK	16.4 f/s	0.7'
MH6 ⇒ MH5	13.0	18"	3.3'	OK	~25%		OK	26 f/s	0.5'
MH5 → OUT	13.0	21" RC	2.4'	OK	0.33%	9.9 cfs	OK	5.4 f/s	full

(2) See FLOWMASTER® OUTPUT

```
***********************************************************************************
          *** BARR WATERSHED MODEL PROGRAM RESULTS SUMMARY ***
                         Version  6/07/91
***********************************************************************************

          *****************************************************
          *   Program Developed By:                           *
          *                                                   *
          *                          Barr Engineering Co.     *
          *                          7803 Glenroy Road        *
          *                          Minneapolis, MN  55439   *
          *                                                   *
          *                          Phone:  (612) 830-0555   *
          *                          Fax  :  (612) 835-0186   *
          *                                                   *
          *****************************************************

Run Date:    2/11/95
Time:        9:08:43


EPOND#3.DAT  = Input data file
NULL         = Output file
EPOND#3.SUM  = Summary file
NULL         = Input external hydrograph file
NULL         = Output external hydrograph file

NSP SHERCO POND #3 VERT. EXPANSION* E AREA *25YR & 50YR STORMS**FINAL COVER SURF

Number of storms modeled       = 10
Number of external hydrographs =  0
Number of Pipe Nodes           =  1
Pipe Nodes Included:
PN1

***********************************************************************************
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BARR HYDROGRAPH INPUT DATA

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UNIT HYETOGRAPHS

Storm frequency and duration = 25 YR-0.5 HR
Standard Short Duration Unit Hyetograph
Time Increment = .50 minutes, Rainfall = 1.90 inches

.11	.18	.23	.26	.29	.32	.37	.41	.46	.52
.62	.68	.78	.93	1.10	1.27	1.49	1.78	2.19	2.62
2.92	3.07	3.06	2.92	2.69	2.42	2.19	1.99	1.81	1.64
1.51	1.41	1.30	1.19	1.10	1.01	.93	.86	.80	.75
.69	.63	.59	.55	.52	.50	.46	.43	.41	.39
.37	.35	.34	.32	.31	.30	.27	.23	.17	.00

Storm frequency and duration = 25 YR-1.0 HR
Standard Short Duration Unit Hyetograph
Time Increment = 1.00 minutes, Rainfall = 2.40 inches

.11	.18	.23	.26	.29	.32	.37	.41	.46	.52
.62	.68	.78	.93	1.10	1.27	1.49	1.78	2.19	2.62
2.92	3.07	3.06	2.92	2.69	2.42	2.19	1.99	1.81	1.64
1.51	1.41	1.30	1.19	1.10	1.01	.93	.86	.80	.75
.69	.63	.59	.55	.52	.50	.46	.43	.41	.39
.37	.35	.34	.32	.31	.30	.27	.23	.17	.00

Storm frequency and duration = 25 YR-2.0 HR
Standard Short Duration Unit Hyetograph
Time Increment = 2.00 minutes, Rainfall = 2.80 inches

.11	.18	.23	.26	.29	.32	.37	.41	.46	.52
.62	.68	.78	.93	1.10	1.27	1.49	1.78	2.19	2.62
2.92	3.07	3.06	2.92	2.69	2.42	2.19	1.99	1.81	1.64
1.51	1.41	1.30	1.19	1.10	1.01	.93	.86	.80	.75
.69	.63	.59	.55	.52	.50	.46	.43	.41	.39
.37	.35	.34	.32	.31	.30	.27	.23	.17	.00

Storm frequency and duration = 25 YR-3.0 HR
Standard Short Duration Unit Hyetograph
Time Increment = 3.00 minutes, Rainfall = 3.00 inches

.11	.18	.23	.26	.29	.32	.37	.41	.46	.52
.62	.68	.78	.93	1.10	1.27	1.49	1.78	2.19	2.62
2.92	3.07	3.06	2.92	2.69	2.42	2.19	1.99	1.81	1.64
1.51	1.41	1.30	1.19	1.10	1.01	.93	.86	.80	.75
.69	.63	.59	.55	.52	.50	.46	.43	.41	.39
.37	.35	.34	.32	.31	.30	.27	.23	.17	.00

Storm frequency and duration = 25 YR-6.0 HR
User Input Unit Hyetograph
Time Increment = 6.00 minutes, Rainfall = 3.50 inches

.24	.24	.30	.42	.42	.48	.54	.66	.72	.66
.66	.60	.48	.48	.42	.36	.36	.30	.18	.24
.36	.42	.48	.60	.72	.72	1.08	1.08	1.26	1.62
1.80	2.34	2.58	2.58	2.64	2.94	3.54	3.00	2.58	2.16
1.92	1.92	1.68	1.62	1.38	1.32	1.26	1.14	.96	.84
.66	.48	.36	.30	.30	.24	.12	.12	.06	.06

Storm frequency and duration = 25 YR-12 HR
User Input Unit Hyetograph
Time Increment = 12.00 minutes, Rainfall = 4.10 inches

.24	.24	.30	.42	.42	.48	.54	.66	.72	.66
.66	.60	.48	.48	.42	.36	.36	.30	.18	.24
.36	.42	.48	.60	.72	.72	1.08	1.08	1.26	1.62
1.80	2.34	2.58	2.58	2.64	2.94	3.54	3.00	2.58	2.16
1.92	1.92	1.68	1.62	1.38	1.32	1.26	1.14	.96	.84
.66	.48	.36	.30	.30	.24	.12	.12	.06	.06

Storm frequency and duration = 25 YR-24 HR
User Input Unit Hyetograph
Time Increment = 24.00 minutes, Rainfall = 4.60 inches

.24	.24	.30	.42	.42	.48	.54	.66	.72	.66
.66	.60	.48	.48	.42	.36	.36	.30	.18	.24
.36	.42	.48	.60	.72	.72	1.08	1.08	1.26	1.62
1.80	2.34	2.58	2.58	2.64	2.94	3.54	3.00	2.58	2.16
1.92	1.92	1.68	1.62	1.38	1.32	1.26	1.14	.96	.84
.66	.48	.36	.30	.30	.24	.12	.12	.06	.06

Storm frequency and duration = 50 YR-0.5 HR
Standard Short Duration Unit Hyetograph
Time Increment = .50 minutes, Rainfall = 2.15 inches

.11	.18	.23	.26	.29	.32	.37	.41	.46	.52
.62	.68	.78	.93	1.10	1.27	1.49	1.78	2.19	2.62
2.92	3.07	3.06	2.92	2.69	2.42	2.19	1.99	1.81	1.64
1.51	1.41	1.30	1.19	1.10	1.01	.93	.86	.80	.75
.69	.63	.59	.55	.52	.50	.46	.43	.41	.39
.37	.35	.34	.32	.31	.30	.27	.23	.17	.00

Storm frequency and duration = 50 YR-1.0 HR
Standard Short Duration Unit Hyetograph
Time Increment = 1.00 minutes, Rainfall = 2.75 inches

.11	.18	.23	.26	.29	.32	.37	.41	.46	.52
.62	.68	.78	.93	1.10	1.27	1.49	1.78	2.19	2.62
2.92	3.07	3.06	2.92	2.69	2.42	2.19	1.99	1.81	1.64
1.51	1.41	1.30	1.19	1.10	1.01	.93	.86	.80	.75
.69	.63	.59	.55	.52	.50	.46	.43	.41	.39
.37	.35	.34	.32	.31	.30	.27	.23	.17	.00

Storm frequency and duration = 50 YR-2.0 HR
Standard Short Duration Unit Hyetograph
Time Increment = 2.00 minutes, Rainfall = 3.25 inches

.11	.18	.23	.26	.29	.32	.37	.41	.46	.52
.62	.68	.78	.93	1.10	1.27	1.49	1.78	2.19	2.62
2.92	3.07	3.06	2.92	2.69	2.42	2.19	1.99	1.81	1.64
1.51	1.41	1.30	1.19	1.10	1.01	.93	.86	.80	.75
.69	.63	.59	.55	.52	.50	.46	.43	.41	.39
.37	.35	.34	.32	.31	.30	.27	.23	.17	.00

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HYETOGRAPH LOSSES (inches)

STORM DURATION	INTERCEPTION imperv.	perv.	DEPRESSION imperv.	perv.	INFILTRATION(in/hr) initial	infinity	..at	time=(min)
25 YR-0.5 HR	.05	.15	.10	.00	2.50	.30	1.70	15.00
25 YR-1.0 HR	.05	.15	.10	.00	2.50	.30	1.70	15.00
25 YR-2.0 HR	.05	.15	.10	.00	2.50	.30	1.70	15.00
25 YR-3.0 HR	.05	.15	.10	.00	2.50	.30	1.70	15.00
25 YR-6.0 HR	.05	.15	.10	.00	2.50	.30	1.70	15.00
25 YR-12 HR	.05	.15	.10	.00	2.50	.30	1.70	15.00
25 YR-24 HR	.05	.15	.10	.00	2.50	.30	1.70	15.00
50 YR-0.5 HR	.05	.15	.10	.00	2.50	.30	1.70	15.00
50 YR-1.0 HR	.05	.15	.10	.00	2.50	.30	1.70	15.00
50 YR-2.0 HR	.05	.15	.10	.00	2.50	.30	1.70	15.00

WATERSHED FEATURES SUMMARY TABLE

WATERSHED	AREA total	Water	Impervious (acres)	.001	.003	.005	AVERAGE VELOCITY (fps)	LONGEST FLOW LENGTH (feet)	TOC (min)
E1	6.1	.0	.0	6.1	.0	.0	.5	600.	20.00
E2	3.6	.0	.0	3.6	.0	.0	.5	500.	16.67
E3	5.8	.0	.0	5.8	.0	.0	.5	600.	20.00
E4	4.7	.0	.0	4.7	.0	.0	.5	500.	16.67
E5	6.1	.0	.0	6.1	.0	.0	.5	600.	20.00
E6	3.6	.0	.0	3.6	.0	.0	.5	500.	16.67

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BARR HYDROGRAPH OUTPUT STATISTICS

WATERSHED	STORM DURATION	PEAK DISCHARGE (cfs)	TIME OF PEAK (minutes)	HYDROGRAPH VOLUME (acft)
E1	25 YR-0.5 HR	7.92	26.50	.38
E1	25 YR-1.0 HR	7.88	42.00	.46
E1	25 YR-2.0 HR	6.08	72.00	.48
E1	25 YR-3.0 HR	5.16	102.00	.51
E1	25 YR-6.0 HR	5.48	252.00	.67
E1	25 YR-12 HR	3.67	480.00	.62
E1	25 YR-24 HR	1.63	936.00	.32
E1	50 YR-0.5 HR	10.11	26.00	.49
E1	50 YR-1.0 HR	10.47	42.00	.62
E1	50 YR-2.0 HR	8.28	72.00	.66
E2	25 YR-0.5 HR	5.29	25.50	.23
E2	25 YR-1.0 HR	5.19	41.00	.28

E2	25 YR-2.0 HR	3.92	70.00	.29	
E2	25 YR-3.0 HR	3.29	99.00	.30	
E2	25 YR-6.0 HR	3.46	246.00	.40	
E2	25 YR-12 HR	2.28	468.00	.37	
E2	25 YR-24 HR	.99	936.00	.19	
E2	50 YR-0.5 HR	6.76	25.00	.29	
E2	50 YR-1.0 HR	6.90	40.00	.37	
E2	50 YR-2.0 HR	5.35	70.00	.40	
E3	25 YR-0.5 HR	7.65	26.50	.37	
E3	25 YR-1.0 HR	7.61	42.00	.45	
E3	25 YR-2.0 HR	5.87	72.00	.46	
E3	25 YR-3.0 HR	4.98	102.00	.49	
E3	25 YR-6.0 HR	5.29	252.00	.65	
E3	25 YR-12 HR	3.54	480.00	.60	
E3	25 YR-24 HR	1.57	936.00	.31	
E3	50 YR-0.5 HR	9.76	26.00	.47	
E3	50 YR-1.0 HR	10.11	42.00	.60	DITCH Q_{MAX} = 10.1 ÷ 2 = 5.1 cfs
E3	50 YR-2.0 HR	7.99	72.00	.64	
E4	25 YR-0.5 HR	6.90	25.50	.30	
E4	25 YR-1.0 HR	6.76	41.00	.36	
E4	25 YR-2.0 HR	5.11	70.00	.38	
E4	25 YR-3.0 HR	4.29	99.00	.39	
E4	25 YR-6.0 HR	4.51	246.00	.52	
E4	25 YR-12 HR	2.97	468.00	.49	
E4	25 YR-24 HR	1.29	936.00	.25	
E4	50 YR-0.5 HR	8.81	25.00	.38	
E4	50 YR-1.0 HR	8.99	40.00	.49	DITCH Q_{MAX} = 9.0 ÷ 2 = 4.5 cfs
E4	50 YR-2.0 HR	6.97	70.00	.52	
E5	25 YR-0.5 HR	8.00	26.50	.38	
E5	25 YR-1.0 HR	7.96	42.00	.47	
E5	25 YR-2.0 HR	6.14	72.00	.49	
E5	25 YR-3.0 HR	5.21	102.00	.51	
E5	25 YR-6.0 HR	5.54	252.00	.68	
E5	25 YR-12 HR	3.70	480.00	.63	
E5	25 YR-24 HR	1.65	936.00	.33	
E5	50 YR-0.5 HR	10.21	26.00	.49	
E5	50 YR-1.0 HR	10.58	42.00	.63	
E5	50 YR-2.0 HR	8.36	72.00	.67	
E6	25 YR-0.5 HR	5.29	25.50	.23	
E6	25 YR-1.0 HR	5.19	41.00	.28	
E6	25 YR-2.0 HR	3.92	70.00	.29	
E6	25 YR-3.0 HR	3.29	99.00	.30	
E6	25 YR-6.0 HR	3.46	246.00	.40	
E6	25 YR-12 HR	2.28	468.00	.37	
E6	25 YR-24 HR	.99	936.00	.19	
E6	50 YR-0.5 HR	6.76	25.00	.29	
E6	50 YR-1.0 HR	6.90	40.00	.37	
E6	50 YR-2.0 HR	5.35	70.00	.40	

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WATERSHED ROUTING OUTPUT

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Storage routing performed through pond at outlet of Watershed E4

STORAGE ROUTING DATA FOR WATERSHED: E4

Input Elevation-Storage-Discharge Curve

ELEVATION (feet)	STORAGE (ac-ft)	DISCHARGE (CFS)
1018.00	.00	.00
1019.00	.05	6.30
1020.00	.45	8.40
1021.00	1.55	9.20

Starting water elevation = 1018.00 feet

STORAGE ROUTING STATISTICS

STORM EVENT	PEAK DISCHARGE Inflow (cfs)	Time (min)	Outflow (cfs)	Time (min)	VOLUME Inflow (acft)	Outflow (acft)	PEAK ELEV (feet)	STORAGE VOLUME (acft)
25 YR-0.5 HR	6.90	25.0	6.12	32.0	.30	.29	1018.97	.05
25 YR-1.0 HR	6.75	40.0	6.23	48.0	.36	.36	1018.99	.05
25 YR-2.0 HR	5.10	72.0	4.88	76.0	.38	.38	1018.77	.04
25 YR-3.0 HR	4.26	96.0	4.14	108.0	.39	.39	1018.66	.03
25 YR-6.0 HR	4.51	246.0	4.41	252.0	.52	.52	1018.70	.04
25 YR-12 HR	2.97	468.0	2.95	480.0	.49	.49	1018.47	.02
25 YR-24 HR	1.29	936.0	1.30	936.0	.25	.25	1018.21	.01
50 YR-0.5 HR	8.81	25.0	6.44	36.0	.38	.38	1019.07	.08
50 YR-1.0 HR	8.99	40.0	6.53	56.0	.49	.49	1019.11	.09
50 YR-2.0 HR	6.97	68.0	6.33	80.0	.52	.52	1019.01	.06

PIPE Qmax

HW @ CB21 = 1.1'

****

No routing perfomed for Watershed POND hydrograph to Pipe Node PN1

HYDROGRAPH STATISTICS

STORM EVENT	PEAK DISCHARGE Inflow (cfs)	Time (min)	Outflow (cfs)	Time (min)	VOLUME Inflow (acft)	Outflow (acft)
25 YR-0.5 HR	6.12	32.0	6.12	32.0	.29	.29
25 YR-1.0 HR	6.23	48.0	6.23	48.0	.36	.36
25 YR-2.0 HR	4.88	76.0	4.88	76.0	.38	.38
25 YR-3.0 HR	4.14	108.0	4.14	108.0	.39	.39
25 YR-6.0 HR	4.41	252.0	4.41	252.0	.52	.52
25 YR-12 HR	2.95	480.0	2.95	480.0	.49	.49

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25 YR-24 HR	1.30	936.0	1.30	936.0	.25	.25
50 YR-0.5 HR	6.44	36.0	6.44	36.0	.38	.38
50 YR-1.0 HR	6.53	56.0	6.53	56.0	.49	.49
50 YR-2.0 HR	6.33	80.0	6.33	80.0	.52	.52

Outflow hydrograph decision: STORE1

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Storage routing performed through pond at outlet of Watershed E3

STORAGE ROUTING DATA FOR WATERSHED: E3

Input Elevation-Storage-Discharge Curve

ELEVATION (feet)	STORAGE (ac-ft)	DISCHARGE (CFS)
1012.40	.00	.00
1013.40	.11	6.30
1014.40	.92	8.90

Starting water elevation = 1012.40 feet

STORAGE ROUTING STATISTICS

	PEAK DISCHARGE				VOLUME		PEAK	STORAGE
STORM EVENT	Inflow (cfs)	Time (min)	Outflow (cfs)	Time (min)	Inflow (acft)	Outflow	ELEV (feet)	VOLUME (acft)
25 YR-0.5 HR	7.64	26.0	5.60	38.0	.37	.36	1013.29	.10
25 YR-1.0 HR	7.61	42.0	6.07	56.0	.45	.45	1013.36	.11
25 YR-2.0 HR	5.87	72.0	5.06	88.0	.46	.46	1013.20	.09
25 YR-3.0 HR	4.98	102.0	4.48	114.0	.49	.49	1013.11	.08
25 YR-6.0 HR	5.29	252.0	4.92	264.0	.65	.65	1013.18	.09
25 YR-12 HR	3.54	480.0	3.37	492.0	.60	.60	1012.94	.06
25 YR-24 HR	1.57	936.0	1.52	936.0	.31	.31	1012.64	.03
50 YR-0.5 HR	9.76	26.0	6.37	40.0	.47	.47	1013.43	.13
50 YR-1.0 HR	10.11	42.0	6.49	62.0	.60	.60	1013.47	.17
50 YR-2.0 HR	7.99	72.0	6.36	88.0	.64	.64	1013.42	.13

HW @ CB 20 = 1.1'

****

No routing perfomed for Watershed POND   hydrograph to Pipe Node PN1

HYDROGRAPH STATISTICS

	PEAK DISCHARGE				VOLUME	
STORM EVENT	Inflow (cfs)	Time (min)	Outflow (cfs)	Time (min)	Inflow (acft)	Outflow
25 YR-0.5 HR	5.60	38.0	5.60	38.0	.36	.36
25 YR-1.0 HR	6.07	56.0	6.07	56.0	.45	.45
25 YR-2.0 HR	5.06	88.0	5.06	88.0	.46	.46
25 YR-3.0 HR	4.48	114.0	4.48	114.0	.49	.49
25 YR-6.0 HR	4.92	264.0	4.92	264.0	.65	.65
25 YR-12 HR	3.37	492.0	3.37	492.0	.60	.60

25 YR-24 HR	1.52	936.0	1.52	936.0	.31	.31
50 YR-0.5 HR	6.37	40.0	6.37	40.0	.47	.47
50 YR-1.0 HR	6.49	62.0	6.49	62.0	.60	.60
50 YR-2.0 HR	6.36	88.0	6.36	88.0	.64	.64

Outflow hydrograph decision: SUM

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No routing perfomed for Pipe Node PN1 hydrograph to Watershed END

HYDROGRAPH STATISTICS

STORM EVENT	PEAK DISCHARGE Inflow (cfs)	Time (min)	Outflow (cfs)	Time (min)	VOLUME Inflow (acft)	Outflow
25 YR-0.5 HR	11.47	34.0	11.47	34.0	.66	.66
25 YR-1.0 HR	12.04	50.0	12.04	50.0	.81	.81
25 YR-2.0 HR	9.77	80.0	9.77	80.0	.84	.84
25 YR-3.0 HR	8.48	108.0	8.48	108.0	.88	.88
25 YR-6.0 HR	9.21	258.0	9.21	258.0	1.17	1.17
25 YR-12 HR	6.26	480.0	6.26	480.0	1.09	1.09
25 YR-24 HR	2.83	936.0	2.83	936.0	.57	.57
50 YR-0.5 HR	12.80	38.0	12.80	38.0	.85	.85
50 YR-1.0 HR	13.01	58.0	13.01	58.0	1.09	1.09
50 YR-2.0 HR	12.67	84.0	12.67	84.0	1.16	1.16

Outflow hydrograph decision: STOP

Pipe Qmax

****

FINAL OUTFLOW HYDROGRAPH STATISTICS

STORM DURATION	PEAK DISCHARGE (cfs)	TIME OF PEAK (minutes)	HYDROGRAPH VOLUME (acft)	ACCUMULATED HYD. VOLUME (acft)
25 YR-0.5 HR	11.47	34.00	.66	.66
25 YR-1.0 HR	12.04	50.00	.81	.81
25 YR-2.0 HR	9.77	80.00	.84	.84
25 YR-3.0 HR	8.48	108.00	.88	.88
25 YR-6.0 HR	9.21	258.00	1.17	1.17 x3
25 YR-12 HR	6.26	480.00	1.09	1.09
25 YR-24 HR	2.83	936.00	.57	.57
50 YR-0.5 HR	12.80	38.00	.85	.85
50 YR-1.0 HR	13.01	58.00	1.09	1.09
50 YR-2.0 HR	12.67	84.00	1.16	1.16

****

BARR ENGINEERING CO.

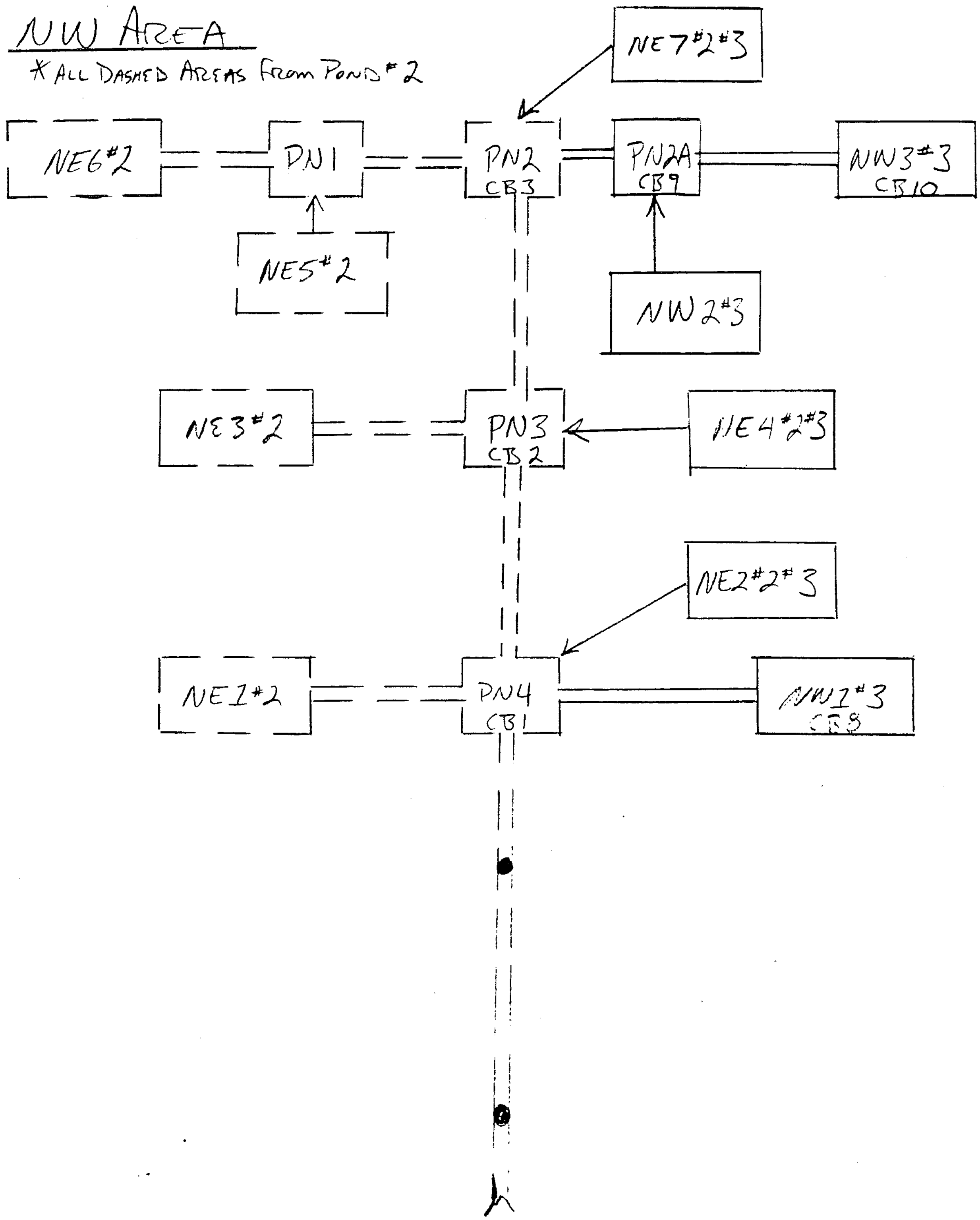
NSP Sherco Pond #3

CHECKED BY ____
DATE ____

NAME KAL
DATE 2-11-95
SHEET ____ IN SET
PAGE 28/96 IN FILE

NW AREA

* ALL DASHED AREAS FROM POND # 2



BARR ENGINEERING CO.

NSP Sherco Pond #3

CHECKED BY ____
DATE ____

NAME KAL
DATE 2-13-95
SHEET ____ IN SET
PAGE 29/96 IN FILE

NW AREA

SUMMARY

ALL Q'S DETERMINED FROM "BARR WATERSHED MODEL" - See Output
DESIGN STORM: 50 YR

SUBWATERSHED	STRUCTURE	DITCH Qmax	DITCH CAPACITY		HW@ CB	(See Barr Model Output)
NW3#3	CB10	5.1 cfs	24 cfs@1%	OK	1.1'	OK
NW2#3	CB9	4.1 cfs	16 cfs@½%	OK	1.0'	OK
NW1#3	CB8	4.1 cfs	16 cfs@½%	OK	0.7'	OK

*THE PIPES BTWN CB3 AND THE OUTLET WERE SIZED FOR THE POND #2 EXPANSION. FLOWS FROM POND #3 WERE ESTIMATED, AND THE PIPES SIZED TO ACCOMODATE FLOWS FROM POND #2 + #3
VERIFY ESTIMATED FLOWS

PIPE BTWN	SIZE + TYPE	POND #2 EST. Q	POND #3 Q	
CB3 ⇒ CB2	28" PE	25.4 cfs	27.3 cfs	Q_{full} = 26 cfs @ 0.5%, PIPE WILL Head up Slightly - OK
CB2 ⇒ CB1	30" PE	40.0 cfs	37.5 cfs	OK
CB1 ⇒ OUT	36" PE	48.4 cfs	46.2 cfs	OK

PIPE BTWN	PIPE Qmax	PIPE SIZE + TYPE	INLET CONTROL HW		PIPE SLOPE	Q_{full} ② PIPE CAPACITY		V @ Qmax	d @ Qmax
CB10 ⇒ CB9	6.4 cfs	12" PE	3.1'	OK	2%	6.6 cfs	OK	9.5 f/s	0.8'
CB9 ⇒ CB3	12.8 cfs	18" PE	3.2'	OK	11%	45 cfs	OK	22 f/s	0.6'
CB8 ⇒ CB1	4.2 cfs	12" PE	1.9'	OK	14%	17 cfs	OK	18 f/s	0.4'

② See FLOWMASTER® OUTPUT

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```
*************************************************************************************
           *** BARR WATERSHED MODEL PROGRAM RESULTS SUMMARY ***
                          Version  6/07/91
*************************************************************************************

           ******************************************************
           *   Program Developed By:                            *
           *                                                    *
           *                       Barr Engineering Co.         *
           *                       7803 Glenroy Road            *
           *                       Minneapolis, MN  55439       *
           *                                                    *
           *                       Phone:  (612) 830-0555       *
           *                       Fax  :  (612) 835-0186       *
           *                                                    *
           ******************************************************


Run Date:    2/11/95
Time:       13:25:51


NWPOND#3.DAT = Input data file
NULL         = Output file
NWPOND#3.SUM = Summary file
NULL         = Input external hydrograph file
NULL         = Output external hydrograph file

NSP SHERCO POND #3 VERT. EXPANSION* NW AREA *25YR & 50YR STORMS**FINAL COVER SUR

Number of storms modeled        = 10
Number of external hydrographs =  0
Number of Pipe Nodes            =  5
Pipe Nodes Included:
PN1
PN2
PN2A
PN3
PN4


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BARR HYDROGRAPH INPUT DATA

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UNIT HYETOGRAPHS

Storm frequency and duration = 25 YR-0.5 HR
Standard Short Duration Unit Hyetograph
Time Increment = .50 minutes, Rainfall = 1.90 inches

.11	.18	.23	.26	.29	.32	.37	.41	.46	.52
.62	.68	.78	.93	1.10	1.27	1.49	1.78	2.19	2.62
2.92	3.07	3.06	2.92	2.69	2.42	2.19	1.99	1.81	1.64
1.51	1.41	1.30	1.19	1.10	1.01	.93	.86	.80	.75
.69	.63	.59	.55	.52	.50	.46	.43	.41	.39
.37	.35	.34	.32	.31	.30	.27	.23	.17	.00

Storm frequency and duration = 25 YR-1.0 HR
Standard Short Duration Unit Hyetograph
Time Increment = 1.00 minutes, Rainfall = 2.40 inches

.11	.18	.23	.26	.29	.32	.37	.41	.46	.52
.62	.68	.78	.93	1.10	1.27	1.49	1.78	2.19	2.62
2.92	3.07	3.06	2.92	2.69	2.42	2.19	1.99	1.81	1.64
1.51	1.41	1.30	1.19	1.10	1.01	.93	.86	.80	.75
.69	.63	.59	.55	.52	.50	.46	.43	.41	.39
.37	.35	.34	.32	.31	.30	.27	.23	.17	.00

Storm frequency and duration = 25 YR-2.0 HR
Standard Short Duration Unit Hyetograph
Time Increment = 2.00 minutes, Rainfall = 2.80 inches

.11	.18	.23	.26	.29	.32	.37	.41	.46	.52
.62	.68	.78	.93	1.10	1.27	1.49	1.78	2.19	2.62
2.92	3.07	3.06	2.92	2.69	2.42	2.19	1.99	1.81	1.64
1.51	1.41	1.30	1.19	1.10	1.01	.93	.86	.80	.75
.69	.63	.59	.55	.52	.50	.46	.43	.41	.39
.37	.35	.34	.32	.31	.30	.27	.23	.17	.00

Storm frequency and duration = 25 YR-3.0 HR
Standard Short Duration Unit Hyetograph
Time Increment = 3.00 minutes, Rainfall = 3.00 inches

.11	.18	.23	.26	.29	.32	.37	.41	.46	.52
.62	.68	.78	.93	1.10	1.27	1.49	1.78	2.19	2.62
2.92	3.07	3.06	2.92	2.69	2.42	2.19	1.99	1.81	1.64
1.51	1.41	1.30	1.19	1.10	1.01	.93	.86	.80	.75
.69	.63	.59	.55	.52	.50	.46	.43	.41	.39
.37	.35	.34	.32	.31	.30	.27	.23	.17	.00

Storm frequency and duration = 25 YR-6.0 HR
User Input Unit Hyetograph
Time Increment = 6.00 minutes, Rainfall = 3.50 inches

.24	.24	.30	.42	.42	.48	.54	.66	.72	.66
.66	.60	.48	.48	.42	.36	.36	.30	.18	.24
.36	.42	.48	.60	.72	.72	1.08	1.08	1.26	1.62
1.80	2.34	2.58	2.58	2.64	2.94	3.54	3.00	2.58	2.16
1.92	1.92	1.68	1.62	1.38	1.32	1.26	1.14	.96	.84
.66	.48	.36	.30	.30	.24	.12	.12	.06	.06

Storm frequency and duration = 25 YR-12 HR
User Input Unit Hyetograph
Time Increment = 12.00 minutes, Rainfall = 4.10 inches

.24	.24	.30	.42	.42	.48	.54	.66	.72	.66
.66	.60	.48	.48	.42	.36	.36	.30	.18	.24
.36	.42	.48	.60	.72	.72	1.08	1.08	1.26	1.62
1.80	2.34	2.58	2.58	2.64	2.94	3.54	3.00	2.58	2.16
1.92	1.92	1.68	1.62	1.38	1.32	1.26	1.14	.96	.84
.66	.48	.36	.30	.30	.24	.12	.12	.06	.06

Storm frequency and duration = 25 YR-24 HR
User Input Unit Hyetograph
Time Increment = 24.00 minutes, Rainfall = 4.60 inches

.24	.24	.30	.42	.42	.48	.54	.66	.72	.66
.66	.60	.48	.48	.42	.36	.36	.30	.18	.24
.36	.42	.48	.60	.72	.72	1.08	1.08	1.26	1.62
1.80	2.34	2.58	2.58	2.64	2.94	3.54	3.00	2.58	2.16
1.92	1.92	1.68	1.62	1.38	1.32	1.26	1.14	.96	.84
.66	.48	.36	.30	.30	.24	.12	.12	.06	.06

Storm frequency and duration = 50 YR-0.5 HR
Standard Short Duration Unit Hyetograph
Time Increment = .50 minutes, Rainfall = 2.15 inches

.11	.18	.23	.26	.29	.32	.37	.41	.46	.52
.62	.68	.78	.93	1.10	1.27	1.49	1.78	2.19	2.62
2.92	3.07	3.06	2.92	2.69	2.42	2.19	1.99	1.81	1.64
1.51	1.41	1.30	1.19	1.10	1.01	.93	.86	.80	.75
.69	.63	.59	.55	.52	.50	.46	.43	.41	.39
.37	.35	.34	.32	.31	.30	.27	.23	.17	.00

Storm frequency and duration = 50 YR-1.0 HR
Standard Short Duration Unit Hyetograph
Time Increment = 1.00 minutes, Rainfall = 2.75 inches

.11	.18	.23	.26	.29	.32	.37	.41	.46	.52
.62	.68	.78	.93	1.10	1.27	1.49	1.78	2.19	2.62
2.92	3.07	3.06	2.92	2.69	2.42	2.19	1.99	1.81	1.64
1.51	1.41	1.30	1.19	1.10	1.01	.93	.86	.80	.75
.69	.63	.59	.55	.52	.50	.46	.43	.41	.39
.37	.35	.34	.32	.31	.30	.27	.23	.17	.00

Storm frequency and duration = 50 YR-2.0 HR
Standard Short Duration Unit Hyetograph
Time Increment = 2.00 minutes, Rainfall = 3.25 inches

.11	.18	.23	.26	.29	.32	.37	.41	.46	.52
.62	.68	.78	.93	1.10	1.27	1.49	1.78	2.19	2.62
2.92	3.07	3.06	2.92	2.69	2.42	2.19	1.99	1.81	1.64
1.51	1.41	1.30	1.19	1.10	1.01	.93	.86	.80	.75
.69	.63	.59	.55	.52	.50	.46	.43	.41	.39
.37	.35	.34	.32	.31	.30	.27	.23	.17	.00

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HYETOGRAPH LOSSES (inches)

STORM DURATION	INTERCEPTION imperv.	INTERCEPTION perv.	DEPRESSION imperv.	DEPRESSION perv.	INFILTRATION(in/hr) initial	INFILTRATION(in/hr) infinity	..at	time=(min)
25 YR-0.5 HR	.05	.15	.10	.00	2.50	.30	1.70	15.00
25 YR-1.0 HR	.05	.15	.10	.00	2.50	.30	1.70	15.00
25 YR-2.0 HR	.05	.15	.10	.00	2.50	.30	1.70	15.00
25 YR-3.0 HR	.05	.15	.10	.00	2.50	.30	1.70	15.00
25 YR-6.0 HR	.05	.15	.10	.00	2.50	.30	1.70	15.00
25 YR-12 HR	.05	.15	.10	.00	2.50	.30	1.70	15.00
25 YR-24 HR	.05	.15	.10	.00	2.50	.30	1.70	15.00
50 YR-0.5 HR	.05	.15	.10	.00	2.50	.30	1.70	15.00
50 YR-1.0 HR	.05	.15	.10	.00	2.50	.30	1.70	15.00
50 YR-2.0 HR	.05	.15	.10	.00	2.50	.30	1.70	15.00

WATERSHED FEATURES SUMMARY TABLE

WATERSHED	AREA (acres) total	Water	Impervious	.001	.003	.005	AVERAGE VELOCITY (fps)	LONGEST FLOW LENGTH (feet)	TOC (min)
NE1#2	2.1	.0	.0	2.1	.0	.0	.5	500.	16.67
NE2#2#3	1.1	.0	.2	.9	.0	.0	.5	200.	6.67
NE3#2	4.7	.0	.0	4.7	.0	.0	.5	550.	18.33
NE4#2#3	2.2	.0	.2	1.9	.0	.0	.5	250.	8.33
NE5#2	3.7	.0	.0	3.7	.0	.0	.5	500.	16.67
NE6#2	5.3	.0	.0	5.3	.0	.0	.5	550.	18.33
NE7#2#3	1.6	.0	.2	1.4	.0	.0	.5	200.	6.67
NW1#3	3.5	.0	.0	3.5	.0	.0	.5	800.	26.67
NW2#3	5.1	.0	.0	5.1	.0	.0	.5	700.	23.33
NW3#3	4.7	.0	.0	4.7	.0	.0	.5	600.	20.00

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BARR HYDROGRAPH OUTPUT STATISTICS

WATERSHED	STORM DURATION	PEAK DISCHARGE (cfs)	TIME OF PEAK (minutes)	HYDROGRAPH VOLUME (acft)
NE1#2	25 YR-0.5 HR	3.09	25.50	.13
NE1#2	25 YR-1.0 HR	3.02	41.00	.16
NE1#2	25 YR-2.0 HR	2.29	70.00	.17
NE1#2	25 YR-3.0 HR	1.92	99.00	.18
NE1#2	25 YR-6.0 HR	2.02	246.00	.23
NE1#2	25 YR-12 HR	1.33	468.00	.22
NE1#2	25 YR-24 HR	.58	936.00	.11
NE1#2	50 YR-0.5 HR	3.94	25.00	.17
NE1#2	50 YR-1.0 HR	4.02	40.00	.22

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NE1#2	50 YR-2.0 HR	3.12	70.00	.23
NE2#2#3	25 YR-0.5 HR	2.82	20.50	.08
NE2#2#3	25 YR-1.0 HR	2.51	34.00	.10
NE2#2#3	25 YR-2.0 HR	1.72	60.00	.11
NE2#2#3	25 YR-3.0 HR	1.35	87.00	.11
NE2#2#3	25 YR-6.0 HR	1.27	234.00	.15
NE2#2#3	25 YR-12 HR	.79	456.00	.15
NE2#2#3	25 YR-24 HR	.37	912.00	.11
NE2#2#3	50 YR-0.5 HR	3.52	20.00	.10
NE2#2#3	50 YR-1.0 HR	3.25	34.00	.13
NE2#2#3	50 YR-2.0 HR	2.30	60.00	.14
NE3#2	25 YR-0.5 HR	6.53	26.00	.30
NE3#2	25 YR-1.0 HR	6.45	42.00	.36
NE3#2	25 YR-2.0 HR	4.93	72.00	.38
NE3#2	25 YR-3.0 HR	4.16	99.00	.40
NE3#2	25 YR-6.0 HR	4.40	246.00	.52
NE3#2	25 YR-12 HR	2.91	468.00	.49
NE3#2	25 YR-24 HR	1.28	936.00	.25
NE3#2	50 YR-0.5 HR	8.34	25.50	.38
NE3#2	50 YR-1.0 HR	8.58	41.00	.49
NE3#2	50 YR-2.0 HR	6.73	70.00	.52
NE4#2#3	25 YR-0.5 HR	4.97	21.50	.15
NE4#2#3	25 YR-1.0 HR	4.54	36.00	.19
NE4#2#3	25 YR-2.0 HR	3.18	64.00	.20
NE4#2#3	25 YR-3.0 HR	2.54	90.00	.21
NE4#2#3	25 YR-6.0 HR	2.47	240.00	.28
NE4#2#3	25 YR-12 HR	1.54	468.00	.27
NE4#2#3	25 YR-24 HR	.70	912.00	.18
NE4#2#3	50 YR-0.5 HR	6.25	21.50	.19
NE4#2#3	50 YR-1.0 HR	5.93	35.00	.25
NE4#2#3	50 YR-2.0 HR	4.28	62.00	.27
NE5#2	25 YR-0.5 HR	5.47	25.50	.23
NE5#2	25 YR-1.0 HR	5.36	41.00	.29
NE5#2	25 YR-2.0 HR	4.05	70.00	.30
NE5#2	25 YR-3.0 HR	3.40	99.00	.31
NE5#2	25 YR-6.0 HR	3.58	246.00	.41
NE5#2	25 YR-12 HR	2.35	468.00	.39
NE5#2	25 YR-24 HR	1.02	936.00	.20
NE5#2	50 YR-0.5 HR	6.98	25.00	.30
NE5#2	50 YR-1.0 HR	7.12	40.00	.39
NE5#2	50 YR-2.0 HR	5.52	70.00	.41
NE6#2	25 YR-0.5 HR	7.32	26.00	.33
NE6#2	25 YR-1.0 HR	7.23	42.00	.41
NE6#2	25 YR-2.0 HR	5.53	72.00	.42
NE6#2	25 YR-3.0 HR	4.66	99.00	.44
NE6#2	25 YR-6.0 HR	4.92	246.00	.59
NE6#2	25 YR-12 HR	3.26	468.00	.55
NE6#2	25 YR-24 HR	1.44	936.00	.28
NE6#2	50 YR-0.5 HR	9.34	25.50	.43
NE6#2	50 YR-1.0 HR	9.61	41.00	.55
NE6#2	50 YR-2.0 HR	7.54	70.00	.58
NE7#2#3	25 YR-0.5 HR	4.15	20.50	.12
NE7#2#3	25 YR-1.0 HR	3.69	34.00	.15
NE7#2#3	25 YR-2.0 HR	2.54	62.00	.16

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NE7#2#3	25 YR-3.0 HR	1.99	87.00	.17	
NE7#2#3	25 YR-6.0 HR	1.89	234.00	.21	
NE7#2#3	25 YR-12 HR	1.16	456.00	.21	
NE7#2#3	25 YR-24 HR	.54	912.00	.16	
NE7#2#3	50 YR-0.5 HR	5.20	20.50	.15	
NE7#2#3	50 YR-1.0 HR	4.81	34.00	.19	
NE7#2#3	50 YR-2.0 HR	3.40	60.00	.21	
NW1#3	25 YR-0.5 HR	3.79	28.00	.22	
NW1#3	25 YR-1.0 HR	3.86	44.00	.27	
NW1#3	25 YR-2.0 HR	3.07	76.00	.28	
NW1#3	25 YR-3.0 HR	2.66	105.00	.29	
NW1#3	25 YR-6.0 HR	2.89	258.00	.39	
NW1#3	25 YR-12 HR	1.99	480.00	.36	
NW1#3	25 YR-24 HR	.90	936.00	.19	
NW1#3	50 YR-0.5 HR	4.84	27.50	.28	
NW1#3	50 YR-1.0 HR	5.13	44.00	.36	DITCH Qmax = 5.1 cfs (most of flow from one direction)
NW1#3	50 YR-2.0 HR	4.18	74.00	.38	
NW2#3	25 YR-0.5 HR	6.03	27.00	.32	
NW2#3	25 YR-1.0 HR	6.07	43.00	.39	
NW2#3	25 YR-2.0 HR	4.77	74.00	.40	
NW2#3	25 YR-3.0 HR	4.09	102.00	.42	
NW2#3	25 YR-6.0 HR	4.40	252.00	.56	
NW2#3	25 YR-12 HR	2.99	480.00	.52	
NW2#3	25 YR-24 HR	1.34	936.00	.27	
NW2#3	50 YR-0.5 HR	7.69	27.00	.41	
NW2#3	50 YR-1.0 HR	8.07	43.00	.52	DITCH Qmax = 8.1 ÷ 2 = 4.1 cfs
NW2#3	50 YR-2.0 HR	6.49	72.00	.56	
NW3#3	25 YR-0.5 HR	6.11	26.50	.29	
NW3#3	25 YR-1.0 HR	6.08	42.00	.36	
NW3#3	25 YR-2.0 HR	4.70	72.00	.37	
NW3#3	25 YR-3.0 HR	3.98	102.00	.39	
NW3#3	25 YR-6.0 HR	4.23	252.00	.52	
NW3#3	25 YR-12 HR	2.83	480.00	.48	
NW3#3	25 YR-24 HR	1.26	936.00	.25	
NW3#3	50 YR-0.5 HR	7.80	26.00	.38	
NW3#3	50 YR-1.0 HR	8.08	42.00	.48	DITCH QMAX = 8.1 ÷ 2 = 4.1 cfs
NW3#3	50 YR-2.0 HR	6.39	72.00	.51	

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WATERSHED ROUTING OUTPUT

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Storage routing performed through pond at outlet of Watershed NE6#2

STORAGE ROUTING DATA FOR WATERSHED: NE6#2

Input Elevation-Storage-Discharge Curve

ELEVATION (feet)	STORAGE (ac-ft)	DISCHARGE (CFS)
1018.80	.00	.00
1019.80	.05	6.30
1020.80	.45	8.40
1021.80	1.55	9.20

Starting water elevation = 1018.80 feet

STORAGE ROUTING STATISTICS

STORM EVENT	PEAK DISCHARGE Inflow (cfs)	Time (min)	Outflow (cfs)	Time (min)	VOLUME Inflow (acft)	Outflow (acft)	PEAK ELEV (feet)	STORAGE VOLUME (acft)
25 YR-0.5 HR	7.32	26.0	6.31	33.0	.33	.33	1019.81	.05
25 YR-1.0 HR	7.23	42.0	6.33	50.0	.41	.41	1019.81	.06
25 YR-2.0 HR	5.53	72.0	5.28	80.0	.42	.42	1019.64	.04
25 YR-3.0 HR	4.65	102.0	4.53	108.0	.44	.44	1019.52	.04
25 YR-6.0 HR	4.92	246.0	4.83	258.0	.59	.59	1019.57	.04
25 YR-12 HR	3.26	468.0	3.26	480.0	.55	.55	1019.32	.03
25 YR-24 HR	1.44	936.0	1.45	936.0	.28	.28	1019.03	.01
50 YR-0.5 HR	9.34	26.0	6.50	38.0	.43	.43	1019.90	.09
50 YR-1.0 HR	9.59	40.0	6.64	58.0	.55	.55	1019.96	.11
50 YR-2.0 HR	7.51	72.0	6.40	84.0	.58	.58	1019.85	.07

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No routing perfomed for Watershed POND hydrograph to Pipe Node PN1

HYDROGRAPH STATISTICS

STORM EVENT	PEAK DISCHARGE Inflow (cfs)	Time (min)	Outflow (cfs)	Time (min)	VOLUME Inflow (acft)	Outflow (acft)
25 YR-0.5 HR	6.31	33.0	6.31	33.0	.33	.33
25 YR-1.0 HR	6.33	50.0	6.33	50.0	.41	.41
25 YR-2.0 HR	5.28	80.0	5.28	80.0	.42	.42
25 YR-3.0 HR	4.53	108.0	4.53	108.0	.44	.44
25 YR-6.0 HR	4.83	258.0	4.83	258.0	.59	.59
25 YR-12 HR	3.26	480.0	3.26	480.0	.55	.55

25 YR-24 HR	1.45	936.0	1.45	936.0	.28	.28
50 YR-0.5 HR	6.50	38.0	6.50	38.0	.43	.43
50 YR-1.0 HR	6.64	58.0	6.64	58.0	.55	.55
50 YR-2.0 HR	6.40	84.0	6.40	84.0	.58	.58

Outflow hydrograph decision: STORE1

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Storage routing performed through pond at outlet of Watershed NE5#2

STORAGE ROUTING DATA FOR WATERSHED: NE5#2

Input Elevation-Storage-Discharge Curve

ELEVATION (feet)	STORAGE (ac-ft)	DISCHARGE (CFS)
1012.80	.00	.00
1013.80	.11	6.30
1014.80	.92	8.90
1015.80	2.19	10.80

Starting water elevation = 1012.80 feet

STORAGE ROUTING STATISTICS

STORM EVENT	PEAK DISCHARGE Inflow (cfs)	Time (min)	Outflow (cfs)	Time (min)	VOLUME Inflow (acft)	Outflow (acft)	PEAK ELEV (feet)	STORAGE VOLUME (acft)
25 YR-0.5 HR	5.46	25.0	3.91	37.0	.23	.23	1013.42	.07
25 YR-1.0 HR	5.35	40.0	4.19	54.0	.29	.28	1013.46	.07
25 YR-2.0 HR	4.04	72.0	3.45	84.0	.30	.30	1013.35	.06
25 YR-3.0 HR	3.38	96.0	3.01	114.0	.31	.31	1013.28	.05
25 YR-6.0 HR	3.58	246.0	3.28	264.0	.41	.41	1013.32	.06
25 YR-12 HR	2.35	468.0	2.21	480.0	.39	.39	1013.15	.04
25 YR-24 HR	1.02	936.0	1.00	936.0	.20	.20	1012.96	.02
50 YR-0.5 HR	6.98	25.0	5.00	36.0	.30	.30	1013.59	.09
50 YR-1.0 HR	7.12	40.0	5.57	54.0	.39	.38	1013.68	.10
50 YR-2.0 HR	5.52	68.0	4.69	84.0	.41	.41	1013.54	.08

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No routing perfomed for Watershed POND hydrograph to Pipe Node PN1

HYDROGRAPH STATISTICS

STORM EVENT	PEAK DISCHARGE Inflow (cfs)	Time (min)	Outflow (cfs)	Time (min)	VOLUME Inflow (acft)	Outflow (acft)
25 YR-0.5 HR	3.91	37.0	3.91	37.0	.23	.23
25 YR-1.0 HR	4.19	54.0	4.19	54.0	.28	.28
25 YR-2.0 HR	3.45	84.0	3.45	84.0	.30	.30
25 YR-3.0 HR	3.01	114.0	3.01	114.0	.31	.31
25 YR-6.0 HR	3.28	264.0	3.28	264.0	.41	.41

25 YR-12 HR	2.21	480.0	2.21	480.0	.39	.39
25 YR-24 HR	1.00	936.0	1.00	936.0	.20	.20
50 YR-0.5 HR	5.00	36.0	5.00	36.0	.30	.30
50 YR-1.0 HR	5.57	54.0	5.57	54.0	.38	.38
50 YR-2.0 HR	4.69	84.0	4.69	84.0	.41	.41

Outflow hydrograph decision: SUM

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No routing perfomed for Pipe Node PN1 hydrograph to Pipe Node PN2

HYDROGRAPH STATISTICS

STORM EVENT	PEAK DISCHARGE Inflow (cfs)	Time (min)	Outflow (cfs)	Time (min)	VOLUME Inflow (acft)	Outflow
25 YR-0.5 HR	10.22	36.0	10.22	36.0	.56	.56
25 YR-1.0 HR	10.51	54.0	10.51	54.0	.69	.69
25 YR-2.0 HR	8.68	80.0	8.68	80.0	.72	.72
25 YR-3.0 HR	7.50	108.0	7.50	108.0	.75	.75
25 YR-6.0 HR	8.09	258.0	8.09	258.0	1.00	1.00
25 YR-12 HR	5.47	480.0	5.47	480.0	.93	.93
25 YR-24 HR	2.45	936.0	2.45	936.0	.49	.49
50 YR-0.5 HR	11.50	37.0	11.50	37.0	.72	.72
50 YR-1.0 HR	12.19	54.0	12.19	54.0	.93	.93
50 YR-2.0 HR	11.09	84.0	11.09	84.0	.99	.99

Outflow hydrograph decision: STORE1

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No routing perfomed for Watershed NE7#2#3 hydrograph to Pipe Node PN2

HYDROGRAPH STATISTICS

STORM EVENT	PEAK DISCHARGE Inflow (cfs)	Time (min)	Outflow (cfs)	Time (min)	VOLUME Inflow (acft)	Outflow
25 YR-0.5 HR	4.15	20.0	4.15	20.0	.12	.12
25 YR-1.0 HR	3.69	34.0	3.69	34.0	.15	.15
25 YR-2.0 HR	2.53	60.0	2.53	60.0	.16	.16
25 YR-3.0 HR	1.98	90.0	1.98	90.0	.17	.17
25 YR-6.0 HR	1.89	234.0	1.89	234.0	.21	.21
25 YR-12 HR	1.16	456.0	1.16	456.0	.21	.21
25 YR-24 HR	.54	912.0	.54	912.0	.16	.16
50 YR-0.5 HR	5.19	20.0	5.19	20.0	.15	.15
50 YR-1.0 HR	4.81	34.0	4.81	34.0	.19	.19
50 YR-2.0 HR	3.40	60.0	3.40	60.0	.21	.21

Outflow hydrograph decision: ADD1

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Storage routing performed through pond at outlet of Watershed NW3#3

STORAGE ROUTING DATA FOR WATERSHED: NW3#3

Input Elevation-Storage-Discharge Curve

ELEVATION (feet)	STORAGE (ac-ft)	DISCHARGE (CFS)
1018.00	.00	.00
1019.00	.05	6.30
1020.00	.45	8.40

Starting water elevation = 1018.00 feet

STORAGE ROUTING STATISTICS

	PEAK DISCHARGE				VOLUME		PEAK	STORAGE
STORM EVENT	Inflow (cfs)	Time (min)	Outflow (cfs)	Time (min)	Inflow (acft)	Outflow (acft)	ELEV (feet)	VOLUME (acft)
25 YR-0.5 HR	6.11	26.0	5.48	33.0	.29	.29	1018.87	.04
25 YR-1.0 HR	6.08	42.0	5.66	48.0	.36	.36	1018.90	.04
25 YR-2.0 HR	4.70	72.0	4.51	80.0	.37	.37	1018.72	.04
25 YR-3.0 HR	3.98	102.0	3.89	108.0	.39	.39	1018.62	.03
25 YR-6.0 HR	4.23	252.0	4.17	258.0	.52	.52	1018.66	.03
25 YR-12 HR	2.83	480.0	2.82	480.0	.48	.48	1018.45	.02
25 YR-24 HR	1.26	936.0	1.26	936.0	.25	.25	1018.20	.01
50 YR-0.5 HR	7.80	26.0	6.35	35.0	.38	.37	1019.03	.06
50 YR-1.0 HR	8.08	42.0	6.43	54.0	.48	.48	1019.06	.07
50 YR-2.0 HR	6.39	72.0	6.13	76.0	.51	.51	1018.97	.05

Qmax Pipe

HW @ CB10 = 1.1'

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No routing perfomed for Watershed POND hydrograph to Pipe Node PN2A

HYDROGRAPH STATISTICS

	PEAK DISCHARGE				VOLUME	
STORM EVENT	Inflow (cfs)	Time (min)	Outflow (cfs)	Time (min)	Inflow (acft)	Outflow (acft)
25 YR-0.5 HR	5.48	33.0	5.48	33.0	.29	.29
25 YR-1.0 HR	5.66	48.0	5.66	48.0	.36	.36
25 YR-2.0 HR	4.51	80.0	4.51	80.0	.37	.37
25 YR-3.0 HR	3.89	108.0	3.89	108.0	.39	.39
25 YR-6.0 HR	4.17	258.0	4.17	258.0	.52	.52
25 YR-12 HR	2.82	480.0	2.82	480.0	.48	.48
25 YR-24 HR	1.26	936.0	1.26	936.0	.25	.25
50 YR-0.5 HR	6.35	35.0	6.35	35.0	.37	.37
50 YR-1.0 HR	6.43	54.0	6.43	54.0	.48	.48
50 YR-2.0 HR	6.13	76.0	6.13	76.0	.51	.51

Outflow hydrograph decision: STORE2

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Storage routing performed through pond at outlet of Watershed NW2#3

STORAGE ROUTING DATA FOR WATERSHED: NW2#3

Input Elevation-Storage-Discharge Curve

ELEVATION (feet)	STORAGE (ac-ft)	DISCHARGE (CFS)
1012.80	.00	.00
1013.80	.11	6.30
1014.80	.92	8.90

Starting water elevation = 1012.80 feet

STORAGE ROUTING STATISTICS

STORM EVENT	PEAK DISCHARGE Inflow (cfs)	Time (min)	Outflow (cfs)	Time (min)	VOLUME Inflow (acft)	Outflow (acft)	PEAK ELEV (feet)	STORAGE VOLUME (acft)
25 YR-0.5 HR	6.03	27.0	4.50	39.0	.32	.32	1013.51	.08
25 YR-1.0 HR	6.06	44.0	4.93	56.0	.39	.39	1013.58	.09
25 YR-2.0 HR	4.75	72.0	4.17	88.0	.40	.40	1013.46	.07
25 YR-3.0 HR	4.09	102.0	3.71	120.0	.42	.42	1013.39	.06
25 YR-6.0 HR	4.40	252.0	4.12	270.0	.56	.56	1013.45	.07
25 YR-12 HR	2.99	480.0	2.86	492.0	.52	.52	1013.25	.05
25 YR-24 HR	1.34	936.0	1.29	936.0	.27	.27	1013.00	.02
50 YR-0.5 HR	7.69	27.0	5.76	39.0	.41	.41	1013.71	.10
50 YR-1.0 HR	8.07	42.0	6.32	58.0	.52	.52	1013.81	.12
50 YR-2.0 HR	6.49	72.0	5.67	88.0	.56	.56	1013.70	.10

HW @ CB 9 = 1.0'

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No routing perfomed for Watershed POND hydrograph to Pipe Node PN2A

HYDROGRAPH STATISTICS

STORM EVENT	PEAK DISCHARGE Inflow (cfs)	Time (min)	Outflow (cfs)	Time (min)	VOLUME Inflow (acft)	Outflow (acft)
25 YR-0.5 HR	4.50	39.0	4.50	39.0	.32	.32
25 YR-1.0 HR	4.93	56.0	4.93	56.0	.39	.39
25 YR-2.0 HR	4.17	88.0	4.17	88.0	.40	.40
25 YR-3.0 HR	3.71	120.0	3.71	120.0	.42	.42
25 YR-6.0 HR	4.12	270.0	4.12	270.0	.56	.56
25 YR-12 HR	2.86	492.0	2.86	492.0	.52	.52
25 YR-24 HR	1.29	936.0	1.29	936.0	.27	.27
50 YR-0.5 HR	5.76	39.0	5.76	39.0	.41	.41
50 YR-1.0 HR	6.32	58.0	6.32	58.0	.52	.52
50 YR-2.0 HR	5.67	88.0	5.67	88.0	.56	.56

Outflow hydrograph decision: ADD2

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No routing perfomed for Pipe Node PN2A hydrograph to Pipe Node PN2

HYDROGRAPH STATISTICS

STORM EVENT	PEAK DISCHARGE Inflow (cfs)	Time (min)	Outflow (cfs)	Time (min)	VOLUME Inflow (acft)	Outflow (acft)
25 YR-0.5 HR	9.79	35.0	9.79	35.0	.61	.61
25 YR-1.0 HR	10.40	52.0	10.40	52.0	.74	.74
25 YR-2.0 HR	8.54	84.0	8.54	84.0	.77	.77
25 YR-3.0 HR	7.49	114.0	7.49	114.0	.81	.81
25 YR-6.0 HR	8.20	264.0	8.20	264.0	1.08	1.08
25 YR-12 HR	5.58	492.0	5.58	492.0	1.01	1.01
25 YR-24 HR	2.55	936.0	2.55	936.0	.52	.52
50 YR-0.5 HR	12.10	39.0	12.10	39.0	.78	.78
50 YR-1.0 HR	12.75	56.0	12.75	56.0	1.00	1.00
50 YR-2.0 HR	11.61	80.0	11.61	80.0	1.07	1.07

Outflow hydrograph decision: SUM

Qmax Pipe

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No routing perfomed for Pipe Node PN2 hydrograph to Pipe Node PN3

HYDROGRAPH STATISTICS

STORM EVENT	PEAK DISCHARGE Inflow (cfs)	Time (min)	Outflow (cfs)	Time (min)	VOLUME Inflow (acft)	Outflow (acft)
25 YR-0.5 HR	21.77	32.0	21.77	32.0	1.29	1.29
25 YR-1.0 HR	22.73	50.0	22.73	50.0	1.58	1.58
25 YR-2.0 HR	18.77	80.0	18.77	80.0	1.65	1.65
25 YR-3.0 HR	16.33	108.0	16.33	108.0	1.73	1.73
25 YR-6.0 HR	17.67	258.0	17.67	258.0	2.29	2.29
25 YR-12 HR	12.07	480.0	12.07	480.0	2.15	2.15
25 YR-24 HR	5.48	936.0	5.48	936.0	1.16	1.16
50 YR-0.5 HR	25.53	32.0	25.53	32.0	1.65	1.65
50 YR-1.0 HR	27.26	50.0	27.26	50.0	2.12	2.12
50 YR-2.0 HR	24.71	80.0	24.71	80.0	2.27	2.27

Outflow hydrograph decision: STORE1

PIPE Qmax

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Storage routing performed through pond at outlet of Watershed NE3#2

STORAGE ROUTING DATA FOR WATERSHED: NE3#2

Input Elevation-Storage-Discharge Curve

ELEVATION (feet)	STORAGE (ac-ft)	DISCHARGE (CFS)
1012.80	.00	.00
1013.80	.11	6.30

42/96

1014.80	.92	8.40

Starting water elevation = 1012.80 feet

STORAGE ROUTING STATISTICS

STORM EVENT	PEAK DISCHARGE Inflow (cfs)	Time (min)	Outflow (cfs)	Time (min)	VOLUME Inflow (acft)	Outflow (acft)	PEAK ELEV (feet)	STORAGE VOLUME (acft)
25 YR-0.5 HR	6.53	26.0	4.73	37.0	.30	.29	1013.55	.08
25 YR-1.0 HR	6.45	42.0	5.10	54.0	.36	.36	1013.61	.09
25 YR-2.0 HR	4.93	72.0	4.23	84.0	.38	.37	1013.47	.07
25 YR-3.0 HR	4.15	102.0	3.72	114.0	.40	.39	1013.39	.06
25 YR-6.0 HR	4.40	246.0	4.07	264.0	.52	.52	1013.45	.07
25 YR-12 HR	2.91	468.0	2.77	492.0	.49	.49	1013.24	.05
25 YR-24 HR	1.28	936.0	1.25	936.0	.25	.25	1013.00	.02
50 YR-0.5 HR	8.33	26.0	6.05	37.0	.38	.38	1013.76	.11
50 YR-1.0 HR	8.56	40.0	6.33	56.0	.49	.49	1013.82	.12
50 YR-2.0 HR	6.70	72.0	5.76	84.0	.52	.52	1013.71	.10

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No routing perfomed for Watershed POND hydrograph to Pipe Node PN3

HYDROGRAPH STATISTICS

STORM EVENT	PEAK DISCHARGE Inflow (cfs)	Time (min)	Outflow (cfs)	Time (min)	VOLUME Inflow (acft)	Outflow (acft)
25 YR-0.5 HR	4.73	37.0	4.73	37.0	.29	.29
25 YR-1.0 HR	5.10	54.0	5.10	54.0	.36	.36
25 YR-2.0 HR	4.23	84.0	4.23	84.0	.37	.37
25 YR-3.0 HR	3.72	114.0	3.72	114.0	.39	.39
25 YR-6.0 HR	4.07	264.0	4.07	264.0	.52	.52
25 YR-12 HR	2.77	492.0	2.77	492.0	.49	.49
25 YR-24 HR	1.25	936.0	1.25	936.0	.25	.25
50 YR-0.5 HR	6.05	37.0	6.05	37.0	.38	.38
50 YR-1.0 HR	6.33	56.0	6.33	56.0	.49	.49
50 YR-2.0 HR	5.76	84.0	5.76	84.0	.52	.52

Outflow hydrograph decision: ADD1

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No routing perfomed for Watershed NE4#2#3 hydrograph to Pipe Node PN3

HYDROGRAPH STATISTICS

STORM EVENT	PEAK DISCHARGE Inflow (cfs)	Time (min)	Outflow (cfs)	Time (min)	VOLUME Inflow (acft)	Outflow (acft)
25 YR-0.5 HR	4.97	22.0	4.97	22.0	.15	.15
25 YR-1.0 HR	4.54	36.0	4.54	36.0	.19	.19
25 YR-2.0 HR	3.18	64.0	3.18	64.0	.20	.20
25 YR-3.0 HR	2.54	90.0	2.54	90.0	.21	.21
25 YR-6.0 HR	2.47	240.0	2.47	240.0	.28	.28

25 YR-12 HR	1.54	468.0	1.54	468.0	.27	.27
25 YR-24 HR	.70	912.0	.70	912.0	.18	.18
50 YR-0.5 HR	6.24	21.0	6.24	21.0	.19	.19
50 YR-1.0 HR	5.92	36.0	5.92	36.0	.25	.25
50 YR-2.0 HR	4.25	64.0	4.25	64.0	.27	.27

Outflow hydrograph decision: ADD1

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No routing perfomed for Pipe Node PN3 hydrograph to Pipe Node PN4

HYDROGRAPH STATISTICS

	PEAK DISCHARGE				VOLUME	
STORM EVENT	Inflow (cfs)	Time (min)	Outflow (cfs)	Time (min)	Inflow (acft)	Outflow
25 YR-0.5 HR	29.41	31.0	29.41	31.0	1.73	1.73
25 YR-1.0 HR	30.62	48.0	30.62	48.0	2.13	2.13
25 YR-2.0 HR	25.15	80.0	25.15	80.0	2.22	2.22
25 YR-3.0 HR	21.91	108.0	21.91	108.0	2.34	2.34
25 YR-6.0 HR	23.68	258.0	23.68	258.0	3.09	3.09
25 YR-12 HR	16.19	480.0	16.19	480.0	2.91	2.91
25 YR-24 HR	7.37	936.0	7.37	936.0	1.60	1.60
50 YR-0.5 HR	35.30	30.0	35.30	30.0	2.22	2.22
50 YR-1.0 HR	37.54	46.0	37.54	46.0	2.85	2.85
50 YR-2.0 HR	33.29	80.0	33.29	80.0	3.05	3.05

Outflow hydrograph decision: STORE1

Pipe Qmax

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Storage routing performed through pond at outlet of Watershed NE1#2

STORAGE ROUTING DATA FOR WATERSHED: NE1#2

Input Elevation-Storage-Discharge Curve

ELEVATION (feet)	STORAGE (ac-ft)	DISCHARGE (CFS)
1012.80	.00	.00
1013.80	.11	6.30
1014.80	.92	8.40

Starting water elevation = 1012.80 feet

STORAGE ROUTING STATISTICS

	PEAK DISCHARGE				VOLUME		PEAK	STORAGE
STORM EVENT	Inflow (cfs)	Time (min)	Outflow (cfs)	Time (min)	Inflow (acft)	Outflow	ELEV (feet)	VOLUME (acft)
25 YR-0.5 HR	3.08	25.0	2.21	37.0	.13	.13	1013.15	.04
25 YR-1.0 HR	3.02	40.0	2.36	54.0	.16	.16	1013.17	.04

25 YR-2.0 HR	2.28	72.0	1.94	84.0	.17	.17	1013.11	.03
25 YR-3.0 HR	1.90	96.0	1.70	114.0	.18	.17	1013.07	.03
25 YR-6.0 HR	2.02	246.0	1.85	264.0	.23	.23	1013.09	.03
25 YR-12 HR	1.33	468.0	1.25	480.0	.22	.22	1013.00	.02
25 YR-24 HR	.58	936.0	.57	936.0	.11	.11	1012.89	.01
50 YR-0.5 HR	3.94	25.0	2.82	36.0	.17	.17	1013.25	.05
50 YR-1.0 HR	4.02	40.0	3.14	54.0	.22	.21	1013.30	.05
50 YR-2.0 HR	3.11	68.0	2.65	84.0	.23	.23	1013.22	.05

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No routing perfomed for Watershed POND hydrograph to Pipe Node PN4

HYDROGRAPH STATISTICS

STORM EVENT	PEAK DISCHARGE Inflow (cfs)	Time (min)	Outflow (cfs)	Time (min)	VOLUME Inflow (acft)	Outflow (acft)
25 YR-0.5 HR	2.21	37.0	2.21	37.0	.13	.13
25 YR-1.0 HR	2.36	54.0	2.36	54.0	.16	.16
25 YR-2.0 HR	1.94	84.0	1.94	84.0	.17	.17
25 YR-3.0 HR	1.70	114.0	1.70	114.0	.17	.17
25 YR-6.0 HR	1.85	264.0	1.85	264.0	.23	.23
25 YR-12 HR	1.25	480.0	1.25	480.0	.22	.22
25 YR-24 HR	.57	936.0	.57	936.0	.11	.11
50 YR-0.5 HR	2.82	36.0	2.82	36.0	.17	.17
50 YR-1.0 HR	3.14	54.0	3.14	54.0	.21	.21
50 YR-2.0 HR	2.65	84.0	2.65	84.0	.23	.23

Outflow hydrograph decision: ADD1

****

No routing perfomed for Watershed NE2#2#3 hydrograph to Pipe Node PN4

HYDROGRAPH STATISTICS

STORM EVENT	PEAK DISCHARGE Inflow (cfs)	Time (min)	Outflow (cfs)	Time (min)	VOLUME Inflow (acft)	Outflow (acft)
25 YR-0.5 HR	2.82	20.0	2.82	20.0	.08	.08
25 YR-1.0 HR	2.51	34.0	2.51	34.0	.10	.10
25 YR-2.0 HR	1.72	60.0	1.72	60.0	.11	.11
25 YR-3.0 HR	1.34	90.0	1.34	90.0	.11	.11
25 YR-6.0 HR	1.27	234.0	1.27	234.0	.15	.15
25 YR-12 HR	.79	456.0	.79	456.0	.15	.15
25 YR-24 HR	.37	912.0	.37	912.0	.11	.11
50 YR-0.5 HR	3.52	20.0	3.52	20.0	.10	.10
50 YR-1.0 HR	3.25	34.0	3.25	34.0	.13	.13
50 YR-2.0 HR	2.30	60.0	2.30	60.0	.14	.14

Outflow hydrograph decision: ADD1

****

Storage routing performed through pond at outlet of Watershed NW1#3

STORAGE ROUTING DATA FOR WATERSHED: NW1#3

Input Elevation-Storage-Discharge Curve

ELEVATION (feet)	STORAGE (ac-ft)	DISCHARGE (CFS)
1012.80	.00	.00
1013.80	.11	6.30
1014.80	.92	8.40

Starting water elevation = 1012.80 feet

STORAGE ROUTING STATISTICS

STORM EVENT	PEAK DISCHARGE Inflow (cfs)	Time (min)	Outflow (cfs)	Time (min)	VOLUME Inflow (acft)	Outflow (acft)	PEAK ELEV (feet)	STORAGE VOLUME (acft)
25 YR-0.5 HR	3.79	28.0	2.87	40.0	.22	.22	1013.26	.05
25 YR-1.0 HR	3.86	44.0	3.18	58.0	.27	.27	1013.30	.06
25 YR-2.0 HR	3.07	76.0	2.71	88.0	.28	.28	1013.23	.05
25 YR-3.0 HR	2.65	108.0	2.44	120.0	.29	.29	1013.19	.04
25 YR-6.0 HR	2.89	258.0	2.73	270.0	.39	.39	1013.23	.05
25 YR-12 HR	1.99	480.0	1.90	492.0	.36	.36	1013.10	.03
25 YR-24 HR	.90	936.0	.86	960.0	.19	.19	1012.94	.01
50 YR-0.5 HR	4.84	28.0	3.68	40.0	.28	.28	1013.38	.06
50 YR-1.0 HR	5.13	44.0	4.24	58.0	.36	.36	1013.47	.07
50 YR-2.0 HR	4.17	76.0	3.70	88.0	.38	.38	1013.39	.06

Qmax Pipe

HW@ CB8 = 0.7'

****

No routing perfomed for Watershed POND hydrograph to Pipe Node PN4

HYDROGRAPH STATISTICS

STORM EVENT	PEAK DISCHARGE Inflow (cfs)	Time (min)	Outflow (cfs)	Time (min)	VOLUME Inflow (acft)	Outflow (acft)
25 YR-0.5 HR	2.87	40.0	2.87	40.0	.22	.22
25 YR-1.0 HR	3.18	58.0	3.18	58.0	.27	.27
25 YR-2.0 HR	2.71	88.0	2.71	88.0	.28	.28
25 YR-3.0 HR	2.44	120.0	2.44	120.0	.29	.29
25 YR-6.0 HR	2.73	270.0	2.73	270.0	.39	.39
25 YR-12 HR	1.90	492.0	1.90	492.0	.36	.36
25 YR-24 HR	.86	960.0	.86	960.0	.19	.19
50 YR-0.5 HR	3.68	40.0	3.68	40.0	.28	.28
50 YR-1.0 HR	4.24	58.0	4.24	58.0	.36	.36
50 YR-2.0 HR	3.70	88.0	3.70	88.0	.38	.38

Outflow hydrograph decision: ADD1

****

No routing perfomed for Pipe Node PN4 hydrograph to Watershed END

HYDROGRAPH STATISTICS

STORM EVENT	PEAK DISCHARGE Inflow (cfs)	Time (min)	Outflow (cfs)	Time (min)	VOLUME Inflow (acft)	Outflow (acft)
25 YR-0.5 HR	35.55	31.0	35.55	31.0	2.16	2.16
25 YR-1.0 HR	37.20	48.0	37.20	48.0	2.65	2.65
25 YR-2.0 HR	30.69	80.0	30.69	80.0	2.77	2.77
25 YR-3.0 HR	26.82	108.0	26.82	108.0	2.92	2.92
25 YR-6.0 HR	29.07	258.0	29.07	258.0	3.86	3.86
25 YR-12 HR	19.94	480.0	19.94	480.0	3.64	3.64
25 YR-24 HR	9.11	936.0	9.11	936.0	2.01	2.01
50 YR-0.5 HR	43.09	30.0	43.09	30.0	2.77	2.77
50 YR-1.0 HR	46.19	46.0	46.19	46.0	3.56	3.56
50 YR-2.0 HR	40.82	80.0	40.82	80.0	3.81	3.81

Outflow hydrograph decision: STOP

PIPE Qmax

****

FINAL OUTFLOW HYDROGRAPH STATISTICS

STORM DURATION	PEAK DISCHARGE (cfs)	TIME OF PEAK (minutes)	HYDROGRAPH VOLUME (acft)	ACCUMULATED HYD. VOLUME (acft)
25 YR-0.5 HR	35.55	31.00	2.16	2.17
25 YR-1.0 HR	37.20	48.00	2.65	2.66
25 YR-2.0 HR	30.69	80.00	2.77	2.78
25 YR-3.0 HR	26.82	108.00	2.92	2.93
25 YR-6.0 HR	29.07	258.00	3.86	3.86
25 YR-12 HR	19.94	480.00	3.64	3.64
25 YR-24 HR	9.11	936.00	2.01	2.01
50 YR-0.5 HR	43.09	30.00	2.77	2.78
50 YR-1.0 HR	46.19	46.00	3.56	3.57
50 YR-2.0 HR	40.82	80.00	3.81	3.81

****

BARR ENGINEERING CO.

NSP Sherco Pond #3

CHECKED BY ______

DATE ______

NAME KAL.

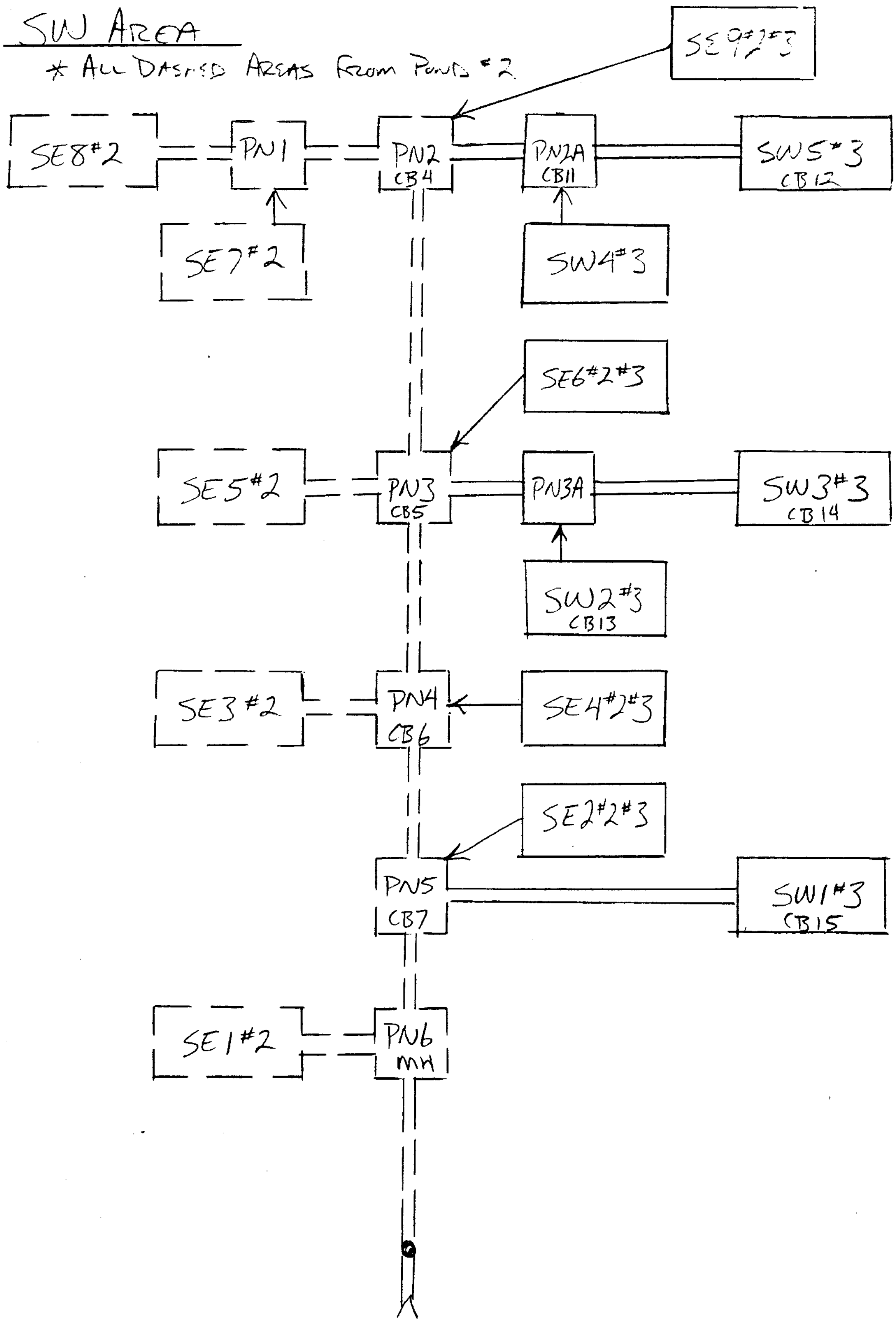
DATE 2-11-95

SHEET ______ IN SET

PAGE 47/96 IN FILE

SW AREA

* ALL DASHED AREAS FROM POND #2



BARR ENGINEERING CO.

NSP Sherco Pond #3

CHECKED BY ____
DATE ____

NAME KAL
DATE 2-13-95
SHEET ____ IN SET
PAGE 48/96 IN FILE

SW AREA

SUMMARY

ALL Q's DETERMINED FROM "BARR WATERSHED MODEL" - SEE OUTPUT
DESIGN STORM: 50 YR

SUBWATERSHED	STRUCTURE	DITCH Q_{MAX}	DITCH CAPACITY		HW @ CB (See Barr Model output)	
SW5 #3	CB 12	3.4 cfs	24 cfs @ 1%	OK	1.0'	OK
SW4 #3	CB 11	3.0 cfs	16 cfs @ ½%	OK	0.8'	OK
SW3 #3	CB 14	3.8 cfs	24 cfs @ 1%	OK	1.0'	OK
SW2 #3	CB 13	3.8 cfs	16 cfs @ ½%	OK	1.0'	OK
SW1 #3	CB 15	2.9 cfs	16 cfs @ ½%	OK	0.6'	OK

* THE PIPES BTWN CB4 AND THE OUTLET WERE SIZED FOR THE POND #2 EXPANS. FLOWS FROM POND #3 WERE ESTIMATED, AND THE PIPES SIZED TO ACCOMODATE FLOWS FROM POND #2 + #3. VERIFY ESTIMATED FLOWS

PIPE BTWN	SIZE + TYPE	POND #2 EST. Q	POND #3 Q	PIPE Slope	Q_{full}	S_{Req}	Add'l h = ΔSL
CB4 → CB5	28" PE	26 cfs	25.4 cfs	0.5%	26 cfs	-	OK
CB5 → CB6	30" PE	40.8 cfs	46.1 cfs	0.6%	41	0.75%	0.15% x 450 = 0.7' OK
CB6 → CB7	36" PE	51.6 cfs	53.7 cfs	0.35%	52	0.38%	0.03% x 400 = 0.1' OK
CB7 → MH	36" PE	53.6 cfs	58.5 cfs	0.38%	54	0.46%	0.08% x 80 = 0.1' OK
MH → OUT	36" PE	59.6 cfs	61.5 cfs	0.33%	63	-	OK

PIPE BTWN	PIPE Q_{MAX}	PIPE SIZE + TYPE	INLET CONTROL HW		PIPE SLOPE	Q_{FULL} ② PIPE CAPACITY		V @ Q_{max}	d @ Q_{max}
CB12 → CB11	6.2 cfs	12" PE	3.1'	OK	2%	6.6 cfs	OK	9.5 f/s	0.8'
CB11 → CB4	10.7 cfs	18" PE	2.5'	OK	11%	45 cfs	OK	21 f/s	0.5'
CB14 → CB13	6.4 cfs	12" PE	3.1'	OK	2%	6.6 cfs	OK	9.5 f/s	0.8'
CB13 → CB5	12.3 cfs	18" PE	3.0'	OK	11%	45 cfs	OK	22 f/s	0.5'
CB15 → CB7	3.5 cfs	12" PE	1.6'	OK	14%	17 cfs	OK	17 f/s	0.3'

② SEE FLOWMASTER® OUTPUT

```
*********************************************************************************
          *** BARR WATERSHED MODEL PROGRAM RESULTS SUMMARY ***
                          Version  6/07/91
*********************************************************************************

          ****************************************************
          *   Program Developed By:                          *
          *                                                  *
          *                          Barr Engineering Co.    *
          *                          7803 Glenroy Road       *
          *                          Minneapolis, MN  55439  *
          *                                                  *
          *                          Phone:  (612) 830-0555  *
          *                          Fax  :  (612) 835-0186  *
          *                                                  *
          ****************************************************


Run Date:   2/11/95
Time:      14:28:24


SWPOND#3.DAT = Input data file
NULL         = Output file
SWPOND#3.SUM = Summary file
NULL         = Input external hydrograph file
NULL         = Output external hydrograph file

NSP SHERCO POND #3 VERT. EXPANSION* SW AREA *25YR & 50YR STORMS**FINAL COVER SUR

Number of storms modeled        = 10
Number of external hydrographs =  0
Number of Pipe Nodes           =  8
Pipe Nodes Included:
PN1
PN2
PN2A
PN3
PN3A
PN4
PN5
PN6

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

BARR HYDROGRAPH INPUT DATA

****

UNIT HYETOGRAPHS

Storm frequency and duration = 25 YR-0.5 HR
Standard Short Duration Unit Hyetograph
Time Increment = .50 minutes, Rainfall = 1.90 inches

.11	.18	.23	.26	.29	.32	.37	.41	.46	.52
.62	.68	.78	.93	1.10	1.27	1.49	1.78	2.19	2.62
2.92	3.07	3.06	2.92	2.69	2.42	2.19	1.99	1.81	1.64
1.51	1.41	1.30	1.19	1.10	1.01	.93	.86	.80	.75
.69	.63	.59	.55	.52	.50	.46	.43	.41	.39
.37	.35	.34	.32	.31	.30	.27	.23	.17	.00

Storm frequency and duration = 25 YR-1.0 HR
Standard Short Duration Unit Hyetograph
Time Increment = 1.00 minutes, Rainfall = 2.40 inches

.11	.18	.23	.26	.29	.32	.37	.41	.46	.52
.62	.68	.78	.93	1.10	1.27	1.49	1.78	2.19	2.62
2.92	3.07	3.06	2.92	2.69	2.42	2.19	1.99	1.81	1.64
1.51	1.41	1.30	1.19	1.10	1.01	.93	.86	.80	.75
.69	.63	.59	.55	.52	.50	.46	.43	.41	.39
.37	.35	.34	.32	.31	.30	.27	.23	.17	.00

Storm frequency and duration = 25 YR-2.0 HR
Standard Short Duration Unit Hyetograph
Time Increment = 2.00 minutes, Rainfall = 2.80 inches

.11	.18	.23	.26	.29	.32	.37	.41	.46	.52
.62	.68	.78	.93	1.10	1.27	1.49	1.78	2.19	2.62
2.92	3.07	3.06	2.92	2.69	2.42	2.19	1.99	1.81	1.64
1.51	1.41	1.30	1.19	1.10	1.01	.93	.86	.80	.75
.69	.63	.59	.55	.52	.50	.46	.43	.41	.39
.37	.35	.34	.32	.31	.30	.27	.23	.17	.00

Storm frequency and duration = 25 YR-3.0 HR
Standard Short Duration Unit Hyetograph
Time Increment = 3.00 minutes, Rainfall = 3.00 inches

.11	.18	.23	.26	.29	.32	.37	.41	.46	.52
.62	.68	.78	.93	1.10	1.27	1.49	1.78	2.19	2.62
2.92	3.07	3.06	2.92	2.69	2.42	2.19	1.99	1.81	1.64
1.51	1.41	1.30	1.19	1.10	1.01	.93	.86	.80	.75
.69	.63	.59	.55	.52	.50	.46	.43	.41	.39
.37	.35	.34	.32	.31	.30	.27	.23	.17	.00

Storm frequency and duration = 25 YR-6.0 HR
User Input Unit Hyetograph
Time Increment = 6.00 minutes, Rainfall = 3.50 inches

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.24	.24	.30	.42	.42	.48	.54	.66	.72	.66
.66	.60	.48	.48	.42	.36	.36	.30	.18	.24
.36	.42	.48	.60	.72	.72	1.08	1.08	1.26	1.62
1.80	2.34	2.58	2.58	2.64	2.94	3.54	3.00	2.58	2.16
1.92	1.92	1.68	1.62	1.38	1.32	1.26	1.14	.96	.84
.66	.48	.36	.30	.30	.24	.12	.12	.06	.06

Storm frequency and duration = 25 YR-12 HR
User Input Unit Hyetograph
Time Increment = 12.00 minutes, Rainfall = 4.10 inches

.24	.24	.30	.42	.42	.48	.54	.66	.72	.66
.66	.60	.48	.48	.42	.36	.36	.30	.18	.24
.36	.42	.48	.60	.72	.72	1.08	1.08	1.26	1.62
1.80	2.34	2.58	2.58	2.64	2.94	3.54	3.00	2.58	2.16
1.92	1.92	1.68	1.62	1.38	1.32	1.26	1.14	.96	.84
.66	.48	.36	.30	.30	.24	.12	.12	.06	.06

Storm frequency and duration = 25 YR-24 HR
User Input Unit Hyetograph
Time Increment = 24.00 minutes, Rainfall = 4.60 inches

.24	.24	.30	.42	.42	.48	.54	.66	.72	.66
.66	.60	.48	.48	.42	.36	.36	.30	.18	.24
.36	.42	.48	.60	.72	.72	1.08	1.08	1.26	1.62
1.80	2.34	2.58	2.58	2.64	2.94	3.54	3.00	2.58	2.16
1.92	1.92	1.68	1.62	1.38	1.32	1.26	1.14	.96	.84
.66	.48	.36	.30	.30	.24	.12	.12	.06	.06

Storm frequency and duration = 50 YR-0.5 HR
Standard Short Duration Unit Hyetograph
Time Increment = .50 minutes, Rainfall = 2.15 inches

.11	.18	.23	.26	.29	.32	.37	.41	.46	.52
.62	.68	.78	.93	1.10	1.27	1.49	1.78	2.19	2.62
2.92	3.07	3.06	2.92	2.69	2.42	2.19	1.99	1.81	1.64
1.51	1.41	1.30	1.19	1.10	1.01	.93	.86	.80	.75
.69	.63	.59	.55	.52	.50	.46	.43	.41	.39
.37	.35	.34	.32	.31	.30	.27	.23	.17	.00

Storm frequency and duration = 50 YR-1.0 HR
Standard Short Duration Unit Hyetograph
Time Increment = 1.00 minutes, Rainfall = 2.75 inches

.11	.18	.23	.26	.29	.32	.37	.41	.46	.52
.62	.68	.78	.93	1.10	1.27	1.49	1.78	2.19	2.62
2.92	3.07	3.06	2.92	2.69	2.42	2.19	1.99	1.81	1.64
1.51	1.41	1.30	1.19	1.10	1.01	.93	.86	.80	.75
.69	.63	.59	.55	.52	.50	.46	.43	.41	.39
.37	.35	.34	.32	.31	.30	.27	.23	.17	.00

Storm frequency and duration = 50 YR-2.0 HR
Standard Short Duration Unit Hyetograph
Time Increment = 2.00 minutes, Rainfall = 3.25 inches

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.11	.18	.23	.26	.29	.32	.37	.41	.46	.52
.62	.68	.78	.93	1.10	1.27	1.49	1.78	2.19	2.62
2.92	3.07	3.06	2.92	2.69	2.42	2.19	1.99	1.81	1.64
1.51	1.41	1.30	1.19	1.10	1.01	.93	.86	.80	.75
.69	.63	.59	.55	.52	.50	.46	.43	.41	.39
.37	.35	.34	.32	.31	.30	.27	.23	.17	.00

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HYETOGRAPH LOSSES (inches)

STORM DURATION	INTERCEPTION imperv.	INTERCEPTION perv.	DEPRESSION imperv.	DEPRESSION perv.	INFILTRATION(in/hr) initial	infinity	..at	time=(min)
25 YR-0.5 HR	.05	.15	.10	.00	2.50	.30	1.70	15.00
25 YR-1.0 HR	.05	.15	.10	.00	2.50	.30	1.70	15.00
25 YR-2.0 HR	.05	.15	.10	.00	2.50	.30	1.70	15.00
25 YR-3.0 HR	.05	.15	.10	.00	2.50	.30	1.70	15.00
25 YR-6.0 HR	.05	.15	.10	.00	2.50	.30	1.70	15.00
25 YR-12 HR	.05	.15	.10	.00	2.50	.30	1.70	15.00
25 YR-24 HR	.05	.15	.10	.00	2.50	.30	1.70	15.00
50 YR-0.5 HR	.05	.15	.10	.00	2.50	.30	1.70	15.00
50 YR-1.0 HR	.05	.15	.10	.00	2.50	.30	1.70	15.00
50 YR-2.0 HR	.05	.15	.10	.00	2.50	.30	1.70	15.00

WATERSHED FEATURES SUMMARY TABLE

WATERSHED	total	Water	AREA Impervious (acres)	.001	.003	.005	AVERAGE VELOCITY (fps)	LONGEST FLOW LENGTH (feet)	TOC (min)
SE1#2	2.5	.0	.0	2.5	.0	.0	.5	650.	21.67
SE2#2#3	.8	.0	.1	.7	.0	.0	.5	200.	6.67
SE3#2	3.0	.0	.0	3.0	.0	.0	.5	500.	16.67
SE4#2#3	1.7	.0	.2	1.5	.0	.0	.5	250.	8.33
SE5#2	5.2	.0	.0	5.2	.0	.0	.5	550.	18.33
SE6#2#3	1.4	.0	.2	1.2	.0	.0	.5	200.	6.67
SE7#2	3.8	.0	.0	3.8	.0	.0	.5	550.	18.33
SE8#2	5.4	.0	.0	5.4	.0	.0	.5	500.	16.67
SE9#2#3	1.5	.0	.2	1.3	.0	.0	.5	250.	8.33
SW1#3	2.6	.0	.0	2.6	.0	.0	.5	650.	21.67
SW2#3	4.5	.0	.0	4.5	.0	.0	.5	650.	21.67
SW3#3	3.9	.0	.0	3.9	.0	.0	.5	500.	16.67
SW4#3	3.1	.0	.0	3.1	.0	.0	.5	500.	16.67
SW5#3	3.5	.0	.0	3.5	.0	.0	.5	500.	16.67

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BARR HYDROGRAPH OUTPUT STATISTICS

WATERSHED	STORM DURATION	PEAK DISCHARGE (cfs)	TIME OF PEAK (minutes)	HYDROGRAPH VOLUME (acft)
SE1#2	25 YR-0.5 HR	3.12	27.00	.16
SE1#2	25 YR-1.0 HR	3.13	43.00	.19
SE1#2	25 YR-2.0 HR	2.43	74.00	.20
SE1#2	25 YR-3.0 HR	2.08	102.00	.21
SE1#2	25 YR-6.0 HR	2.22	252.00	.28

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SE1#2	25 YR-12 HR	1.50	480.00	.26
SE1#2	25 YR-24 HR	.67	936.00	.13
SE1#2	50 YR-0.5 HR	3.99	26.50	.20
SE1#2	50 YR-1.0 HR	4.16	42.00	.26
SE1#2	50 YR-2.0 HR	3.32	72.00	.28
SE2#2#3	25 YR-0.5 HR	2.14	20.50	.06
SE2#2#3	25 YR-1.0 HR	1.90	34.00	.08
SE2#2#3	25 YR-2.0 HR	1.30	60.00	.08
SE2#2#3	25 YR-3.0 HR	1.02	87.00	.09
SE2#2#3	25 YR-6.0 HR	.96	234.00	.11
SE2#2#3	25 YR-12 HR	.60	456.00	.11
SE2#2#3	25 YR-24 HR	.28	912.00	.08
SE2#2#3	50 YR-0.5 HR	2.67	20.00	.08
SE2#2#3	50 YR-1.0 HR	2.46	34.00	.10
SE2#2#3	50 YR-2.0 HR	1.74	60.00	.11
SE3#2	25 YR-0.5 HR	4.40	25.50	.19
SE3#2	25 YR-1.0 HR	4.31	41.00	.23
SE3#2	25 YR-2.0 HR	3.26	70.00	.24
SE3#2	25 YR-3.0 HR	2.73	99.00	.25
SE3#2	25 YR-6.0 HR	2.88	246.00	.33
SE3#2	25 YR-12 HR	1.89	468.00	.31
SE3#2	25 YR-24 HR	.82	936.00	.16
SE3#2	50 YR-0.5 HR	5.62	25.00	.24
SE3#2	50 YR-1.0 HR	5.73	40.00	.31
SE3#2	50 YR-2.0 HR	4.45	70.00	.33
SE4#2#3	25 YR-0.5 HR	4.04	21.50	.12
SE4#2#3	25 YR-1.0 HR	3.69	36.00	.15
SE4#2#3	25 YR-2.0 HR	2.59	62.00	.17
SE4#2#3	25 YR-3.0 HR	2.06	90.00	.17
SE4#2#3	25 YR-6.0 HR	2.00	240.00	.22
SE4#2#3	25 YR-12 HR	1.24	468.00	.22
SE4#2#3	25 YR-24 HR	.57	912.00	.15
SE4#2#3	50 YR-0.5 HR	5.07	21.50	.16
SE4#2#3	50 YR-1.0 HR	4.81	35.00	.20
SE4#2#3	50 YR-2.0 HR	3.47	62.00	.22
SE5#2	25 YR-0.5 HR	7.14	26.00	.32
SE5#2	25 YR-1.0 HR	7.05	42.00	.40
SE5#2	25 YR-2.0 HR	5.39	72.00	.41
SE5#2	25 YR-3.0 HR	4.55	99.00	.43
SE5#2	25 YR-6.0 HR	4.80	246.00	.57
SE5#2	25 YR-12 HR	3.18	468.00	.53
SE5#2	25 YR-24 HR	1.40	936.00	.28
SE5#2	50 YR-0.5 HR	9.11	25.50	.42
SE5#2	50 YR-1.0 HR	9.38	41.00	.53
SE5#2	50 YR-2.0 HR	7.35	70.00	.57
SE6#2#3	25 YR-0.5 HR	3.74	20.50	.11
SE6#2#3	25 YR-1.0 HR	3.33	34.00	.13
SE6#2#3	25 YR-2.0 HR	2.28	60.00	.14
SE6#2#3	25 YR-3.0 HR	1.80	87.00	.15
SE6#2#3	25 YR-6.0 HR	1.69	234.00	.19
SE6#2#3	25 YR-12 HR	1.04	456.00	.19
SE6#2#3	25 YR-24 HR	.49	912.00	.14
SE6#2#3	50 YR-0.5 HR	4.68	20.00	.13
SE6#2#3	50 YR-1.0 HR	4.32	34.00	.17
SE6#2#3	50 YR-2.0 HR	3.06	60.00	.19

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SE7#2	25 YR-0.5 HR	5.22	26.00	.24	
SE7#2	25 YR-1.0 HR	5.15	42.00	.29	
SE7#2	25 YR-2.0 HR	3.94	72.00	.30	
SE7#2	25 YR-3.0 HR	3.32	99.00	.32	
SE7#2	25 YR-6.0 HR	3.51	246.00	.42	
SE7#2	25 YR-12 HR	2.33	468.00	.39	
SE7#2	25 YR-24 HR	1.02	936.00	.20	
SE7#2	50 YR-0.5 HR	6.66	25.50	.30	
SE7#2	50 YR-1.0 HR	6.86	41.00	.39	
SE7#2	50 YR-2.0 HR	5.38	70.00	.42	
SE8#2	25 YR-0.5 HR	7.88	25.50	.34	
SE8#2	25 YR-1.0 HR	7.72	41.00	.41	
SE8#2	25 YR-2.0 HR	5.84	70.00	.43	
SE8#2	25 YR-3.0 HR	4.89	99.00	.45	
SE8#2	25 YR-6.0 HR	5.15	246.00	.60	
SE8#2	25 YR-12 HR	3.39	468.00	.56	
SE8#2	25 YR-24 HR	1.47	936.00	.29	
SE8#2	50 YR-0.5 HR	10.06	25.00	.43	
SE8#2	50 YR-1.0 HR	10.27	40.00	.56	
SE8#2	50 YR-2.0 HR	7.96	70.00	.59	
SE9#2#3	25 YR-0.5 HR	3.68	21.00	.11	
SE9#2#3	25 YR-1.0 HR	3.35	35.00	.14	
SE9#2#3	25 YR-2.0 HR	2.35	62.00	.15	
SE9#2#3	25 YR-3.0 HR	1.87	90.00	.16	
SE9#2#3	25 YR-6.0 HR	1.78	240.00	.21	
SE9#2#3	25 YR-12 HR	1.11	468.00	.21	
SE9#2#3	25 YR-24 HR	.52	912.00	.15	
SE9#2#3	50 YR-0.5 HR	4.60	21.00	.14	
SE9#2#3	50 YR-1.0 HR	4.34	35.00	.18	
SE9#2#3	50 YR-2.0 HR	3.14	62.00	.20	
SW1#3	25 YR-0.5 HR	3.27	27.00	.16	
SW1#3	25 YR-1.0 HR	3.28	43.00	.20	
SW1#3	25 YR-2.0 HR	2.55	74.00	.21	
SW1#3	25 YR-3.0 HR	2.18	102.00	.22	
SW1#3	25 YR-6.0 HR	2.33	252.00	.29	
SW1#3	25 YR-12 HR	1.57	480.00	.27	
SW1#3	25 YR-24 HR	.70	936.00	.14	
SW1#3	50 YR-0.5 HR	4.18	26.50	.21	
SW1#3	50 YR-1.0 HR	4.36	42.00	.27	DITCH Qmax ≈ 4.4 x 2/3 ≈ 2.9cfs
SW1#3	50 YR-2.0 HR	3.48	72.00	.29	
SW2#3	25 YR-0.5 HR	5.60	27.00	.28	
SW2#3	25 YR-1.0 HR	5.61	43.00	.34	
SW2#3	25 YR-2.0 HR	4.37	74.00	.36	
SW2#3	25 YR-3.0 HR	3.73	102.00	.38	
SW2#3	25 YR-6.0 HR	3.99	252.00	.50	
SW2#3	25 YR-12 HR	2.69	480.00	.46	
SW2#3	25 YR-24 HR	1.20	936.00	.24	
SW2#3	50 YR-0.5 HR	7.15	26.50	.36	
SW2#3	50 YR-1.0 HR	7.46	42.00	.46	DITCH Qmax = 7.5 ÷ 2 = 3.8 cfs
SW2#3	50 YR-2.0 HR	5.95	72.00	.49	
SW3#3	25 YR-0.5 HR	5.72	25.50	.24	
SW3#3	25 YR-1.0 HR	5.60	41.00	.30	
SW3#3	25 YR-2.0 HR	4.24	70.00	.31	
SW3#3	25 YR-3.0 HR	3.55	99.00	.33	

SW3#3	25 YR-6.0 HR	3.74	246.00	.43	
SW3#3	25 YR-12 HR	2.46	468.00	.40	
SW3#3	25 YR-24 HR	1.07	936.00	.21	
SW3#3	50 YR-0.5 HR	7.30	25.00	.31	
SW3#3	50 YR-1.0 HR	7.45	40.00	.40	DITCH Qmax = 7.5 ÷ 2 = 3.8
SW3#3	50 YR-2.0 HR	5.78	70.00	.43	
SW4#3	25 YR-0.5 HR	4.55	25.50	.19	
SW4#3	25 YR-1.0 HR	4.46	41.00	.24	
SW4#3	25 YR-2.0 HR	3.37	70.00	.25	
SW4#3	25 YR-3.0 HR	2.82	99.00	.26	
SW4#3	25 YR-6.0 HR	2.97	246.00	.34	
SW4#3	25 YR-12 HR	1.96	468.00	.32	
SW4#3	25 YR-24 HR	.85	936.00	.17	
SW4#3	50 YR-0.5 HR	5.80	25.00	.25	
SW4#3	50 YR-1.0 HR	5.92	40.00	.32	DITCH Qmax = 5.9 ÷ 2 = 3.0 cfs
SW4#3	50 YR-2.0 HR	4.59	70.00	.34	
SW5#3	25 YR-0.5 HR	5.19	25.50	.22	
SW5#3	25 YR-1.0 HR	5.09	41.00	.27	
SW5#3	25 YR-2.0 HR	3.85	70.00	.28	
SW5#3	25 YR-3.0 HR	3.22	99.00	.30	
SW5#3	25 YR-6.0 HR	3.40	246.00	.39	
SW5#3	25 YR-12 HR	2.23	468.00	.37	
SW5#3	25 YR-24 HR	.97	936.00	.19	
SW5#3	50 YR-0.5 HR	6.63	25.00	.29	
SW5#3	50 YR-1.0 HR	6.76	40.00	.37	DITCH Qmax = 6.8 ÷ 2 = 3.4 cfs
SW5#3	50 YR-2.0 HR	5.24	70.00	.39	

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WATERSHED ROUTING OUTPUT

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Storage routing performed through pond at outlet of Watershed SE8#2

STORAGE ROUTING DATA FOR WATERSHED: SE8#2

Input Elevation-Storage-Discharge Curve

ELEVATION (feet)	STORAGE (ac-ft)	DISCHARGE (CFS)
1018.80	.00	.00
1019.80	.05	6.30
1020.80	.45	8.40
1021.80	1.55	9.20

Starting water elevation = 1018.80 feet

STORAGE ROUTING STATISTICS

	PEAK DISCHARGE				VOLUME		PEAK	STORAGE
STORM EVENT	Inflow (cfs)	Time (min)	Outflow (cfs)	Time (min)	Inflow (acft)	Outflow	ELEV (feet)	VOLUME (acft)
25 YR-0.5 HR	7.88	25.0	6.35	34.0	.34	.34	1019.82	.06
25 YR-1.0 HR	7.71	40.0	6.37	52.0	.41	.41	1019.83	.06
25 YR-2.0 HR	5.83	72.0	5.57	76.0	.43	.43	1019.68	.04
25 YR-3.0 HR	4.86	96.0	4.73	108.0	.45	.45	1019.55	.04
25 YR-6.0 HR	5.15	246.0	5.04	252.0	.60	.60	1019.60	.04
25 YR-12 HR	3.39	468.0	3.37	480.0	.56	.56	1019.33	.03
25 YR-24 HR	1.47	936.0	1.49	936.0	.29	.29	1019.04	.01
50 YR-0.5 HR	10.06	25.0	6.57	38.0	.43	.43	1019.93	.10
50 YR-1.0 HR	10.27	40.0	6.72	58.0	.56	.56	1020.00	.13
50 YR-2.0 HR	7.95	68.0	6.46	84.0	.59	.59	1019.88	.08

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No routing perfomed for Watershed POND hydrograph to Pipe Node PN1

HYDROGRAPH STATISTICS

	PEAK DISCHARGE				VOLUME	
STORM EVENT	Inflow (cfs)	Time (min)	Outflow (cfs)	Time (min)	Inflow (acft)	Outflow
25 YR-0.5 HR	6.35	34.0	6.35	34.0	.34	.34
25 YR-1.0 HR	6.37	52.0	6.37	52.0	.41	.41
25 YR-2.0 HR	5.57	76.0	5.57	76.0	.43	.43
25 YR-3.0 HR	4.73	108.0	4.73	108.0	.45	.45
25 YR-6.0 HR	5.04	252.0	5.04	252.0	.60	.60
25 YR-12 HR	3.37	480.0	3.37	480.0	.56	.56

25 YR-24 HR	1.49	936.0	1.49	936.0	.29	.29
50 YR-0.5 HR	6.57	38.0	6.57	38.0	.43	.43
50 YR-1.0 HR	6.72	58.0	6.72	58.0	.56	.56
50 YR-2.0 HR	6.46	84.0	6.46	84.0	.59	.59

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Outflow hydrograph decision: STORE1

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Storage routing performed through pond at outlet of Watershed SE7#2

STORAGE ROUTING DATA FOR WATERSHED: SE7#2

Input Elevation-Storage-Discharge Curve

ELEVATION (feet)	STORAGE (ac-ft)	DISCHARGE (CFS)
1012.80	.00	.00
1013.80	.11	6.30
1014.80	.92	8.90
1015.80	2.19	10.80

Starting water elevation = 1012.80 feet

STORAGE ROUTING STATISTICS

STORM EVENT	PEAK DISCHARGE Inflow (cfs)	Time (min)	Outflow (cfs)	Time (min)	VOLUME Inflow (acft)	Outflow (acft)	PEAK ELEV (feet)	STORAGE VOLUME (acft)
25 YR-0.5 HR	5.22	26.0	3.78	37.0	.24	.23	1013.40	.07
25 YR-1.0 HR	5.15	42.0	4.08	54.0	.29	.29	1013.45	.07
25 YR-2.0 HR	3.94	72.0	3.38	84.0	.30	.30	1013.34	.06
25 YR-3.0 HR	3.32	102.0	2.97	114.0	.32	.31	1013.27	.05
25 YR-6.0 HR	3.51	246.0	3.25	264.0	.42	.42	1013.32	.06
25 YR-12 HR	2.33	468.0	2.21	492.0	.39	.39	1013.15	.04
25 YR-24 HR	1.02	936.0	1.00	936.0	.20	.20	1012.96	.02
50 YR-0.5 HR	6.66	26.0	4.84	37.0	.30	.30	1013.57	.08
50 YR-1.0 HR	6.84	40.0	5.43	54.0	.39	.39	1013.66	.09
50 YR-2.0 HR	5.36	72.0	4.60	84.0	.41	.41	1013.53	.08

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No routing perfomed for Watershed POND hydrograph to Pipe Node PN1

HYDROGRAPH STATISTICS

STORM EVENT	PEAK DISCHARGE Inflow (cfs)	Time (min)	Outflow (cfs)	Time (min)	VOLUME Inflow (acft)	Outflow (acft)
25 YR-0.5 HR	3.78	37.0	3.78	37.0	.23	.23
25 YR-1.0 HR	4.08	54.0	4.08	54.0	.29	.29
25 YR-2.0 HR	3.38	84.0	3.38	84.0	.30	.30
25 YR-3.0 HR	2.97	114.0	2.97	114.0	.31	.31
25 YR-6.0 HR	3.25	264.0	3.25	264.0	.42	.42

25 YR-12 HR	2.21	492.0	2.21	492.0	.39	.39
25 YR-24 HR	1.00	936.0	1.00	936.0	.20	.20
50 YR-0.5 HR	4.84	37.0	4.84	37.0	.30	.30
50 YR-1.0 HR	5.43	54.0	5.43	54.0	.39	.39
50 YR-2.0 HR	4.60	84.0	4.60	84.0	.41	.41

Outflow hydrograph decision: SUM

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No routing perfomed for Pipe Node PN1 hydrograph to Pipe Node PN2

HYDROGRAPH STATISTICS

STORM EVENT	PEAK DISCHARGE Inflow (cfs)	Time (min)	Outflow (cfs)	Time (min)	VOLUME Inflow (acft)	Outflow
25 YR-0.5 HR	10.12	37.0	10.12	37.0	.57	.57
25 YR-1.0 HR	10.44	54.0	10.44	54.0	.70	.70
25 YR-2.0 HR	8.84	80.0	8.84	80.0	.73	.73
25 YR-3.0 HR	7.64	108.0	7.64	108.0	.76	.76
25 YR-6.0 HR	8.22	258.0	8.22	258.0	1.01	1.01
25 YR-12 HR	5.56	480.0	5.56	480.0	.95	.95
25 YR-24 HR	2.49	936.0	2.49	936.0	.49	.49
50 YR-0.5 HR	11.41	37.0	11.41	37.0	.73	.73
50 YR-1.0 HR	12.13	54.0	12.13	54.0	.94	.94
50 YR-2.0 HR	11.06	84.0	11.06	84.0	1.01	1.01

Outflow hydrograph decision: STORE1

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No routing perfomed for Watershed SE9#2#3 hydrograph to Pipe Node PN2

HYDROGRAPH STATISTICS

STORM EVENT	PEAK DISCHARGE Inflow (cfs)	Time (min)	Outflow (cfs)	Time (min)	VOLUME Inflow (acft)	Outflow
25 YR-0.5 HR	3.68	21.0	3.68	21.0	.11	.11
25 YR-1.0 HR	3.35	36.0	3.35	36.0	.14	.14
25 YR-2.0 HR	2.34	64.0	2.34	64.0	.15	.15
25 YR-3.0 HR	1.87	90.0	1.87	90.0	.16	.16
25 YR-6.0 HR	1.78	240.0	1.78	240.0	.21	.21
25 YR-12 HR	1.11	468.0	1.11	468.0	.21	.21
25 YR-24 HR	.52	912.0	.52	912.0	.15	.15
50 YR-0.5 HR	4.60	21.0	4.60	21.0	.14	.14
50 YR-1.0 HR	4.33	34.0	4.33	34.0	.18	.18
50 YR-2.0 HR	3.13	60.0	3.13	60.0	.20	.20

Outflow hydrograph decision: ADD1

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Storage routing performed through pond at outlet of Watershed SW5#3

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STORAGE ROUTING DATA FOR WATERSHED: SW5#3

Input Elevation-Storage-Discharge Curve

ELEVATION (feet)	STORAGE (ac-ft)	DISCHARGE (CFS)
1017.40	.00	.00
1018.40	.05	6.30
1019.40	.45	8.40

Starting water elevation = 1017.40 feet

STORAGE ROUTING STATISTICS

STORM EVENT	PEAK DISCHARGE Inflow (cfs)	Time (min)	Outflow (cfs)	Time (min)	VOLUME Inflow (acft)	Outflow (acft)	PEAK ELEV (feet)	STORAGE VOLUME (acft)
25 YR-0.5 HR	5.19	25.0	4.60	32.0	.22	.22	1018.13	.04
25 YR-1.0 HR	5.08	40.0	4.69	48.0	.27	.27	1018.14	.04
25 YR-2.0 HR	3.84	72.0	3.67	76.0	.28	.28	1017.98	.03
25 YR-3.0 HR	3.20	96.0	3.12	108.0	.30	.30	1017.89	.02
25 YR-6.0 HR	3.40	246.0	3.32	252.0	.39	.39	1017.93	.03
25 YR-12 HR	2.23	468.0	2.22	480.0	.37	.37	1017.75	.02
25 YR-24 HR	.97	936.0	.98	936.0	.19	.19	1017.56	.01
50 YR-0.5 HR	6.63	25.0	5.87	32.0	.29	.28	1018.33	.05
50 YR-1.0 HR	6.76	40.0	6.23	46.0	.37	.37	1018.39	.05
50 YR-2.0 HR	5.24	68.0	5.01	76.0	.39	.39	1018.20	.04

PIPE Q_{max}

HW@CB 12 = 1.0'

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No routing perfomed for Watershed POND hydrograph to Pipe Node PN2A

HYDROGRAPH STATISTICS

STORM EVENT	PEAK DISCHARGE Inflow (cfs)	Time (min)	Outflow (cfs)	Time (min)	VOLUME Inflow (acft)	Outflow (acft)
25 YR-0.5 HR	4.60	32.0	4.60	32.0	.22	.22
25 YR-1.0 HR	4.69	48.0	4.69	48.0	.27	.27
25 YR-2.0 HR	3.67	76.0	3.67	76.0	.28	.28
25 YR-3.0 HR	3.12	108.0	3.12	108.0	.30	.30
25 YR-6.0 HR	3.32	252.0	3.32	252.0	.39	.39
25 YR-12 HR	2.22	480.0	2.22	480.0	.37	.37
25 YR-24 HR	.98	936.0	.98	936.0	.19	.19
50 YR-0.5 HR	5.87	32.0	5.87	32.0	.28	.28
50 YR-1.0 HR	6.23	46.0	6.23	46.0	.37	.37
50 YR-2.0 HR	5.01	76.0	5.01	76.0	.39	.39

Outflow hydrograph decision: STORE2

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Storage routing performed through pond at outlet of Watershed SW4#3

STORAGE ROUTING DATA FOR WATERSHED: SW4#3

Input Elevation-Storage-Discharge Curve

ELEVATION (feet)	STORAGE (ac-ft)	DISCHARGE (CFS)
1012.40	.00	.00
1013.40	.11	6.30
1014.40	.92	8.90

Starting water elevation = 1012.40 feet

STORAGE ROUTING STATISTICS

	PEAK DISCHARGE				VOLUME		PEAK	STORAGE
STORM EVENT	Inflow (cfs)	Time (min)	Outflow (cfs)	Time (min)	Inflow (acft)	Outflow (acft)	ELEV (feet)	VOLUME (acft)
25 YR-0.5 HR	4.54	25.0	3.25	37.0	.19	.19	1012.92	.06
25 YR-1.0 HR	4.45	40.0	3.48	54.0	.24	.24	1012.95	.06
25 YR-2.0 HR	3.36	72.0	2.87	84.0	.25	.24	1012.85	.05
25 YR-3.0 HR	2.81	96.0	2.51	114.0	.26	.26	1012.80	.04
25 YR-6.0 HR	2.97	246.0	2.73	264.0	.34	.34	1012.83	.05
25 YR-12 HR	1.96	468.0	1.84	480.0	.32	.32	1012.69	.03
25 YR-24 HR	.85	936.0	.83	936.0	.17	.17	1012.53	.01
50 YR-0.5 HR	5.80	25.0	4.16	36.0	.25	.25	1013.06	.07
50 YR-1.0 HR	5.92	40.0	4.63	54.0	.32	.32	1013.14	.08
50 YR-2.0 HR	4.59	68.0	3.90	84.0	.34	.34	1013.02	.07

HW @ CB11 = 0.8'

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No routing perfomed for Watershed POND hydrograph to Pipe Node PN2A

HYDROGRAPH STATISTICS

	PEAK DISCHARGE				VOLUME	
STORM EVENT	Inflow (cfs)	Time (min)	Outflow (cfs)	Time (min)	Inflow (acft)	Outflow (acft)
25 YR-0.5 HR	3.25	37.0	3.25	37.0	.19	.19
25 YR-1.0 HR	3.48	54.0	3.48	54.0	.24	.24
25 YR-2.0 HR	2.87	84.0	2.87	84.0	.24	.24
25 YR-3.0 HR	2.51	114.0	2.51	114.0	.26	.26
25 YR-6.0 HR	2.73	264.0	2.73	264.0	.34	.34
25 YR-12 HR	1.84	480.0	1.84	480.0	.32	.32
25 YR-24 HR	.83	936.0	.83	936.0	.17	.17
50 YR-0.5 HR	4.16	36.0	4.16	36.0	.25	.25
50 YR-1.0 HR	4.63	54.0	4.63	54.0	.32	.32
50 YR-2.0 HR	3.90	84.0	3.90	84.0	.34	.34

Outflow hydrograph decision: ADD2

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1019.40	.45	8.40

Starting water elevation = 1017.40 feet

STORAGE ROUTING STATISTICS

STORM EVENT	PEAK DISCHARGE Inflow (cfs)	Time (min)	Outflow (cfs)	Time (min)	VOLUME Inflow (acft)	Outflow	PEAK ELEV (feet)	STORAGE VOLUME (acft)
25 YR-0.5 HR	5.71	25.0	5.07	32.0	.24	.24	1018.20	.04
25 YR-1.0 HR	5.59	40.0	5.16	48.0	.30	.30	1018.22	.04
25 YR-2.0 HR	4.23	72.0	4.04	76.0	.31	.31	1018.04	.03
25 YR-3.0 HR	3.53	96.0	3.43	108.0	.33	.33	1017.95	.03
25 YR-6.0 HR	3.74	246.0	3.65	252.0	.43	.43	1017.98	.03
25 YR-12 HR	2.46	468.0	2.44	480.0	.40	.40	1017.79	.02
25 YR-24 HR	1.07	936.0	1.08	936.0	.21	.21	1017.57	.01
50 YR-0.5 HR	7.30	25.0	6.31	32.0	.31	.31	1018.40	.05
50 YR-1.0 HR	7.45	40.0	6.35	50.0	.40	.40	1018.42	.06
50 YR-2.0 HR	5.77	68.0	5.52	76.0	.43	.43	1018.28	.04

PIPE Q_{max} HW @ CB14 = 1.0'

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No routing perfomed for Watershed POND hydrograph to Pipe Node PN3A

HYDROGRAPH STATISTICS

STORM EVENT	PEAK DISCHARGE Inflow (cfs)	Time (min)	Outflow (cfs)	Time (min)	VOLUME Inflow (acft)	Outflow
25 YR-0.5 HR	5.07	32.0	5.07	32.0	.24	.24
25 YR-1.0 HR	5.16	48.0	5.16	48.0	.30	.30
25 YR-2.0 HR	4.04	76.0	4.04	76.0	.31	.31
25 YR-3.0 HR	3.43	108.0	3.43	108.0	.33	.33
25 YR-6.0 HR	3.65	252.0	3.65	252.0	.43	.43
25 YR-12 HR	2.44	480.0	2.44	480.0	.40	.40
25 YR-24 HR	1.08	936.0	1.08	936.0	.21	.21
50 YR-0.5 HR	6.31	32.0	6.31	32.0	.31	.31
50 YR-1.0 HR	6.35	50.0	6.35	50.0	.40	.40
50 YR-2.0 HR	5.52	76.0	5.52	76.0	.43	.43

Outflow hydrograph decision: STORE2

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Storage routing performed through pond at outlet of Watershed SW2#3

STORAGE ROUTING DATA FOR WATERSHED: SW2#3

Input Elevation-Storage-Discharge Curve

ELEVATION (feet)	STORAGE (ac-ft)	DISCHARGE (CFS)
1012.40	.00	.00
1013.40	.11	6.30

1014.40 .92 8.90

Starting water elevation = 1012.40 feet

STORAGE ROUTING STATISTICS

STORM EVENT	PEAK DISCHARGE Inflow (cfs)	Time (min)	Outflow (cfs)	Time (min)	VOLUME Inflow (acft)	Outflow	PEAK ELEV (feet)	STORAGE VOLUME (acft)
25 YR-0.5 HR	5.60	27.0	4.14	38.0	.28	.28	1013.06	.07
25 YR-1.0 HR	5.60	42.0	4.52	56.0	.34	.34	1013.12	.08
25 YR-2.0 HR	4.36	72.0	3.79	88.0	.36	.36	1013.00	.07
25 YR-3.0 HR	3.73	102.0	3.36	114.0	.38	.38	1012.93	.06
25 YR-6.0 HR	3.99	252.0	3.72	270.0	.50	.50	1012.99	.06
25 YR-12 HR	2.69	480.0	2.57	492.0	.46	.46	1012.81	.04
25 YR-24 HR	1.20	936.0	1.16	936.0	.24	.24	1012.58	.02
50 YR-0.5 HR	7.14	26.0	5.30	38.0	.36	.36	1013.24	.09
50 YR-1.0 HR	7.46	42.0	6.02	56.0	.46	.46	1013.36	.11
50 YR-2.0 HR	5.95	72.0	5.16	84.0	.49	.49	1013.22	.09

HW@CB 13 = 1.0'

No routing perfomed for Watershed POND hydrograph to Pipe Node PN3A

HYDROGRAPH STATISTICS

STORM EVENT	PEAK DISCHARGE Inflow (cfs)	Time (min)	Outflow (cfs)	Time (min)	VOLUME Inflow (acft)	Outflow
25 YR-0.5 HR	4.14	38.0	4.14	38.0	.28	.28
25 YR-1.0 HR	4.52	56.0	4.52	56.0	.34	.34
25 YR-2.0 HR	3.79	88.0	3.79	88.0	.36	.36
25 YR-3.0 HR	3.36	114.0	3.36	114.0	.38	.38
25 YR-6.0 HR	3.72	270.0	3.72	270.0	.50	.50
25 YR-12 HR	2.57	492.0	2.57	492.0	.46	.46
25 YR-24 HR	1.16	936.0	1.16	936.0	.24	.24
50 YR-0.5 HR	5.30	38.0	5.30	38.0	.36	.36
50 YR-1.0 HR	6.02	56.0	6.02	56.0	.46	.46
50 YR-2.0 HR	5.16	84.0	5.16	84.0	.49	.49

Outflow hydrograph decision: ADD2

No routing perfomed for Pipe Node PN3A hydrograph to Pipe Node PN3

HYDROGRAPH STATISTICS

STORM EVENT	PEAK DISCHARGE Inflow (cfs)	Time (min)	Outflow (cfs)	Time (min)	VOLUME Inflow (acft)	Outflow
25 YR-0.5 HR	8.99	34.0	8.99	34.0	.52	.52
25 YR-1.0 HR	9.44	50.0	9.44	50.0	.64	.64
25 YR-2.0 HR	7.67	80.0	7.67	80.0	.67	.67
25 YR-3.0 HR	6.66	108.0	6.66	108.0	.70	.70
25 YR-6.0 HR	7.25	258.0	7.25	258.0	.93	.93

25 YR-12 HR	4.94	480.0	4.94	480.0	.87	.87
25 YR-24 HR	2.24	936.0	2.24	936.0	.45	.45
50 YR-0.5 HR	11.50	35.0	11.50	35.0	.67	.67
50 YR-1.0 HR	12.34	54.0	12.34	54.0	.87	.87
50 YR-2.0 HR	10.46	80.0	10.46	80.0	.92	.92

Outflow hydrograph decision: ADD1

PIPE Qmax

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No routing perfomed for Watershed SE6#2#3 hydrograph to Pipe Node PN3

HYDROGRAPH STATISTICS

	PEAK DISCHARGE				VOLUME	
STORM EVENT	Inflow (cfs)	Time (min)	Outflow (cfs)	Time (min)	Inflow (acft)	Outflow (acft)
25 YR-0.5 HR	3.74	20.0	3.74	20.0	.11	.11
25 YR-1.0 HR	3.33	34.0	3.33	34.0	.13	.13
25 YR-2.0 HR	2.28	60.0	2.28	60.0	.14	.14
25 YR-3.0 HR	1.78	90.0	1.78	90.0	.15	.15
25 YR-6.0 HR	1.69	234.0	1.69	234.0	.19	.19
25 YR-12 HR	1.04	456.0	1.04	456.0	.19	.19
25 YR-24 HR	.49	912.0	.49	912.0	.14	.14
50 YR-0.5 HR	4.68	20.0	4.68	20.0	.13	.13
50 YR-1.0 HR	4.32	34.0	4.32	34.0	.17	.17
50 YR-2.0 HR	3.06	60.0	3.06	60.0	.19	.19

Outflow hydrograph decision: ADD1

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No routing perfomed for Pipe Node PN3 hydrograph to Pipe Node PN4

HYDROGRAPH STATISTICS

	PEAK DISCHARGE				VOLUME	
STORM EVENT	Inflow (cfs)	Time (min)	Outflow (cfs)	Time (min)	Inflow (acft)	Outflow (acft)
25 YR-0.5 HR	35.52	32.0	35.52	32.0	2.05	2.05
25 YR-1.0 HR	37.07	48.0	37.07	48.0	2.52	2.52
25 YR-2.0 HR	30.58	80.0	30.58	80.0	2.63	2.63
25 YR-3.0 HR	26.54	108.0	26.54	108.0	2.77	2.77
25 YR-6.0 HR	28.59	258.0	28.59	258.0	3.65	3.65
25 YR-12 HR	19.46	480.0	19.46	480.0	3.44	3.44
25 YR-24 HR	8.81	936.0	8.81	936.0	1.87	1.87
50 YR-0.5 HR	43.56	32.0	43.56	32.0	2.63	2.63
50 YR-1.0 HR	46.14	48.0	46.14	48.0	3.38	3.38
50 YR-2.0 HR	40.40	80.0	40.40	80.0	3.61	3.61

Outflow hydrograph decision: STORE1

PIPE Qmax

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Storage routing performed through pond at outlet of Watershed SE3#2

STORAGE ROUTING DATA FOR WATERSHED: SE3#2

Input Elevation-Storage-Discharge Curve

ELEVATION (feet)	STORAGE (ac-ft)	DISCHARGE (CFS)
1012.80	.00	.00
1013.80	.11	6.30
1014.80	.92	8.40

Starting water elevation = 1012.80 feet

STORAGE ROUTING STATISTICS

STORM EVENT	PEAK DISCHARGE Inflow (cfs)	Time (min)	Outflow (cfs)	Time (min)	VOLUME Inflow (acft)	Outflow (acft)	PEAK ELEV (feet)	STORAGE VOLUME (acft)
25 YR-0.5 HR	4.40	25.0	3.15	37.0	.19	.19	1013.30	.05
25 YR-1.0 HR	4.30	40.0	3.37	54.0	.23	.23	1013.33	.06
25 YR-2.0 HR	3.25	72.0	2.77	84.0	.24	.24	1013.24	.05
25 YR-3.0 HR	2.72	96.0	2.43	114.0	.25	.25	1013.19	.04
25 YR-6.0 HR	2.88	246.0	2.64	264.0	.33	.33	1013.22	.05
25 YR-12 HR	1.89	468.0	1.78	480.0	.31	.31	1013.08	.03
25 YR-24 HR	.82	936.0	.81	936.0	.16	.16	1012.93	.01
50 YR-0.5 HR	5.62	25.0	4.03	36.0	.24	.24	1013.44	.07
50 YR-1.0 HR	5.73	40.0	4.48	54.0	.31	.31	1013.51	.08
50 YR-2.0 HR	4.44	68.0	3.77	84.0	.33	.33	1013.40	.07

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No routing perfomed for Watershed POND   hydrograph to Pipe Node PN4

HYDROGRAPH STATISTICS

STORM EVENT	PEAK DISCHARGE Inflow (cfs)	Time (min)	Outflow (cfs)	Time (min)	VOLUME Inflow (acft)	Outflow (acft)
25 YR-0.5 HR	3.15	37.0	3.15	37.0	.19	.19
25 YR-1.0 HR	3.37	54.0	3.37	54.0	.23	.23
25 YR-2.0 HR	2.77	84.0	2.77	84.0	.24	.24
25 YR-3.0 HR	2.43	114.0	2.43	114.0	.25	.25
25 YR-6.0 HR	2.64	264.0	2.64	264.0	.33	.33
25 YR-12 HR	1.78	480.0	1.78	480.0	.31	.31
25 YR-24 HR	.81	936.0	.81	936.0	.16	.16
50 YR-0.5 HR	4.03	36.0	4.03	36.0	.24	.24
50 YR-1.0 HR	4.48	54.0	4.48	54.0	.31	.31
50 YR-2.0 HR	3.77	84.0	3.77	84.0	.33	.33

Outflow hydrograph decision: ADD1

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No routing perfomed for Watershed SE4#2#3 hydrograph to Pipe Node PN4

HYDROGRAPH STATISTICS

STORM EVENT	PEAK DISCHARGE Inflow (cfs)	Time (min)	Outflow (cfs)	Time (min)	VOLUME Inflow (acft)	Outflow (acft)
25 YR-0.5 HR	4.04	22.0	4.04	22.0	.12	.12
25 YR-1.0 HR	3.69	36.0	3.69	36.0	.15	.15
25 YR-2.0 HR	2.59	64.0	2.59	64.0	.17	.17
25 YR-3.0 HR	2.06	90.0	2.06	90.0	.17	.17
25 YR-6.0 HR	2.00	240.0	2.00	240.0	.22	.22
25 YR-12 HR	1.24	468.0	1.24	468.0	.22	.22
25 YR-24 HR	.57	912.0	.57	912.0	.15	.15
50 YR-0.5 HR	5.07	21.0	5.07	21.0	.16	.16
50 YR-1.0 HR	4.80	36.0	4.80	36.0	.20	.20
50 YR-2.0 HR	3.45	60.0	3.45	60.0	.22	.22

Outflow hydrograph decision: ADD1

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No routing perfomed for Pipe Node PN4 hydrograph to Pipe Node PN5

HYDROGRAPH STATISTICS

STORM EVENT	PEAK DISCHARGE Inflow (cfs)	Time (min)	Outflow (cfs)	Time (min)	VOLUME Inflow (acft)	Outflow (acft)
25 YR-0.5 HR	41.09	31.0	41.09	31.0	2.36	2.36
25 YR-1.0 HR	42.80	48.0	42.80	48.0	2.90	2.90
25 YR-2.0 HR	35.12	80.0	35.12	80.0	3.03	3.03
25 YR-3.0 HR	30.51	108.0	30.51	108.0	3.19	3.19
25 YR-6.0 HR	32.82	258.0	32.82	258.0	4.21	4.21
25 YR-12 HR	22.36	480.0	22.36	480.0	3.97	3.97
25 YR-24 HR	10.13	936.0	10.13	936.0	2.19	2.19
50 YR-0.5 HR	50.62	31.0	50.62	31.0	3.02	3.02
50 YR-1.0 HR	53.73	46.0	53.73	46.0	3.88	3.88
50 YR-2.0 HR	46.55	76.0	46.55	76.0	4.16	4.16

Outflow hydrograph decision: STORE1

PIPE Qmax

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No routing perfomed for Watershed SE2#2#3 hydrograph to Pipe Node PN5

HYDROGRAPH STATISTICS

STORM EVENT	PEAK DISCHARGE Inflow (cfs)	Time (min)	Outflow (cfs)	Time (min)	VOLUME Inflow (acft)	Outflow (acft)
25 YR-0.5 HR	2.13	20.0	2.13	20.0	.06	.06
25 YR-1.0 HR	1.90	34.0	1.90	34.0	.08	.08
25 YR-2.0 HR	1.30	60.0	1.30	60.0	.08	.08
25 YR-3.0 HR	1.01	90.0	1.01	90.0	.09	.09
25 YR-6.0 HR	.96	234.0	.96	234.0	.11	.11

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25 YR-12 HR	.60	456.0	.60	456.0	.11	.11
25 YR-24 HR	.28	912.0	.28	912.0	.08	.08
50 YR-0.5 HR	2.67	20.0	2.67	20.0	.08	.08
50 YR-1.0 HR	2.46	34.0	2.46	34.0	.10	.10
50 YR-2.0 HR	1.74	60.0	1.74	60.0	.11	.11

Outflow hydrograph decision: ADD1

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Storage routing performed through pond at outlet of Watershed SW1#3

STORAGE ROUTING DATA FOR WATERSHED: SW1#3

Input Elevation-Storage-Discharge Curve

ELEVATION (feet)	STORAGE (ac-ft)	DISCHARGE (CFS)
1012.40	.00	.00
1013.40	.11	6.30
1014.40	.92	8.40

Starting water elevation = 1012.40 feet

STORAGE ROUTING STATISTICS

STORM EVENT	PEAK DISCHARGE Inflow (cfs)	Time (min)	Outflow (cfs)	Time (min)	VOLUME Inflow (acft)	Outflow (acft)	PEAK ELEV (feet)	STORAGE VOLUME (acft)
25 YR-0.5 HR	3.27	27.0	2.42	38.0	.16	.16	1012.78	.04
25 YR-1.0 HR	3.28	42.0	2.64	56.0	.20	.20	1012.82	.05
25 YR-2.0 HR	2.55	72.0	2.22	88.0	.21	.21	1012.75	.04
25 YR-3.0 HR	2.18	102.0	1.96	114.0	.22	.22	1012.71	.03
25 YR-6.0 HR	2.33	252.0	2.17	270.0	.29	.29	1012.74	.04
25 YR-12 HR	1.57	480.0	1.50	492.0	.27	.27	1012.64	.03
25 YR-24 HR	.70	936.0	.68	936.0	.14	.14	1012.51	.01
50 YR-0.5 HR	4.17	26.0	3.10	38.0	.21	.21	1012.89	.05
50 YR-1.0 HR	4.36	42.0	3.52	56.0	.27	.27	1012.96	.06
50 YR-2.0 HR	3.48	72.0	3.01	84.0	.29	.29	1012.88	.05

Pipe Qmax HW@CB 15 = 0.6'

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No routing perfomed for Watershed POND hydrograph to Pipe Node PN5

HYDROGRAPH STATISTICS

STORM EVENT	PEAK DISCHARGE Inflow (cfs)	Time (min)	Outflow (cfs)	Time (min)	VOLUME Inflow (acft)	Outflow (acft)
25 YR-0.5 HR	2.42	38.0	2.42	38.0	.16	.16
25 YR-1.0 HR	2.64	56.0	2.64	56.0	.20	.20
25 YR-2.0 HR	2.22	88.0	2.22	88.0	.21	.21
25 YR-3.0 HR	1.96	114.0	1.96	114.0	.22	.22
25 YR-6.0 HR	2.17	270.0	2.17	270.0	.29	.29

25 YR-12 HR	1.50	492.0	1.50	492.0	.27	.27
25 YR-24 HR	.68	936.0	.68	936.0	.14	.14
50 YR-0.5 HR	3.10	38.0	3.10	38.0	.21	.21
50 YR-1.0 HR	3.52	56.0	3.52	56.0	.27	.27
50 YR-2.0 HR	3.01	84.0	3.01	84.0	.29	.29

Outflow hydrograph decision: ADD1

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No routing perfomed for Pipe Node PN5 hydrograph to Pipe Node PN6

HYDROGRAPH STATISTICS

STORM EVENT	PEAK DISCHARGE Inflow (cfs)	Time (min)	Outflow (cfs)	Time (min)	VOLUME Inflow (acft)	Outflow
25 YR-0.5 HR	44.47	31.0	44.47	31.0	2.58	2.58
25 YR-1.0 HR	46.36	48.0	46.36	48.0	3.17	3.17
25 YR-2.0 HR	38.08	80.0	38.08	80.0	3.32	3.32
25 YR-3.0 HR	33.12	108.0	33.12	108.0	3.50	3.50
25 YR-6.0 HR	35.67	258.0	35.67	258.0	4.61	4.61
25 YR-12 HR	24.34	480.0	24.34	480.0	4.35	4.35
25 YR-24 HR	11.05	936.0	11.05	936.0	2.41	2.41
50 YR-0.5 HR	54.90	31.0	54.90	31.0	3.31	3.31
50 YR-1.0 HR	58.45	46.0	58.45	46.0	4.25	4.25
50 YR-2.0 HR	50.54	76.0	50.54	76.0	4.55	4.55

Outflow hydrograph decision: STORE1

PIPE Qmax

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Storage routing performed through pond at outlet of Watershed SE1#2

STORAGE ROUTING DATA FOR WATERSHED: SE1#2

Input Elevation-Storage-Discharge Curve

ELEVATION (feet)	STORAGE (ac-ft)	DISCHARGE (CFS)
1012.80	.00	.00
1013.80	.11	6.30
1014.80	.92	8.40

Starting water elevation = 1012.80 feet

STORAGE ROUTING STATISTICS

STORM EVENT	PEAK DISCHARGE Inflow (cfs)	Time (min)	Outflow (cfs)	Time (min)	VOLUME Inflow (acft)	Outflow	PEAK ELEV (feet)	STORAGE VOLUME (acft)
25 YR-0.5 HR	3.12	27.0	2.31	38.0	.16	.15	1013.17	.04
25 YR-1.0 HR	3.13	42.0	2.52	56.0	.19	.19	1013.20	.04

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25 YR-2.0 HR	2.43	72.0	2.12	88.0	.20	.20	1013.14	.04
25 YR-3.0 HR	2.08	102.0	1.87	114.0	.21	.21	1013.10	.03
25 YR-6.0 HR	2.22	252.0	2.07	270.0	.28	.28	1013.13	.04
25 YR-12 HR	1.50	480.0	1.43	492.0	.26	.26	1013.03	.02
25 YR-24 HR	.67	936.0	.65	936.0	.13	.13	1012.90	.01
50 YR-0.5 HR	3.98	26.0	2.96	38.0	.20	.20	1013.27	.05
50 YR-1.0 HR	4.16	42.0	3.36	56.0	.26	.26	1013.33	.06
50 YR-2.0 HR	3.32	72.0	2.88	84.0	.28	.27	1013.26	.05

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No routing perfomed for Watershed POND hydrograph to Pipe Node PN6

HYDROGRAPH STATISTICS

STORM EVENT	PEAK DISCHARGE Inflow (cfs)	Time (min)	Outflow (cfs)	Time (min)	VOLUME Inflow (acft)	Outflow (acft)
25 YR-0.5 HR	2.31	38.0	2.31	38.0	.15	.15
25 YR-1.0 HR	2.52	56.0	2.52	56.0	.19	.19
25 YR-2.0 HR	2.12	88.0	2.12	88.0	.20	.20
25 YR-3.0 HR	1.87	114.0	1.87	114.0	.21	.21
25 YR-6.0 HR	2.07	270.0	2.07	270.0	.28	.28
25 YR-12 HR	1.43	492.0	1.43	492.0	.26	.26
25 YR-24 HR	.65	936.0	.65	936.0	.13	.13
50 YR-0.5 HR	2.96	38.0	2.96	38.0	.20	.20
50 YR-1.0 HR	3.36	56.0	3.36	56.0	.26	.26
50 YR-2.0 HR	2.88	84.0	2.88	84.0	.27	.27

Outflow hydrograph decision: ADD1

****

No routing perfomed for Pipe Node PN6 hydrograph to Watershed END

HYDROGRAPH STATISTICS

STORM EVENT	PEAK DISCHARGE Inflow (cfs)	Time (min)	Outflow (cfs)	Time (min)	VOLUME Inflow (acft)	Outflow (acft)
25 YR-0.5 HR	46.53	31.0	46.53	31.0	2.74	2.74
25 YR-1.0 HR	48.69	48.0	48.69	48.0	3.36	3.36
25 YR-2.0 HR	40.12	80.0	40.12	80.0	3.51	3.51
25 YR-3.0 HR	34.92	108.0	34.92	108.0	3.70	3.70
25 YR-6.0 HR	37.69	258.0	37.69	258.0	4.89	4.89
25 YR-12 HR	25.73	480.0	25.73	480.0	4.61	4.61
25 YR-24 HR	11.70	936.0	11.70	936.0	2.55	2.55
50 YR-0.5 HR	57.55	31.0	57.55	31.0	3.51	3.51
50 YR-1.0 HR	61.50	48.0	61.50	48.0	4.51	4.51
50 YR-2.0 HR	53.28	80.0	53.28	80.0	4.83	4.83

Outflow hydrograph decision: STOP

PIPE Qmax

****

FINAL OUTFLOW HYDROGRAPH STATISTICS

71/96

STORM DURATION	PEAK DISCHARGE (cfs)	TIME OF PEAK (minutes)	HYDROGRAPH VOLUME (acft)	ACCUMULATED HYD. VOLUME (acft)
25 YR-0.5 HR	46.53	31.00	2.74	2.75
25 YR-1.0 HR	48.69	48.00	3.36	3.38
25 YR-2.0 HR	40.12	80.00	3.51	3.53
25 YR-3.0 HR	34.92	108.00	3.70	3.71
25 YR-6.0 HR	37.69	258.00	4.89	4.89
25 YR-12 HR	25.73	480.00	4.61	4.61
25 YR-24 HR	11.70	936.00	2.55	2.55
50 YR-0.5 HR	57.55	31.00	3.51	3.52
50 YR-1.0 HR	61.50	48.00	4.51	4.52
50 YR-2.0 HR	53.28	80.00	4.83	4.84

****

SURFACE WATER DITCH - FLOW CAPACITY AND FLOOD STORAGE

73/96

Triangular Channel Analysis & Design
Open Channel - Uniform flow

Worksheet Name: NSP SHERCO POND #3

Comment: SURFACE WATER DTCH-TYP FLOW-BARE SOIL S=0.5%

Solve For Depth

Given Input Data:

Left Side Slope..	3.00:1 (H:V)
Right Side Slope.	50.00:1 (H:V)
Manning's n......	0.022
Channel Slope....	0.0050 ft/ft
Discharge........	4.00 cfs TYPICAL

Computed Results:

Depth............	0.33 ft
Velocity.........	1.42 fps PERMISSIBLE SEE TABLE 10 AND 11-3
Flow Area........	2.81 sf
Flow Top Width...	17.27 ft
Wetted Perimeter.	17.33 ft
Critical Depth...	0.27 ft
Critical Slope...	0.0138 ft/ft
Froude Number....	FULL

74/96

Triangular Channel Analysis & Design
Open Channel - Uniform flow

Worksheet Name: NSP SHERCO POND #3

Comment: SURFACE WATER DTCH-TYP FLOW-BARE SOIL S=1.0%

Solve For Depth

Given Input Data:

Left Side Slope..	3.00:1 (H:V)
Right Side Slope.	50.00:1 (H:V)
Manning's n......	0.022
Channel Slope....	0.0100 ft/ft
Discharge........	4.00 cfs TYPICAL

Computed Results:

Depth............	0.29 ft
Velocity.........	1.84 fps PERMISSIBLE SEE TABLE 10 AND 11-3
Flow Area........	2.17 sf
Flow Top Width...	15.17 ft
Wetted Perimeter.	15.21 ft
Critical Depth...	0.27 ft
Critical Slope...	0.0138 ft/ft
Froude Number....	FULL

Open Channel Flow Module, Version 3.21 (c) 1990
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TABLE 10. Maximum Permissible Mean Velocities Recommended by Fortier and Scobey for Straight, Aged Channels on Small Slope*

Material	Mean velocity, clear water, fps	Mean velocity, silty water, fps
Fine sand, colloidal	1.50	2.50
Sandy loam, noncolloidal	1.75	2.50
Silt loam, noncolloidal	2.00	3.00
Alluvial silts, noncolloidal	2.00	3.50
Ordinary firm loam	2.50	3.50
Volcanic ash	2.50	3.50
Stiff clay, very colloidal	3.75	5.00
Alluvial silts, colloidal	3.75	5.00
Shales and hardpans	6.00	6.00
Fine gravel	2.50	5.00
Graded loam to cobbles, noncolloidal	3.75	5.00
Graded silts to cobbles, colloidal	4.00	5.50
Coarse gravel, noncolloidal	4.00	6.00
Cobbles and shingles	5.00	5.50

*1926 Special Committee on Irrigation, ASCE.

TABLE 11. Permissible Velocities in Cohesive Soils

Material	Loose, fps	Fairly compact, fps	Compact, fps	Very compact, fps
Lean clayey soils	1.2	2.5	3.4	4.4
Clays	1.3	2.8	3.9	5.4
Heavy clayey soils	1.5	3.0	4.1	5.8
Sandy clays (sand<50%)	1.7	3.2	4.3	6.0

TABLE 12. Correction Factors to Be Applied to Permissible Velocity*

Average depth, ft.	Correction factor	Average depth, ft.	Correction factor
1	0.81	6	1.14
2	0.91	7	1.18
3	0.99	8	1.21
4	1.04	9	1.24
5	1.11	10	1.26

*For cohesive and noncohesive soils.

Triangular Channel Analysis & Design
Open Channel - Uniform flow

Worksheet Name: NSP SHERCO POND #2

Comment: DITCH CAPACITY @ SLOPE=0.5% AND DEPTH=1.5 FT

Solve For Discharge

Given Input Data:

Left Side Slope..	3.00:1 (H:V)
Right Side Slope.	50.00:1 (H:V) 2% TOP SLOPE
Manning's n......	0.320
Channel Slope....	0.0050 ft/ft
Depth............	1.50 ft

Computed Results:

Discharge........	16.13 cfs
Velocity.........	0.27 fps NON EROSIVE See TABLE 11-3
Flow Area........	59.63 sf
Flow Top Width...	79.50 ft
Wetted Perimeter.	79.76 ft
Critical Depth...	0.47 ft
Critical Slope...	2.4297 ft/ft
Froude Number....	0.06 (flow is Subcritical)

USE FIGURE 4-5 TO DETERMINE "n" FOR A CLASS "B" GRASSED CHA

Assume depth = 1.5'

FIND VR AND CORRESPONDING "n"

R = FLOW AREA / WETTED PERIMETER

$= 59.63\ ft^2 / 79.76 = 0.748$

$VR = 0.27\ fps \times 0.748 = 0.20$

CORRESPONDING n = 0.32 <u>CHECK</u>

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Triangular Channel Analysis & Design
Open Channel - Uniform flow

Worksheet Name: NSP SHERCO POND #2

Comment: DITCH CAPACITY @ SLOPE=1.0% AND DEPTH=1.5 FT

Solve For Discharge

Given Input Data:

Left Side Slope..	3.00:1 (H:V)
Right Side Slope.	50.00:1 (H:V)
Manning's n......	0.300
Channel Slope....	0.0100 ft/ft
Depth............	1.50 ft

Computed Results:

Discharge........	24.33 cfs
Velocity.........	0.41 fps NON EROSIVE SEE TABLE 11-3
Flow Area........	59.63 sf
Flow Top Width...	79.50 ft
Wetted Perimeter.	79.76 ft
Critical Depth...	0.55 ft
Critical Slope...	2.0216 ft/ft
Froude Number....	0.08 (flow is Subcritical)

USE Figure 4-5 TO DETERMINE "n" FOR A CLASS "B" GRASSED CHANNEL

Assume depth = 1.5'

$$VR = 0.41\ \text{fps} \times \left(59.63\ \text{ft}^2 / 79.76\ \text{ft}\right)$$

$$= 0.31$$

CORRESPONDING "n" = 0.30 <u>check</u>

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channels" described at the end of the table clearly cover such a wide range of conditions that some field experience is desirable before a value of n can be estimated with reasonable confidence. However, the photographs given by Ven Te Chow [6] form a useful supplement to, or even substitute for, field experience.

The last entry in the table gives the result of Eq. (4–22), applicable mainly to alluvial channels of coarse noncohesive gravel or cobbles (known as *shingle* in British countries). The D-75 size may be taken as a good approximation to the value of d (larger than the median) with which the bed tends to become armored.

The reader will easily be able to verify that the values of k_s in Table 4–1 are generally consistent, via Eq. (4–22), with the above values of n.

When the channel bed and banks are thickly covered with vegetation an appreciable part of the flow takes place through the vegetation at low velocities. If the growth is of fine material such as grass the Reynolds number Re defined with respect to the stalk thickness will be low, and the resistance, and therefore the Manning n, will be dependent on Re. Since n will therefore depend on the velocity, it may possibly depend on Re defined with respect to the channel size as well as with respect to the stalk thickness. This has been shown to be true by the experiments of the U. S. Soil Conservation Service [3];

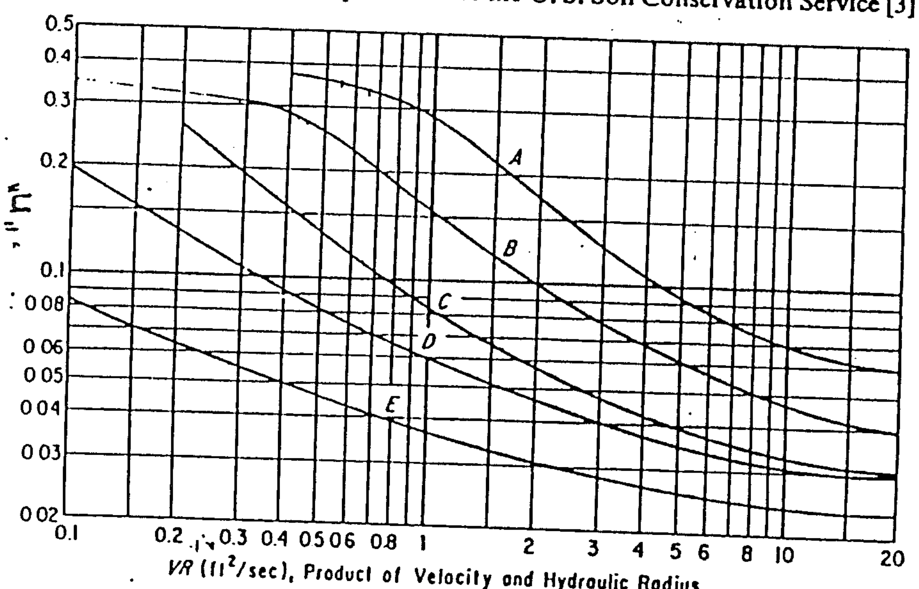


Figure 4-5. The Behavior of Manning's n in Grassed Channels

their results, for a number of North American grass species, are summarized in Fig. 4-5. The division into classes depends mainly on the length and the "stand"—i.e., the vigour and thickness of growth, according to the following table:

'PEN CHANNEL FLOW – HENDERSON

TABLE 4–3

Average length of grass	*Class* Good stand	Fair stand
More than 30 in.	A	B
11–24 in.	B	C
6–10 in.	C	D
2–6 in.	D	D
less than 2 in.	E	E

Wide shallow grassed channels are a popular solution to the problem passing large discharges down steep slopes without developing unduly l velocities.

4.3 Uniform Flow: Its Computation and Applications

Significance of Uniform Flow

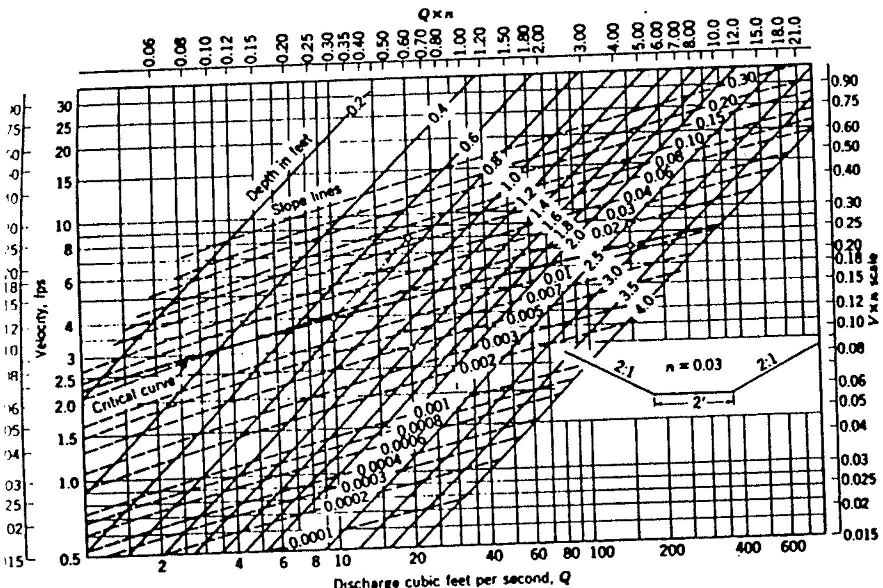
Uniform flow has now been defined and a dynamic equation develop the Manning equation—which adequately describes both uniform and uniform flow.

Uniform flow seldom occurs in nature, since natural channels are usu irregular. Even in artificial channels of uniform section, the occurrenc uniform flow may be relatively infrequent because of the existence of cont such as weirs, sluice gates, etc., which dictate a depth-discharge relation different from that appropriate to uniform flow.

However, uniform flow is a condition of such basic importance that it be considered in all channel-design problems. For example, if it is prop to instal certain controls in an irrigation canal it is necessary to compare depth-discharge relation with those of uniform flow; as we shall see, the w character of the flow in the canal will depend on the form this compar takes. Again, if a canal is to be laid on a certain slope, is to have a lining certain coefficient n, and is to take a certain discharge, then the uniform-condition is the criterion governing the *minimum* cross-sectional area requi Other criteria may of course determine that the section must be greater this minimum, but the section cannot conceivably be any smaller or the c will be unable to take the required discharge.

Economical Design of a Channel Cross Section

A typical uniform-flow problem in the design of artificial canals is economical proportioning of the cross section. A al having a gi Manning coefficient n and slope S_0 is to carry a ... discharge Q,



11–5. Flow in a trapezoidal channel with 2-ft flat bottom and sides on 2:1 slopes. ical depth is independent of channel roughness and must be read only from Q scale; ical slope is dependent on channel roughness and is read at intersection of critical ıth and vertical line $Q \cdot n$. (Source: *FHWA Hydraulic Design Series No. 3.*)

xample 1. Given: Discharge. $Q = 150$ ft³/s; roughness, $n = 0.03$; slope, $S = 0.02$. ıd upward from $Q = 150$ to intersection with $S = 0.02$, and find normal depth, d_n 2.5 ft and normal velocity, $V_n = 8.5$ ft/s. Also, for $Q = 150$, critical depth, $d_c = 2.8$ critical velocity; $V_c = 7.0$ ft/s, and critical slope, $S_c = 0.013$ or 1.3%. Thus flow is su- ıcritical and control is upstream.

Example 2. Given: Discharge, $Q = 10$ ft³/s, roughness, $n = 0.06$; slope, $S = 0.5\%$ 0.005. Read down from $Q \times n = 10 \times 0.06$ or 0.6 to slope, $S = 0.005$, and find rmal depth, $d_n = 1.4$ ft and $V \cdot n = 0.09$. Compute $V = 0.09/0.06 = 1.5$ ft/s. To find tical depth and critical velocity for 10 ft³/s discharge, read upward from $Q = 10$ to itical depth, $d_c = 0.72$ ft, and critical velocity, $V_c = 4.0$ ft/s. Critical slope for rough- ss, $n = 0.06$ is read at intersection of diagonal line $d_c = 0.72$ and $Q \cdot n = 0.6$ and uals 0.07 or 7%

ound with cement mortar is another effective means of channel protection, articularly for roadside ditches. It is rough and has high erosion resistance but ay be costly, as the individual stones are laid by hand. Paving with concrete r dense-graded bituminous mixtures is often done on small and large channels ... these linings can be placed successfully on steep side slopes and have

HIGHWAY ENGINEERING, Oglesby + Hicks

TABLE 11–3. Maximum Safe Velocities When Channel Erosion Is To Be Prevented.

Type of Lining	*Allowable Velocity (ft/s)*
Well-established grass on any good soil	6
Meadow type of grass with short, pliant blades, heavy stand, such as bluegrass	5
Bunch grasses, exposed soil between plants	2–4
Grains, stiff-stemmed grasses that do not bend over under shallow flow	2–3
Earth without vegetation:	
Fine sand or silt, little or no clay	1–2
Ordinary firm loam	2–3
Stiff clay, highly colloidal	4
Clay and gravel	4
Coarse gravel	4
Soft shale	5

pation must be made at the lower end of the channel unless discharge is into a rocky stream bed or into a pool deep enough to force a hydraulic jump.[20]

Streams carrying sediment bring particularly difficult channel-design problems. It has been established that the ability of water to transport solids along the stream bed varies as a power of the velocity greater than the square. It follows that any sizable velocity decrease will cause the stream to drop part of its load. This debris may clog the channel or fill culverts, causing troublesome and sometimes costly overflow and heavy maintenance expense. The most acceptable solution is to design channels and structures so that the upstream velocity is equaled or exceeded throughout. Then the sediments will be transported on past the highway as before. In situations where the initial velocity cannot be maintained, sediments may be trapped in strategically placed debris basins designed for easy cleaning with mechanical equipment.

At times highway improvements require that existing streams be transferred to new channels. For example, stream alignment may be straightened as in Fig. 6–3. Again the road may intersect a stream twice as it cuts directly across a meander or looping bend. Here the first cost is often far less to carry the stream in a channel paralleling the road than to construct two bridges or culverts. Changes like these increase the slope of the channel and often improve its hydraulic properties. Both measures bring increased velocity unless the excess energy is absorbed by means of drops or other devices. Without such controls, unstable conditions are set up in streams having erodible beds. During succeeding storms, the current will cut and fill until a new balance is established. Often these adjustments in grade and alignment are sizable in amount and extend far

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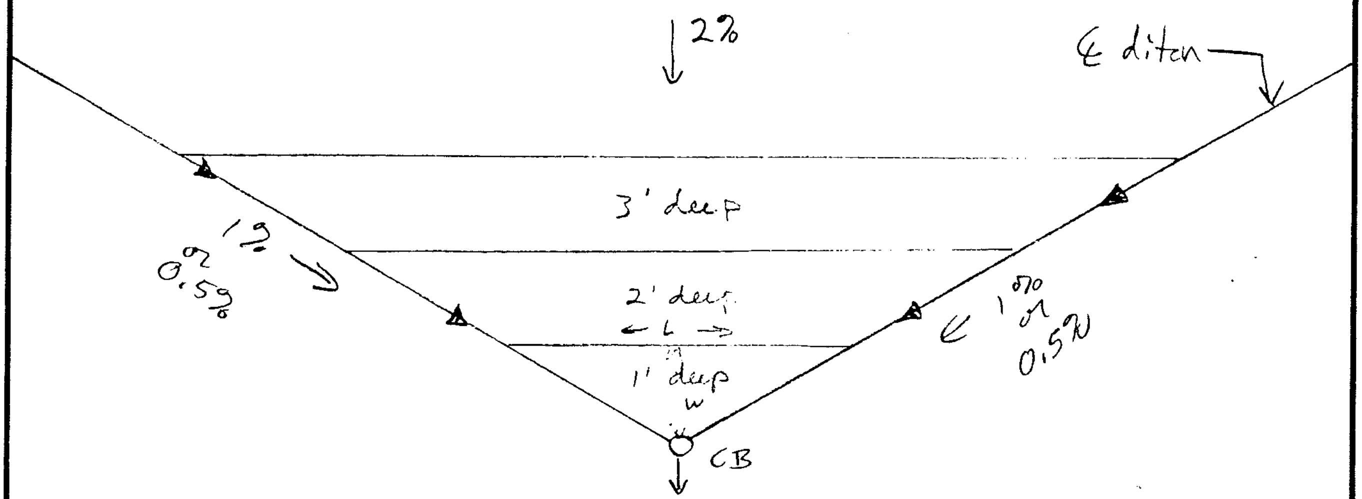
TOP SLOPE STORAGE - TYPICAL



$Vol = \frac{1}{2} A \times depth$

$A = \frac{1}{2} L \times W$

$W = d/.02$

$L = 2 \times d/.01$ or $2 \times d/.005$

$A = \frac{1}{2}(d/.02)(2d/.01)$ or $\frac{1}{2}(d/.02)(2d/.005)$

DITCH SLOPE = 1%

d	W ft	L ft	A ft²	Vol
1.0	50	200	5000	0.05 ac-ft
2.0	100	400	20,000	0.45
3.0	150	600	45,000	1.55

DITCH SLOPE = 0.5%

d	W	L	A	Vol
1.0	50	400	10,000	0.11 ac ft
2.0	100	800	40,000	0.92 ac ft
3.0	150	1200	90,000	3.10

* ADJUST STORAGE VOLS. FOR NON-SYMETTRICAL DITCH LAYOUTS

81/96

PIPE AND CATCH BASIN INLET CAPACITIES

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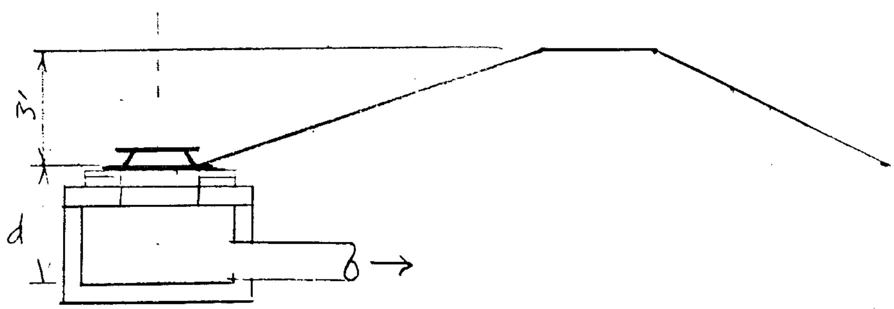

$Q_{WEIR} = 3.3P(h)^{1/2}$

$Q_{ORIFICE} = 0.6A\sqrt{2gh}$

d = 3' for 12" pipe out
d = 4' for 18" + 24" pipes out

- INLET CAPACITY OF CASTING (NEENAH R-4341)
  P = PERIMETER = 5.8' A = OPEN AREA = 2.6 ft^2 (22" OPENING)

(h) HEAD	Q_{WEIR}	Q_{ORIF}	Q ½ PLUG
0.5'	6.8 CFS	8.9 cfs	3.4
1.0	19	12.6	6.3
2.0		17.8	8.9
3.0		21.7	10.8

- INLET CAPACITY OF OUTLET PIPE

HW	12" HW/D	Q	18" HW/D	Q	24" HW/D	Q
1.0	1.0	2.2	0.67	3.5	0.5	4.5
2.0	2.0	4.5	1.33	9.0	1.0	13
3.0	3.0	6.0	2.0	12.5	1.5	20
4.0	4.0	7.2	2.67	15.0	2.0	25
5.0	5.0	8.4	3.33	17.5	2.5	30
6.0	6.0	9.2	4.0	20.0	3.0	35
7.0			4.67	22		

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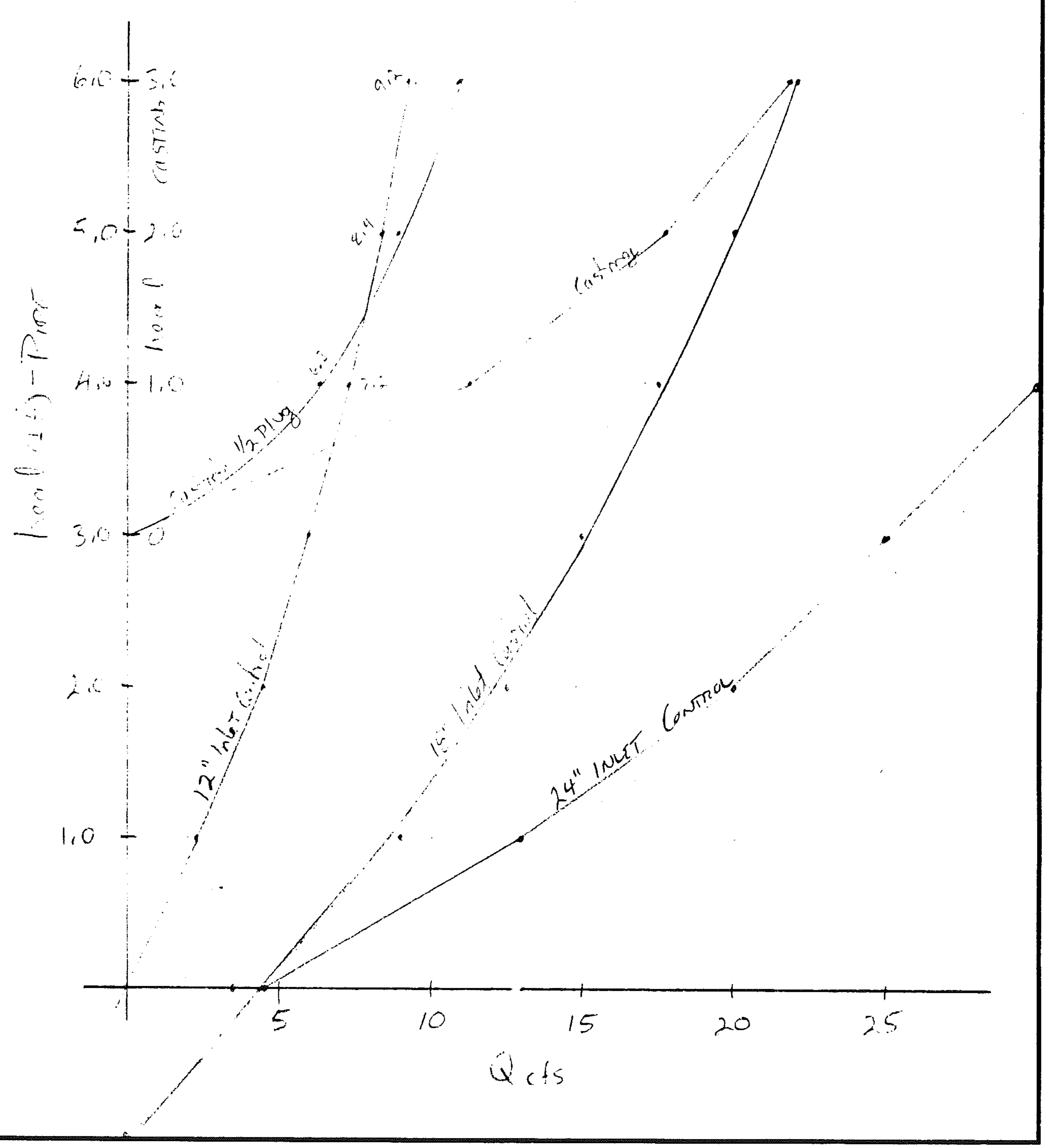


84/01

FULL FLOW PIPE CAPACITIES

85/96

Circular Channel Analysis & Design
Solved with Manning's Equation

Open Channel - Uniform flow

Worksheet Name: NSP SHERCO POND #3

Comment: 12" RC PIPE CAPACITY AT SLOPE = 2.0%

Solve For Full Flow Capacity

Given Input Data:

Diameter..........	1.00 ft
Slope.............	0.0200 ft/ft
Manning's n.......	0.010
Discharge.........	6.55 cfs

Computed Results:

Full Flow Capacity.....	6.55 cfs
Full Flow Depth........	1.00 ft
Velocity..........	8.34 fps
Flow Area.........	0.79 sf
Critical Depth....	0.97 ft
Critical Slope....	0.0176 ft/ft
Percent Full......	100.00 %
Full Capacity.....	6.55 cfs
QMAX @.94D........	7.05 cfs
Froude Number.....	FULL

88/96

Circular Channel Analysis & Design
Solved with Manning's Equation

Open Channel - Uniform flow

Worksheet Name: NSP SHERCO POND #3

Comment: 18" PE PIPE CAPACITY AT SLOPE = 11.0%

Solve For Full Flow Capacity

Given Input Data:

Diameter..........	1.50 ft
Slope.............	0.1100 ft/ft
Manning's n.......	0.010
Discharge.........	45.29 cfs

Computed Results:

Full Flow Capacity.....	45.29 cfs
Full Flow Depth........	1.50 ft
Velocity..........	25.63 fps
Flow Area.........	1.77 sf
Critical Depth....	1.50 ft
Critical Slope....	0.1073 ft/ft
Percent Full......	100.00 %
Full Capacity.....	45.29 cfs
QMAX @.94D........	48.72 cfs
Froude Number.....	FULL

89/96

Circular Channel Analysis & Design
Solved with Manning's Equation

Open Channel - Uniform flow

Worksheet Name: NSP SHERCO POND #3

Comment: 18" RC PIPE CAPACITY AT OUTLET

Solve For Full Flow Capacity

Given Input Data:

Diameter..........	1.50 ft
Slope.............	0.0033 ft/ft
Manning's n.......	0.012
Discharge.........	6.54 cfs

Computed Results:

Full Flow Capacity.....	6.54 cfs
Full Flow Depth........	1.50 ft
Velocity..........	3.70 fps
Flow Area.........	1.77 sf
Critical Depth....	0.99 ft
Critical Slope....	0.0055 ft/ft
Percent Full......	100.00 %
Full Capacity.....	6.54 cfs
QMAX @.94D........	7.03 cfs
Froude Number.....	FULL

90/96

Circular Channel Analysis & Design
Solved with Manning's Equation

Open Channel - Uniform flow

Worksheet Name: NSP SHERCO POND #3

Comment: 21" RC PIPE CAPACITY AT OUTLET

Solve For Full Flow Capacity

Given Input Data:

Diameter..........	1.75 ft
Slope.............	0.0033 ft/ft
Manning's n.......	0.012
Discharge.........	9.86 cfs

Computed Results:

Full Flow Capacity.....	9.86 cfs
Full Flow Depth........	1.75 ft
Velocity..........	4.10 fps
Flow Area.........	2.41 sf
Critical Depth....	1.17 ft
Critical Slope....	0.0053 ft/ft
Percent Full......	100.00 %
Full Capacity.....	9.86 cfs
QMAX @.94D........	10.61 cfs
Froude Number.....	FULL

x½x±½x±½½½x±xÁ½½½½xÁxÁx±

91/96

Circular Channel Analysis & Design
Solved with Manning's Equation

Open Channel - Uniform flow

Worksheet Name: NSP SHERCO POND #3

Comment: 24" RC PIPE CAPACITY AT OUTLET

Solve For Full Flow Capacity

Given Input Data:

Diameter..........	2.00 ft
Slope.............	0.0033 ft/ft
Manning's n.......	0.012
Discharge.........	14.08 cfs

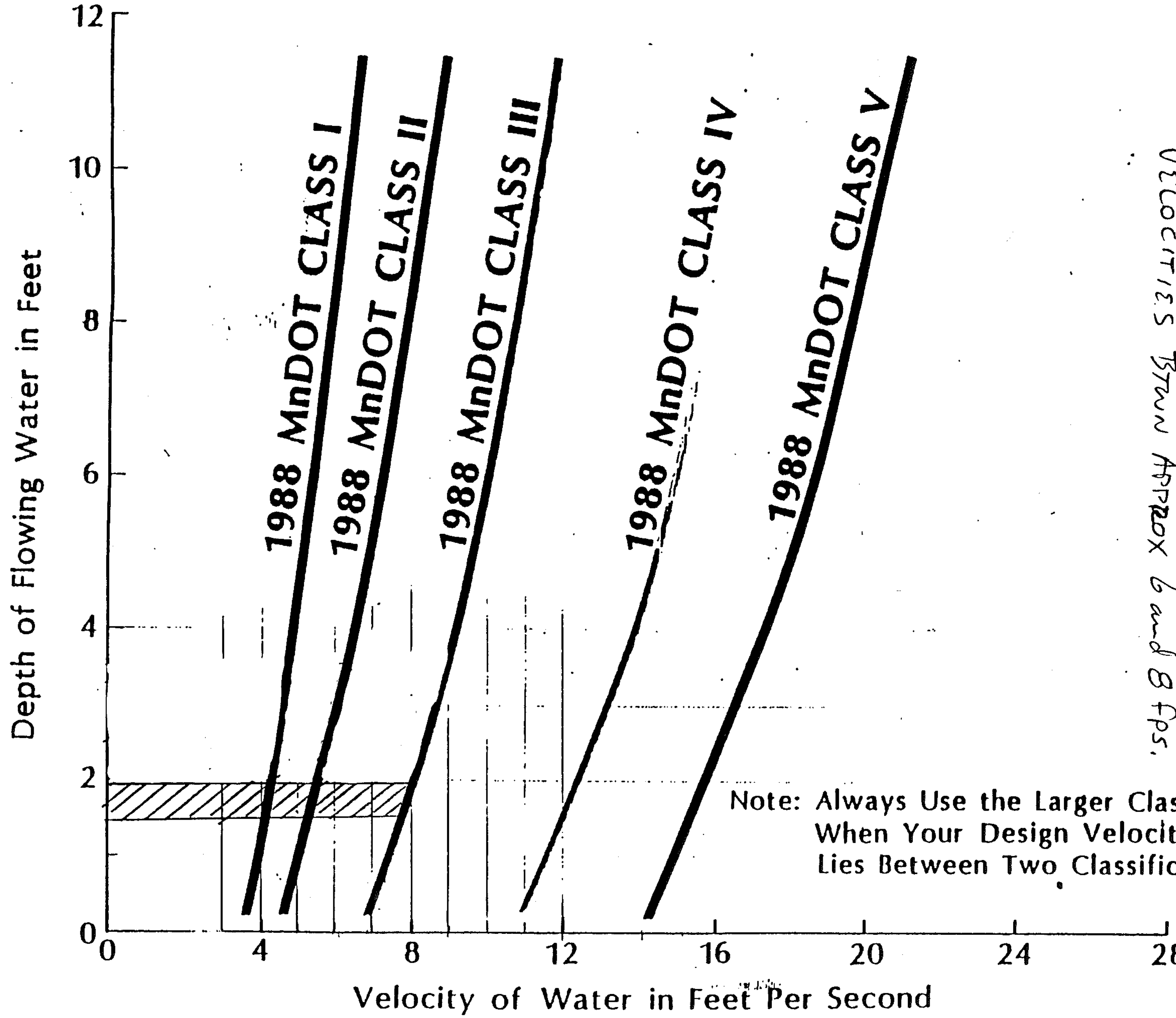
Computed Results:

Full Flow Capacity.....	14.08 cfs
Full Flow Depth........	2.00 ft
Velocity..........	4.48 fps
Flow Area.........	3.14 sf
Critical Depth....	1.35 ft
Critical Slope....	0.0052 ft/ft
Percent Full......	100.00 %
Full Capacity.....	14.08 cfs
QMAX @.94D........	15.14 cfs
Froude Number.....	FULL

92/

RIPRAP SIZING

RIPRAP NOMOGRAPH FOR MINNESOTA DEPARTMENT OF TRANSPORTATION CLASSIFICATIONS



NSP Sherco Pond #3

Outlet Pipe Sizes 18" → 21"

∴ depth of flow = 1.5' → 1.75'

Use Cl III Riprap for outlet velocities btwn approx 6 and 8 fps.

USED TO DETERMINE RIPRAP CLASS @ CULVERTS

94/a.

SEDIMENTATION BASIN SIZING

BARR ENGINEERING CO.

NSP Sherco Pond #3

CHECKED BY
DATE

NAME KAL
DATE 2-14-95
SHEET ____ IN SET
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SEDIMENTATION PONDS

ASSUME MATERIAL EXCAVATED TO CREATE SED. PONDS IS USED AS RANDOM FILL FOR CONSTRUCTION OF THE FINAL COVER SYSTEM.

ASSUME PONDS HAVE NO OUTLET PIPES.
SOILS ARE HIGHLY PERMEABLE ∴ INFILTRATION/EVAPOR. WILL BE THE PRIMARY "Outlet".

OVERFLOW FROM THE PONDS WILL TRAVEL OVERLAND AND EVENTUALLY FLOW INTO THE MISS. RIVER.

SIZE BASINS TO HOLD THE 25YR PEAK VOLUME. THE VOL. IS FROM THE BARR MODEL OUTPUT.

- N 1/2 OF WEST SLOPE DRAINS TO POND CONSTRUCTED FOR POND #2
- S 1/2 OF WEST SLOPE DRAINS TO POND CONSTRUCTED FOR POND #2
  - * BOTH THESE SED PONDS WILL NEED TO BE ENLARGED TO STORE ADD'L VOLUME

    TOTAL Pond #2

    N POND ADD'L VOLUME = 1.9 ac-ft (3.9 − 2.0 = 1.9)

    S POND ADD'L VOLUME = 2.4 ac-ft (4.9 − 2.5 = 2.4)

- N + S SLOPES CAN BE DIVERTED TO ABOVE REF. PONDS OR NEW SED PONDS CAN BE CONSTRUCTED Vol_{25yr} = 0.85 ac-ft

- CONSTRUCT NEW SED POND FOR EAST SLOPE
  Vol_{25yr} = 1.17 x 3 = 3.51 ac-ft

CONFIGURATION

MAKE NARROW AND LONG − EXCAVATE w/ SCRAPER

USE $100'_{Avg}$ width, 4' water depth + 1 ft for Sed Storage = 5'

N Pond Add'l Vol	$Length_{Ave}$ =	1.9 ac-ft ÷ 4 x 43560 ÷ 100' = 210'
S Pond Add'l Vol	$Length_{Ave}$ =	2.4 ac-ft ÷ 4 x 43560 ÷ 100' = 260'
N+S Pond	$Length_{Ave}$ =	0.85 ÷ 4 x 43560 ÷ 100 = 95'
E Pond	$Length_{Ave}$ =	3.5 ÷ 4 x 43560 ÷ 100 = 380'

TABLE 23
SETTLING VELOCITIES OF SELECTED PARTICLES (After Hazen)

Kind of Material	Particle Diameter (microns)	Settling Velocity (cm/sec)
Coarse sand	1,000	10.0
Coarse sand	200	2.1
Fine sand	100	0.8
Fine sand	60	0.38
Fine sand	40	0.21
Silt	10	0.015
Coarse clay	1	0.00015
Fine clay	0.1	0.0000015

TABLE 24
MINIMUM SEDIMENT-BASIN AREA REQUIREMENTS FOR SELECTED PARTICLES (1 cfs Outflow Rate)

Kind of Material	Particle Diameter (micron)	Minimum Area Required (sq ft)/CFS
Coarse sand	1,000	3.0
Coarse sand	200	14.5
Fine sand	100	38.2
Fine sand	60	80.0
Fine sand	40	145.0
Silt	10	2,030.0
Coarse clay	1	203,000.0
Fine clay	0.1	20,300,000.0

feet; an outflow rate of 2.0 cfs requires at least 160.0 square feet. Actual area required will be greater than that given in the table since the calculated areas assume ideal conditions.

In order to put these figures into use, the range of sizes for sediment particles must be known. A typical sediment analysis is as shown in Table 25, Typical Sediment Sample Analysis.

A pond with an outflow of 40 cfs will require about 81,200 square feet of surface area to remove particles of 10 microns, removing all but 10 percent of the sediment load. Particles of a 40-micron size will require about 5,800 square feet for sedimentation, removing all but about 12 percent of the sediment load. Removal of the additional 2

TABLE 25
TYPICAL SEDIMENT SAMPLE ANALYSIS

Size (Microns)	Percent Finer
250	99
150	95
100	91
40	12
8	7
3	6
1	2

percent of the total sediment, therefore, requires an extra ponding area of 75,400 square feet, an area about 13 times greater than the initial area. It must be emphasized that this computed area is theoretical, because the flow rate often will not be as high as the maximum discharge rate, and the collection efficiency of the pond will be increased for lower-than-peak flow discharge velocities.

FROM APWA

PRACTICES IN DETENTION OF URBAN STORMWATER

SPECIAL REPT #43

1974

POND	AREA	Assume $Q_{IN}=Q_{OUT}$ 25 YR	ft²/cfs
N	21,000 ft²	37 cfs	567 ft²/cfs
S	26,000	49 cfs	531 ft²/cfs
N+S	9,500	9 cfs	1055 ft²/cfs
E	38,000	36 cfs	1055 ft²/cfs

Construction Quality Assurance Plan
Scrubber Solids Pond No. 3
NPDES Permit No. 0002186
Sherburne County Generating Plant
Northern States Power Company
(dba Xcel Energy, Inc.)

Prepared for

Xcel Energy

June 2002

Prepared by

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Construction Quality Assurance Plan
Scrubber Solids Pond No. 3
NPDES Permit No. 0002186
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List of Tables

Section 1—Introduction

This plan presents the quality assurance and quality control activities that will be conducted for construction of the proposed Scrubber Solids Pond No. 3 at Northern States Power Company's (dba Xcel Energy, Inc.) Sherburne County Generating Plant (Sherco) in Becker, Minnesota. The location of the facility is presented on the construction drawings. Table 1 presents the frequency of construction material tests. Table 2 summarizes construction material test requirements.

The testing and surveying defined in this plan will assist in evaluation of the quality and quantity of construction materials placed, and will provide guidelines for documenting test results which may be used for professional certification. Contractor-performed testing will be conducted as described in the Contract Documents for each construction project.

An overview of the construction planned for the facility is presented in Section 2. Section 3 describes standard soil testing procedures. Section 4 discusses preconstruction and construction testing of materials. Section 5 describes the material thickness testing. Section 6 describes the quality control measures for installation of the geosynthetic clay liner (GCL). Geomembrane material testing for liner and cover construction are discussed in Section 7. Section 8 describes the method for placement of the drainage layer over the geomembrane. Section 9 describes the electrical leak detection testing used to survey the integrity of the geomembrane after placement of the overlying drainage layer. Section 10 describes the inspection of the discharge structures and dewatering system. Sections 11 and 12 describe inspection of vegetation and surface-water drainage systems, respectively. Section 13 discusses the method of documentation and data presentation. Acceptable test results and responses to failed tests are presented in Section 14.

Section 2—Construction Overview

Construction activities related to this plan include Pond 3 composite Geosynthetic Clay Liner (GCL) overlain by a geomembrane liner, upstream dike construction with a select clay barrier core, final cover construction, and other related features. Reference should be made to the Contract Drawings and Technical Specifications for details of construction requirements on each phase.

Pond 3 lined space development will be constructed in six (6) separate phases as described in the Engineering Report. Material used for construction of the various Pond 3 phases and construction of new discharge structures will include GCL, geomembrane, granular drainage material, vegetative soils, piping, concrete, and manholes.

Final cover construction activities will be completed in phases as the pond reaches final plan elevations. Final cover construction materials will include geomembrane, sand, rooting soil, topsoil, and surface water management controls.

Section 3—Standard Soil Testing Procedures

The material properties that will be tested, and the analytical methods to be used for testing soils used in the construction of the pond are listed below for reference and will apply as appropriate:

A) **Particle Size Distribution**

Particle size distribution according to American Society for Testing and Materials (ASTM) (most recent version) D421 (Dry Preparation of Soil Samples for Particle-Size Analysis and Determination of Soils), and ASTM D2217 (Wet Preparation of Soil Samples for Particle- Size Analysis and Determination of Soil Constants);

B) **Percent Fines**

Percent fines according to ASTM Dl140 (Amount of Material in Soils Finer than the No. 200 Sieve);

C) **Atterberg Limits**

Atterberg limits according to ASTM D4318 (Liquid Limit, Plastic Limit, and Plasticity Index of Soils -NOTE: This ASTM designation replaced ASTM D423 and ASTM D424 in 1983.), and ASTM D427 (Shrinkage Factors of Soils);

D) **Specific Gravity**

Specific gravity according to ASTM D854 (Specific Gravity of Soils);

E) **Soil Description and Classification**

Unified Soils Classification System soil description and classification according to ASTM D2488 (Standard Practice for Description and Identification of Soils [Visual-Manual Procedure]);

F) **Lab Test Soil Classification**

Soil classification according to ASTM D2487 (Classification of Soils for

Engineering Purposes);

G) Water Content

Water content according to ASTM D2216 (Laboratory Determination of Water Content of Soil, Rock, and Soil-Aggregate Mixtures) and ASTM D3017 (Moisture Content of Soil and Soil-Aggregate in Place by Nuclear Methods [Shallow Depth]);

H) Moisture-Density

Moisture-density according to ASTM D698 (Moisture-Density Relations of Aggregate Mixtures Using 5.5-lb Rammer and 12-in Drop) or ASTM D1557 (Moisture-Density Relations of Soil and Soil-Aggregate Mixtures Using 10-lb Rammer and 18-in Drop);

I) Consolidation

Consolidation according to ASTM D2435 (One-Dimensional Consolidation Properties of Soils);

J) Permeability

Permeability according to ASTM D2434 (Permeability of Granular Soils) and flexible wall falling head permeability according to U.S. Army Corps of Engineers Method or ASTM D5084;

K) Unconfined Compression

Unconfined compression according to ASTM D2166 (Unconfined Compressive Strength of Cohesive Soil);

L) Triaxial Compression

Triaxial compression according to ASTM D2850 (Unconsolidated, Undrained Compressive Strength of Cohesive Soils in Triaxial Compression);

M) Nutrient Content, pH, Percent Organic Matter

Nutrient content, pH, and percent organic matter testing according to Recommended Chemical Soil Test Procedures for the North Central Region, North Dakota State University Agricultural Experiment Station, Fargo, North Dakota, Bulletin No.499 (Revised).

The tests which will be performed on construction materials are listed in the tables at the end of this plan. Tests listed above which are appropriate for material used in construction will be performed.

Minimum frequency testing requirements are presented in Table 1. Additional testing will be performed on materials that exhibit inconsistent characteristics in composition or substance, and in response to failed testing results.

4.1 Preconstruction Testing

Prior to construction, testing may be performed on select clay, granular drainage material, rooting soil and topsoil as identified in Table 1. The purpose of these tests is to demonstrate that the soil can meet the requirements of the Technical Specifications. The results of the preconstruction testing will be submitted to the MPCA prior to construction, if available. However, primary reliance will be on testing of materials that are transported to the site for use in construction.

4.1.1 Select Clay

Select clay will be used for construction of the upstream barrier. The following tests will be conducted on borrow area samples for the select clay material:

a. Atterberg Limits ASTM D4318,
b. Moisture-Density ASTM D698,
c. Compacted Falling Head Permeability according to U.S. Army Corps of Engineers Method or ASTM D5084, and
d. Soil Description and Classification ASTM D2488.

The above tests will be conducted prior to mining to verify that the clay can meet the requirements defined in the Technical Specifications for construction.

4.1.2 Granular Drainage Material

A representative preconstruction sample of granular drainage material from each source will be tested using a particle size distribution test ASTM D421, D422, D2217 or percent fines and a laboratory hydraulic permeability test according to ASTM D2434.

4.1.3 Topsoil

Topsoil may be obtained from on-site or off-site sources. Organic matter and pH testing will be conducted on each source prior to placement.

4.2 Construction Testing

Final cover and liner materials will be tested and observed at the frequencies defined in Table 1 to assist in evaluating conformance to the Technical Specifications during placement.

4.2.1 Common Borrow

Common borrow will be used for construction of roadways, dikes, berms, and to level subgrade prior to placement of the liner and/or final cover materials. The material may be obtained from an on-site source. The following tests will be performed on in-place common borrow samples:

a. Description and Identification of Soils ASTM D2488

b. Mn/DOT Ordinary Compaction Observation

4.2.2 Select Clay

In-place density and moisture content testing will be used to assess the effectiveness of placement of select clay. Permeability testing will be conducted on extruded cores of in-place samples to verify that the permeability requirements are met. The tests used will be as follows:

a. Density-Sand Cone or Nuclear -ASTM D1556 or D2922

b. Moisture Content -ASTM D2216 or D3017

c. Falling Head Permeability Test -U.S. Army Corps of Engineers or ASTM D5084

d. Atterberg Limits

e. #200 Sieve and Hydrometer test

f. Description and Classification

The sand cone or nuclear density tests shall be conducted at the frequency shown in Table 1. representative moisture-density relationship will be provided for each in-place moisture and density test. Sufficient description, particle size, Atterberg limits, and moisture density tests will be conducted to determine the representative moisture-density relationship.

The permeability tests will be performed on extracted, 3-inch minimum diameter, thin-wall tube samples from the in-place clay. The holes from the extracted thin-wall tubes will be filled with clay, or wetted in-place bentonite pellets and hand-compacted with a tamping rod.

4.2.3 Coarse Filter Aggregate/Fine Filter Aggregate

A representative qualification sample of the coarse and fine filter aggregates to be supplied by the contractor will be tested using particle size distribution test ASTM D421, D427, D2217 or percent fines before the material is brought to the site. The material brought to the site will be visually compared to the qualification sample. Particle size testing may be conducted on the material brought to the site.

4.2.4 Rooting Soil

Rooting soil will be described in-place in accordance with ASTM D2488. It is anticipated that the material will be obtained from an on-site source.

Minnesota Department of Transportation ordinary compaction (visual inspection method) will be used to monitor the compaction of the rooting soil during placement.

4.2.5 Concrete

Batch plant slips from each truck that delivers concrete will be checked for conformance to technical specifications. On-site tests will include slump and percent air. Cylinders will be made for future compression testing activities.

Section 5—Soil Thickness Testing

This section discusses the methods of measuring the thickness of select clay, granular drainage material, rooting soil, and topsoil during placement. Locations for measuring the thickness of the cover and drainage layer materials are listed in Table 1. Required minimum thicknesses for the materials are presented in Table 2.

5.1 Select Clay

The thickness of select clay in the upstream barrier will be measured horizontally by surveying the inside and outside of the barrier layer at 100-foot intervals along the alignment of the dikes. At every interval, the clay barrier thickness will be measured at 2-foot vertical increments.

5.2 Granular Drainage Material

The granular drainage material thickness will be measured by using a marked soft wood probe with a blunt end. The blunt end of the probe will be inserted in the granular drainage material until the probe is resisted by the underlying barrier layer. The length of probe that enters the ground will be measured and recorded as the granular drainage material depth at that point.

5.3 Rooting Soil and Topsoil

Rooting soil placement will be monitored by using grade stakes or by digging test holes and measuring. The topsoil thickness will be measured by digging test holes to verify that a minimum of 6 inches exists above the rooting soil material. The combined rooting soil and topsoil thickness will be measured to determine if the specified thickness exists over granular drainage material placed for final cover.

Section 6—Geosynthetic Clay Liner (GCL) Installation

Prior to installation of the GCL, the subgrade will be smooth graded and free of vegetation, sharp-edged rocks stones, sticks, or other foreign matter. The GCL installer will inspect the subgrade prior in installation of the GCL, and will approve the subgrade by signing the subgrade acceptance form included in the Technical Specifications for construction.

Prior to installation, the GCL manufacturer will submit documentation for the GCL rolls to be used on the project. Submittals will include the test results and roll information as required by the Technical Specifications. The Owner or Owner's representative will review all submittals to verify the GCL meets the minimum requirements for use in the project. GCL rolls without proper documentation will not be allowed to be installed.

GCL will be installed as recommended by the manufacturer and as required by the Technical Specifications. The Owner will have full-time qualified field personnel on site at all times during construction to observe and document the installation procedures. The number of on-site field personnel will be increased as necessary to insure full-time continuous observation of the installer's work.

The GCL installer is required to submit a proposed panel and seam layout diagram, which will be reviewed by the Engineer. On-site personnel will insure the GCL is installed in accordance with the panel layout. During start-up of the GCL installation, an agent or representative of the manufacturer will be on site to provide assistance and instruction regarding product installation.

On-site personnel will observe and document panel placement, overlap, seaming, pipe penetrations, and repair patches as part of the construction quality assurance program. All observations will be documented and reported in the documentation report as described in Section 13. GCL roll certificati ,and submittals will also be included in the report.

Section 7—Geomembrane Testing

7.1 Geomembrane Cover

A geomembrane will be used as the barrier layer for final cover construction. The geomembrane will consist of a 40 mil LLDPE geomembrane material, or an Owner approved alternate. Prior to installation of the material, the entire installation area will be observed and approved by the installer in writing, using the Certificate of Geomembrane Subgrade Acceptance presented in the Contract Documents. The anchor trench locations will be field surveyed. Field seam testing will be conducted by the geomembrane installer as required in the technical specifications for construction. All field seams will be tested, and results will be recorded and reviewed by the Owner or Owner's on site representative. Seam testing will be observed by the Owner or Owner's on site representative, and results will be presented in the documentation report as described in Section 13.

7.2 Geomembrane Liner

The geomembrane used for liner construction will consist of a 60 mil HDPE geomembrane or an Owner approved alternate. Prior to installation of the material, the entire installation area will be observed and approved by the installer in writing, using the Certificate of Geomembrane Subgrade Acceptance presented in the Contract Documents. The anchor trench locations will be field surveyed. Prior to placement of the drainage layer over the geomembrane liner, field seam testing will be conducted by the geomembrane installer as required in the technical specifications for construction. All field seams will be tested, and results will be recorded and reviewed by the Owner or Owner's on site representative. Seam testing will be observed by the Owner or Owner's on site representative, and results will be presented in the documentation report as described in Section 13.

Section 8—Drainage Layer Installation

After the geomembrane has been installed and tested as described in the preceding section, the drainage layer will be placed over the geomembrane. Xcel Energy will continue to provide an adequate number of qualified field personnel during the installation to observe and document the installation procedure, and to insure the material is placed in accordance with the Technical Specifications.

Cover material will be a granular type material with the ability to convey liquids to the dewatering pipes during the dewatering phase of pond operations. Preconstruction testing will be performed on the material to insure it meets the requirements of the Technical Specifications.

Inspectors will observe and document the placement methods and insure material is placed in accordance with the Technical Specifications. No construction traffic will be allowed to travel directly on the geomembrane, and a minimum 2-foot thickness will be maintained at all times where construction vehicles travel. The contractor is required to take drainage layer thickness measurements on a grid system, by placing blunt objects on the geomembrane (such as traffic cones or the flat end of construction lath) and marking the required thickness on the object. Excel Energy's Inspectors will observe and document the contractor's drainage layer thicknesses measurement methods to insure that adequate thickness of the drainage layer is maintained, and that no construction traffic comes into direct contact with the geomembrane. Final thickness measurements will be recorded and presented in the documentation report as described in Section 13.

Section 9—Electrical Leak Detection Testing

After placement of the drainage layer over the geomembrane has been completed, an electrical leak detection survey will be completed. Selection of the method for leak detection will be performed in accordance with ASTM D6747-02. The leak detection test will be performed by an independent company hired directly by Xcel Energy, Inc.. Electrical leak detection testing can detect damage to the geomembrane which may have occurred during placement of the drainage layer. Damage to the geomembrane which is detected by the electrical leak survey will be exposed, repairs to the geomembrane (and GCL if necessary) will be repaired, and the seams will be re-tested as described in Section 7 prior to replacement of the drainage material. Electrical leak detection testing will be performed in the presence of the Owner or Owner's on-site representative, and results of the survey will be presented in the documentation report as described in Section 13.

Section 10—Discharge Structures and Dewatering System

10.1 Discharge Structures and Dewatering Pipes

The discharge structures, dewatering pipes, and boot assemblies will be visually observed prior to placement of additional materials covering such features. They will be checked for conformance with the requirements of the Engineering Plans and Technical Specifications. The entire piping system will be observed and surveyed every 100 lineal feet to check and document locations and elevations. Grades and elevations must meet the tolerances stated in the Technical Specifications for construction.

10.2 Manholes, Cleanouts, and appurtenances

Manholes will be checked for conformance with the dimensions and layout shown on the Engineering Plans. Inverts and castings will be surveyed to confirm grades and locations are within tolerance. Cleanouts will be checked for accessibility and function.

Section 11—Vegetation System

Vegetation will be monitored over a period of one year from construction to observe that it becomes well established. Areas in which the vegetation fails to grow will be reseeded, fertilized, and mulched.

Section 12—Surface Water Drainage System

The surface water drainage materials to be monitored will include diversion dikes and ditches, surface water pipe, inlet structures, and riprap for erosion protection.

12.1 Surface Water Diversion Dikes and Ditches

The surface water diversion dikes and ditches will be constructed according to the Contract Documents. Ditch inverts will be surveyed to verify conformance with the Technical Specificatons for construction.

12.2 Surface Water Pipe and Riprap

Surface water pipes will be visually checked for dirt, rocks, or other obstructions. Fusing of polyethylene pipe, and other pipe connections will be observed to verify conformance with the Technical Specification for construction. Riprap placement will be observed for the correct location and class of riprap specified.

Section 13—Method of Documentation and Data Presentation

Following each phase of construction, a construction documentation report will be prepared. This report will include photographs, material test results, and record drawings showing locations and elevations of the major components of construction.

Photographs will illustrate at a minimum the subgrade preparation, GCL installation, geomembrane liner installation, pipe installation, upstream dike construction including clay barrier construction, topsoil, rooting soil, granular drainage material placement, construction of return structures, surface water runoff control structures, and roads.

The results of the soil tests will be presented in tabular form when possible. Tabulated data typically will include the test number and results along with the date the test was performed and the ground surface elevation at the test location.

Test results for other components of construction will be included in the report, such as the geomembrane seam testing and destructive testing, survey data showing material thickness, pipe invert and location data, and other miscellaneous survey data.

Results from the leak detection survey will also be included in the report, along photographic documentation of the results of the survey. Test results of geomembrane (and GCL if necessary) repairs performed as a result of the electrical leak detection test will be included in the report.

The construction documentation report will be signed by a professional engineer registered in the State of Minnesota. The report will state the portion of the pond cover or liner which was completed in accordance with MPCA and MnDNR approved plans and specifications.

Section 14—Acceptable Construction Test Results and Response to Failed Tests

The test results must meet the requirements defined by the Technical Specifications. Material failing to meet specifications will be reworked, removed, and/or retested until the specification is met. If a retest fails, a visual/manual classification of the material will be completed to determine the area to be reworked, or removed, and retested. This procedure should be repeated until the material meets specifications.

Any areas which indicate deficiencies in the quantity or quality of cover or liner material will be outlined in the field by marking with stakes or orange spray paint. The deficiency will be corrected as appropriate and will either be visually checked or physically tested to verify that the minimum requirements are met.

Table 1

Minimum Frequency Construction Material Tests

Component	Test Method	Sampling Location	Minimum Testing Frequency
Common Borrow	MnDOT Ordinary Compaction or 95% Standard Proctor	In-place	1/acre as subgrade (min) or 1/3,000 CY as construction material
	Soil Description and Classification	Source or in-place	1/3,000 CY
Select Clay (Upstream Barrier)	Soil Description and Classification	Source or in-place	1/3,000 CY
	Sand Cone Density or Nuclear Density	In-place	1/200CY
	Moisture Content	In-place	1/200CY
	Thin-wall Permeability	In-place	1/3,000 CY
	Measure Thickness	In-place	2-foot vertical increments every 100-feet along alignment
	Recompacted Permeability	Source	1/5,000 CY (min) or 1/soil type
	Moisture Density (4 point Proctor)	Source	1/5,000 CY (min) or 1/soil type
	Atterberg Limits	Source	1/5,000 CY (min) or 1/soil type
	#200 Sieve and Hydrometer	Source	1/5,000 CY (min) or 1/soil type
Granular Drainage Material	Particle Size	Source or in-place	1/10,000 CY
	Permeability (Constant Head)	Source or in-place	1/10,000 CY
	Measure Thickness	In-place	100-foot grid
Rooting Soil	MnDOT Ordinary Compaction	In-place	1/acre
	Measure Thickness	In-place	100-foot grid
	Soil Description and Classification	Source or in-place	1/acre
Topsoil	Soil Description and Classification	Source or in-place	1/acre
	Particle Size, Soluble Salts, Nutrients, pH, % Organic Matter	Source or in-place	1/1500 CY
	Measure Thickness	In-place	100-foot grid
Coarse Filter Aggregate/ Fine Filter Aggregate	Particle Size	On-site	1/source
Surface Water Pipes and Diversion Dikes	Measure Invert, Elevation, and Location	In-place	1 measurement/100-feet
Decant Structure and Dewatering Pipes	Measure Invert, Elevation, and Location	In-place	1 measurement/100-feet
Concrete	Slump, entrained air	On-site	1/8 CY
	Compression	On-site	1/24 CY

Table 1 (continued)
Minimum Frequency Construction Material Tests

Component	Test Method	Sampling Location	Minimum Testing Frequency
Geomembrane	Visual	Geomembrane surface and seams	Continuous
	Non-destructive (pressure testing)	Split-wedge fused seams	All split-wedge fused seams
	Non-destructive (vacuum testing)	Extrusion welded seams	All extrusion welds
	Destructive	Welded seams	1/500 LF of seam
Geosynthetic Clay Liner	Visual	GCL surface and seams	Continuous

Table 2
Required Construction Material Test Results[1]

Component	Field Density	Field Moisture	Particle Size Distribution	Permeability	pH/Atterberg	% Organic Matter	Thickness
Select Clay (Upstream Barrier)	95% Standard Proctor	0-5% above optimum	Min 50% pass. #200 Max 5% gravel Max 1" rock dia. Max 3" clod	1×10^{-7} cm/s (max)	LL $\geq$ 25% PI $\geq$ 12%	0	4.5 feet perpendicular to slope
Rooting Soil	MnDOT Ordinary Compaction	Less than saturated	See Tech Spec.	NA	NA	NA	Min 1 foot
Granular Drainage Layer	NA	NA	100% pass 3/4"	1×10^{-3} cm/s (min)	NA	0	Min 2 feet
Topsoil	NA	Less than saturated	90% pass #10	NA	pH 6.1 min ph 7.5 max	3 min 20 max	Min 0.5 feet
Coarse Filter Aggregate	NA	NA	MnDOT 3149.2H	NA	NA	0	Varies (see plan)
Fine Filter Aggregate	NA	NA	MnDOT 3149.2J	NA	NA	0	Varies (see plan)
Common Borrow	MnDOT Ordinary compaction, or 95% Standard Proctor as subgrade material	Less than saturated	NA	NA	NA	0	Varies (see plan)

[1]Refer to Technical Specifications for requirements for GCL and geomembrane

Technical Specifications
Scrubber Solids Pond No. 3
NPDES Permit No. 0002186
Sherburne County Generating Plant
Northern States Power Company
(dba Xcel Energy, Inc.)

Prepared for

Xcel Energy

June 2002

Prepared by

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Technical Specifications

Liner and Upstream Dikes

Technical Specifications

Scrubber Solids Pond No. 3 - Liner and Upstream Dikes

Sherburne County Generating Plant

Northern States Power Company

(dba Xcel Energy, Inc.)

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Certification

I hereby certify that this specification was prepared by me or under my direct supervision and that I am a duly Registered Professional Engineer under the laws of the State of Minnesota.

John R. McCain

Date: 06/28/02 Reg. No. 21835

SECTION 01010

SUMMARY OF WORK

1.01 CONTRACT DOCUMENTS

A. The Contract Documents are as defined in the Agreement. The terms of the Contract Documents apply to these Specifications as fully as though repeated herein.

B. The format of these Specifications is based upon the CSI MASTERFORMAT, however differences in format and subject matter location do exist. It is the Contractor's sole responsibility to thoroughly read and understand these Specifications and request written clarification of those portions which are unclear

C. Division of the Work as made in these Contract Documents is for the purpose of specifying and describing work which is to be completed. There has been no attempt to make a classification according to trade or agreements which may exist between Contractor , Subcontractors, or trade unions or other organizations. Such division and classification of the Work shall be the Contractor's sole responsibility.

1.02 EXISTING SITE CONDITIONS AND USES

A. The site is located within the Sherco Plant property, south of Highway 10 in Becker, Minnesota.

B. Initial Pond No.3 construction (Phases 1 and 2) is on a greenfield site, adjacent to existing Pond No.2. Pond No.2 is an active scrubber solids disposal pond. Scrubber solids are discharged by slurry along the west and south sides of Pond No.2.

C. Subsequent Pond No.3 construction (Phases 3 through 5) will occur during the time that Pond No.3 is the active scrubber solids disposal pond. Scrubber solids are discharged by slurry along the west and south sides of Pond No.3. Slurry pipelines are present along the west and portions of the south sides of the pond.

D. Owner's and other contractor's vehicles use roadways within and near the Site. Owner's vehicles shall have the right-of-way at all times.

E. Groundwater monitoring wells are present at the Site and are sampled regularly.

1.03 WORK COVERED BY CONTRACT DOCUMENTS

A. The overall scope of the Work which is more fully described in these Contract Documents includes, but is not necessarily limited to, furnishing all labor , tools, equipment, and materials necessary to:
   1. Maintain free access to the pond for Owner's vehicles and equipment at all times.
   2. Phases 1 and 2:
      a. Strip topsoil, excavate, and backfill to prepare base grades.
      b. Construct a GCL liner on pond base and sideslopes.
      c. Construct a geomembrane liner on the pond base and sideslopes.
      d. Construct a drainage layer on the pond base and sideslopes.
      e. Construct upstream dikes, including placing ash fill, constructing a clay barrier , and placing random fill.

3. Phases 3 through 5: Construct vertical extensions of existing pond dikes, including placing ash fill, constructing a clay barrier, and placing random fill.
4. All phases:
   a. Construct precast concrete discharge structures.
   b. Install pre-engineered truss bridges.
   c. Place topsoil and establish turf.
   d. Construct aggregate road surface at dike crest.

B. It is the intent of the Contract Documents to cover all aspects of the Project. Should there be some item or items not shown on the Contract Drawings or not described in these Specifications which are required for the Work, those items and the furnishing of all labor, materials, and equipment shall be considered incidental to the Work and no additional compensation will be provided.

C. The Work includes the furnishing of all labor, equipment, tools, machinery, materials, and other items required for the construction of a complete project as specified. Equipment furnished shall be in safe operating condition and of adequate size, capacity, and condition for the performance of the Work. Contractor shall obtain all measurements necessary for the Work and shall be responsible for establishing all dimensions, levels, and layout of the Work.

D. Contractor shall be solely responsible for the coordination of its activities with regard to the Project and the activities of Subcontractors and Owner .

1.04. WORK BY OWNER

A. Owner will provide bench mark and site coordinate information necessary for construction of the Work. Once provided, it is Contractor's responsibility to protect the information in accordance with Paragraph 1.06E of this Section. Contractor shall request such information from Owner a minimum of five days prior to the time when such information is needed.

1.05 OWNER FURNISHED PRODUCTS

A. Owner will provide access to stockpiled bottom ash material, random fill, and topsoil for use in the Project.

1.06 CONTRACTOR USE OF PREMISES

A. Definition of Site: The Site is defined as the area within the Property Boundary shown on the Drawings. Contractor shall limit operations, including material and equipment storage, to within those boundaries.

B. Hours of Operation: Contractor's operations shall be limited to the hours of 7:00 am to 7:00 pm (Central Daylight Time), Monday through Saturday, unless prior arrangements are made with Owner .

C. Protection and Repair of Existing Facilities and Utilities: Contractor shall perform operations carefully and in such a manner as to protect existing facilities and utilities. Obstructions not shown on the Drawings may exist and shall be exposed by Contractor without damage. Contractor shall be responsible for damage to existing facilities and utilities resulting from Contractor's operations, and shall repair or replace damaged items to Owner's satisfaction. Groundwater monitoring wells shall be protected during construction.

D. Unfavorable Construction Conditions: When unfavorable weather, soil, drainage, or other unsuitable construction conditions exist, Contractor shall confine operations to work which will not be adversely affected by such conditions. No portion of the Work shall be constructed under conditions which would adversely affect the quality of the Work, unless special means or precautions are taken to perform the Work in a proper and satisfactory manner .

E. Survey Markers: Contractor shall conduct operations so as to preserve bench marks, survey reference points, and stakes existing or established by Owner for the construction. Contractor will be charged the expense of repairing or replacing survey markers and shall be responsible for mistakes or lost time that results from damage or destruction of survey markers due to Contractor's operations.

END OF SECTION 01010

SECTION 01400

QUALITY CONTROL

FIELD QUALITY CONTROL

1.01

A. The Contractor shall retain an independent registered land surveyor licensed in the State of Minnesota for performing quality control on line and grade of the Work. The quality control survey data shall be available for review at all times by Owner or Owner's On-Site Representative.

B. Pond base and sideslopes: Contractor's independent registered land surveyor shall verify that grades, slopes, and material thicknesses (drainage layer constructed by Contractor) are within the tolerances specified in Section 02220 by determining elevations at specific locations on a matrix of survey points as described below:
   1. For elevation, grade, and material thickness verification the following points shall be surveyed:
      a. Top, bottom, and midpoint of interior sideslopes at 50-foot intervals. Top and bottom points shall be located along the grade-break line of the GCL surface.
      b. Every node on an orthogonal 50-foot grid in the base area of the cell. The grid layout shall been established by the registered land surveyor such that there is not more than 50 feet of distance between the toe-of-slope and the first grid line.
   2. For elevation and grade verification the following points shall be surveyed:
      a. Top of dewatering pipes at 50-foot intervals.
      b. Discharge structure invert and top.

C. Upstream dikes: Contractor's independent registered land surveyor shall verify that alignments, grades, slopes, and material thicknesses constructed by Contractor are within the tolerances specified in Section 02220 by determining locations and elevations as described below:
   1. Clay Barrier Location: The alignment and elevation of the inside face of the clay barrier shall be determined at 100-foot intervals along the dike and at alignment shifts. Alignment shall be determined at the base of the clay barrier at the point of connection to the existing clay barrier and at the top of the clay barrier at the completion of each phase of the Project. Alignment shall be reported in terms of station and offset with respect to the dike centerline.
   2. Clay Barrier Thickness: The clay barrier thickness (horizontal dimension) shall be measured and verified as correct at the base (point of connection to existing clay barrier), top (completion of each phase), and a 2-foot intervals between base and top.
   3. Finished Dike Road Surface: Alignment, elevation, and aggregate thickness of the finished dike road surface (for each phase) shall be verified by staking the dike centerline at 100-foot intervals and determining centerline coordinates and elevations for aggregate subgrade and finished aggregate surface. Owner will verify finished dike width by measuring from centerline stakes.

D. Visually inspect lines between survey points to verify a relatively straight-grade (no sag or crown).

E. Prior to acceptance of the Work, Contractor shall submit to Owner, in printed and electronic spreadsheet format, a tabulation of results of survey work performed. The tabulation shall be signed by the registered land surveyor. The tabulation shall contain the following information for each survey location:
   1. A unique identification number.
   2. Project coordinates or station and offset as appropriate.
   3. Elevation or thickness.

4. Description (e.g. clay barrier alignment, dewatering pipe elevation, etc).

F. For purposes of documenting construction, Owner or Owner's On-Site Representative will be conducting a Quality Assurance/Quality Control (QA/QC) program during construction. The QA/QC program will include collecting random samples and performing tests on materials used in construction. Testing will determine whether the properties of the materials proposed for use in this Project comply with the requirements of these Specifications. Contractor shall provide access to materials shipped to the site for sampling.
   1. Material property tests for random fill and ash fill include Standard Proctor maximum dry density.
   2. Material property tests for the clay barrier include sieve and hydrometer analysis, Atterberg Limits, saturated hydraulic conductivity, and Standard Proctor maximum dry density.
   3. Material tests for drainage layer include sieve analysis.
   4. Material property tests for aggregate surface course material includes sieve analysis and Standard Proctor maximum dry density.
   5. Material property tests for topsoil include sieve analysis, organic content, and pH.

G. Owner's QA/QC program will also include conducting field tests during construction to determine whether the constructed materials meet compaction and permeability requirements. Contractor shall provide access to the construction area for testing throughout construction. Tests will be performed as described below:
   1. Random fill, ash fill, and undisturbed subgrade: Density tests will be performed at random verify that compaction requirements are met.
   2. Clay Barrier: Density and moisture content tests will be performed on each lift of clay placed. Contractor shall notify Owner or Owner's On-Site Representative upon completion of each clay lift and provide time and access for testing work to be completed prior to placing subsequent lifts. The tests will be performed at a rate of 1 per 200 C.Y. of clay placed.
   3. Thinwall samples of the constructed clay barrier will be retrieved for laboratory permeability testing. Samples will be collected at random locations at the rate of 1 sample for every 3,000 cubic yards of clay placed. Contractor shall assist in retrieving samples by providing equipment (dozer or grader) and operator to insert and retract sample tube.
   4. Aggregate Surface Course: Density tests will be performed at random on aggregate surfacing placed on the access road to verify that compaction requirements are met.

H. It is Contractor's sole responsibility to perform testing deemed necessary to satisfy requirements of these Specifications prior to delivery of materials to the Site. Materials that do not meet the requirements of these Specifications shall be removed from the Site by Contractor.

I. Work failing to meet specifications as outlined herein and as may be identified as a result of Owner's QAIQC program shall be repaired at Contractor's expense. Owner will perform additional testing after repairs are completed. The expense of retesting will be charged to Contractor.

J. Contractor may ask to review results of Owner's QA/QC testing program during construction. Test results are the property of the Owner and will be submitted to Contractor at Owner's discretion.

END OF SECTION

SECTION 01500

TEMPORARY CONTROLS

PART 1 GENERAL

1.01 SECTION INCLUDES

A. Controlling dust generation on access roads to the Site and within construction limits.

B. Controlling soil erosion and sediment transport at the Site.

1.02 SUBMITTALS

A. Submit proof of agreement between Contractor and local water source indicating permission for Contractor to obtain dust control water from a source near the Site.

1.03 BASIS FOR COMPENSATION

NOT USED

PART 2 PRODUCTS

2.01 MATERIALS

A. Acceptable temporary erosion control devices include, but are not necessarily limited to, silt fence, straw and hay bales, geotextiles, and vegetative cover .

B. Water used for dust control shall be potable water only. There is no source of dust control water at the Site.

2.02 EQUIPMENT

A. Water tank trucks equipped with water cannon capable of delivering water through either front- or rear-mounted nozzles. Tank trucks shall be of sufficient size and mobility and carry a sufficient quantity of water to control dust generated by Contractor's activities.

PART 3 EXECUTION

3.01 DUST CONTROL WATERING

A. Apply water to roads used by Contractor's equipment as directed by Owner or Owner's On- Site Representative to control dust generated by wind or by Contractor's vehicle traffic.

B. Apply water to ground surfaces within the construction limits as directed by Owner or Owner's On-Site Representative to control dust generated by Contractor's activities at the site.

3.02 EROSION CONTROL

A. Install erosion control devices and materials at locations as directed by Owner or Owner's On-Site Representative where soil erosion and sediment transport from the Site may occur due to Contractor's activities.

B. Install temporary erosion control devices during the progress of the work and maintain them until permanent erosion control (turf establishment, aggregate surfacing, etc) has been established.

END OF SECTION 01500

SECTION 02100

SITE PREPARATION

PART 1 GENERAL

1.01 SECTION INCLUDES

A. Topsoil stripping and stockpiling.

1.02 BASIS FOR COMPENSATION

NOT USED

PART 2 PRODUCTS

NOT USED

PART 3 EXECUTION

3.01 STRIPPING TOPSOIL

A. Strip topsoil to a minimum depth of 6 inches from areas shown on the Contract Drawings and in soil borrow areas. Strip topsoil to full-depth where the depth exceeds 6 inches, as directed by Owner or Owner's On-Site Representative. Stockpile stripped topsoil within the construction limits as shown on the Contract Drawings or as directed by Owner . Neatly trim excess topsoil stockpiles to be free-draining, to present a uniform appearance and to prevent erosion and the transport of the topsoil off-site.

END OF SECTION 02100

SECTION 02220

EXCAVATING, BACKFILLING, AND COMPACTING

PART 1 GENERAL

1.01 SECTION INCLUDES

A. Phases 1 and 2:
   1. Excavating native soils for base grade preparation.
   2. Segregating granular soils obtained from excavation which may be suitable for use as granular drainage layer material for future final cover construction. Such soils would be relatively clean (minimal fines content).
   3. Placing and compacting random fill and ash fill for dikes.
   4. Stockpiling excess native soil obtained from excavation. Clean soils shall be stockpiled separately from other soils.
   5. Constructing clay barrier layer.
   6. Placing drainage layer material

B. Phases 3 through 5:
   1. Placing and compacting random fill and ash fill for upstream dikes.
   2. Constructing clay barrier.

C. All Phases:
   1. Placing topsoil and establishing turf.
   2. Constructing aggregate road surface at dike crest.
   3. Performing quality control as specified in Section 01400.

1.02 BASIS FOR COMPENSATION

NOT USED

1.03 REFERENCES

A. Minnesota Department of Transportation Standard Specifications for Construction, 1988 Edition, hereafter referred to as Mn/DOT Standard Specifications.

B. American Society for Testing and Materials, Current Edition, hereafter referred to as ASTM.

1.04 SUBMITTALS

A. Submit the following information regarding the proposed clay borrow source **with the bid:**
   1 Identification/location of borrow source.
   2. Estimated clay reserves available at the borrow source.
   3. Test reports for the following properties for the borrow source material:
      a. Sieve and hydrometer analysis.
      b. Atterberg Limits.
      c. In-place moisture content.
      d. Optimum moisture content based upon Standard Proctor maximum dry density.
      e. Saturated hydraulic conductivity when compacted to 95 percent Standard Proctor maximum dry density.

B. Submit test results of at least two random samples of Class 5 Aggregate when the material is delivered to the Site. Testing shall be conducted according to appropriate ASTM or Mn/DOT standards to confirm required material properties or classifications specified in Article 2.01 of this Section.

1.05 DELIVERY, STORAGE, AND HANDLING

A. Upon delivery of materials to the Site, provide access for sampling or observation of loads by Owner or Owner's On-Site Representative prior to unloading.

B. Store materials where designated on Drawings or as directed by Owner or Owner's On-Site Representative. Prevent segregation of graded materials and mixing of dissimilar materials during unloading, stockpiling, or removal from stockpile.

1.06 SEQUENCING AND SCHEDULING

A. Owner will be evaluating results of Contractor's independent registered land surveyor's alignment, elevation, and material thickness verifications, collecting material samples, and conducting field testing of materials throughout the duration of the Project, as described in Section 01400 of these Specifications. Do not proceed with subsequent operations until Owner or Owner's On-Site Representative has been notified and has been given opportunity to verify that Work meets the requirements of these Specifications.

1.07 JOB CONDITIONS

A. It shall be the Contractor's sole responsibility to review available tests and reports, conduct additional tests, and otherwise determine to its own satisfaction the location and nature of all surface and subsurface features and the soil and water conditions that may be encountered. Owner's information on site conditions may be reviewed at Owner's offices as scheduled with Owner .

B. Use of explosives will not be permitted.

C. Contractor shall be solely responsible for determining the means and methods for meeting the compaction requirements unless otherwise specified herein, except that compaction by flooding or puddling or other means that involve saturation or over-wetting the soil will not be permitted. Contractor shall be solely responsible for utilizing means and methods that protect adjacent structures and utilities from damage resulting from Contractor's operations, specifically including, but not limited to, settlement, consolidation, displacement, cracking, vibration, undermining, washout, and uplift caused by excavating, compaction, dewatering, or any other operation. If requested by Contractor, Owner will accompany Contractor in examination of existing adjacent structures prior to beginning the Work. Examination will be intended to provide Contractor opportunity to document relevant existing structural damage or problems.

D. If it is necessary to remove surface water that is in contact with scrubber solids or ash, Contractor shall direct such surface water into Pond No.2.

E. Provide all shoring, bracing, sheet piling, trench boxes, tie backs, and other measures required to perform all Work in accordance with Laws and Regulations. Specifically, all excavations shall conform to the requirements of OSHA set forth in 29 CFR 1926, Subpart P (Occupational Safety and Health Standards-Excavations).

PART 2 PRODUCTS

2.01 MATERIALS

A. Owner will provide access to bottom ash, ash fill, topsoil, and random fill stockpiles or borrow areas for use in the Project. Contractor shall be responsible for opening, maintaining, and closing stockpiles and borrow areas, loading and transporting materials, and controlling dust and erosion at stockpiles and borrow areas and along haul routes. Contractor shall furnish all other materials specified in this Section.

B. Random Fill: On-site sands and silty sands, gravels or sandy clays and silty clays from designated borrow areas, all free of organic material, roots, stumps, and solid mineral materials larger than 4 inches in diameter

C. Drainage Layer: Bottom ash or granular material with a maximum 3/4-inch particle size. Contractor shall screen the stockpiled material to meet the particle size requirement.

D. Ash Fill: Bottom ash material obtained from designated stockpile locations, or suitable ash material excavated from the dike crest. Suitability of ash will be determined by Owner or Owner's On-Site Representative.

E. Clay: An inorganic mineral soil with the following properties:
1. A minimum of 50 percent by weight which passes the #200 sieve.
2. A maximum particle size of 1/2 the compacted lift thickness.
3. A Liquid Limit of 25 percent or greater.
4. A Plasticity Index of 12 percent or greater .
5. A moisture content at or above optimum at time of placement and compaction.
6. A maximum saturated hydraulic conductivity of 1×10^{-7} cm/s when compacted to 95 percent Standard Proctor maximum dry density at a moisture content at or above optimum.
7. Frozen clay shall not be used for clay barrier construction.

F. Coarse Filter Aggregate: A mineral product in conformance with MNDOT Std. Spec. 3149.2H.

G. Fine Filter Aggregate: A mineral product in conformance with MNDOT Std. Spec. 3149.2J.

H. Class 5 Aggregate: An aggregate material in conformance with Mn/DOT Standard Specification 3138.2 for Class 5, except that use of crushed concrete or salvaged bituminous material will not be permitted.

I. Topsoil: On-site surface soil stripped and stockpiled during site preparation per Section 02100 or previously stockpiled, and identified by Owner or Owner's On-Site Representative as a suitable growing medium.

2.02 SOURCE QUALITY CONTROL

A. Owner may perform an independent clay borrow source evaluation either prior to awarding the contract or prior to Contractor mobilizing for the clay haul. Contractor shall provide Owner with access to the borrow source to conduct sampling and exploration. If the results of Owner's evaluation indicate that the borrow source is not acceptable, based upon either available reserves or material properties, Contractor shall be responsible for the costs associated with subsequent evaluations of the same source or alternate sources.

B. Owner may also take samples of the materials after they have been furnished to the Site for additional testing. Owner will pay for testing of samples that meet Specifications. Contractor shall pay for testing of samples that do not meet Specifications.

PART 3 EXECUTION

3.01 GENERAL EXCAVATION

A. Locate and protect overhead and underground utilities.

B. Construct excavations in accordance with applicable Laws and Regulations.

C. Excavate native soil to the elevations, slopes, and dimensions shown on the Drawings.

D. Soil excavation in the soil borrow area shall be within the vertical and horizontal limits shown on the Drawings. Excess excavated soil from the soil borrow area shall be stockpiled within the soil borrow area limits. Stockpile slopes shall be 3H: 1 V or flatter . Borrow area slopes shall be 2H:1V or flatter when the borrow area is active.

E. Provide temporary controls such as diversions and dewatering equipment to prevent surface runoff from entering excavations and to remove ponded water from excavations. Maintain excavations in a dry and stable condition at all times.

3.02 ASH EXCAVATION

A. Excavate existing ash material at the dike crest as shown on the Drawings. Excavated ash shall be placed toward the pond interior, on the pond-side of the clay barrier .

B. Smooth-grade the ash backslope (clay barrier foundation) to the slopes and elevations shown on the Drawings.

3.03 EXISTING CLAY SURFACE PREPARATION

A. Connection of clay barrier to previously constructed clay surfaces shall be performed as described below.

B. Prepare existing clay surfaces by scraping the clay surface to remove ash, soil, and other non-clay materials which may be embedded at the surface. Do not remove more than 2 inches of clay from the existing clay surface.

C. Scarify the cleaned clay surface to a depth of 4 inches using discs, harrows, or other suitable equipment. Scarify the surface to the width shown on the Drawings.

D. Scarify only that portion of existing clay surfaces which will be promptly covered by a lift of new clay material, to prevent drying of existing clay at the connection point. Scarified clay which has dried to a point such that the moisture content is below optimum shall be wetted and reworked so that a suitable bond to the new clay can be constructed.

3.04 BACKFILL AND COMPACTION

A. Place backfill materials at the locations and to the dimensions and thicknesses shown on the Drawings. Furnish equipment suitable for soil conditions and compactive effort required to meet compaction criteria specified herein.

B. Place Random Fill and Ash Fill in maximum 12-inch loose lifts. Lifts shall be constructed in a generally horizontal orientation. Compact each lift to at least 95 percent Standard Proctor Density (ASTM D 698) before proceeding to the next lift.

C. Clay Barrier:
   1. Clay shall be at or above optimum moisture content at time of placement and compaction. If moisture conditioning of the clay is necessary prior to placement, such conditioning shall be performed outside of the area where the clay barrier is to be constructed, and on a clay pad at least 1 foot thick to prevent mixing with non-clay materials. The clay pad shall be maintained throughout moisture conditioning operations. Clay used for the pad shall not be used for clay barrier construction. Moisture conditioning may be performed at the borrow source prior to delivery to the Site.
   2. Over-wetted clay shall not be used for construction of the clay barrier. Clay shall be determined to be over-wetted if displacement of the clay occurs under the weight of vehicle traffic or if the required compaction cannot be achieved with a reasonable number of passes with compaction equipment.
   3. Place clay lifts in a horizontal orientation. Place clay in maximum 9-inch loose lifts, or thinner so that each compacted lift is not greater than 6 inches thick. Compact each lift to at least 95 percent Standard Proctor maximum dry density. Compaction shall be performed with sheepsfoot compactors. The surface of intermediate clay lifts shall be in a roughened condition at the time of placement of an overlying lift, such as from imprints from a sheepsfoot compactor.
   4. The surface of each clay lift shall be kept moist until the next clay lift is placed. If the clay surface becomes dry, apply water and rework the surface with a sheepsfoot compactor, scarifier, or other suitable equipment to thoroughly remoisten the clay.
   5. The finished clay barrier surface shall be maintained in a moist condition until covered by soil or ash materials. Frequent water application may be required, especially during hot, dry, or windy weather

D. Coarse and Fine Filter Aggregates: Place coarse filter aggregate over the geotextile to a uniform 6-inch thickness before installing dewatering pipes. Place coarse filter aggregate carefully by dropping from backhoe or loader bucket from a height of less than 2 feet. Spread by hand with rakes or other suitable tools. Do not spread with mechanical equipment. After dewatering pipes have been installed, place coarse and fine filter aggregates over pipes to form a mound to the dimensions shown in the Drawings. Again, place aggregates carefully by dropping from a height of less than 2 feet and spread, if necessary , by hand.

E. Drainage Layer:
   1. No backfill material shall be placed over the geomembrane until inspection and testing of the geomembrane have been completed and all test results and required documentation have been submitted to Owner/Owner's On-Site Representative in accordance with Section 02770. After geomembrane inspection and review of the documentation, Owner will give Contractor written notice to proceed with the placement of materials over geomembrane. This notice does not imply final acceptance of the geomembrane or related work. Final acceptance of the geomembrane is covered in Section 02770. Inspection and submission of required documentation for geomembrane work may be done in phases to facilitate timely placement of drainage layer material .

2. Place drainage layer over the geomembrane in a single lift. Placement of the drainage layer over the geomembrane shall be performed in accordance with the geomembrane manufacturer's recommendations, and under the supervision of the geomembrane installer's on-site representative as specified in Section 02770.
3. In no case shall any construction equipment be allowed to travel directly on the geomembrane. A minimum 2-foot lift of drainage layer material shall be placed over the geomembrane for vehicle traffic.
4. Spreading shall be performed by pushing drainage layer from discrete dumping points along the built-up traffic areas, and pushing the materials outward over that material already placed. Drainage layer material shall be "rolled" over the edge of the material already placed, rather than pushed or slid across the surface of the geomembrane.
5. No special compactive effort other than that realized by placement of the drainage layer shall be performed.

F. Place Class 5 Aggregate in maximum 6-inch lifts (compacted thickness). Compact each lift to at least 100 percent Standard Proctor maximum dry density.

G. Place Topsoil in a single 6-inch lift on exterior slopes of berms, along sides of access roads, and in other locations shown on the Drawings or disturbed by Contractor's activities.

3.05 SITE GRADING

A. Smooth-grade finished ground on exterior slopes of berms, along access roads, and other areas disturbed by Contractor's activities, to uniform levels or slopes between points where elevations are shown, or between such points and existing ground.

B. Smooth-grade dike crest to the slopes shown on the Drawings.

3.06 RESTORATION OF DISTURBED AREAS

A. Excess topsoil and other excess soils excavated from the soil borrow areas shall remain in stockpiles as specified in Section 02100 (Site Preparation). Borrow area slopes shall be left no steeper than 3H:IV.

B. Smooth-grade areas which were disturbed by Contractor's activities, including roadways, off-road areas, borrow areas, and exterior dike slopes.

C. Augment topsoil in disturbed areas with topsoil borrow so that a minimum of 6 inches of topsoil is present. Revegetate disturbed areas in accordance with Section 02930.

3.07 TOLERANCES

A. Construct the excavation and backfill work within the dimensional tolerances given below. Alignment, elevation, and thickness tolerances are acceptable deviations from the dimensions shown on the Drawings.

B. Elevation Tolerances:
1. Excavation/Clay Subgrade: +0.0 foot, -0.5 foot.
2. Random Fill/Clay Subgrade: +0.0 foot, -0.5 foot.
3. Random Fill/Exterior Berm Slopes: +/-0.2 foot.
4. Finished Clay Surface: +0.2 foot, -0.0 foot.
5. Finished Drainage Layer: +0.2 foot, -0.0 foot
6. Finished Topsoil Surface: +0.3 foot, -0.0 foot.

7. Dike Road Surface: +/- 0.2 foot.

C. Thickness Tolerances:
   1. Clay Barrier (horizontal dimension): -0.0 foot, + 2 feet.
   2. Drainage Layer Material: -0.0 foot, + 0.2 foot.
   3. Topsoil: -0.0 foot, + 0.2 foot.
   4. Coarse and Fine Filter Aggregates (below and above dewatering pipes): +/-0.1 foot.
   5. Aggregate Surface Course: -0.0 foot, + 0.2 foot.

D. Grade Tolerances:
   1. Pond Bottom (finished GCL surface slope): 1.0 percent or greater at any location.
   2. Dewatering Pipes: 0.5 percent or greater.
   3. Access Road Cross-Slope: 1.5 to 2.5 percent.

E. Alignment Tolerances:
   1. Finished clay barrier (pond-side surface): +/- 0.2 foot.
   2. Finished dike centerline: +/- 0.2 foot.

3.08 FIELD QUALITY CONTROL

A. Contractor shall perform field quality control as specified in Section 01400 of these Specifications.

END OF SECTION 02220

SECTION 02605

PRECAST CONCRETE STRUCTURES

PART 1 GENERAL

1.01 DESCRIPTION

A. Work covered under this Section shall include constructing sectional precast reinforced concrete manholes, precast box culvert sections, catch basins, and appurtenances.

B. Related Sections:
   1. Section 03300: Cast-in-Place Concrete

1.02 REFERENCES

A. Minnesota Department of Transportation Standard Plates Manual, hereafter referred to as Mn/DOT Standard Plates.

B. Minnesota Department of Transportation Standard Specifications for Construction, 1988 Edition, hereafter referred to as Mn/DOT Standard Specifications.

C. American Society for Testing and Materials, current edition, hereafter referred to as ASTM.

1.03 SUBMITTALS

A. Submit shop drawings, in accordance with Section 01300, for the precast box culvert sections.

1.04 BASIS FOR COMPENSATION

NOT USED

PART 2 PRODUCTS

2.01 PRECAST CONCRETE BOX CULVERT AND END SECTIONS

A. Precast concrete box culverts and end sections shall meet the requirements of Mn/DOT Standard Specification 3238.

B. Box culvert and end sections shall be of the size and shape shown on the drawings.

C. Concrete for box culverts and end sections shall have a minimum compressive strength, fc' = 5,000 psi.

D. Securely fasten all embedded plates prior to pouring concrete section.

2.02 JOINT SEALS

A. External-type rubber gaskets, mastic, and protective film in conformance with ASTM C 877 for box riser sections.

PART 3 EXECUTION

3.01 BOX CULVERT SECTIONS AND END SECTIONS

A. Install box culvert in accordance with manufacturer's recommendations

B. Any cast-in-place concrete required shall be in accordance with Section C. Tie end sections and base box section together with steel tie rods as shown on the Drawings.

END OF SECTION 02605

SECTION 02610

PIPES AND FITTINGS

PART 1 GENERAL

1.01 SECTION INCLUDES

A. Furnishing and installing perforated PVC dewatering pipes.

1.02 BASIS FOR COMPENSATION

NOT USED

PART 2 PRODUCTS

2.01 PERFORATED PVC DEWATERING PIPES

A. Pipe and fittings shall be Schedule 80 solvent-weld materials in conformance with the requirements of AASHTO M 278.

B. Pipes diameters and perforations shall be as shown on the Drawings.

PART 3 EXECUTION

3.01 PERFORATED PVC DEWATERING PIPES

A. Install pipes in aggregate bedding with perforations oriented downward as shown on the Drawings.

B. Install pipes at the slopes shown on the Drawings.

C. Ends of pipe shall be cut square and deburred. Follow manufacturer's instructions for making solvent-weld joints, including cleaning, priming, solvent application, joining method, and curing.

3.02 FIELD QUALITY CONTROL

A. Pipe and pipe installation will be subject to rejection for any of the following reasons:
   1. Fractures, cracks, chips, or deformities in pipe wall.
   2. Defects indication improper proportioning, mixing, or molding.
   3. Damaged ends where such damage would prevent making a satisfactory joint.
   4. Deflection from true-round cross section.

END OF SECTION 02610

SECTION 02770

GEOMEMBRANE

PART 1 GENERAL

1.01 SECTION INCLUDES

A. Installing textured and smooth 60-mil HDPE geomembrane.

B. Performing on-site quality control testing for geomembrane installation.

C. Supervising placement of geomembrane cover materials.

1.02 SUBMITTALS

A. Submittals shall be made prior to or at the time of delivery of geomembrane materials to the Site.

B. HDPE Resin: Submit for documentation the following information for HDPE resin used in the manufacture of geomembrane and extrudate rod:
1. Resin type and cell classification (ASTM D 3350).
2. Physical properties as specified herein.
3. Production dates of the resin used for this project

C. HDPE Geomembrane: Submit for documentation the following information for HDPE geomembrane to be used for this project.
1. Test methods and results defining physical properties as specified herein, of the geomembrane to be used for this project. Test results shall be representative of each roll of geomembrane furnished for this project (e.g., a test sample taken between two consecutive rolls from a continuous run will be considered representative of both rolls). Test results shall be reported with corresponding roll identification numbers. Test results which may not be available prior to construction (e.g., environmental stress crack resistance) shall be presented as preliminary information prior to construction, with final test results submitted within 60 days of the start of geomembrane installation.
2. Statement of the geomembrane manufacturer's quality control procedures and frequency of sampling.
3. Details of any factory seaming process proposed.

D. Geomembrane Installation: Submit for review the following information regarding the geomembrane installation:
1. A proposed panel and seam layout diagram specifying the type and location of all field and factory seams. The layout diagram shall be to scale and used as a construction plan and shall include all necessary dimensions and details. The layout diagram shall be compatible with the panel and seam layout requirements specified in Article 3.03 of this Section.
2. An installation schedule.
3. A list of personnel performing field supervision, seaming supervision, and quality control, along with experience records and resumes.
4. A list of equipment types proposed to be used in panel layout, membrane seaming, and destructive and nondestructive testing.

E. Prior to the installation of any geomembrane, the Contractor shall submit for documentation installer's certification in writing that the surface upon which the geomembrane is to be installed is acceptable (use the form at end of this Section or Installer's equivalent).

1.03 EXPERIENCE

A. The geomembrane manufacturer shall have at least 5 years continuous experience in manufacturing smooth and textured HDPE geomembrane rolls and/or a manufacturing record totaling not less than 5 million square feet of HDPE geomembrane. The manufacturer shall have produced HDPE geomembrane for at least 10 completed facilities similar in scope to this project.

B. The geomembrane installer (hereafter referred to as Installer) shall have at least 5 years continuous experience in the installation of HDPE geomembranes and an installation record totaling at least 5 million square feet. Installer shall have installed HDPE geomembrane for at least 10 completed sites similar in scope to this project.

C. Geomembrane installation shall be performed under the direct supervision of a single field supervisor who shall remain on-site throughout installation, including inspection of the surface upon which the geomembrane is to be installed, geomembrane handling and storage, panel layout and placement, seaming, seam testing, panel and seam repair, installation of appurtenances, anchorage, protective cover placement, and other geomembrane-related work. The field supervisor shall have complete supervisory responsibility for the installation, testing, and repair, and have a personal HDPE geomembrane installation record totaling at least 1 million square feet.

D. Field seaming of geomembrane panels shall be performed under the direction of a seaming supervisor who may or may not be the same person as the field supervisor. The seaming supervisor shall have a personal HDPE geomembrane installation record totaling at least 1 million square feet with the mil-thicknesses and using the seaming methods proposed for this project.

E. The geomembrane manufacturer and installer must be approved by Owner prior to mobilization for geomembrane installation. Owner has the right to reject any geomembrane manufacturer or installer, and request that Contractor select an alternate.

1.04 PREINSTALLATION CONFERENCE

A. Contractor and Installer shall attend a meeting at the site prior to installation of the geomembrane to discuss details of the proposed design and installation.

1.05 REFERENCES

A. American Society for Testing and Materials, Current Edition, hereafter referred to as ASTM.

B. National Sanitation Foundation, Standard 54 For Flexible Membrane Liners, Current Edition.

1.06 BASIS FOR COMPENSATION

A. Compensation for all Work covered under this Section of these Specifications will be included under the lump sum Contract Price bid.

PART 2 PRODUCTS

2.01 MATERIALS

A. HDPE Resin

1. Smooth and textured HDPE geomembrane and extrudate rods used for this project shall be manufactured of new, first quality resins, designed specifically for use in flexible membrane liner installations.
2. HDPE resin used in manufacturing geomembranes used for this Project shall meet the following specifications:

Property	HDPE	Test Method
Specific Gravity	≥0.940	ASTM D 792 86 Method A or ASTM D-1505
Melt Index	<0.3 g/10 min.	ASTM D 1238 88 Condition 190/2.16

3. Recycled polymer shall not be added to the resin. However, the resin may contain polymer reclaimed during the manufacturing process if reclaimed polymer content does not exceed 2 percent by weight.

B. Geomembrane

1. HDPE geomembrane sheets used for this project shall meet the following specifications:

GEOMEMBRANE SHEET SPECIFICATIONS

Property	40 mil Smooth HDPE	40 mil Textured HDPE	60 mil Smooth HDPE	60 mil Textured HDPE	Test Method
Nominal Sheet Thickness (mils)	40 ± 10%	40 ± 10%	60 ± 10%	60 ± 10%	ASTM D 751 NSF Annex A
Density (g/cm^3, min.)	0.940	0.940	0.940	0.940	ASTM D 792 or ASTM D 1505
Tensile Strength at yield (lbs/in. width)	≥84	≥78	>126	≥117	ASTM D 638
Tensile strength at break (lbs/in. width)	≥152	≥60	≥228	≥90	ASTM D 638
Elongation at yield (percent)	≥12	≥12	≥12	≥12	ASTM D 638
Elongation at break (percent)	≥560	≥100	≥560	≥100	ASTM D 638
Tear Resistance (lbs)	≥26	≥24	≥39	≥39	ASTM D 1004
Low Temperature Impact (°C, max. failure temp.)	-60	-60	-60	-60	ASTM D 746
Dimensional stability (max. percent change)	±2	±2	±2	±2	ASTM D 1204 1 hour at 100°C
Environmental Stress Crack (min. hours with no failures)	1500	1500	1500	1500	ASTM D 1693 NSF Annex A
Puncture Resistance (lbs.)	≥48	≥45	≥72	≥70	FTMS 101 Method 2065
Carbon black content (% allowable range)	2-3	2-3	2-3	2-3	ASTM D 1603
Carbon black dispersion	A-1,A-2, or B-1	A-1, A-2, or B-1	A-1, A-2, or B-1	A-1, A-2, or B-1	ASTM D-3015 NSF Annex A

NOTE: (NSF) National Sanitation Foundation - Standard No. 54, 1991

2. The geomembranes shall contain at a maximum 3 percent by weight additives, fillers, or extenders.
3. The geomembranes shall be free of holes, blisters, striations, undispersed raw material, and contamination by foreign matter.
4. The geomembranes shall be supplied in rolls. Each roll shall be labeled with the mil-thickness, length, width, manufacturer, lot number, and a unique roll identification number. This identification number shall be used to identify roll location on the panel layout record drawing.

C. Extrudate: Resin used in the extrudate rod shall be the same as that used to manufacture the geomembrane sheets. Extrudate rods are to be delivered in original containers with the manufacturer's labeling. Extrudate rods shall be free of dirt, grease, moisture, other contaminants, and shall be free of damage.

D. Neoprene Foam: Closed cell, weatherproof, black neoprene foam with adhesive backing suitable for long-term sun and liquid exposure. Dimensions shall be as specified on the Drawings.

E. Clamped Boots: Boots required to seal the HDPE geomembrane to the structures passing through it shall be made of the same materials as the geomembrane. The boots shall be fabricated so that all field assembly, welding, and seam testing can be accomplished using equipment and procedures regularly employed in the field for HDPE geomembrane installation. Smooth geomembrane shall be used in all geomembrane boots.

F. Banding Straps: Type 302 stainless steel banding straps suitable for use on the pipe diameters shown on the Drawings. Banding strap dimensions shall be as specified on the Drawings. All surfaces of the banding straps shall be machined smooth to prevent tearing or puncturing of the HDPE pipe boots.

2.02 EQUIPMENT

A. Extruding equipment shall be equipped with a temperature gauge at the barrel and nozzle.

B. Fusion equipment shall be equipped with a temperature gauge capable of continuous monitoring.

C. Provide digital or dial continuous temperature recording instruments, in satisfactory working condition, with each welding unit. Welding equipment shall not be operated without functioning temperature recording instruments.

D. A coupon cutter and a calibrated tensiometer shall be provided for in-field seaming prequalification testing and destructive sample testing.

E. Store, transport, and operate all equipment to avoid damage to geomembranes.

PART 3 EXECUTION

3.01 SUBGRADE INSPECTION

A. Installer shall certify in writing that the surface upon which the geomembrane is to be installed is acceptable (use the form at end of this Section or Installer's equivalent).

B. After subsurface has been accepted by Installer, it shall be Installer's responsibility to indicate to Contractor any change in subsurface conditions that may require repair work. Damage to subsurface caused by work involved in installing geomembrane shall be repaired at Contractor's expense. Geomembrane cover placement over unsuitable surfaces will not be permitted.

3.02 HANDLING, TRANSPORTATION, AND STORAGE

A. Geomembrane rolls shall be packaged and labeled prior to transporting to the site. Geomembrane rolls delivered to the site shall be wrapped in a relatively impermeable and opaque protective cover which may consist of a sacrificial wrap of geomembrane. The sacrificial wrap shall be removed and not used as part of the geomembrane installation.

B. Geomembrane transportation shall be in a manner that reduces the possibility of material damage during shipment.

C. On-site storage of the geomembrane rolls shall be in a safe manner, with rolls protected from grease, dirt, moisture, excessive heat, direct sunlight, vehicle traffic, and other possible sources of damage including theft and vandalism. Storage areas shall be at the Contractor's discretion unless otherwise specified by the Owner.

D. Geomembrane and appurtenant materials delivered to the site shall be checked for proper labeling and visually inspected for transport or manufacturing damage. Owner reserves the right to reject any unacceptable material at no cost to Owner.

E. Only that quantity of geomembrane that is to be placed on a particular day shall be removed from the packaging. Geomembrane rolls shall be transported from the storage area to the construction area using wide lifting straps and properly sized forklifts, front end loaders, or other appropriate equipment. Under no circumstances shall any heavy equipment be allowed directly on the geomembranes. Prior to placement, the geomembranes shall be visually inspected for damage and manufacturing defects. Geomembrane material which, in the opinion of Owner or Owner's Representative, is damaged or otherwise unsuitable shall not be used for the project. Minor damage may be repaired as specified in Article 3.08 of this Section. Damage to geomembranes caused by Installer during handling shall be repaired or replaced at Contractor's expense.

3.03 PANEL LAYOUT AND PLACEMENT

A. Panel and Seam Layout Diagram:
   1. Prepare panel and seam layout diagram so that panel seams run parallel to the direction of maximum slope.
   2. Run panels lengthwise through leachate collection trenches so that there are no seams in the trenches except where the trench is longer than a full roll length.
   3. Textured slope panels, where required, shall extend past grade-break lines as shown on the Drawings.
   4. Slope panels shall not be constructed from more than two pieces of geomembrane (i.e., not more than one cross-seam shall be permitted on slope panels).
   5. Cross seams in slope panels shall be oriented at 45°.
   6. Cross seams in adjacent panels shall be staggered.
   7. Panels shall be seamed in a rain-lap fashion.
   8. Assign identification number to each seam for reference to test results and record Drawings.

B. Panel Placement:
   1. Panel size and placement shall be in general accordance with the panel layout diagram. Place geomembrane of the type (smooth or textured) and mil-thickness, and at the locations and to the dimensions as shown on the Drawings.
   2. Do not slide textured geomembrane across filter fabric surfaces. If textured geomembrane is not placed as desired or required, reroll the geomembrane panel, reposition, and redeploy the panel.
   3. If textured geomembrane is slid across filter fabric and results in a disruption of the fiber network on the surface of the fabric such that adherence of the textured geomembrane to the body of the filter fabric is reduced, or results in the filter fabric peeling away from an underlying synthetic drainage net, the filter fabric and drainage net shall be replace at Contractor's expense.
   4. Panels shall be anchored with sand bags or other approved methods to prevent uplift and damage by wind.
   5. The roll identification number and a unique panel number shall be marked on each panel as the panel is placed. The roll and panel numbers shall appear on the Record Drawings.
   6. Place panels with appropriate slack incorporated into geomembrane to accommodate expansion and contraction without jeopardizing the integrity of the geomembrane.
   7. Smoking during placement of panels is prohibited. Wearing damaging shoes or engaging in any behavior which may damage the geomembrane is prohibited.

C. All geomembrane panels shall be seamed on the same day that they are deployed.

D. Owner or Owner's Representative and Contractor will visually inspect in-place panels prior to seaming. Any damaged panels shall be repaired, and if requested by Owner or Owner's Representative, replaced, at no additional cost to Owner. Repairs shall be made in accordance with Article 3.08 of this Section. All damages and repairs shall be recorded on the Record Drawings.

3.04 SEAMING

A. Seaming Methods: All seams shall be joined using a heat extrusion or hot fusion (split wedge) weld process in accordance with the manufacturer's recommendations. The Installer shall maintain in working order at the site at least one spare seaming apparatus for each type of welder used. The use of extrusion welded seams shall be limited to repairs and any areas or seam configuration inaccessible to fusion welding equipment.

B. Factory and field seams shall meet the following minimum specifications:

Geomembrane Type	HDPE Textured		HDPE Smooth		
Nominal Gauge	40 mil	60 mil	40 mil	60 mil	Test Method
Bonded Seam Strength (shear) (lbs/in. width)	≥70, FTB	≥105, FTB	≥80, FTB	≥120, FTB	ASTM D 4437 NSF Annex A
Seam Peel Adhesion (extrusion) (lbs/in. width)	≥42, FTB	≥63, FTB	≥47, FTB	≥70, FTB	
Seam Peel Adhesion (fusion), (lbs/in. width)	≥47, FTB	≥70, FTB	≥52, FTB	≥78, FTB	ASTM D 4437 NSF Annex A

Note: All seams must fail at film tear bond (FTB).

C. Seam Configuration and Preparation:
1. Overlap panels to be seamed at least 3 inches but not more than 6 inches. The loose end of the upper panel shall extend no more than 3 inches from the weld.
2. Cross seams on slopes shall be made at a 45 degree angle to the edge of the panel.
3. The contact area between panels shall be clean and free of moisture, dust, dirt, debris, and foreign material. A protective layer of filter fabric or scrap geomembrane shall be used directly beneath each seam overlap to achieve proper support and a clean work surface, if necessary.
4. Where extrusion welding is used, the contact surfaces between panels shall be ground to remove oxidation prior to welding. Grinding shall not result in grooving of the liner nor reduction of the liner thickness by more than 10 percent. The grinding motion shall be made perpendicular to the seam. Grinding in a direction parallel to the seam will not be permitted.
5. Seams shall be aligned to minimize the number and size of wrinkles.

D. Test Seam Specimen Preparation:
1. At least two test seam samples shall be prepared with each piece of seaming equipment at the beginning of each seaming period (usually morning and afternoon), unless otherwise directed by Owner or Owner's Representative. Samples shall be prepared by the corresponding operator. Samples shall be at least 6 feet long (in the direction of the seam) by at least 1 foot wide, and may be prepared from scrap pieces of geomembrane.

2. Six 1-inch wide specimens (coupons) from each test seam sample shall be prepared for on-site field testing for shear and peel strength. Coupons shall be prepared using a sheet cutter so that consistent, uniform 1-inch wide coupons are obtained. Three 12-inch long specimens shall be prepared for retention by Owner, Owner's Representative, and Installer.
3. Each specimen shall be labeled with an equipment and operator identification number, date, ambient air temperature, operating temperature, speed of seaming equipment, and field test results.
4. Seaming equipment shall not be used until satisfactory test seams have been prepared.

E. Climatic Conditions for Seaming:
1. Seaming shall be performed only when panel temperatures are between 40°F and 115°F, unless otherwise approved by Owner or Owner's Representative. If seaming is permitted to be performed at panel temperatures below 40°F, the panel contact surface shall be preheated and Installer shall certify in writing that the low-temperature seaming procedures will not cause any short- or long-term damage to the geomembrane.
2. Seaming during rainy weather or when dew is present on panels will not be permitted.
3. Contractor shall provide any special lighting required for seaming during low-light or dark hours. Installer shall leave slack in geomembrane as necessary to account for thermal expansion or contraction of geomembrane. Stress on panels due to thermal expansion and contraction shall be minimized by performing field seaming operations during the coolest parts of the day or night, if necessary. Special scheduling or extended hours of operation require approval by the Owner.

F. All welding shall provide a tight, leakproof, homogeneous bond between panels. All seams shall extend to ends of panels.

G. Welding equipment shall be continuously monitored to control the temperature of extrudate and wedge.

3.05 SEAMING PREQUALIFICATION TESTING

A. Seaming prequalification coupons (prepared per Paragraph 3.04D of this Section) shall be tested for shear and peel strength with the on-site tensiometer prior to starting production seaming. Three coupons shall be tested in shear and three in peel. All coupons shall exhibit the required strength at yield or break, and failure mechanism (FTB) as set forth in Paragraph 3.04B of this Section. If any of the coupons fail, another test seam shall be prepared and coupons cut and tested. If any of the second set of coupons fail, the reason for the failure shall be identified and corrected prior to preparing another test seam. No production seaming shall be performed with any seaming equipment or by any operator without a passed seaming prequalification test witnessed by the Owner or Owner's Representative.

3.06 NONDESTRUCTIVE TESTING OF PRODUCTION SEAMS

A. Visual Inspection: A visual inspection of all seams shall be performed. This inspection shall look for obvious flaws in seaming, patches, penetration sealing, material defects, or other problems. Deviations from acceptable workmanship standards shall be noted and corrected.

B. Pressure Testing (Split-Wedge System): Where a split-wedge fusion seaming system is employed, the continuity of the seam shall be tested with air pressure in accordance with the following procedure. Installer shall provide all equipment and personnel to conduct the testing specified herein. The flow channel must not be obstructed by foreign objects or geomembrane material throughout the length of seam being tested. The vacuum test described in Paragraph 3.06C of this Section must be employed for testing of all seams that do not have a contiguous flow channel.
1. A test device consisting of an inflation needle and pressure gauge mounted on a "T" fitting shall be

used for air pressure testing. Insert the needle into the flow channel and seal the end of the channel around the needle. Connect a pump (such as a small bicycle pump) to the test device.

2. Ascertain that the flow channel is contiguous by leaving the other end of the channel open and pumping air through the channel. If air does not pass through the channel the test length must be shortened until a contiguous length of flow channel is found.
3. Seal and clamp both ends of the flow channel to assure an airtight seal. Inflate the flow channel to 25 to 30 psig. Allow one minute for the seam to stabilize.
4. Reinflate to 25 to 30 psig and test for a period of five minutes.
5. At the end of the test period, if the pressure has not dropped more than 2 psi, the test shall be considered a pass and the following procedure will be implemented:
   a. Remove the test device and clamps.
   b. Make any repairs, if necessary, to the area where the flow channel was clamped or inflated.
   c. Record the test results, mark the seam as a pass, and proceed to the next seam.
6. If the pressure drops below the 2 psi allowance, the test shall be considered a failure and the following procedure shall be implemented to identify the failure:
   a. Check to determine if there is excessive seepage around the inflation needle.
   b. Check both ends of the seam to ensure the flow channel is completely sealed off.
   c. Walk the length of the seam; look and listen for air leaks.
   d. If either of these procedures fail to identify the leak, trim the seam overlap and vacuum test the seam to locate the leak.
   e. Once the leak is identified, make the necessary repairs and retest the seam.

C. Vacuum Testing: Vacuum testing shall be used to test the continuity of extrusion welded and mechanical seams. Installer shall provide all equipment and personnel to conduct the testing specified herein. The following procedure shall be followed:
   1. Wet seam to be tested with a soapy solution mixed at a ratio of 1 ounce soap to 1 gallon water.
   2. Place clear-topped vacuum box over seam to be tested, evacuate box to a vacuum of 3 to 5 inches water column, and tug up to ensure a leaktight seal has developed.
   3. Examine the seam for 5 to 10 seconds; watch for soap bubble formation.
   4. If bubbles are not evident, move to next test location.
   5. If bubbles are present, mark area clearly for repair.
   6. If the vacuum testing indicates leakage, the area shall be spot patched; or if major leaks are detected, the entire seam shall be reworked.

3.07 DESTRUCTIVE TESTING OF PRODUCTION SEAMS

A. The purpose of destructive testing is to verify that the seaming process has produced seams of acceptable physical integrity. Installer shall provide all equipment and personnel to conduct on-site destructive testing. One seam sample shall be taken at random for each 500 feet of seam. Sample locations shall be designated by Owner or Owner's Representative. Each sample shall be assigned a unique identification number and the location shall be shown on the panel layout drawing. All holes in the installed geomembrane resulting from obtaining samples shall be repaired immediately. All repairs shall be 100 percent vacuum tested for continuity.

B. Each sample shall be approximately 18 inches long by 12 inches wide with the seam centered lengthwise. Samples shall be divided as follows:
   1. Six 1-inch wide coupons for on-site testing by Installer for shear and peel strength.
   2. One 6-inch wide coupon for independent laboratory testing.
   3. One 6-inch wide coupon for archival storage.

C. Installer shall conduct shear strength and peel adhesion tests on each sample using an on-site tensiometer. The sample shall exhibit film tearing bond (FTB) in both shear and peel and meet the minimum strength requirements set forth in Section 3.04B of this Section. The samples shall be delivered to Owner who will retain them for one year after contract completion. Destructive seam testing shall be performed under the observation of the Owner or Owner's Representative.

D. In case of disputes regarding the test results, arrangements will be made to test samples at an independent testing laboratory. Installer shall label the samples with the location and date that they were taken.

E. The following procedure will be followed in the event of a destructive seam test failure:
   1. Determine the extent of the area in question by finding a boundary of two passed seam samples. Samples shall be taken at least 10 feet away on both sides of the failure location.
   2. If both of these new samples pass the destructive field test, then the seam between shall be reconstructed by extrusion welding.
   3. If one or both of these new samples fail, then the procedure shall continue until two passed seam samples bound the seam area in question.
   4. Reconstruct by extrusion welding the entire seam bounded by two passed seam samples.
   5. All unacceptable seams shall be bounded by two passed seam sample locations.

F. All testing equipment required for these quality control tests shall be provided by Installer. Any seams failing the quality control tests shall be repaired at Contractor's expense until passing test results are obtained. At all times, care shall be exercised to avoid damaging the geomembrane.

3.08 GEOMEMBRANE PANEL AND SEAM REPAIR

A. Pin holes, creases, scratches, and other defects in the geomembrane shall be repaired by either patching:
   1. Patches shall be round or oval in shape, made of the same geomembrane material as the panel being repaired, and extend at least 6 inches beyond the edge of the defective area.
   2. Patch seaming shall be performed in accordance with Article 3.04 of this Section.

B. Wrinkles in the geomembrane shall be removed or repaired as directed by Owner or Owner's Representative.
   1. Wrinkles shall be repaired by cutting the geomembrane at the top edge of the wrinkle and overlapping the cut panels.
   2. The cut panels shall be repaired in accordance with Article 3.04 of this Section.

C. Any protuberances in the geomembrane caused by rocks, vegetation, or other foreign matter located on the subgrade below the geomembrane shall be repaired by cutting out the protuberance and patching the hole.

D. All repairs shall be tested in accordance with Article 3.06.

E. All repair locations shall be identified on Record Drawings.

3.09 APPURTENANCES

A. The geomembrane shall be installed around pipes and other appurtenances protruding through or adjacent to the geomembrane.

3.10 ANCHORAGE

A. The geomembrane shall be anchored as shown on the Drawings.

3.11 SUPERVISION OF PROTECTIVE COVER PLACEMENT

A. Geomembrane shall be covered as shown on the Drawings as soon as possible after seam testing has been completed and approved by Owner or Owner's Representative. Testing and covering may be completed in phases to facilitate timely placement of cover materials. Any geomembrane left uncovered overnight shall be visually inspected the following day for damage before cover materials are placed.

B. Installer shall provide qualified personnel to direct and supervise placement of granular drainage materials or protective covers over the geomembranes. Installer shall remain on-site during until cover material placement is complete.

C. Equipment traffic shall not be permitted over the geomembrane until a minimum 1-foot thick layer of material has been placed over the geomembrane. Vehicles with tires shall not be permitted to travel over the geomembrane until a minimum 2-foot thick cover has been placed.

D. Areas of geomembrane damaged during cover placement shall be repaired and tested. The cost of repairing and testing these damaged areas shall be borne by Contractor.

3.12 RESTORATION

A. The Contractor shall restore all areas affected by geomembrane-related work to preexisting conditions and to the satisfaction of Owner.

3.13 GEOMEMBRANE ACCEPTANCE

A. Contractor shall retain all ownership and responsibility for the geomembrane and related work until written acceptance from Owner is received.

B. Owner will provide written acceptance after the geomembrane installation and all related work, including cover material placement, has been satisfactorily completed and a written certification letter and Record Drawings reflecting all geomembrane-related work have been provided to Owner. The written certification letter and Record Drawings reflecting all geomembrane-related work shall be submitted in accordance with the general requirements to Owner not more than ten (10) working days after completion of all field seaming.

C. A 20-year material and 5-year workmanship warranty shall be provided by the Contractor.

END OF SECTION 02770

SECTION 02771

GEOSYNTHETIC CLAY LINER (GCL)

PART 1 GENERAL

1.01 SECTION INCLUDES

A. Furnishing and installing geosynthetic clay liner (GCL).

1.02 BASIS FOR COMPENSATION

A. Compensation for all Work covered under this Section of these Specifications will be included under the lump sum Contract Price bid.

1.03 SUBMITTALS

A. GCL: Submit for documentation the following information for GCL to be used for this project.
   1. Test methods and results defining physical properties as specified herein, of the GCL to be used for this project. Test results shall be representative of each roll of GCL furnished for this project (e.g., a test sample taken between two consecutive rolls from a continuous run will be considered representative of both rolls). Test results shall be reported with corresponding roll identification numbers.
   2. Statement of the GCL manufacturer's quality control procedures and frequency of sampling.

B. GCL Installation: Submit for review the following information regarding the GCL installation:
   1. A proposed panel and seam layout diagram. The layout diagram shall be to scale and used as a construction plan and shall include all necessary dimensions and details. The layout diagram shall be compatible with the panel and seam layout requirements specified in Article 3.04 of this Section.
   2. An installation schedule.
   3. A list of personnel performing field supervision and quality control, along with experience records and resumes.
   4. A list of equipment types proposed to be used in panel deployment and accessory bentonite application.

C. Submit for documentation, prior to the installation of any GCL, Installer's certification in writing that the surface upon which the GCL is to be installed is acceptable (use the form at end of this Section or Installer's equivalent).

D. Submit for documentation a material and workmanship warranty prior to substantial completion.

1.04 GCL MANUFACTURERS

A. The GCL manufacturer shall have a minimum of 5 years of continuous experience in the manufacture of GCL products.

B. The GCL manufacturer shall have a record of at least 10 million square feet of installed GCL products.

1.05 GCL INSTALLERS

A. The GCL installer (hereafter referred to as Installer) shall have at least 3 years continuous experience in the installation of GCL's and an installation record totalling at least 1 million square feet, or provide satisfactory evidence to Owner and Engineer, through similar experience in the installation of other types of geosynthetics that the GCL will be installed in a competent, professional manner.

B. GCL installation shall be performed under the direct supervision of a single field supervisor who shall remain on-site throughout installation, including inspection of the surface upon which the GCL is to be installed, GCL handling and storage, panel layout and placement, accessory bentonite application, panel repair, installation of appurtenances, and other GCL-related work. The field supervisor shall have complete supervisory responsibility for the installation, repair, and quality control, and have a personal GCL installation record totalling at least 500,000 square feet.

C. The GCL installer is subject to approval by Owner prior to mobilization for GCL installation. Owner has the right to reject any GCL installer, and request that Contractor select an alternate.

1.06 PREINSTALLATION CONFERENCE

A. Contractor and Installer shall attend a meeting at the site prior to installation of the GCL to discuss details of the proposed design and installation.

1.07 MANUFACTURER REPRESENTATIVE

A. During start-up of the GCL installation, an agent or representative of the manufacturer shall provide on-site assistance and instruction to the Contractor and Engineer regarding product installation.

PART 2 PRODUCTS

2.01 GEOSYNTHETIC CLAY LINER (GCL)

A. The GCL shall be and manufactured from polypropylene geotextiles and natural sodium bentonite.

B. The GCL used on sideslopes shall be reinforced for internal shear resistance.

C. No disassociation of geotextile components from the bentonite core shall occur. A sample of the GCL placed in 70°F tap water for one hour shall not delaminate.

D. Rolls shall be a minimum of 12 feet wide and 80 feet long. A 6-inch lap line and a 9-inch match line shall be printed or marked in the field on both edges of the upper geotextile of the GCL (as installed) to assist in overlap quality control.

E. Each roll shall be marked with the following information:
   1. Manufacturer's name and brand name.
   2. Lot and roll number.
   3. Roll length and width.
   4. Total roll weight.

F. All rolls shall be and bagged in packaging that is resistant to photodegradation by ultraviolet light.

G. GCL Properties:
   1. Bentonite Mass/Area: minimum of one pound bentonite per square foot GCL panel area at a 12 percent moisture content (ASTM D5261).
   2. GCL Panel and Seam Permeability: $\leq 6 \times 10^{-9}$ cm/s at 5 psi confining pressure (ASTM D5084).
   3. Hydrated Internal Shear Resistance: $\geq$ 150 psf at 5 psi normal stress (ASTM D5321).
   4. Non-woven Geotextile Weight: $\geq$ 6 oz./sq. yd.
   5. Woven Geotextile Weight: $\geq$ 3 oz./sq. yd.

2.02 ACCESSORY BENTONITE

A. Accessory bentonite used to augment seam overlaps, penetrations, and panel edges at structures shall be powdered or granulated bentonite of the same type used in the manufacture of the GCL.

2.03 ADHESIVES

A. Adhesive used to hold a GCL patch or panel edge in position shall be a non-toxic, water soluble product such as Elmer's glue.

PART 3 EXECUTION

3.01 SUBGRADE INSPECTION

A. The subgrade shall be prepared and compacted in accordance with Section 02220. Debris, roots, solid mineral particles larger than 1/2-inch diameter, and other material which may damage the GCL shall be removed. Prior to the deployment of the GCL, the subgrade shall be final-graded to fill any voids or cracks and rolled to provide a smooth surface for the installation of the GCL.

B. Installer shall certify in writing that the surface upon which the GCL is to be installed is acceptable (complete form contained at end of this Section).

3.02 SUBGRADE MAINTENANCE

A. After subgrade has been accepted by Installer, it shall be Installer's responsibility to indicate to Contractor any change in subgrade condition that may require repair work. Special care shall be taken to maintain prepared GCL subgrade. Daily observations shall ascertain effects of precipitation and desiccation upon integrity of subgrade. Damage to subgrade caused by precipitation and desiccation shall be repaired at Contractor's expense.

B. Subgrade shall be smooth and firm at time of GCL deployment. All depressions, ridges, and other irregularities shall be raked smooth. Imprints and ridges resulting from foot and vehicle traffic shall be raked smooth.

C. Particular attention shall be paid to subgrade condition at the panel edges. Panel edges shall lay flat against the subgrade with no puckering, creasing, or curling.

3.03 HANDLING, TRANSPORTATION, AND STORAGE

A. Rolls shall be stored on a flat, dry surface. Tarping of stored materials is suggested to avoid any unnecessary stress on the packaging.

B. Rolls shall be handled using a solid steel bar inserted through the core bar and slings or chains attached to the ends of the bar. The core bar shall be suspended from a spreader bar so that the edges of the liner are not damaged by the suspending straps or chains. The steel bar shall be of sufficient strength so as to allow minimal bending of the bar or roll of GCL.

3.04 INSTALLATION

A. Work on the top slope shall be undertaken before work on the side slopes to permit drainage in the event of rainfall. Panel edges shall be perpendicular to the toe of the slope.

B. Panels shall be placed with the nonwoven side against the subgrade and the woven side oriented upwards.

C. Panel overlap areas shall be clean and panel edges shall be pulled tight to maximize contact and to smooth out any wrinkles, creases and curls.

D. Panel overlaps shall be in direct and continuous contact with no puckering, creasing, or curling. Edge overlaps shall be a minimum of 6 inches. A proper edge seam shall cover the 6-inch lap line and leave the 9-inch match line exposed. End overlaps shall be a minimum of 2 feet and in a rainlap orientation.

E. Panel overlaps shall be augmented with granular bentonite to ensure seam integrity, unless indicated in writing by product manufacturer that GCL placement without augmenting seams will in no way diminish the performance of the overall barrier layer system. Granular bentonite shall be dispersed evenly, using calibrated mechanical dispensing equipment, from the panel edge to the lap line at a minimum rate of 1/4 pound per lineal foot continuously along all seams or overlap areas. Accessory bentonite shall be of the same type as used in manufacture of the GCL.

F. The Contractor shall only work on an area that can be completed in one working day. Completion is defined as the full installation and anchoring of the bentonite panel and installation (including seaming) of the overlying geomembrane.

G. GCL panels which become hydrated prior to installation and seaming of the overlying GCL and placement of the first 12 inches of cover soil shall be removed and replaced at Contractor's expense.

H. For penetrations or structures which the GCL will contact, the GCL shall be brought up to the appurtenance and trimmed to fit. Installer shall then hand apply a pure bead of bentonite, or compact a mixture of one part bentonite to four parts soil (by volume), to fill the area between the GCL and the structure, both below and above the GCL.

3.05 FIELD REPAIRS

A. Rips or tears in the GCL shall be either repaired or replaced, at the sole discretion of Owner or Engineer.

B. Repairs shall be completed by exposing the affected area, removing all foreign objects or soil, and by then placing a patch over the damage, with a minimum overlap of 12 inches on all edges. Accessory bentonite shall be placed between the patch and the repaired material at a rate of 1/2 pound per lineal foot of edge, spread in a 6-inch width.

C. GCL patches or panel edges which may be subject to displacement during installation of the overlying geomembrane or cover soil shall be secured to the main panel using adhesives or by methods recommended by the GCL manufacturer or approved by the Engineer. Adhesives shall be applied only to the outer edge of overlap and shall not interfere with the placement or funtion of accessory bentonite used for seam augmentation.

3.06 PROTECTION AFTER INSTALLATION

A. Prevent movement of GCL after installation by sandbagging or other approved methods.

B. The GCL shall be kept clean and free of soil, debris, and foreign material until covered by the geomembrane. The geomembrane shall be installed in direct contact with the GCL.

C. No vehicle traffic will be permitted directly on the GCL. Only soft-soled/rubber-soled boots and shoes shall be worn on the GCL. Tracked vehicles and trucks with low-pressure tires will be permitted to travel on a minimum of 12-inch thickness of cover soil over the GCL. Vehicles with high-pressure tires will be permitted to travel on a minimum of 2-foot thickness of cover soil over the GCL.

D. GCL Installer shall coordinate with Contractor and geomembrane installer regarding deployment, seaming, and testing of geomembrane and placement of cover soils over GCL such that geomembrane installation and cover soil placement occurs expeditiously and without damage to the GCL.

E. Geomembrane deployment and positioning shall be done such that no disruption of the GCL occurs, particularly at the overlapped seams.

END OF SECTION 02771

Certificate of Acceptance of
GCL Subgrade Surface by GCL Installer

Installer:

Name:
Address:

Authorized
Representative:

Project:

Location:
Project:
Area Accepted:

Owner:

Description of Area to Be Certified ____

Certification

The undersigned, ______________, certifies that he/she is a representative of ____________________duly authorized to execute this certificate, that he/she visually inspected the subgrade surface described above on ______ _______ and found the surface to be acceptable for installation of the geosynthetic clay liner.

This certification is based on observations of the surface of the subgrade only. No subsurface inspections or tests have been performed and ____________________ makes no representations or warranties regarding conditions which may exist below the surface of the subgrade.

Date:

Signature:

Name:

Title:

Certificate Received by Contractor:

Date:

Company:

Signature:

Name:

Title:

Certificate Received by Owner:

Date:

Company:

Signature:

Name:

Title:

SECTION 02930

TURF ESTABLISHMENT

PART 1 GENERAL

1.01 SECTION INCLUDES

A. Establishing vegetation on all topsoiled areas of the site.

1.02 BASIS FOR COMPENSATION

A. Compensation for all Work and materials covered under this Section of these Specifications will be included under the lump sum Contract Price bid.

1.03 REFERENCES

Minnesota Department of Transportation Standard Specifications for Construction, 1988 Edition, hereafter referred to as Mn/DOT Standard Specifications.

PART 2 PRODUCTS

2.01 MATERIALS

A. Seed: In accordance with Mn/DOT Standard Specification 3876 with seed mixture as follows:
Base Seed Mixture:

Park Kentucky Bluegrass	75 lbs./acre
Creeping Red Fescue	60 lbs./acre
Perennial Ryegrass	15 lbs./acre

Spring Seed Mixture:

Norcen, Leo, or Carroll Birdsfoot Trefoil	10 lbs./acre

Dormant Seed Mixture:

Base Seed Mixture and;	
Annual Ryegrass	10 lbs./acre

B. Fertilizer: In accordance with Mn/DOT Standard Specification 3881, at the minimum rate of 750 pounds per acre, at a mixture of 0-26-26; with sulfur at the rate of 100 pounds per acre.

C. Mulch: Type I in accordance with Mn/DOT Standard Specification 3882.

PART 3 EXECUTION

3.01 SEQUENCING AND SCHEDULE

A. The Contractor shall coordinate the turf establishment work with the topsoiling and finishing operations, so as to reduce to a minimum the lag time between the initial and final phases of the combined work and to establish turf protection as soon as possible after the graded areas have been topsoiled or finish graded.

3.02 TURF ESTABLISHMENT

A. Place topsoil as specified in Section 02220 to the dimensions and in locations as indicated on the Contract Drawings.

B. Establish turf on all disturbed and topsoiled areas, excluding the borrow pit. Turf establishment includes:
   1. Soil preparation (Mn/DOT Standard Specification 2575.3B).
   2. Fertilizing (Mn/DOT 2575.3C).
   3. Sowing seed (Mn/DOT 2575.3D3).
   4. Seedbed firming (Mn/DOT 2575.3E).
   5. Applying mulch (Mn/DOT 2575.3FI).
   6. Disk anchoring (Mn/DOT 2575.3H).

   Sowing seed shall include sowing the Base or Dormant seed mixture, and the Spring seed mixture.

C. Sow the appropriate seed mixture depending upon the sowing date, as specified below:
   1. July 20 to September 20: sow Base Seed Mixture.
   2. After September 20: sow Dormant Seed Mixture.
   3. Sow the Spring Seed Mixture between April 15 and May 15 of the spring following the initial seed sowing.

3.03 WATERING

A. Watering shall be performed at the discretion of the Contractor, at the rate and frequency as may be necessary to initiate and sustain seed germination. Watering shall be performed by and at the expense of the Contractor until the work is accepted by the Owner .

3.04 MAINTENANCE

A. Rework/replace topsoil where original topsoil has eroded or washed away as directed by Owner or Engineer .

B. Remulch any areas on which the original mulch has eroded, washed away, or blown off, as directed by Owner or Owner's On-Site Representative.

C. Reseed any areas on which the original seed has failed to grow, using the specified seed mixture, as directed by Owner or Engineer .

D. Perform all necessary maintenance, replacement and repair work until acceptance of the Work by Owner. The expense of maintenance, replacement, and repair shall be borne by Contractor. Acceptance of work by Owner will occur in the spring of the year following performance of turf establishment when it is evident that seed has germinated.

END OF SECTION 02930

SECTION 03100

CONCRETE FORMWORK

PART 1 GENERAL

1.01 DESCRIPTION

A. All Work included in this Section shall be performed in accordance with the following paragraphs, the General Requirements set forth in Division 1 of these Specifications, and the provisions of the other Contract Documents.

B. Work covered under this Section shall include furnishing all labor, materials, equipment, and performing operations necessary to provide formwork and shoring for the placement of all cast-in-place concrete and any embedments or items to be cast into the concrete.

C. Concrete, reinforcing steel and embedments are not included in this Section.

1.02 REFERENCES

A. American Concrete Institute, hereinafter referred to as ACI. Current edition of reference.

B. Work covered under this Section shall be in accordance with the latest available version of the following references unless otherwise noted:
1. ACI 117, "Standard Tolerances for Concrete Construction and Materials, Chapter 2"
2. ACI 301, "Specifications for Structural Concrete for Buildings, Chapter 4"
3. ACI 318, "Building Code Requirements for Reinforced Concrete"
4. ACI 347, "Recommended Practice for Concrete Formwork"
5. ACI SP-4, "Formwork for Concrete"

1.03 SUBMITTALS

A. No submittals are necessary for materials and supplies covered under this Section which comply with the applicable Specifications.

1.04 SEQUENCING AND SCHEDULING

A. The erection and removal of formwork shall be scheduled and sequenced to provide for the minimum curing and form removal requirements as set forth in Section 03300 of the Specifications. The Contractor shall be responsible for sequencing form erection and removal to match any concrete pours, curing, and any other adjacent or related work which may affect the placement, removal or availability of any concrete formwork.

1.05 WARRANTIES AND GUARANTEES

A. The Contractor shall be responsible for the stability, performance and structural integrity of all formwork.

1.06 BASIS FOR COMPENSATION

A. Compensation for all Work covered under this Section of these Specifications shall be in accordance with the provisions set forth in Section 01025, Measurement and Payment.

PART 2 PRODUCTS

2.01 MATERIALS

A. Forms shall be constructed of wood, metal, or other material subject to review by the Engineer. Forms shall provide a smooth continuous surface.

B. Chamfer strips shall be constructed of wood, metal, or other material subject to review by the Engineer.

C. Form accessories to be partially or wholly embedded in the concrete, such as ties and hangers, shall be a commercially manufactured type. Wire is not acceptable. Ties shall be a type which leave no metal closer than 1 inch from the surface of the finished concrete.

D. Form coating or release agent shall be a non-staining form release which prevents adhesion of concrete to formwork, and shall be compatible with the type of form materials used. Acceptable agents include North Central Form Release, Eucoslip Form Release, Nox-Crete form coating and Crembeton 103.

2.02 MANUFACTURE

A. Forms may be either pre-manufactured or constructed on-site by the Contractor.

B. The design and engineering of the formwork, as well as the construction, shall be the responsibility of the Contractor. The formwork shall be designed for loadings, lateral pressures and allowable stresses in accordance with Chapter 1 of ACI 347. Forms shall also be designed in accordance with ACI SP-4.

C. Forms shall be manufactured so as to provide smooth continuous surfaces in contact with concrete, as recommended in ACI 301 and 347.

PART 3 EXECUTION

3.01 PRODUCT DELIVERY, STORAGE AND HANDLING

A. Forms shall be protected from deterioration, weather and shrinkage prior to concreting by proper storage, oiling, wetting, or other appropriate methods.

B. Forms shall be free of rust, rot, or other detrimental forms of deterioration.

3.02 ERECTION

A. Forms shall conform to the shape, lines and dimensions of the components shown on the Drawings, true to line, plumb and level as required to conform to ACI 117.

B. Forms shall be adequately designed, erected, supported and maintained to safely support all vertical loads that might be applied, including construction loads and loads resulting from the placement and vibration of concrete.

C. Forms for exposed concrete shall be constructed with particular care to avoid appreciable deflection in order to eliminate bulges, off-sets, or other unsightly features in the finished surfaces.

D. Forms shall be sufficiently tight to prevent leakage of grout or cement paste.

E. Forms shall be provided for all openings in concrete except pipe sleeves. The location, number, and details of such items as openings, chases, recesses, construction joints, control joints, expansion joints, waterstops, and inserts shall be carefully coordinated.

F. Forms shall be designed so they may be removed in proper sequence and without damage to the concrete. Hammering or prying against concrete surfaces shall be avoided to prevent damage to concrete.

G. Formwork supported on ground shall have satisfactory foundations to carry the loads imposed during and after construction without appreciable settlement.

H. Where necessary to maintain the specified tolerances the formwork shall be cambered to compensate for anticipated deflections in the formwork due to the weight and pressure of the plastic concrete and construction loads. Positive means of adjustment (e.g., wedges, jacks, shores and struts) shall be provided and all settlement taken up during concrete placing operations.

I. Forms for exposed concrete shall be treated with a non-staining form oil. Care shall be taken to avoid placement of form oil on reinforcing steel, embedded anchorages, anchor bolts, bearing plates, or other items which require bonding to concrete. Care shall be taken to avoid excess accumulation of form oil in form work.

J. Forms shall be thoroughly cleaned of all dirt, mortar, sawdust and other foreign matter prior to use, and the bottoms of forms inaccessible from within shall be provided with access panels to permit removal of extraneous materials before placing concrete.

3.03 ATTACHMENTS

A. Openings in formwork shall be provided to accommodate any conduits, fixtures, or other appurtenances extending through the formwork.

B. Items which will be directly embedded into concrete shall be accurately located, securely supported, level, plumb and straight. This shall include items such as anchors, bearing plates, trunnion pin assemblies, sill and side plates, bolts, sleeves, conduits, pipes, and other inserts.

3.04 INSPECTION AND ACCEPTANCE

A. The Contractor shall make formwork accessible for inspection of reinforcing, embedments and any other necessary portions of the concrete work required by the Engineer.

B. The Contractor shall make inspection holes as requested by the Engineer to verify consolidation of concrete.

3.05 FIELD QUALITY CONTROL

A. The Contractor shall establish and maintain quality control for work covered under this Section of the Specifications to assure compliance with contract requirements. The Contractor shall maintain records, available to the Engineer, regarding quality control measures.

END OF SECTION 03100

SECTION 03200

CONCRETE REINFORCEMENT

PART 1 GENERAL

1.01 DESCRIPTION

A. All Work included in this Section shall be performed in accordance with the following paragraphs, the General Requirements set forth in Division 1 of these Specifications, and the provisions of the other Contract Documents.

B. Work covered under this Section shall include furnishing all labor, materials, equipment, and performing operations necessary for the fabrication, supply and placement of reinforcing steel, including bars, dowels, wire strand, tie supports, and other reinforcement accessories.

C. Anchor plates, anchor bolts, form ties, and other embedments are not included in this Section.

1.02 REFERENCES

A. American Concrete Institute, hereinafter referred to as ACI. Current edition of reference.

B. American Society for Testing and Materials, Current Edition, hereinafter referred to as ASTM.

C. Concrete Reinforcing Steel Institute, hereinafter referred to as CRSI. Current edition of reference.

D. Work covered under this Section shall be in accordance with the latest available version of the following references unless otherwise noted:
1. ACI SP-66, "Detailing Manual - 1988"
2. ACI 315, "Details and Detailing of Concrete Reinforcement"
3. ACI 318, "Building Code Requirements for Reinforced Concrete and Commentary"
4. CRSI, "Manual of Standard Practice"
5. CRSI, "Placing Reinforcing Bars"
6. ASTM Designation A615/A615M, "Deformed and Plain Billet-Steel Bars for Concrete Reinforcing"
7. ASTM Designation A616/A616M, "Specification for Rail-Steel Deformed and Plain Bars for Concrete Reinforcement"
8. ASTM Designation A617/A617M, "Specification for Axle-Steel Deformed and Plain Bars for Concrete Reinforcement"
9. ASTM Designation A706, "Specification for Low-Alloy Steel Deformed Bars for Concrete Reinforcement"
10. ASTM Designation A722, "Uncoated High-Strength Steel Bar For Prestressing Concrete"

1.03 SUBMITTALS

A. In accordance with Section 01300, the manufacturer's certificates giving properties of the steel (i.e., mill tests) furnished under this section of the Specifications shall be submitted for documentation.

1.04 SEQUENCING AND SCHEDULING

A. Placement and securing of reinforcing steel and formwork and review of reinforcing shall be scheduled so that reinforcing work may be observed by the Engineer before it becomes inaccessible, as required in Part 3.03 of this section.

1.05 BASIS FOR COMPENSATION

A. Compensation for all Work covered under this Section of these Specifications shall be in accordance with the provisions set forth in Section 01025, Measurement and Payment.

PART 2 PRODUCTS

2.01 MATERIALS

A. Reinforcing bars and dowels shall conform to the latest ASTM Designation A615, A616, A617 or A706, Grade 60.

B. [NOT USED]

C. All bar supports resting on or within 4 inches of a formed surface, free surface, ground, or any other location in which corrosion of the bar or support could occur shall conform to requirements set forth in the CRSI Manual of Standard Practice for Type C plastic-protected or Type E stainless steel protected bar supports.

D. Tie wire shall be No. 16 annealed wire.

2.02 MANUFACTURE

A. All reinforcing bars shall be bent cold to the dimensions required before placing. Diameter of hooks and bends shall be as set forth in ACI 315. Bars with kinks or bends not shown on the Drawings shall not be incorporated into the Work. Bar lengths, depths, and bends exceeding specified fabrication tolerances shall not be permitted in the work.

B. Tension tiedown rod tendons shall be either shop fabricated or field fabricated in accordance with approved details, using personnel trained and qualified in this type of work.

PART 3 EXECUTION

3.01 PRODUCT DELIVERY, STORAGE AND HANDLING

A. Steel reinforcement shall be stored above the surface of the ground on platforms, skids or other supports, and shall be reasonably protected from injury and surface deterioration caused by exposure to conditions producing rust. When placed in the Work, reinforcement shall be free of injurious seams, flaws, cracks, scale, excess rust or other foreign materials.

3.02 ERECTION

A. All reinforcing shall be accurately placed to the dimensions shown on the Drawings, and securely held in place by bar supports, chairs, spacers or wire and tied with wire at all cross points in a manner that will provide the required concrete covering.

B. Reinforcing shall be placed within 1 inch of the locations shown on the Drawings and in no case shall the total number of reinforcing bars be less than the number of bars indicated on the Drawings.

C. Unless otherwise specified, the clear distance between the reinforcing steel and concrete surfaces shall be 2 inches ± ¼ inch. When concrete is placed against soil, the clear distance between the reinforcing and the soil shall be 3 inches ± ¼ inch. Care shall be taken to prevent sagging between reinforcement supports which would reduce clear cover distances below the above values.

D. Reinforcing shall NOT be tack welded.

E. Adequate chairs, ties, etc., shall be placed at such intervals as to prevent bars or welded wire fabric from sagging or deflecting and to hold the reinforcement rigidly against displacement of the concrete.

F. Reinforcing steel shall be placed strictly in accordance with the details shown on the Drawings.

G. Control and construction joints shall be located only in the locations shown on the Drawings, and shall be constructed strictly in accordance with joint details shown on the Drawings.

H. All lap splices shall conform to the requirements set forth in ACI 318. Deformed reinforcing splices shall be Class B.

I. Reinforcement shall be free of loose rust and mill scale, earth, ice, cement, mortar and other materials prior to placement of new concrete which reduce or prevent complete bond with concrete.

3.03 INSPECTION AND ACCEPTANCE

A. Concrete shall not be placed until the reinforcing steel has been directly observed by Engineer and Engineer agrees that reinforcement steel complies with the requirements of the Contract Documents. Formwork which makes the reinforcing inaccessible for observation shall not be placed until the reinforcing area in question has been observed and accepted by the Owner.

3.04 FIELD QUALITY CONTROL

A. The Contractor shall establish and maintain quality control for work covered under this Section of the Specifications to assure compliance with contract requirements. The Contractor shall maintain records, available to the Owner, regarding quality control measures. Records shall be kept of the grades, size and location of reinforcing, the type of supports provided for reinforcing, and the class and dimension of reinforcing splices.

END OF SECTION 03200

SECTION 03300

CAST-IN-PLACE CONCRETE

PART 1 GENERAL

1.01 DESCRIPTION

A. All Work included in this Section shall be performed in accordance with the following paragraphs, the General Requirements set forth in Division 1 of these Specifications, and the provisions of the other Contract Documents.

B. Work covered under this Section shall include furnishing all labor, materials, equipment, and performing all operations necessary for cast-in-place concrete work as shown on the Drawings.

C. Reinforcing steel, embedments and formwork are not included in this Section.

1.02 REFERENCES

A. American Society for Testing and Materials, Current Edition, hereinafter referred to as ASTM.

B. American Concrete Institute, latest edition, hereinafter referred to as ACI.

C. American Association of State Highway and Transportation Officials, latest edition, hereinafter referred to as AASHTO.

D. North Dakota Department of Transportation Standard Specifications for Road and Bridge Construction, 1992 Edition, hereafter referred to as NDDOT Standard Specifications.

E. Work covered under this Section shall be in accordance with the latest available version of the following references unless otherwise noted:
1. ACI 117, "Standard Tolerances for Concrete Construction and Materials"
2. ACI 211, "Standard Practice for Selecting Proportions for Normal, Heavyweight, and Mass Concrete"
3. ACI 214-77, "Recommended Practice for Evaluation of Strength Test Results of Concrete"
4. ACI 224-1R, "Causes, Evaluation, and Repair of Cracks in Concrete Structures"
5. ACI 301, "Specifications for Structural Concrete for Buildings"
6. ACI 304R, "Guide for Measuring, Mixing, Transporting and Placing Concrete"
7. ACI 305R, "Hot Weather Concreting"
8. ACI 306R, "Cold Weather Concreting"
9. ACI 308, "Standard Practice for Curing Concrete"
10. ACI 309R, "Guide for Consolidation of Concrete"
11. ACI 318-89, "Building Code Requirements for Reinforced Concrete"
12. ACI 347R, "Guide to Formwork for Concrete"
13. ACI SP-46-8, "A Method of Proportioning Structural Concrete Mixes with Fly Ash and Other Pozzolans"
14. ASTM Designation C31, "Test Methods of Making and Curing Concrete Test Specimens in the Field"
15. ASTM Designation C33, "Specifications for Concrete Aggregate"
16. ASTM Designation C39, "Test Method for Compressive Strength of Cylindrical Concrete Specimens"
17. ASTM Designation C40, "Test Method for Organic Impurities in Fine Aggregate for Concrete"

18. ASTM Designation C88, "Test Method for Soundness of Aggregates by Use of Sodium Sulfate or Magnesium Sulfate"
19. ASTM Designation C94, "Specification for Ready-Mixed Concrete"
20. ASTM Designation C117, "Test Method for Material Finer Than 75 μm (No. 200) Sieve in Mineral Aggregates by Washing"
21. ASTM Designation C123, "Test Method for Lightweight Pieces in Aggregate"
22. ASTM Designation C127, "Test Method for Specific Gravity and Absorption of Coarse Aggregate"
23. ASTM Designation C128, "Test Method for Specific Gravity and Absorption of Fine Aggregate"
24. ASTM Designation C131, "Test Method for Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine"
25. ASTM Designation C136, "Method for Sieve Analysis for Fine and Coarse Aggregates"
26. ASTM Designation C142, "Test Method for Clay Lumps and Friable Particles and Aggregates"
27. ASTM Designation C150, "Specification for Portland Cement"
28. ASTM Designation C171, "Specifications for Sheet Materials for Curing Concrete"
29. ASTM Designation C260, "Specifications for Air-Entraining Admixtures for Concrete"
30. ASTM Designation C309, "Specifications for Liquid Membrane-Forming Compounds for Curing Concrete"
31. ASTM Designation C494, "Specifications for Chemical Admixtures for Concrete"
32. ASTM Designation C618, "Specification for Fly Ash and Raw or Calcined Natural Pozzolan for Use as a Mineral Admixture in Portland Cement Concrete"
33. AASHTO Designation T26, "Quality of Water to be Used in Concrete"

1.03 SUBMITTALS

A. Make all submittals in accordance with Section 01300.

B Prior to the start of work, manufacturer's data and product information relating to all concrete material products shall be submitted as documentation.

C. Prior to the start of work, Certificates of material properties signed by the material producer or processor and the Contractor verifying compliance with Contract material specifications shall be submitted for review. Certification shall include project name and number, date of report, name of Contractor, source of material, manufacturer or processor, and brand name for proprietary products.

D. Prior to the start of work, the concrete mix designs shall be submitted for review.

E. If concrete production facility records are utilized as the basis for proportioning the mix, all concrete strength test data for each concrete designation to be used shall be submitted for review.

F. If a sprayed-on membrane is used for curing, the manufacturer's certification shall be submitted as documentation, verifying that the material furnished has been tested and conforms to the required tests as described in the appropriate sections below.

G. The Contractor shall submit for review a concrete quality assurance program. The program will include material source as well as production.

1.04 SEQUENCING AND SCHEDULING

A. The Contractor shall provide a schedule for all product, material and testing submittals and concrete placement.

1.05 QUALITY ASSURANCE PROGRAM

A. The Contractor shall provide a quality assurance program for the products and material sources and for the concrete construction as set forth in PARTS 2 and 3 of this section.

B. The Contractor shall provide access and make materials available to the Engineer for testing as required.

C. Any required testing not specifically indicated to be done at the Owner's expense, including retesting of rejected materials and installed work, shall be conducted at the Contractor's expense.

1.06 BASIS FOR COMPENSATION

A. Compensation for all Work covered under this Section of these Specifications shall be in accordance with the provisions set forth in Section 01025, Measurement and Payment.

PART 2 PRODUCTS

2.01 MATERIALS

A. Form Materials—See Section 03100

B. Reinforcing Materials—See Section 03200

C. Concrete Materials
1. Cement: To ASTM C150, Type I.
2. Fine Aggregate: To ASTM C33 and having a specific gravity (ASTM Designation C128) of less than 2.60 will be rejected.
3. Coarse Aggregate: To ASTM C33, Size Number 67, Class Designation 4S and having a specific gravity (ASTM Designation C128) of less than 2.60 will be rejected.
4. Water: To ASTM C94. The quality of questionable water shall be determined in accordance with the latest AASHTO Designation T26.
5. Air Entraining Admixtures: To ASTM C260..
6. Water Reducing Admixture: To ASTM C494, Type A or D.
7. Pozzolans: To ASTM C618, Type F.

D. Curing Materials
1. Sheet Materials: To ASTM C171. Polyethylene sheet shall be white opaque.
2. Liquid Membrane Forming Compounds: To ASTM C309, Type 1-D or 2. Compound shall be non-permanent type and shall deteriorate within 60 days of application.
3. Water: Fresh and free from injurious amounts of oil, acid, salt, alkali, organic matter or other deleterious substances.

2.02 MANUFACTURE

A. General Mix Requirements:
1. Concrete shall be composed of Portland cement, air-entraining admixture, coarse aggregate, fine aggregate, and water. Water reducing admixture shall be incorporated as required by the Contractor. Pozzolan shall be incorporated into the concrete mix in accordance with these Specifications.
2. Concrete shall be sulfate resistant concrete in conformance with ACI Section 318.4.2 for Very Severe Sulfate Exposure.
3. The concrete mixes shall be designed with the intention of producing the quality specified, and proportioned and mixed in accordance with the requirements as set forth. Ready-mixed concrete shall be batched in an approved plant in accordance with ASTM C94.

B. Proportioning: The concrete mix to be furnished under this contract shall be in accordance with the following characteristics:

1.	Specified 28-day compressive strength p'_c (psi)	4,000
2.	Max. Nominal aggregate size (inches)	1-1/2
3.	Max. Slump (inches)	6
4.	Min. Slump (inches)	4
5.	Air Content (%)	6.5 to 7.5
6.	Minimum cement content (lbs. per cubic yard)	410
7.	Minimum pozzolan content (lbs. per cubic yard)	72
8.	Max. water cement ratio	0.57
9.	Water reducing admixture	If Reqd.

C. Design and Testing

1. Design and testing for the concrete mix to be used under this contract shall be made using the cement, aggregates and pozzolans and other admixtures which will be used for the project. The mix shall be designed in accordance with ACI 211 and Chapter 5 of the "Building Code Requirements for Reinforced Concrete", ACI 318-89 to attain the required strengths and slumps, using the required aggregate sizes and admixtures. Proportioning by use of the water-cement ratio limits will not be permitted. Concrete containing pozzolans shall be designed in accordance with ACI SP-46-8.
2. If concrete production facility records are utilized as the basis for proportioning the mix, all concrete strength test data shall be submitted to the Engineer as required under the Submittals portions of this Specification.
3. In the design of concrete mixes requiring a water reducing admixture, the specified slump shall be obtained by maximizing the amount of water-reducing admixture used in the mix and minimizing the water-cement ratio.

2.03 SOURCE QUALITY CONTROL

A. The manufacturer shall maintain a source quality control program to insure that materials conform to the Specifications. Each type of material shall be provided from one source to the fullest extent practical. The records shall be maintained regarding the source of all materials and submitted to the Owner.

PART 3 EXECUTION

3.01 MIXING AND TRANSPORTATION

A. Concrete shall be produced, transported and handled in accordance with "Design and Control of Concrete Mixes" and ACI 304R. Ready-mixed concrete shall be batched in an approved plant and transported to the job site in accordance to ASTM C94 and ACI 304R.

B. Additional air-entraining admixture may be added at the site to compensate for loss of air-entrainment provided the concrete is then rotated in the mixer or ready mix truck a minimum of 30 revolutions and is retested for air and slump.

C. Retempering of the concrete with water at the site is prohibited.

3.02 PLACEMENT

A. General
1. Before concrete is placed, all equipment for mixing and transportation of concrete shall be cleaned, all debris and ice shall be removed from the spaces to be occupied by the concrete, and all forms shall be thoroughly cleaned of debris, ice and other coatings. All embedded items, including reinforcing steel, anchors, inserts, bolt cans, sleeves, and other items specified under this and other sections of the Specifications shall be properly located, accurately positioned, built into the construction, and maintained securely in place.
2. Screeds shall be placed on proper supports to maintain required thickness of slabs, and bulkheads be placed shall as required to limit each pour to distinct predetermined construction joints.
3. Concrete which has started to set or which is retempered with water shall not be used.

B. Placement
1. Existing concrete surfaces receiving new concrete shall be prepared as specified in Section 02051 of these Specifications.
2. Surfaces shall be pre-wet with water to saturated surface dry with no standing water before concrete is placed.
3. Concrete shall be transferred from the mixer to the place of final deposit by methods which prevent the separation of aggregate from mortar, and prevent the loss of ingredients. Methods of deposit shall prevent splattering wet concrete on reinforcing steel or forms before the actual placement of concrete against these surfaces. Concrete may be conveyed in buckets, buggies, chutes, or other approved means. All concrete shall be placed in continuous approximately horizontal layers.
4. Concrete shall be dropped from a height that is as close to its final location as possible and in no case from a height not more than 4 feet.
5. Special care shall be taken to prevent splashing of the forms or reinforcement with concrete. Any such splashes or accumulations of hardened concrete on the forms or on any items to be embedded in the concrete above the general level of the concrete already in place shall be removed before the work proceeds.
6. Concrete shall not be deposited in or through water unless the procedures for placement have been reviewed by the Engineer and approved by the Owner. The placement procedures shall include provisions to prevent segregation or dilution of cement paste.

C. Placement Time Limitations

Concrete containing a water reducing admixture which does not retard the setting time of the mix shall be placed within 1 hour after mixing. If the water reducing admixture incorporated into the mix retards the setting time of the concrete, the concrete shall be placed within 1½ hours after mixing. The use of additional water reducer beyond the normal recommended amount by the manufacturer shall not be used to retard the concrete.

D. Consolidation

Concrete shall be consolidated in accordance with ACI 301 and 309R.

E. Curing and Protection
1. General: All concrete shall be protected against mechanical damage until the completion of work.
2. Removal of Forms
   a. Forms shall be removed in a manner to ensure complete safety of the structure.
   b. The periods of time specified in this section represent cumulative periods of time (not necessarily consecutive) during which the temperature of the concrete is above 50°F.
   c. Forms for the tops of sloping surfaces shall not be removed until the concrete has attained adequate strength, and in no case less than 48 hours.

d. In no case shall forms, shoring or reshoring be removed until the members have acquired sufficient strength to safely support the weight and the loads thereon.

e. Procedures for reshoring shall follow the recommendations outlined in ACI 347R Section 3.7.

3. Curing: Cure concrete in accordance with ACI 301.

F. Cold Weather Protection

1. When the temperature of the surrounding air falls below 40°F during placing or 72 hours thereafter, adequate means shall be provided to prevent the concrete, as placed, from falling below 55°F for the duration of the 72-hour period.
2. Calcium chloride shall not be used.
3. Frozen concrete shall be immediately removed upon direction of the Engineer and replaced with new work and materials at no expense to the Owner. In order to maintain the temperature specified, the work shall be entirely enclosed, and all fuel and suitable heating equipment and the necessary labor and supervision shall be furnished. Non-vented heaters shall not be used within enclosures where concrete slabs are being water cured so as to prevent the unfavorable reaction between carbon dioxide and fresh concrete.
4. During cold weather, temperature records shall be kept by the Contractor and furnished to the Engineer daily, showing the temperature at 4-hour intervals of the outside air, of the air in the coldest part of the enclosure near the concrete, of the concrete as it is placed, and of the concrete in place at such points as the Engineer may direct. During freezing weather, such temperature records shall be kept night and day.

G. Hot Weather Protection

1. Care shall be taken during hot weather to keep concrete temperatures and mixing and placing times to a minimum.
2. Transport trucks shall be dispatched to avoid delays and the work shall be organized to use the concrete promptly to prevent unnecessary additional mixing at the job site.
3. When necessary, arrangements for installation of windbreaks, shading, spraying, sprinkling, or wet covering of a light color shall be made in advance of placement, and such protective measures shall be undertaken as quickly as concrete hardening and finishing operations will allow.
4. Production, delivery, placement and protection of concrete during hot weather shall comply with ACI 305R.

H. Concrete Finishes: Repair of surface defects and finishing of concrete surfaces shall be in accordance with ACI 301 and details shown on the drawings.

I. Tolerances: All concrete structures shall be constructed in accordance with the tolerances set forth in ACI 117.

J. Crack Repair: The evaluation and repair of cracks shall conform with recommendations set forth in ACI 224.1R.

3.03 INSPECTION AND ACCEPTANCE

A. General:

1. The Contractor shall notify the Engineer of scheduled concreting operations at least 24 hours prior to the time such operations are initiated. Proper facilities shall be provided by the Contractor for the Engineer to inspect the ingredients and the proportioning process. The Engineer may take, without charge, samples of the ingredients and of the concrete to determine if the concrete conforms to the requirements set forth in the Specifications.
2. The Engineer may take samples for any of the following tests from any portion of the batch. All tests will be made in accordance with the appropriate ASTM specification.

B. Slump: Prior to the placement of any concrete, the Engineer may take a slump test. When the slump is greater than the allowable, the Engineer will reject the concrete and the Contractor shall remove the concrete from the site. <u>Addition of water to compensate for stiffening of the concrete before placing will not be allowed.</u>

C. Air Content: Air content determinations will be made by the Engineer. If the measured air content falls outside of the specified limits, the placing of concrete shall immediately be stopped, and the Engineer will immediately make another air content determination from the same batch. See paragraph 3.01C for the addition of air-entraining admixture. In the event of a second failure, the concrete shall be considered to have failed to comply with the Specifications and the Contractor shall remove all of the concrete of that batch from the site. For concrete containing pozzolans, the Engineer may perform one air test every 20 minutes during the placement of each load of concrete.

D. Strength
   1. The concrete strengths will be evaluated and accepted in accordance with subsection 5.6 of ACI 318-89 unless otherwise specified. The Engineer will make sets of test cylinders in accordance with the frequency recommended by ACI. Each set of cylinders shall consist of three cylinders made from the same batch of concrete, one cylinder shall be tested at seven days, and another at 28 days. The third cylinder will be tested after the 28-day test if requested by the Owner, Engineer, or Contractor. The method of making, curing and testing the cylinders shall be in accordance with the requirements of the latest ASTM Designation C31 and C39, unless otherwise specified by these Specifications. Test cylinders will be placed in the vicinity of and subjected to the same curing conditions as the pour from which they were taken for the first 24 hours. The testing of the cylinders will be made by an independent testing laboratory. The cost of testing all cylinders that fail to meet the requirements of the Specifications shall be paid by the Contractor. All testing that meets requirements of the Specifications will be paid by the Owner.
   2. If any test cylinders show a strength at 28 days which fails to meet the specified strength, the concrete represented by such test cylinders shall be further tested in accordance with subsection 5.6.4 of ACI 318-89. Such additional tests shall be paid for by the Contractor. If such tests indicate that the concrete does not meet the compressive strength requirements established by this Specification, the Owner will either reject the concrete or require reinforcement or modification of the structure as is necessary to satisfy the design requirements. All rejected concrete shall be removed and replaced with new concrete of the specified strength at the expense of the Contractor. All reinforcement or modification of a structure required as a result of concrete which does not comply with the specified requirements shall be subject to review by the Engineer and approval by the Owner. All costs associated with reinforcement or modification shall be at the expense of the Contractor and shall not be limited to the costs of design, inspection, and construction of the work.

3.05 FIELD QUALITY CONTROL

A. The Contractor shall establish and maintain quality control for work covered under this Section of the Specifications to assure compliance with contract requirements. The Contractor shall maintain records, available to the Owner and Engineer, regarding quality control measures. Records shall be kept of the location, dimensions and the volume of concrete placed for each pour. Concrete strength test results shall be evaluated in accordance with ACI 214-77.

END OF SECTION 03300

SECTION 03600

GROUT

PART 1 GENERAL

1.01 DESCRIPTION

A. All Work included in this Section shall be done in accordance with the following Sections as well as the general specifications as outlined in Division 1.

B. The Work covered under this Section shall include all materials, labor, and equipment necessary to grout anchors, pins, dowels and rebars in concrete as shown on the Drawings.

C. Miscellaneous attached hardware items, as well as cast-in-place concrete, are not included in this Section.

D. Related sections: Section 03300 -Cast-In-Place Concrete

1.02 REFERENCES

Work covered under this Section shall be in accordance with the latest available version of the following references, unless otherwise noted:

1. CRD C-621, "Corps of Engineers Specification for Nonshrink Grout"
2. ASTM C191, "Test Method for Time of Setting of Hydraulic Cement by Vicat Needle"
3. ASTM C309, "Specification for Liquid Membrane-Forming Compounds for Curing Concrete"
4. ASTM C496, "Test Method for Splitting Tensile Strength of Cylinder Concrete Specimens"
5. ASTM C580, "Test Method for Flexural Strength and Modulus of Elasticity of Chemical-Resistant Mortars, Grouts and Monolithic Surfacings"
6. ASTM C827, "Test Methods for Early Volume Change of Cementations Mixtures"
7. ASTM C882, "Test Method for Bond Strength of Epoxy-Resin Systems Used With Concrete"

1.03 SUBMITTALS

A. Submittals are not required for material which meets the requirements of this Section.

1.04 SEQUENCING AND SCHEDULING

A. Sequencing and scheduling of the work included in this Section shall coincide with the related work and adjacent work areas to correspond with required set and cure times of grout material, material surfaces to which grout is applied, and to correspond with the erection schedule of attached and adjacent hardware items.

1.05 BASIS FOR COMPENSATION

NOT USED

PART 2 PRODUCTS

2.01 MATERIALS

A. General: Grout material shall be a nonshrink grout consisting of a nonmetallic Portland cement grout, durable in wetting and drying, freezing and thawing conditions, and shall conform with the requirements set forth in CRD C-621. The grout shall not contain gypsum.

B. Materials for forming, if required, shall be approved by the Engineer. Curing compound conforming to ASTM C309, as required for the designated work, shall be approved by the Engineer .

2.02 MANUFACTURE -PERFORMANCE CRITERIA

A. Mixed portland cement grout shall meet the following requirements:
1. Time of Set (ASTM C191)
   a. Initial Set: 3.0 hours min.
   b Final Set: 6.5 hours max.
2. Flow (CRD C-621): 100-124%.
3. Color: concrete gray.
4. The grout shall not exhibit bleeding.
5. The grout shall not segregate.
6. The grout shall be pump able through standard grout pumping equipment.

B. Cured portland cement grout shall meet the following requirements:
1. Compressive Strength (CRD C-621)
   a. 1 day: 3,000 psi min.
   b. 28 day: 6,000 psi min.
2. Splitting Tensile Strength (ASTM C496) at 28 days: 500 psi min.
3. Flexural Strength (ASTM C580) at 28 days: 1,200 psi min.
4. Bond Strength (ASTM C882 Modified) Plastic grout to hardened concrete at 28 days (moist cure): 1,950 psi min.
5. Expansion (CRD C-621) at 28 days: +0.015% min.
6. The grout shall not produce a vapor barrier .
7. The grout shall exhibit positive expansion when tested in accordance to ASTM C827.
8. The grout shall conform to United States Army Corps of Engineers Specification CRD C-621.
9. The grout shall be approved by the United States Department of Agriculture.

PART 3 EXECUTION

3.01 PRODUCT DELIVERY, STORAGE AND HANDLING

A. Grout products shall be delivered in original, unopened containers with the manufacturer's name, labels, product identification and batch numbers. Products shall be stored and conditioned as recommended by the manufacturer .

3.02 APPLICATION

A. Surface Preparation: Before grout is placed, all debris, standing water, ice and any loose or deleterious materials shall be removed from the surfaces where grout is to be applied.

B. Environmental Conditions: Grout shall not be applied if it is raining or snowing, or if rain or snow appears imminent and the area of application is not adequately protected.

C. Mixing Equipment: All equipment used to mix and apply the grout material shall be clean and free from oil, ice or other deleterious substances.

D. Protection: Precautions should be taken to avoid damage to any surface near the work area due to the mixing, handling and application of grout material

E. Workmanship: Grout shall be applied to the designated areas in a neat and orderly fashion.

3.03 FIELD QUALITY CONTROL

A. The Contractor shall establish and maintain quality control for work covered under this Section of the Specifications to assure compliance with contract requirements,

END OF SECTION 03600

SECTION 05500

METAL FABRICATIONS

PART 1 GENERAL

1.01 SECTION INCLUDES

A. Deck grating, railing, and miscellaneous metal fabrications for discharge structures.
B. Prefabricated steel truss bridge.

1.02 REFERENCES

A. The following are complete titles of references cited in this Section:
1. American Institute of Steel Construction CAISC) "Specifications for the Design, Fabrication and Erection of Structural Steel for Buildings"
2. AISC "Code of Standard Practice for Steel Buildings and Bridges"
3. American Society for Testing and Materials CASTM) A36, "Specification for Structural Steel"
4. ASTM A123, "Specification for Zinc CHot-Dip Galvanized) Coating on Iron and Steel Products"
5. ASTM A307, "Specification for Carbon Steel Externally Threaded Standard Fasteners"
6. ASTM Designation A616/A616M, "Deformed and Plain Billet-Steel Bars for Concrete Reinforcing"
7. ASTM Designation A722, "Uncoated High-Strength Steel Bar For Prestressing Concrete"
8. ASTM C 150, "Standard Specification for Portland Cement"
9. American Welding Society CAWS) publication "Structural Welding"

1.03 SUBMITTALS

A. The bridge supplier shall submit shop drawings in accordance with Section 01300, showing the bridge layout, member sizes, and design loads.

1.04 BASIS FOR COMPENSATION

NOT USED

PART 2 PRODUCTS

2.01 PREFABRICATED BRIDGE

A. Design stresses shall be accordance with the specifications for the design, fabrication, and erection of structural steel for buildings, Eighth Edition CAISC).

B. Bridge members shall be fabricated from high strength, self-weathering, low alloy, atmospheric corrosion resistant ASTM A847 cold-formed welded square and rectangular tubing, and ASTM A588, ASTM A606, or ASTM A242 plate and structural shapes CFY = 50,000 psi).

C. Bridge decking nominal 2-inch thick select structural west coast region douglas fir. Timber deck material shall be treated with chromated copper arsenate (CCA) to a 0.4 pcf retention.

D. E80 series electrodes for welding.

E. All top and bottom chord shop splices to be complete penetration type welds. Weld between top chord and end vertical shall be partial penetration.

F. Unless otherwise noted, welded connections shall be fillet welds of a size equal to the thickness of the lightest gage member in the connection. The fillet welds shall be applied as follows:
1. Both ends of verticals, diagonals, and floor beams shall be welded all around.
2. Brace diagonals will be welded for full length of top, bottom, and outside vertical faces.
3. Bottom of stringers will be stitch welded to top of floor beams.
4. Miscellaneous nonstructural members will be stitch welded to their supporting members.

G. Bridge design shall be based on combinations of the following loads which will produce maximum critical member stresses:
1. 100 psf uniform live loading on the full deck area or 20 psf uniform live loading on the full deck area plus one 10,000-pound vehicle load.
2. 30 psf wind load on the full height of the bridge, as if enclosed.
3. 20 psf upward force applied at the windward quarter point of the transverse bridge width (AASHTO 3.15.3).

2.02 MATERIALS

A. Structural Steel Shapes and Plates: All steel shapes and plates shall be the size and shape shown on the Drawings, shall conform to the latest ASTM Designation A36. Other components not designated as painted shall be hot dipped galvanized.

B. Bolts: All bolts shall be the size and shape shown on the Drawings and shall conform to the latest ASTM Designation A307, except as otherwise specified on the Drawings, and shall have a corrosion resistant coating.

C. Expansion Anchors: Expansion anchors shall be a wedge type anchor as manufactured by Hilti (kwik bolt) or equal, unless otherwise indicated on the Drawings.

2.03 FABRICATION

A. General: All structural and architectural metal shall be fabricated in accordance with the Drawings and in a neat workmanship manner .

B. Structural Steel:
1. All structural steel components shall be fabricated and erected in accordance with the applicable requirements set forth by the American Institute of Steel Construction (AISC) publications "Specifications for the Design, Fabrication and Erection of Structural Steel for Buildings", Section 1.23 entitled "Fabrication", and "Code of Standard Practice for Steel Buildings and Bridges", Section 6 entitled "Fabrication and Delivery".

2. All members shall be straight with no bends or kinks. Steel shall be accurately cut with shears, mechanically guided torches capable of forming smooth cut or hand guided torches. Hand guided cuts or other rough surfaces which are exposed or visible shall be ground smooth. All exposed sharp edges and corners shall be machine filleted or chamfered. All bolt holes shall be accurately located and orientated normal to the bolting surfaces. Oversized bolt holes conforming to subsection E below are acceptable for field connections.

C. Welds: All welds for the structural components shall conform to the applicable standard specifications set forth by the American Welding Society CAWS) publication "Structural Welding". All welds shall be of the type and size shown on the Drawings.

D. Galvanized Coating: Walers, base plates, bolts, rods, studs, nuts, washers, and other miscellaneous angles and plates not scheduled for painting shall be hot dipped galvanized as set forth in ASTM A123 after cut and fabricated.

E. Damage caused to galvanized surfaces by transport, erection, welding, or other operations shall be field repaired using a cold galvanizing process.

F. Quality Control:
   1. The manufacturer or fabricator shall maintain a documented quality control program. The quality control program shall conform to the AISC Specifications and Code of Standard Practice.
   2. Welders shall conform to the requirements set forth in AWS 01.1 Section 5 for the work performed. All welds shall be inspected in accordance with AWS Dl.1 Section 6. All welds shall be visibly inspected and measured.
   3. The Owner may perform additional nondestructive testing of the welded joints. If the welds have crack, lack of fusion, entrapped slag or welding rod, excess porosity or other detrimental defects, the Contractor shall pay for the testing which indicates the defect and shall correct the deficiency at no cost to the Owner .

PART 3 EXECUTION

3.01 PRODUCT DELIVERY, STORAGE AND HANDLING

A. Care shall be utilized throughout the delivery , storage and handling so as to not scratch, bend, warp or otherwise damage the components.

B. Metal chords, cable or straps likely to damage the galvanized or painted coating shall not be used.

C. All components shall be stored above ground on level timbers or other materials.

3.02 ERECTION

A. General: All metal components shall be erected in a neat workmanship like manner. All components shall be plumb, horizontal at the designated slope and square as appropriate.

B. Structural Steel: Structural steel shall be erected in accordance with the AISC Specifications Section 1.25 entitled "Erection", the Code of Standard Practice Section 7 entitled "Erection" and Commentaries. This includes the tolerance requirements.

C. Field Connections: All field connections shall be performed in a neat workmanship like manner. Applicable welding requirements set forth in Part 2 of this Section for fabrication shall also pertain to the erection.

D. Anchor Bolts: Anchor bolts shall be accurately placed and embedded in the concrete when plastic. Templates shall be utilized to match bolt holes spacing for the final components.

3.03 FIELD CONTROL QUALITY

A. The Contractor shall establish and maintain quality control for work under this Section to assure compliance with contract requirements and maintain records of his quality control for all construction operations. In addition, the Contractor shall coordinate, verify and check the precast concrete, cast-in-place concrete and other operations which directly affect placement of the steel and iron components.

END OF SECTION 05500

Technical Specifications

Final Cover

Technical Specifications

Scrubber Solids Pond No. 3 - Final Cover

Sherburne County Generating Plant
Northern States Power Company
(dba Xcel Energy, Inc.)

Table of Contents

Certification

I hereby certify that this specification was prepared by me or under my direct supervision and that I am a duly Registered Professional Engineer under the laws of the State of Minnesota.

John R. McCain

Date: 06/28/02 Reg. No. 21835

SECTION 01010

SUMMARY OF WORK

1.01 CONTRACT DOCUMENTS

A. The Contract Documents are as defined in the Agreement. The terms of the Contract Documents apply to these Specifications as fully as though repeated herein.

B. The format of these Specifications is based upon the CSI MASTERFORMAT, however , differences in format and subject matter location do exist. It is the Contractor's sole responsibility to thoroughly read and understand these Specifications and request written clarification of those portions which are unclear .

C. Division of the Work as made in these Contract Documents is for the purpose of specifying and describing work which is to be completed. There has been no attempt to make a classification according to trade or agreements which may exist between Contractor, Subcontractors, or trade unions or other organizations. Such division and classification of the Work shall be the Contractor's sole responsibility.

1.02 EXISTING SITE CONDITIONS AND USES

A. The site is located withing the Sherco Plant property, south of Highway 10 in Becker , Minnesota.

B. Owner's and other Contractor's vehicles use roadways within and near the Site. Owner's vehicles shall have the right-of-way at all times.

C. Groundwater monitoring wells are present at the Site and are sampled regularly.

1.03 WORK COVERED BY CONTRACT DOCUMENTS

A. The overall scope of the Work which is more fully described in these Contract Documents includes, but is not necessarily limited to, furnishing all labor , tools, equipment, and materials necessary to:
   1. Maintain free access to the pond for Owner's vehicles and equipment at all times.
   2. Protect and maintain free access to groundwater monitoring wells.
   3. Perform surveying for construction staking and documentation of alignments, elevations, and material thicknesses.
   4. Prepare geomembrane subgrade by grading and smooth-rolling existing bottom ash fill.
   5. Construct a final cover system with a geomembrane and cover soils.
   6. Furnish and install concrete manholes and catch basins.
   7. Furnish and install surface and subsurface drainage piping systems.
   8 Construct surface water control dikes, ditches, and drainage channels.
   9. Perform general site grading, topsoiling, and turf establishment.
   10. Submit CAD files presenting results of surveying and liner panel layout and test locations.

1.04 ABBREVIATIONS

A. Where used in these Specifications, the following abbreviations have the meanings indicated:
   1. AASHTO -American Association of State Highway and Transportation Officials
   2. ACI -American Concrete Institute
   3. ANSI -American National Standards Institute
   4. ASPA -American Sod Producers Association
   5. ASTM -American Society for Testing Materials

6. CSI -Construction Specifications Institute
7. Mn/DOT -Minnesota Department of Transportation
8. MPCA -Minnesota Pollution Control Agency
9. OSHA -Occupational Safety and Health Administration
10. AQCS -Air Quality Control System

SECTION 01400

QUALITY CONTROL

1.01 FIELD QUALITY CONTROL

A. The Contractor shall retain an independent land surveyor licensed in the State of Minnesota for performing quality control on line and grade of the Work. The quality control survey data shall be available for review at any time, on request by the Owner or Owner's On-Site Representative. Grade and thickness tolerances of each material type must be verified and approved in writing by the Owner or Owner's On-Site Representative prior to placement of overlying materials. It shall be the Contractor's responsibility to provide the Owner or Owner's On-Site Representative with two days advance notification that approval of grades and thicknesses will be requested. The Owner or Owner's On-Site Representative shall provide approval of grades and tolerances within one day of request, or shall request modification of the Work such that it fully complies with requirements of the Specifications. Subsequent requests by the Contractor for approval of grades and tolerances shall receive a response from the Owner or Owner's On-Site Representative within one day of request.

B. A survey grid shall be established for the site by the Contractor's Registered Land Surveyor. The grid shall consist of a series of coordinate points which will be used to verify that the grade and thicknesses of the constructed work meets the tolerances specified in Section 02220. The survey grid for each successive layer shall be coincident with that for the layer below. N o offset will be allowed.

C. The survey grid shall provide coverage for the site as described below:
   1. Survey points shall be established at the nodes of a 100-foot orthogonal grid for the top of the final cover surface.
   2. Break lines shall be surveyed at a maximum of a 100-foot intervals.
   3. Ditch and swale inverts shall be surveyed at 50-foot intervals.

D. The elevation at each survey point shall be determined by Contractors' Registered Land Surveyor after placement of each of the following materials:
   1. Subgrade preparation (grading and smooth-rolling)
   2. Granular drainage material
   3. Rooting soil
   4. Topsoil.

E. Results from the survey shall be presented in tabular format listing the following information:
   1. Point number
   2. Coordinates
   3. Elevation of top of each material type
   4. Thickness of each material type.

F. Elevations of drainage pipes, manhole and catch basin castings and inverts, and all other elevations specifically identified on the Drawings shall be verified by Contractor's Registered Land Surveyor. Pipe grades shall be verified at 50-foot intervals.

G. Contractor shall establish and maintain quality control for Work under this Section to assure compliance with the Contract Documents and maintain records of Contractor's quality control for all operations, including, but not limited to, the following:
   1. Volume of granular materials used.
   2. Monitoring of lift thickness and uniformity during backfill.

3. Compaction tests and density tests to verify compliance with Specifications.
4. Locations and elevations of all tests and material tested by Contractor .

H. Prior to acceptance of the Work and within one week of request by Owner, Contractor shall submit to Owner all results of survey work performed. Contractor shall also submit a Record Drawing indicating the as-constructed thickness of the final cover system (excluding bottom ash below the geomembrane) at each survey point. The drawing shall use a scale of 1" = 200', and shall schematically represent the capped area similar to Drawing 14. The drawing shall be prepared and signed by the independent registered land surveyor that performed the survey verifications during construction. Additionally, a final contour map shall be prepared for all area receiving final cover, and all dikes and ditches, with a maximum contour interval of 2 feet. The map shall be provided on reproducible mylar and in digital CAD format, as stated in the General Requirements. In addition to submittal of CAD files, electronic data files for survey results shall also be submitted.

I. For purposes of documenting construction, Owner or Owner's On-Site Representative will be conducting a Quality Assurance/Quality Control (QA/QC) program during construction. The QA/QC program will consist of collecting random samples and performing tests on materials used in construction. Testing will determine whether the properties of the materials proposed for use in this Project comply with the requirements of these Specifications, and whether the constructed materials meet compaction requirements.
   1. Material property tests include grain size analyses and hydraulic conductivity tests for Granular Drainage Material; grain size analysis for Coarse Filter Material; nutrient content, organic content, and pH tests of Topsoil, and Standard Proctor Density tests for each material that has a compaction requirement.
   2. Compaction tests will be performed during construction of surface water diversion dikes at the rate of one test per 1,600 cubic yards of material placed. Compaction tests will be performed at random frequency for drainage channel dike and ditch construction.
   3. Work failing to meet specifications as outlined herein and as may be identified as a result of Owner's QA/QC program shall be repaired at Contractor's expense.
   4. It is Contractor's sole responsibility to perform testing deemed necessary to satisfy requirements of these Specifications prior to delivery of materials to the Site. Materials that do not meet the requirements of these Specifications shall be removed from the Site by Contractor .
   5. After a failed test, retests will be performed by Owner and the expense of retesting charged to Contractor .
   6. At the time of construction, Contractor may question the Owner or Owner's On-Site Representative with regard to test results obtained. Test results are the property of the Owner and will be submitted to Contractor at Owner's discretion.
   7. Geomembrane testing will be performed as described in Section 02770.

END OF SECTION

SECTION 01500

TEMPORARY CONTROLS

PART 1 GENERAL

1.01 SECTION INCLUDES

A. Controlling dust generation on access roads to the Site and within construction limits.

B. Controlling soil erosion and sediment transport at the Site.

1.02 SUBMITTALS

A. Submit proof of agreement between Contractor and local water source indicating permission for Contractor to obtain dust control water from a source near the Site.

1.03 BASIS FOR COMPENSATION

NOT USED

PART 2 PRODUCTS

2.01 MATERIALS

A. Acceptable temporary erosion control devices include, but are not necessarily limited to, silt fence, straw and hay bales, geotextiles, and vegetative cover .

B. Water used for dust control shall be potable water only. There is no source of dust control water at the Site.

2.02 EQUIPMENT

A. Water tank trucks equipped with water cannon capable of delivering water through either front- or rear-mounted nozzles. Tank trucks shall be of sufficient size and mobility and carry a sufficient quantity of water to control dust generated by Contractor's activities.

PART 3 EXECUTION

3.01 DUST CONTROL WATERING

1. Apply water to roads used by Contractor's equipment as directed by Owner or Owner's On- Site Representative to control dust generated by wind or by Contractor's vehicle traffic.

2. Apply water to ground surfaces within the construction limits as directed by Owner or Owner's On-Site Representative to control dust generated by Contractor's activities at the site.

3.02 EROSION CONTROL

1. Install erosion control devices and materials at locations as directed by Owner or Owner's On-Site Representative where soil erosion and sediment transport from the Site may occur due to Contractor's activities.

2. Install temporary erosion control devices during the progress of the work and maintain them until permanent erosion control (turf establishment, aggregate surfacing, etc) has been established.

END OF SECTION 01500

SECTION 02100

SITE PREPARATION

PART 1 GENERAL

1.01 SECTION INCLUDES

A. Stripping and stockpiling surface soils.

1.02 BASIS FOR COMPENSATION

NOT USED

1.03 DEFINITIONS

A. Topsoil shall be that material identified in the field by the Owner or Owner's On-Site Representative as a suitable growing medium for turf establishment. It shall, in general, be that surface layer or buried layer of natural material containing decayed vegetable matter and roots.

B. Stripping shall be defined as removing topsoil to a minimum depth of 6 inches and shall include stockpiling.

PART 2 PRODUCTS

NOT USED

PART 3 EXECUTION

3.01 STRIPPING TOPSOIL

A. Strip topsoil to a minimum depth of 6 inches from areas shown on the Contract Drawings and in soil borrow areas. Strip topsoil to full-depth where the depth exceeds 6 inches, as directed by Owner or Owner's On-Site Representative. Stockpile stripped topsoil within the construction limits as shown on the Contract Drawings or as directed by Owner . Neatly trim excess topsoil stockpiles to be free-draining, to present a uniform appearance and to prevent erosion and the transport of the topsoil off-site.

END OF SECTION

SECTION 02220

EXCAVATING, BACKFILLING, AND COMPACTING

PART 1 GENERAL

1.01 SECTION INCLUDES

A. Preparing subgrade.

B. Placing cover soils.

C. Finish grading on-site borrow areas.

D. Constructing water diversion dikes and ditches.

1.02 BASIS FOR COMPENSATION

NOT USED

1.03 REFERENCES

A. Minnesota Department of Transportation Standard Specifications for Construction, 1988 Edition, hereafter referred to as MnDOT Standard Specifications.

B. American Society for Testing and Materials, Current Edition, hereafter referred to as ASTM.

1.04 SUBMITTALS

A. Submit list of all off-site sources of materials specified in this Section to Owner or Owner's On-Site Representative at least two weeks prior to delivery of materials to the Site.

B. Provide certificates for materials obtained from off-site sources indicating compliance of materials with Specifications prior to delivery to the site. Owner will take random samples of the material to verify compliance with the specifications.

C. Provide test results of at least two random samples of each material showing gradation and classification.

1.05 DELIVERY, STORAGE, AND HANDLING

A. Upon delivery of materials to the Site, provide access for sampling or observation of loads by Owner or Owner's On-Site Representative prior to unloading.

B. Prevent mixing of dissimilar materials during unloading, stockpiling, or removal from stockpile.

1.06 JOB CONDITIONS

A. It shall be the Contractor's sole responsibility to review available tests and reports, conduct additional tests, and otherwise determine to its own satisfaction the location and nature of all surface and subsurface features and the soil and water conditions that will be encountered, as more fully set forth elsewhere in these Contract Documents. Information regarding on-site conditions may be reviewed at Owner's offices as scheduled with Owner .

B. Contractor shall be solely responsible for determining the means and methods for meeting the compaction requirements specified herein, except that compaction by flooding or puddling or other means that involve saturation or over-wetting the soil will not be permitted.

C. If it is necessary to remove surface water that is in contact with the scrubber solids or ash in Pond No.2, Contractor shall direct the surface water to existing Pond No.3.

D. Provide shoring, bracing, sheet piling, trench boxes, tie backs, and other measures required to perform all Work in accordance with Laws and Regulations. Specifically, all excavations shall conform to the requirements of OSHA set forth in 29 CFR 1926, Subpart P (Occupational Safety and Health Standards-Excavations).

PART 2 PRODUCTS

2.01 MATERIALS

A. Owner will provide access to stockpiled bottom ash, random fill, and topsoil for use in the Project. Stockpiled random fill material will be suitable for use as rooting soil and granular drainage material (with screening as described below). Contractor shall be responsible for opening, maintaining, and closing stockpiles, loading and transporting materials, and controlling dust and erosions at stockpiles and along haul routes. Contractor shall furnish all other materials specified in this section.

B. Random Fill: On-site sands and silty sands, gravels or sandy clays and silty clays from designated borrow areas, all free of organic material, roots, stumps, and solid mineral materials larger than 4 inches in diameter .

C. Bottom Ash Borrow: Stockpiled material obtained from Owner at the location shown on the Drawings.

D. Coarse Filter Aggregate: An aggregate material meeting the following gradation requirements:

Sieve Size	Percent Passing
1"	100
3/8"	75-100
#4	50-80
#10	10-40
#40	0-5

E. Granular Drainage Material: Aggregate material meeting all of the following requirements:
1. minimum hydraulic conductivity of 1 x 10^{-3} cm/s at 95 percent standard Proctor density
2. maximum 5 percent by weight which passes the #200 sieve
3. maximum particle size of 3/8 inch
4. 4. uniformity coefficient less than 6

Material from the designated on-site borrow area may be used for Granular Drainage Material. Processing of on-site material by screening to remove particles larger than 3/8-inch will be necessary.

As requested on the Bid Form, Bids shall assume that on-site granular soils excavated from the designated borrow area need only be screened to 3/8-inch in order to meet the requirements of this specification for Granular Drainage Material. The lump sum Contract Price shall include the cost to excavate, screen, and place on-site granular materials.

In the event the Owner determines that some or all excavated screened granular materials will not meet requirements of this Specification without further processing, the Contractor shall import and place granular drainage material complete, in-place, as specified, for the add-on unit price bid as requested on the Bid Form. In this case, measurement will be by quantity required to complete construction as specified on the plans, using plan dimensions for quantity computation.

F. Rooting Soil: Rooting soil shall consist of on-site fine-grained natural soil material from designated borrow areas having a Unified Soil Classification of ML, CL, SM, or mixture thereof. Rooting soil may contain organics but shall be, in the opinion of the Owner or Owner's On-Site Representative, of such a mixture that will not result in excessive settlement or consolidation of the rooting soil layer .Rooting soil can also consist of topsoil.

G. Topsoil: Material obtained from stripping and stockpiling topsoil from the designated on- site borrow area as specified in Section 02100 or from designated stockpiles.

H. Riprap: Shall conform to Mn/DOT Standard Specification 3601 for the class shown on the Drawings.

2.02 SOURCE QUALITY CONTROL

A. Provide Owner with test results from all potential off-site sources of materials so that the materials can be evaluated for conformance with specifications.

B. Owner may also take samples of the materials after they have been furnished to the site for additional testing. Owner will pay for testing of samples that meet Specifications. Contractor shall pay for testing of samples that do not meet Specifications.

C. Preliminary testing has been performed on bottom ash and granular drainage material, the results of which are contained in the Appendix.

PART 3 EXECUTION

3.01 EXCAVATION

A. Locate and protect overhead and underground utilities.

B. Excavate soil from surface water drainage channels to the elevations and dimensions shown on the Contract Drawings. Excavated soils may be used in cap construction provided they meet specifications. Excess excavated soil shall be stockpiled within the soil borrow area limits as shown on the Contract Drawings.

C. Soil excavation in the soil borrow area shall be within the vertical and horizontal limits shown on the Contract Drawings. Excess excavated soil from the soil borrow area shall be stockpiled within the soil borrow area limits.

3.02 SUBGRADE PREPARATION

A. Grading existing bottom ash material on Pond No.3 to the elevations and grades shown on the Drawings as required for geomembrane installation. Additional bottom ash required to achieve the required grades shall be taken from the designated stockpile.

B. Compact graded surface to at least 90 percent Standard Proctor maximum dry density using vibratory compaction equipment.

C. Smooth-roll compacted surface to remove irregularities.

3.03 BACKFILL AND COMPACTION

A. Place random fill in maximum 12-inch lifts at the locations and to the grades shown on the Drawings. Compact each lift to at least 95 percent of Standard Proctor Density before proceeding to the next lift.

B. Place coarse filter aggregate material as shown on the Drawings.

C. Granular Drainage Layer:
   1. No granular drainage material shall be placed over geomembrane cover until the cover has been inspected, tested, and all test results and required documentation is submitted to Owner or Owner's On-Site Representative in accordance with Section 02770 or as otherwise approved by Engineer. Inspection of the geomembrane cover and required documentation may be submitted in phases to facilitate timely placement of cover soils. After cover inspection and the review of documentation, Owner shall give Contractor written notice to proceed with the placement of cover soils. This notice does not imply final acceptance of the cover or related work. Final acceptance of the cover is covered in Section 02770.
   2. Place granular drainage material over the geomembrane cover in a single lift. Placement of the granular drainage material over the geomembrane cover shall be performed in accordance with the geomembrane manufacturer's recommendations, and under the supervision of the geomembrane installer's on-site representative as outlined in Section 02770.
   3. Spreading shall occur by pushing the material from discrete dumping points, and pushing the newly dumped materials outward over that material already placed. The granular drainage material shall be "rolled" over the edge of the material already placed, rather than pushed or slid across the surface of the geomembrane cover. Compaction shall be limited to that provided by construction vehicle traffic.
   4. In no case shall any construction equipment be allowed to travel directly on the geomembrane. To support truck traffic, a temporary 2-foot lift of granular drainage material shall be placed over the geomembrane in traffic areas.
   5. The granular drainage layer and other cover soils are susceptible to sliding during and shortly after rainfall events. The Contractor shall take precautions necessary to limit this potential and shall repair all damage from sliding at Contractor's expense.

D. Rooting soil and topsoil placement shall be to the dimensions and at the locations indicated on the Drawings. Rooting soil and topsoil shall be placed so as to not mix with the granular drainage material. Compaction shall be limited to that provided by construction vehicle traffic.

3.04 RIPRAP

A. Riprap placement shall be performed in accordance with the requirements of Mn/DOT Standard Specification 2511. Riprap and geotextile fabric shall be extended laterally from inlet and outlet structures to the minimum dimensions indicated on the Contract Drawings and Section 02270. All materials which directly support riprap shall be covered with a layer of geotextile fabric prior to placement of the riprap.

3.05 RESTORATION OF ON-SITE BORROW AREAS

A. Excess topsoil and other excess soils excavated from the soil borrow areas shall remain in stockpiles as specified in Section 02100 (Site Preparation). Borrow area slopes shall be left no steeper than 3H:IV.

3.06 TOLERANCES

A. Geomembrane Subgrade:
   1. General: Grade and compact bottom ash subgrade to plan contours +/- 0.2 foot with a minimum positive slope of 2.0 percent from the center of the top area toward the perimeter.

2. Grade tolerance along centerline of ditches and drain tubing: Grade and compact bottom ash to plan contours +/- 0.1 foot with a minimum positive slope of 1.0 percent.

B. Random Fill: +/- 0.2 foot

C. Place cover soils within the following dimensional tolerances:
   1. Granular Drainage Material: Thickness Tolerance: -0.0 foot to +0.2 foot.
   2. Rooting Soil: Thickness Tolerance: -0.0 foot to +0.2 foot.
   3. Topsoil: Thickness Tolerance: -0.0 foot to +0.2 foot.

END OF SECTION

SECTION 02270

GEOTEXTILES

PART 1 GENERAL

1.01 SECTION INCLUDES

A. Furnishing and installing woven and non-woven geotextile fabric.

B. Furnishing and installing erosion control blanket.

1.02 BASIS FOR COMPENSATION

A. Compensation for all Work and materials covered under this Section of these Specifications will be included in the lump sum Contract Price bid.

1.03 REFERENCES

A. Minnesota Department of Transportation Standard Specifications for Construction, 1988 Edition, hereafter referred to as Mn/DOT Standard Specifications.

1.04 SUBMITTALS

A. Submit for documentation Certificates of Compliance from the manufacturer for each roll of geotextile delivered to the Site. The document shall certify the test results of the physical properties specified below. A quality control certificate shall be submitted for each 50,000 square feet of continuously produced material (or other standard manufacturer frequency). A quality control certificate shall be submitted for each roll of material that is not from a continuous production run for which a certificate has previously been provided.

PART 2 PRODUCTS

2.01 MATERIALS

A. Woven Geotextile Fabric: Amoco 2006, Mirafi 600X, or approved equal.

B. Non-woven Geotextile Fabric: Amoco 4506, Mirafi 160N, Trevira Spunbond 1120, or approved equal.

C. Erosion Control Blanket: North American Green SC150 or approved equal.

PART 3 EXECUTION

3.01 INSTALLATION

A. Install geotextile fabrics at the locations and to the dimensions shown on the Drawings.

B. Non-woven filter fabric shall be placed as a cushion in the leachate collection trench inverts prior to placement of drainage aggregates. Panels shall be overlapped a minimum of 18 inches.

C. Woven filter fabric shall be placed under riprap at catch basins, pipe aprons, surge basins, etc. as shown on the Drawings. Adjacent panels shall be overlapped a minimum of 18 inches.

D. Install erosion control blanket in the side slope ditch inverts as shown on the Drawings. Overlap edges of adjacent panels and anchor the blanket with staples in accordance with the manufacturer's recommendations.

END OF SECTION 02270

SECTION 02605

CONCRETE STRUCTURES

PART 1 GENERAL

1.01 SECTION INCLUDES

A. Constructing sectional precast reinforced concrete manholes, catch basins, and appurtenances.

1.02 BASIS FOR COMPENSATION

NOT USED

1.03 REFERENCES

A. Minnesota Department of Transportation Standard Plates Manual, hereafter referred to as Mn/DOT Standard Plates.

B. Minnesota Department of Transportation Standard Specifications for Construction, 1988 Edition, hereafter referred to as Mn/DOT Standard Specifications.

C. American Society for Testing and Materials, current edition, hereafter referred to as ASTM.

PART 2 PRODUCTS

2.01 PRECAST REINFORCED CONCRETE SURFACE WATER MANHOLES

A. Precast reinforced concrete products used for manhole structures shall meet the requirements of Mn/DOT Standard Specification 3622.

B. Base: Precast reinforced concrete base section shall be monlithic with the bottom riser section (integral base).

C. Riser: Precast circular pipe sections in conformance with ASTM C 76, Class II, Wall B.

D. Top Slab: Precast top slab in conformance with Mn/DOT Standard Plate 4020E, for the manhole and casting diameters specified or shown on the Drawings.

E. Adjusting Rings: In accordance With Mn/DOT Standard Plate 4010.

2.02 PRECAST REINFORCED CONCRETE CATCH BASINS

A. Precast reinforced concrete products used for catch basins shall meet the requirements of Mn/DOT Standard Specification 3622.

B. Base: Precast reinforced concrete base section shall be monlithic with the bottom riser section (integral base).

C. Riser: Precast circular pipe sections in conformance with ASTM C 76, Class II, Wall B.

D. Top Slab: Precast top slab in conformance with Mn/DOT Standard Plate 4020, for the catch basin and casting diameters specified or shown on the Drawings.

E. Adjusting Rings: In accordance with Mn!DOT Standard Plate 4010.

2.03 CASTINGS

A. Surface Water Manholes: Neenah R-1729 at geomembrane penetration locations. Neenah R-1642 at other locations. Surface water manhole castings shall have "Storm Sewer" imprinted on the cover .

B. Catch Basins: Neenah R-4341.

2.04 JOINT SEALS

A. Continuous O-ring rubber gaskets for manhole and catch basin riser sections in conformance with ASTM C 443.

B. Mortar bed between top riser section and top slab and between adjusting rings.

2.05 PIPE CONNECTIONS

A. Connections between polyethylene pipes and surface water manhole or catch basins shall be made with rubber boots: PSX, Kor-n-Seal, Snap-in Sleeve or Cast-in Sleeve, Link Seal, or approved equal.

B. Connections between reinforced concrete pipe and surface water manholes or catch basins shall be made with either rubber boots or grout.

PART 3 EXECUTION

3.01 SURFACE WATER MANHOLES AND CATCH BASINS

A. Construct surface water manholes in accordance with MnDOT Standard Plate 4020.

B. Construct catch basins in accordance with the Drawings.

C. Shape inverts in manholes and catch basins with mortar to 1/2 the pipe diameter to direct flow to the outlet pipe as shown on MnDOT Standard Plate 4005.

D. Connect pipes to manholes and catch basins as specified in Article 2.05.

E. Manholes and catch basins greater than 4 feet deep shall be furnished with Type W steps as shown on MnDOT Standard Plate 4180.

F. Manhole and catch basin inverts shall be set within 0.10 foot of the elevation shown on the Drawings.

END OF SECTION 02605

SECTION 02610

PIPES AND FITTINGS

PART 1 GENERAL

1.01 SECTION INCLUDES

A. Furnishing and installing perforated corrugated polyethylene drain tubing.

B. Furnishing and installing reinforced concrete pipe (RCP).

C. Furnishing and installing polyethylene pipe.

1.02 BASIS FOR COMPENSATION

NOT USED

1.03 REFERENCES

A. Minnesota Department of Transportation Standard Plates Manual, hereafter referred to as MNDOT Standard Plates.

B. Minnesota Department of Transportation Standard Specifications for Construction, 1988 Edition, hereafter referred to as MNDOT Standard Specifications.

C. American Water Works Association Standards, current edition, hereafter referred to as AWWA.

D. American National Standards Institute, hereafter referred to as ANSI.

PART 2 PRODUCTS

2.01 CORRUGATED POLYETHYLENE DRAIN TUBING WITH FILTER FABRIC SOCK

A. Corrugated polyethylene drain tubing and fittings shall meet the requirements of ASTM F 405 or AASHTO M252. The drain tubing shall meet the dimensional requirements indicated on the Contract Drawings and be manufactured by Prinsco, ADS, Hancor, or other approved manufacturer .

B. Drain tubing shall be factory slotted and/or perforated with a minimum inlet area of 1 square inch/ft. The maximum allowable slot opening shall be 1/8 inch.

C. Drain tubing fittings shall be from the same manufacturer of the tubing.

D. Drain tubing shall be wrapped with a factory-applied filter fabric sock. The filter fabric shall have a minimum apparent opening size (AOS) of 40.

2.02 REINFORCED CONCRETE PIPE (RCP)

A. Reinforced concrete pipes and aprons shall conform to the requirements of ASTM C- 76.

B. All joints shall include rubber O-ring gaskets and shall meet the requirements for Bureau of Reclamation Type R-4 joints.

C. All reinforced concrete pipe shall be Class V unless otherwise specified on the Contract Drawings.

2.03 POLYETHYLENE PIPE (PEP)

A. PEP shall be manufactured from materials meeting the requirement of ASTM D 1248 for Type III, Grade P34, Category 5, Class C, and have a PPE rating of PE3408. The pipe produced from this material shall have the dimensions and wall thickness as set forth in ASTM F 714 for the size and Standard Dimension Ration (SDR) shown on the Drawings.

B. PEP shall be marked at maximum 5-foot intervals with the manufacturer's name or trademark, nominal size and SDR, cell classification, ASTM D 1248, and extrusion date, period of manufacture, or lot number .

PART 3 EXECUTION

3.01 CORRUGATED POLYETHYLENE DRAIN TUBING AND FITTINGS

A. Install drain tubing of the size and in the locations and to the elevations and grades shown on the Drawings.

B. Do not install drain tubing with bends of smaller radius than the minimum recommended by the manufacturer.

C. Extreme care shall be taken to prevent crushing or deflecting the drain tubing by construction equipment traffic. After installation, Contractor shall mark locations of the drain tubing and restrict heavy equipment from travelling over the tubing. As directed by Owner or Owner's On-Site Representative, Contractor shall perform deflection testing of the drain tubing. Installed tubing with deflection exceeding 15 percent of the tubing diameter shall be removed and replaced.

3.02 REINFORCED CONCRETE PIPE (RCP)

A. Install RCP of the size and at the locations and elevations shown on the Contract Drawings.

B. Place reinforced concrete flared aprons at pipe outlets. Tie last three joints at outlet. Trash racks are not required.

C. All pipe shall be laid at a constant slope and in a straight line.

3.03 POLYETHYLENE PIPE

A. Construct PEP of the size and SDR and in the locations and to the elevations and grades shown on the Drawings.

B. Join PEP section by the thermal butt fusion process in accordance with the manufacturer's recommendations. Use of hand-held fusion plates will not be permitted. The joints shall have a tensile and shear strength equal or greater than that of the pipe and the joint shall be watertight.

C. Approved flanged connections shall be allowed in instances where butt fusion joints cannot be made. Flanged joints shall be equipped with stainless steel backup rings, stainless steel bolts, and neoprene gaskets. Flanged joints shall be properly aligned and watertight.

3.04 FILL PLACEMENT AROUND PIPES

A. Do not use frozen fill material or place on frozen subgrade.

B. Place granular material in maximum 6-inch loose lifts under pipe haunches and compact with hand-operated vibrating compactor until firmly compacted to pipe spring line.

C. Cover remainder of pipe trench with appropriate cover soils or granular backfill in maximum 12-inch loose lifts. Compact each lift to minimum 90 percent modified Proctor density.

D. Proper placement and compaction of pipe bedding materials around flexible pipe such as PEP and drain tubing is critical. Install PEP in accordance with ASTM D 2321.

3.05 FIELD QUALITY CONTROL

A. Pipe and pipe installation will be subject to rejection for any of the following reasons:
   1. Failure to conform to the Specifications, particularly compaction under and around the pipe.
   2. Fractures or cracks passing through pipe wall or socket.
   3. Chips or fractures on interior of pipe exceeding 2 inches in length, 1 inch in width, and depth more than 1/4 barrel thickness.
   4. Cracks which, in the opinion of Owner or Owner's Resident Project Representative, may impair strength, durability, or serviceability of pipe.
   5. Defects indicating improper proportioning, mixing, or molding.
   6. Damaged ends where such damage would prevent making a satisfactory joint. 7. Excessive deflection of pipe.

END OF SECTION

SECTION 02770

GEOMEMBRANE

PART 1 GENERAL

1.01 SECTION INCLUDES

A. Furnishing and installing 40-mil (smooth and textured) and 60-mil (textured) Linear Low Density Polyethylene (LLDPE) geomembrane.

B. Furnishing and installing 60-mil smooth High Density Polyethylene (HDPE) geomembrane.

C. Performing on-site quality control testing for geomembrane installation.

D. Supervising placement of geomembrane cover materials.

1.02 SUBMITTALS

A. Submittals shall be made prior to or at the time of delivery of geomembrane materials to the Site.

B. PE Resin: Submit for documentation the following information for resin used in the manufacture of geomembrane and extrudate rod:
   1. Resin type and cell classification (ASTM D 3350).
   2. Physical properties as specified herein.
   3. Production dates of the resin used for this project

C. PE Geomembrane: Submit for documentation the following information for PE geomembrane to be used for this project.
   1. Test methods and results defining physical properties as specified herein, of the geomembrane to be used for this project. Test results shall be representative of each roll of geomembrane furnished for this project (e.g., a test sample taken between two consecutive rolls from a continuous run will be considered representative of both rolls). Test results shall be reported with corresponding roll identification numbers. Test results which may not be available prior to construction (e.g., environmental stress crack resistance) shall be presented as preliminary information prior to construction, with final test results submitted within 60 days of the start of geomembrane installation.
   2. Statement of the geomembrane manufacturer's quality control procedures and frequency of sampling.
   3. Details of any factory seaming process proposed.

D. PE Geomembrane Installation: Submit for review the following information regarding the geomembrane installation:
   1. A proposed panel and seam layout diagram specifying the type and location of all field and factory seams. The layout diagram shall be to scale and used as a construction plan and shall include all necessary dimensions and details. The layout diagram shall be compatible with the panel and seam layout requirements specified in Article 3.03 of this Section.
   2. An installation schedule.
   3. A list of personnel performing field supervision, seaming supervision, and quality control, along with experience records and resumes.
   4. A list of equipment types proposed to be used in panel layout, membrane seaming, and destructive and nondestructive testing.

E. Prior to the installation of any geomembrane, the Contractor shall submit for documentation installer's certification in writing that the surface upon which the geomembrane is to be installed is acceptable (use the form at end of this Section or Installer's equivalent).

1.03 EXPERIENCE

A. The PE geomembrane manufacturer shall have at least 5 years continuous experience in manufacturing smooth and textured PE geomembrane rolls and/or a manufacturing record totaling not less than 5 million square feet of PE geomembrane. The manufacturer shall have produced PE geomembrane for at least 10 completed facilities similar in scope to this project.

B. The geomembrane installer (hereafter referred to as Installer) shall have at least 5 years continuous experience in the installation of PE geomembranes and an installation record totaling at least 5 million square feet. Installer shall have installed PE geomembrane for at least 10 completed sites similar in scope to this project.

C. Geomembrane installation shall be performed under the direct supervision of a single field supervisor who shall remain on-site throughout installation, including inspection of the surface upon which the geomembrane is to be installed, geomembrane handling and storage, panel layout and placement, seaming, seam testing, panel and seam repair, installation of appurtenances, anchorage, protective cover placement, and other geomembrane-related work. The field supervisor shall have complete supervisory responsibility for the installation, testing, and repair, and have a personal PE geomembrane installation record totaling at least 1 million square feet.

D. Field seaming of geomembrane panels shall be performed under the direction of a seaming supervisor who may or may not be the same person as the field supervisor. The seaming supervisor shall have a personal PE geomembrane installation record totaling at least 1 million square feet with the mil-thicknesses and using the seaming methods proposed for this project.

E. The geomembrane manufacturer and installer must be approved by Owner prior to mobilization for geomembrane installation. Owner has the right to reject any geomembrane manufacturer or installer, and request that Contractor select an alternate.

1.04 PREINSTALLATION CONFERENCE

A. Contractor and Installer shall attend a meeting at the site prior to installation of the geomembrane to discuss details of the proposed design and installation.

1.05 REFERENCES

A. American Society for Testing and Materials, Current Edition, hereafter referred to as ASTM.

B. National Sanitation Foundation, Standard 54 For Flexible Membrane Liners, Current Edition.

1.06 BASIS FOR COMPENSATION

A. Compensation for all Work covered under this Section of these Specifications will be included under the lump sum Contract Price bid.

PART 2 PRODUCTS

2.01 MATERIALS

A. PE Resin

1. Smooth and textured PE geomembrane and extrudate rods used for this project shall be manufactured of new, first quality resins, designed specifically for use in flexible membrane liner installations.
2. PE resin used in manufacturing geomembranes used for this Project shall meet the following specifications:

PE RESIN SPECIFICATIONS

Property	HDPE	LLDPE	Test Method
Specific Gravity	≥0.940	0.915 to 0.930	ASTM D 792 86 Method A or ASTM D-1505
Melt Index	<0.3 g/10 min.	< 1.0 g/10 min.	ASTM D 1238 88 Condition 190/2.16

3. Recycled polymer shall not be added to the resin. However, the resin may contain polymer reclaimed during the manufacturing process if reclaimed polymer content does not exceed 2 percent by weight.

B. Geomembrane

1. PE geomembrane sheets used for this project shall meet the following specifications:

PE GEOMEMBRANE SHEET SPECIFICATIONS

Property	40 mil Smooth HDPE	40 mil Textured HDPE	60 mil Smooth HDPE	60 mil Textured HDPE	40 mil textured LLDPE	Test Method
Nominal Sheet Thickness (mils)	40 ± 10%	40 ± 10%	60 ± 10%	60 ± 10%	40 ± 10%	ASTM D 751 or ASTM D 1593 NSF Annex A
Density (g/cm^3, min.)	0.940	0.940	0.940	0.940	0.915 to 0.930	ASTM D 792, ASTM D 1505, or ASTM D 1238 Condition A
Tensile Strength at yield (lbs/in. width)	≥84	≥78	>126	≥117	N/A	ASTM D 638
Tensile strength at break (lbs/in. width)	≥152	≥60	≥228	≥90	≥170	ASTM D 638
Elongation at yield (percent)	≥12	≥12	≥12	≥12	N/A	ASTM D 638
Elongation at break (percent)	≥560	≥100	≥560	≥100	≥650	ASTM D 638
Tear Resistance (lbs)	≥26	≥24	≥39	≥40	≥24	ASTM D 1004
Low Temperature Impact (°C, max. failure temp.)	-60	-60	-60	-60	-90	ASTM D 746
Dimensional stability (max. percent change)	±2	±2	±2	±2	±3	ASTM D 1204 1 hour at 100°C
Environmental Stress Crack (min. hours with no failures)	1500	1500	1500	1500	1500	ASTM D 1693 NSF Annex A
Puncture Resistance (lbs.)	≥48	≥45	≥72	≥70	≥50	FTMS 101 Method 2065
Carbon black content (% allowable range)	2-3	2-3	2-3	2-3	2-3	ASTM D 1603
Carbon black dispersion	A-1,A-2, or B-1	A-1, A-2, or B-1	A-1, A-2, or B-1	A-1, A-2, or B-1	A-1, A-2, or B-1	ASTM D-3015 NSF Annex A

NOTE: (NSF) National Sanitation Foundation - Standard No. 54, 1991

2. The geomembranes shall contain at a maximum 3 percent by weight additives, fillers, or extenders.
3. The geomembranes shall be free of holes, blisters, striations, undispersed raw material, and contamination by foreign matter.

4. The geomembranes shall be supplied in rolls. Each roll shall be labeled with the mil-thickness, length, width, manufacturer, lot number, and a unique roll identification number. This identification number shall be used to identify roll location on the panel layout record drawing.

C. Extrudate: Resin used in the extrudate rod shall be the same as that used to manufacture the geomembrane sheets. Extrudate rods are to be delivered in original containers with the manufacturer's labeling. Extrudate rods shall be free of dirt, grease, moisture, other contaminants, and shall be free of damage.

D. Neoprene Foam: Closed cell, weatherproof, black neoprene foam with adhesive backing suitable for long-term sun and liquid exposure. Dimensions shall be as specified on the Drawings.

E. Clamped Boots: Boots required to seal the PE geomembrane to the structures passing through it shall be made of the same materials as the geomembrane. The boots shall be fabricated so that all field assembly, welding, and seam testing can be accomplished using equipment and procedures regularly employed in the field for PE geomembrane installation. Smooth geomembrane shall be used in all geomembrane boots.

F. Banding Straps: Type 302 stainless steel banding straps suitable for use on the pipe diameters shown on the Drawings. Banding strap dimensions shall be as specified on the Drawings. All surfaces of the banding straps shall be machined smooth to prevent tearing or puncturing of the PE pipe boots.

2.02 EQUIPMENT

A. Extruding equipment shall be equipped with a temperature gauge at the barrel and nozzle.

B. Fusion equipment shall be equipped with a temperature gauge capable of continuous monitoring.

C. Provide digital or dial continuous temperature recording instruments, in satisfactory working condition, with each welding unit. Welding equipment shall not be operated without functioning temperature recording instruments.

D. A coupon cutter and a calibrated tensiometer shall be provided for in-field seaming prequalification testing and destructive sample testing.

E. Store, transport, and operate all equipment to avoid damage to geomembranes.

PART 3 EXECUTION

3.01 SUBGRADE INSPECTION

A. Installer shall certify in writing that the surface upon which the geomembrane is to be installed is acceptable (use the form at end of this Section or Installer's equivalent).

B. After subsurface has been accepted by Installer, it shall be Installer's responsibility to indicate to Contractor any change in subsurface conditions that may require repair work. Damage to subsurface caused by work involved in installing geomembrane shall be repaired at Contractor's expense. Geomembrane cover placement over unsuitable surfaces will not be permitted.

3.02 HANDLING, TRANSPORTATION, AND STORAGE

A. Geomembrane rolls shall be packaged and labeled prior to transporting to the site. Geomembrane rolls delivered to the site shall be wrapped in a relatively impermeable and opaque protective cover which may consist of a sacrificial wrap of geomembrane. The sacrificial wrap shall be removed and not used as part of the geomembrane installation.

B. Geomembrane transportation shall be in a manner that reduces the possibility of material damage during shipment.

C. On-site storage of the geomembrane rolls shall be in a safe manner, with rolls protected from grease, dirt, moisture, excessive heat, direct sunlight, vehicle traffic, and other possible sources of damage including theft and vandalism. Storage areas shall be at the Contractor's discretion unless otherwise specified by the Owner.

D. Geomembrane and appurtenant materials delivered to the site shall be checked for proper labeling and visually inspected for transport or manufacturing damage. Owner reserves the right to reject any unacceptable material at no cost to Owner.

E. Only that quantity of geomembrane that is to be placed on a particular day shall be removed from the packaging. Geomembrane rolls shall be transported from the storage area to the construction area using wide lifting straps and properly sized forklifts, front end loaders, or other appropriate equipment. Under no circumstances shall any heavy equipment be allowed directly on the geomembranes. Prior to placement, the geomembranes shall be visually inspected for damage and manufacturing defects. Geomembrane material which, in the opinion of Owner or Owner's Representative, is damaged or otherwise unsuitable shall not be used for the project. Minor damage may be repaired as specified in Article 3.08 of this Section. Damage to geomembranes caused by Installer during handling shall be repaired or replaced at Contractor's expense.

3.03 PANEL LAYOUT AND PLACEMENT

A. Panel and Seam Layout Diagram:
   1. Prepare panel and seam layout diagram so that panel seams run parallel to the direction of maximum slope.
   2. Run panels lengthwise through leachate collection trenches so that there are no seams in the trenches except where the trench is longer than a full roll length.
   3. Textured slope panels, where required, shall extend past grade-break lines as shown on the Drawings.
   4. Slope panels shall not be constructed from more than two pieces of geomembrane (i.e., not more than one cross-seam shall be permitted on slope panels).
   5. Cross seams in slope panels shall be oriented at 45°.
   6. Cross seams in adjacent panels shall be staggered.
   7. Panels shall be seamed in a rain-lap fashion.
   8. Assign identification number to each seam for reference to test results and record Drawings.

B. Panel Placement:
   1. Panel size and placement shall be in general accordance with the panel layout diagram. Place geomembrane of the type (smooth or textured) and mil-thickness, and at the locations and to the dimensions as shown on the Drawings.
   2. Do not slide textured geomembrane across filter fabric surfaces. If textured geomembrane is not placed as desired or required, reroll the geomembrane panel, reposition, and redeploy the panel.
   3. If textured geomembrane is slid across filter fabric and results in a disruption of the fiber network on the surface of the fabric such that adherence of the textured geomembrane to the body of the filter

fabric is reduced, or results in the filter fabric peeling away from an underlying synthetic drainage net, the filter fabric and drainage net shall be replace at Contractor's expense.

4. Panels shall be anchored with sand bags or other approved methods to prevent uplift and damage by wind.
5. The roll identification number and a unique panel number shall be marked on each panel as the panel is placed. The roll and panel numbers shall appear on the Record Drawings.
6. Place panels with appropriate slack incorporated into geomembrane to accommodate expansion and contraction without jeopardizing the integrity of the geomembrane.
7. Smoking during placement of panels is prohibited. Wearing damaging shoes or engaging in any behavior which may damage the geomembrane is prohibited.

C. All geomembrane panels shall be seamed on the same day that they are deployed.

D. Owner or Owner's Representative and Contractor will visually inspect in-place panels prior to seaming. Any damaged panels shall be repaired, and if requested by Owner or Owner's Representative, replaced, at no additional cost to Owner. Repairs shall be made in accordance with Article 3.08 of this Section. All damages and repairs shall be recorded on the Record Drawings.

E. Protection of GCL During Geomembrane Installation:

1. The GCL shall be kept clean and free of soil, debris, and foreign material until covered by the geomembrane. The geomembrane shall be installed indirect contact with the GCL.

2. No vehicle traffic will be permitted directly on the GCL. Only soft-soled /rubber-soled boots and shoes shall be worn on the GCL. Tracked vehicles and trucks with low-pressure tires will be permitted to travel on a minimum of 12-inch thickness of cover soil on the GCL. Vehicles with high-pressure tires will be permitted to travel on a minimum of 2-foot thickness of cover soil over the GCL.

3. Geomembrane Installer shall coordinate with Contractor and GCL installer regarding deployment, seaming, and testing of geomembrane and placement of cover soils over GCL such that geomembrane installation and cover soil placement occurs expeditiously and without damage to the GCL.

4. All GCL shall be covered by geomembrane (including seaming) on the same day that the GCL is installed. Secure the edge of the geomembrane at the top of the slope such that water does not run under the geomembrane onto the GCL.

5. Geomembrane deployment and positioning shall be done such that no disruption of the GCL occurs, particularily at overlapped seams.

3.04 PE GEOMEMBRANE SEAMING

A. Seaming Methods: All seams shall be joined using a heat extrusion or hot fusion (split wedge) weld process in accordance with the manufacturer's recommendations. The Installer shall maintain in working order at the site at least one spare seaming apparatus for each type of welder used. The use of extrusion welded seams shall be limited to repairs and any areas or seam configuration inaccessible to fusion welding equipment.

B. Factory and field seams shall meet the following minimum specifications:

Geomembrane Type	HDPE Textured		HDPE Smooth		LLDPE Textured	
Nominal Gauge	40 mil	60 mil	40 mil	60 mil	40 mil	Test Method
Bonded Seam Strength (shear) (lbs/in. width)	≥70, FTB	≥105, FTB	≥80, FTB	≥120, FTB	≥60, FTB	ASTM D 4437 NSF Annex A
Seam Peel Adhesion (extrusion) (lbs/in. width)	≥42, FTB	≥63, FTB	≥47, FTB	≥70, FTB	≥40, FTB	ASTM D 4437 NSF Annex A
Seam Peel Adhesion (fusion), (lbs/in. width)	≥47, FTB	≥70, FTB	≥52, FTB	≥78, FTB	≥40, FTB	ASTM D 4437 NSF Annex A

Note: All seams must fail at film tear bond (FTB).

C. Seam Configuration and Preparation:

1. Overlap panels to be seamed at least 3 inches but not more than 6 inches. The loose end of the upper panel shall extend no more than 3 inches from the weld.
2. Cross seams on slopes shall be made at a 45 degree angle to the edge of the panel.
3. The contact area between panels shall be clean and free of moisture, dust, dirt, debris, and foreign material. A protective layer of filter fabric or scrap geomembrane shall be used directly beneath each seam overlap to achieve proper support and a clean work surface, if necessary.
4. Where extrusion welding is used, the contact surfaces between panels shall be ground to remove oxidation prior to welding. Grinding shall not result in grooving of the liner nor reduction of the liner thickness by more than 10 percent. The grinding motion shall be made perpendicular to the seam. Grinding in a direction parallel to the seam will not be permitted.
5. Seams shall be aligned to minimize the number and size of wrinkles.

D. Test Seam Specimen Preparation:

1. At least two test seam samples shall be prepared with each piece of seaming equipment at the beginning of each seaming period (usually morning and afternoon), unless otherwise directed by Owner or Owner's Representative. Samples shall be prepared by the corresponding operator. Samples shall be at least 6 feet long (in the direction of the seam) by at least 1 foot wide, and may be prepared from scrap pieces of geomembrane.
2. Six 1-inch wide specimens (coupons) from each test seam sample shall be prepared for on-site field testing for shear and peel strength. Coupons shall be prepared using a sheet cutter so that consistent, uniform 1-inch wide coupons are obtained. Three 12-inch long specimens shall be prepared for retention by Owner, Owner's Representative, and Installer.
3. Each specimen shall be labeled with an equipment and operator identification number, date, ambient air temperature, operating temperature, speed of seaming equipment, and field test results.
4. Seaming equipment shall not be used until satisfactory test seams have been prepared.

E. Climatic Conditions for Seaming:

1. Seaming shall be performed only when panel temperatures are between 40°F and 115°F, unless otherwise approved by Owner or Owner's Representative. If seaming is permitted to be performed at panel temperatures below 40°F, the panel contact surface shall be preheated and Installer shall certify in writing that the low-temperature seaming procedures will not cause any short- or long-term damage to the geomembrane.
2. Seaming during rainy weather or when dew is present on panels will not be permitted.
3. Contractor shall provide any special lighting required for seaming during low-light or dark hours.

Installer shall leave slack in geomembrane as necessary to account for thermal expansion or contraction of geomembrane. Stress on panels due to thermal expansion and contraction shall be minimized by performing field seaming operations during the coolest parts of the day or night, if necessary. Special scheduling or extended hours of operation require approval by the Owner.

F. All welding shall provide a tight, leakproof, homogeneous bond between panels. All seams shall extend to ends of panels.

G. Welding equipment shall be continuously monitored to control the temperature of extrudate and wedge.

3.05 SEAMING PREQUALIFICATION TESTING

A. Seaming prequalification coupons (prepared per Paragraph 3.04D of this Section) shall be tested for shear and peel strength with the on-site tensiometer prior to starting production seaming. Three coupons shall be tested in shear and three in peel. All coupons shall exhibit the required strength at yield or break, and failure mechanism (FTB) as set forth in Paragraph 3.04B of this Section. If any of the coupons fail, another test seam shall be prepared and coupons cut and tested. If any of the second set of coupons fail, the reason for the failure shall be identified and corrected prior to preparing another test seam. No production seaming shall be performed with any seaming equipment or by any operator without a passed seaming prequalification test witnessed by the Owner or Owner's Representative.

3.06 NONDESTRUCTIVE TESTING OF PRODUCTION SEAMS

A. Visual Inspection: A visual inspection of all seams shall be performed. This inspection shall look for obvious flaws in seaming, patches, penetration sealing, material defects, or other problems. Deviations from acceptable workmanship standards shall be noted and corrected.

B. Pressure Testing (Split-Wedge System): Where a split-wedge fusion seaming system is employed, the continuity of the seam shall be tested with air pressure in accordance with the following procedure. Installer shall provide all equipment and personnel to conduct the testing specified herein. The flow channel must not be obstructed by foreign objects or geomembrane material throughout the length of seam being tested. The vacuum test described in Paragraph 3.06C of this Section must be employed for testing of all seams that do not have a contiguous flow channel.

1. A test device consisting of an inflation needle and pressure gauge mounted on a "T" fitting shall be used for air pressure testing. Insert the needle into the flow channel and seal the end of the channel around the needle. Connect a pump (such as a small bicycle pump) to the test device.
2. Ascertain that the flow channel is contiguous by leaving the other end of the channel open and pumping air through the channel. If air does not pass through the channel the test length must be shortened until a contiguous length of flow channel is found.
3. Seal and clamp both ends of the flow channel to assure an airtight seal. Inflate the flow channel to 25 to 30 psig. Allow one minute for the seam to stabilize.
4. Reinflate to 25 to 30 psig and test for a period of five minutes.
5. At the end of the test period, if the pressure has not dropped more than 2 psi, the test shall be considered a pass and the following procedure will be implemented:
   a. Remove the test device and clamps.
   b. Make any repairs, if necessary, to the area where the flow channel was clamped or inflated.
   c. Record the test results, mark the seam as a pass, and proceed to the next seam.
6. If the pressure drops below the 2 psi allowance, the test shall be considered a failure and the following procedure shall be implemented to identify the failure:
   a. Check to determine if there is excessive seepage around the inflation needle.
   b. Check both ends of the seam to ensure the flow channel is completely sealed off.
   c. Walk the length of the seam; look and listen for air leaks.

d. If either of these procedures fail to identify the leak, trim the seam overlap and vacuum test the seam to locate the leak.
e. Once the leak is identified, make the necessary repairs and retest the seam.

C. Vacuum Testing: Vacuum testing shall be used to test the continuity of extrusion welded and mechanical seams. Installer shall provide all equipment and personnel to conduct the testing specified herein. The following procedure shall be followed:
1. Wet seam to be tested with a soapy solution mixed at a ratio of 1 ounce soap to 1 gallon water.
2. Place clear-topped vacuum box over seam to be tested, evacuate box to a vacuum of 3 to 5 inches water column, and tug up to ensure a leaktight seal has developed.
3. Examine the seam for 5 to 10 seconds; watch for soap bubble formation.
4. If bubbles are not evident, move to next test location.
5. If bubbles are present, mark area clearly for repair.
6. If the vacuum testing indicates leakage, the area shall be spot patched; or if major leaks are detected, the entire seam shall be reworked.

3.07 DESTRUCTIVE TESTING OF PRODUCTION SEAMS

A. The purpose of destructive testing is to verify that the seaming process has produced seams of acceptable physical integrity. Installer shall provide all equipment and personnel to conduct on-site destructive testing. One seam sample shall be taken at random for each 500 feet of seam. Sample locations shall be designated by Owner or Owner's Representative. Each sample shall be assigned a unique identification number and the location shall be shown on the panel layout drawing. All holes in the installed geomembrane resulting from obtaining samples shall be repaired immediately. All repairs shall be 100 percent vacuum tested for continuity.

B. Each sample shall be approximately 18 inches long by 12 inches wide with the seam centered lengthwise. Samples shall be divided as follows:
1. Six 1-inch wide coupons for on-site testing by Installer for shear and peel strength.
2. One 6-inch wide coupon for independent laboratory testing.
3. One 6-inch wide coupon for archival storage.

C. Installer shall conduct shear strength and peel adhesion tests on each sample using an on-site tensiometer. The sample shall exhibit film tearing bond (FTB) in both shear and peel and meet the minimum strength requirements set forth in Section 3.04B of this Section. The samples shall be delivered to Owner who will retain them for one year after contract completion. Destructive seam testing shall be performed under the observation of the Owner or Owner's Representative.

D. In case of disputes regarding the test results, arrangements will be made to test samples at an independent testing laboratory. Installer shall label the samples with the location and date that they were taken.

E. The following procedure will be followed in the event of a destructive seam test failure:
1. Determine the extent of the area in question by finding a boundary of two passed seam samples. Samples shall be taken at least 10 feet away on both sides of the failure location.
2. If both of these new samples pass the destructive field test, then the seam between shall be reconstructed by extrusion welding.
3. If one or both of these new samples fail, then the procedure shall continue until two passed seam samples bound the seam area in question.
4. Reconstruct by extrusion welding the entire seam bounded by two passed seam samples.
5. All unacceptable seams shall be bounded by two passed seam sample locations.

F. All testing equipment required for these quality control tests shall be provided by Installer. Any seams failing the quality control tests shall be repaired at Contractor's expense until passing test results are obtained. At all times, care shall be exercised to avoid damaging the geomembrane.

3.08 GEOMEMBRANE PANEL AND SEAM REPAIR

A. Pin holes, creases, scratches, and other defects in the geomembrane shall be repaired by either patching:
   1. Patches shall be round or oval in shape, made of the same geomembrane material as the panel being repaired, and extend at least 6 inches beyond the edge of the defective area.
   2. Patch seaming shall be performed in accordance with Article 3.04 of this Section.

B. Wrinkles in the geomembrane shall be removed or repaired as directed by Owner or Owner's Representative.
   1. Wrinkles shall be repaired by cutting the geomembrane at the top edge of the wrinkle and overlapping the cut panels.
   2. The cut panels shall be repaired in accordance with Article 3.04 of this Section.

C. Any protuberances in the geomembrane caused by rocks, vegetation, or other foreign matter located on the subgrade below the geomembrane shall be repaired by cutting out the protuberance and patching the hole.

D. All repairs shall be tested in accordance with Article 3.06.

E. All repair locations shall be identified on Record Drawings.

3.09 APPURTENANCES

A. The geomembrane shall be installed around pipes and other appurtenances protruding through or adjacent to the geomembrane.

3.10 ANCHORAGE

A. The geomembrane shall be anchored as shown on the Drawings.

3.11 SUPERVISION OF PROTECTIVE COVER PLACEMENT

A. Geomembrane shall be covered as shown on the Drawings as soon as possible after seam testing has been completed and approved by Owner or Owner's Representative. Testing and covering may be completed in phases to facilitate timely placement of cover materials. Any geomembrane left uncovered overnight shall be visually inspected the following day for damage before cover materials are placed.

B. Installer shall provide qualified personnel to direct and supervise placement of granular drainage materials or protective covers over the geomembranes. Installer shall remain on-site during until cover material placement is complete.

C. Equipment traffic shall not be permitted over the geomembrane until a minimum 1-foot thick layer of material has been placed over the geomembrane. Vehicles with tires shall not be permitted to travel over the geomembrane until a minimum 2-foot thick cover has been placed.

D. Areas of geomembrane damaged during cover placement shall be repaired and tested. The cost of repairing and testing these damaged areas shall be borne by Contractor.

3.12 RESTORATION

A. The Contractor shall restore all areas affected by geomembrane-related work to preexisting conditions and to the satisfaction of Owner.

3.13 GEOMEMBRANE ACCEPTANCE

A. Contractor shall retain all ownership and responsibility for the geomembrane and related work until written acceptance from Owner is received.

B. Owner will provide written acceptance after the geomembrane installation and all related work, including cover material placement, has been satisfactorily completed and a written certification letter and Record Drawings reflecting all geomembrane-related work have been provided to Owner. The written certification letter and Record Drawings reflecting all geomembrane-related work shall be submitted in accordance with the general requirements to Owner not more than ten (10) working days after completion of all field seaming.

C. A 20-year material and 5-year workmanship warranty shall be provided by the Contractor.

END OF SECTION 02770

SECTION 02930

TURF ESTABLISHMENT

PART 1 GENERAL

1.01 SECTION INCLUDES

A. Establishing vegetation on all topsoiled areas of the site.

1.02 BASIS FOR COMPENSATION

A. Compensation for all Work and materials covered under this Section of these Specifications will be included under the lump sum Contract Price bid.

1.03 REFERENCES

Minnesota Department of Transportation Standard Specifications for Construction, 1988 Edition, hereafter referred to as Mn/DOT Standard Specifications.

PART 2 PRODUCTS

2.01 MATERIALS

A. Seed: In accordance with Mn/DOT Standard Specification 3876 with seed mixture as follows:
Base Seed Mixture:

Park Kentucky Bluegrass	75 lbs./acre
Creeping Red Fescue	60 lbs./acre
Perennial Ryegrass	15 lbs./acre

Spring Seed Mixture:
Norcen, Leo, or Carroll Birdsfoot Trefoil 10 lbs./acre

Dormant Seed Mixture:
Base Seed Mixture and;
Annual Ryegrass 10 lbs./acre

B. Fertilizer: In accordance with Mn/DOT Standard Specification 3881, at the minimum rate of 750 pounds per acre, at a mixture of 0-26-26; with sulfur at the rate of 100 pounds per acre.

C. Mulch: Type I in accordance with Mn/DOT Standard Specification 3882.

PART 3 EXECUTION

3.01 SEQUENCING AND SCHEDULE

A. The Contractor shall coordinate the turf establishment work with the topsoiling and finishing operations, so as to reduce to a minimum the lag time between the initial and final phases of the combined work and to establish turf protection as soon as possible after the graded areas have been topsoiled or finish graded.

3.02 TURF ESTABLISHMENT

A. Place topsoil as specified in Section 02220 to the dimensions and in locations as indicated on the Contract Drawings.

B. Establish turf on all disturbed and topsoiled areas, excluding the borrow pit. Turf establishment includes:
   1. Soil preparation (Mn/DOT Standard Specification 2575.3B).
   2. Fertilizing (Mn/DOT 2575.3C).
   3. Sowing seed (Mn/DOT 2575.3D3).
   4. Seedbed firming (Mn/DOT 2575.3E).
   5. Applying mulch (Mn/DOT 2575.3Fl).
   6. Disk anchoring (Mn/DOT 2575.3H).

   Sowing seed shall include sowing the Base or Dormant seed mixture, and the Spring seed mixture.

C. Sow the appropriate seed mixture depending upon the sowing date, as specified below:
   1. July 20 to September 20: sow Base Seed Mixture.
   2. After September 20: sow Dormant Seed Mixture.
   3. Sow the Spring Seed Mixture between April 15 and May 15 of the spring following the initial seed sowing.

3.03 WATERING

A. Watering shall be performed at the discretion of the Contractor, at the rate and frequency as may be necessary to initiate and sustain seed germination. Watering shall be performed by and at the expense of the Contractor until the work is accepted by the Owner .

3.04 MAINTENANCE

A. Rework/replace topsoil where original topsoil has eroded or washed away as directed by Owner or Engineer .

B. Remulch any areas on which the original mulch has eroded, washed away, or blown off, as directed by Owner or Owner's On-Site Representative.

C. Reseed any areas on which the original seed has failed to grow, using the specified seed mixture, as directed by Owner or Engineer .

D. Perform all necessary maintenance, replacement and repair work until acceptance of the Work by Owner. The expense of maintenance, replacement, and repair shall be borne by Contractor. Acceptance of work by Owner will occur in the spring of the year following performance of turf establishment when it is evident that seed has germinated.

END OF SECTION 02930

Permit Application Drawings
Scrubber Solids Pond No. 3
NPDES Permit No. 0002186
Sherburne County Generating Plant
Northern States Power Company
(dba Xcel Energy, Inc.)

Prepared for

Xcel Energy

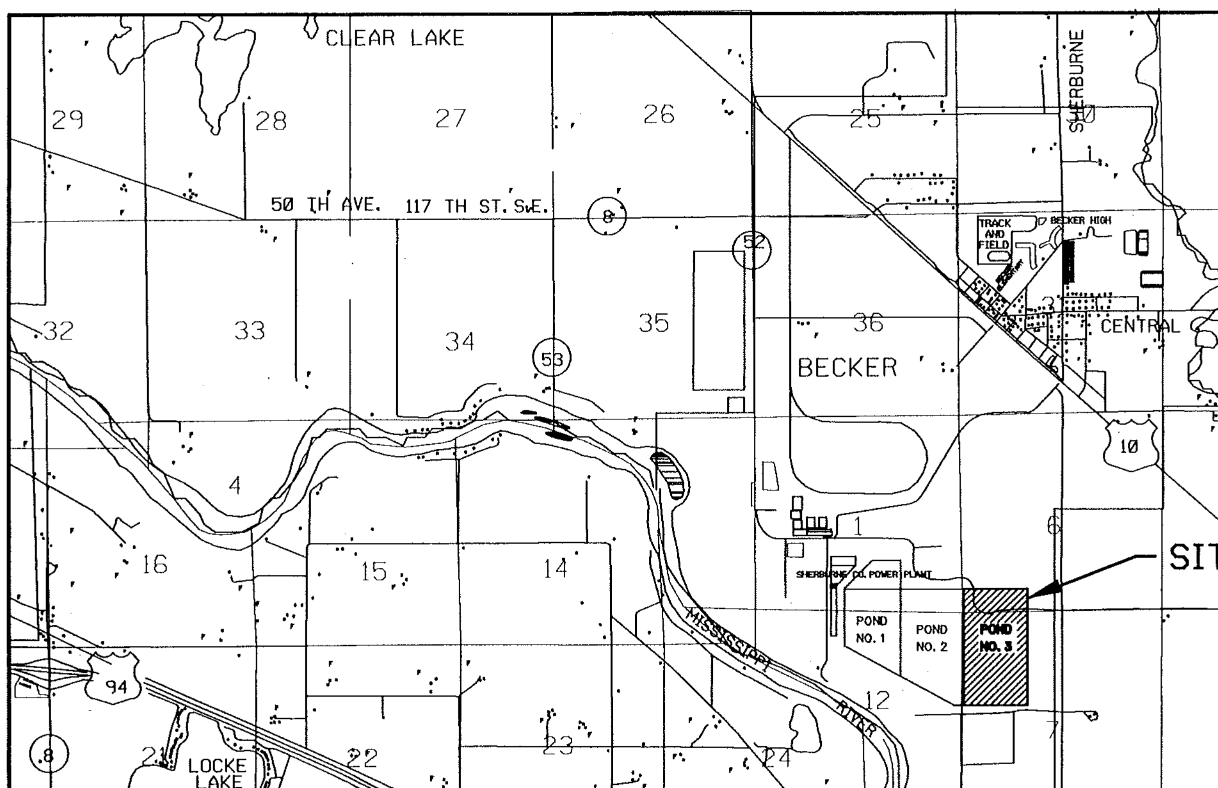
June 2002

Prepared by

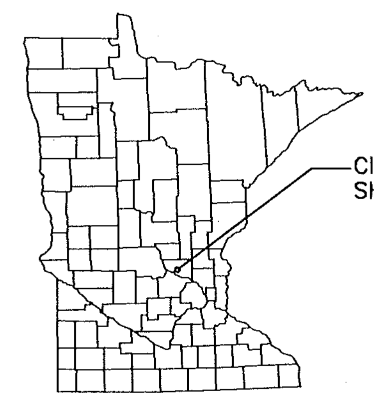
McCain and Associates, Inc.
434 2nd Street
Excelsior, MN 55331
ph 952-881-0347
fx 952-470-0728

SHERBURNE COUNTY GENERATING PLANT (SHERCO)

SCRUBBER SOLIDS POND NO. 3
PERMIT APPLICATION DRAWINGS
NORTHERN STATES POWER COMPANY
dba XCEL ENERGY, INC.
OWNER AND OPERATOR



SITE LOCATION MAP



MINNESOTA

DRAWING INDEX

DRAWING TITLE	DRAWING NUMBER
INDEX SHEET	1
EXISTING CONDITIONS	2
DEVELOPMENT SEQUENCE	3
DEVELOPMENT SEQUENCE	4
SITE CROSS SECTIONS	5
SITE CROSS SECTIONS	6
PHASE 1A PLAN	7
PHASE 1B PLAN	8
PHASE 2A PLAN	9
PHASE 2B PLAN	10
PHASE 3 PLAN	11
PHASE 4 PLAN	12
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DIKE & LINER SECTIONS	15
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REVISIONS

REV	DATE	DESCRIPTION	BY	DWN	CK'D
0	06/28/02	ISSUED FOR PERMITTING	DSS	DSS	JRM

I hereby certify that this plan was prepared by me or under my direct supervision and that I am a duly Licensed Professional Engineer under the laws of the State of Minnesota.
Signature
Print Name John R. McCain
Date 06/28/02 Reg. No. 21835

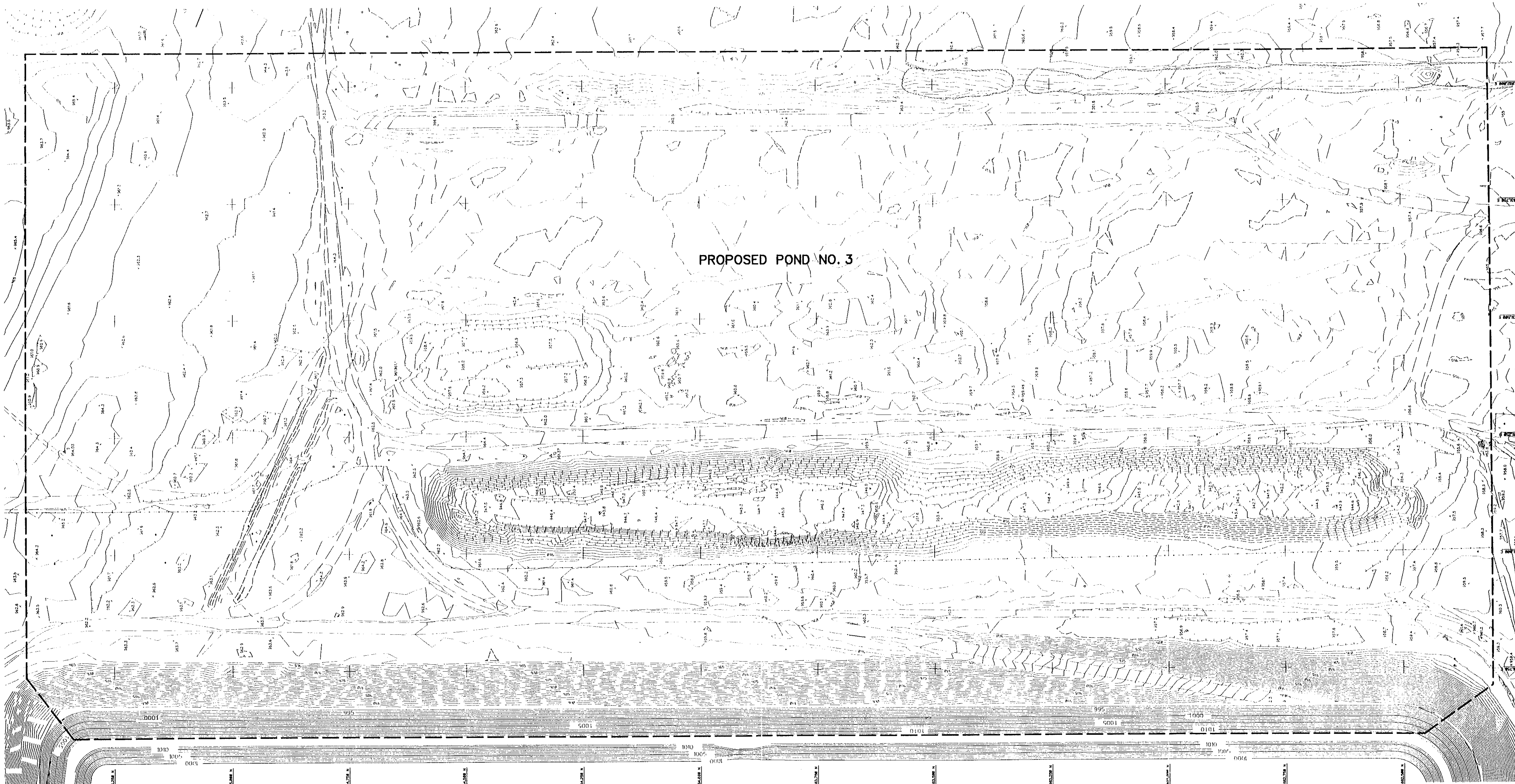
McCain and Associates, Inc.
434 2nd Street
Excelsior, MN 55331
ph 952-470-1611
fx 952-470-0728

DWN DSS	DATE 06/28/02	FACILITY:	SHERBURNE COUNTY GENERATING PLANT
DSGN DSS	CHK'D JRM	TITLE:	POND NO. 3 INDEX SHEET
APP'D & CERT.			
FILMED			

NORTHERN STATES POWER COMPANY
NSP Minneapolis Minnesota

CADD FILENAME Shrcp301.dgn
DWG NO. SHT 1 OF 27 SHTS
REV 0

NH-



SCALE IN FEET 0 100 200

EXISTING TOPOGRAPHY PROVIDED BY: HORIZONS, INC. 10-11-94.

LEGEND

— — — POND NO. 3 DISPOSAL FOOTPRINT

REV	DATE	DESCRIPTION	BY	DWN	CHK'D
0	06/28/02	ISSUED FOR PERMITTING	JRM	DSS	JRM

I hereby certify that this plan was prepared by me or under my direct supervision and that I am a duly Licensed Professional Engineer under the laws of the State of Minnesota.

Signature

Print Name John R. McCain

Date 06/28/02 Reg. No. 21835

McCain and Associates, Inc.
434 2nd Street
Excelsior, MN 55331
ph 952-470-1611
fx 952-470-0728

DWN DSS DATE 06/28/02

DGN'R JRM CHK'D JRM

APP'D & CERT.

FILMED

FACILITY: SHERBURNE COUNTY GENERATING PLANT

TITLE: POND NO. 3

EXISTING CONDITIONS

NORTHERN STATES POWER COMPANY
NSP Minneapolis Minnesota

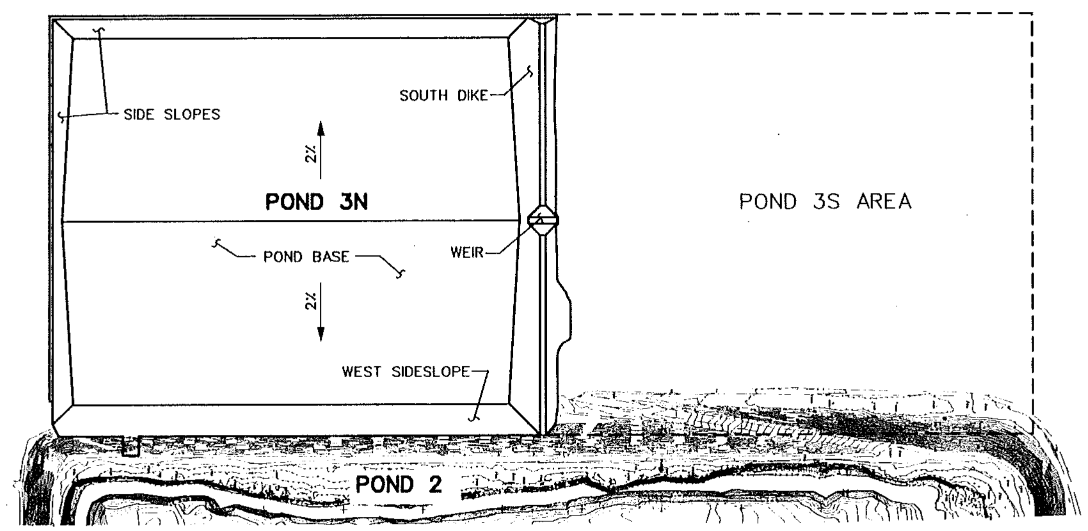
CADD FILENAME Shrcp302.dgn

DWG NO. NH-

SHT 2 OF 27 SHTS

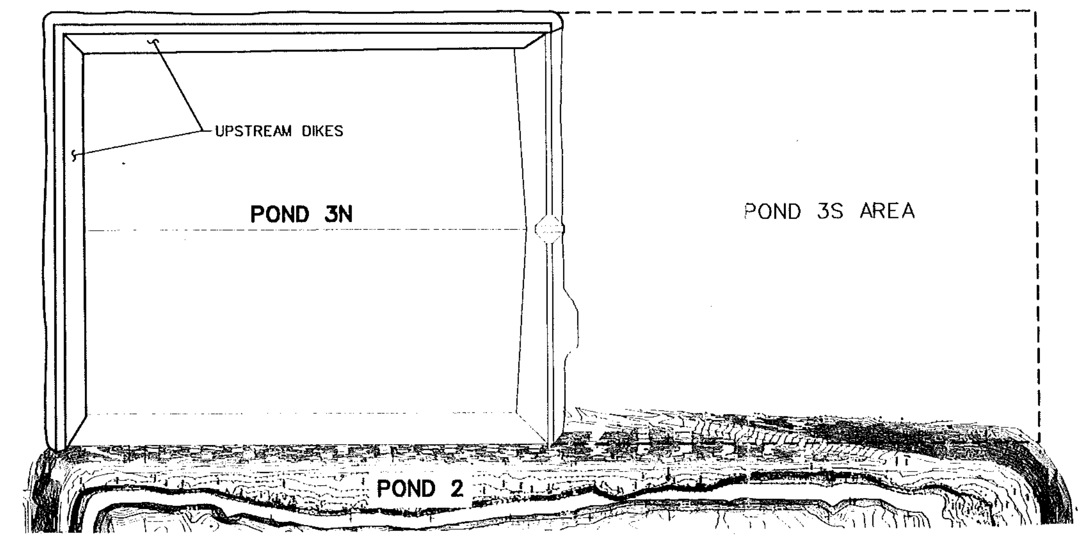
REV 0

NH-



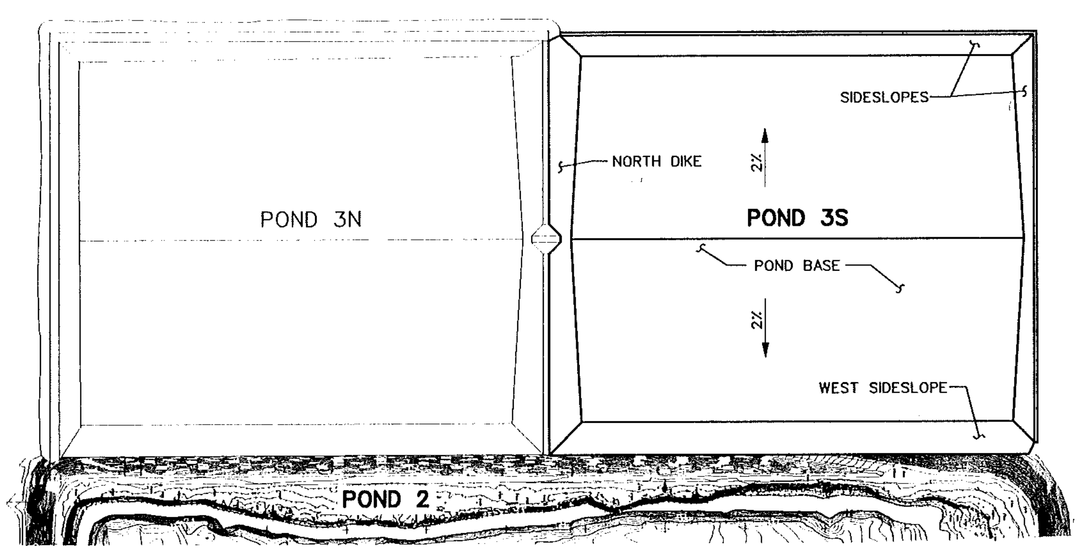
PLAN: PHASE 1A

CONSTRUCTION: COMPOSITE LINER ON BASE, SIDE SLOPES, AND SOUTH DIKE OF POND 3N



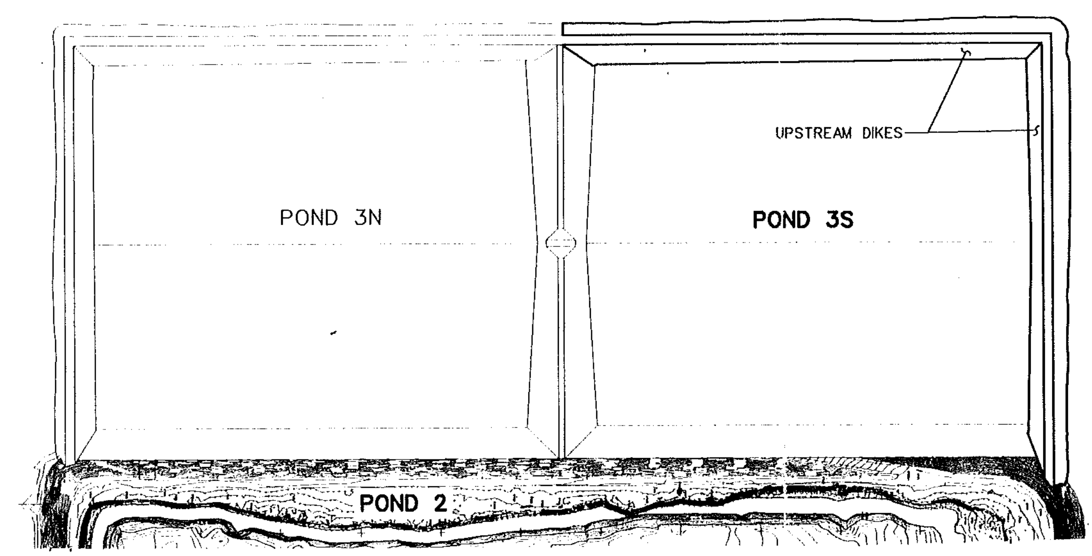
PLAN: PHASE 1B

CONSTRUCTION: UPSTREAM DIKES ON NORTH AND EAST SIDES OF POND 3N



PLAN: PHASE 2A

CONSTRUCTION: COMPOSITE LINER ON BASE, SIDE SLOPES, AND NORTH DIKE OF POND 3S



PLAN: PHASE 2B

CONSTRUCTION: UPSTREAM DIKES ON SOUTH AND EAST SIDES OF POND 3S

Z

0 300 600
SCALE IN FEET

I hereby certify that this plan was prepared by me or under my direct supervision and that I am a duly Licensed Professional Engineer under the laws of the State of Minnesota.
Signature
Print Name John R. McCain
Date 06/28/02 Reg. No. 21835

McCain and Associates, Inc.
434 2nd Street
Excelsior, MN 55331
ph 952-470-1611
fx 952-470-0728

DWN DSS | DATE 06/28/02
DCHK'D JRM | CHK'D JRM
APP'D & CERT.
FILMED

FACILITY: SHERBURNE COUNTY GENERATING PLANT

TITLE: POND NO. 3
DEVELOPMENT SEQUENCE

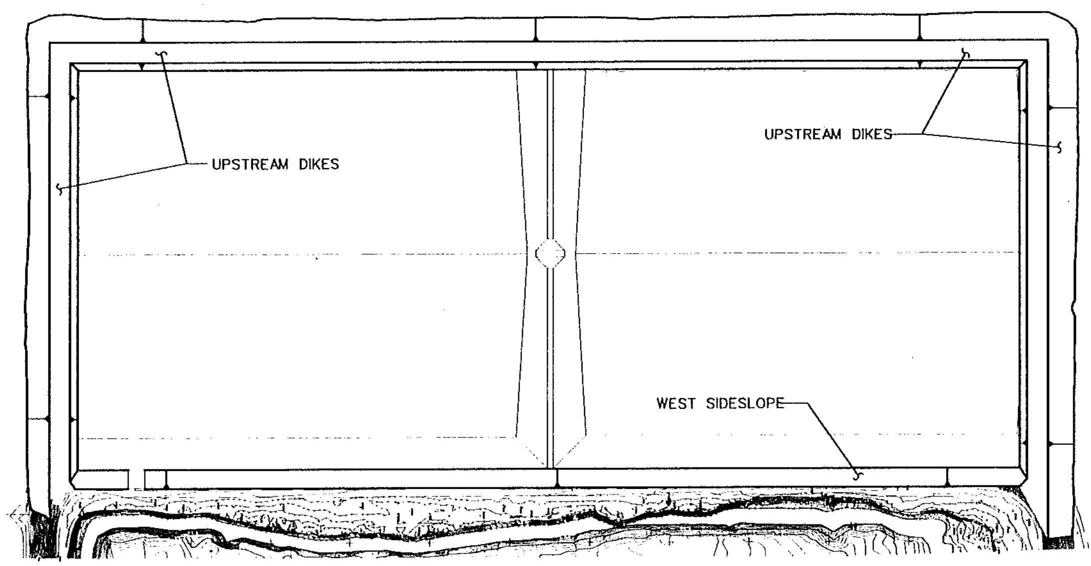
NORTHERN STATES POWER COMPANY
NSP Minneapolis Minnesota

CADD FILENAME Shrcp303.dgn
DWG NO. SHT 3 OF 27 SHTS
REV 0

REVISIONS

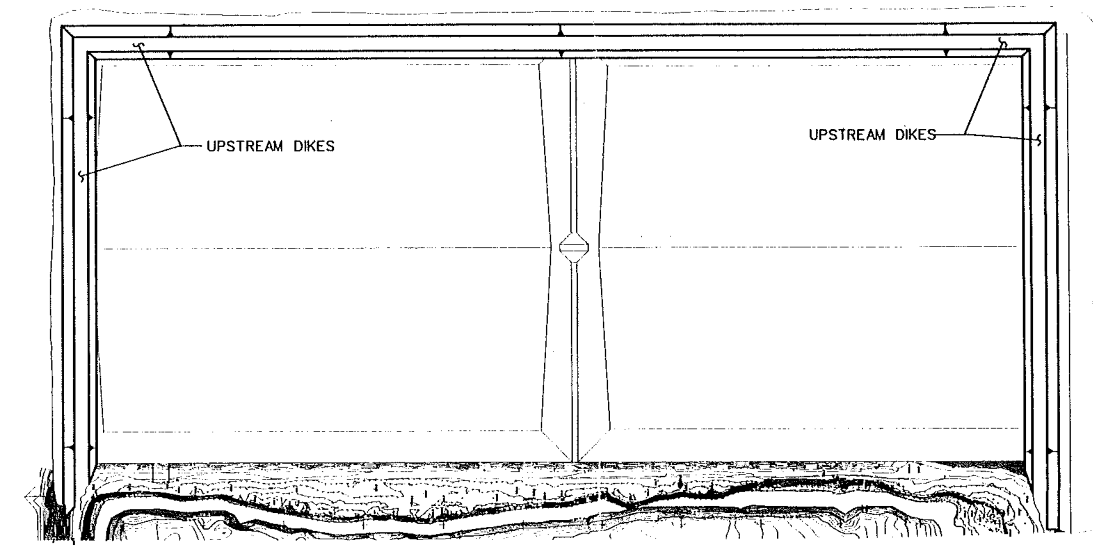
REV	DATE	DESCRIPTION	BY	DWN	CK'D
0	06/28/02	ISSUED FOR PERMITTING	JRM	DSS	JRM

NH-



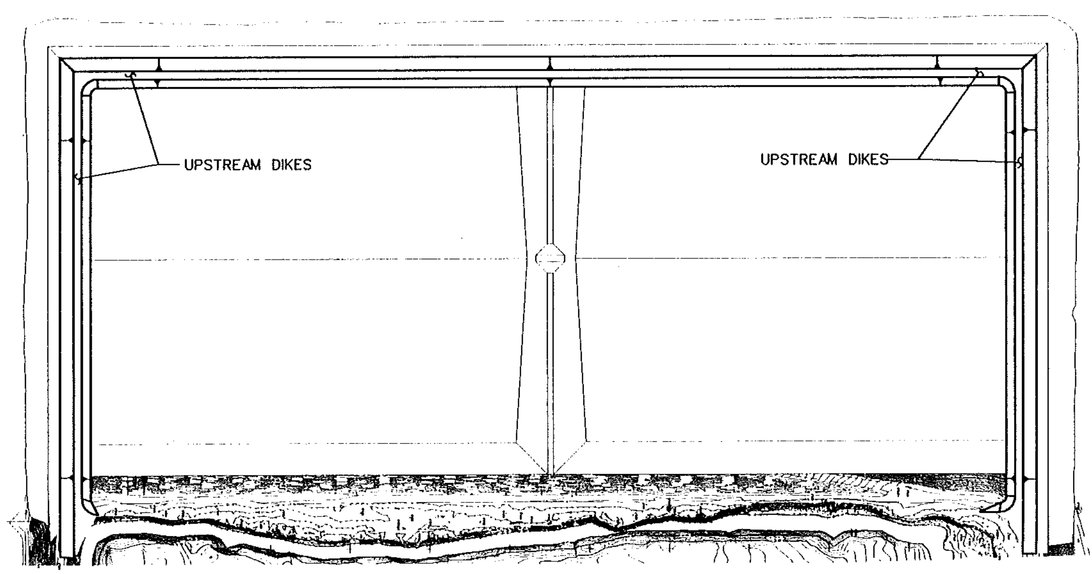
PLAN: PHASE 3

CONSTRUCTION: COMPOSITE LINER ON WEST SIDESLOPE AND UPSTREAM DIKE EXTENSION ON NORTH, EAST, AND SOUTH SIDES OF POND NO.3



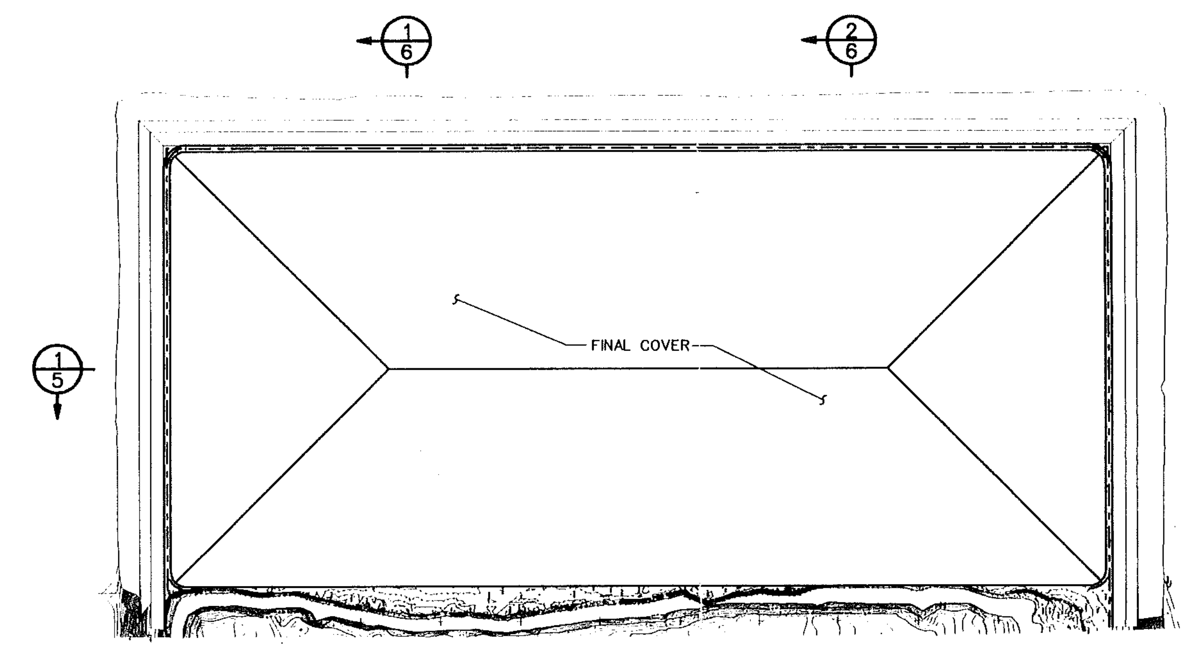
PLAN: PHASE 4

CONSTRUCTION: UPSTREAM DIKE EXTENSION ON NORTH, EAST, AND SOUTH SIDES OF POND NO. 3



PLAN: PHASE 5

CONSTRUCTION: UPSTREAM DIKE EXTENSION ON NORTH, EAST, AND SOUTH SIDES OF POND NO. 3



PLAN: PHASE 6 - FINAL COVER

CONSTRUCTION: FINAL COVER ON POND NO. 3

Z

0 300 600
SCALE IN FEET

REVISIONS					
0	06/28/02	ISSUED FOR PERMITTING	JRM	DSS	JRM
REV	DATE	DESCRIPTION	BY	DWN	CHK'D

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fx 952-470-0728

DWN DSS DATE 06/28/02
DGN'R JRM CHK'D JRM
APP'D & CERT.
FILMED

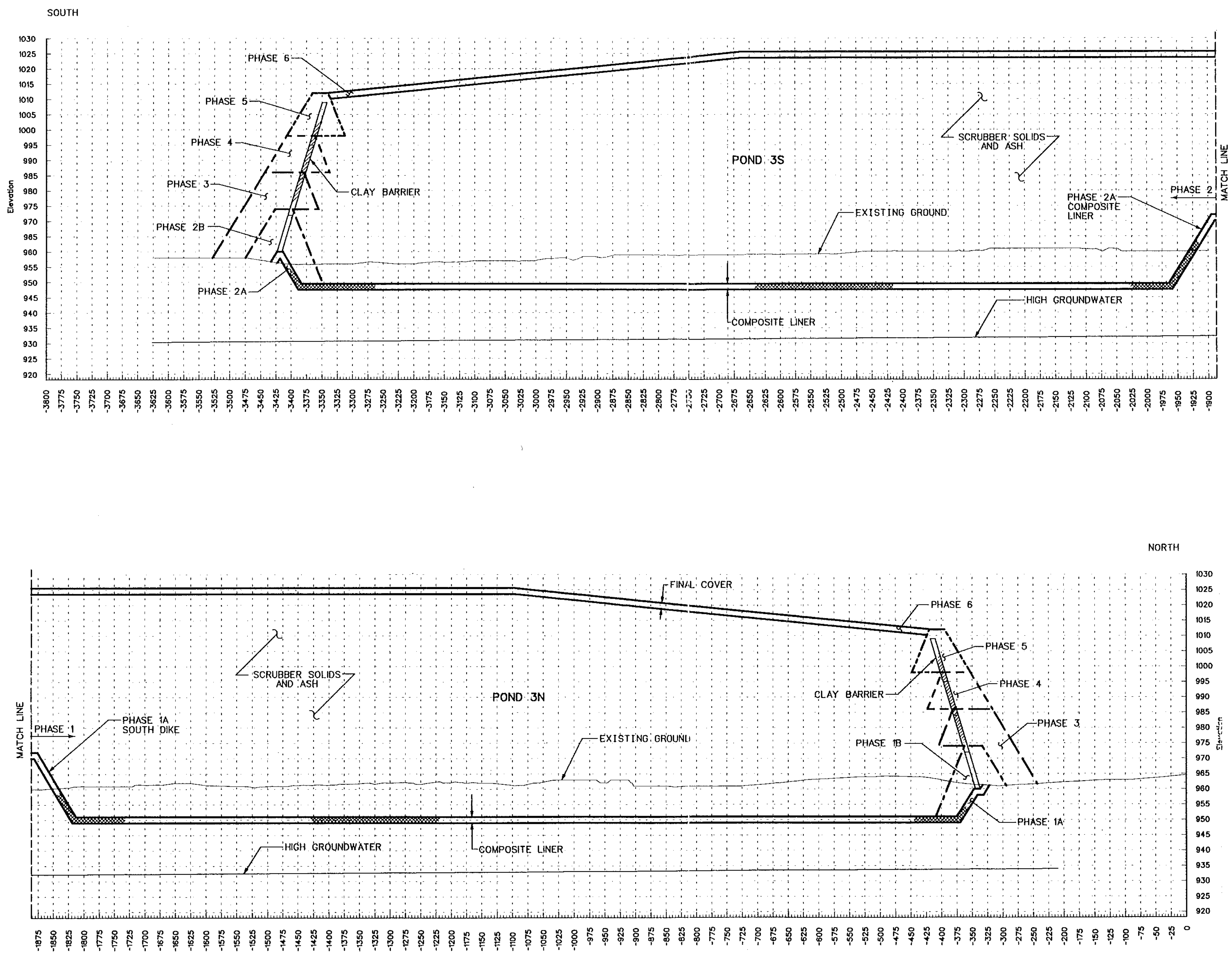
FACILITY: SHERBURNE COUNTY GENERATING PLANT

TITLE: POND NO. 3
DEVELOPMENT SEQUENCE

NORTHERN STATES POWER COMPANY
NSP Minneapolis Minnesota

CADD FILENAME Shrcp304.dgn
DWG NO. SHT 4 OF 27 SHTS
REV 0

NH-



LEGEND:

- COMPOSITE LINER
- CLAY BARRIER
- PHASE 1 & 2
- PHASE 3
- PHASE 4
- PHASE 5

1/5 CROSS SECTION: NORTH - SOUTH (POND NO. 3)

SCALE: 1"-20' VERT.
1"-100' HORZ.

REVISIONS					
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0	06/28/02	ISSUED FOR PERMITTING	JRM	DSS	JRM

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fx 952 470 0728

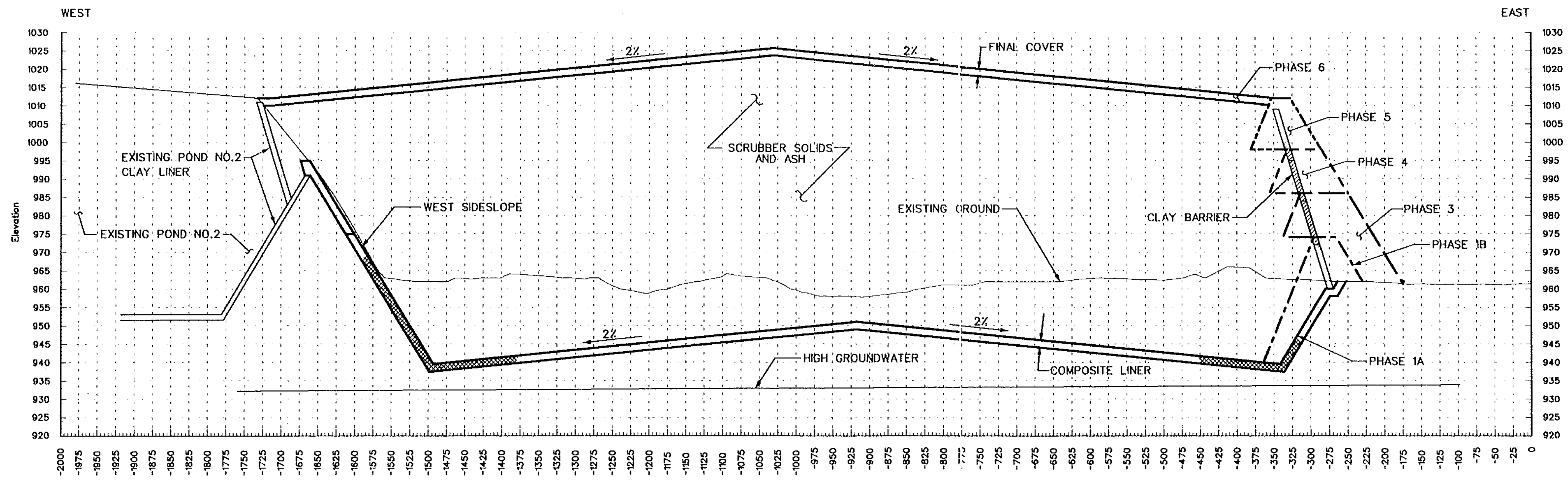
DWN DSS DATE 06/28/02
DCHK'D JRM CHK'D JRM
APP'D & CERT.
FILMED

FACILITY: SHERBURNE COUNTY GENERATING PLANT

TITLE: POND NO. 3
SITE CROSS SECTIONS

NORTHERN STATES POWER COMPANY
NSP Minneapolis Minnesota

CADD FILENAME Shrcp305_6.dgn
DWG NO. SHT 5 OF 27 SHTS
REV 0

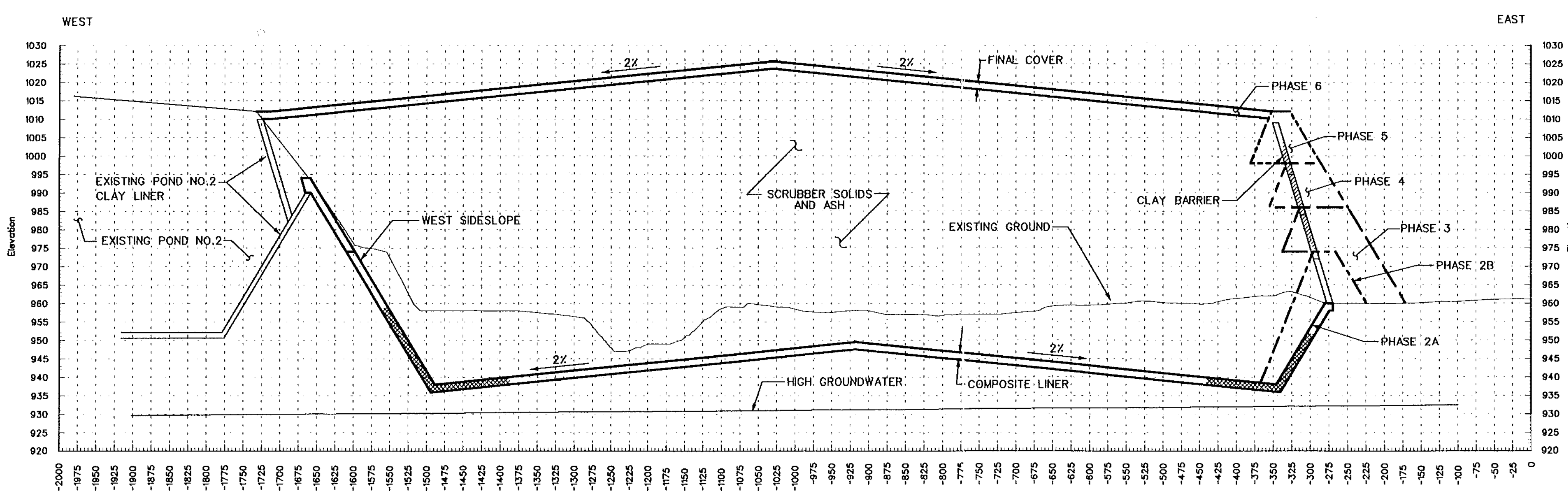


1/6 CROSS SECTION: EAST - WEST (POND 3N)

SCALE: 1"=20' VERT.
1"=100' HORZ.

LEGEND:

(crosshatch)	COMPOSITE LINER
(hatch)	CLAY BARRIER
— · — · —	PHASE 1 & 2
— — —	PHASE 3
- - - - -	PHASE 4
- - - - - -	PHASE 5



2/6 CROSS SECTION: EAST - WEST (POND 3S)

SCALE: 1"=20' VERT.
1"=100' HORZ.

NH-

REVISIONS					
REV	DATE	DESCRIPTION	BY	DWN	CK'D
0	06/28/02	ISSUED FOR PERMITTING	JRM	DSS	JRM

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434 2nd Street
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fx 952 470-0728

DWN DSS DATE 06/28/02
DGN'R JRM CHK'D JRM
APP'D & CERT.
FILMED

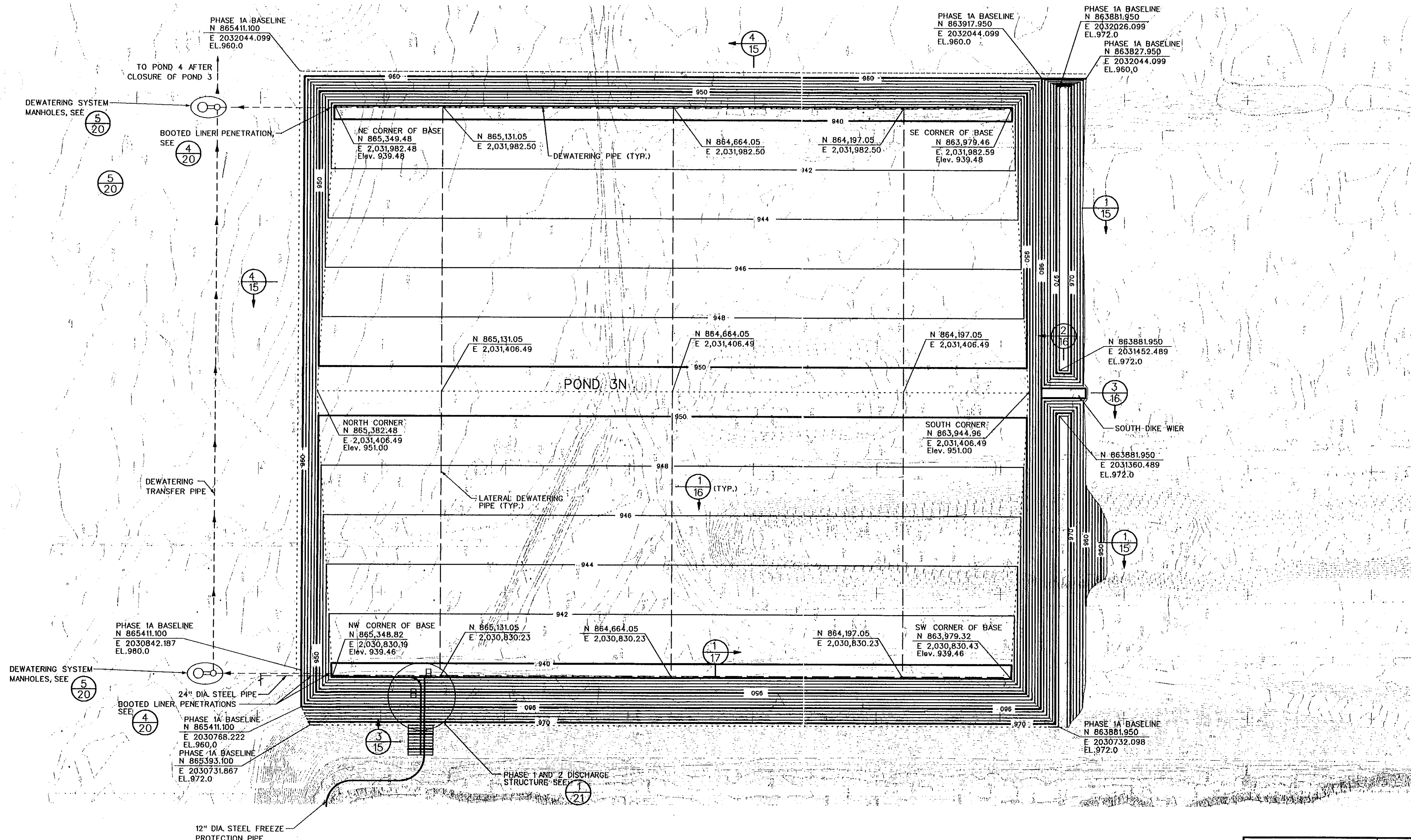
FACILITY: SHERBURNE COUNTY GENERATING PLANT

TITLE: POND NO. 3
SITE CROSS SECTIONS

NORTHERN STATES POWER COMPANY
NSP Minneapolis Minnesota

CADD FILENAME Shrcp305_6.dgn
DWG NO. SHT 6 OF 27 SHTS
REV 0

NH-



NOTE:
PROPOSED CONTOURS
REPRESENT TOP OF CLAY

LEGEND:

995	EXISTING CONTOURS
1000	INDEX CONTOURS (PROPOSED)
	INTERMEDIATE CONTOURS (PROPOSED)
	GRADE BREAKS
	DEWATERING PIPE

0 100 200
SCALE IN FEET

EXISTING TOPOGRAPHY PROVIDED BY:
HORIZONS, INC. 10-11-94.

REVISIONS

REV	DATE	DESCRIPTION	BY	DWN	CH'D
0	06/28/02	ISSUED FOR PERMITTING	JRM	DSS	JRM

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fx 952-470-0728

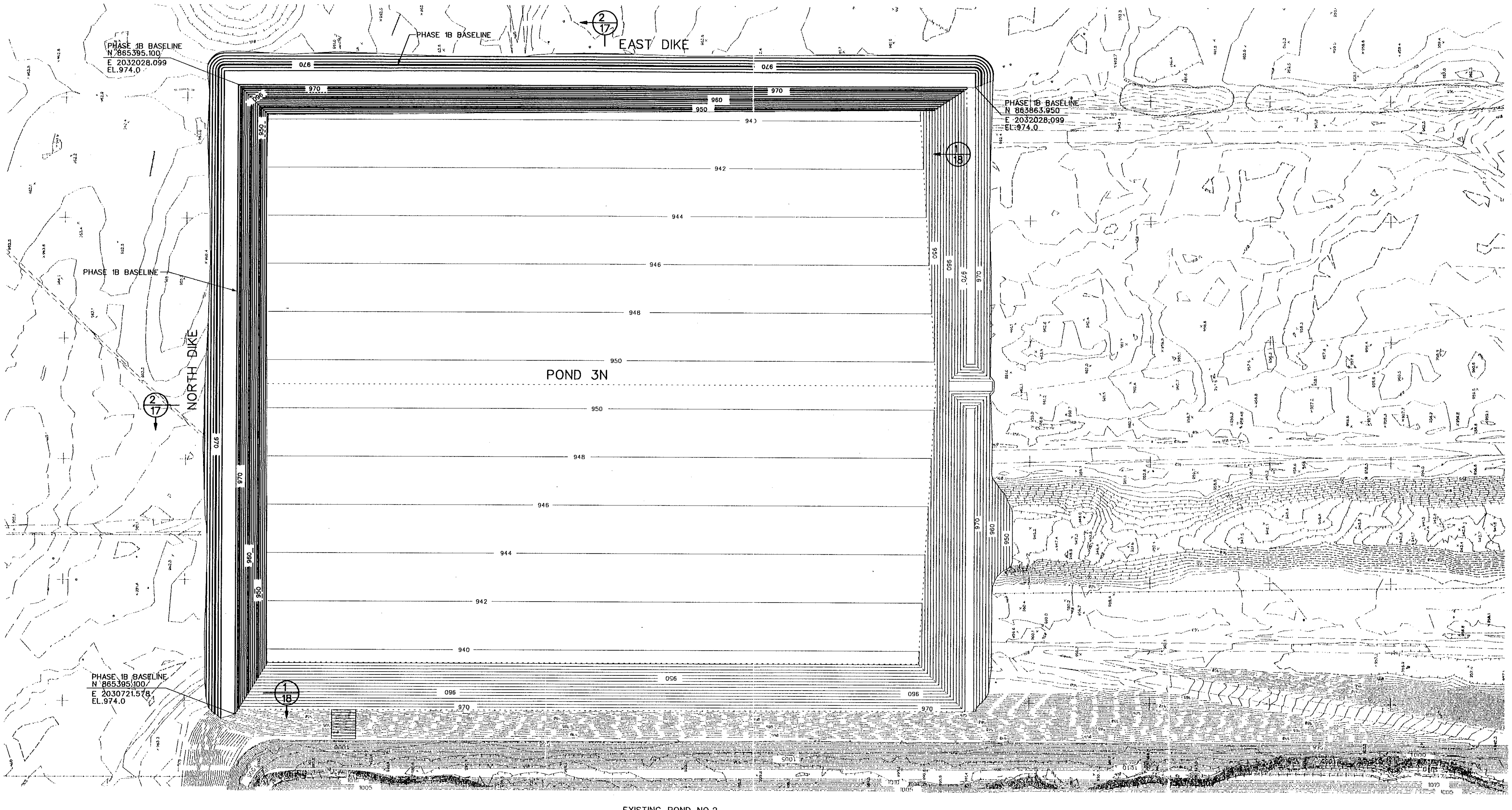
DWN DSS DATE 06/28/02
DSGN JRM CHK'D JRM
APP'D & CERT.
FILMED

FACILITY: SHERBURNE COUNTY GENERATING PLANT

TITLE: POND NO. 3
PHASE 1A PLAN

NORTHERN STATES POWER COMPANY
NSP Minneapolis Minnesota

CADD FILENAME Shrcp307.dgn
DWG NO. SHT 7 OF 27 SHTS
REV 0



LEGEND:

995	EXISTING CONTOURS
1000	INDEX CONTOURS (PROPOSED)
	INTERMEDIATE CONTOURS (PROPOSED)
	GRADE BREAKS

0 100 200
SCALE IN FEET

EXISTING TOPOGRAPHY PROVIDED BY: HORIZONS, INC. 10-11-94.

REVISIONS

REV	DATE	DESCRIPTION	BY	DWN	CHK'D
0	06/28/02	ISSUED FOR PERMITTING	JRM	DSS	JRM

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ph 952-470-1611
fx 952-470-0728

DWN DSS	DATE 06/28/02
DGN'R JRM	CHK'D JRM
APP'D & CERT.	
FILMED	

FACILITY: SHERBURNE COUNTY GENERATING PLANT

TITLE: POND NO. 3

PHASE 1B PLAN

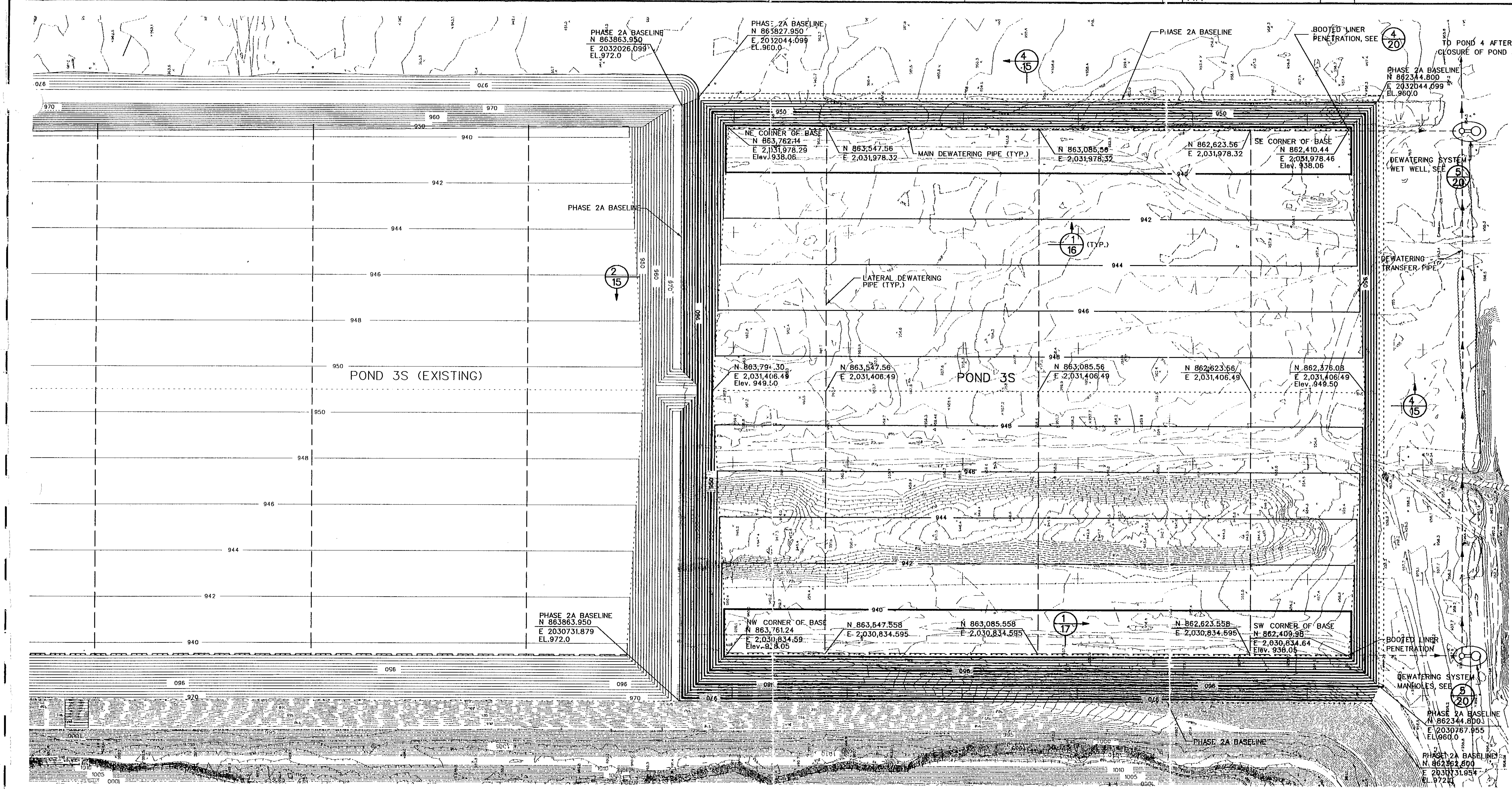
NORTHERN STATES POWER COMPANY
NSP Minneapolis Minnesota

CADD FILENAME Shrcp308.dgn

DWG NO. SHT 8 OF 27 SHTS

REV 0

NH-



EXISTING POND NO. 2

LEGEND:

995	EXISTING CONTOURS
1000	INDEX CONTOURS (PROPOSED)
	INTERMEDIATE CONTOURS (PROPOSED)
	GRADE BREAKS
	DEWATERING PIPE

0 100 200
SCALE IN FEET

EXISTING TOPOGRAPHY PROVIDED BY: HORIZONS, INC. 10-11-94.

REVISIONS

REV	DATE	DESCRIPTION	BY	DWN	CHK'D
0	06/28/02	ISSUED FOR PERMITTING	JRM	DSS	JRM

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DWN DSS DATE 06/28/02
DGN'R JRM CHK'D JRM
APP'D & CERT.
FILMED

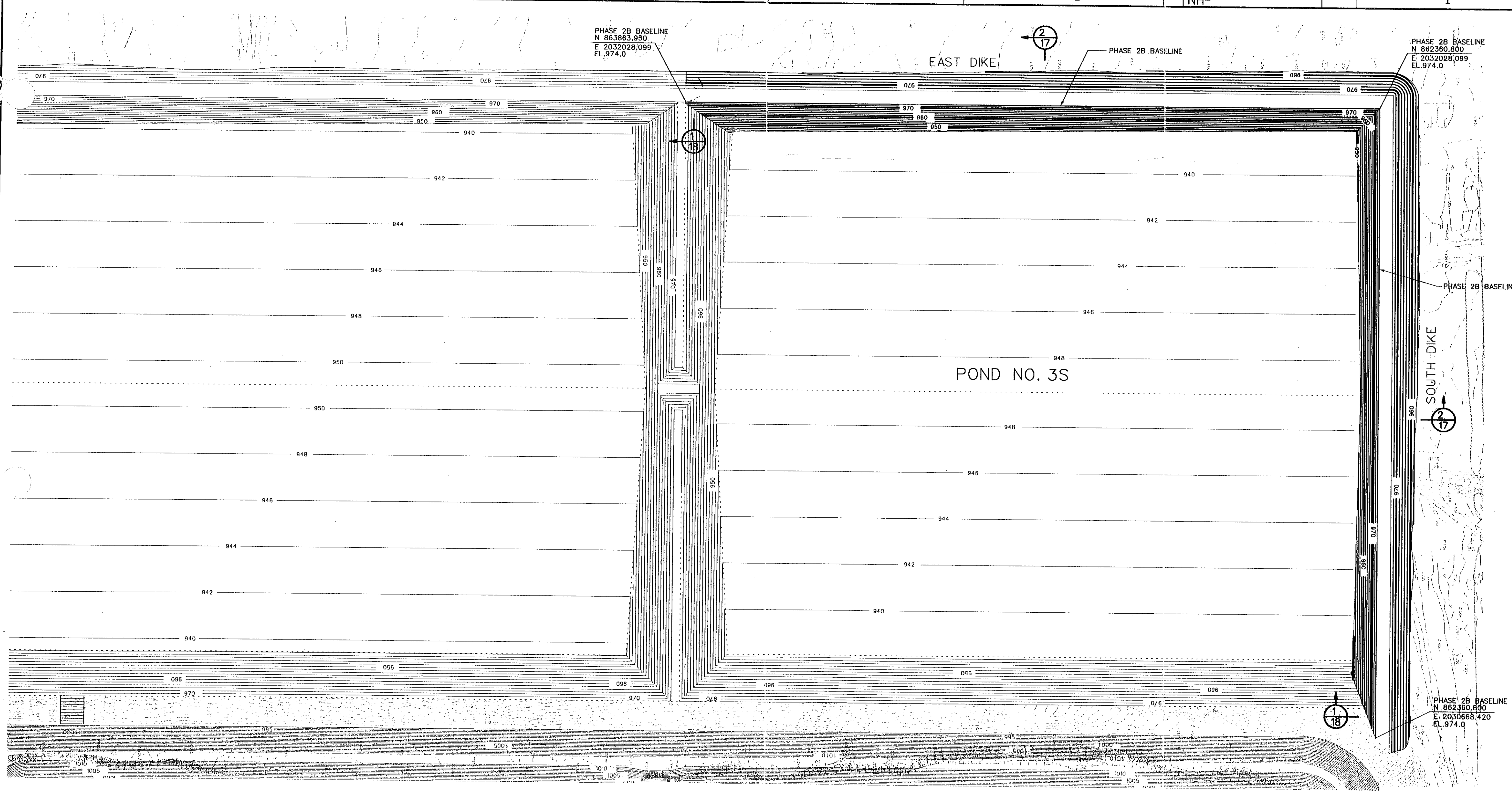
FACILITY: SHERBURNE COUNTY GENERATING PLANT

TITLE: POND NO. 3
PHASE 2A PLAN

NORTHERN STATES POWER COMPANY
NSP Minneapolis Minnesota

CADD FILENAME Shrcp309.dgn
DWG NO. SHT 9 OF 27 SHTS
REV 0

NH-



EXISTING POND NO. 2

LEGEND:

995	EXISTING CONTOURS
1000	INDEX CONTOURS (PROPOSED)
	INTERMEDIATE CONTOURS (PROPOSED)
	GRADE BREAKS
	LATERAL DEWATERING PIPE

0 100 200
SCALE IN FEET

EXISTING TOPOGRAPHY PROVIDED BY:
HORIZONS, INC. 10-11-94.

REVISIONS

REV	DATE	DESCRIPTION	BY	DWN	CHK'D
0	06/28/02	ISSUED FOR PERMITTING	JRM	DSS	JFM

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434 2nd Street
Excelsior, MN 55331
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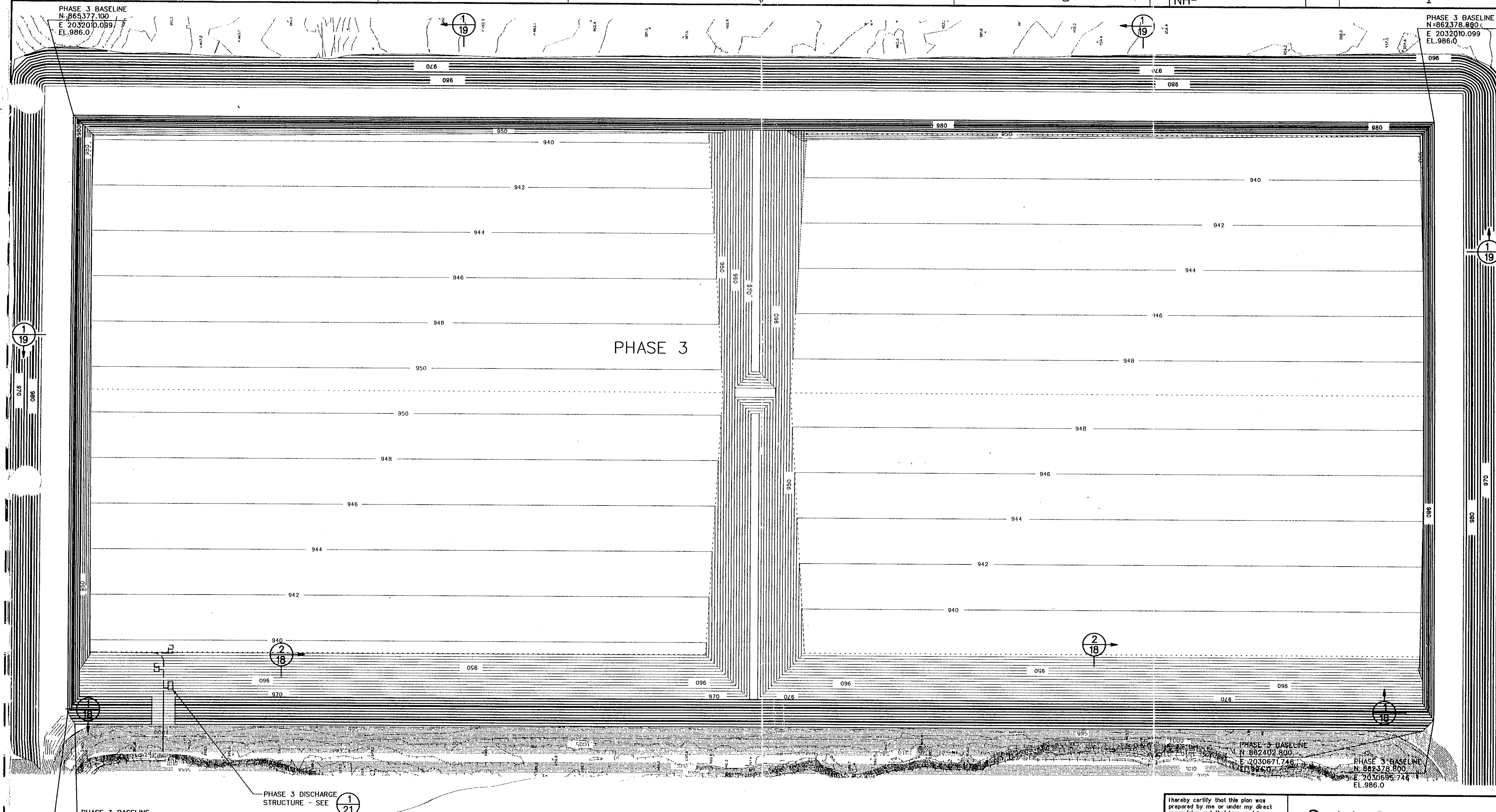
DWN DSS	DATE 06/28/02	FACILITY:	SHERBURNE COUNTY GENERATING PLANT
DGN'R JRM	CHK'D JRM	TITLE:	POND NO. 3
APP'D & CERT.			PHASE 2B PLAN
FILMED			

NORTHERN STATES POWER COMPANY
NSP Minneapolis Minnesota

CADD FILENAME Shrcp310.dgn
DWG NO.
SHT 10 OF 27 SHTS
REV 0

NH-



LEGEND:

995	EXISTING CONTOURS
1000	INDEX CONTOURS (PROPOSED)
	INTERMEDIATE CONTOURS (PROPOSED)
	GRADE BREAKS
	LATERAL DEWATERING PIPE

0 100 200
SCALE IN FEET

EXISTING TOPOGRAPHY PROVIDED BY: HORIZONS, INC. 10-11-94.

REVISIONS

REV	DATE	DESCRIPTION	BY	DWN	CHK'D
0	06/28/02	ISSUED FOR PERMITTING	JRM	DSS	JFM

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434 2nd Street
Excelsior, MN 55331
ph 952-470-1611
fx 952-470-0728

DWN DSS	DATE 06/28/02
DGN'R JRM	CHK'D JRM

APP'D & CERT.

FILMED

FACILITY: SHERBURNE COUNTY GENERATING PLANT

TITLE: POND NO. 3

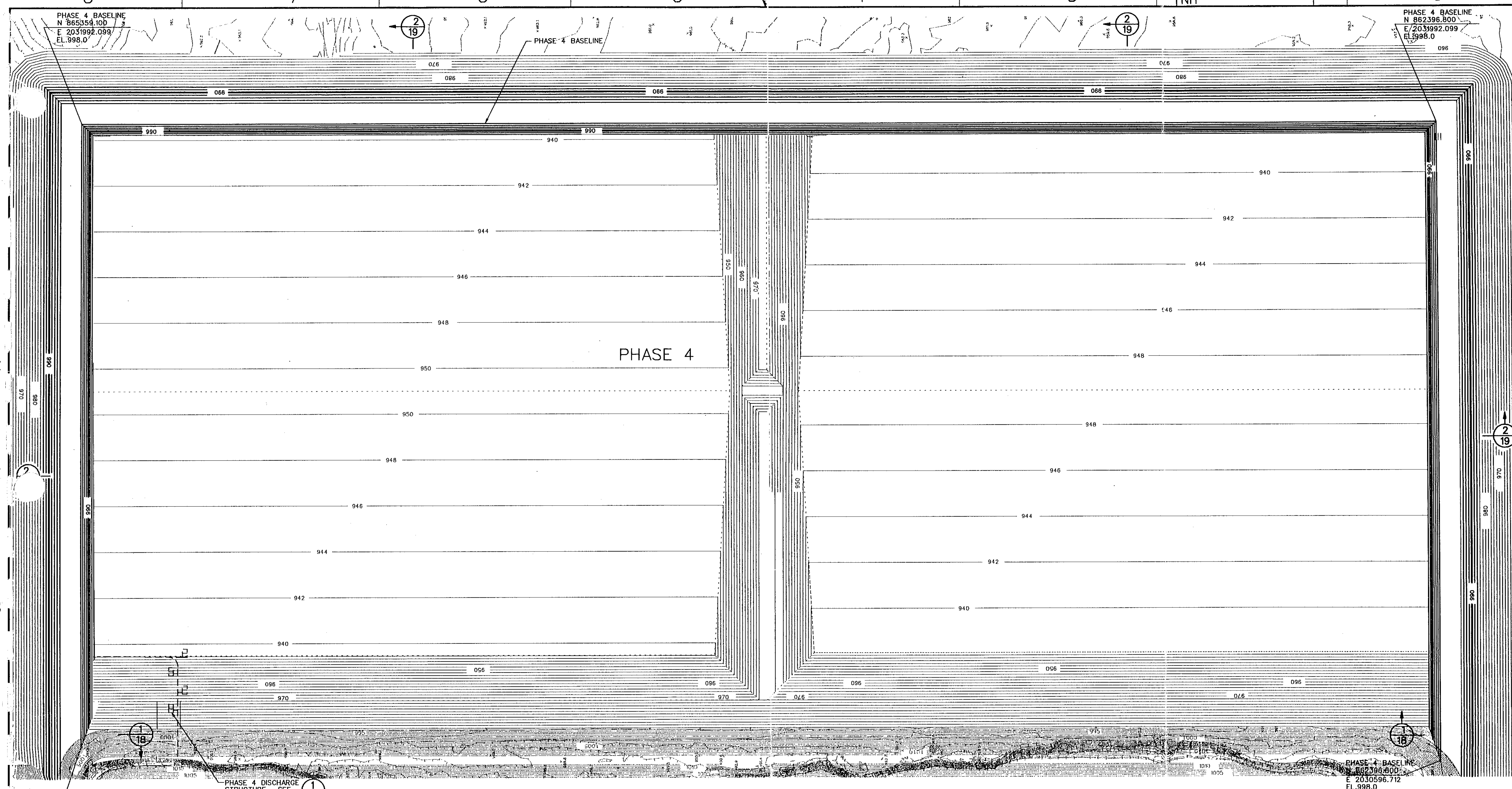
PHASE 3 PLAN

NORTHERN STATES POWER COMPANY
NSP Minneapolis Minnesota

CADD FILENAME Shrcp311.dgn

DWG NO. SHT 11 OF 27 SHTS

REV 0



LEGEND:

995	EXISTING CONTOURS
1000	INDEX CONTOURS (PROPOSED)
	INTERMEDIATE CONTOURS (PROPOSED)
	GRADE BREAKS

SCALE IN FEET: 0 100 200

EXISTING TOPOGRAPHY PROVIDED BY: HORIZONS, INC. 10-11-94.

REVISIONS

REV	DATE	DESCRIPTION	BY	DWN	CHK'D
0	06/28/02	ISSUED FOR PERMITTING	JRM	DSS	JRM

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Date 06/28/02 Reg. No. 21835

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434 2nd Street
Excelsior, MN 55331
ph 952-470-1611
fx 952-470-0728

DWN DSS	DATE 06/28/02
DGN'R JRM	CHK'D JRM
APP'D & CERT.	
FILMED	

FACILITY: SHERBURNE COUNTY GENERATING PLANT

TITLE: POND NO. 3

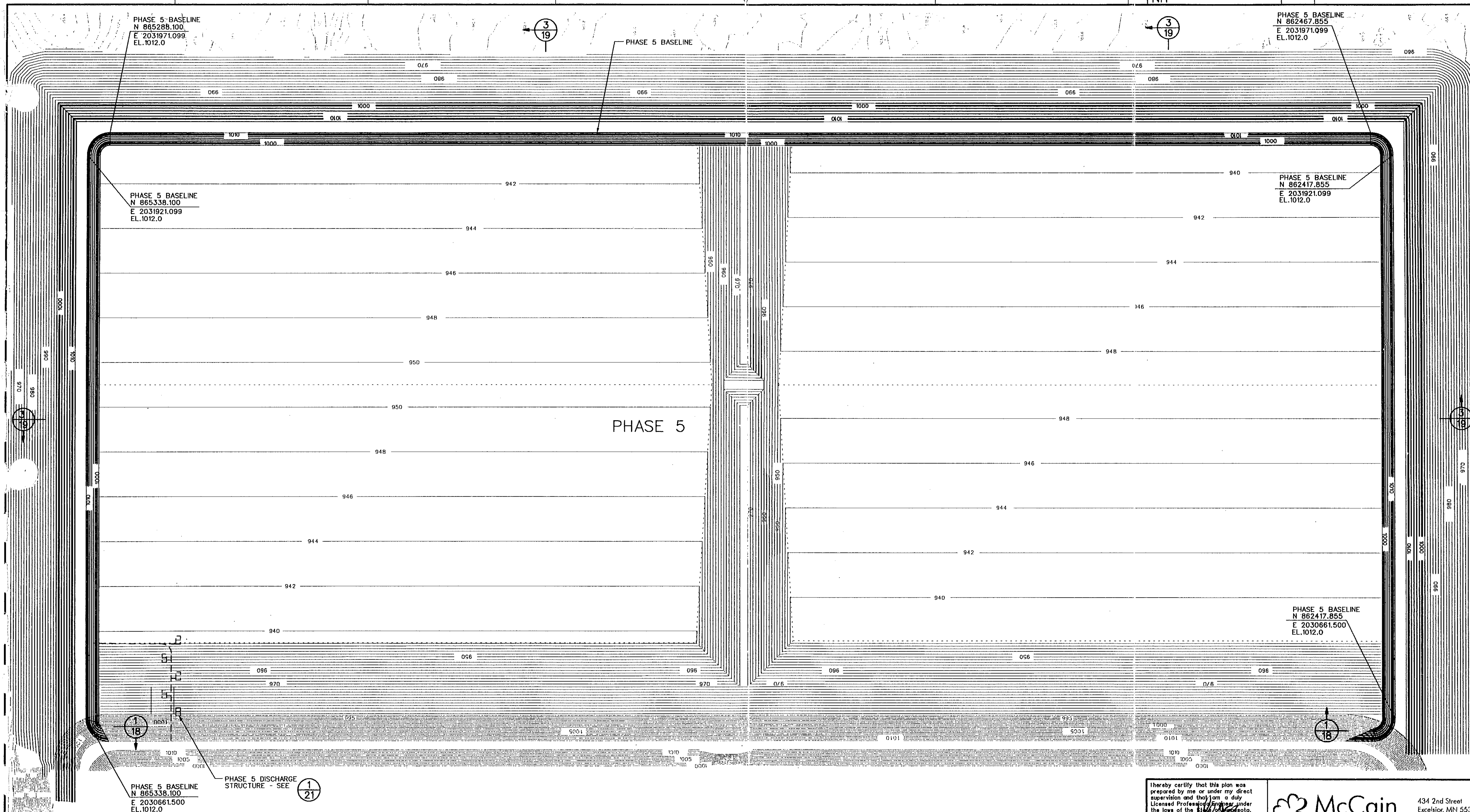
PHASE 4 PLAN

NORTHERN STATES POWER COMPANY
NSP Minneapolis Minnesota

CADD FILENAME Shrcp312.dgn

DWG NO. SHT 12 OF 27 SHTS

REV 0



LEGEND:

------ 995 ------	EXISTING CONTOURS
—— 1000 ——	INDEX CONTOURS (PROPOSED)
————	INTERMEDIATE CONTOURS (PROPOSED)
- - - - - - - -	GRADE BREAKS

0 100 200
SCALE IN FEET

EXISTING TOPOGRAPHY PROVIDED BY: HORIZONS, INC. 10-11-94.

REVISIONS

REV	DATE	DESCRIPTION	BY	DWN	CHK'D
0	06/28/02	ISSUED FOR PERMITTING	JRM	DSS	JRM

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Date 6/28/02 Reg. No. 21835

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Excelsior, MN 55331
ph 952-470-1611
fx 952-470-0728

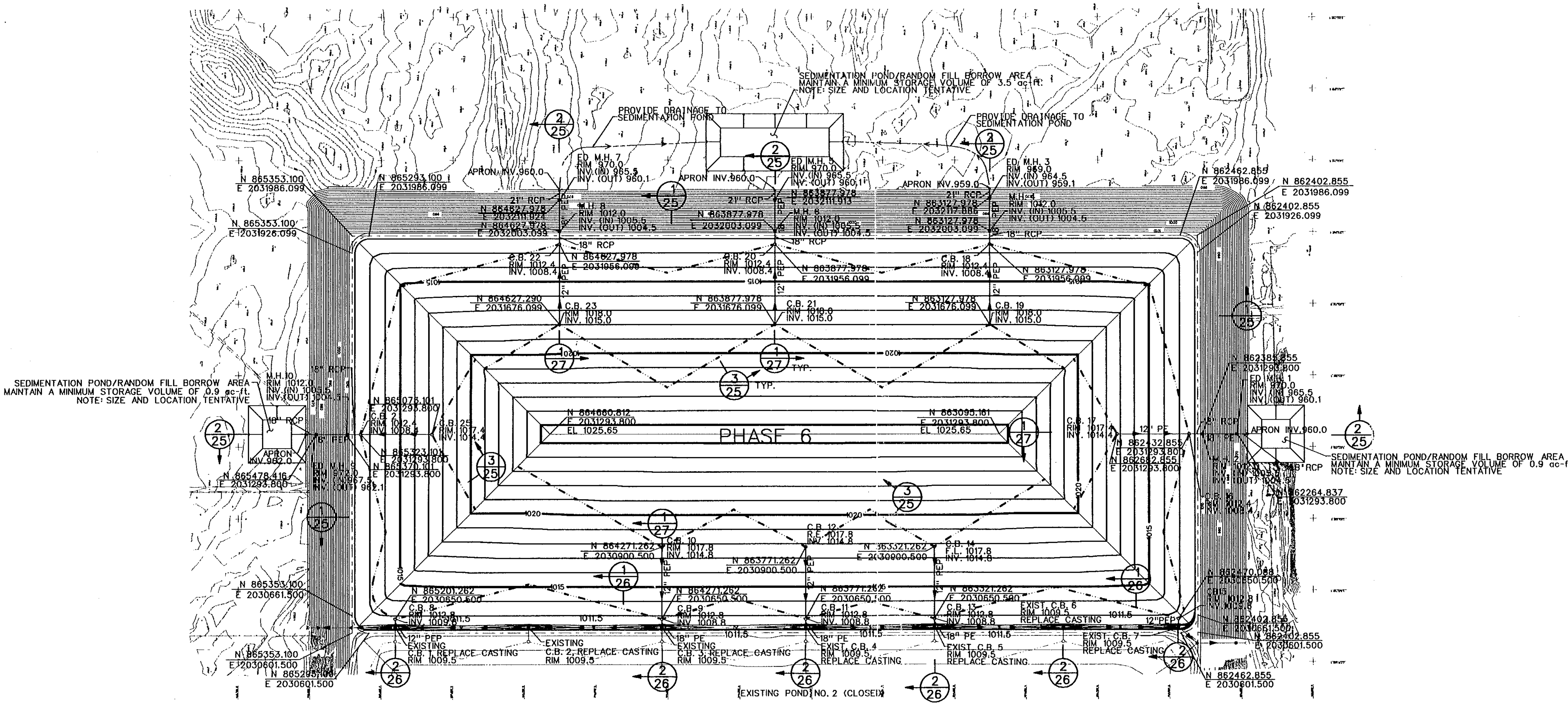
DWN DSS DATE 06/28/02
DCH'D JRM CHK'D JRM
APP'D & CERT.
FILMED

FACILITY: SHERBURNE COUNTY GENERATING PLANT

TITLE: POND NO. 3
PHASE 5 PLAN

NORTHERN STATES POWER COMPANY
NSP Minneapolis Minnesota

CADD FILENAME Shrcp313.dgn
DWG NO. SHT 13 OF 27 SHTS
REV 0



NOTE: CONTOURS REPRESENT TOP OF FINAL COVER

LEGEND:

- EXISTING CONTOURS
- PROPOSED CONTOURS
- DIKE CENTERLINE
- CATCH BASIN
- MANHOLE
- DITCH WITH DRAIN TUBING
- SURFACE WATER PIPE

0 200 400
SCALE IN FEET

EXISTING TOPOGRAPHY PROVIDED BY: HORIZONS, INC. 10-11-94.

REVISIONS

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fx 952-470-0728

DWN DSS DATE 06/28/02
DSGN JRM CHK'D JRM
APP'D & CERT.
FILMED

FACILITY: SHERBURNE COUNTY GENERATING PLANT

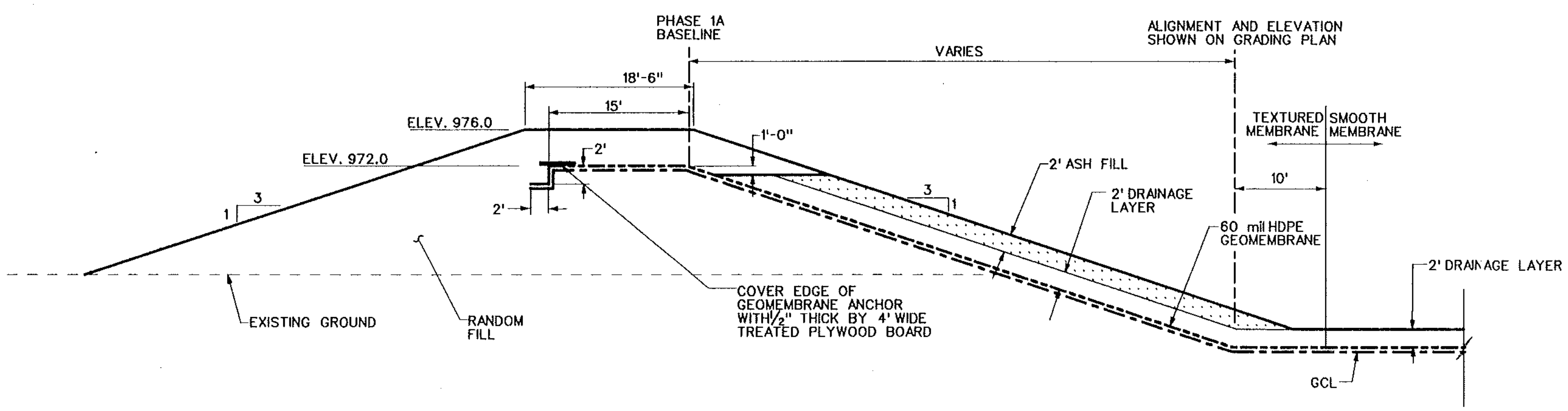
TITLE: POND NO. 3
PHASE 6 PLAN

NORTHERN STATES POWER COMPANY
NSP Minneapolis Minnesota

CADD FILENAME Shrcp314.dgn
REV 0
DWG NO.
SHT 14 OF 27 SHTS

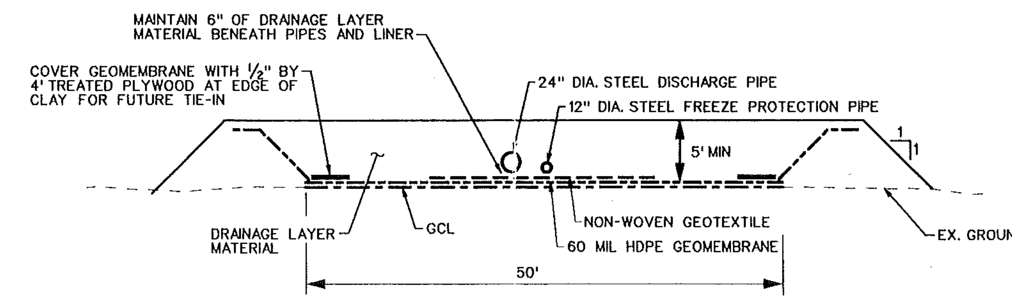
NH-

NH-



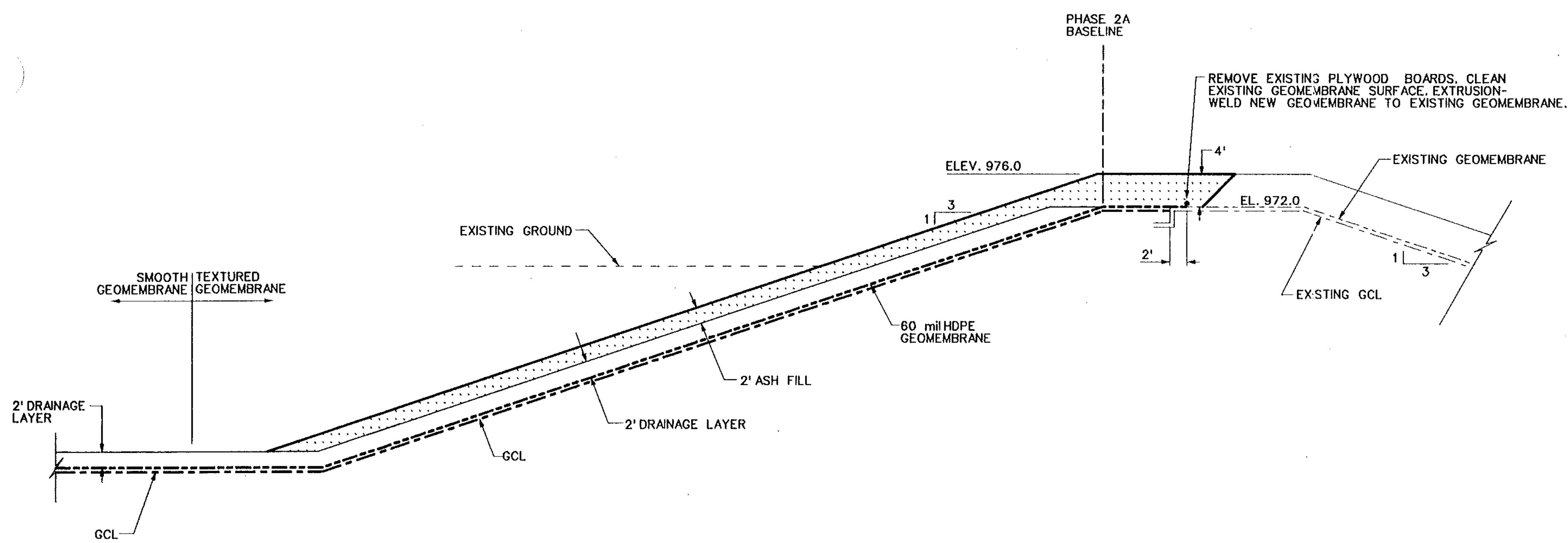
SECTION: PHASE 1A - SOUTH DIKE

0 10 20
SCALE IN FEET



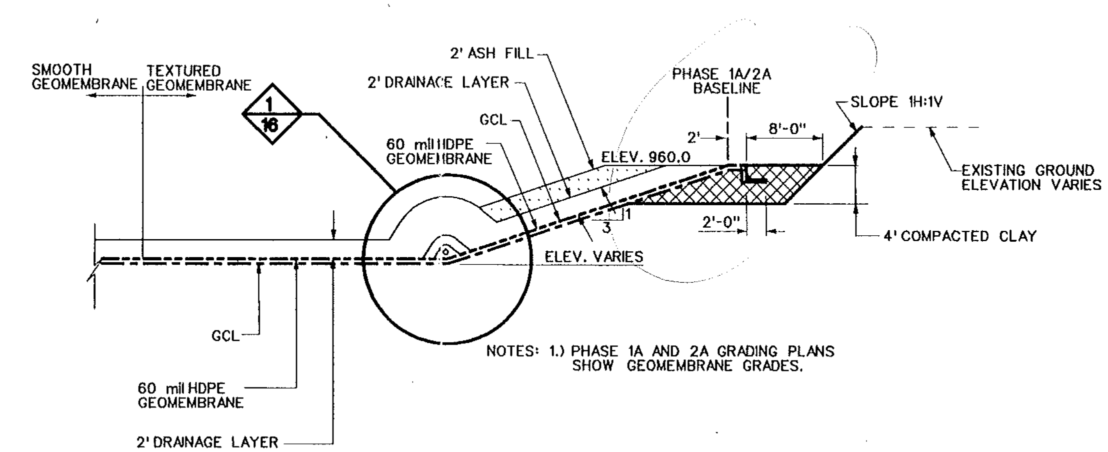
SECTION: PHASE 1A - WEST DIKE LINER EXTENSION

0 10 20
SCALE IN FEET



SECTION: PHASE 2A - NORTH DIKE

0 10 20
SCALE IN FEET



NOTES: 1.) PHASE 1A AND 2A GRADING PLANS SHOW GEOMEMBRANE GRADES.

SECTION: PHASE 1A (NORTH AND EAST DIKES) AND 2A (EAST AND SOUTH DIKES) - BASE/SLOPE LINER

0 10 20
SCALE IN FEET

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Date 06/28/02 Reg. No. 21835

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fx 952-470-0728

DWN DSS DATE 06/28/02
DSGN JRM CHK'D JRM
APP'D & CERT.
FILMED

FACILITY: SHERBURNE COUNTY GENERATING PLANT

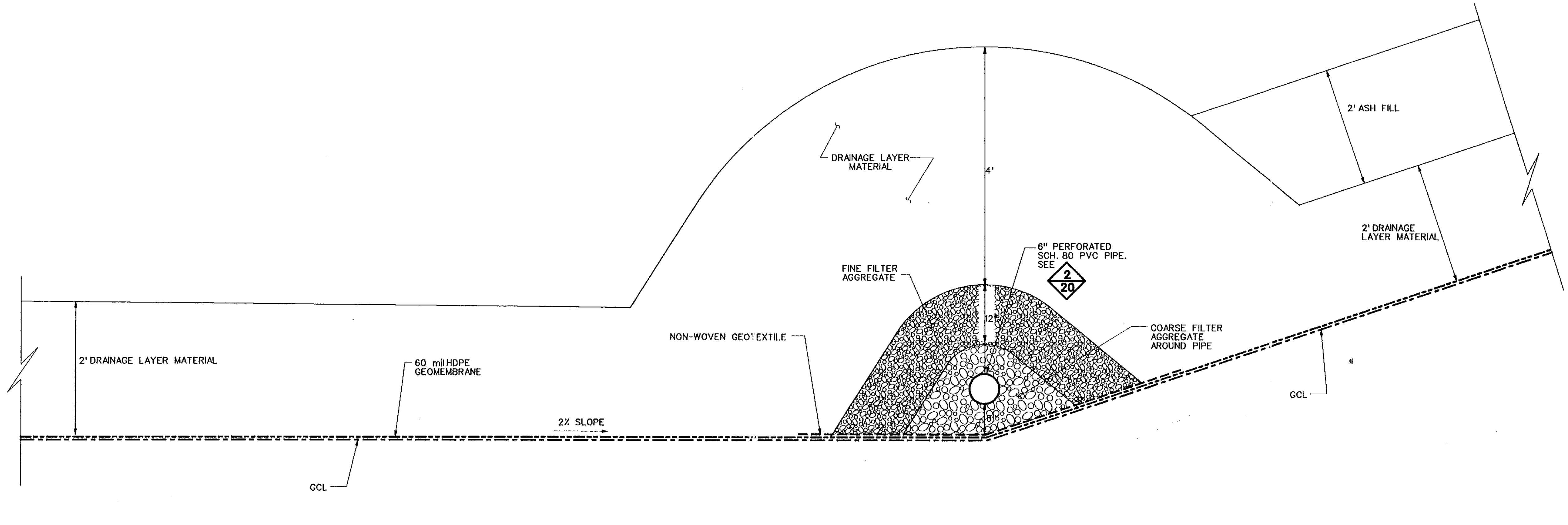
TITLE: POND NO. 3
DIKE & LINER SECTIONS

NORTHERN STATES POWER COMPANY
NSP Minneapolis Minnesota

CADD FILENAME Shrcp315_16.dgn
DWG NO. SHT 15 OF 27 SHTS
REV 0

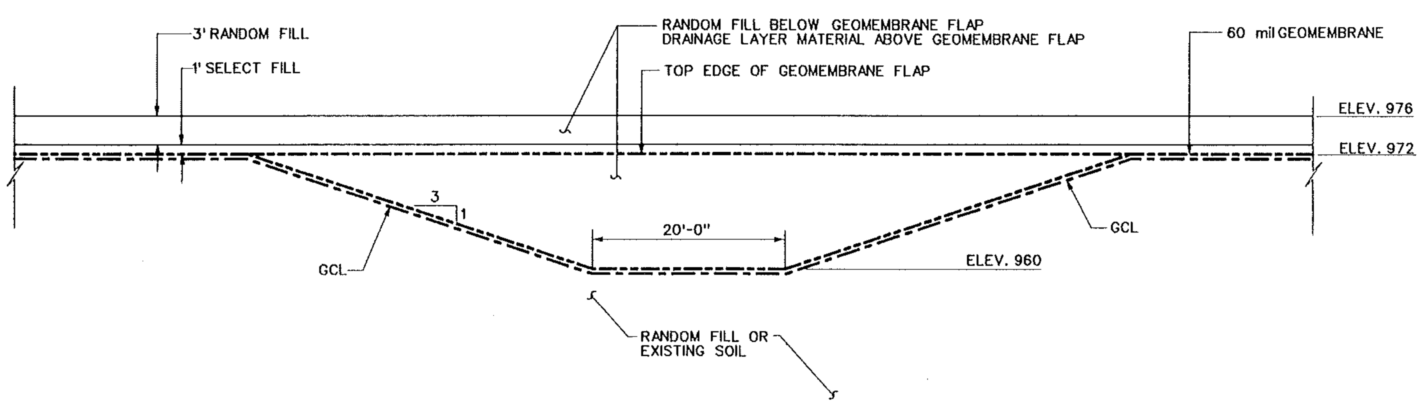
REVISIONS

REV	DATE	DESCRIPTION	BY	DWN	CK'D
0	06/28/02	ISSUED FOR PERMITTING	JRM	DSS	JRM



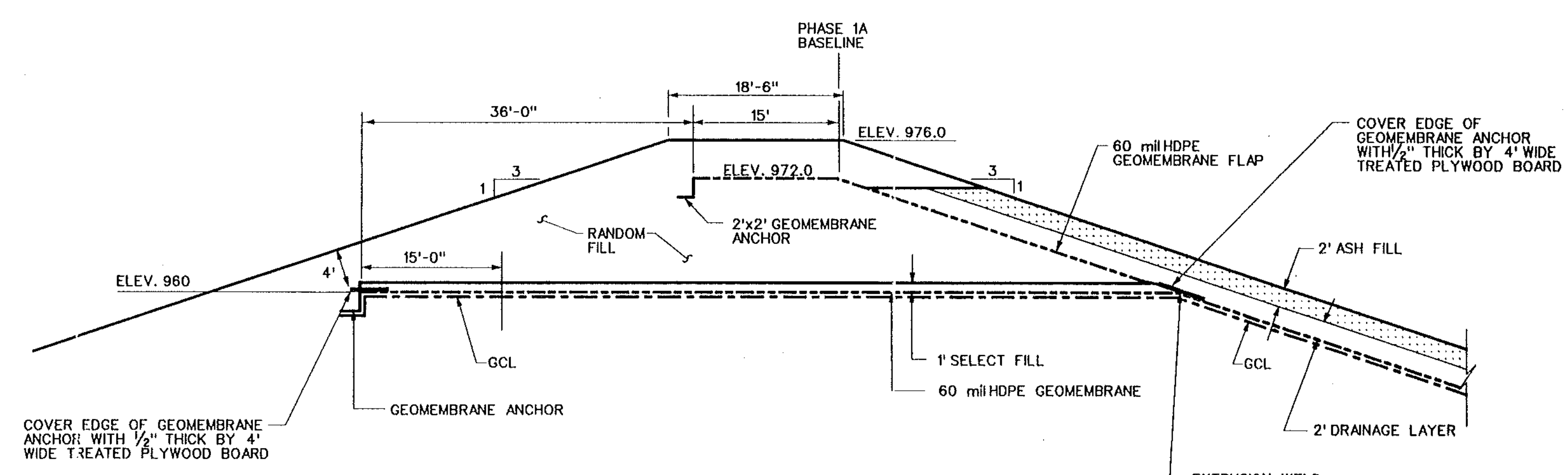
1/16 DETAIL: PHASE 1A AND 2A - DEWATERING PIPE

0 1 2 SCALE IN FEET



2/16 SECTION: PHASE 1A - SOUTH DIKE WEIR

0 10 20 SCALE IN FEET



3/16 SECTION: PHASE 1A - SOUTH DIKE WEIR

0 10 20 SCALE IN FEET

NH-

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Date 06/28/02 Reg. No. 21835

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434 2nd Street
Excelsior, MN 55331
ph 952-470-1611
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DWN DSS	DATE 06/28/02	FACILITY: SHERBURNE COUNTY GENERATING PLANT
DGN'R JRM	CHK'D JRM	TITLE: POND NO. 3
APP'D & CERT.		DIKE & LINER SECTIONS
FILMED		

NORTHERN STATES POWER COMPANY
NSP Minneapolis Minnesota

CADD FILENAME Shrcp315_16.dgn REV
DWG NO. SHT 16 OF 27 SHTS 0

REVISIONS

REV	DATE	DESCRIPTION	BY	DWN	CHK'D
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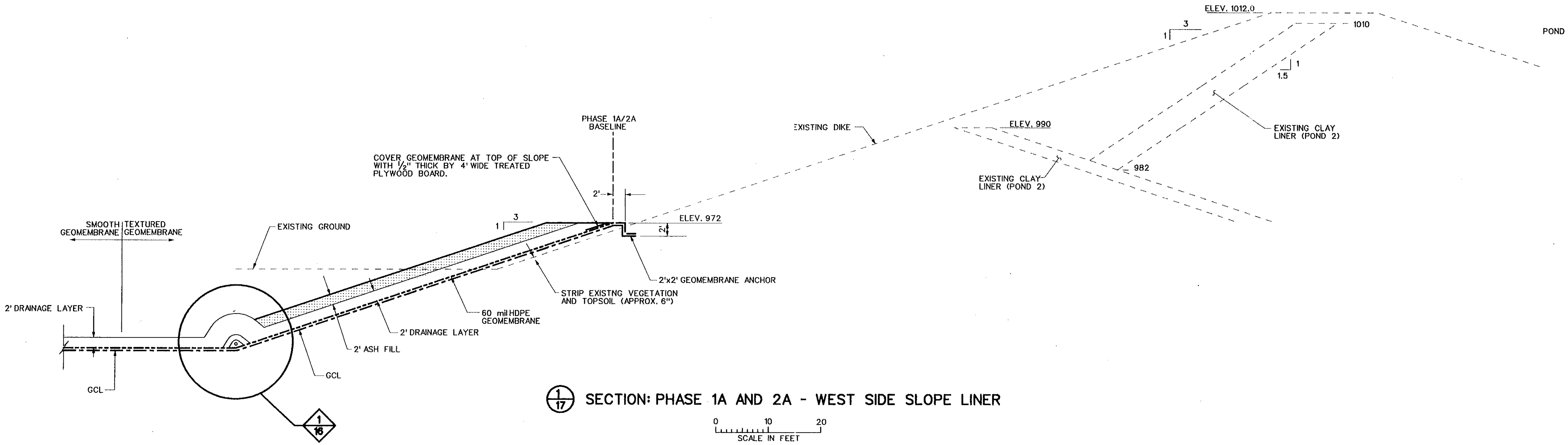
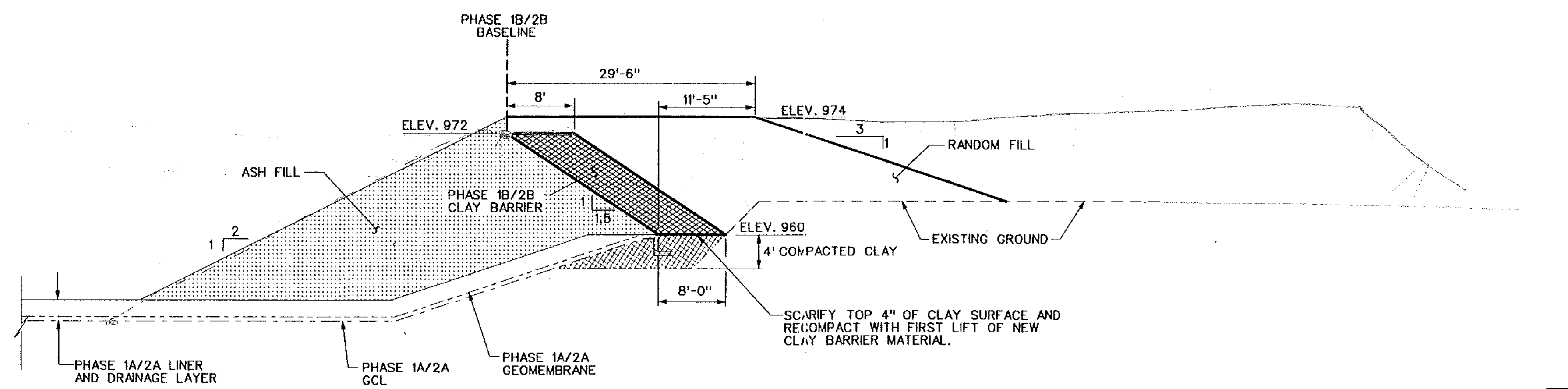
NH-



SECTION: PHASE 1A AND 2A - WEST SIDE SLOPE LINER (1/17)

0 10 20
SCALE IN FEET



SECTION: PHASE 1B AND 2B UPSTREAM CLAY BARRIER AND DIKE (2/17)

0 10 20
SCALE IN FEET

REVISIONS

REV	DATE	DESCRIPTION	BY	DWN	CK'D
0	06/28/02	ISSUED FOR PERMITTING	JRM	DSS	JRM

I hereby certify that this plan was prepared by me or under my direct supervision and that I am a duly Licensed Professional Engineer under the laws of the State of Minnesota.
Signature
Print Name John R. McCain
Date 06/28/02 Reg. No. 21835

McCain and Associates, Inc.
434 2nd Street
Excelsior, MN 55331
ph 952-470-1611
fx 952-470-0728

DWN DSS DATE 06/28/02
DGN'R JRM CHK'D JRM
APP'D & CERT.
FILMED

FACILITY: SHERBURNE COUNTY GENERATING PLANT

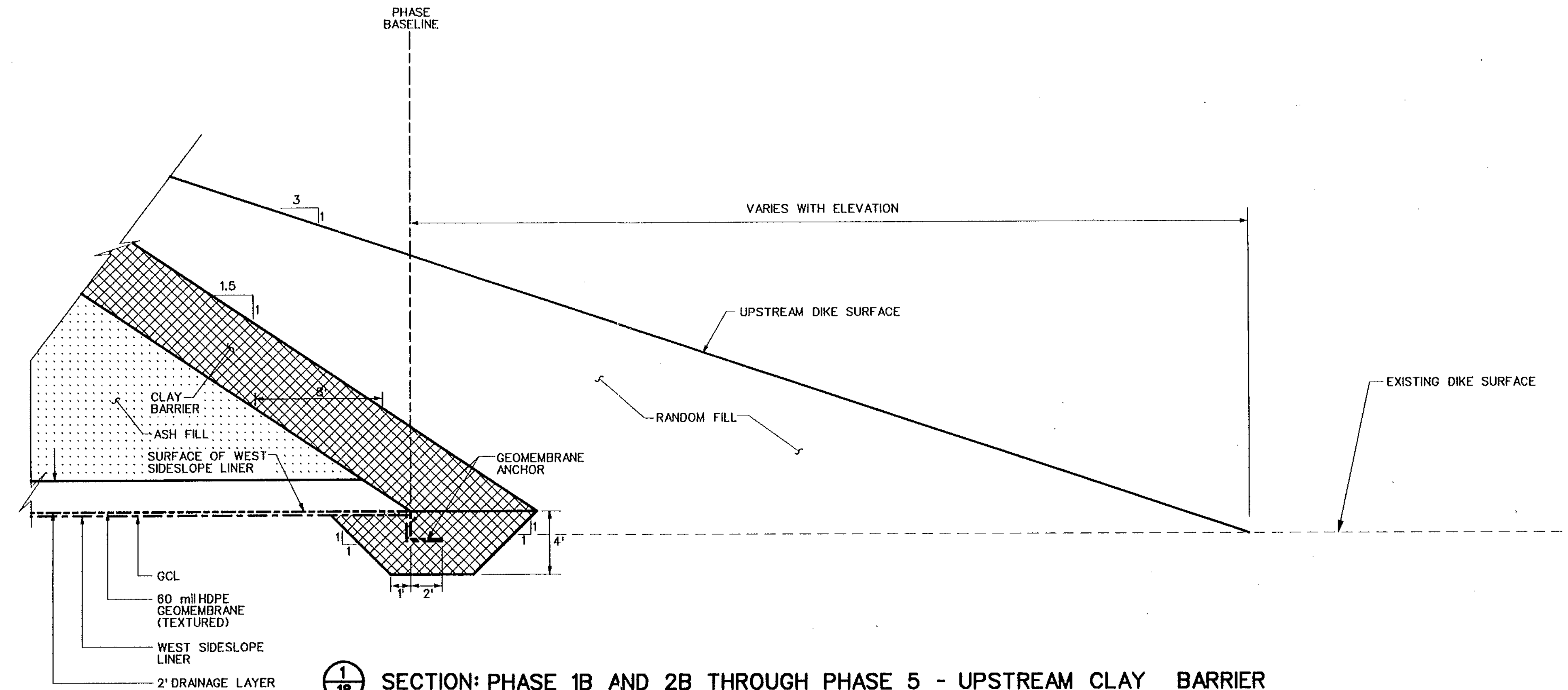
TITLE: POND NO. 3

DIKE & LINER SECTIONS

NORTHERN STATES POWER COMPANY
NSP Minneapolis Minnesota

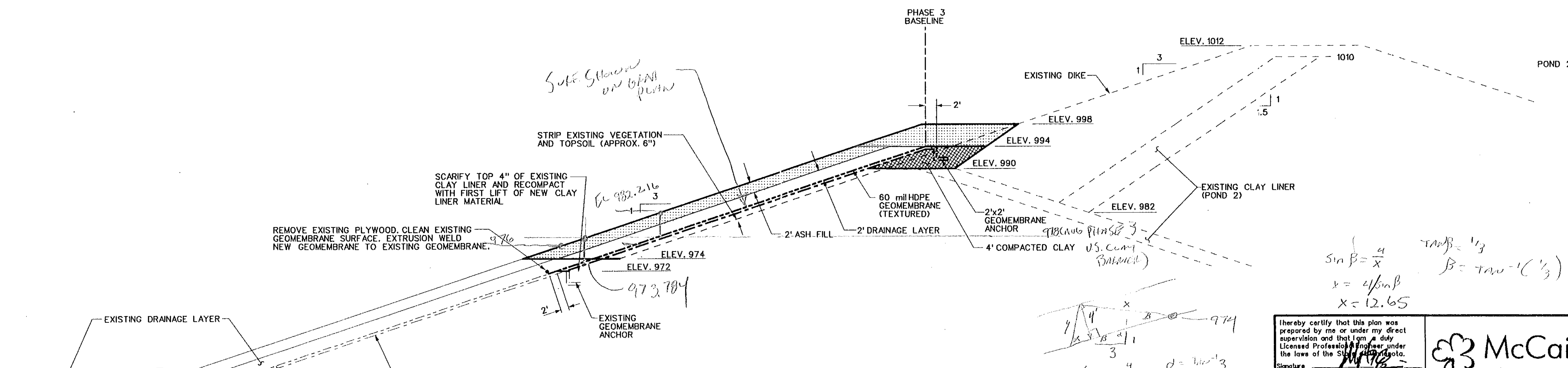
CADD FILENAME Shrcp317_318.dgn
DWG NO.
SHT 17 OF 27 SHTS
REV 0

NH-



1/18 SECTION: PHASE 1B AND 2B THROUGH PHASE 5 - UPSTREAM CLAY BARRIER CONNECTION TO SIDESLOPE LINER

0 5 10 SCALE IN FEET



2/18 SECTION: PHASE 3 - WEST SIDESLOPE LINER

0 10 20 SCALE IN FEET

$\sin\beta = \frac{4}{x}$ $\tan\beta = 1/3$
$\beta = \tan^{-1}(1/3)$
$x = 4/\sin\beta$
$x = 12.65$

974
$\sin\alpha = \frac{4}{y}$ $\alpha = \tan^{-1}3$
$y = \frac{4}{\sin\alpha} = 4.216$

REVISIONS					
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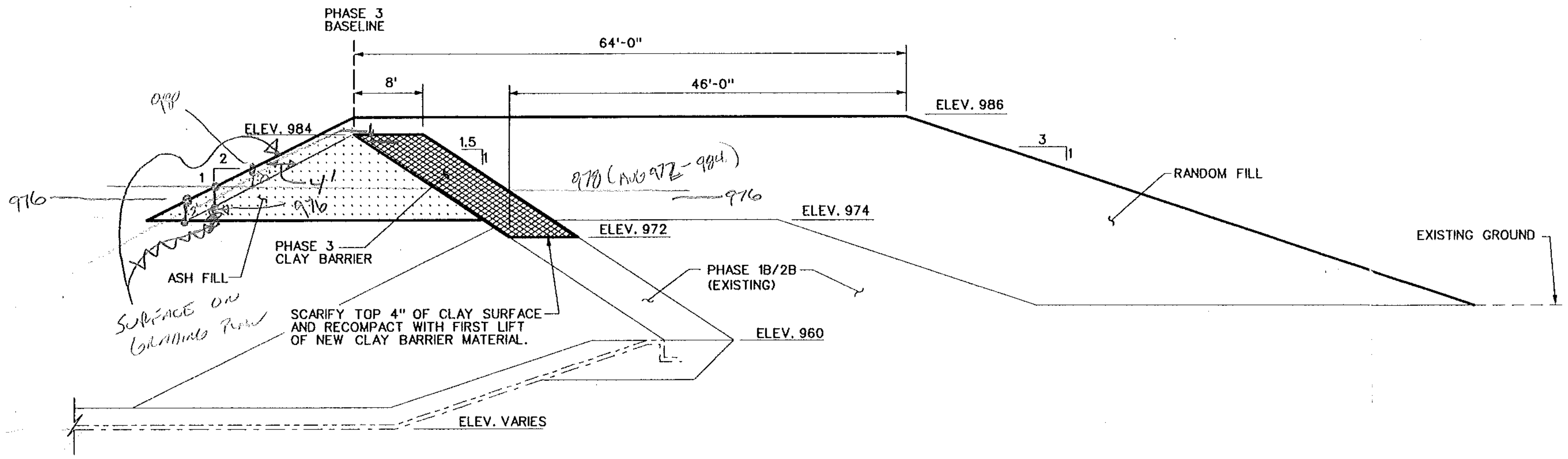
DWN DSS | DATE 06/28/02
DGN JRM | CHK'D JRM
APP'D & CERT.
FILMED

FACILITY: SHERBURNE COUNTY GENERATING PLANT
TITLE: POND NO. 3
DIKE & LINER SECTIONS

NORTHERN STATES POWER COMPANY
NSP Minneapolis Minnesota

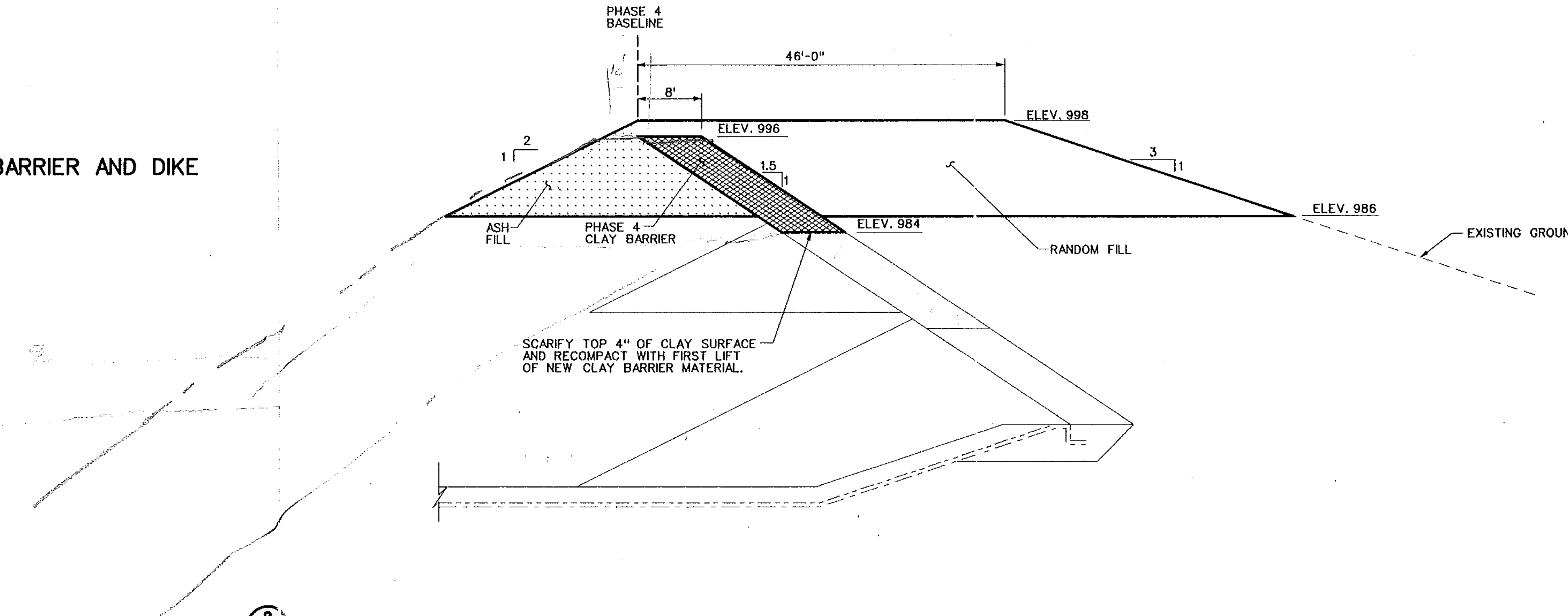
CADD FILENAME Shrcp317_318.dgn
DWG NO. SHT 18 OF 27 SHTS
REV 0

NH-



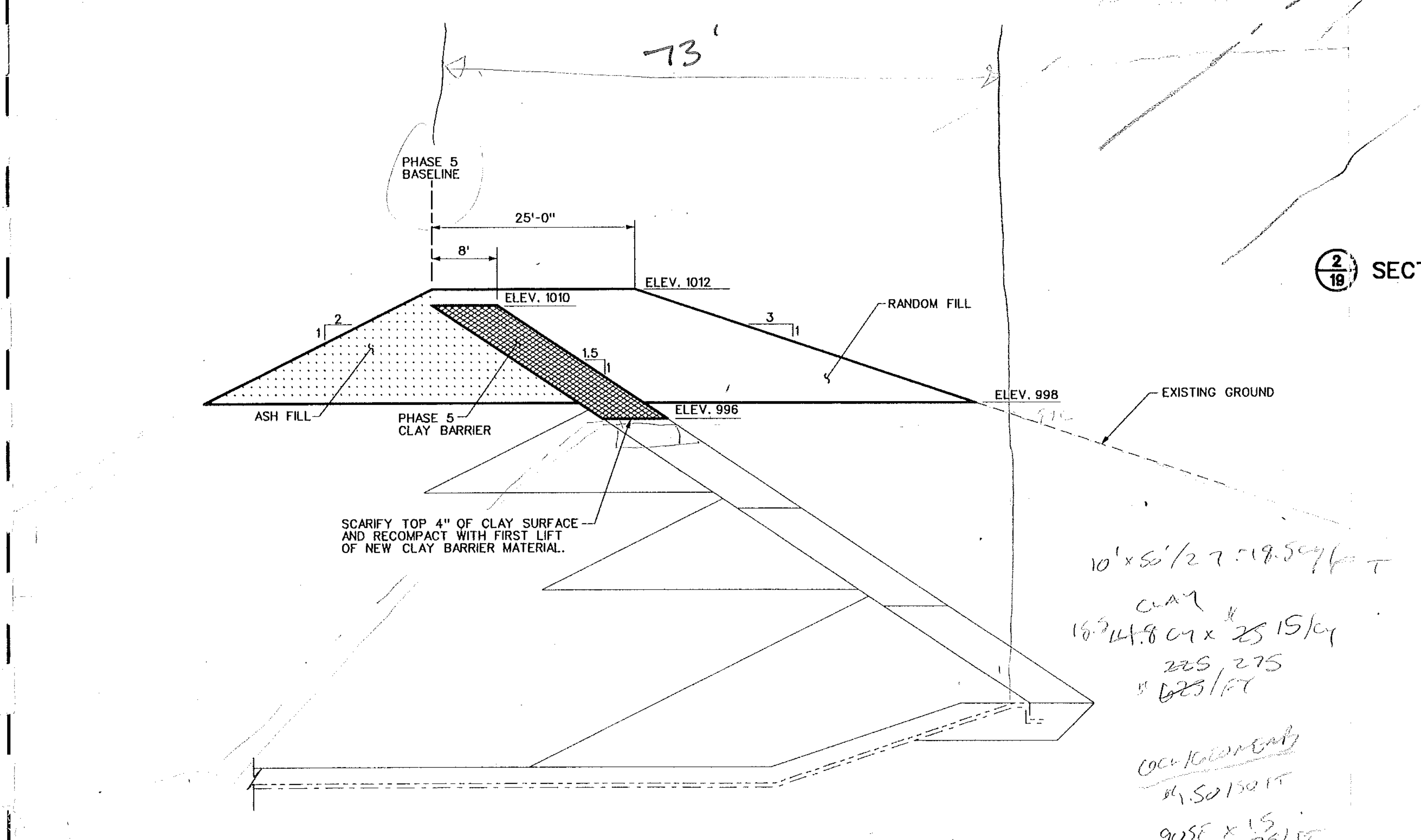
SECTION: PHASE 3 - UPSTREAM CLAY BARRIER AND DIKE

0 10 20 SCALE IN FEET



SECTION: PHASE 4 - UPSTREAM CLAY BARRIER AND DIKE

0 10 20 SCALE IN FEET



SECTION: PHASE 5 - PHASE 5 UPSTREAM CLAY BARRIER AND DIKE

0 10 20 SCALE IN FEET

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DWN DSS	DATE 06/28/02	FACILITY:	SHERBURNE COUNTY GENERATING PLANT
DGN'R JRM	CHK'D JRM	TITLE:	POND NO. 3 DIKE & LINER SECTIONS
APP'D & CERT.			
FILMED			

REVISIONS

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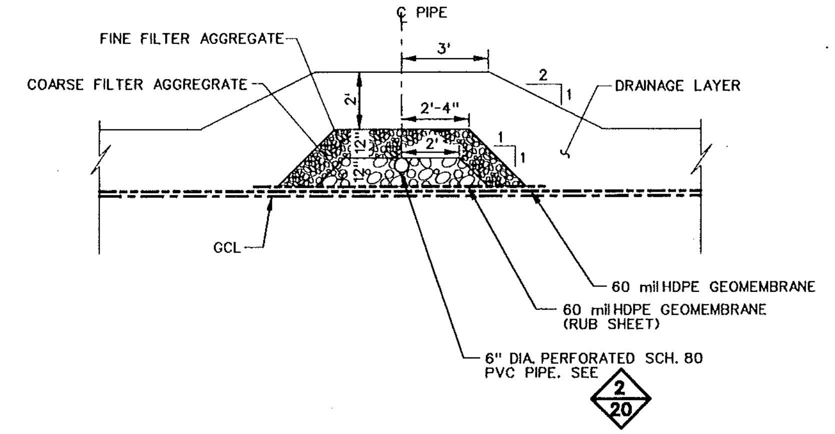
0	06/28/02	ISSUED FOR PERMITTING	JRM	DSS	JRM

NORTHERN STATES POWER COMPANY
NSP Minneapolis Minnesota

CADD FILENAME Shrcp319.dgn

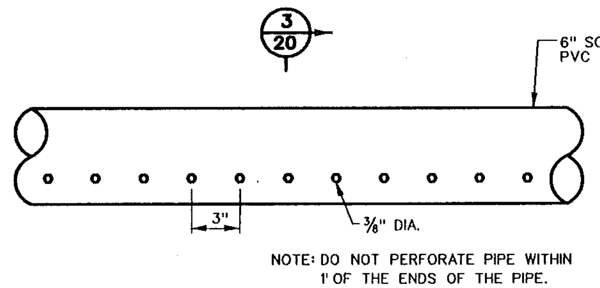
DWG NO. SHT 19 OF 27 SHTS

REV 0



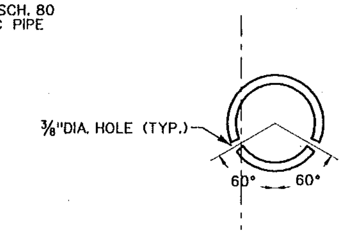
1/20 SECTION: LATERAL DEWATERING PIPE

0 3 6
SCALE IN FEET



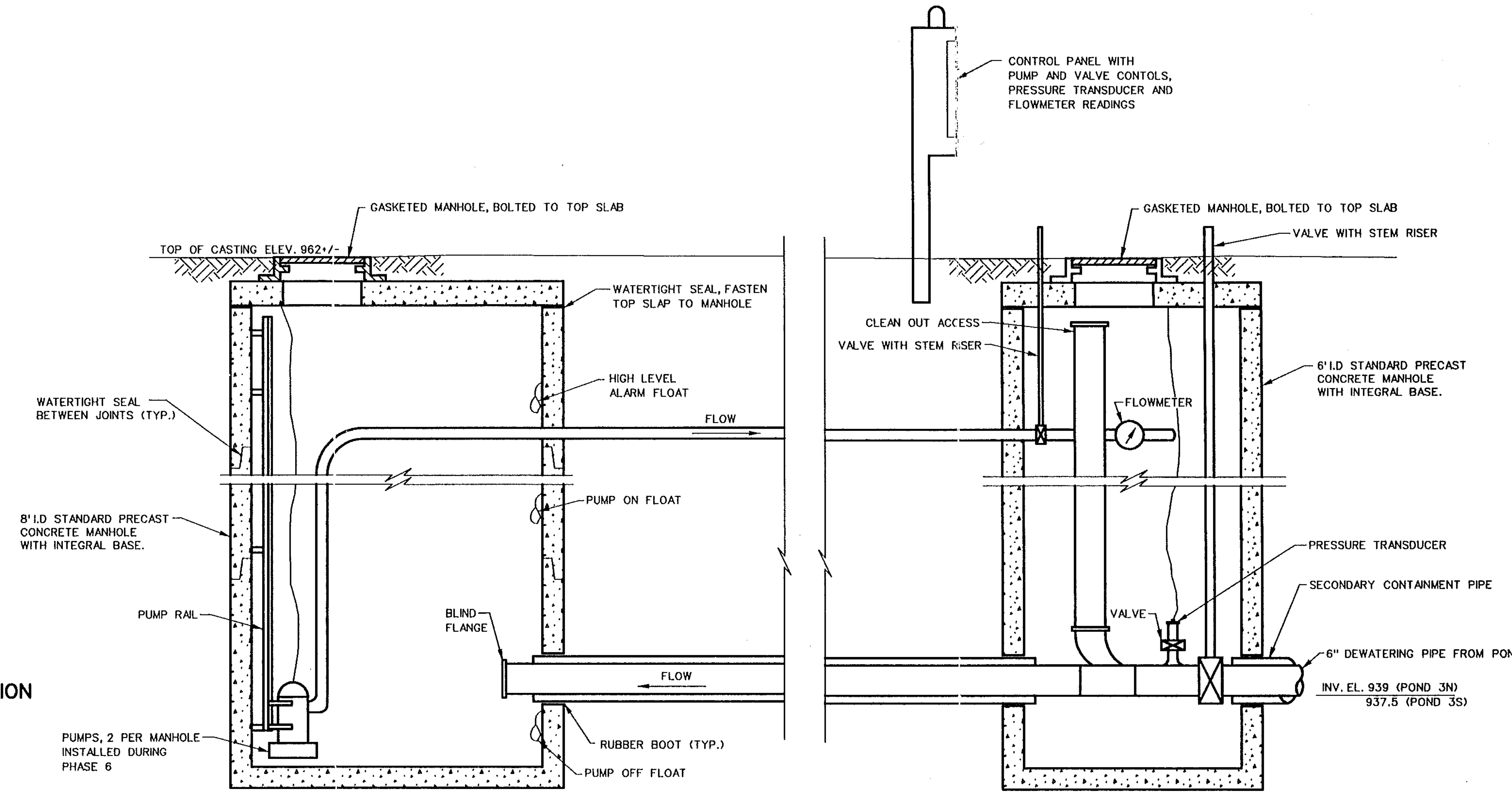
2/20 DETAIL: PIPE PERFORATIONS

NOT TO SCALE



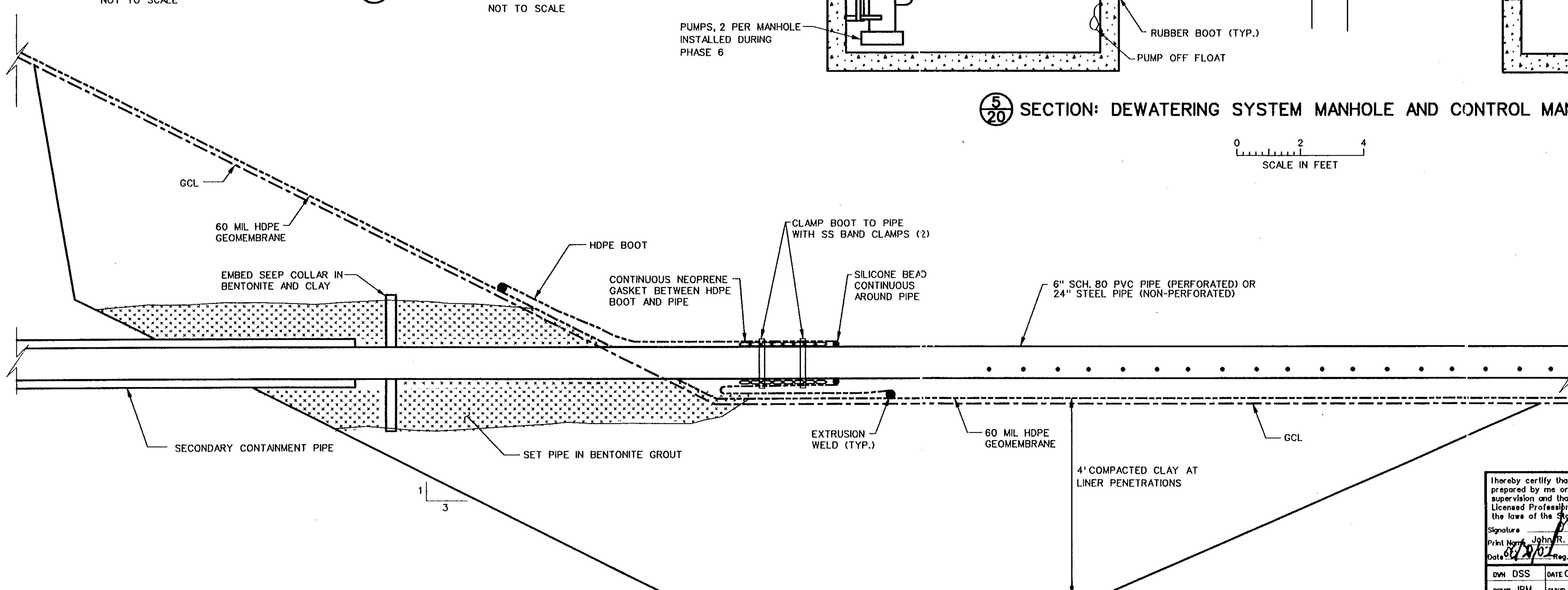
3/20 SECTION: PIPE PERFORATION

NOT TO SCALE



5/20 SECTION: DEWATERING SYSTEM MANHOLE AND CONTROL MANHOLE

0 2 4
SCALE IN FEET



NOTE: DRAINAGE AGGREGATE AND DRAINAGE LAYER NOT SHOWN.

4/20 SECTION: LINER PENETRATION

NOT TO SCALE

REVISIONS

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DWN DSS DATE 06/28/02
DGN'R JRM CHK'D JRM
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FILMED

FACILITY: SHERBURNE COUNTY GENERATING PLANT

TITLE: POND NO. 3
DEWATERING SYSTEM SECTIONS AND DETAILS

NORTHERN STATES POWER COMPANY
NSP Minneapolis Minnesota

CADD FILENAME Shrcp320.dgn
DWG NO. SHT 20 OF 27 SHTS
REV 0

NH-

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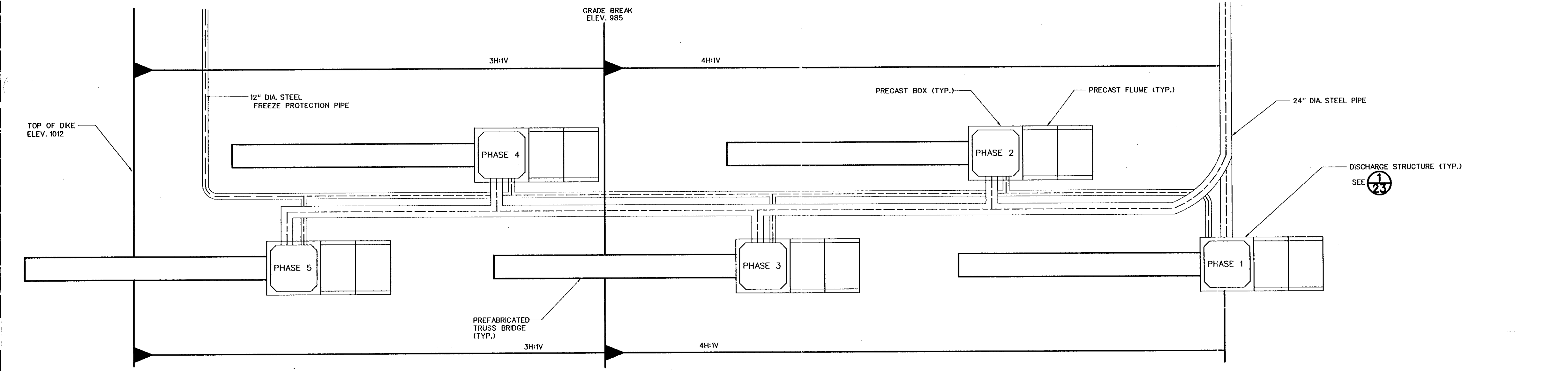
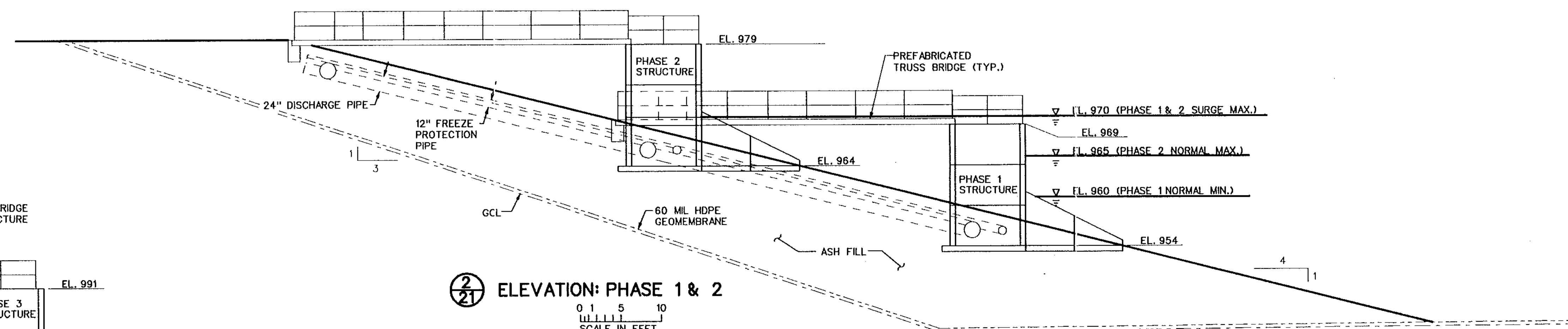


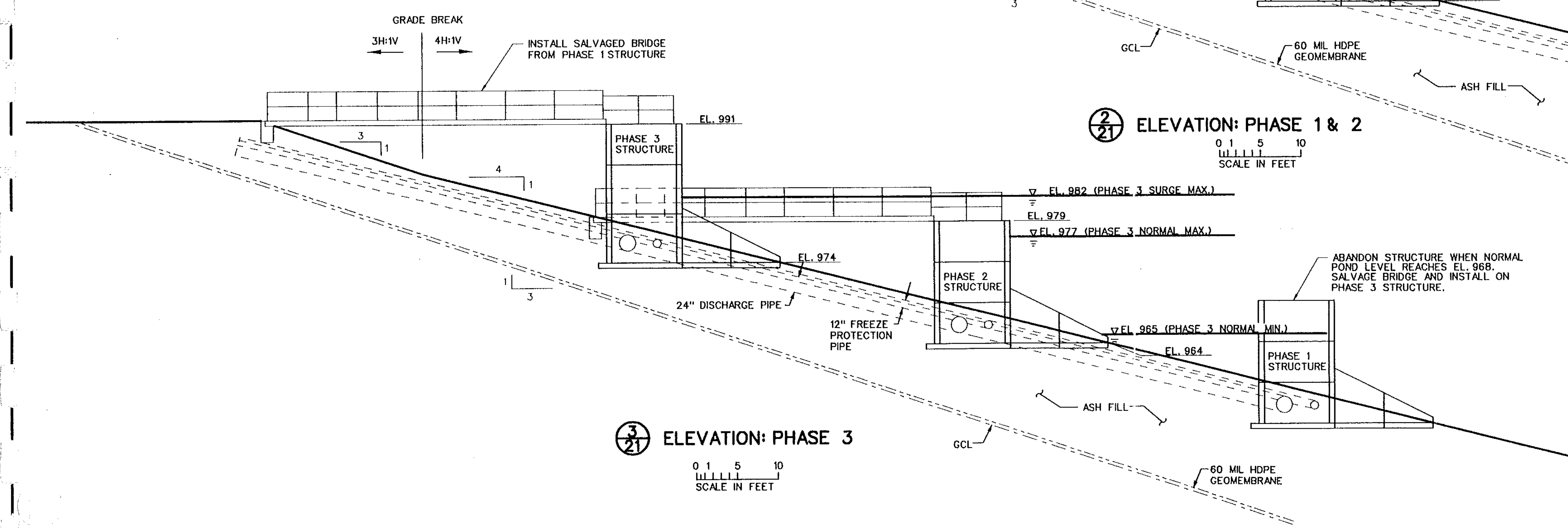
1/21 PLAN: DISCHARGE STRUCTURE

0 1 5 10
SCALE IN FEET



2/21 ELEVATION: PHASE 1 & 2

0 1 5 10
SCALE IN FEET



3/21 ELEVATION: PHASE 3

0 1 5 10
SCALE IN FEET

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fx 952-470-0728

DWN DSS	DATE 06/28/02	FACILITY:	SHERBURNE COUNTY GENERATING PLANT
DSN'R JRM	CHK'D JRM	TITLE:	POND NO. 3 DISCHARGE STRUCTURE PLAN AND ELEVATIONS
APP'D & CERT.			
FILMED			

NORTHERN STATES POWER COMPANY
NSP Minneapolis Minnesota

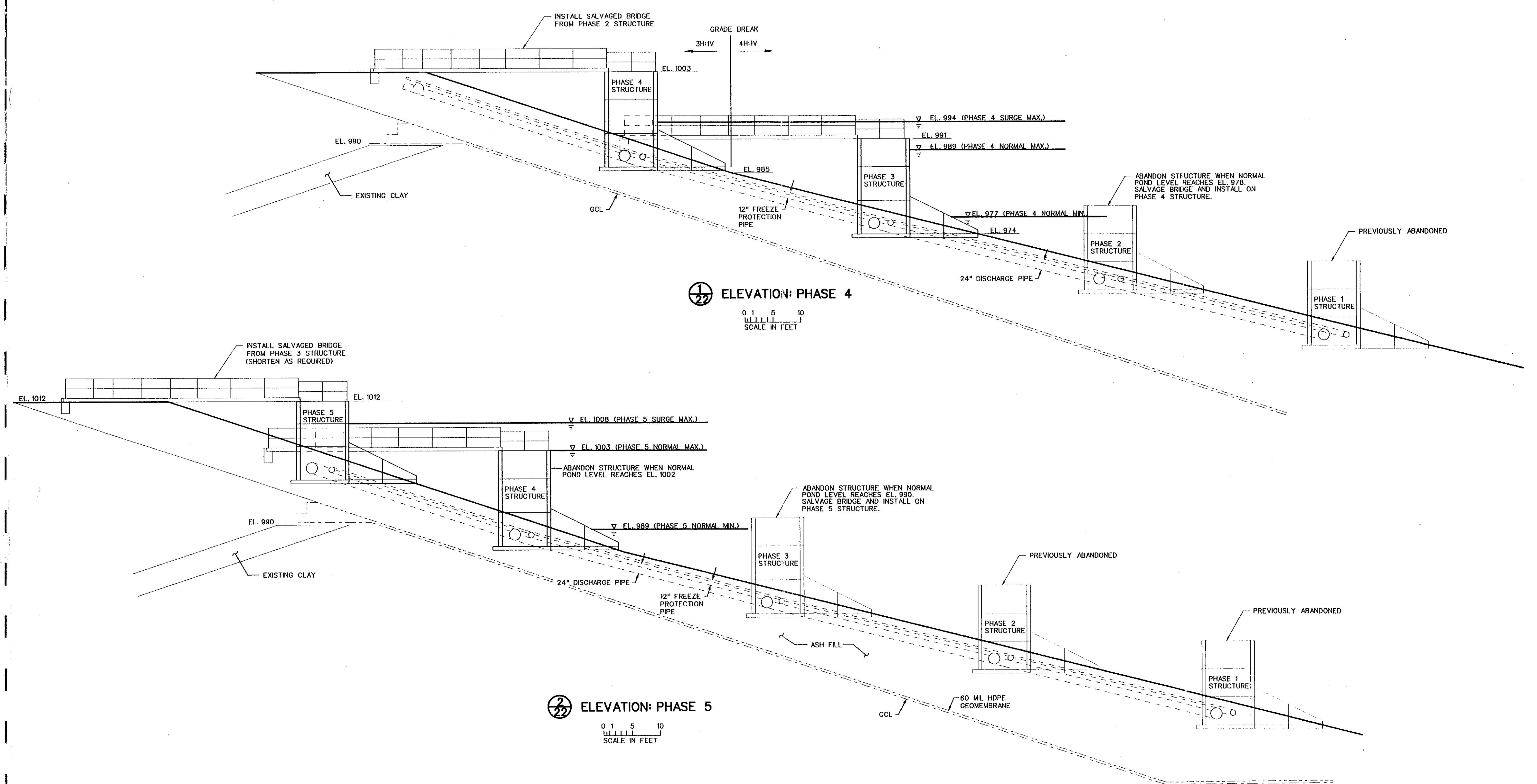
CADD FILENAME Shrcp321_22.dgn

DWG NO. SHT 21 OF 27 SHTS

REV 0

REVISIONS

REV	DATE	DESCRIPTION	BY	DWN	CHK'D
0	06/28/02	ISSUED FOR PERMITTING	JRM	DSS	JRM



REVISIONS					
0	06/28/02	ISSUED FOR PERMITTING	JRM	DSS	JRM
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DWN DSS DATE 06/28/02
DGN'R JRM CHK'D JRM
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FILMED

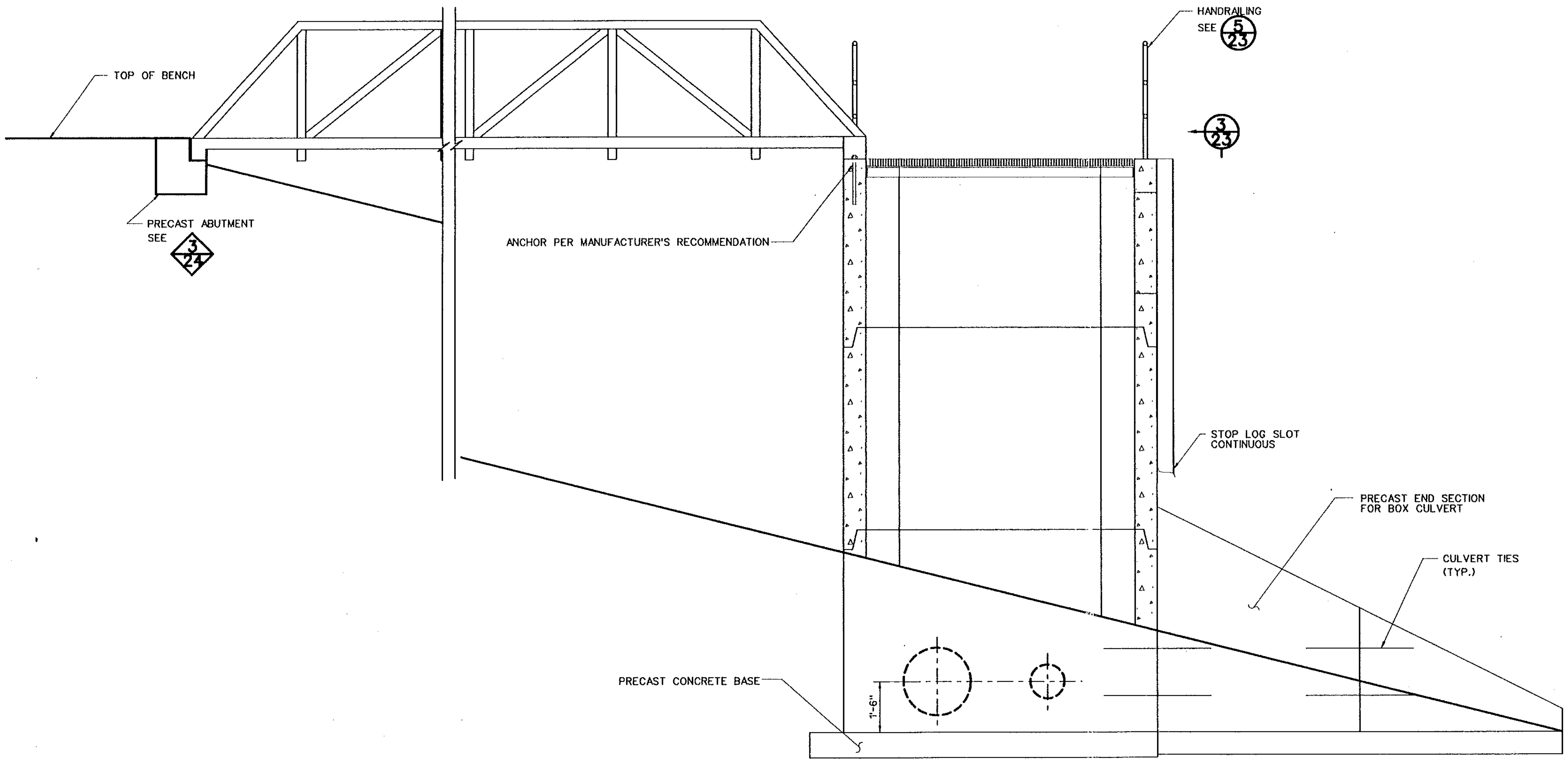
FACILITY: SHERBURNE COUNTY GENERATING PLANT

TITLE: POND NO. 3
DISCHARGE STRUCTURE PLAN AND ELEVATIONS

NORTHERN STATES POWER COMPANY
NSP Minneapolis Minnesota

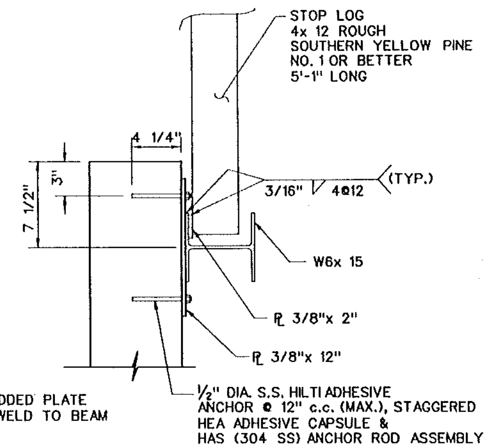
CADD FILENAME Shrcp321_22.dgn
DWG NO. SHT 22 OF 27 SHTS
REV 0

NH-



1/24 SECTION: DISCHARGE STRUCTURE

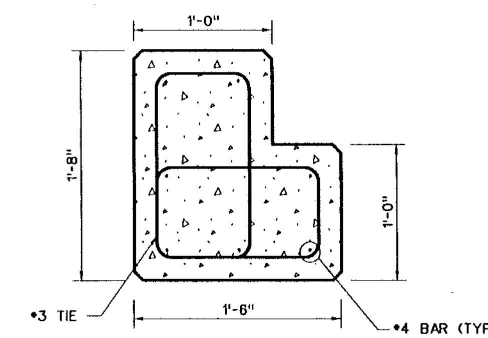
0 1 2 3 4 5
SCALE IN FEET



NOTE: ALTERNATE-EMBEDDED PLATE W/STUDS, FIELD WELD TO BEAM

2/24 DETAIL: STOP LOG SLOT

0 3" 6" 9" 1' 2'
SCALE



3/24 DETAIL: PRECAST ABUTMENT

0 3" 6" 9" 1' 2'
SCALE

REVISIONS					
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DWN DSS	DATE 06/28/02
DGN'R JRM	CHK'D JRM
APP'D & CERT.	
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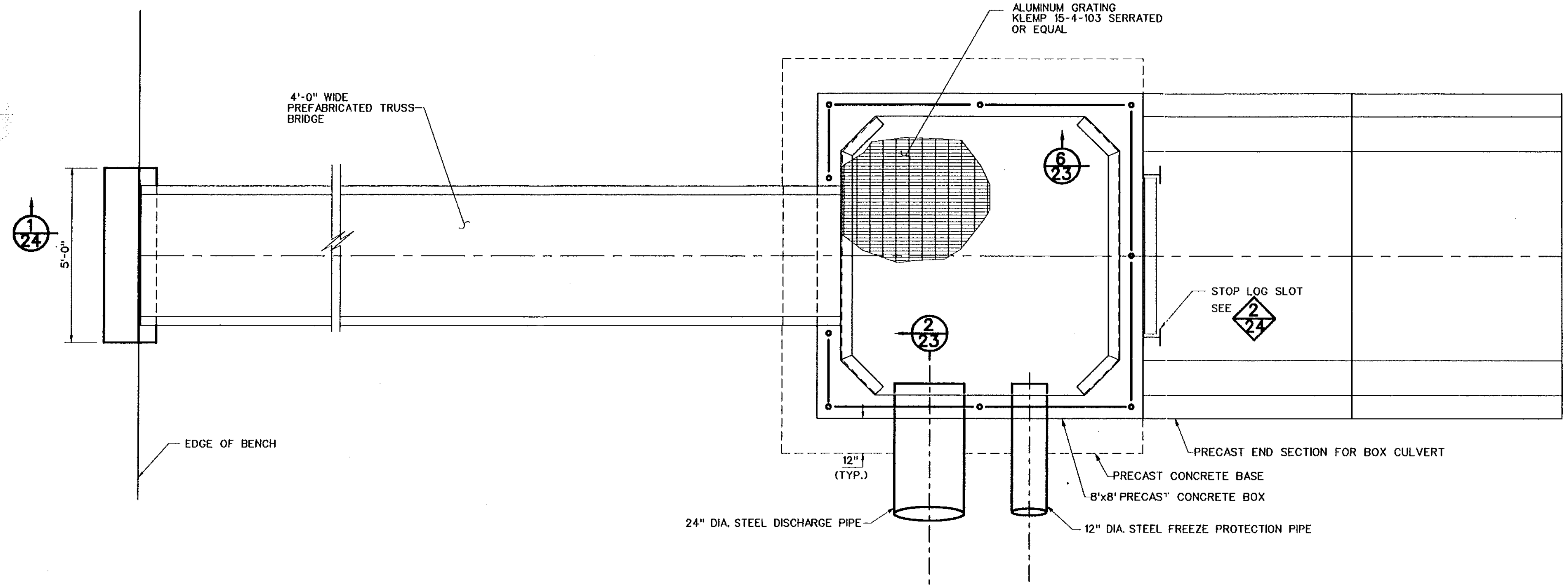
FACILITY: SHERBURNE COUNTY GENERATING PLANT

TITLE: POND NO. 3
DISCHARGE STRUCTURE SECTIONS AND DETAILS

NORTHERN STATES POWER COMPANY
NSP Minneapolis Minnesota

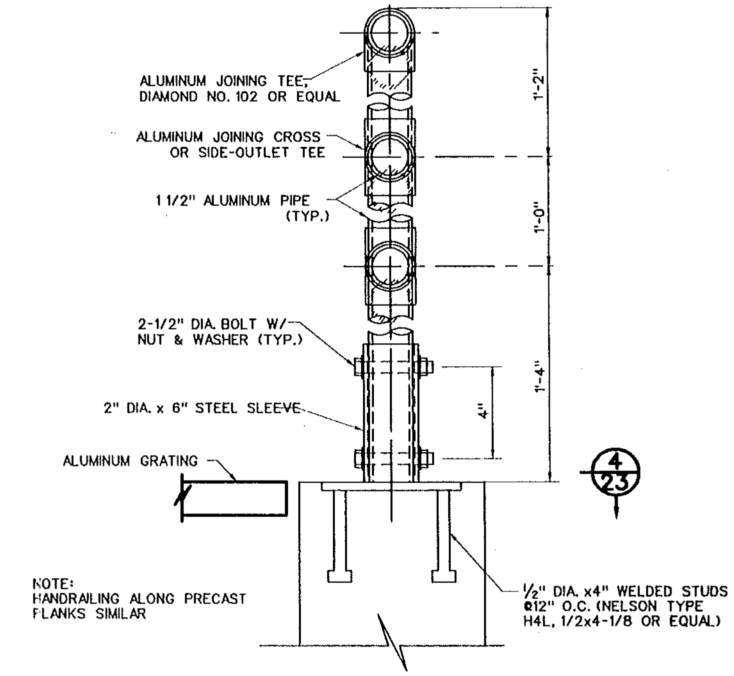
CADD FILENAME Shrcp323_24.dgn
DWG NO. SHT 24 OF 27 SHTS
REV 0

NH-



1/23 PLAN: DISCHARGE STRUCTURE

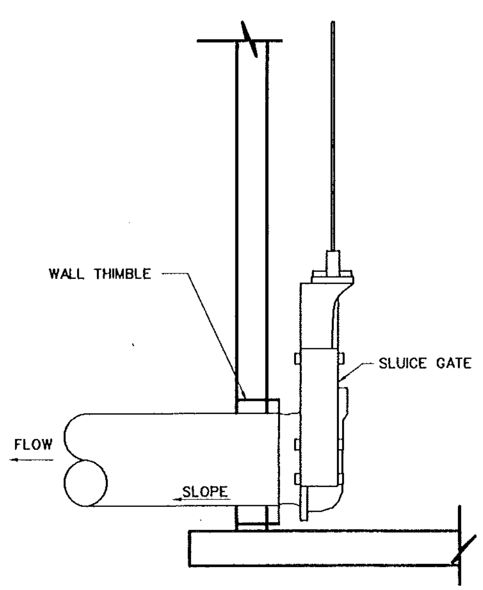
0 1 2 3 4 5 SCALE IN FEET



NOTE:
HANDRAILING ALONG PRECAST
FLANKS SIMILAR

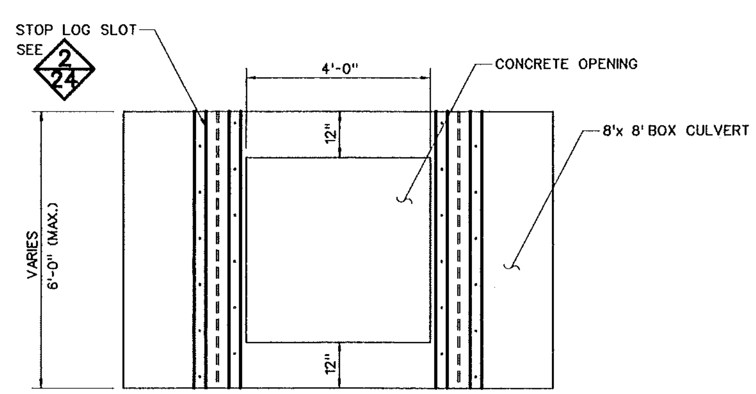
5/23 SECTION: HANDRAILING

0 3 6 12 SCALE IN INCHES



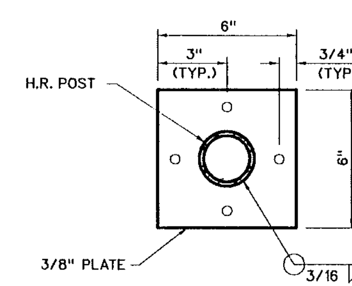
2/23 SECTION: DISCHARGE PIPE

0 1 2 3 4 5 SCALE IN FEET



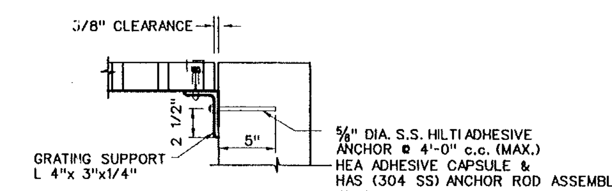
3/23 SECTION: CONCRETE OPENING

0 3" 6" 9" 1' 2' SCALE



4/23 SECTION: BASE PLATE

0 3 6 12 SCALE IN INCHES



6/23 SECTION: GRATING SHELF ANGLE

0 3" 6" 9" 1' 2' SCALE

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FACILITY: SHERBURNE COUNTY GENERATING PLANT

TITLE: POND NO. 3
DISCHARGE STRUCTURE SECTIONS AND DETAILS

NORTHERN STATES POWER COMPANY
NSP Minneapolis Minnesota

CADD FILENAME Shrcp323_24.dgn
DWG NO. SHT 23 OF 27 SHTS
REV 0

REVISIONS

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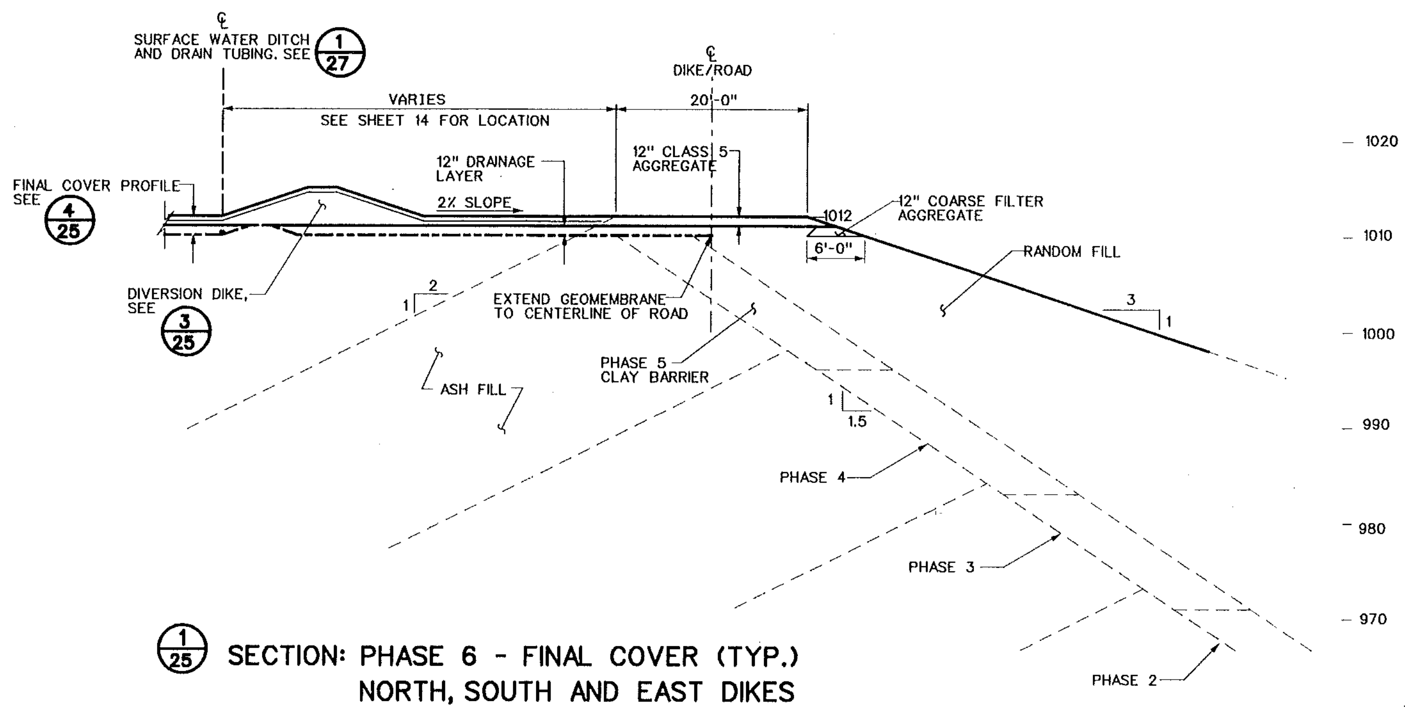
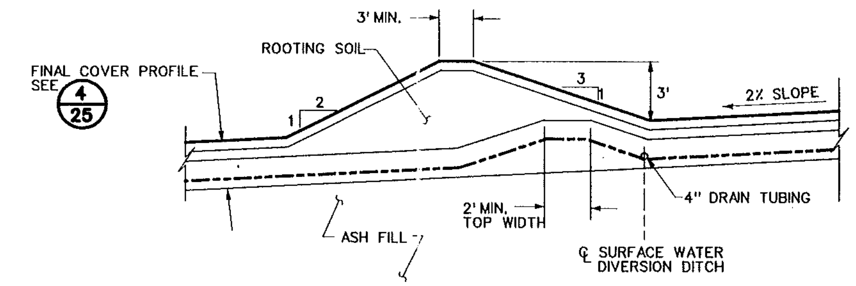
0	06/28/02	ISSUED FOR PERMITTING	JRM	DSS	JRM



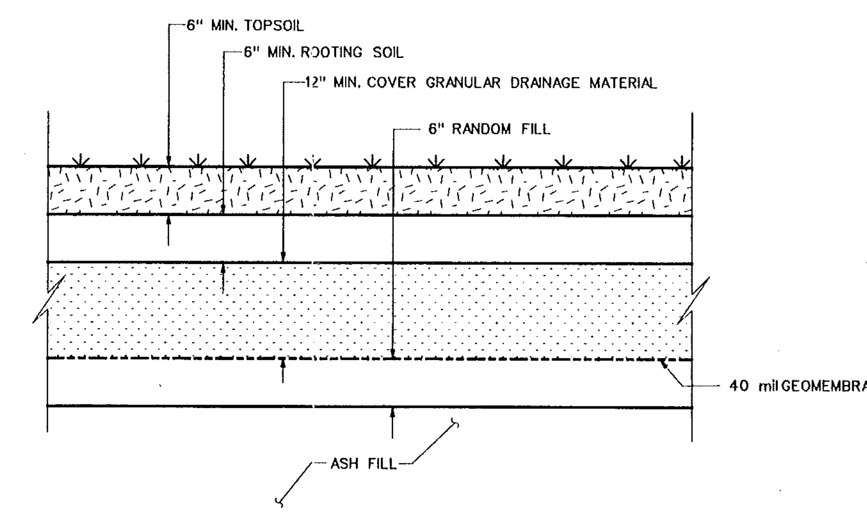
1/25 SECTION: PHASE 6 - FINAL COVER (TYP.)
NORTH, SOUTH AND EAST DIKES

0 10 20
SCALE IN FEET



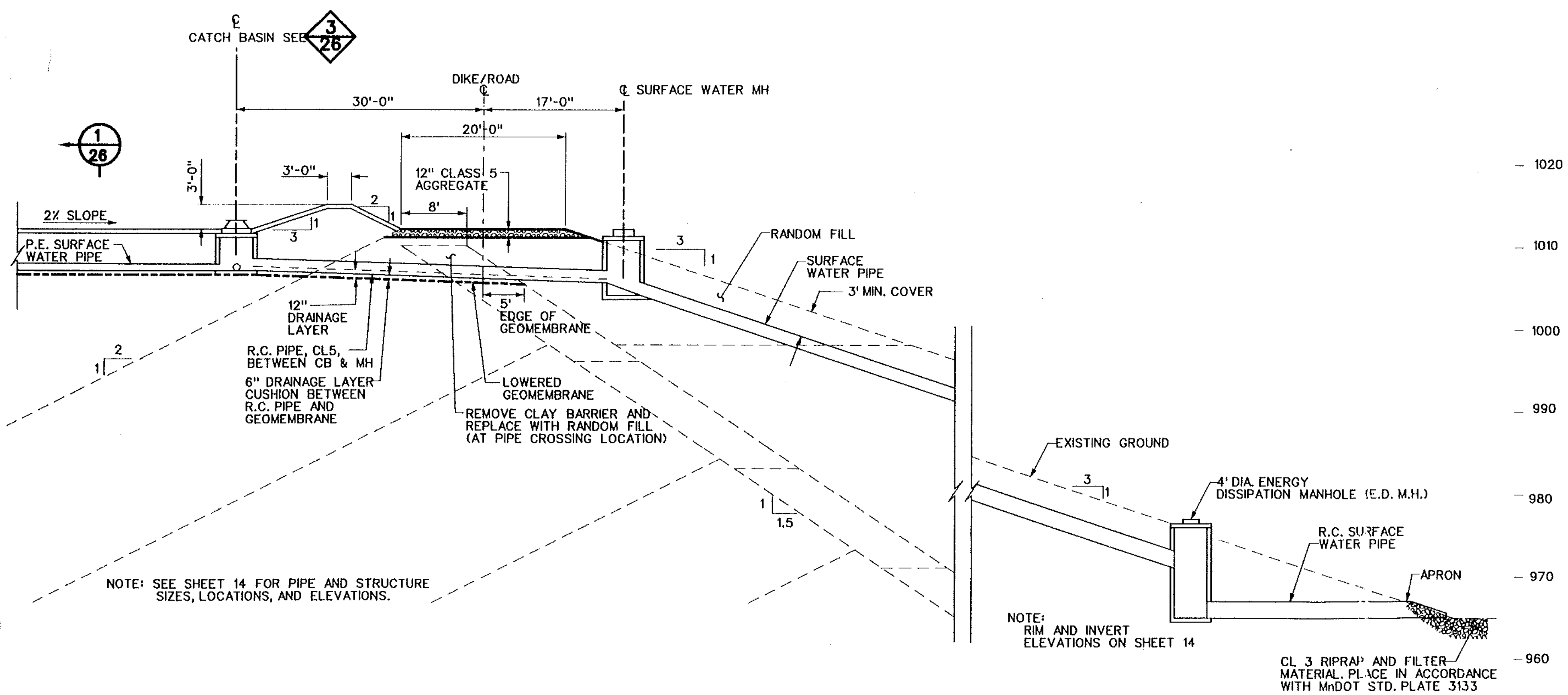
3/25 SECTION: SURFACE WATER DIVERSION DIKE AND DRAIN TUBING

0 5 10
SCALE IN FEET



4/25 SECTION: FINAL COVER PROFILE (TYP.)

0 1 2
SCALE IN FEET



2/25 SECTION: PHASE 6 - FINAL COVER AND SURFACE WATER PIPES AND STRUCTURES (TYP.)
NORTH, SOUTH AND EAST DIKE

0 10 20
SCALE IN FEET

REVISIONS

REV	DATE	DESCRIPTION	BY	DWN	CK'D
0	06/28/02	ISSUED FOR PERMITTING	JRM	DSS	JRM

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DWN DSS DATE 06/28/02
DSGN JRM CHK'D JRM
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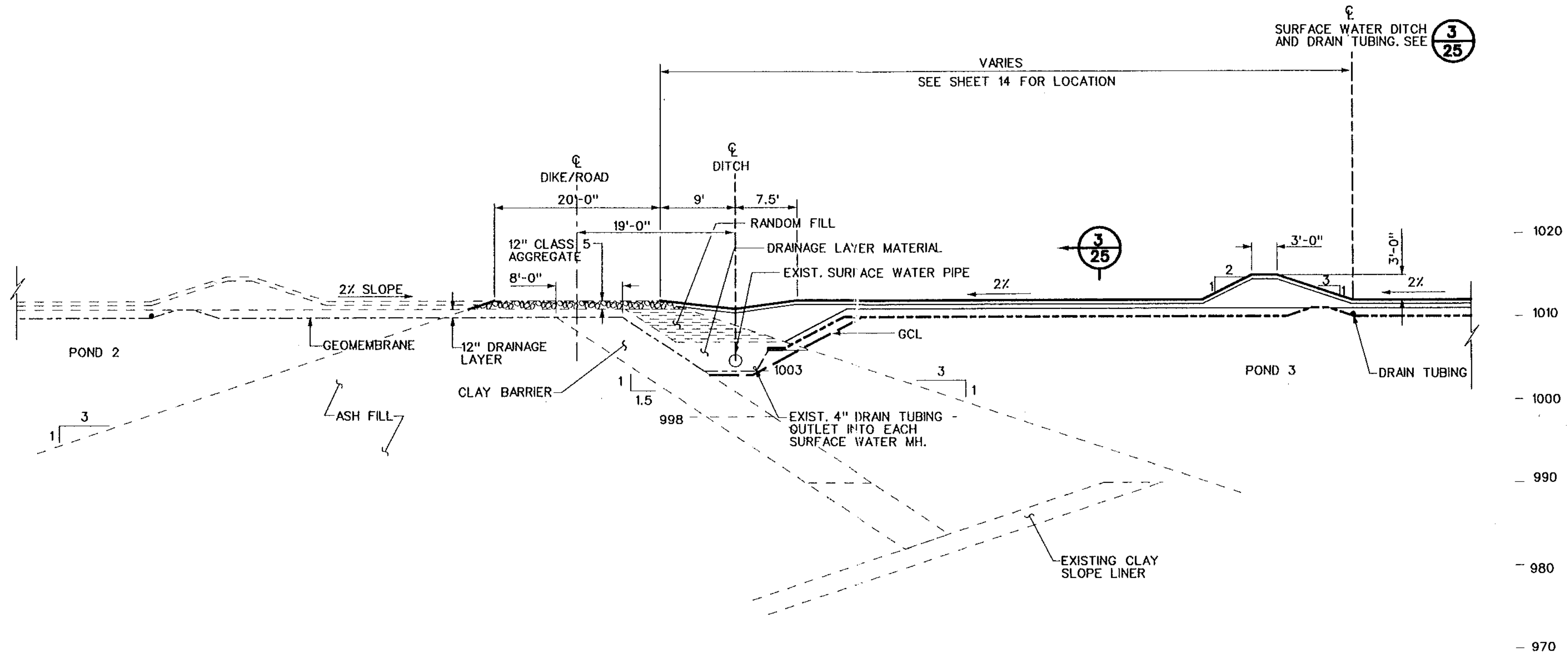
FACILITY: SHERBURNE COUNTY GENERATING PLANT
TITLE: POND NO. 3
FINAL COVER SECTIONS AND DETAILS

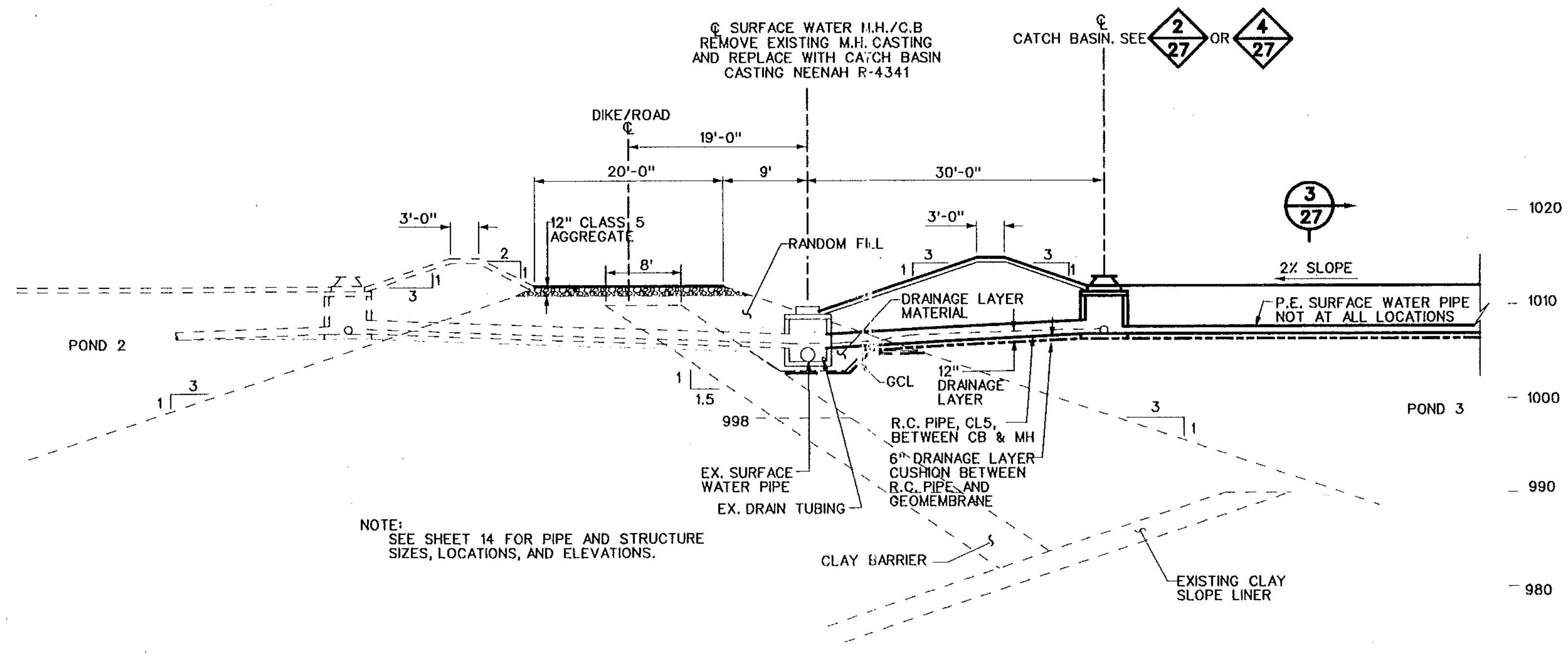
NORTHERN STATES POWER COMPANY
NSP Minneapolis Minnesota

CADD FILENAME Shrcp25_26.dgn
DWG NO. SHT 25 OF 27 SHTS
REV 0



1/26 SECTION: PHASE 6 - FINAL COVER AND SURFACE WATER PIPE (TYP.)
WEST DIKE

0 10 20
SCALE IN FEET



NOTE:
SEE SHEET 14 FOR PIPE AND STRUCTURE SIZES, LOCATIONS, AND ELEVATIONS.

2/26 SECTION: PHASE 6 - FINAL COVER AND SURFACE WATER PIPES AND STRUCTURES (TYP.)
WEST DIKE

0 10 20
SCALE IN FEET

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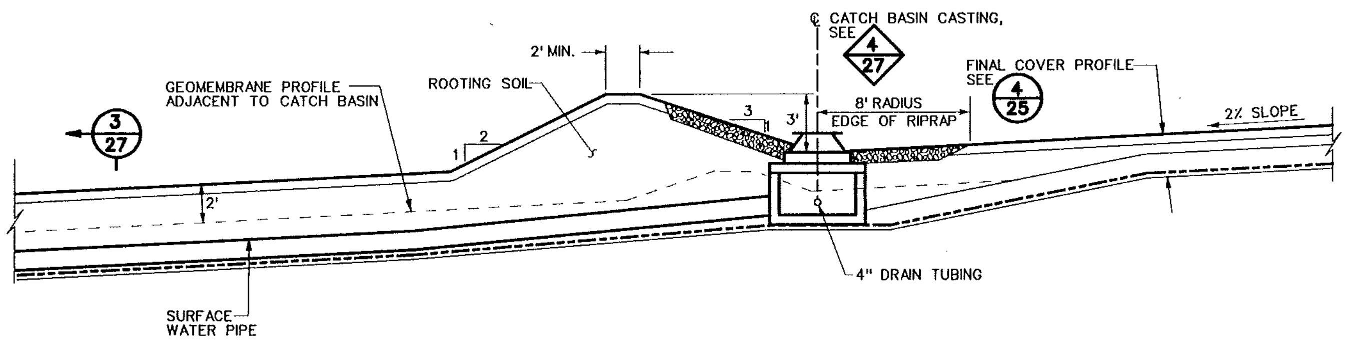
TITLE: POND NO. 3
FINAL COVER SECTIONS AND DETAILS

NORTHERN STATES POWER COMPANY
NSP Minneapolis Minnesota

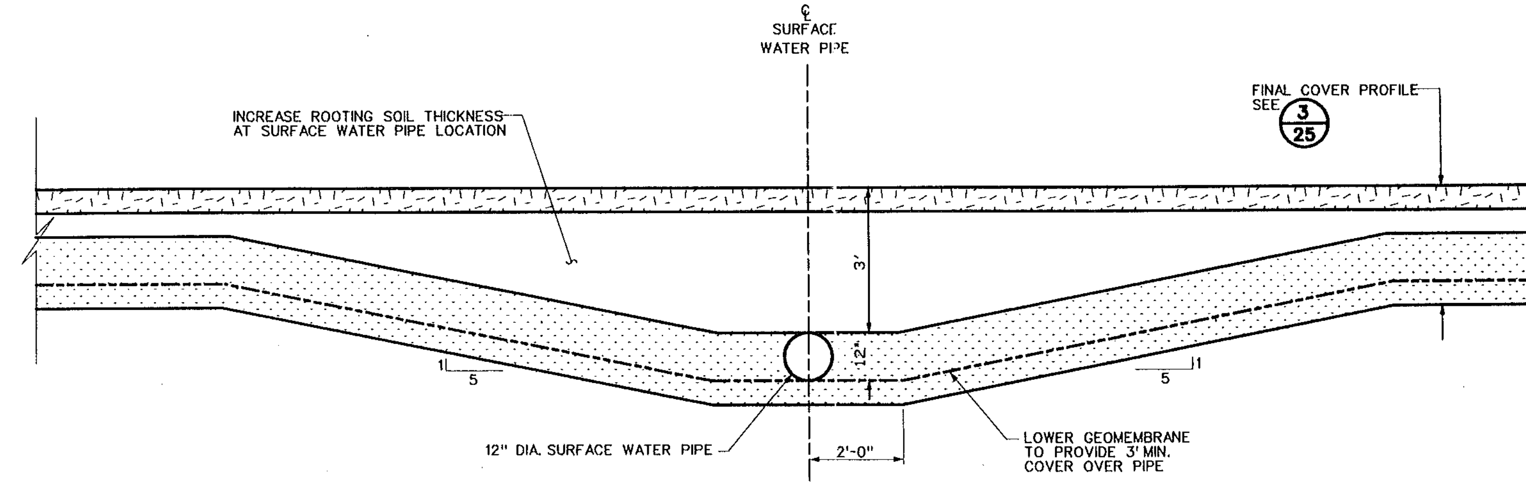
CADD FILENAME Shrcp25_26.dgn
DWG NO. SHT 26 OF 27 SHTS
REV 0

NH-



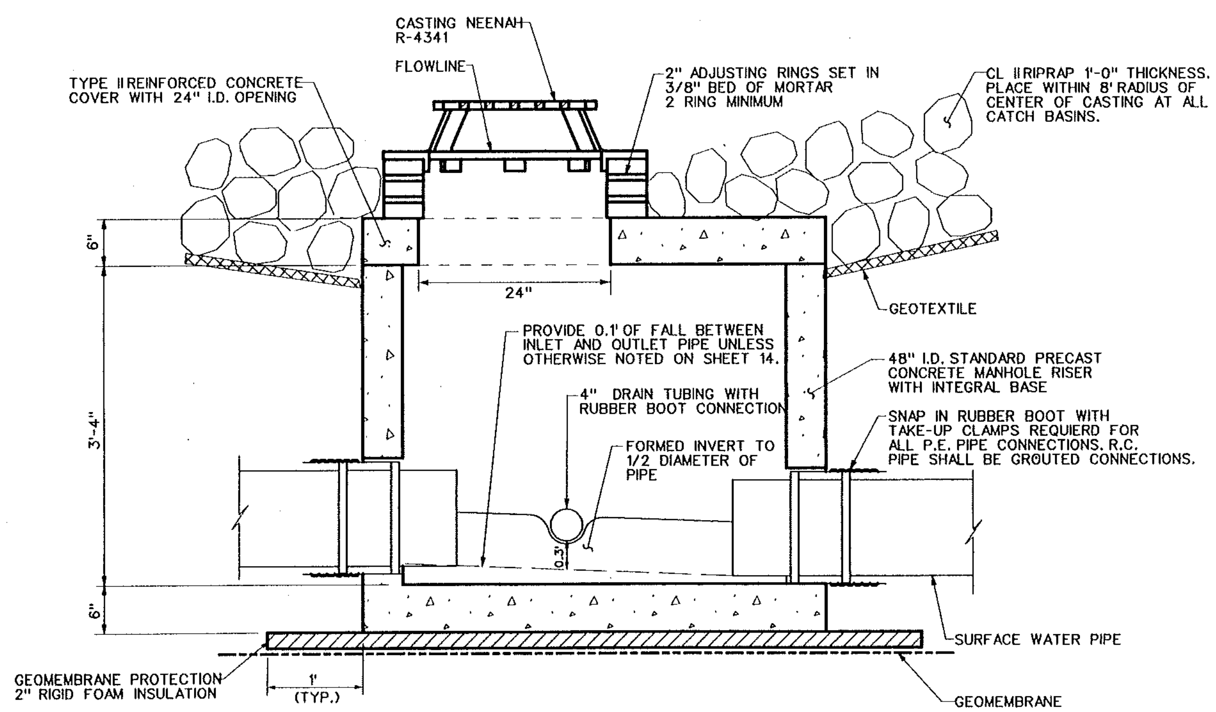
1/27 SECTION: SURFACE WATER DIVERSION DIKE AND CATCH BASIN

0 5 10 SCALE IN FEET



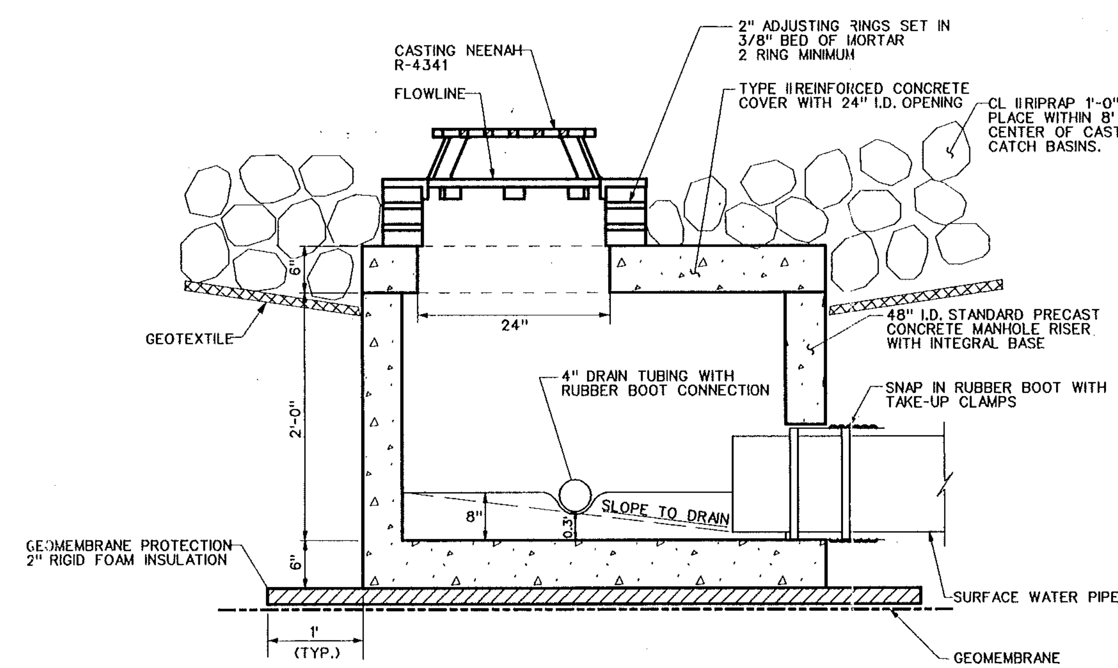
3/27 SECTION: FINAL COVER AND SURFACE WATER PIPE (TYP.)

0 2 4 SCALE IN FEET



2/27 DETAIL: CATCH BASIN-INLET AND OUTLET PIPE

0 1 2 SCALE IN FEET



4/27 DETAIL: CATCH BASIN-SINGLE OUTLET PIPE

0 1 2 SCALE IN FEET

REVISIONS					
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DWN DSS	DATE 06/28/02
DGN'R JRM	CHK'D JRM
APP'D & CERT.	
FILMED	

FACILITY: SHERBURNE COUNTY GENERATING PLANT

TITLE: POND NO. 3

FINAL COVER SECTIONS AND DETAILS

NORTHERN STATES POWER COMPANY
NSP Minneapolis Minnesota

CADD FILENAME Shrcp327.dgn

DWG NO. SHT 27 OF 27 SHTS

REV 0