Golder Associates Inc.

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June 2, 2009

093-82538

Progress Energy Florida, Inc.
299 1st Avenue, North
St. Petersburg, Florida 33733

Attention: Mr. Michael Shrader, Lead Environmental Specialist

RE: SITE CERTIFICATION MODIFICATION
CRCA UNITS 4 AND 5 FGD BLOWDOWN PONDS
CRYSTAL RIVER PLANT
CRYSTAL RIVER, FLORIDA

Dear Mr. Shrader:

Golder Associates Inc. (Golder) is pleased to provide Progress Energy Florida, Inc. (PEF) with the enclosed materials related to the FGD Blowdown Ponds component of the Crystal River Clean Air (CRCA) Units 4 and 5 at the Crystal River Plant located in Crystal River, Florida.

INTRODUCTION

Progress Energy Florida (PEF) is adding wet flue gas desulfurization (FGD) equipment to Units 4 and 5 at the Crystal River coal fired power plant. The plant is located approximately 10 miles north and west of Crystal River, Florida. The addition of the FGD equipment will create a liquid blowdown waste stream containing solids. The waste stream will be discharged to a FGD settling pond system to settle out most of the suspended solids, and the liquid overflow will be pumped to the existing plant south percolation pond. This narrative has been prepared to modify the existing site certification for the facility that will permit the addition of the FGD blowdown ponds into the operations at the facility. The following sections include a description of the FGD blowdown ponds as designed and a description of the ponds' operational characteristics.

Drawings are included in this FGD blowdown pond package and provide topographic conditions prior to construction (Drawing 3). The drawings also include information on the geotechnical investigation conducted and additional proposed borings in the pond area and subsurface remediation required for the area (Drawing 4). Drawings also include the pond layout and cross sections, inlet and outlet piping systems, effluent removal system, the associated pumps and controls, and the final constructed conditions. These drawings will be referenced throughout this narrative. It is noted that the plant datum EL 89.29 feet is equivalent to 0.0 feet MSL. The referenced elevations in this document and shown on the drawings refer to the plant datum unless stated otherwise.

Other attachments to the site certification modification include technical specifications for the various components of the FGD blowdown ponds, construction quality assurance (CQA) plan for the construction of the ponds, and appropriate calculations for the design and construction of the ponds.

FGD BLOWDOWN (SETTLING) PONDS DESCRIPTION

The blowdown from the FGD system will be pumped to one of two lined settling ponds to allow the removal of the suspended solids from the waste stream; the Primary Pond and the Backup Pond. The Primary Pond will be the primary location to which blowdown will be pumped, with the Backup Pond being available for cleanout or maintenance of the Primary Pond[1]. Overflow effluent from the FGD blowdown ponds will flow into a manhole to be pumped to the existing south plant percolation ponds for discharge to groundwater. The FGD blowdown ponds will be lined with a 60-mil thick, linear low density polyethylene (LLDPE) liner. The liner will be textured for enhanced frictional resistance (stability) with the subgrade soils. The pond berms will be constructed of compacted soils to the lines and grades shown on Drawing 6, with a top of berm elevation of 116.0 feet and 3 horizontal to 1 vertical (3H:1V) side slopes. The bottom of the Primary FGD blowdown pond will be at elevation 94.0 feet; the bottom of the Backup Pond will be at elevation 100 feet. An emergency spillway will be located on the western side of the Primary Pond that will be constructed at elevation 112.0 feet. The spillway elevation of 112.0 feet was determined based on wave height calculations. The maximum wave height was calculated to be over 3.6 feet; therefore, a 4-foot elevation difference between the spillway and the top of the berm was selected. Two (2) 12-inch diameter HDPE pipes will be installed between the two ponds and will serve as an overflow outlet for the Backup Pond. The pipe invert elevations in the Backup Pond will be at 113 feet. The FGD blowdown ponds plan view is shown on Drawing 6.

The FGD blowdown will be pumped from the FGD system via fiberglass reinforced plastic (FRP) pipe and will be installed both above and below grade before tying in to the inlet piping at the FGD Blowdown Ponds below grade at the tie-in point shown on Drawing 6. FGD blowdown will flow into the FGD blowdown ponds through a HDPE piping system that will allow flow to enter the Primary Pond at four different locations (see Drawing 6); there is only one inlet location for the Backup Pond based on the limited service requirements anticipated. The inlet piping will control the direction of flow and inlet discharge location via valves and wyes installed in a series of concrete vaults. Cleanouts are also provided in each vault to allow access to the inlet piping at critical locations. The wye sections allow flow in two directions. Each leg of the wye has a valve to close or open the section of wye in which flow is desired or cut off. The inlet flow either goes to the east or west side of the Primary Pond where there are two inlet pipes on each side. A vault is at each location at which an inlet pipe is installed to discharge into the pond. Each vault at these locations include a wye to direct flow to the pond, valves to direct the flow to only one inlet pipe, and a cleanout. Each vault is shown on Drawings 11 and 12.

The liquid overflow will be located at the southwest corner of the Primary Pond and will consist of an overflow pipe leading to a concrete manhole into which the liquid flows. An overflow pipe will also be installed on the south side of the Backup Pond that will gravity flow to the manhole at the southwest corner of the Primary Pond. The details of the overflow pipes, manhole, and pumps are shown on Drawing 13. The overflow pipe for both ponds will be set at elevation 111.24 feet which, under normal operating conditions, will be the normal pool elevation for the ponds. However, because the Backup Pond will only be operated when the Primary Pond requires service, both outlets will not be flowing into the manhole simultaneously. Pumps will

[1] It is noted that because of schedule issues, the Backup Pond will be put into service first, until the construction of the Primary Pond is complete.

remove the liquid from the manhole to outlet piping that will be connected to piping that extends to the south percolation pond. The pumps will be controlled by liquid level sensors that are linked to a motor control center (MCC) that will be set to the appropriate levels to maintain the pond at the desired level. The MCC readings will remotely be submitted to the main plant for continuous evaluation of the operation (see Drawing 15). Additionally, the flow from the pumps will be measured using a flow meter installed on the outlet piping outside the manhole.

Drawing 8 shows the final grading for the area of the FGD Blowdown Ponds and the remainder of the area that was the former ash pond. Drawing 8A provides an overlay of the limits of the former ash pond with the final grading plan (Drawing 8). As shown, final grading for the FGD Blowdown Ponds and the surrounding area includes grading so that all surface water within the former ash pond is directed to the west end of the former ash pond. Surface water drainage from the outside slopes and to the east of the Backup Pond is routed to the south and west through a 24-inch or greater diameter corrugated plastic pipe (CPP) culvert located at the southeast portion of the Primary Pond berm. Flow from the outside slopes of the Primary Pond and flow coming from the east (through the culvert) continues to the west until approximately 200 feet west of the base of the Primary Pond slope such that no water is allowed to stand near the FGD Blowdown Ponds. As were the conditions in the former ash pond area, the only outlet for surface water for the FGD Ponds is the overflow weir at the northwest corner of the area. Although there is an outlet for the flow, the intent of the design is to contain all the water from the 25-year, 24-hour storm within the former ash pond without discharging from the outlet point.

FGD BLOWDOWN POND OPERATION

As described above, the blowdown from the FGD system will be pumped to the FGD blowdown Primary Pond or the Backup Pond via five outlet/discharge locations. The various locations for the inlet piping are provided based on the settling characteristics of the blowdown. The material tends to settle relatively quickly once discharged and the various inlet locations allow the material to be distributed around the inlet end (north end) of the ponds more evenly. This will allow more time between required removal of solids from the bottom of the pond. The top of the sludge storage zone for both the Primary and Backup Ponds, per the design is elevation 105.0 feet. The elevations of the Primary Pond structure, as described above, result in the following operational depths for the material in the Primary Pond:

- Freeboard: 4 feet (minimum before berm overtopping)
- Water depth: 17.24 feet (minimum)/18.0 feet (maximum w/o utilizing spillway)
- Sludge Depth: 11 feet (maximum)
- Water Column: 6.24 feet (minimum)

Based on the above, the estimated total pond storage volume at the overflow inlet of the Primary Pond is 1,982,600 cubic feet, or 45.5 acre-feet, or 14.8 million gallons.

Similarly, the Backup Pond has the following operational depths:

- Freeboard: 3 feet
- Water depth: 11.24 feet (minimum)/13.0 feet (maximum w/o utilizing overflow pipes)
- Sludge Depth: 5 feet (maximum)
- Water Column: 6.24 feet (minimum)

Based on these depths, the estimated total pond storage volume at the overflow inlet of the Backup Pond is approximately 400,300 cubic feet, or 9.2 acre-feet, or 3 million gallons.

Based on information provided by PEF, the following are the expected FGD blowdown characteristics:

- Influent Flow Rate of 300 gpm
- Chloride (Cl) concentrations of 20,000 to 25,000 mg/l (40,000 mg/l maximum)
- Total Suspended Solids (TSS) concentrations of 6,000 mg/l average; 20,000 mg/l peak
- pH will be approximately 7.0 to 7.5
- Maximum temperature of 140 degrees Fahrenheit

Given these characteristics, the FGD blowdown ponds are designed to allow the solids to settle out such that the TSS in the outflow will be less than 40 mg/l under average operating conditions (i.e., incoming TSS of 6,000 mg/l).

CLOSING

Golder appreciates the opportunity to provide our services to PEF on this project. If there are any questions or comments on the enclosed, please call.

Sincerely,

GOLDER ASSOCIATES INC.

Kenneth B. Karably

Kenneth B Karably, P.E.
Principal
6/2/2009

Attachments: Technical Specifications
Drawings
Supporting Calculations

FN: G:\Projects\093\093-82\093-82538\Permit Application Components\Permit Mod Narrative 0609.docx

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Golder Associates

RE: TECHNICAL SPECIFICATIONS
FGD BLOWDOWN POND
CRYSTAL RIVER ENERGY COMPLEX – UNITS 4 AND 5
CRYSTAL RIVER, FLORIDA

The following Technical Specifications for the Crystal River Energy Complex – Units 4 and 5, FGD Blowdown Ponds were prepared by Golder Associates Inc. (Florida Professional Engineering Certificate of Authorization #1670) and under the responsible charge of Kenneth B. Karably (Florida Professional Engineer License #42366):

Specification	Title	Date	Rev.	No. of Pages
01010	Summary of Work	May 2009	1	6
01050	Survey and Stake-Out	May 2009	2	3
02200	Earthwork	May 2009	1	7
02271	Limerock Road	May 2009	0	3
02275	Riprap	May 2009	0	2
02540	Erosion and Sedimentation Control	May 2009	0	2
02560	Topsoil, Seeding, and Mulching	May 2009	0	3
02770	LLDPE Geomembrane Liner	May 2009	0	22
13060	Non-woven Geotextiles	May 2009	0	4
13080	Reinforcing Geotextile	May 2009	1	4
13100	Compaction Grouting	May 2009	1	5
15410	Pipes and Valves	May 2009	2	10
Appendix A	CQA Plan	May 2009	1	32
Appendix B	Soil Boring Logs	May 2009	1	70

GOLDER ASSOCIATES INC.

Kenneth B. Karably

Kenneth B. Karably
Florida P.E. 42366
6/2/2009

SECTION 01010

SUMMARY OF WORK

PART 1 – GENERAL

1.01 LOCATION OF WORK

Work included in this Contract will be conducted at the Crystal River Units 4 & 5 coal fired power plant located approximately 10 miles north and west of Crystal River, Florida. The Crystal River Plant is operated by Progress Energy Florida, Inc. (PEF).

1.02 DESCRIPTION OF WORK

A. The Work of this construction project, in general, is construction of Flue Gas Desulfurization (FGD) Blowdown Ponds and associated operating components to the limits and elevations shown on the drawings. The ponds include a primary pond and a backup pond to be used during interruptions in service to the primary pond. Engineering is complete for the primary pond and drawings are included. A preliminary sketch of the backup pond is also included; design drawings for the backup pond will be provided at a later date. The Work includes all initial grading; subsurface remediation (as defined by **ENGINEER**); all earthwork related to the construction of the pond berms and access roadway, installation of Linear Low Density Polyethylene (LLDPE) geomembrane as the pond liner, all work related to the installation of FGD Blowdown inlet piping (from identified point), all work related to installation of the outlet structure and piping (to an identified point), all work related to the final grading of exterior of pond berms and entire former ash pond area (as defined on the drawings), and all other incidentals as are required by drawings, specifications, contract documents and permits along with all other appurtenances and incidentals, complete in-place and ready for operation and use by the **OWNER**.

In so far as the power plant operations by the **OWNER** are required to be ongoing during the construction period, the **CONTRACTOR** is required to sequence the work to eliminate interruption of the **OWNER's** operations.

B. In general, the work components for the approximate 4-acre Primary FGD blowdown pond and smaller backup pond include but are not limited to:

- Grading the existing former ash pond area to the lines and grades shown on the drawings, including the excavation and stockpile of material in the existing perimeter berms (and a limited amount on the base) for use as fill material on the FGD blowdown ponds. **CONTRACTOR** shall assume all of this material is suitable for re-use subject to **ENGINEER** approval. **CONTRACTOR** shall provide erosion control measures to ensure sediment is not allowed to discharge outside the former ash storage area;

- The use of a heavy-duty vibratory smooth drum roller to compact the area of the footprint of the FGD blowdown ponds for the purpose of identifying potential weak areas in the near-surface subgrade that may form sinkholes;

- The performance of subsurface remediation in areas identified by the **ENGINEER** and as shown on the drawings as well as areas identified by the vibratory compaction efforts. This work shall be conducted by an **ENGINEER-**approved specialty contractor as a subcontractor to the **CONTRACTOR**;

- Providing additional **ENGINEER-**approved fill material as required;

- The installation of two layers of a reinforcing geotextile over the area of the FGD blowdown pond footprint and covering of same with a minimum of 1 foot of soil (each layer) to elevation 94 feet. The installation of the reinforcing geotextile shall be conducted by an **ENGINEER-**approved specialty contractor as a subcontractor to **CONTRACTOR**;

- Construction of the FGD blowdown pond berms and access ramp;

- Installation of the LLDPE pond liner system;

- Installation of the inlet piping system from an identified point northeast of the access ramp, including valves, pipes, cleanouts and multiple vaults to provide four inlet locations for discharge into the ponds;

- Installation of the outlet structure and appurtenances including overflow pipe, concrete manhole, pumps, piping, motor control center, communication system, and outlet piping to an identified point south of the former ash storage area;

- Coating of the inside of the concrete manhole;

- Construction and installation of the pond spillway and associated erosion protection on the west side of the pond;

- Coating of the concrete spillway;

- Grading and installation of surface water controls (culverts/ditches) and erosion controls (topsoil and seeding/sodding) to provide drainage away from the ponds base such that there will be no standing water within 200 feet of the outside toe of the pond berms; and

- Installation of lighting and controls around the perimeter of the roadway at the top of the berm and in the area of the MCC and outlet pump manhole.

C. **CONTRACTOR** shall cooperate with and not hinder work by other contractors or **OWNER** during the construction of the FGD blowdown ponds. Specifically, other work may include the installation of the FGD blowdown piping to the point of tie-in and the installation of the outlet piping from the point of tie-in to the south percolation pond (which is located outside the former ash storage area). If already in place, any damage to the tie-in points for the FGD blowdown piping and outlet piping is required to be reported to the **OWNER** at once and repaired immediately by **CONTRACTOR** at **CONTRACTOR's** expense. The **CONTRACTOR** is required to prepare a specific plan for the tie-in of the two piping systems for **OWNER** approval and coordination.

D. The **CONTRACTOR** shall complete all work described above and all other incidental work, whether specifically mentioned or not in accordance with the Drawings, Specifications, and Contract Documents. **OWNER** has an Approved Vendor List (attached) from which the **CONTRACTOR** shall obtain materials and equipment, if possible. If material or equipment is not available through one of the approved vendors, **CONTRACTOR** shall submit vendor to **OWNER** for approval.

E. Work shall conform to the following Drawings that form a part of these Contract Documents.

DRAWING NO.	TITLE
1	COVER SHEET
2	Number Reserved for Future Use
3	TOPOGRAPHIC MAP - FORMER ASH POND AREA
4	SUBSURFACE BORINGS AND REMEDIATION LOCATIONS
5	INITIAL GRADING PLAN AND LIMITS OF REINFORCING GEOTEXTILE
6	PLAN VIEW OF POND LAYOUT
6A	BACKUP POND SKETCH
7	CROSS SECTIONS
8	FINAL GRADING PLAN
9	FINAL GRADING PLAN DETAILS
10	LINER SYSTEM AND ROADWAY DETAILS
11	INLET PIPING DETAILS (SHEET 1 OF 2)
12	INLET PIPING DETAILS (SHEET 2 OF 2)
13	OUTLET PIPING DETAILS
14	PROCESS AND INSTRUMENTATION DIAGRAM
15	ELECTRICAL SERVICE ROUTING AND DETAILS

1.03 WORK BY OWNER

A. **OWNER** will continue the operation of the power facility during construction but the area of construction of the FGD blowdown ponds is generally isolated from plant activities. However, material deliveries, including soil, piping, concrete, etc., will require use of plant roadways outside the FGD blowdown ponds area. **CONTRACTOR** shall coordinate with **OWNER** regarding all deliveries, haul routes, etc. such that minimal interference with plant operation and all other construction activities occurs.

B. **OWNER** will furnish the outlet pumps, Motor Control Center (MCC), radio control equipment for communication back to plant DCS, and transformer**.** **OWNER** will provide a pad-mounted transformer in the area of the new ponds. Transformer will be fed with underground service from an area outside the ponds. **CONTRACTOR** shall cooperate with **OWNER** for installation of the transformer and feed. **CONTRACTOR** will be responsible for the transportation from on-site storage, installation and connections to the equipment supplied by **OWNER.** **CONTRACTOR** to also provide commissioning of

OWNER-supplied equipment; also to provide installation, commissioning and connections for DCS equipment at pond including full loop path checks, HMI verification, and equipment testing. See attached List of **OWNER** Supplied Material for details.

C. **OWNER** will furnish reinforcing geotextile. **CONTRACTOR** will be responsible to receive, unload, store, and install reinforcing geotextile (as above, installation shall be performed by an **ENGINEER-**approved specialty contractor). See attached List of **OWNER** Supplied Material for details.

D. **OWNER** will provide Construction Quality Assurance (CQA) during construction activities. CQA activities will include on-site inspection and quality assurance during construction including scheduled checking of soil placement testing, liner testing, and construction observation of the materials and equipment component installation. The complete CQA Plan included as Appendix A to the Technical Specification package. Some of the functions are as follows:

- Inspection of materials,
- Review of site layout,
- Sub-grade compaction verification,
- Verification of geosynthetic characteristics,
- Geosynthetic deployment and seaming observation,
- Observation of cover placement over geotextile,
- Inspection of pipe placement and backfill compaction,
- Review of pipe testing, and
- Inspection of **CONTRACTOR**'s quality control procedures associated with soil classification, lift thickness, permeability, and compaction verification.

CONTRACTOR shall adhere to CQA procedures and work in cooperation with the **OWNER'**s representatives toward the successful completion of the project.

1.04 WORK BY CONTRACTOR

A. The **CONTRACTOR** shall furnish all labor, materials, equipment (except as listed above to be provided by **OWNER**), tools, services and incidentals to complete all of the work required as shown on the Drawings and included in the Specifications.

B. The **CONTRACTOR** shall complete the work, in place, ready for continuous service, and shall include repairs, testing, permits, cleanup, replacements, and restoration required as a result of damages caused during construction.

C. All material, equipment, skills, tools, and labor which are reasonably and properly inferable and necessary for the proper completion of the work, in a substantial manner and in compliance with the requirements stated or implied by the Specifications or Drawings, shall be furnished (except as noted above) and installed by the **CONTRACTOR** without additional compensation, whether specifically indicated in the Contract Documents or not.

D. The **CONTRACTOR** shall comply with all municipal, county, state, and federal laws, rules, guidelines, and codes, which are applicable to the work.

E. The **CONTRACTOR** shall provide a Health and Safety Plan (HASP) prior to commencing work on site that provides the **CONTRACTOR**'s health and safety practices and any site specific health and safety requirements for work at this site. **CONTRACTOR** must provide a HASP that is acceptable to **OWNER** and that conforms to the **OWNER**'s health and safety requirements for the plant.

F. The **CONTRACTOR** will be responsible for any and all traffic control around the construction area.

G. The **CONTRACTOR** shall maintain dust control on all roads used for access to construction and all construction areas.

H. The **CONTRACTOR** shall provide marked-up drawings to the **ENGINEER** necessary for the preparation of as-built drawings.

I. The **CONTRACTOR** shall provide manufacturer recommended spare parts and all Operations and Maintenance Manuals.

J. The **CONTRACTOR** shall provide a Storm Preparation Plan prior to commencing work on site. The Storm Preparation Plan shall be submitted for **OWNER** approval.

1.05 SITE CONDITIONS

A. Test borings made at the FGD blowdown pond area for use in the design are included in Appendix B to the Technical Specification package for **CONTRACTOR**'s use.

B. The **CONTRACTOR** shall be responsible for having determined to his satisfaction, prior to the submission of his Bid, the conformation of the ground, the character and quality of the substrate, the types and quantities of materials to be encountered, the nature of the ground water conditions, the execution of the work, the general and local conditions and all other matters which can, in any way, affect the work under this Contract. No claim for extras based on substrate or ground water table conditions will be allowed.

C. The **OWNER** does not make any representation regarding the information at the time of Bidding and during construction, and Contractors are encouraged to visit the site or obtain their own data and make their own judgment as to the existing conditions.

1.06 SCHEDULE OF ACTIVITIES

A. The **CONTRACTOR** shall be responsible for all submittals and approvals required by the Technical Specifications. A summary of the required submittals, along with due date, are shown on the attached Schedule of Activities. However, it is the **CONTRACTOR's** responsibility to provide all submittals required by the Technical Specifications, regardless of their inclusion on the Schedule of Activities. All submittals and approvals must be in writing.

B. Submittals to the attention of **OWNER** shall be sent to Mr. Dale Wilterdink, 15760 West Powerline Street, Crystal River, Florida 34428 or his designee.

C. Submittals to the attention of **ENGINEER** shall be sent to Mr. Ken Karably, 9428 Baymeadows Road, Suite 400, Jacksonville, Florida 32256, or his designee. All submittals to the **ENGINEER** shall copy the **OWNER**.

PART 2 – PRODUCTS (Not used)

PART 3 – EXECUTION (Not used)

END OF SECTION

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SECTION 01050

SURVEY AND STAKEOUT

PART 1 - GENERAL

1.01 SUMMARY

The Work shall consist of the performance of all necessary survey work related, but not limited to, staking out, layouts, and establishment of lines, elevations, grades and slopes, and final as-built survey as required, in accordance with the Contract Documents and/or Drawings.

1.02 EXAMINATION

A. The **CONTRACTOR** shall verify locations of survey control points prior to starting work.

B. The **CONTRACTOR** will promptly notify **OWNER** of any discrepancies discovered.

1.03 SURVEY REFERENCE POINTS

A. **OWNER** will be responsible for establishing primary reference points. The **CONTRACTOR** shall be responsible for all other survey and layout work. Maintenance of the reference points established by **OWNER** shall be the responsibility of the **CONTRACTOR**.

B. Control datum for survey will be provided by **OWNER**.

C. Protect survey control points prior to starting site work; preserve permanent reference points during construction.

D. Promptly report to **OWNER** the loss or destruction of any reference point or relocation required because of changes in grades or other reasons.

E. Replace dislocated survey control points based on original survey control. Make no changes without approval of **OWNER**.

1.04 SURVEY REQUIREMENTS

A. All work under this Contract shall be constructed in accordance with the lines and grades shown on the Drawings or as directed by **OWNER**. **OWNER** will provide benchmark with appropriate horizontal and vertical control. Elevation of existing ground, structures and appurtenances are believed to be reasonably correct but are not guaranteed to be absolute and, therefore, are presented only as approximations. Any error or apparent discrepancy in the data shown, or omissions of data required for accurately accomplishing the stakeout survey should be referred immediately to **OWNER** for interpretation or correction.

Other general requirements include:

1. Provide field surveying services. Utilize recognized engineering survey practices.

2. The **CONTRACTOR** shall furnish for the survey work and stakeout, competent and qualified personnel acceptable to **OWNER**.

3. It shall be the **CONTRACTOR**'s responsibility to maintain the survey and stakeout stakes in their proper position and location at all times.

4. Any existing stakes or markers defining property lines and survey monuments which may be disturbed during construction shall be properly tied in to fixed reference points and accurately reset in their proper position upon completion of the Work.

5. Provide final as-built survey of constructed ponds, limits of geotextile, limits of liner, locations of all pipes, vaults, manholes, and appurtenances, electrical conduit, control systems, etc. as directed. Final as-built survey shall be signed and sealed by a Registered Professional Land Surveyor.

B. The exact position of all Work shall be established from control points, base line points or other points that are shown on the Drawings or as modified by **OWNER**.

C. The **CONTRACTOR** shall be responsible for the accuracy of his work and shall maintain all reference point stakes, etc., throughout the life of the Contract. Damaged or destroyed points, bench marks or stakes or any reference points made inaccessible by the progress of the construction shall be replaced or transferred by the **CONTRACTOR**. Existing or new control points that will be destroyed during construction shall be transferred or reestablished before they are damaged or destroyed and all reference ties recorded therefore shall be furnished to **OWNER**.

D. All stakeout survey work shall be referenced to the lines shown on the Drawings or as directed by **OWNER**.

E. All computations necessary to establish the exact position of the Work from control points shall be made and preserved by the **CONTRACTOR**. All computations, survey notes and other records necessary to accomplish the Work shall be neatly made, shall be made available to **OWNER** upon request.

F. **OWNER** may check all or any portion of the stakeout survey work or notes made by the **CONTRACTOR**. The **CONTRACTOR** shall make any necessary correction to the Work immediately. Such checking by **OWNER** shall not relieve the **CONTRACTOR** of any responsibilities for the accuracy or completeness of his work.

G. The **CONTRACTOR** shall place offset stakes or references as required for construction and at such points as **OWNER** may direct. From computations and measurements made by the **CONTRACTOR**, these stakes shall be clearly marked with the offset and cut or fill so as to permit the establishment of the exact location and elevation during construction. If markings become faded or blurred for any reason the **CONTRACTOR** at the request of **OWNER** shall restore them. The **CONTRACTOR** shall locate and place all cut, fill, slope, grade or other stakes and points as may direct for the proper progress of the work. All control points shall be properly guarded and flagged for easy identification.

H. Any additional permanent survey marker locations necessary for the work shall be established and referenced by the **CONTRACTOR**.

I. Prior to the final as-built survey of the project by **CONTRACTOR** by a Florida PLS, the **CONTRACTOR** shall reestablish the base line points, as well as any necessary benchmarks and control points, as required by **OWNER**.

J. The final as-built survey shall be performed by the **CONTRACTOR** and include a minimum 50-foot grid across the work area and extending out 200 feet beyond the limits of work, except where the work extends to the limit of the ash pond area. In addition to the grid survey, additional features required in the as-built survey include all components of the work, including, but not limited to: any breaks in slope (crest and toe) for ditches, swales, and ponds; culvert inlets/outlets (invert and location); overflow piping; roads (subgrade and finish surface); spillways; erosion control structures; inlet and outlet piping (invert and location); vaults and manholes; pumps; electrical conduits, MCC, electrical service; etc. or as directed by the **ENGINEER**.

PART 2 – PRODUCTS (Not used)

PART 3 - EXECUTION

3.01 SURVEY REFERENCE POINTS

A. Locate and protect control points prior to starting site Work, and preserve all permanent reference points during construction. All Work will be referenced to the site coordinate system, which will be provided by **OWNER**.

B. Make no changes or relocations without approval of **OWNER**.

C. Report to **OWNER** when any reference point is lost or destroyed, or requires relocation because of necessary changes in grades or locations.

D. Replace control points that may be lost or destroyed at no additional cost to **OWNER**. Establish replacements based on original survey control.

3.02 TOLERANCES

Each design feature shall be staked by the **CONTRACTOR** to the lines and grades as shown on the Construction Drawings to within 0.1-foot.

END OF SECTION

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SECTION 02200

EARTHWORK

PART 1 - GENERAL

1.01 SCOPE

A. The Work under this section includes the excavation and general fill placement as part of the preparation for the geotextile installation, pond berm construction (including top of berm roadway), and geomembrane installation.

B. Key elevations are shown on the drawings for proposed and existing structures. The **CONTRACTOR** shall construct all Work specified herein in accordance with these elevations. If there are any substantial differences in the present elevations shown on the drawings, the **CONTRACTOR** shall call attention to such differences before proceeding with the Work.

1.02 SUBMITTALS

A. Minimum of fourteen (14) days prior to the use of a soil material on site, the **CONTRACTOR** shall submit information for the fill from the existing pond area and any proposed off-site source(s) of material, including results of testing that has been performed on samples from each source. Testing shall include, at a minimum, the following:

- Natural moisture content (1 test per 25,000 cubic yards);
- Grain size distribution (1 test per 25,000 cubic yards);
- Atterberg limits (1 test per 25,000 cubic yards); and
- Standard Proctor (1 test per 25,000 cubic yards).

B. Once the material has been approved for use and prior to delivery to the site, the **CONTRACTOR** shall submit to **OWNER** or its representative, samples of each material type and from each borrow source, such that **OWNER** may perform necessary confirmation tests to determine compliance with the specifications. The **CONTRACTOR** shall not change the material source without submitting additional samples for testing and approval by **OWNER**. **OWNER** will record the costs associated with testing of the materials proposed by the **CONTRACTOR** and the **CONTRACTOR** shall reimburse **OWNER** for the cost of the tests that indicate the material does not meet the specifications.

C. Each Standard Proctor Compaction Test sample submitted by the **CONTRACTOR** shall be at least 50 pounds in weight and shall include a nominal 50 gram specimen sealed for natural moisture content testing. One sample per each 25,000 cubic yards to be placed shall be provided, but no less than one per borrow source.

1.03 RELEVANT SECTIONS

Section 13080 Reinforcing Geotextile
Section 02770 LLDPE Geomembrane
Section 13100 Compaction Grouting
Section 01050 Surveying and Stakeout

1.04 REFERENCES

A. Latest version of American Society for Testing and Materials (ASTM) Standards:

1. ASTM D422 — Standard Test Method for Particle-Size Analysis of Soils.

2. ASTM D698 — Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort (5.5 lb. hammer and 12-inch drop).

3. ASTM D1140 — Standard Test Methods for Amount of Material in Soils Finer than No. 200 Sieve.

4. ASTM D1556 — Standard Test Method for Density and Unit Weight of Soil in Place by the Sand-Cone Method.

5. ASTM D2167 — Standard Test Method for Density and Unit Weight of Soil in Place by the Rubber Balloon Method.

6. ASTM D2216 — Standard Test Method for Laboratory Determination of Waster (Moisture) Content of Soil and Rock by Mass.

7. ASTM D2487 — Standard Test Method for Classification of Soils for Engineering Purposes.

8. ASTM D2434 — Standard Test Method for Permeability of Granular Soils (Constant Head).

9. ASTM D2937 — Standard Test Method for Density of Soil in Place by the Drive-Cylinder Method.

10. ASTM D4318 — Standard Test Method for Liquid Limit, Plastic Limit, and Plasticity Index of Soils.

11. ASTM D6938 — Standard Test Methods of Soil and Soil-Aggregate in Place by Nuclear Methods (Shallow Depth).

B. Standard Specifications for Road and Bridge Construction, Florida Department of Transportation (FDOT), 1993 Edition or update (FDOT Specifications).

PART 2 - PRODUCTS

2.01 MATERIALS

A. Obtain material for compacted fill from the existing pond area as shown on the initial grading plan (Drawing 5). Obtain additional compacted fill material, if required, from off-site borrow areas identified by the **CONTRACTOR** and as approved by **ENGINEER**.

B. Compacted fill material shall be relatively homogeneous natural soils which are free of materials which, due to nature or size, are deleterious to the intended use. Do not allow rock fragments larger than 2 inches unless approved by the **ENGINEER**. Acceptable compacted fill material shall meet the requirements of the specification applicable to the intended use of the material.

C. Borrow material to be used for the interior of the pond berm, which is any area that is not within a minimum of 6 inches of the outside face of the berm or the bottom of the pond, shall meet the following gradation specifications:

Sieve Size	% Finer Range
3-inch	100
1.5-inch	90-100
0.75-inch	75-100
0.375-inch	40-98
No. 4	30-90
No. 10	20-80
No. 40	15-65
No. 100	10-40
No. 200	5-25

D. Borrow material to be used for the geomembrane subgrade (within minimum 6 inches of the surface of the pond) shall meet the following gradation specifications:

Sieve Size	% Finer Range
3-inch	100
1.5-inch	90-100
0.75-inch	85-100
0.375-inch	80-98
No. 4	70-98
No. 10	70-95
No. 40	60-93
No. 100	25-60
No. 200	10-25

E. Material to be used as backfill around inlet and outlet piping and for the backfill of the geomembrane anchor trench shall be either the material excavated for the trench or as-constructed as berm material, but will generally be similar to the geomembrane subgrade material, unless specified otherwise on the drawings.

F. Material for roadway on the top of the berm shall be limerock that meets the project requirements as provided in Section 02271.

G. Riprap for the slope protection shall meet the project requirements as provided in Section 02275.

H. Material for repair of sinkholes (if necessary) will include washed stone (#57 stone, or as approved by **ENGINEER**) and soil borrow material that meets the requirements of D. above.

PART 3 - EXECUTION

3.01 GENERAL

A. The **CONTRACTOR** may use any method and equipment that is demonstrated, to the satisfaction of the **OWNER**, to accomplish excavation and placement of general fill and limestone in conformance with the requirements of the specifications and the construction drawings. The **CONTRACTOR** shall excavate and place fill materials to achieve the elevations shown on the construction drawings, or as directed by the **OWNER**.

3.02 REINFORCING GEOTEXTILE SUBGRADE PREPARATION

A. The **CONTRACTOR** shall excavate soils to meet excavation grades for the reinforcing geotextile subgrade as shown on the construction drawings. Excavated materials shall be stockpiled on site, at an agreed-upon location(s).

B. All general fill soil shall be obtained from the existing pond area or off-site borrow source(s), and the material shall be approved by **OWNER**.

C. The geosynthetic subgrade shall be smooth and level such that any shallow depressions and humps do not exceed six (6) inches in depth and height.

D. The reinforcing geotextile subgrade shall be compacted with a smooth drum, vibrating roller with a minimum operating weight of 30,000 lbs. The **CONTRACTOR** shall compact the subgrade with a minimum of three passes of the roller in two directions each with the vibrating mechanism engaged over the entire reinforcing geotextile subgrade area. Roller passes should overlap sufficiently to assure the entire area is compacted. Compacted material shall not exhibit ruts more than 1 inch in depth nor pumping of areas larger than 1 foot in diameter. One of the main objectives of the vibratory rolling of this area is to evaluate the possible formation of a sinkhole underneath the pond. If **CONTRACTOR** suspects an area may be showing signs of a sinkhole opening up, the area shall be located by survey, including location and approximate size, and **CONTRACTOR** shall notify the **ENGINEER** and **OWNER** immediately.

E. Should a sinkhole form during construction of the pond (assumed to be during vibratory rolling efforts), the **CONTRACTOR** shall provide equipment, labor, and materials to execute a repair of the sinkhole as described herein. The **CONTRACTOR** shall excavate the collapsed area (to the extent determined necessary by the **ENGINEER** or **OWNER** or its representative), backfill with washed stone (#57 stone or as approved by the **ENGINEER**) to within one foot of the original ground level, compact the stone in place, replace and recompact the stone as necessary to establish a firm, unyielding surface, and install a filter geotextile within the excavated area above the stone. The top one-foot of the area shall be backfilled with soil similar to that surrounding the sinkhole and the soil compacted as per the compaction specifications.

F. Areas have been identified (see Drawing 4) for subsurface remediation beneath the base of the pond. The subsurface remediation work in the areas identified, as well as those that may be identified during compaction efforts, will be conducted by a Specialty Contractor retained by the **CONTRACTOR**. This work is described in Section 13100 of the Specifications.

G. Prior to placement of the reinforcing geotextile, the subgrade shall be checked to verify that the area is free of rocks, debris, sharp objects, organic materials, and other deleterious materials.

H. In areas where unsuitable soils are encountered (soft or rutting soils, not sinkhole areas), remove and replace the soil to depths as approved by the **ENGINEER**. Fill the area with compacted fill material to at least 98 percent standard Proctor maximum dry density (ASTM D698).

I. Dispose of unsuitable soil as directed by **OWNER**.

J. Maintain the subgrade surface free of standing water and compact to meet the requirements of this Section as approved by the **ENGINEER**. Maintain area in this condition until overlying construction is complete.

K. Reinforcing geotextile shall be installed over the area as shown on the drawings and immediately covered with a minimum of 2 feet of soil (to reach elevation 94 feet on the base of the pond area). Overlying soil shall be material as described in D. above and shall be placed in an initial 12-inch thick lift and compacted to 98 percent standard Proctor maximum dry density (ASTM D698). Lifts above the initial lift shall be minimum 8-inch loose lifts and shall be compacted to the above specified density.

3.03 POND BERMS AND GEOMEMBRANE SUBGRADE PREPARATION

A. Fill material shall be placed as part of the pond berm construction to meet the geomembrane design subgrade elevations shown on the construction drawings.

B. All fill material shall be obtained from the existing pond area or off-site borrow source(s), and the material shall be approved by **OWNER**.

C. Remove particles with a maximum dimension larger than 2 inches, or of the maximum size approved by the **ENGINEER**.

D. The as-placed moisture content of general fill shall be within 5 percent of optimum moisture content as determined from the Standard Proctor Compaction Test (ASTM D698).

E. The fill material in each lift shall be compacted to at least 98 percent of the standard Proctor maximum dry density (ASTM D698).

F. Do not place fill during periods of precipitation or in areas of standing water.

3.04 PERIMETER ROAD AT TOP OF BERM

A. The **CONTRACTOR** shall construct a roadway at the top of the berm consisting of a 10-inch lift of lime rock, to the lines and grades shown on the Drawings.

B. Lime rock shall be obtained from an off-site borrow source and the material shall be approved by **OWNER**.

C. The as-placed moisture content of general fill shall be within 5 percent of optimum moisture content as determined from the Standard Proctor Compaction Test (ASTM D698).

D. The fill material in each lift shall be compacted to at least 98 percent of the standard Proctor maximum dry density (ASTM D698).

3.05 SURVEY CONTROL

Survey the limits and elevations of excavations, subgrade, reinforcing geotextile, top of the compacted fill over reinforcing geotextile, pond berms, anchor trenches, and limits of geomembrane, in accordance with Section 01050.

3.06 TOLERANCES

Perform the earthwork construction to within ±0.1 feet of the grades indicated on the Drawings, unless otherwise required within the Technical Specifications or as approved by the **ENGINEER**.

3.07 QUALITY CONTROL

A. Field density tests shall be made by **OWNER** when and where required to ensure that the compaction specified for the fill is obtained. If field density tests indicate compaction to be less than that specified herein, the **CONTRACTOR** shall continue to compact the material until further test results indicate the specified density has been attained.

B. The method of compacting backfill material for the pond berms shall be at the **CONTRACTOR's** option, subject to the approval of **OWNER**, provided the compaction requirements hereinbefore specified are obtained. If tests for in place density consistently fail to meet the requirements, **OWNER** may require the **CONTRACTOR** to change his method of compaction without claiming additional compensation.

C. Soil testing will be performed by one or more of the following methods:

Parameters	ASTM Standard Number
Standard Proctor Compaction	D698
Field Moisture/Density	D2937, Drive Cylinder Method D6938, Nuclear Method D2167, Rubber Balloon Method D1556, Sand-Cone Method
Particle Size	D422
Percent Passing 200 sieve	D1140
Laboratory Moisture Content	D2216
Atterberg Limits	D4318

END OF SECTION

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SECTION 02271

LIMEROCK ROAD

PART 1 - GENERAL

1.01 SCOPE OF WORK

A. The Work under this section includes the construction of a limerock road for the FGD Pond area, including soil fill and a compacted limerock final surface, as shown on the construction drawings.

B. Key elevations are shown on the drawings for the road. The **CONTRACTOR** shall construct all Work specified herein in accordance with these elevations.

1.02 REFERENCES

FDOT Specifications Section 911 for Limerock Material.

1.03 RELATED SECTIONS

02200 EARTHWORK

PART 2 - MATERIALS

2.01 SOIL FILL

FGD Blowdown Ponds will be constructed of soil fill as described in Section 02200, Earthwork. The limerock road described herein to be constructed on top of the soil berms and along the ramp, as shown on the drawings.

2.02 LIMEROCK

A. Sources of limerock material will be obtained by the **CONTRACTOR**. Off-site mineral aggregate characteristics shall be furnished by the **CONTRACTOR** as obtained from the supplier/source of the material.

B. The minimum of carbonates of calcium and magnesium in the limerock material shall be 70 percent. The maximum percentage of water-sensitive clay mineral shall be 3. The liquid limit shall not exceed 35 and the material shall be non-plastic. Information confirming these values shall be provided by the supplier/source, with all testing under the direction of the supplier.

C. Limerock material shall not contain cherty or other extremely hard pieces, or lumps, balls or pockets of sand or clay size material in sufficient quantity as to be detrimental to the proper bonding, finishing, or strength of the limerock.

D. At least 97 percent (by weight) of the material shall pass a 3 ½-inch sieve and the material shall be graded uniformly down to dust. The fine material shall consist entirely of dust of fracture. All crushing or breaking-up, which might be necessary in order to meet such size requirements, shall be done before the material is placed on the road.

E. The following testing shall be performed by the **CONTRACTOR** on both the on-site and off-site limerock materials and results will be provided to **OWNER** prior to placement of the material:

- Natural moisture content (1 test per 10,000 cu. yds.);
- Grain size distribution (1 test per 10,000 cu. yds.);
- Standard proctor (1 test per 10,000 cu. yds.).

PART 3 - EXECUTION

3.01 GENERAL

The **CONTRACTOR** may use any method and equipment that he demonstrates, to the satisfaction of **OWNER**, will accomplish the placement of the soil fill and limerock for the purposes of constructing an access road in conformance with the requirements of the specifications and the construction drawings. The **CONTRACTOR** shall construct the access road to the lines and grades shown on the construction drawings, or as directed by **OWNER**.

3.02 SOIL FILL PLACEMENT

Soil fill for the FGD Blowdown Pond berms shall be placed as described in Section 02200, Earthwork. The limerock road described herein to be constructed on top of the soil berms and along the ramp, as shown on the drawings.

3.03 LIMEROCK PLACEMENT

A. All limerock material shall be obtained from an off-site borrow source(s), and the material shall be approved by the **OWNER**.

B. Limerock material shall be spread uniformly. Remove all segregated areas of fine or coarse rock and replace with properly graded rock.

C. Limerock shall be placed such that the compacted thickness is a minimum of 12 inches.

D. When the material does not have the proper moisture content to ensure the required density, wet or dry it as required. When adding moisture, uniformly mix it in by disking to the full depth of the course.

E. Material shall be compacted to not less than 95 percent of the maximum dry density as determined by the Standard Proctor Compaction Test (ASTM D698).

3.04 QUALITY CONTROL

A. Field density tests shall be made by the **OWNER** when and where required to ensure that the compaction specified for the limerock is obtained. If field density tests indicate compaction to be less than that specified herein, the **CONTRACTOR** shall continue to compact the material until further test results indicate the specified density has been attained at no additional cost to the **OWNER**.

B. The method of compacting backfill material shall be at the **CONTRACTOR's** option, subject to the approval of **OWNER**, provided the compaction requirements hereinbefore specified are obtained. If tests for in-place density consistently fail to meet the requirements, **OWNER** may require the **CONTRACTOR** to change his method of compaction without claiming additional compensation.

C. Limerock testing will be performed by one or more of the following methods:

Parameters	ASTM Standard Number.
Standard Proctor Compaction	D698
Field Moisture/Density	D2937, Drive Cylinder Method D2922 or D3017, Nuclear Method D1556, Sand-Cone Method
Particle Size	D422
Percent Passing Number 200 sieve	D1140
Laboratory Moisture Content	D2216
Atterberg Limits	D4318

END OF SECTION

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SECTION 02275

RIPRAP

PART 1 - GENERAL

1.01 SCOPE

Provide all labor, materials, services, equipment and transportation required to place riprap for the construction of the spillway as shown on the Drawings.

1.02 REFERENCES

Florida Department of Transportation (DOT) Standard Specifications, Section 530.

PART 2 - MATERIALS

A. Riprap shall be composed of rubble consisting of broken stone or broken concrete.

B. Riprap shall consist of hard, durable, subangular material. It shall be free from any considerable amount of flat, laminated or elongated particles; and shall be free from cracks, overburden shells, clay, organic matter, or other deleterious matter.

C. The riprap shall sustain a loss of not more than 40 percent after 500 revolutions in the ASTM abrasion test (Los Angles machine - ASTM C535), and shall pass the soundness test (ASTM C88). Stone riprap shall have a minimum specific gravity of 2.50, as defined by ASTM C127.

D. The riprap shall be composed of an evenly distributed mixture such that 50 percent of the mixture by weight shall be larger than the D_{50} size of 6-inches. The diameter of the largest stone size in such a mixture shall be 2.0 times the D_{50} size (12-inches). The diameter of the smallest stone size in such a mixture shall be 0.3 times the D_{50} size (1.8-inches).

E. The breadth or thickness of a single stone shall not be less than 1/3 its length.

F. The area for riprap will be lined with non-woven geotextile meeting the Specifications, Section 13060.

PART 3 - EXECUTION

3.01 PLACEMENT

A. The non-woven geotextile shall be in place prior to placing the riprap in the areas indicated on the Drawings.

B. Riprap shall be dumped into place forming a compact layer conforming to the neat lines and thickness as shown on the Drawings. Ensure that rubble does not segregate so that smaller pieces evenly fill the voids between the larger pieces.

C. Riprap shall be placed in a manner that will not damage non-woven geotextile, utilities or other facilities. Riprap shall not be dropped from a height exceeding three feet.

END OF SECTION

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SECTION 02540

EROSION AND SEDIMENTATION CONTROL

PART 1 - GENERAL

1.01 SCOPE

Work to be performed under this Section refers to temporary vegetation cover, mulching, drainage ditches, silt fencing, and other erosion control measures to be implemented or installed at the construction site and all areas disturbed during construction. In addition to the requirements of these Specifications, the **CONTRACTOR** will comply with all local laws, rules and regulations and all other federal, state and local requirements for erosion and sedimentation control.

1.02 GENERAL

The **CONTRACTOR** shall comply with the highest erosion and sedimentation controls standards, whether they are federal, state, or local.

PART 2 – PRODUCTS

2.01 MATERIALS - GENERAL

All materials such as seeds, mulch, sod, and silt fencing shall conform to these Specifications and those of all applicable federal, state, and local requirements. The **CONTRACTOR** shall prepare a submittal of all proposed materials for review and approval by the **OWNER** at least 30 days prior to the scheduled start of construction.

PART 3.0 – EXECUTION

3.01 GENERAL

A. Silt fences shall be placed prior to and during grading and excavation operations. Disturbed areas shall be stabilized by seeding, mulching or sodding.

B. All erosion and sediment control practices shall meet all applicable federal, state and local standards where the Work is being performed.

C. Once permanent erosion protection is in place and established, the **CONTRACTOR** shall remove any temporary erosion protection and regrade or recontour, as necessary, to cause as little disturbance as possible and to restore the area to the design grades.

3.02 SILT FENCE

A. The **CONTRACTOR** shall install silt fence around the entire perimeter of the project area (see Drawings) and across all disturbed areas with slopes greater than 2 percent at a maximum spacing of 200 feet (as measured perpendicular to slope).

B. The **CONTRACTOR** shall install silt fence in accordance with the manufacturer's installation procedures. An Installation Plan will be submitted to the **OWNER** for approval at least 14 days prior to the scheduled start of installation.

END OF SECTION

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SECTION 02560

TOPSOIL, SEEDING, AND MULCHING

PART 1 – GENERAL

1.01 DESCRIPTION OF WORK

Scope of Work: The **CONTRACTOR** shall furnish all labor, materials, equipment, and incidentals necessary and place topsoil finish grade, seed, and maintain all seeded areas as specified herein including all areas disturbed by the **CONTRACTOR's** operations except on areas of the sideslope which shall be grassed with sod.

1.02 GUARANTEE

All restoration and revegetation work shall be subject to the one (1) year guarantee period of the Contract.

PART 2 – PRODUCTS

2.01 MATERIALS

A. Topsoil.

1. General: Imported, natural, friable, sandy loam, obtained from well drained areas, free from objects larger than 1 inch maximum dimension, and free of subsoil, roots, grass, other foreign matter, hazardous or toxic substances, and deleterious material that may be harmful to plant growth or may hinder grading, planting, or maintenance. Granular fill may be used as topsoil layer, if properly amended and meets the following topsoil mechanical requirements:

Component	Max. Percentage	Min. Percentage
Sand	90 percent	50 percent
Silt	50 percent	
Clay	25 percent	5 percent
Organic Matter		1.5 percent (AASHTO T190)

2. The **CONTRACTOR** shall take at least five representative topsoil samples to County Agriculture Extension Service or similar service for soil analysis. Based on the test results and recommendations by the extension service, lime and fertilizer shall be added to amend the topsoil.

3. The **CONTRACTOR** shall submit the soil test results and recommendations from the extension service to the **ENGINEER** for review prior to any application.

4. For bidding purposes, the **CONTRACTOR** shall assume at least one ton of dolomate per acre and ½-ton of fertilizer per acre will be added. The actual amendment rate will vary from the assumed rates and shall be based on the soil test results. No additional compensation will be made to the **CONTRACTOR** for the differences in amendment rate.

B. Lime.

1. Composition: Ground limestone with not less than 85 percent total carbonate ASTM C602-90.

2. Gradation:

a. Minimum 50 percent passing No. 100 sieve.

b. Minimum 90 percent passing No. 20 sieve.

c. Coarser material acceptable, provided rates of application are increased proportionately on basis of quantities passing No. 100 sieve.

C. Fertilizer shall be complete commercial fertilizer, 10-10-10 grade. It shall be delivered to the site in the original unopened containers, each showing the manufacturer's guaranteed analysis. Store fertilizer so that when used it shall be dry and free flowing.

D. Seed shall be from the same or previous year's crop; each variety of seed shall have a percentage of germination not less than 90, a percentage of purity not less than 85, and shall have not more than one percent weed content.

E. Seed shall be delivered in sealed containers bearing the dealer's guaranteed analysis.

F. Mulch shall be clean small-grain straw.

PART 3 – EXECUTION

3.01 INSTALLATION

A. Topsoil shall be placed to a minimum depth of 5 inches for sod and 6 inches for seed.

B. Seed shall be a Scarified Argentine Bahia applied at a rate of 400 pounds per acre.

C. Lime shall be applied at the rate necessary to achieve a pH of 5.5 to 6.5.

D. Fertilizer shall be applied at the rate of 800 pounds per acre or as recommended.

E. The subgrade of all areas to receive topsoil and seed shall be raked and all rubbish, sticks, roots, and stones larger than 2 inches shall be removed. Topsoil shall be spread and lightly compacted to finished grade. Compacted topsoil shall not be less than the depth specified. No topsoil shall be spread in water or while frozen or muddy.

F. After the topsoil is placed and before it is raked to true lines and rolled, limestone shall be spread evenly over topsoil surface and thoroughly incorporated with topsoil. Lime shall be added in sufficient quantity to provide a soil pH of 5.5 to 6.5. If pH is above limits, apply a suitable soil amendment to bring pH into compliance.

G. Fertilizer shall be uniformly spread and immediately mixed with the upper 2 inches of topsoil.

H. Immediately following this presentation, the seed shall be uniformly applied and lightly raked into the surface. Lightly roll the surface and water with fine spray.

I. All seeded areas shall be mulched with clean small-grain straw at a rate of 1-1/2 to 2 tons per acre.

J. The **CONTRACTOR** shall keep all seeded areas watered and in good condition, reseeding if and when necessary, until a good, healthy, uniform growth is established over the entire area seeded, and shall maintain these areas in an approved condition until final acceptance of the Contract.

K. On slopes, the **CONTRACTOR** shall provide against washouts by an approved method. Any washout which occurs shall be regraded and reseeded at the **CONTRACTOR's** expense until good grass is established.

L. The **CONTRACTOR** shall maintain the areas in grass in a neat manner by watering, mowing, raking clippings and leaves, and appurtenances until the project is completed, as required.

END OF SECTION

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SECTION 02770

LLDPE GEOMEMBRANE LINER

PART 1-GENERAL

1.1 SCOPE

A. This Section includes the requirements for materials, installation and testing for geomembrane liner for installation in the FGD Blowdown Pond.

B. The liner system geomembrane shall consist of minimum 60-mil thick, textured, linear low-density polyethylene (LLDPE) sheet.

1.2 REFERENCES

A. Latest version of American Society for Testing and Materials (ASTM) Standards:

1. ASTM D638 — Standard Test Method for Tensile Properties of Plastics.

2. ASTM D746 — Standard Test Method for Brittleness, Temperatures of Plastics and Elastomers by Impact.

3. ASTM D792 — Standard Test Methods for Specific Gravity (Relative Density) and Density of Plastics by Displacement.

4. ASTM D1004 — Standard Method of Initial Tear Resistance of Plastic Film and Sheeting.

5. ASTM D1204 — Standard Plastics Test Method for Lineal Dimensional Changes of Nonrigid Thermoplastic Sheeting or Film at Elevated Temperature.

6. ASTM D1238 — Standard Test Method for Flow Rates of Thermoplastics by Extrusion Plastometer.

7. ASTM D1505 — Standard Test Methods for Density of Plastics by Density-Gradient Technique.

8. ASTM D1603 — Standard Test Method for Carbon Black in Olefin Plastics.

9. ASTM D3895 — Test Method for Oxidative Induction Time of Polyolefins by Thermal Analysis.

10. ASTM D4833 — Test Method for Index Puncture Resistance of Geotextiles, Geomembranes, and Related Products.

11. ASTM D5321 — Test Method for Determining the Coefficient of Soil and Geosynthetic or Geosynthetic and Geosynthetic Friction by Direct Shear Method.

12. ASTM D5323 Practice for Determination of 2% Secant Modulus for Polyethylene Geomembranes.

13. ASTM D5397 Standard Test Method for Evaluation of Stress Crack Resistance of Polyolefin Geomembranes Using Notched Constant Tensile Load Test.

14. ASTM D5596 Recommended Practice for Microscopical Examination of Pigment Dispersion in Plastic Compounds.

15. ASTM D5199 Standard Test Method for Measuring the Thickness of Smooth Geomembrane.

16. ASTM D6392 Test Methods for Determining the Integrity of Nonreinforced Geomembrane Seams Produced Using Thermo-Fusion Methods.

17 ASTM D6693 Test Method for Determining Tensile Properties of Nonreinforced Polyethylene and Nonreinforced Flexible Polypropylene Geomembranes.

B. Latest version of Federal Test Method Standard (FTMS).

1. FTMS 101/2065 Federal Test Method Standard for Puncture Resistance and Elongation Test (1/8 Inch Radius Probe Method).

C. Latest version of Geosynthetic Research Institute (GRI) standards.

1. GRI GM11 Accelerated Weathering of Geomembranes using a Fluorescent UVA-Condensation Exposure Device

2. GRI GM12 Measurement of the Asperity Height of Textured Geomembranes Using a Depth Gage.

3. GRI GM17 Test Properties, Testing Frequency and Recommended Warranty for Linear Low Density Polyethylene (LLDPE) Smooth and Textured Geomembranes.

1.03 SUBMITTALS

A. Submit the following information to the **OWNER** and/or **ENGINEER** for review not less than 20 calendar days prior to geomembrane use.

1. Geomembrane Manufacturer capabilities, including:

a. daily production capacity available for this project; and

b. manufacturing quality control procedures.

2. A list of 10 completed facilities for which the Manufacturer has manufactured a minimum total of 10,000,000 square feet of polyethylene geomembrane. Provide the following information for each facility:

   a. Name, location, purpose of facility, and date of installation;

   b. Names of owner, project manager, design engineer, and installer; and

   c. Thickness and surface area of geomembrane provided.

3. Origin (resin supplier's name, resin production plant) and identification (brand name, number) of the polyethylene resin used.

4. Certification of minimum average roll values (95 percent lower confidence limit) for physical, mechanical, and environmental properties and the corresponding test procedures for the geomembrane properties listed in the table in Attachment A. Submit values that are specific to the resin used in manufacture.

5. Certification that welding rod is compatible with the specifications and consists of the same resin as the geomembrane.

6. Manufacturer Warranty as specified in this Section.

B. Submit to the **OWNER** and/or **ENGINEER** for review not less than 30 calendar days prior to geomembrane use the following documentation on the resin used to manufacture the geomembranes:

1. Copies of quality control certificates issued by the resin supplier including the production dates and origin of the resin used to manufacture the geomembrane for this project.

2. Results of tests conducted by the Manufacturer to verify the quality of the resin used to manufacture the geomembrane rolls assigned to the project.

3. Certification that no reclaimed polymer is added to the resin during the manufacturing of the geomembrane to be used for this project.

C. Submit to the **OWNER** and/or **ENGINEER** for review the following documentation on geomembrane roll production at least 14 calendar days prior to transporting any geomembrane to the site:

1. Manufacturing certificates for each shift's production of geomembrane, signed by the Manufacturer quality control manager, and notarized.

2. Certificate shall include:

   a. Roll numbers and identification;

   b. Sampling procedures; and

c. Results of Manufacturer quality control tests, including descriptions of the test methods used (the Manufacturer quality control tests to be performed are given in Part 2 of this Section).

D. Submit to the **OWNER** and/or **ENGINEER** for review the following information from the **INSTALLER** at least 14 calendar days prior to mobilization of the **INSTALLER** to the site:

1. Layout drawings showing the installation layout identifying geomembrane panel configurations, dimensions, details, locations of seams, as well as any variance or additional details which deviate from the Construction Drawings. The layout drawings shall be adequate for use as a construction plan and shall include dimensions, details, etc. The layout drawings, as modified and/or approved by the **OWNER** and/or **ENGINEER**, shall become part of the contract.

2. Installation schedule.

3. Copy of **INSTALLER**'s letter of approval or license by the Manufacturer.

4. Installation capabilities, including:

a. Information on equipment proposed for this project;

b. Average daily production anticipated for this project; and

c. Quality control procedures to include quality control organization.

5. A list of 10 completed facilities for which the **INSTALLER** has installed a minimum of 5,000,000 square feet of polyethylene geomembrane. The following information shall be provided for each facility:

a. The name and purpose of the facility, its location, and dates of installation;

b. The names of the **OWNER**, project manager, and geomembrane manufacturer;

c. Name and qualifications of the supervisor of the installation crew;

d. Thickness and surface area of installed geomembrane;

e. Type of seaming and type of seaming apparatus used; and

f. Duration of installation.

6. Resumes of the Installer Superintendent and quality control chief to be assigned to this project, including dates and duration of employment.

7. Resumes of all personnel who will perform seaming operations on this project, including dates and duration of employment.

8. Evidence that the installation crew has the following experience.

    a. The Superintendent shall have supervised the installation of a minimum of 5,000,000 square feet of polyethylene geomembrane.

    b. At least one seamer shall have experience seaming a minimum of 500,000 square feet of polyethylene geomembrane using the same type of seaming apparatus to be used at this site. Seamers with such experience will be designated “master seamers” and shall provide direct supervision over less experienced seamers.

    c. All other seaming personnel shall have seamed at least 100,000 square feet of polyethylene geomembrane using the same type of seaming apparatus to be used at this site. Personnel who have seamed less than 100,000 square feet of seams shall be allowed to seam only under the direct supervision of the master seamer or Superintendent.

E. Submit to the **OWNER** and/or **ENGINEER** for review at least 14 days prior to geomembrane placement, a Certificate of Calibration less than 12 months old for the field tensiometer. Tensiometer shall be calibrated within one year of date of test. Calibration shall be traceable to national or industry recognizable standards where possible.

F. During installation, submit to the **OWNER** and/or **ENGINEER** daily reports summarizing the day’s activities. These reports will contain, at a minimum, the following items: weather conditions; areas worked; daily production (quantities installed and seam lengths); personnel on site; equipment used; type and results of quality control testing completed, including results of all non-destructive seam strength tests; results of all destructive seam tests; documentation of tracking, repair, and testing of all seam reconstructed as a result of failed non-destructive or destructive testing; problems encountered during construction; and resolution of problems.

G. Upon completion of geomembrane installation, submit to the **OWNER** and/or **ENGINEER** the following:

1. Certification that material installation is complete and in accordance with the Specifications.

2. Record panel layout diagram.

3. Summary and log of all laboratory quality control testing completed by the **CONTRACTOR/INSTALLER**.

4. Summary and log of all field quality control testing completed by the **CONTRACTOR/INSTALLER.**

5. Statement of material warranty from the geomembrane manufacturer.

6. Statement of workmanship warranty from the **CONTRACTOR/ INSTALLER**.

PART 2-PRODUCTS

2.01 RESIN

A. Provide geomembrane manufactured from new, first-quality polyethylene resin. Do not add reclaimed polymer to the resin. The use of polymer recycled during the manufacturing process is permitted if performed with appropriate cleanliness and if the recycled polymer during the manufacturing process does not exceed 2 percent by weight of the total polymer weight.

B. Use LLDPE resin having the following properties:

1. Density: 0.915 minimum (0.939 maximum) (ASTM D792 Method B, or ASTM D1505)

2. Melt Flow Index: 1.0 g/10 min., maximum (ASTM D1238, 190^{o}C, 2.16 kg)

2.02 GEOMEMBRANE PROPERTIES

A. Provide 60-mil LLDPE geomembrane having properties that comply with the required values shown in the table in Attachment A. Material shall be 60-mil LLDPE textured geomembrane manufactured by AgruAmerica or equivalent.

B. In addition, provide geomembrane that:

1. Contains a maximum of 1 percent by weight of additives, fillers, or extenders not including carbon black;

2. Does not have striations, pinholes, bubbles, blisters, nodules, undispersed raw materials, or any sign of contamination by foreign matter on the surface or in the interior;

3. Is free of holes, blisters, modules, undispersed raw materials, or any sign of contamination by foreign matter; and

4. Is manufactured in a single layer (thinner layers shall not be welded together to produce the final required thickness).

2.03 MANUFACTURING QUALITY CONTROL

A. Resin:

1. Sample and test resin at a minimum frequency of one test per rail car (200,000 lbs) to demonstrate that the resin complies with the requirements of this Section. Perform tests on resin after the addition of additives to the virgin resin. Certify in writing that the resin meets the requirements of this Section.

2. Do not use any nonconforming resin.

B. Rolls:

1. Continuously monitor (including continuous spark testing) for geomembrane defects during manufacture.

2. Do not supply geomembrane that exhibits any defects.

3. Regularly monitor for geomembrane thickness during manufacture.

4. Do not supply geomembrane that fails to meet the specified thickness.

5. Sample and test the geomembrane, to demonstrate that its properties conform to the values specified in the table in Attachment A. The tests and frequencies are presented in the table in Attachment A.

6. If a geomembrane sample fails to meet the quality control requirements of this Section, sample and test rolls manufactured, in the same resin batch, or at the same time, as the failing roll. Continue to sample and test the rolls until the extent of the failing rolls are bracketed by passing rolls. Do not supply any failing rolls.

C. Permit the CQA Consultant and/or **OWNER's** Representative to visit the manufacturing plant for project specific visits. If possible, such visits will be prior to, or during, the manufacturing of the geomembrane rolls for this project.

2.04 LABELING

A. Label the geomembrane rolls with the following information.

1. Thickness of the material;

2. Length and width of the roll;

3. Name of Manufacturer;

4. Product identification;

5. Lot number; and

6. Roll number.

B. Geomembrane rolls not labeled in accordance with this Section or on which labels are illegible will be rejected and replaced.

2.05 TRANSPORTATION, HANDLING AND STORAGE

A. Deliver geomembranes to the site at least 14 calendar days prior to the planned deployment date, or allow CQA Consultant to obtain samples from the manufacturing facility, to allow the CQA Consultant adequate time to perform conformance testing on the geomembrane samples.

B. Provide proper handling and storage of the geomembrane at the site. Protect the geomembrane from excessive heat or cold, dirt, puncture, cutting, or other damaging or deleterious conditions. Provide any additional storage procedures required by the Manufacturer.

C. Store geomembrane rolls on prepared surface. Do not store geomembrane rolls in mud, standing water or in areas prone to flooding. Do not store more than 3 rolls high.

PART 3-EXECUTION

3.01 GEOMEMBRANE DEPLOYMENT

A. General:

1. The **CONTRACTOR** shall produce layout drawings prior to geomembrane deployment. These drawings shall indicate the geomembrane configuration, dimensions, details, locations of seams, etc. The layout drawings must be approved by the **OWNER** and/or **ENGINEER** prior to the installation of any geomembranes. The layout drawings, as modified and/or approved by the **OWNER** and/or **ENGINEER**, shall become part of these specifications.

2. Do not deploy geomembrane until the layout drawings are approved by the **OWNER** and/or **ENGINEER**.

3. Do not deploy geomembranes until **CQA CONSULTANT** completes conformance evaluation of the geomembrane.

4. Deploy each geomembrane panel in accordance with the approved layout drawings.

B. Earthwork

1. Geomembrane Subgrade Preparation: **CONTRACTOR** shall be responsible for preparation of the soil subgrade and underlying geosynthetic reinforcement layers upon which the liner is to be installed. **CONTRACTOR** and **CQA CONSULTANT** shall approve the subgrade before geomembrane installation. The **CONTRACTOR** shall furnish a signed Certificate of Subgrade Acceptance prior to the installation over a particular area indicating acceptance of the subgrade in that area. The following conditions shall be a minimum for the subgrade:

1. No foreign objects such as rocks, sticks, glass, sharp objects, stones larger than ½-inch diameter and any other harmful materials shall be on the area to be lined.

2. The subgrade surface shall have a smooth, finished, even surface (to ensure that the area is free of irregularities), free from loose earth and abrupt changes in grade.

3. Perimeter anchor trenches shall be excavated to the lines and width shown on the plans prior to geomembrane placement.

4. The subgrade surface shall not be excessively wet or dry or in any condition which will impede proper installation. Under no circumstances shall the geomembrane be placed over standing water on the subgrade.

C. Field Panel Identification:

1. A geomembrane field panel is a roll or a portion of roll cut in the field.

2. Give each field panel an identification code (number or letter-number). This identification code shall be agreed upon by the **CQA CONSULTANT** and the **CONTRACTOR**.

D. Field Panel Placement:

1. Place each geomembrane panel one at a time and seam each panel immediately after its placement.

2. Do not place geomembrane panels when the ambient temperature is below 40° Fahrenheit (F), unless authorized in writing by the **OWNER** and/or **ENGINEER**.

3. Do not place geomembranes during any precipitation, in the presence of heavy fog or dew, in an area of ponded water, or in the presence of high wind (generally exceeding 20 miles per hour).

4. Ensure that:

   a. No vehicular traffic drives directly on the geomembrane.

   b. Equipment used does not damage the geomembrane by handling, trafficking, or leakage of hydrocarbons (i.e., fuels).

   c. Personnel working on the geomembrane do not smoke, bring glass onto the geomembrane, or engage in other activities that could damage the geomembrane.

   d. The method used to unroll the panels does not scratch or crimp the geomembrane and does not damage lower geosynthetics or the supporting soil.

e. The method used to place the panels minimizes wrinkles (especially differential wrinkles between adjacent panels). The method used to place the panels results in intimate contact with the underlying geomembrane. Adjust or repair any area of geomembrane wrinkles where the wrinkle height, measured perpendicular to the slope during the hottest portion of the day, is more than 4 inches.

f. The method used to place the panels does not cause the panels to lift up or trampoline during the coolest portion of the day.

g. The geomembrane is anchored or weighted with sandbags, or the equivalent, to prevent damage or uplift from wind. Install sufficient anchoring or weighting to prevent uplift and maintain such system until installation is complete.

5. Replace any field panel or portion thereof that becomes damaged (torn, twisted, or crimped). Remove from the work area damaged panels or portions of damaged panels.

E. Do not install geomembrane between one hour before sunset and one hour after sunrise unless approved by the **OWNER** and/or **ENGINEER**.

3.02 FIELD SEAMING

A. Personnel shall be experienced as specified in this Section. Do not perform seaming unless a "master seamer" and the **CQA CONSULTANT** are on-site.

B. On slopes exceeding 10 percent, orient seams parallel to the line of maximum slope (i.e., oriented down, not across, the slope). Minimize the number of seams in corners and at odd-shaped geometric locations. No horizontal seam shall be less than 5 feet from the toe or crest of slopes except where approved by the **OWNER** and/or **ENGINEER**. Do not locate seams at an area of potential stress concentration. Where horizontal seams are allowed (on slopes less than 10 percent), overlap seams in a shingle fashion such that the upper sheet is over the lower sheet in the direction of slope.

C. Weather Conditions for Seaming:

1. Do not seam geomembrane at ambient temperatures below 40°F or above 104°F, unless authorized in writing by the **OWNER** and/or **ENGINEER**.

2. Measure ambient temperatures between 0 to 6 inches above the geomembrane surface.

3. In all cases, the geomembrane seam areas shall be dry and protected from wind.

D. Overlapping and Temporary Bonding:

1. Sufficiently overlap geomembrane panels for welding and to allow peel tests to be performed on the seam. Any seams that cannot be destructively tested because of insufficient overlap shall be considered a failing seam.

2. Control the temperature of the air at the nozzle of heat bonding apparatus such that the geomembrane is not damaged.

E. Seam Preparation:

1. Prior to seaming, clean the seam area and ensure that area to be bonded is free of moisture, dust, dirt, debris of any kind and foreign material.

2. If seam overlap grinding is required, complete the process according to the Manufacturer's instructions or within 20 minutes of the seaming operation. Do not grind to a depth that exceeds 5 percent of the geomembrane thickness. Grinding marks shall not appear beyond 1/8 inch of the extrudate after it is placed.

3. Align seams with the fewest possible number of wrinkles and "fish mouths".

F General Seaming Requirements:

1. Extend seams to the outside edge of panels to be placed in the anchor trench.

2. If required, place a firm substrate such as a flat board or similar hard surface directly under the seam overlap to achieve proper support.

3. Cut fish mouths or wrinkles at the seam overlaps along the ridge of the wrinkle to achieve a flat overlap. Seam the cut fish mouths or wrinkles and patch any portion where the overlap is less than 6 inches with an oval or round patch of geomembrane that extends a minimum of 6 inches beyond the cut in all directions.

4. Place the electric generator used for power supply to the welding machines outside the area to be lined or mount it on soft tires such that no damage occurs to the geomembrane. Properly ground the electric generator. Place a smooth insulating plate or fabric beneath the hot welding apparatus after use.

G. Seaming Process:

1. Approved processes for field seaming are extrusion welding and fusion welding. The primary method of welding shall be fusion. Seaming equipment shall not damage the geomembrane. Use only geomembrane Manufacturer-approved equipment.

2. Extrusion Equipment and Procedures:

   a. Maintain at least one spare operable seaming apparatus on site.

   b. Equip extrusion welding apparatus with gauges giving the temperature in the apparatus and at the nozzle.

   c. Prior to beginning a seam, purge the extruder until all heat-degraded extrudate has been removed from the barrel. Whenever the extruder is stopped, purge the barrel of all heat-degraded extrudate.

3. Fusion Equipment and Procedures:

   a. Maintain at least one spare operable seaming apparatus on site.

   b. Fusion-welding apparatus shall be automated self-propelled devices equipped with gauges giving the applicable temperatures and pressures.

   c. Fusion-welding apparatus shall produce a double-track seam.

   d. Abrade the edges of cross seams to a smooth incline (top and bottom) prior to extrusion welding.

H. Trial Seams:

1. Make trial seams on excess pieces of geomembrane to verify that seaming conditions are adequate. Conduct trial seams on the same material to be installed and under similar field conditions as production seams. Conduct trial seaming at the beginning of each seaming period, and at least once each five hours, for each seaming apparatus used that day prior to seaming. Also, each seamer shall make at least one trial seam each day, for each day that seaming is performed by that seamer. Conduct trial seaming under the same conditions as the actual seaming. Prepare trial seams that are at least 5 feet long by 1 foot wide (after seaming) with the seam centered lengthwise for fusion equipment and at least 3 feet long by 1 foot wide for extrusion equipment. Prepare seam overlap as indicated in Part 3.02.D of this Section.

2. Cut four specimens, each 1 inch wide, from the trial seam sample. Test two specimens in shear and two in peel, using a field tensiometer. The table in Attachment B includes the minimum values for passing seam tests. The test specimens shall not fail in the seam. If a specimen fails, repeat the entire operation. If the additional specimen fails, do not accept the seaming apparatus or seamer until the deficiencies are corrected and two consecutive successful trial seams are achieved. A seamer may start production seaming prior to testing of the trial seams. However, in the event the trial seam fails, all production seams by the seamer shall be considered a failed seam.

I. Nondestructive Seam Continuity Testing:

1. Nondestructively test for continuity field seams over their full length. Perform continuity testing as the seaming work progresses, not at the completion of field seaming. Complete any required repairs in accordance with Part 3.02.K of this Section. Apply the following procedures:

   a. Use vacuum testing for extrusion welds or single-track fusion seams; and

   b. Use air pressure testing for double-track fusion seams.

2. Vacuum Testing:

   a. Use the following equipment:

      i. A vacuum box assembly consisting of a stiff housing, a transparent viewing window, a soft neoprene gasket attached to the bottom, port hole or valve assembly, and a vacuum gauge.

      ii. A system for applying 5 pounds per square inch (psi) gauge suction to the box.

      iii. A bucket of soapy solution and applicator.

   b. Follow these procedures:

      i. Energize the vacuum pump and reduce the tank pressure to 5±1 psi gauge.

      ii. Wet an area of the geomembrane seam larger than the vacuum box with the soapy solution.

      iii. Place the box over the wetted area.

      iv. Close the bleed valve and open the vacuum valve.

      v. Ensure that a leak tight seal is created.

      vi. Examine the geomembrane through the viewing window for the presence of soap bubbles for not less than 10 seconds.

      vii. If no bubbles appear after 10 seconds, close the vacuum valve and open the bleed valve, move the box over the next adjoining area with a minimum 3 inch overlap, and repeat the process.

      viii. Mark all areas where soap bubbles appear with a marker that will not damage the geomembrane and repair in accordance with Part 3.02.K of this Section.

3. Air Pressure Testing:

a. Use the following equipment:

i. An air pump (manual or motor driven) or air reservoir, equipped with a pressure gauge, capable of generating and sustaining a pressure between 25 and 30 pounds per square inch;

ii. A rubber hose with fittings and connections; and

iii. A hollow needle, or other approved pressure feed device.

b. Follow these procedures:

i. Seal both ends of the seam to be tested.

ii. Insert needle, or other approved pressure feed device, into the tunnel created by the fusion weld.

iii. Insert a protective cushion between the air pump and the geomembrane.

iv. Energize the air pump to a pressure between 25 and 30 pounds per square inch, close valve, and sustain the pressure for not less than 5 minutes.

v. If loss of pressure exceeds the specified value below, or does not stabilize, locate faulty area and repair in accordance with Part 3.02.K of this Section:

Geomembrane Sheet Thickness	Maximum Allowable Pressure Loss
60 mil	3 psi

vi. Cut opposite end of air channel from pressure gauge and observe release of pressure to ensure air channel is not blocked.

vii. Remove needle, or other approved pressure feed device, and seal both ends in accordance with the Part 3.02.K of this Section.

J. Destructive Testing:

1. Perform destructive seam tests to evaluate seam strength and integrity Perform destructive testing as the seaming work progresses, not at the completion of field seaming.

2. Sampling and Testing:

a. Collect destructive test samples at a minimum average frequency of one test location per 500 feet of seam length and at additional locations of suspected nonperformance. The CQA Consultant will select test locations, including locations with evidence of excess geomembrane crystallinity, contamination, offset seams, or any other evidence of inadequate seaming.

b. Cut samples at the locations designated by the CQA Consultant at the time the locations are designated. Number each sample and identify the sample number and location on the panel layout drawing. Immediately repair all holes in the geomembrane resulting from the destructive seam sampling in accordance with the repair procedures described in Part 3.03.K of this Section. Test the continuity of the new seams in the repaired areas according to Part 3.02.I of this Section.

c. Cut two strips 1 inch wide and 12 inches long with the seam centered parallel to the width from either side of the sample location. Test the two 1-inch wide strips in the field tensiometer in the peel mode. The Table in Attachment B includes the minimum values for passing seam tests. The test specimens shall not fail in the seam. The CQA Consultant may request an additional test in the shear mode. If these samples pass the field test, prepare a laboratory sample at least 1 foot wide by 3.5 feet long with the seam centered lengthwise. Cut the laboratory sample into three parts and distribute as follows:

i. One portion 1 foot long to the Installer;

ii. One portion 1.5 feet long to the CQA Consultant for testing; and

iii. One portion 1 foot long to the **OWNER** and/or **ENGINEER** for archival storage.

3. In the event of failing field or laboratory test results (per values in the Table in Attachment B), the **CONTRACTOR** may reconstruct the entire seam between two passing destructive tests; otherwise, the CQA Consultant will identify the extent of the nonconforming area. Obtain additional samples for testing as requested by the CQA Consultant.

K. Defects and Repairs:

1. Inspect the geomembrane before and after seaming for evidence of defects, holes, blisters, undispersed raw materials, and any sign of contamination by foreign matter. The surface of the geomembrane shall be clean at the time of inspection. Sweep or wash the geomembrane surface if surface contamination inhibits inspection.

2. Test each suspect location, both in seam and non-seam areas, using the methods described in Part 3.02.K of this Section. Repair each location that fails nondestructive testing.

3. Cut and reseam wrinkles not conforming to Part 3.01.C(5)(e) of this Section. Test the seams thus produced like any other seam.

4. Repair Procedures:

   a. Repair any portion of the geomembrane exhibiting a flaw, or failing a destructive or nondestructive test. Use the most appropriate of the available procedures:

      i. Patching, used to repair large holes, tears, undispersed raw materials, and contamination by foreign matter;

      ii. Abrading and reseaming, used to repair small sections of extruded seams;

      iii. Spot seaming, used to repair minor, localized flaws;

      iv. Capping, used to repair long lengths of failed seams;

      v. Topping, used to repair areas of inadequate seams, which have an exposed edge of at least 4 inches; and

      vi. Removing bad seam and replacing with a strip of new material seamed into place (used with long lengths of fusion seams).

   b. When making repairs, satisfy the following:

      i. Abrade surfaces of the geomembrane (no more than 5 percent of the original sheet thickness) that are to be repaired no more than 20 minutes prior to the repair;

      ii. Clean and dry all geomembrane surfaces immediately prior to repair;

      iii. Only use approved seaming equipment;

      iv. Extend patches or caps at least 6 inches beyond the edge of the defect, and round comers of patches to a radius of at least 3 inches; and

      v. Cut the geomembrane below large caps to avoid potential for water or gas collection between the two sheets.

5. Repair Verification:

a. Test each repair using the methods described in Part 3.02.K. Repairs that pass the nondestructive test are adequate unless the CQA Consultant elects to also perform destructive tests. Re-repair and retest failed tests.

3.03 CREST ANCHORAGE SYSTEM

A. The anchor trench shall be excavated prior to geomembrane placement to the lines, grades, and configuration indicated on the Drawings.

B. Slightly rounded comers shall be provided in the trench where the geomembrane adjoins the trench to avoid sharp bends in the geomembrane.

C. Temporarily anchor each geomembrane panel in the anchor trench at the crest of the slope as soon as the panel is deployed or positioned.

D. Do not entrap loose soil, sand bags, or other materials beneath the geomembrane.

E. Backfill in accordance with the Drawings. Do not damage the geomembrane when backfilling the anchor trench.

3.04 MATERIALS IN CONTACT WITH THE GEOMEMBRANE

A. Take all necessary precautions to prevent damage to the geomembrane during the installation of other components of the pond system.

B. Do not drive equipment directly on the geomembrane.

3.05 PENETRATIONS AND CONCRETE CONNECTIONS

A. Install the geomembrane at penetrations, and connect the geomembrane to penetrating pipes in accordance with the Drawings. Take extreme care while seaming around appurtenances as neither nondestructive nor destructive testing may be feasible in certain areas. Penetrations shall be vacuum tested as the design provides for attaching the geomembrane to a pre-manufactured boot through which the pipe penetrations extend. The welds on the pre-manufactured boot and pipes will be tested and certified by the manufacturer.

B. Install the geomembrane to concrete surfaces in accordance with the Drawings. Care shall be taken to assure that the bolt installation does not tear the liner and that for vertical structures/surfaces, there is sufficient slack in the liner below the connections to allow for expansion and contraction of the liner. Each anchor bolt assembly will include a closed cell neoprene sponge attached to the concrete with neoprene adhesive. The liner will be extended across the neoprene sponge as shown on the Drawings and then covered with a batten strip, followed by a FRP washer and nut. Caulking will be added around the washer for additional sealing.

3.06 SURVEY CONTROL

A. Survey the installed geomembrane liner in accordance with Section 01050.

B. Locate panel seams and intersections as requested by the **CQA CONSULTANT**.

3.07 GEOMEMBRANE ACCEPTANCE

A. The **CONTRACTOR** shall retain all ownership and responsibility of the geomembrane until acceptance by the **OWNER**.

B. The geomembrane will be accepted by the **OWNER** when:

1. The installation is completed;

2. All documentation of installation is completed; and

3. Verification of the adequacy of all field seams and repairs, including associated testing, is complete.

3.08 PROTECTION OF THE WORK

The **CONTRACTOR** shall use all means necessary to protect all prior work and all materials and completed work of other Sections.

ATTACHMENT A

Geomembrane Manufacturer’s Specification Table

Linear Low Density Polyethylene (LLDPE) Geomembrane Specification Table

Property	Test Method	Test Value	Test Frequency
Thickness, nominal, mil		60	per roll
Thickness (min. average), mil	ASTM D5994	57	
Thickness (lowest individual for 8 out of 10 spec.), mil	ASTM D5994	54	
Thickness (lowest individual for 1 out of 10 spec.), mil	ASTM D5994	51	
Asperity Height (min. average), mil	GRI GM12	16	per roll
Density (maximum), g/cc	ASTM D792, Method B	0.939	200,000 lbs (railcar on finished liner)
Tensile Properties (Note 1)	ASTM D6693m Type IV		20,000 lbs
Strength at Break (min. avg.), lb/in. width	2 in/min	168	
Elongation at Break (min. avg.), %	5 specimens in each direction	400	
Tear Resistance (min. avg.), lbs.	ASTM D1004	36	45,000 lbs.
Puncture Resistance (min. avg.), lbs.	ASTM D4833	70	45,000 lbs.
Carbon Black Content (range in %)	ASTM D4812	2 - 3	20,000 lbs
Carbon Black Dispersion (Category)	ASTM D5596	(Note 2)	45,000 lbs.
Oxidative Induction Time, minutes	ASTM D3895, 200^{o}C, 1 atm O_2	$\geq$ 100	200,000 lbs (railcar on finished liner)
Melt Flow Index, g/10 minutes	ASTM D1238, 190^{o}C, 2.16 kg	$\leq$ 1.0	200,000 lbs (railcar on incoming resin)
Over Aging with High Pressure Oxidative Induction Time (min avg), % retained after 90 days	ASTM D5721 ASTM D5885, 150^{o}C, 500 psi O_2	60	per resin formulation
UV Resistance (Note 3) with High Pressure Oxidative Induction Time (min avg), % retained after 1600 days	GRI GM11 ASTM D5885, 150^{o}C, 500 psi O_2	35	per resin formulation
2% Secant Modulus (max.), lb/in.	ASTM D5323	3600	per resin formulation
Axi-Symmetric Break Resistance Strain, % (min.)	ASTM D5617	30	per resin formulation

Notes:

1. Machine direction and cross machine direction average values should be on the basis of 5 test specimen each direction. Break elongation is calculated using a gage length of 2.0 in. at 2.0 in./min.
2. Carbon black dispersion (only neat spherical agglomerates) for 10 different views: 9 in Categories 1 or 2 and 1 in Category 3.
3. The condition of the test should be 20 hr. UV Cycle at 75^{o}C followed by 4 hr. condensation at 60^{o}C.

ATTACHMENT B

Geomembrane Specification Strength Values

TABLE

REQUIRED LLDPE GEOMEMBRANE SEAM PROPERTIES

Properties	**Qualifier**	**Units**	**Specified Values 60-MIL LLDPE**	**Test Method**
Shear Strength[1]				
Fusion Seams	minimum	lb/in	90	ASTM D6392
Extrusion Seams	minimum	lb/in	90	ASTM D6392
Peel Strength				
Fusion Seams	minimum	lb/in	72 FTB[2]	ASTM D6392
Extrusion Seams	minimum	lb/in	75 FTB[2]	ASTM D6392

Notes:

1. Also called "Bonded Seam Strength".
2. Film Tear Bond. Seam separation shall not extend more than 10 percent into the seam. Testing shall be discontinued when the sample has visually yielded. Sample shall conform to a passing configuration as outlined in Figures A-4 (fillet extrusion) and A-6 (double wedge fusion) of the United States Environmental Protection Agency, "Lining of Waste Containment and Other Impoundment Facilities," EPA/600/2-88/052.

END OF SECTION

SECTION 13060

NON-WOVEN GEOTEXTILES

PART 1 - GENERAL

1.01 SCOPE

A. This Section includes the requirements for materials, installation and testing for the non-woven geotextiles to be placed in the construction of the spillway of the FGD Pond at Crystal River Plant.

1.02 REFERENCES

A. Latest version of American Society for Testing and Materials (ASTM) Standards:

1. ASTM D3786 Standard Test Method for Hydraulic Bursting Strength of Knitted Goods and Non-woven Fabric-Diaphragm Bursting Strength Method.
2. ASTM D4355 Standard Test Method for Deterioration of Geotextiles from Exposure to Ultraviolet Light and Water.
3. ASTM D4491 Standard Test Method for Water Permeability of Geotextiles by Permeability.
4. ASTM D4533 Standard Test Method for Trapezoidal Tearing Strength of Geotextiles.
5. ASTM D4632 Standard Test Method for Breaking Load and Elongation of Geotextiles (Grab Method).
6. ASTM D4751 Standard Test Method for Determining Apparent Opening Size of a Geotextile.
7. ASTM D4833 Standard Test Method for Index Puncture Resistance of Geotextiles, Geomembranes, and Related Products.
8. ASTM D4873 Standard Guide for Identification, Storage, and Handling of Geotextiles.
9. ASTM D526 Standard Test Method for Measuring Mass Per Unit Area of Geotextiles.

B. Technical Specifications, Section 02275, Riprap.

PART 2 - PRODUCTS

2.01 MATERIALS

A. Provide non-woven geotextile products with minimum average roll values (95 percent lower confidence limit) meeting or exceeding the required property values listed in Table 1.

B. Provide non-woven geotextiles that are stock products.

C. Provide non-woven geotextiles that are manufactured from first quality polymers, with not more than 20 percent retained polymer used in production.

2.02 MANUFACTURING QUALITY CONTROL

A. Manufacturing quality control tests demonstrating that the non-woven geotextile properties conform to the values listed in Table 1, performed at a minimum frequency of one test per 90,000 square feet of material produced:

Test	Method
Mass per unit area	ASTM D5261
Grab Strength	ASTM D4632
Tear Strength	ASTM D4533
Puncture Strength	ASTM D4833
Burst Strength	ASTM D3786
Apparent opening size	ASTM D4751
Permittivity	ASTM D4491

B. Do not supply any non-woven geotextile roll that does not comply with the manufacturing quality control requirements.

2.03 PACKAGING AND LABELING

A. Supply non-woven geotextiles in rolls wrapped in relatively impermeable and opaque protective wrapping. Wrapping which becomes torn or damaged shall be repaired with similar materials.

B. Mark or tag roll numbers in accordance with ASTM D4873 with the following information:

1. Manufacturer's name;

2. Product identification;

3. Lot or batch number;

4. Roll number; and

5. Roll dimensions.

C. Non-woven geotextile rolls not labeled in accordance with this Section or on which labels are illegible shall be rejected and replaced at no additional cost to the Owner.

2.04 HANDLING AND STORAGE

A. Protect non-woven geotextiles from sunlight, moisture, excessive heat or cold, puncture, mud, dirt, and dust or other damage or deleterious conditions. Follow all geotextile manufacturer recommendations for handling and storage.

B. Store non-woven geotextile rolls on pallets or other elevated structures. Do not store non-woven geotextile rolls directly on the ground.

C. Outdoor storage of rolls shall not exceed the manufacturer’s recommendation.

PART 3-EXECUTION

3.01 PLACEMENT

A. Handle non-woven geotextiles so as to ensure they are not damaged in any way.

B. Take care not to entrap stones, excessive dust, or moisture in the non-woven geotextiles during placement.

3.02 SEAMS AND OVERLAPS

A. Non-woven geotextiles shall be overlapped a minimum of 12 inches.

B. No horizontal seams shall be allowed on slopes.

C. Continuously overlap a minimum of 12 inches.

D. No seaming of non-woven geotextile will be required.

3.03 REPAIR

A. Repair any holes or tears in the geotextiles using a patch made from the same non-woven geotextile material. Extend geotextile patches a minimum of 1 foot beyond the damaged area.

B. Remove any soil or other material that may have penetrated the torn non-woven geotextiles.

TABLE 1

REQUIRED PROPERTY VALUES FOR NON-WOVEN GEOTEXTILE

PROPERTIES	QUALIFIER	UNITS	SPECIFIED[(1)] VALUES	TEST METHOD
Type				
Non-woven needle punched				(-)
Polymer composition	Minimum	%	95 polypropylene or polyester by weight	(-)
Mass per unit area	Minimum	oz/yd^2	16	ASTM D5261
Filter Requirements				
Apparent opening size (O_{95})	Maximum	Mm	0.150	ASTM D4751
Permittivity	Minimum	sec^{-1}	0.7	ASTM D4491
Mechanical Requirements				
Grab strength	Minimum	Lb	390	ASTM D4632[(2)]
Tear strength	Minimum	Lb	150	ASTM D4533[(3)]
Puncture strength	Minimum	Lb	250	ASTM D4833[(4)]
Burst strength	Minimum	Psi	800	ASTM D3786

Notes:

(1) All values represent minimum average roll values.
(2) Minimum of values measured in machine and cross machine directions with 1-inch clamp on Constant Rate of Extension (CRE) machine.
(3) Minimum value measured in machine and cross machine direction.
(4) Tension testing machine with a 1.75-inch diameter ring clamp, the steel ball replaced with 0.31-inch diameter solid steel cylinder with flat tip centered within the ring clamp.
(5) mm = millimeter
% = percent
oz/yd^2 = ounce per square yard
sec = second
lb = pound
psi = pound per square inch

END OF SECTION

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SECTION 13080

REINFORCING GEOTEXTILE

PART 1 - GENERAL

1.01 SECTION INCLUDES

Installation of the reinforcing geotextile to provide reinforcement for the foundation of the FGD Blowdown Ponds. The primary function of the reinforcing geotextile is to provide tensile support beneath the liner should a small (<6 foot diameter) sinkhole develop in the pond bottom subgrade following construction. The reinforcing geotextile material will be provided by the **OWNER** and will be available to the **CONTRACTOR** at the Crystal River Plant. **CONTRACTOR** will be responsible for the transportation from the storage area to the project site, deployment, and seaming/sewing or overlap (as required). Deployment and seaming shall be conducted by an **ENGINEER-**approved specialty contractor as a subcontractor to **CONTRACTOR**.

1.02 RELATED SECTIONS

Section 02200 - Earthwork

1.03 REFERENCES

A. AASHTO Standards:

1. T88 - Particle Size Analysis of Soils
2. T90 - Determining the Plastic Limit and Plasticity Index of Soils
3. T99 - The Moisture-Density Relations of Soils Using a 5.5lb (2.5 kg) Rammer and a 12in (305 mm) Drop
4. Standard Specifications for Highway Bridges

B. American Society for Testing and Materials (ASTM):

1. D123 - Standard Terminology Relating to Textiles
2. D276 - Test Method for Identification of Fibers in Textiles
3. D4354 - Practice for Sampling of Geosynthetics for Testing
4. D4355 - Test Method for Deterioration of Geotextiles from Exposure to Ultraviolet Light and Water (Xenon-Arc Type Apparatus)
5. D4439 - Terminology for Geotextiles
6. D4595 - Test Method for Tensile Properties of Geotextiles by the Wide-Width Strip Method

7. D 4759 - Practice for Determining the Specification Conformance of Geosynthetics

8. D4873 - Guide for Identification, Storage, and Handling of Geotextiles

9. D4884 - Strength of Sewn or Thermally Bonded Seams of Geotextiles

10. D5262 - Test Method for Evaluating the Unconfined Tension Creep Behavior of Geosynthetics

11. D5321 - Test Method for Determining the Coefficient of Soil and Geosynthetic or Geosynthetic and Geosynthetic Friction by the Direct Shear Method

12. D5818 - Exposure and Retrieval of Samples to Evaluate Installation Damage of Geosynthetics

B. Geosynthetic Research Institute:

1. GRI-GT6 - Geotextile Pullout

2. GRI-GT7 - Determination of the Long-Term Design Strength of Geotextiles

3. GRI-GG5 - Test Method for Geogrid Pullout

4. GRI-GG7 - Carboxyl End Group Content of PET Yarns

5. GRI-GG8 - Determination of the Number Average Molecular Weight of PET Yarns Based on a Relative Viscosity Value

C. Federal Highway Administration (FHWA)

1. FHWA SA-96-071 - Mechanically Stabilized Earth Walls and Reinforced Soil Slopes Design and Construction Guidelines

2. FHWA SA-96-072 - Corrosion/Degradation of Soil Reinforcements for Mechanically Stabilized Earth Walls and Reinforced Soil Slopes

D. American Association for Laboratory Accreditation (A2LA)

E. Geosynthetic Accreditation Institute (GAI) - Laboratory Accreditation Program (LAP).

PART 2.0 - PRODUCTS

2.01 MATERIALS

A. Reinforcement Geotextiles – **OWNER** will provide the reinforcing geotextile to be installed at the FGD Ponds. The geotextile shall have the following characteristics:

TABLE 1 - REINFORCEMENT GEOTEXTILE

Property	Test Method	Minimum Geotextile Property Requirements[1]	
		Roll Direction (MD)	Cross Roll (CD)
Ultimate Tensile Strength	ASTM D4595	600 kN/m (41,112 lb/ft)	100 kN/m (6,853 lb/ft)
Tensile Strength in Roll Direction (MD) at 5% Strain	ASTM D4595	270 kN/m (18,500 lb/ft)	
Creep Reduced Strength	ASTM D5262	360 kN/m (24,671 lb/ft)	60 kN/m (4,111 lb/ft)
Long-Term Design Strength[2]	GRI-GT7	297.5 kN/m (20,389 lb/ft)	49.5 kN/m (3,392 lb/ft)
Seam Breaking Strength	ASTM D4884	50 kN/m (3,425 lb/ft)	
Ultraviolet (UV) Radiation Stability	ASTM D4355	Min. 50% Strength Retained after 250 hrs	

[1]All geotextile properties listed above are minimum average roll values (i.e., the test result for any sampled roll in a lot shall meet or exceed the values listed within a 97.5% confidence limit).

[2]Long Term Allowable Design values are for sand, silt and clay

PART 3.0 - EXECUTION

3.01 PREPARATION

Foundation soil shall be excavated/filled to the lines and grades as shown on the Drawings or as directed by the **ENGINEER**. Over-excavated areas shall be filled with compacted backfill material as per specifications or as directed by the **ENGINEER**. As a minimum, foundation soil shall be proof-rolled under the observation of the **ENGINEER** prior to backfill and reinforcing geotextile placement (see Section 02200).

3.02 INSTALLATION

A. Deployment and seaming of the reinforcing geotextile shall be conducted by an **ENGINEER**-approved specialty contractor as a subcontractor to the **CONTRACTOR**. The preferred specialty contractor is Flint Industries of Metter, Georgia.

B. The deployment of the lower layer of reinforcing geotextile shall be at the proper elevation and orientation as indicated on the Drawings. Correct orientation of the reinforcing geotextiles shall be verified by **CONTRACTOR** and **ENGINEER**.

C. Reinforcing geotextile may be temporarily secured in-place with staples, pins, sand bags or backfill as required by fill properties, fill placement procedure or weather conditions, or as directed by the **ENGINEER**.

D. To the extent possible, single panel lengths are required in the primary strength (machine) direction. Reinforcement on any seams required in the primary roll strength (machine) direction will be as directed by the **ENGINEER**. Seams between adjacent east-west oriented rolls will be double 401 stitched and must achieve 50 percent of the specified cross-directional ultimate strength. **ENGINEER** will direct the **CONTRACTOR** as to the locations and frequency that destructive samples will be collected and tested.

E. Machine direction (end) seams will be allowed only at the direction and approval of the **ENGINEER**.

F. Any repairs of flaws or damage to the reinforcing geotextile will be at the direction of the **ENGINEER** but will typically include either deployment and seaming of a section of reinforcing geotextile of a full roll width extending at least 10 feet (in machine direction) either side from the location of the flaw or damage <u>or</u> removal and replacement of the entire roll.

G. Backfill material shall be placed in a 1-foot thick lift and compacted as directed under project specifications. Backfill shall be placed, spread and compacted in such a manner as to minimize the development of wrinkles in and/or movement of the reinforcing geotextile. A minimum fill thickness of 300 mm (12 in) is required prior to the operation of tracked vehicles over the reinforcing geotextile.

H. Turning of tracked vehicles should be kept to minimum to prevent tracks from displacing the fill and damaging the reinforcing geotextile. Rubber tired equipment may pass over the reinforcing geotextile reinforcement at low speeds, less than 8 km/hr (5 mph). Sudden braking and sharp turns shall be avoided. Any reinforcing geotextile damaged during installation shall be replaced by the **CONTRACTOR** at no additional cost to the **OWNER**.

I. The upper layer of reinforcing geotextile shall be deployed in a direction perpendicular to the lower layer. All other installation and backfilling shall be the same as described above except for seaming which will be a 1 foot shingle style lap seam rather than a double-sewn seam.

END OF SECTION

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SECTION 13100

COMPACTION GROUTING

PART 1 – GENERAL

1.01 SCOPE OF WORK

The work covered by this section consists of providing project control, supervision, all labor and equipment, and performing all operations in connection with improvement of the soil beneath the FGD Blowdown Ponds at Progress Energy's Crystal River Facility as indicated on the drawings by injection of compaction grout. The following provides general information about compaction grouting:

A. The placement of compaction grout within the soil shall act to compress and consolidate the surrounding soil in such a way to reduce the probability of future sinkhole development. Mortar grouts with a slump of less than four inches at the injection point shall be used.

B. Soil improvement shall consist of injection under pressure of a low slump compaction grout at such locations as are necessary to fill voids within the soil.

1.02 CONTRACTOR PRE-QUALIFICATIONS

The preferred **SUB-CONTRACTOR** for the compaction grouting work is Hayward-Baker. Other **SUB-CONTRACTORs** will be considered and are subject to **ENGINEER** approval.

Prior to being eligible to bid, the **CONTRACTOR** shall submit the following for approval:

A. Due to the nature of the compaction grouting operation required to perform the specified stabilization, proposals shall only be accepted from pre-qualified Grouting Contractors. To apply for pre-qualification, the Grouting Contractor shall submit a list of compaction grouting projects undertaken in the past five years. The majority of the grouting projects specified shall be of equivalent difficulty and/or scope as this project. No **CONTRACTOR** will be considered acceptable with less than five years experience in compaction grouting.

B. The Grouting Contractor shall submit along with his bid a list of personnel to be used on this project outlining their experience in this type of work.

C. The Grouting Contractor shall submit along with his bid a list of equipment to be used in performance of the specified grouting work, specifically detailing the equipment production and quality assurance capabilities.

D. The Grouting Contractor shall submit along with his bid a detailed description of the compaction grouting program he intends to pursue. A detailed description of the work procedure, shop drawings, heave monitoring techniques, and instrumentation program shall be included.

E. The Grouting Contractor shall submit along with his bid the mix design to be used, and information regarding all materials and suppliers, including the source for fine aggregate.

PART 2 – PRODUCTS

2.01 MATERIALS

A. Portland Cement shall conform to Federal Specifications SS-C-192 for "Cement Portland," or current ASTM Standards, Designation C-150.

B. The aggregate shall be natural sand material. The fine aggregate shall have soil fines content of not less than 10 percent and not more than 30 percent passing the No. 200 sieve, and shall be approved by the Geotechnical Engineer. The gradation of the mix shall be such that sand blocking is eliminated at the grout working pressures specified.

C. Water shall be clean and potable.

D. Grout Mix - low slump sand-cement mixture with appropriate additives and a minimum two-day compressive strength of 150 pound per square inch (psi) and a minimum 28-day compressive strength of 500 psi. Designs mix to be submitted to the **ENGINEER** for approval.

E. Fly Ash - Type "F" fly ash is allowable as a filler if the minimum compressive strength is maintained.

F. Ready-Mix supply is permissible.

PART 3 – EXECUTION

3.01 EQUIPMENT

A. Only approved pumping equipment shall be used in the preparation or handling of compaction grout. All oil or rust inhibitors shall be removed from the mixing drums, stirring mechanisms and other portions of the equipment in contact with the grout before the mixers are used. All equipment shall be maintained in first class condition at all times.

B. Compaction grout pumps must be capable of achieving 500-psi injection pressure and have a variable range of speeds between one cubic foot per minute and ten cubic feet per minute.

C. The mixing equipment shall have scales, gauges, meters, or other calibrated devices to monitor the quality of all components of the grout mix (cement, fly ash, water, sand, bentonite, etc.).

D. Approval of equipment onto the job site does not imply final acceptance.

E. The **CONTRACTOR** shall provide vertical survey control at each injection point to determine when surface heave has occurred.

3.02 MIX PROPORTIONS

A. All materials shall be accurately measured by volume, weight, or other approved method.

B. The grout mix shall include a minimum of 12 percent cement of the dry weight of sand (i.e., for a hypothetical mix, if you have 100 pounds of dry sand, you need at least 12 pounds of cement).

C. Addition of water to ensure pumpability shall not be allowed. The CONTRACTOR needs to evaluate and adjust his sand sources, along with his bentonite, fly ash, and other mix proportions.

D. The grout mix may have a maximum 25 pounds per cubic yard of bentonite.

E. Calibration of mixing devices and grout pumps shall be required as directed by the **ENGINEER**.

F. Ready-mix tickets shall be saved and used for comparison purposes, if ready mix grout is used.

G. The proposed mix design shall be submitted to the **ENGINEER** for approval. Approval does not imply acceptance. The **CONTRACTOR** is responsible for mix strength, pumpability, etc.

3.03 INJECTION POINT SPACING AND PLACEMENT

A. Existing boreholes - Temporary 4-inch diameter PVC casing shall be removed from the boreholes and injection points shall be installed in the borehole to the depth of the removed temporary casing.

B. Primary injection points shall be installed (typically 30 feet from the borehole location) as on the drawings.

C. If necessary, secondary injection points shall be installed (typically 15 feet from the borehole location and between primary injection points) as on the drawings.

D. All spacing changes, grout pressure changes, or grout quantities shall be determined by the **ENGINEER**.

E. Primary injection points shall be drilled and/or driven through the surface sands and into the limestone layer to a depth of approximately 30 feet below existing grade. Secondary injection points shall be drilled and/or driven in similar manner, when required. These depths may be varied by the **ENGINEER** during the field operations, to whatever depth is deemed necessary. The **CONTRACTOR** shall prepare for a maximum depth of 50 feet.

F. Rotary wash drilling is acceptable as long as a tight fit results between the pipe and the surrounding ground.

G. The diameter of injection pipes shall be adequate to permit injection of compaction grout. A minimum of three inch inside diameter pipe shall be used.

H. For all types of injection points, accurate installation records shall be kept by the **CONTRACTOR**, including location and depth of injection points, method of installation, and other pertinent data such as difficulties encountered during drilling or pipe driving.

3.04 BACKFILL GROUT PROCEDURES AT EXISTING BOREHOLE LOCATIONS

A. Backfill grouting shall be performed at existing borehole locations as identified on the drawings prior to proceeding with the compaction grouting.

B. For these borehole locations, after the PVC casing is removed, the grout pipe shall be withdrawn in a controlled manner and with sufficient pressure on the grout to assure that the drilled hole is filled with grout.

C. The injection of the grout shall start at the bottom depth and proceed upward.

D. At the five compaction grout borehole locations, the backfill grout shall be stopped at a depth of 30 feet below ground surface (bgs). The remainder of the grouting in these boreholes shall be compaction grouting according to the next section.

3.05 COMPACTION GROUT INJECTION PROCEDURES

A. The compaction grouting shall proceed starting with the five designated borehole locations to complete the top 30 feet and proceed to the primary injection points as shown on the drawings.

B. The injection of grout shall begin at the bottom depth (30 feet bgs) and proceed upward in two-foot intervals.

C. The initial grout take will require a minimum grout pressure of a 100-psi increase over the static line pressure to initiate grout movement.

D. The **CONTRACTOR** shall participate in a Grout Injection Test Program using three of the initial injection points for the test. The test program will enable the **ENGINEER** to evaluate and determine production grout pressure criteria along with confirming refusal criteria. Injection at each interval shall continue until one of the following occurs:

1. Maximum grout pressures at the ground surface of 300 psi or as directed by the **ENGINEER**.

2. Maximum grout quantity of five cubic yards per two-foot interval.

3. Maximum 50 cubic yards of grout shall be placed in each primary injection point. Secondary injection points will be at the direction of the **ENGINEER**.

4. Maximum total (not each interval) one inch of surface heave adjacent to each injection point.

F. Grout injection shall take place from 30 feet below grade up to the surface of limestone formation.

G. The grouting procedure shall continue until the casing is retracted. The grout pipe shall then be withdrawn in a controlled manner and with sufficient pressure on the grout to assure that the drilled hole is filled with grout. The **ENGINEER** may stop the withdrawal at preselected depth intervals for the compaction grouting of voids or near void conditions.

H. Accurate records shall be kept by the **CONTRACTOR** for grout mix proportions, quantities of grout take and injection pressures. The actual sequence of grouting operations, proportions of grout mixes, etc. shall be as herein provided, except that the provisions may be modified by the **ENGINEER** as required by field conditions.

I. All daily drilling, grouting and testing reports shall be submitted to the **ENGINEER** within 24 hours.

J. Drilling reports shall be required and shall contain at least the following information: name of driller, type of drill and method being used, date started, date completed, location of hole, type and depth of materials encountered.

K. Grouting reports shall be required and shall contain at least the following information: name of grouting technician, constituents and proportions of grout, log of quantity injected per lineal foot of hole, date, rate of pumping, and pressure at the hole.

L. A level control system shall be installed and operated by the **CONTRACTOR** for use during grouting. The monitoring shall be carried out so as to detect any movement within 25 feet of the grouting operations whenever grouting is occurring.

M. Any work done by the **CONTRACTOR** without representation of the **ENGINEER** shall not be compensated and processes shall be repeated.

N. Calibration for volume production, pressure loss, and slump loss shall be performed to the satisfaction and at the frequency directed by the **ENGINEER**.

3.06 TESTING AND QUALITY CONTROL

The testing and on-site observation shall be done at the **OWNER'S** expense, by the **ENGINEER**. Activities shall include, but are not limited to, observing the grouting activities, monitoring grout volumes and depths, and obtaining daily grout samples.

END OF SECTION

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SECTION 15410

PIPE AND VALVES

PART I - GENERAL

1.01 DESCRIPTION OF WORK

A. **CONTRACTOR** shall furnish, install, and properly label a complete piping system as shown on the Contract Drawings and as specified herein.

B. Section includes, but is not limited to:

1. Pipe and pipe fittings

2. Valves

1.02 REFERENCES

A. ASME - Boiler and Pressure Vessel Code

B. ASTM A53 - Pipe, Steel, Black and Hot-Dipper Zone Coated, Welded Seals

C. ASTM A120 - Pipe, Steel, Black and Hot-Dipper Zone Coated (Galvanized), Welded and Seamless

D. ASTM A312 - Seamless and Welded Austenitic Stainless Steel Pipes

E. ASTM D1784 – Rigid Polyvinyl Chloride (PVC) and Chlorinated Polyvinyl Chloride (CPVC) Plastic Pipe, Schedules, 40, 80, and 120

F. ASTM D2235 - Solvent Cement for Acrylonitrile - Butadiene - Syrene (ABS) Plastic Pipe Fittings

G. ASTM D2241 – PVC Plastic Pipe

H. ASTM D2466 - PVC Plastic Pipe Fittings, Schedule 40

I. ASTM D2683 - Socket-Type Polyethylene Fittings for Outside Diameter-Controlled Polyethylene Pipe

J. ASTM D2564 - Solvent Cements for PVC Plastic Pipe and Fittings

K. ASTM D2855 - Making Solvent-Cemented Joints with PVC Pipe and Fittings

L. ASTM F477 - Elastometric Seals (Gaskets) for Joining Plastic Pipe

M. ANSI – B16.5 – Pipe Flanges and Flanged Fittings

1.03 SUBMITTALS

A. **CONTRACTOR** shall submit under provisions of Section 01010 of these specifications.

B. Product Data: Provide data on pipe materials, pipe fittings, valves, and accessories. Provide Manufacturers catalog information. Indicate valve data and ratings.

C. Manufacturer’s installation instructions. Indicate hanging and support methods, joining procedures.

1.04 PROJECT RECORD DOCUMENTS

A. **CONTRACTOR** shall record actual locations of valves, pressure gauges, flow monitoring devices, and other monitoring and control devices.

1.05 OPERATION AND MAINTENANCE DATA

A. Maintenance Data: Include installation instructions, spare parts lists, exploded assembly views.

1.06 QUALITY ASSURANCE

A. Valves: Manufacturer’s name and pressure rating marked on the valve body.

B. The **MANUFACTURER** must be regularly engaged in the design and fabrication of similar equipment with a minimum of 5 years experience.

C. The pipe, valves, and other accessories shall be designed for a minimum plant operating life of ten years under service conditions.

D. All components must be of an industrial quality.

1.07 QUALIFICATIONS

A. **MANUFACTURER**: Company specializing in manufacturing the Products specified in this Section.

B. **INSTALLER**: Company specializing in performing the Work of this Section.

1.08 DELIVERY, STORAGE, AND HANDLING

A. **CONTRACTOR** shall deliver, store, protect, and handle products to Site.

B. **CONTRACTOR** shall accept valves on-site in shipping containers with labeling in place. Inspect for damage.

C. **CONTRACTOR** shall provide protective coating on metal valves.

D. **CONTRACTOR** shall provide temporary end caps and closures on piping and fittings. Maintain in place until installation.

E. **CONTRACTOR** shall protect piping systems from entry of foreign materials by temporary covers, completing sections of the Work, and isolating parts of completed system.

1.09 ENVIRONMENTAL REQUIREMENTS

A. **CONTRACTOR** shall ensure that all underground piping be installed in a dry trench condition.

PART 2 - PRODUCTS

2.01 PVC AND CPVC PIPE

A. Pipe and Fittings

1. PVC: Type I, Grade I conforming to ASTM D1784.

2. CPVC: Type IV, Grade I conforming to ASTM D1784

B Pressure Rating

1. Schedule 80

C. Flanges

1. Flat faced, conforming to ANSI B16.5

2. Class 150 Lbs.

D. Gaskets

1. PTFE full-face elastomeric gasket.

2. Minimum 1/8-inch thick flat type.

2.02 STEEL PIPE

A. Pipe and Fittings

1. Galvanized and Carbon Steel: Seamless, conforming to ASTM A53, schedule 40; Threaded or Welded connections

2. Stainless Steel: Seamless, conforming to ASTM A312, schedule 40; Welded connections.

B. Pressure Rating

1. Schedule 40.

2. Class 150 Lbs.

C. Flanges

1. Raised faced, conforming to ANSI B16.5

2. Class 150 Lbs.

D. Gaskets

1. PTFE ring gasket.

2. Minimum 1/16-inch thick.

2.03 HDPE PIPE

A. Pipe and Fittings

1. Polyethylene pipe shall be made from high density, high molecular weight resin meeting the requirements of ASTM D3350-05. The cell classification according to ASTM D3350 shall be 345464C, and the pipe shall have a rating of PE3408 or better, according to the rating system of the Plastic Pipe Institute, a division of the Plastics Industry, Inc.

2. The pipe shall be joined with thermal, butt fusion welds. All welds shall be made in strict compliance with the manufacturer's recommendations.

3. Polyethylene fittings shall be made from high density, high molecular weight resin meeting the requirements of ASTM D 3350-05. The cell classification according to ASTM D3350-05 shall be 345464C, and the pipe shall have a rating of PE3408 or better, according to the rating system of the Plastic Pipe Institute, a division of the Plastics Industry, Inc.

B. Pressure Rating

1. SDR 11

2. The pressure rating of the pipe fittings shall be equivalent to the pipe SDR rating.

C. Flanges

1. Backup rings for HDPE flange connections shall be ANSI B16.5 Class 150#, or AWWA C-207 Class D. Flange material shall be Epoxy Coated Carbon Steel.

2. Flanges used on the non-piped side of valves shall be carbon steel per ASTM A105, ASME Class 150, flat face, Standard 3.2/6.3 Ra facing per ASME B46.1, per ASTMI B16.5 with a four inch diameter FNPT threaded connection.

D. Gaskets

1. Gaskets shall be full faced rubber gaskets, 55-75 Durometer Shore D Hardness.

2. Minimum 1/8 inch thick.

2.04 VALVES

A. Provide valves in sizes and locations as indicated on the Contract Drawings.

B. Butterfly – Inlet Piping

1. Cast carbon steel per ASTM A126 B, ASME Class 150, wafer style, Standard 3.2/6.3 Ra facing per ASTM B46.1, ASME B16.34, one piece stem and disc constructed of type 17-4 ph stainless steel and with EPDM elastomer molded to the disc and EPDM seat, lever handle.

2. Manufacturer: Bray 21-128, or equal.

B. Butterfly – Pump Vault and Outlet Piping

1. Fiberglass reinforced vinyl ester composite body, full-face lug style with EPDM/DCI coated discs, EPDM seats, multiple positions ductile iron handle. The valve shall be flanged and conform to the face-to-face dimensions of ANSI/ASME B16.10. Flange bolt sizes and spacing shall conform to ANSI B16.5 Class 150. Gear operator for 8” and 10“sizes. Valves located in pump vault shall be furnished with extension rod to allow for exterior operation.

2. Manufacturer: Nil-Cor 700 L-E-E-S-LD, or equal.

1.

C. Ball

1. 1” through 6”

a. Fiberglass reinforced vinyl ester composite body, gland and stem Hastelloy-C, PTFE-coated seals and seats, ball compression molded graphite fiber and vinyl ester resin. The valve shall be flanged and conform to the face-to-face dimensions of ANSI/ASME B16.10. Flange bolt sizes and spacing shall conform to ANSI B16.5 Class 150. Lever handle operator.

b. Manufacturer: Nil-Cor 310 ST-T-H or equal.

2. 8” valves

a. Graphite fiber reinforced vinyl ester body, full-face wafer style, Hastelloy-C bolts, PFA encapsulated silicone seals and cavity filler seats, stainless steel handle adapter with locking provision and gear operator. Body shall be suitable for bolting between ANSI CLASS 150 flanges.

b. Manufacturer: Nil-Cor 300 CF-P-H or equal.

D. Ball (if used with a diagram seal to isolate fluid medium)

1. Cast stainless steel ball valve, threaded, reinforced TFE seats and stuffing box ring, adjustable packing gland, lever handle operator.

2. Manufacturer: Apollo 76-100, or equal.

E. Check

1. Wafer Swing style with glass fiber-reinforced vinyl ester resin body and disc. Viton seats. Body shall be suitable for bolting between ANSI CLASS 150 flanges.

2. Manufacturer: Nil-Cor SC-310-V or equal

F. Valves shall be supplied with manual operators.

G. Valves shall be capable of accepting a lock to comply with energy-isolation procedures (LOTO).

2.05 ACCESSORIES

A. Flange Bolts

1. Provide steel studs/bolts alloy steel bolts and studs, ASTM A193 Gr. B7, and ASTM A194 Gr. 2H heavy hex nuts, per ASTM B1.1.

2. Fasteners shall be corrosion resistant.

3. Bolts shall be tightened to recommended torque values.

PART 3 - EXECUTION

3.01 EXAMINATION

A. **CONTRACTOR** will provide shop drawings of all piping runs and connections.

3.02 GENERAL INSTRUCTIONS

A. Where more than one piping system material is specified, ensure system components are compatible and joined to ensure that the integrity of the system is not jeopardized. Provide necessary joining fittings. Ensure flanges, unions, and couplings for servicing are consistently provided.

B. Use unions, flanges, and couplings downstream of valves and at equipment or apparatus connections. Do not use direct welded or threaded connections to valves, equipment or other apparatus.

3.03 PREPARATION

A. Remove scale and dirt, on inside and outside of piping, before assembly.

B. Prepare piping connections to equipment with flanges or unions.

3.04 ABOVE GROUND PIPING INSTALLATION

A. Install in accordance with Manufacturer's instructions or Contract documents as appropriate.

B. **CONTRACTOR** shall route piping in orderly manner and maintain gradient, if required.

C. Group piping whenever practical at common elevations.

D. Install piping to allow for expansion and contraction without stressing pipe, joints, or connected equipment.

E. Provide clearance for access to valves and fittings.

F. Where pipe support members are welded to structural fitting, **CONTRACTOR** shall scrape, brush clean, and apply one coat of zinc rich primer to welding.

G. **CONTRACTOR** shall install valves with stems upright or horizontal, not inverted.

3.05 UNDERGROUND PIPING INSTALLATION

A. Install in accordance with Manufacturer's instructions or Contract documents as appropriate.

B. Excavate and backfill in accordance with Section 02200 of these specifications.

C. Plastic Piping:

1. Install plastic piping in accordance with ASTM D2321.

2. Pipe bedding shall meet the requirements of clean sand as defined in the Specifications.

3. Install bedding at sides and top of pipe to minimum thickness of 3.0 inches over top of pipe and compact.

D. Pipes shall be leak tested according to manufacturer's recommendations. Water for testing will be supplied by **OWNER**.

3.06 CLEANING AND TESTING

A. The pipes, which are to be operated under pressure, shall be pressure tested prior to backfilling of the trenches.

B. CLEANING

1. The **CONTRACTOR** shall provide and install temporary connections, strainers, and other equipment to thoroughly clean the piping systems before start-up. Cleaning shall include a thorough rinsing with water to remove sediments of pipe material shavings and other debris. The OWNER'S Representative shall visually observe a clean piping system free of shavings and/or other debris prior to start-up.

2. The **CONTRACTOR** shall collect and dispose of cleaning agents in accordance with OWNER's requirements and shall remove all temporary connections and strainers after cleaning is complete.

3. Piping shall be cleaned just prior to installation and again prior to start-up. Cleaned piping material shall be protected against contamination by sealing open ends with clear plastic sheets, metal foil, or other approved materials.

C. TESTING

1. Upon completion of piping installation, but prior to covering concealing or burying piping, test all newly installed piping systems.

2. The timing and sequence of testing shall be scheduled by the **CONTRACTOR**, subject to the favorable review by the **OWNER's Representative**. The **CONTRACTOR** shall provide the **OWNER's Representative** two (2) working days notice prior to all testing.

3. Isolate equipment which may be damaged by the specified test conditions.

4. Perform pressure tests using calibrated pressure gauges. Select each gauge so that the specified test pressure falls within the upper half of the gauge's range.

5. Unless otherwise specified, completely assemble and test new piping systems prior to connection to existing piping systems.

6. All piping (in a completed system) shall be pressure tested to 1.5 times the maximum intended operating pressure. Gravity flow lines shall be tested at minimum pressure of 10 PSIG. Pressure testing shall be done in place, in the presence of the **OWNER's Representative**, for a period of 1 hour after completing the initial expansion phases of testing, with no noticeable loss of pressure.

7. **CONTRACTOR** shall provide **OWNER's Representative** a copy of proposed test procedures for review prior to conducting testing.

CONTRACTOR shall receive **OWNER's Representative's** comments prior to conducting testing.

8. No pipe installation will be accepted should there be evidence of exterior surface damage to the pipe that, in the option of the **OWNER's Representative**, may compromise the integrity of the piping system, even though it may pass the testing requirements.

9. All tests shall be made before piping is painted, covered, or otherwise concealed. The **CONTRACTOR**, at the **CONTRACTOR's** own expense, shall uncover and retest any piping not satisfactorily tested in the presence of the **OWNER's Representative**. Testing shall be conducted after laying or modifying of the piping systems and prior to backfilling and then repeated after final grading.

10. The testing requirements for the respective systems shall include all those of applicable Codes, Laws and Regulations. All code-required inspection certificates, if required, shall be furnished to the **OWNER's Representative**.

D. PIPE TEST SCHEDULE

1. Upon completion of each piping system or sub-system, clean and test the lines. All piping shall be tested:

   a. After completion of a section or subsection prior to backfilling of trench

   b. After completion of entire system after installation of any heat tracing and insulation cover.

2. Repair and retest any piping system found to be leaking until results are satisfactory to the **OWNER's Representative**.

E. REPAIRS

1. The point or points of leakage shall be sought out and remedied by the **CONTRACTOR** at the **CONTRACTOR's** expense.

2. All repairs will be observed by the **OWNER's Representative**.

3. Repair methods must be satisfactory to the **OWNER's Representative**.

F. FINAL ACCEPTANCE

1. No pipeline installation or hydraulic structure will be accepted until all leaks have been repaired. All repairs will be observed by the **OWNER's Representative**.

G. The **CONTRACTOR** shall provide the **OWNER's Representative** with written certification and test charts clearly identifying location of pipe being tested of equipment/system cleaning and testing in accordance with this Section. All test data and documentation shall be provided to the **OWNER's Representative** as part of the written certification.

END OF SECTION

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APPENDIX A

CQA Plan
FGD Blowdown Ponds

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CONSTRUCTION QUALITY ASSURANCE PLAN
CRYSTAL RIVER ENERGY COMPLEX
FGD POND CONSTRUCTION
CRYSTAL RIVER, FLORIDA

Prepared for:

PROGRESS ENERGY FLORIDA, INC.
15760 WEST POWERLINE STREET
CRYSTAL RIVER, FLORIDA 34428

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1.0 INTRODUCTION

1.1 Scope

The CQA Plan addresses the construction quality assurance procedures for the components of the FGD Blowdown Pond at Crystal River Energy Complex. The pond construction includes a combination of the following components: earthworks (grading and berm construction), reinforcing geotextile installation, flexible geomembrane (LLDPE) installation, and the installation of inlet and outlet piping and removal system (pumps, motor control center, etc.).

The purpose of this document is to achieve quality construction and installation of the various components of the FGD pond construction. This document describes the construction quality assurance procedures required for construction. The work will be performed to conform to the approved Drawings and the Technical Specifications, hereafter collectively referred to as the "project requirements", including project-specific addenda and construction change orders.

1.2 Definitions

The terms, "quality assurance" (QA) or "construction quality assurance" (CQA) and "quality control" (QC) or "construction quality control" (CQC) are used in this document.

<u>Quality Assurance (QA) or Construction Quality Assurance (CQA)</u>: A planned system of activities that provides Progress Energy Florida (PEF) and the permitting agencies assurance that the facility was constructed as specified in the permit. CQA includes inspections, verifications, audits, and evaluations of materials and workmanship necessary to determine and document the quality of the constructed facility. CQA refers to measures taken by PEF, through the CQA Consultant, to assess if the Installer or Contractor is in compliance with the plans and specifications for a project.

<u>Quality Control (QC) or Construction Quality Control (CQC)</u>: A planned system of inspections that is used to directly monitor and control the quality of a construction project. CQC is typically performed by the Contractor or, for Geosynthetics, by the Geosynthetics Installer, and is necessary to achieve quality in the constructed or installed system. CQC refers to measures taken by the Contractor or Installer to determine compliance with the requirements for materials and workmanship as stated in the plans and specifications for the project.

2.0 QUALIFICATIONS AND RESPONSIBILITY OF CQA CONSULTANT

2.1 General

The CQA Consultant is the party, independent from PEF and the Contractor, responsible for observing, testing, and documenting activities related to the CQA and CQC of the soil, geotextile, geomembrane components, piping, pumps and controls, and other activities related to the construction of the FGD Pond described in this CQA Plan.

2.2 Qualifications

The CQA Consultant shall be a well-established firm specializing in liner system design, construction management, and CQA. The CQA Consultant shall possess the equipment, personnel, and licenses necessary to conduct the monitoring and testing activities required by this CQA Plan and the FGD Pond Drawings and Technical Specifications. The CQA Consultant shall also be experienced in the installation and CQA of soil and geosynthetic material similar to those materials being used for the FGD Pond. The CQA Consultant will be experienced in the preparation of CQA documentation including CQA plans, field documentation, field testing procedures, laboratory testing procedures, construction specification and plans, and CQA certification reports. A summary of the qualifications and specific experience guidelines for the each of the parties responsible for CQA is detailed in below:

	General	Soils	Geomembrane	Geotextile
CQA Consultant hired by the Client	CQA Consultant must have verifiable experience in providing quality assurance services. Must be a registered professional engineer in Florida.	Minimum of 5 projects of similar scope and with similar materials of construction.	Minimum of 10 projects totaling a minimum of 200,000 square feet of geomembrane installation of similar scope, in the past two (2) years.	Minimum of 10 projects totaling a minimum of 200,000 square feet of geotextile installation of similar scope, in the past two (2) years.
CQA Monitor	CQA Monitor(s) responsible for observation and documentation of the FGD pond will be quality assurance personnel specifically trained in the quality assurance of earthworks and geosynthetics.	Demonstrated ability to perform testing required.	At a minimum, one of every four CQA Monitors, or at least one per project, will have in excess of 110,000 square feet of geomembrane quality assurance field experience.	At a minimum, one of every four CQA Monitors, or at least one per project, will have in excess of 110,000 square feet of geotextile quality assurance field experience.

The following minimum information will be required to confirm the CQA Consultant's past experience in CQA:

- Name and location of project(s) of similar nature;
- Name and telephone number of project's owner;
- Contact person with first-hand knowledge of the project; and
- Size of and duties associated with the project.

In addition to the above, the CQA Consultant will also submit a diagram outlining the position, titles, names and pertinent experience of the individuals to be employed on CQA activities for the project. At a minimum, the CQA Consultant and the CQA Monitors will be specified. Resumes of these individuals are to be included. Once the CQA personnel have been selected, substitutions of any of these personnel during the project will not be permitted without prior notification and approval by PEF.

2.3 General CQA Responsibilities

2.3.1 Overview

The CQA Consultant is responsible for the implementation of the CQA requirements as set forth in this plan. In order to do this, the CQA Consultant is responsible for becoming thoroughly familiar with the permit and the technical and regulatory intent of the constructed FGD Pond. This familiarity will assist the CQA Consultant in identifying potential problems, suggesting solutions to problems, and identifying inadequacies discovered during the construction process, so that the technical requirements of the project are met during construction.

The CQA Consultant is responsible for providing senior technical oversight of the CQA process. The CQA Consultant is responsible for reviewing the CQA Plan as well as the project requirements for the project so that the CQA Plan can be implemented without contradictions or unresolved discrepancies. At the completion of pond construction, the CQA Consultant is responsible for a certification stating that the FGD Pond was constructed in general accordance with the approved project requirements, the CQA Plan, and the applicable rules of the governing state regulatory body.

The CQA Consultant will attend, participate, and document meetings related to the CQA activities of this project. The CQA Consultant is responsible for conducting the following meetings: implementation meeting, preconstruction meeting, daily progress meetings, weekly progress meetings, and/or problem or deficiency resolution meetings.

During implementation of the CQA Plan, the CQA Consultant, or a CQA monitor, will observe, document and report the daily project activities. The CQA Consultant will also be responsible for observing and documenting the completion of each component prior to placement of the subsequent layer. In addition, the CQA Consultant is responsible for the soil and/or geosynthetic material sampling and testing necessary to comply with the CQA Plan and the project requirements. This includes marking, packaging, and shipping of CQA laboratory and CQA test samples.

The CQA Consultant will record CQA/CQC activities and progress on a daily basis. The CQA Consultant will immediately report any activities, observations, or test results that indicate the construction activities are not in conformance with the project requirements to PEF, or designated PEF representative. The CQA Consultant is responsible for development and issuance of the final report.

The CQA Monitor(s) will be the CQA Consultant's official on-site CQA representative(s). The CQA Consultant is responsible for implementing the site-specific Health and Safety Plan for the CQA personnel.

2.3.2 Specific CQA Responsibilities of the CQA Consultant

The CQA responsibilities of the CQA Consultant include scheduling and coordination of daily CQA activities with the Contractor or the Geosynthetic Installer. Additionally, the CQA Consultant is responsible for the following:

- Educating the CQA Monitors as necessary on the requirements, procedures and any special steps that are needed,
- Verifying that the proper procedures are followed,
- Verifying that testing laboratories are conforming to the CQA requirements and procedures,

- Verifying that sample custody procedures are followed,
- Confirming that test data are accurately reported,
- Confirming that test data are maintained for later reporting,
- Preparing the daily summary report, and
- Preparing the final certification report.

In the event of non-conformance with the project requirements, the CQA Consultant is responsible for notifying the Contractor and/or Installer as to the details and, if appropriate, direct remedial action and/or work stoppage.

2.3.3 Responsibilities of the CQA Monitors

The CQA Monitors are responsible for making observations, sampling, and performing field tests to verify that the FGD Pond is constructed in accordance with the project requirements. Documentation of these activities is the primary responsibility of the CQA Monitor to assure that the CQA requirements are met.

3.0 SOIL PLACEMENT

3.1 General

CQA evaluation of the soil placement at the FGD Pond will consist of monitoring the daily construction activities for compliance with the project requirements. The soil components of the FGD Pond include excavation and stockpiling of existing soils, geotextile subgrade preparation, pond berm construction, geomembrane subgrade preparation, and site grading. In addition to conducting construction evaluations, the CQA Consultant is responsible for monitoring the construction activities, sampling, and testing soils in accordance with the project requirements. The prepared subgrade soils which will support the geotextile and geomembrane will require preparation in the form of grading, placement, and/or compaction prior to the installation of geosynthetics.

3.2 Borrow Source Evaluation

The CQA Consultant will observe, test, evaluate, and document that soil, rock and/or other earthen materials to be used for this project are obtained from borrow sources which have been evaluated in accordance with the project requirements. The CQA Consultant may visit the borrow sources to visually evaluate the quality and quantity of the borrow material available.

3.3 As-Built Surveys

During construction of the soil components of the FGD Pond, the CQA Consultant shall routinely review record drawings submitted by the Surveyor. The drawings are used to verify location of work, percent work completed, layer thickness, or final grades. Prior to placement of successive soil layers, the CQA Consultant shall review as-built surveys which indicate compliance of the preceeding layer thickness, lines and grades. Once an as-built survey has been received, it will be the responsibility of the CQA Consultant to review the information in a timely manner and notify the Contractor and Construction Manager of any non-compliance.

3.4 Laboratory Testing

The laboratory test methods will be based on the requirements set forth in the project requirements and will be used to develop data to evaluate construction. The laboratory test results will be evaluated and compared with the field test results to confirm that the materials being placed are in accordance with the project requirements. The CQA Consultant will confirm that the testing frequencies required by the project requirements are met. Soils placed which do not meet the specifications will be reworked or removed.

3.5 Field Testing

Unless soil characteristics preclude its use, direct or backscatter nuclear densimeter test methods will be used to determine the in-place moisture/density of the placed soils. Other suitable method(s) of determining the in-place moisture/density of the soil may be used as provided in the project requirements, if the nuclear densimeter method is not used. The nuclear densimeter should be calibrated and checked in accordance with the requirements of the project requirements on a regular basis. Similarly, the moisture content may be checked using the oven dry method (ASTM D-2216-90).

If field testing results indicate densities or moisture contents which do not comply with the project requirements, the CQA Consultant will document actions taken by the Contractor to rework the failing areas to meet the project requirements, and perform a re-test of the area.

Should test results indicate unacceptable soil characteristics despite the Contractor's efforts, the compaction characteristics of the borrow material will be re-evaluated by performing either a standard Proctor test (ASTM D-698-91) or a modified Proctor test (ASTM D-1557-91), as appropriate, on the failing material. Alternatively, the soils may be removed and replaced with acceptable material. In all cases, the failing areas will be reworked to achieve compliance with the project requirements.

3.6 Quality Assurance Testing

The terms "layer" and "lift" used throughout this document are defined as follows:

- A "lift" is a segment of a soil layer compacted in general to a nominal thickness as specified in the project requirements;
- A "layer" is compacted strata constructed of several lifts with no horizontal or vertical construction joints.

Increased testing frequencies may be instituted if observations by the CQA Consultant of specified testing frequency results indicate potential problems. Additional testing may be warranted when:

- The material repeatedly fails to meet specifications;
- The degree of compaction is doubtful;
- The materials appear to differ from those specified;
- Less than the required number of compaction equipment passes are made;
- The material moisture content differs from those specified;
- The lift thicknesses differ from those specified; or
- Adverse weather conditions occur.

3.7 Field Testing Sample Locations

Grid pattern sampling strategies will be used on placed and compacted material. Grids will be based on a 100-foot grid system superimposed on the construction plans. Grid patterns will have line spacings of 100 feet. Grids and stations will be clearly marked. Sample locations will be selected at random and coordinates identified on a daily field test result form and a reduced scale site plan.

Samples will be randomly located within a grid section and varied with each lift. Elevation or lift number will be identified.

3.8 Defective Work

The extent and nature of defective work will be determined through additional tests, observations, review of records and test results or other means that the CQA Consultant deems appropriate. After the extent and nature of the deficiency has been ascertained, the Contractor will implement corrective actions required to satisfy the project requirements. Areas that have been reworked will be retested. Retests must verify that the entire deficient area has been corrected prior to additional work being performed in that area.

3.9 Monitoring of the Soil Placement

The following construction activities will be monitored and documented by the CQA Consultant:

- Field testing (including CQC testing) as described in the project requirements and in Section 3.5 of this CQA Plan;
- Visual examination of the subgrade for areas that are unacceptable for geotextile and/or geomembrane placement;
- Method of final soil surface preparation;
- Loose lift thicknesses prior to compaction;
- Volume of soils placed and compacted from each borrow source and corresponding soil sampling frequencies;
- Compaction equipment (type and weight) and method;
- Removal of organic material, rocks, and other materials which do not meet the specifications;
- Observation of the number of equipment passes made during compaction of each lift;
- Areas or units of work being tested, identifying lift, or elevation and location. Test locations will be documented by increasing chronological order and, by approximate coordinates;
- Failed test areas defined by coordinate boundaries, corrective action under taken by the Contractor in these areas and results of retests. Retests will cross-reference the numbers and dates of failed tests;
- Fluid Leaks or spills from the Contractor's equipment or activities and corrective actions taken;
- Effectiveness of corrective actions for deficient work;
- Methods of adjusting soil moisture conditions, and;
- Documentation of compacted soil repair.

4.0 GEOSYNTHETICS MANUFACTURER'S QUALITY CONTROL DOCUMENTATION REVIEW

The CQA Consultant will review each of the geosynthetic manufacturer's quality control (MQC) data for conformance with the project requirements prior to deployment of the reinforcing geotextile and geomembrane material. The CQA Consultant may visit the Manufacturer's plant site during production of the geosynthetic materials to inspect production and/or obtain samples. A manufacturer's plant visit is optional. If a plant visit is performed, the CQA Consultant will prepare and submit a report of the plant visit.

The CQA Consultant will review, at a minimum, the following Manufacturer's QC information as appropriate for the material being manufactured at that particular plant:

For the geomembrane:

- Copies of QC Certificates issued by the Raw Materials Supplier. These certificates will contain the raw material supplier's name, production plant, brand name or type of raw material, resin chemical composition, resin number, and resin production date. Additionally, resin QC Certificate will provide test results at the frequencies specified in the project requirements for, at least, resin density, Melt Flow Index, and Carbon Black Content;

- Manufacturer's Statement certifying the geomembrane cleanliness and amount of reclaimed polymer;

- Composition of material;

- Manufacturer's Certificate guaranteeing minimum values required by the project requirements;

- Manufacturer's QC Certificates verifying the material properties of the geomembrane. These certificates must be reviewed to verify that test results are within acceptable ranges, the tests are performed at acceptable frequencies, proper tests are performed and they are certified by the manufacturer's representative. Typically, these QC Certificates will contain the roll (or panel) identification numbers, resin material batch, sampling procedures and results of geomembrane material testing as required in the project requirements.

- The CQA Consultant will review the Manufacturer's QC information and report any discrepancies from the project requirements. The purposes of the review of the MQC information are to verify that:

  - The properties of the geosynthetic materials certified by the manufacturer meet the guaranteed minimum values shown on the project requirements;

  - Measurement of the material properties is properly documented and tested by acceptable methods;

  - QC Certificates are provided at the specified frequencies for each roll, and are coordinated with the roll (or panel) identification; and

  - The rolls (or panels) are appropriately numbered.

2. For the reinforcing geotextile:

- Manufacturer's certified roll material data sheets. The certified data sheets shall be attested to by a person having legal authority to bind the manufacturing company.

- Manufacturer's warranty statement.

- Manufacturer's quality control (QC) manual which describes testing procedures, frequency of testing and acceptance/rejection criteria for QC testing.

- Manufacturer's, installer's, QC inspectors, and QC laboratory's qualification statements including resumes of key personnel involved in this project.

- Shear strength test results at least 25 days prior to deployment.

- Manufacturer’s QC laboratory test results including description of equipment and test methods.

It is the ultimate responsibility of the Contractor/Installer to verify that the documentation required for the geosynthetic materials has been submitted. The CQA Consultant will not approve that a geosynthetic material be deployed until the MQC information for that material has been received, reviewed, and deemed acceptable.

5.0 GEOSYNTHETICS CONSTRUCTION QUALITY ASSURANCE PROCEDURES

5.1 General

For the geosynthetics components (reinforcing geotextile and flexible geomembrane liner) of the FGD Pond construction, the CQA evaluation will include the following general categories:

- Delivery evaluation;
- Material surface evaluation;
- Conformance testing;
- Monitoring of the geosynthetic layer installation; and
- Documentation of the daily construction activities related to the installation of the reinforcing geotextile and geomembrane for compliance with the project requirements.

General CQA procedures are discussed in the following sections.

5.2 Delivery Evaluation

The delivery evaluation of geosynthetic materials will be essentially the same for each type of geosynthetic, regardless of the specific product being delivered to the project site. The CQA Consultant will document the arrival of the geosynthetic material delivered to the site. During transportation, handling, and storage, the reinforcing geotextile shall be protected from ultraviolet light exposure, precipitation or other inundation, mud, dirt, dust, puncture, cutting or any other damaging or deleterious conditions. It will be the responsibility of the Contractor to protect the geosynthetics stored on-site from theft, vandalism, and damage.

Upon delivery at the site, the Contractor and CQA Consultant shall conduct an inspection of the geosynthetic rolls for defects and damage. This inspection shall be conducted without unrolling the materials unless defects or damages are found or suspected. The CQA Consultant shall indicate to PEF:

- Rolls, or portions thereof, which should be rejected and removed from the site because they have severe or nonrepairable flaws which may compromise geosynthetic quality; and

- Rolls which include minor or repairable flaws which do not compromise geosynthetic quality.

The CQA Consultant shall also monitor that on-site equipment used to handle the geosynthetics is adequate and does not pose any risk of damage to the geosynthetics when used properly.

5.3 Material Surface Evaluation

Material surface evaluation will consist of observation and documentation of deployment locations and procedures, as well as visual examination of the geosynthetic material surface during, and immediately after, deployment to assess material appearance, continuity, and integrity.

5.4 Conformance Testing

The CQA Consultant will observe the sampling of geosynthetic materials from the rolls (or panels) that are delivered to the site. These samples will be taken such that they are representative of the geosynthetic layer delivered to the project site.

Geosynthetic conformance samples shall be 3 feet long and taken across the entire width of the roll and shall not include the first 3 feet of material. The CQA Consultant will visually inspect the sample to verify that it is not damaged (scratches, crimps, blemishes, etc.). If damage is noted, the sample will be withdrawn from testing and the geosynthetic material will be resampled by the Contractor or the Geosynthetics Installer.

Each geosynthetic material will be tested in accordance with the methods detailed in the appropriate sections of the project requirements. The results of the tests performed on each sample will, at a minimum, meet the material property value detailed in the project requirements and the geosynthetic layer Manufacturer's minimum property values, as submitted in accordance with the project requirements.

If conformance testing indicates project criteria are not met, a retest of the sample will be conducted, if possible based on the test and the material available. If the material cannot be retested, or if the retest indicates failure, then two additional conformance samples from adjacent rolls on either side of the failing roll (based on roll numbers) will be tested and the process continued until passing tests are achieved. Rolls between passing tests shall be rejected and not used for the project.

5.5 Monitoring of the Geosynthetic Material Installation

5.5.1 General

Geosynthetic materials installation will be monitored by the CQA Consultant. Monitoring will include: visual examination of the subgrade for unacceptable areas or materials; observation of deployment equipment operation to verify that none is allowed to travel directly on the geosynthetic material without adequate protection (as defined in the project requirements); observation and documentation of geosynthetic material placement procedures including sewing of the reinforcing geotextile and non-destructive and destructive testing of the geomembrane seams; observation of weather conditions during the installation of the geosynthetic; observation and documentation of geosynthetic material panel locations; observation, documentation, and periodic measurement of geosynthetic material overlaps and/or seams; observation and documentation of the locations of geosynthetic material cuts, tears, holes, or irregularities and the repair of such; observation and documentation of geosynthetic material temporary and permanent anchoring systems; observation that geosynthetic material is protected at the end of work day; and observation of the geosynthetic Installer's workmanship and performance of required tasks.

In the event that testing indicates the material or seam does not meet the required criteria, the test will be considered failing. The extent and nature of defective work will be determined through additional tests, observations, review of records and test results or other means as detailed in the project requirements. After the extent and nature of the deficiency has been ascertained, the Contractor or the Geosynthetics Installer will implement corrective actions required to satisfy the project requirements. Areas that have been repaired will be retested. Retests must verify that the entire deficient area has been corrected prior to additional work being performed in that area.

5.5.2 Reinforcing Geotextile Construction Quality Assurance

The installation of the reinforcing geotextile shall be monitored to assure that the installation is conducted in accordance with the project specifications. Monitoring requirements include the deployment of the material in accordance with the specification, i.e., with the end seams staggered and the ends (at the outside edges) anchored with soil as shown on the drawings. The overlap provided during deployment should be monitored to assure the material overlap is sufficient for sewing. The sewing of the geotextile should be monitored to assure that the seams are installed in accordance with the specifications and that the sewing machine is operating properly, there are no areas of the seam that are skipped, and that the thread is not breaking too often.

5.5.3 Gemembrane Construction Quality Assurance

5.5.3.1 Geomembrane Placement

Field Panel Placement

The CQA Consultant shall verify that the Installer has taken all necessary precautions to protect the underlying geotextile during geomembrane deployment operations. The CQA Consultant shall verify that all geomembrane is handled in such a manner as to ensure it is not damaged in any way, and the following conditions are met:

- On slopes, the geomembrane is secured and then deployed down the slope in such a manner as to continually keep the geomembrane panel in tension;
- In the presence of wind, all geomembrane is weighted with sandbags or other method approved by the Engineer;
- Geomembrane panels are kept continually under tension to minimize the presence of wrinkles;
- The geomembrane is cut using a utility blade in a manner recommended by the manufacturer;
- During placement, care is taken not to entrap loose soil, sand, stones, or other debris under the geomembrane;
- The exposed geomembrane is protected from damage in heavily trafficked areas; and
- A visual examination of the geomembrane is carried out over the entire surface, after installation, to assure that damaged areas, if any, are identified and repaired.

The CQA Consultant shall verify that field panels are installed in substantial conformance with the Installer's panel layout plan, as approved or modified. The CQA Consultant shall record the field panel identification code, manufacturers roll number, location, date of installation, and dimensions of each field panel.

Geomembrane installation shall not proceed at an ambient temperature below 40 degrees Fahrenheit (°F) or above 104°F unless authorized in writing by the Engineer. Geomembrane installation shall not proceed during any precipitation, in the presence of excessive moisture (e.g., fog, dew), in an area of ponded water, or in the presence of excessive winds. The CQA Consultant shall monitor that the above conditions are fulfilled.

The CQA Consultant shall monitor geomembrane deployment for the following:

- Any equipment used does not damage the geomembrane by handling, trafficking, excessive heat, leakage of hydrocarbons or other means;
- Any geosynthetic elements immediately underlying the geomembrane are clean and free of foreign objects or debris;
- Personnel working on the geomembrane do not smoke, wear damaging shoes, or engage in other activities which could damage the geomembrane;
- The method used to unroll the panels does not cause scratches or crimps in the geomembrane and does not damage the supporting soil and does not damage the underlying geotextile;
- The method used to place the panels minimizes wrinkles (especially differential wrinkles between adjacent panels);
- Adequate temporary loading and/or anchoring (e.g., sand bags, tires), not likely to damage the geomembrane, has been placed to prevent uplift by wind (in case of high winds, continuous loading, e.g., by adjacent sand bags, is recommended along edges of panels to minimize risk of wind flow under the panels); and
- Direct contact with the geomembrane is minimized; i.e., the geomembrane is protected by geotextiles, extra geomembrane, or other suitable materials, in areas where excessive traffic may be expected.

The CQA Consultant shall observe the geomembrane panels, after placement and prior to seaming, for damage. The CQA Site Manager shall advise PEF which panels, or portions of panels, should be rejected, repaired, or accepted.

Damaged panels or portions of damaged panels that have been rejected shall be marked and their removal from the work area recorded by the CQA Consultant. Repairs shall be made according to procedures described in this Section.

Field Panel Identification

A field panel is the unit area of geomembrane which is to be seamed in the field, i.e., a field panel is a roll or a portion of roll cut in the field. The CQA Consultant shall assure that each field panel is given an "identification code" (number or letter-number) consistent with the layout plan. This identification code shall be agreed upon by the Installer and CQA Consultant. This field panel identification code shall be as simple and logical as possible. The Geosynthetic Manufacturer's roll numbers shall be traceable to the field panel identification code. The CQA Consultant shall document the correspondence between roll numbers, factory panels, and field panel identification codes. The field panel identification code shall be used for all quality assurance/quality control records.

5.5.3.2 Field Panel Seaming

Panel Layout Drawing

The CQA Consultant shall review the panel layout drawing submitted to PEF by the Installer and verify that it is consistent with accepted state of practice. In general, seams should be oriented parallel to the line of maximum slope, i.e., oriented along, not across, the slope. In corners and odd-shaped geometric locations, the number of seams should be minimized. No horizontal seam should be less than 5 feet beyond the toe of the slope, or areas of potential stress concentrations, unless otherwise authorized by the Engineer. A seam numbering system compatible with the field panel identification numbering system shall be agreed upon prior to any seaming.

Seaming Equipment and Products

General

Approved processes for field seaming are extrusion welding and fusion welding. Proposed alternate processes shall be documented and submitted to PEF for approval. Only equipment which has been specifically recommended by the Geosynthetics Manufacturer by make and model shall be used. All seaming equipment shall be permanently marked with an identification number.

Fillet Extrusion Seam Process

The fillet extrusion welding apparatus shall be equipped with gauges giving the temperature in the apparatus and at the nozzle. The CQA Consultant shall verify that the extrudate is comprised of the same resin as the geomembrane sheeting. The CQA Consultant shall monitor extrudate temperatures, ambient temperatures, and geomembrane surface temperatures at appropriate intervals.

The CQA Consultant shall also monitor that:

- The number of spare operable seaming apparatus agreed by PEF are maintained on site;
- Equipment used for seaming is not likely to damage the geomembrane;
- The extruder is purged prior to beginning a seam until all heat-degraded extrudate has been removed from the barrel;
- The electric generator is placed on a smooth base such that no damage occurs to the geomembrane; and
- A smooth insulating plate or fabric is placed beneath the hot welding apparatus after usage.

Fusion Seam Process

The fusion welding apparatus must be automated, self-propelled devices. The fusion welding apparatus shall be equipped with gauges giving the applicable temperatures and welding speed. The CQA Consultant shall monitor ambient temperatures, geomembrane surface temperatures, apparatus speed, and apparatus temperatures at appropriate intervals.

The CQA Consultant shall also monitor that:

- The number of spare operable seaming apparatus agreed by PEF are maintained on site;
- Equipment used for seaming will not damage the geomembrane;

- The electric generator is placed on a smooth base such that no damage occurs to the geomembrane;

- For cross seams, the edge of the cross seam is ground to a smooth incline (top and bottom) prior to welding;

- A smooth insulating plate or fabric is placed beneath the hot welding apparatus after usage; and

- A movable protective layer is used, as necessary, directly below each overlap of geomembrane that is to be seamed to prevent build-up of moisture between the sheets.

Seam Preparation

The CQA Consultant shall monitor that:

- Prior to seaming, the seam area is clean and free of moisture, dust, dirt, debris of any kind, and foreign material;

- Seams are overlapped a minimum of 5 inches for fusion seams and 3 inches for extrusion seams;

- If seam overlap grinding is required, the process is completed according to the Geosynthetics Manufacturer's instructions or Section 02770 of the Technical Specifications, whichever is the more stringent, prior to the seaming operation, and in a way that does not damage the geomembrane;

- The grind depth shall not exceed 5 percent of the nominal geomembrane thickness;

- Grinding marks shall not appear beyond the extrudate after it is placed; and

- Seams are aligned with the fewest possible number of wrinkles and fishmouths.

Overlapping and Temporary Bonding

The CQA Consultant shall monitor that:

- The panels of geomembrane have a finished overlap of a minimum of 5 inches for fusion seams and 3 inches for extrusion seams, but in any event sufficient overlap shall be provided to allow peel tests to be performed on the seam;

- No solvent or adhesive is used; and

- The procedure used to temporarily bond adjacent panels together does not damage the geomembrane; in particular, the temperature of hot air at the nozzle of any spot welding apparatus is controlled such that the geomembrane is not damaged.

Trial Seams

The CQA Consultant shall verify that the Installer performs trial seam tests in accordance with Section 02770 of the Technical Specifications. The CQA Consultant shall observe and document the Installer's trial seam testing procedures. The trial seam samples shall be assigned an identification number and marked accordingly by the CQA Consultant. Each sample shall be marked with the date, time, machine temperature(s) and setting(s), number of seaming unit, and name of seaming technician. Trial seam samples shall be maintained until destructive seam testing of the applicable seams are tested and pass.

General Seaming Procedures

No geomembrane seaming shall be performed unless the CQA Consultant is on-site. The CQA Consultant shall monitor the general seaming procedure used by the Installer as follows:

- If required for fusion welding, a movable protective layer of plastic will be placed directly below each overlap of geomembrane that is to be seamed. This is to prevent any moisture build-up between the sheets to be welded.

- If required, a firm substrate shall be provided by using a flat board, a conveyor belt, or similar hard surface directly under the seam overlap to achieve proper support.

- Fishmouths or wrinkles at the seam overlaps shall be cut along the ridge of the wrinkle in order to achieve a flat overlap. The cut fishmouths or wrinkles shall be seamed and any portion where the overlap is inadequate shall then be patched with an oval or round patch of the same geomembrane extending a minimum of 6 inches beyond the cut in all directions.

- If seaming operations are carried out at night, adequate illumination shall be provided by the Contractor to the satisfaction of the CQA Consultant.

- Seaming shall extend to the outside edge of panels to be placed in the anchor trench.

Nondestructive Seam Continuity Testing

The CQA Consultant shall verify that the Installer nondestructively tests all field seams over their full length using a vacuum test unit (for extrusion or single-wedge fusion seams) or air pressure test (for double-wedge fusion seams). Spark testing may be performed if the seam cannot be tested using the vacuum or air pressure test methods, such as around geomembrane/pipe boots. The purpose of nondestructive tests is to check the continuity of seams. Continuity testing shall be carried out as the seaming work progresses, not at the completion of all field seaming. The CQA Consultant shall:

- Monitor nondestructive testing;
- Document the results of the nondestructive testing; and
- Inform the Installer and PEF of any noncompliance.

Any required seam repairs shall be made in accordance with the Technical Specifications. The CQA Consultant shall:

- Observe the repair procedures;
- Observe the retesting procedures; and
- Document the results.

The seam number, date of observation, dimensions and/or descriptive location of the seam length tested, name of person performing the test, and outcome of the test shall be recorded by the CQA Consultant.

Destructive Testing

Overview

Destructive seam testing shall be performed during the geomembrane installation. The purpose of this testing is to evaluate seam strength. Destructive seam testing shall be done as the seaming work progresses, not at the completion of all field seaming.

Location and Frequency

The CQA Consultant shall select all destructive seam test sample locations. Sample locations shall be established as follows:

- A minimum frequency of one test location per 500 feet of seam length. This minimum frequency is to be determined as an average taken throughout the entire facility.
- A destructive test sample shall be obtained on all reconstructed seams or caps exceeding 150 feet in length. Other repairs will be sampled for destructive testing at the discretion of the CQA Consultant and at least once for every 500 feet of welding.
- Test locations shall be determined during seaming at the CQA Consultant's discretion. Selection of such locations may be prompted by suspicion of excess crystallinity, contamination, off-set welds, or any other potential cause of defective welding.

The Installer shall not be informed in advance of the locations where the seam samples will be taken.

Sampling Procedures

Destructive seam testing shall be performed as the seaming progresses in order to obtain the Geosynthetic CQA Laboratory test results before the geomembrane is covered by overlying materials. The CQA Consultant shall:

- Observe sample cutting;
- Assign a number to each sample, and mark it accordingly; and
- Record sample location on the record panel layout drawing.

All holes in the geomembrane resulting from destructive seam test sampling shall be immediately repaired in accordance with repair procedures described in Section 02770 of the Technical Specifications. The continuity of the new seams in the repaired area shall be nondestructively tested as described in Section 1.3.7.

Size of Samples

At a given sampling location, two types of samples (field test samples and laboratory test samples) shall be taken. First, a minimum of two field samples or test strips should be taken for field testing. Each of these test strips shall be 1 inch wide by 12 inches long, with the seam centered parallel to the width. The distance between these two specimens shall be 42 inches. If both specimens pass the field test described a full laboratory destructive sample shall be taken for testing by the Geosynthetics CQA Laboratory.

The test strips shall be tested in the field for peel adhesion using a calibrated tensiometer. In addition to meeting the strength requirements outlined in Section 02770 of the Technical Specifications, all specimens shall exhibit a Film Tear Bond (FTB) (i.e., the seam shall not fail in the weld). If any field test specimens fails to meet these requirements, the destructive sample will be considered failing. The CQA Consultant shall witness all field tests and mark all samples and portions with the sample number. The CQA Consultant shall also log the date, number of the seaming unit, seaming technician identification, destructive sample number and the test result (pass or fail).

The full destructive sample shall be located between the two field test strips. The sample shall be 12 inches wide by 42 inches long with the seam centered lengthwise. The sample shall be cut into three parts and distributed as follows:

- One 12-inch by 12-inch portion to the Installer;
- One 12-inch by 12-inch portion to PEF for archive storage; and
- One 12-inch by 18-inch portion for Geosynthetics CQA Laboratory testing.

Geosynthetics CQA Laboratory Testing

Destructive test samples shall be tested by the Geosynthetics CQA Laboratory. Testing shall include “bonded seam strength” (shear) and “peel adhesion” (peel) in accordance with ASTM D 4437. The minimum acceptable values to be obtained in these tests are listed in Section 02770 of the Technical Specifications. Five specimens shall be tested for each test method. Specimens shall be selected alternately by test from the samples (i.e., peel, shear, peel, shear…). Both the inside and outside tracks of the double-wedge fusion seams shall be tested for peel adhesion. A passing test shall meet the minimum required values in at least four out of five specimens for each test method (shear and peel).

The Geosynthetics CQA Laboratory shall provide test results no more than 24 hours after sample receipt. The CQA Site Manager shall review laboratory test results as soon as they become available, and make appropriate recommendations to PEF.

Procedures for Destructive Test Failure

The following procedures shall apply whenever a sample fails a destructive test, whether that test was conducted in the field or by the Geosynthetics CQA Laboratory. The CQA Consultant will verify that the Installer follows one of the two options below:

- The Installer can reconstruct the seam (e.g., remove the old seam and reseam) between any two passing destructive test sample locations or between points judged by the CQA Consultant to represent conditions of the failed seam (e.g., a tie-in seam or a seam made by the apparatus and/or operator used in the failing seam); or

- The Installer can trace the welding path to an intermediate location a minimum of 10 feet from the point of the failed test in each direction and take a sample for additional field testing in accordance with the destructive test procedure at each location. If these additional isolation samples pass the field test, then full laboratory samples are taken at both locations. If these laboratory samples meet the specified strength criteria, then the seam is reconstructed between these locations. If either sample the field or laboratory sample fails, then the process is repeated to establish the zone in which the seam should be reconstructed.

All failed seams must be bounded by two locations from which passing laboratory destructive test samples have been taken, unless the entire seam is reconstructed and retested. In cases exceeding 150 feet of reconstructed seam, a sample taken from the zone in which the seam has been reconstructed must also pass destructive testing. Repairs shall be made in accordance with Section 1.3.2. The CQA Consultant shall document all actions taken in conjunction with destructive test failures.

5.5.3.3 Defects and Repairs

Identification

All seams and non-seam areas of the geomembrane shall be examined by the CQA Consultant for identification of defects, holes, blisters, undispersed raw materials and any sign of contamination by foreign matter. Because light reflected by the geomembrane helps to detect defects, the surface of the geomembrane shall be clean at the time of examination. PEF shall require the geomembrane surface to be broom cleaned or washed by the Installer if the amount of dust or mud inhibits examination.

Repair Procedures

Any portion of the geomembrane exhibiting a flaw, or failing a destructive or nondestructive test, shall be repaired by the Geosynthetics Installer in accordance with Section 02770 of the Technical Specifications. Several procedures exist for the repair of these areas. The final decision as to the appropriate repair procedure shall be agreed upon between the Installer and CQA Consultant.

In addition, the following conditions shall be monitored by the CQA Consultant:

- Surfaces of the geomembrane which are to be repaired shall be abraded no more than one hour prior to the repair;
- All surfaces must be clean and dry at the time of the repair;
- All seaming equipment used in repairing procedures must be approved;
- The repair procedures, materials, and techniques shall be approved by the CQA Consultant in advance of the specific repair;
- Patches or caps shall extend at least 6 inches beyond the edge of the defect, and all corners of patches shall be rounded with a radius of at least 3 inches; and
- The geomembrane below large caps should be appropriately cut to avoid trapped water or gas between the two sheets.

Verification of Repairs

Each repair shall be numbered and logged. Each repair shall be non-destructively tested using approved methods. Repairs which pass the non-destructive test shall be taken as an indication of an adequate repair. Reconstructed seams or caps exceeding 150 feet in length shall require destructive test sampling. Other repairs will be sampled for destructive testing at the discretion of the CQA Consultant and at least once for every 500 feet of welding. The CQA Consultant shall observe all non-destructive testing of repairs and shall record the number of each repair, date, and test result (pass or fail).

5.6 Liner System Acceptance

The Contractor shall retain all responsibility for the geosynthetics until acceptance by PEF. The terms for liner system acceptance are described in Section 02770 of the specifications.

6.0 DOCUMENTATION

6.1 General

The CQA Consultant will confirm that quality assurance requirements have been addressed and documented. Further, the CQA Consultant will provide field reports, data sheets and checklists to substantiate that required monitoring tasks have been completed. The CQA Consultant will maintain a job site file of plans, specifications, checklists, test procedures, daily reports, logs and other project relevant documents.

6.2 Daily Record Keeping

For the FGD pond system construction and/or installation activities, the daily record keeping by the CQA Consultant will include at a minimum the following CQA/CQC related information:

- Daily Summary Report, reporting meetings and/or discussions with the Contractor and/or the Installer and a summary of the daily reports completed by each CQA Monitor (if more than one);
- Daily reports from each of the CQA Consultant's site personnel (CQA Monitors) describing the observations made of construction/installation activities and CQA/CQC monitoring/testing;
- Permit modification and clarification documentation;
- Weather conditions, including maximum and minimum ambient temperatures and precipitation events (external to any enclosures that may be used to protect the work); and
- Name and title of Construction Supervisor.

When construction activities include earthworks, the CQA daily record keeping will also include:

- Daily soils field test result data sheets;
- Laboratory soils test result data sheets;
- Identification of borrow source and the associated optimum moisture content/maximum dry density;
- Compaction equipment (type and weight) and the typical number of passes;

- Equipment used to place and spread materials adjacent to geosynthetic materials;
- Reduced scale site plan showing locations of soil tests and procured samples; and
- Equipment calibration or recalibration forms as applicable.

When construction activities include the installation of the geosynthetics components, the CQA daily record keeping will also include:

- Conformance test result data sheets;
- Equipment used for deployment and welding, if any;
- Installation problem and resolution reports and summaries; and
- Installation progress reports.

These documents will be accessible on site for review by interested parties.

Each Daily Summary Report will include:

- Date, project name, project number, and location;
- Identification of parties and personnel on-site or participating in meetings and discussions;
- Start-Up and end times of daily construction activities;
- Documentation of observations of construction and CQA activities/test results;
- Methods used to correct construction/installation deficiencies;
- Installation/Construction activities completed that day and summary of progress;
- A summary of the CQA/CQC tests performed and an indication of the results (which passed and which failed the project requirements);
- Summary of problems and their resolutions;
- Summary of meetings and discussions;

- Proposed activities for the next day; and
- Relevant discussions and the outcome of each.

6.3 Construction/Installation Problem Resolution Documentation

Construction/Installation problem and resolution documents will reference specific observations and test result data forms. These documents will include the following information:

- A detailed description of the problem, non-conformance or deficiency;
- Location identified by coordinates (if appropriate), and probable cause for the problem, nonconformance or deficiency;
- Detailed description of how and when the problem was identified;
- Detailed description of how the problem, non-conformance or deficiency was solved or corrected;
- Reference to results of any retests performed; and
- Detailed description of measures implemented to prevent recurrence of the problem nonconformance or deficiency.

These documents or descriptions will be incorporated as part of the Daily Summary Report. Any resulting modification or clarification to the permit plans or specifications will be documented and approved by the Engineer and Owner.

6.4 Permit and/or Specification Modification/Clarifications

During the course of construction or the installation of the components of the cover system, modifications or clarifications to the Permit or project requirements will be documented by the CQA Consultant. The Design Engineer will be notified for review and approval of any modification or clarification prior to implementation.

6.5 Photographic Records

Photographic records will adequately represent work progress, construction problems and resolutions, observations, typical testing procedures, and construction procedures. Photographs will be logged by the photographer and include the date and a brief description of the location and situation. Electronic copies of the photographs will be provided to PEF upon completion of the work, if requested. Photographs will be digitally recorded and filed on a CD or other appropriate electronic file, with the photograph log.

6.6 Final Report

Upon completion of the work, the CQA Consultant will submit a final certification report. The report will indicate that the work has been constructed in substantial compliance with the intent of the project permit and the project requirements, or any modification to same, and will be signed and sealed by the CQA Consultant representing the CQA responsible party. The final report will provide necessary supporting documentation compiled during the implementation of the CQA Plan.

The CQA final certification report will present the following information:

- Description of construction/installation activities;
- Summary of the project scope, materials used, observations, and sampling/testing procedures and criteria;
- List of construction/installation parties;
- Daily Inspection Summary Reports;
- Problem Identification/Resolution Reports;
- Permit and Specification Modification and Clarifications;
- Internal CQA memoranda with data interpretation or analyses, as applicable;
- Other pertinent data regarding the construction/installation; and
- A statement certifying that the project was completed in substantial compliance with the intent of the project and the project requirements under the signature and seal of the CQA Consultant.

The final certification report will include documentation related to the construction and the installation of the soils and geosynthetics components of the cover system, as follows:

- Description of construction equipment;
- Field test data summaries including sample numbers, test locations, lift, and pass or fail status for each test;

- Method of adjusting moisture, procedures used to control desiccation cracks, and method of repairing failing areas;
- Summary of laboratory test data;
- Geosynthetics conformance test data summaries;
- Subgrade surface acceptance forms;
- Observation of geosynthetic materials upon delivery;
- Inventory of geosynthetic rolls (or panels) shipped to the project;
- Resin and roll (or panel) certificates of analysis;
- Diagrams illustrating the location of tests; and
- Record drawings sealed by the Land Surveyor, including the elevation of the subgrade surface and the elevation of the top of each subsequent soil surface (including the USGS and site coordinate systems and the elevations and locations of vaults, manholes, trenches, piping, and other critical features).

Surveying, survey base maps and survey data supporting the record drawings will be developed by a Registered Land Surveyor. The record drawings will depict details pertaining to construction/installation, dimensions, elevations, final elevations, layer thicknesses, and appurtenance locations.

6.7 Acceptability of the Work

6.7.1 General

It is the responsibility of the CQA Consultant to determine and report to PEF whether the work, or a portion of the work, has been completed in substantial compliance with the intent of the permit, prevailing industry practice, and the project requirements.

6.7.2 Soils

Soil subgrades will be approved and accepted by the CQA Consultant prior to the installation of the geosynthetics. Density and moisture testing shall be complete such that any failing tests or areas have been retested to assure all areas have compliant test results.

6.7.3 Geosynthetics

Geosynthetic materials will be approved and accepted by the CQA Consultant prior to the installation of overlying layers, if any. Portions of a geosynthetic material installation which are to be approved as complete will be cleaned by the Geosynthetics Installer to remove any debris, scrap geosynthetics, mud or other material which would interfere with the inspection of the geosynthetic layer.

The CQA Consultant will inspect the geosynthetic materials for any damage that may have occurred during or after the initial installation activities and verify that identified repairs have been completed, non-destructive testing has been performed, and destructive test samples from the area to be approved have either been passed or are bound by passing destructive tests and the failed seams reconstructed.

Upon satisfactorily completing this review, and if no additional damage to the geosynthetic material is identified, the CQA Consultant will recommend the approval of the installation, or that specific portion of the installation. The approval process will be staged, and will occur as the work progresses rather than at the end of the installation process.

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APPENDIX B

Soil Boring Logs
FGD Blowdown Ponds

WILLIAMS BORING LOGS

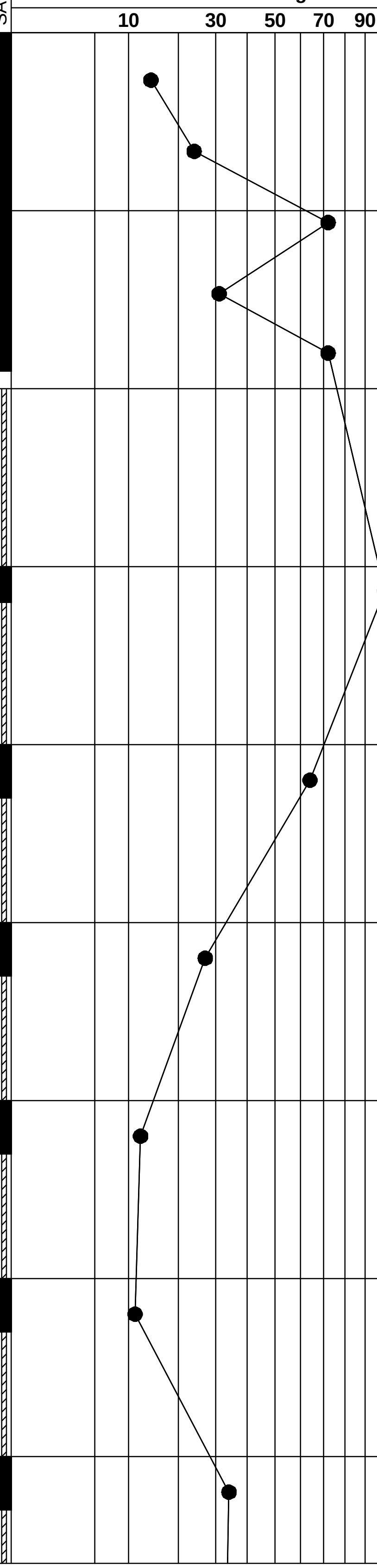
TEST BORING LOG

WILLIAMS
EARTH SCIENCES, INC.

Project	Crystal River, FGD Borings 1-6	Boring No.	B-1
Boring Location	ERI Line 2, Station 60	Sheet	1 of 2
Ground Elevation	92.8 92.76'	Job No.	1307-011-07
Groundwater Depth	⊻ 4'	Boring Completed	10/23/2008
Length of Casing Set	15'	Driller	CARNEY
		Drill Rig	CME 75 AUTOMATIC

DEPTH FEET	CLASSIFICATION	BLOWS ON SAMPLER PER 6"
	MEDIUM DENSE brown silty fine SAND with limestone seams (SM)	8/7/7/10 REC 24"
	Cream colored medium hard to hard LIMESTONE	7/8/16/16 REC 24"
⊻		
5		15/43/29/28 REC 24"
		15/16/15/21 REC 18"
		12/22/50 REC 12"
10	CR 1, Cream dense fine grained medium hard to hard fossiliferous LIMESTONE Rockcore from 10' to 15' Rec 100% RQD 95% Gear 2nd PSI 120 RPM 78 Drill Time - Min:Sec 12:57, 16:05, 10:07, 2:10, 2:50	
15	20% Loss of circulation @ 15'	21/50=6" REC 5"
	CR 2, Cream dense fine grained medium hard to hard fossiliferous LIMESTONE Rockcore from 15' to 20' Rec 100% RQD 77% Gear 2nd PSI 120 RPM 78 Drill Time - Min:Sec 1:06, 5:49, 3:03, 20:05, 12:13	
20	CR 3, Cream porous fine grained soft to medium hard LIMESTONE Rockcore from 20' to 25' Rec 100% RQD 0% Gear 2nd PSI 120 RPM 78 Drill Time - Min:Sec 10:30, 3:07, 14:15, 16:16, 1:01	18/37/27 REC 18"
25	CR 4, Cream porous fine grained soft to medium hard LIMESTONE Rockcore from 25' to 30' Core size - 4 inch Rec 100% RQD 97% Gear 2nd PSI 120 RPM 78 Drill Time - Min:Sec 0:57, 1:07, 0:44, 0:43, 0:38	10/15/12 REC 18"
30	CR 5, Cream soft weakly cemented LIMESTONE Rockcore from 30 to 35' Rec 57% RQD 0% Gear 2nd PSI 120 RPM 78 Drill Time - Min:Sec 2:46, 0:42, 1:45, 4:17, 1:55	4/5/7 REC 18"
35	CR 6, Tan soft weakly cemented LIMESTONE Rockcore from 35' to 40' Rec 53% RQD 0% Gear 2nd PSI 120 RPM 78 Drill Time - Min:Sec 0:29, 043, 1:18, 0:55, 5:06	3/4/7 REC 18"
40	CR 7, Tan soft fine grained poorly cemented LIMESTONE Rockcore from 40' to 45' Rec 96% RQD 47%	10/21/13 REC 18"

STANDARD PENETRATION TEST
Blows per foot on 2" O.D. Sampler with 140 lb. hammer falling 30"



TEST BORING LOG

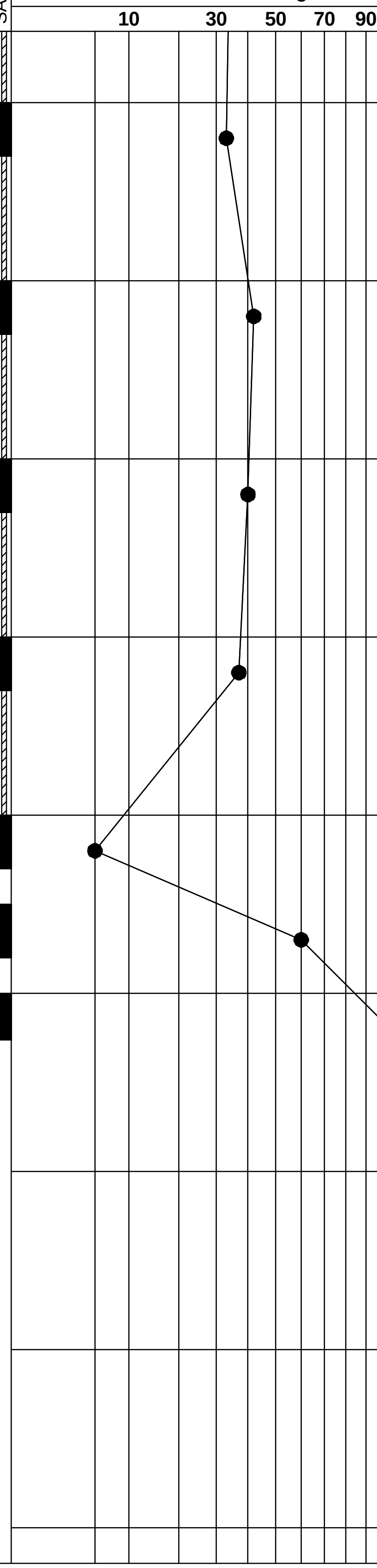
WILLIAMS
EARTH SCIENCES, INC.

Project: **Crystal River, FGD Borings 1-6**

Boring No. **B-1**
Sheet **2** of **2**
Job No. **1307-011-07**

DEPTH FEET	LITH-OLOGY	CLASSIFICATION	SAMPLE	BLOWS ON SAMPLER PER 6"
45		Gear 2nd PSI 120 RPM 78 Drill Time - Min:Sec 1:28, 1:06, 1:45, 3:02, 6;10		
45–50		CR 8, Tan soft fine grained poorly cemented LIMESTONE Rockcore from 45' to 50' Rec 97% RQD 60% Gear 2nd PSI 120 RPM 78 Drill Time - Min:Sec 0:40, 0:52, 1:04, 0:54, 0:33		16/15/18 REC 18"
50–55		CR 9, Tan medium hard fine grained LIMESTONE with small vugs Rockcore from 50' to 55' Rec 100% RQD 90% Gear 2nd PSI 120 RPM 78 Drill Time - Min:Sec 0:43, 1:04, 0:55, 0:32, 1:01		10/24/18 REC 18"
55–60		CR 10, Tan soft to medium hard fine grained LIMESTONEl Rockcore from 55' to 60' Rec 67% RQD 28% Gear 2nd PSI 120 RPM 78 Drill Time - Min:Sec 0:46, 3:30, 2:23, 22:58, 11:58		15/22/18 REC 18"
60–65		CR 11, Tan soft to medium hard, weakly cemented LIMESTONE Rockcore from 60' to 65' Rec 47% RQD 0% Gear 2nd PSI 120 RPM 78 Drill Time - Min:Sec 0;50, 1:57, 4:38, 6:17, 0:18		8/25/12 REC 18"
65–70		FIRM to HARD gray calcareous clayey SILT (Limestone Formation)		1/2/3 REC 18" 4/18/42 REC 12"
70		HARD cream colored calcareous SILT (Limestone Formation)		19/44/50=3" REC 12"
75–85		Boring Terminated @ 71.3' Notes: Borehole Chipped Percent Recovery and RQD based on portion of Core Run not including SPT. Drill times per foot include total Core Run.		

STANDARD PENETRATION TEST
Blows per foot on 2" O.D. Sampler with 140 lb. hammer falling 30"



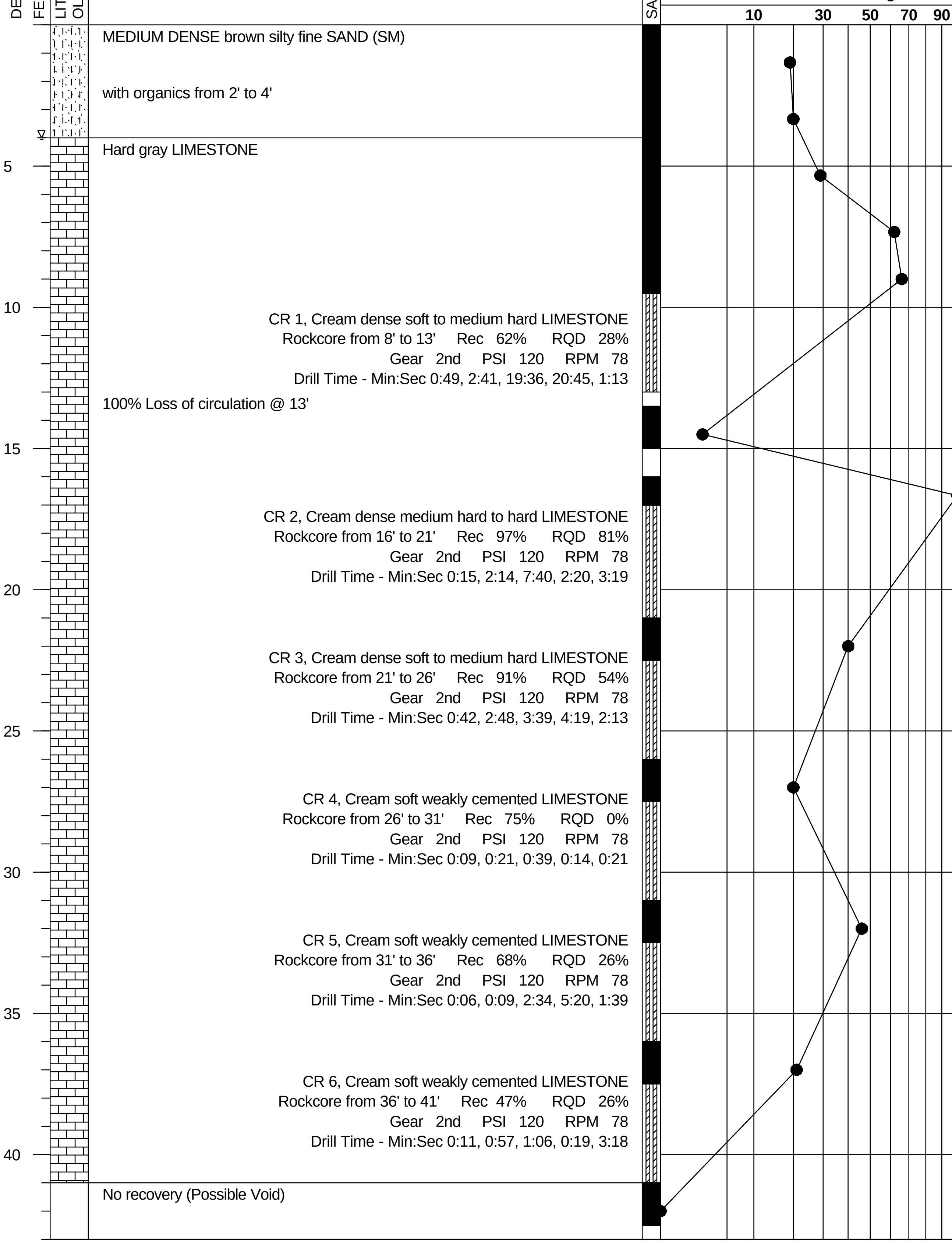
TEST BORING LOG

WILLIAMS
EARTH SCIENCES, INC.

Project	Crystal River, FGD Borings 1-6
Boring Location	ERI Line 1, Station 170
Ground Elevation	92.8 92.80'
Groundwater Depth	4'
Length of Casing Set	60'
Boring No.	B-2
Sheet	1 of 2
Job No.	1307-011-07
Boring Completed	10/31/2008
Driller	CARNEY
Drill Rig	CME 75 AUTOMATIC

DEPTH FEET	CLASSIFICATION	BLOWS ON SAMPLER PER 6"
0	MEDIUM DENSE brown silty fine SAND (SM)	
	with organics from 2' to 4'	5/10/9/10 REC 24"
		2/7/13/17 REC 24"
4	Hard gray LIMESTONE	28/19/10/19 REC 24"
		15/36/26/23 REC 24"
		22/29/37/40 REC 24"
10	CR 1, Cream dense soft to medium hard LIMESTONE Rockcore from 8' to 13' Rec 62% RQD 28% Gear 2nd PSI 120 RPM 78 Drill Time - Min:Sec 0:49, 2:41, 19:36, 20:45, 1:13	
13	100% Loss of circulation @ 13'	1/1/1/1 REC 4"
		31/50=6" REC 11"
	CR 2, Cream dense medium hard to hard LIMESTONE Rockcore from 16' to 21' Rec 97% RQD 81% Gear 2nd PSI 120 RPM 78 Drill Time - Min:Sec 0:15, 2:14, 7:40, 2:20, 3:19	
		16/15/25 REC 14"
	CR 3, Cream dense soft to medium hard LIMESTONE Rockcore from 21' to 26' Rec 91% RQD 54% Gear 2nd PSI 120 RPM 78 Drill Time - Min:Sec 0:42, 2:48, 3:39, 4:19, 2:13	
		10/11/9 REC 15"
	CR 4, Cream soft weakly cemented LIMESTONE Rockcore from 26' to 31' Rec 75% RQD 0% Gear 2nd PSI 120 RPM 78 Drill Time - Min:Sec 0:09, 0:21, 0:39, 0:14, 0:21	
		4/15/31 REC 16"
	CR 5, Cream soft weakly cemented LIMESTONE Rockcore from 31' to 36' Rec 68% RQD 26% Gear 2nd PSI 120 RPM 78 Drill Time - Min:Sec 0:06, 0:09, 2:34, 5:20, 1:39	
		18/9/12 REC 16"
	CR 6, Cream soft weakly cemented LIMESTONE Rockcore from 36' to 41' Rec 47% RQD 26% Gear 2nd PSI 120 RPM 78 Drill Time - Min:Sec 0:11, 0:57, 1:06, 0:19, 3:18	
41	No recovery (Possible Void)	WOR=18" REC 0"

STANDARD PENETRATION TEST
Blows per foot on 2" O.D. Sampler with 140 lb. hammer falling 30"



TEST BORING LOG

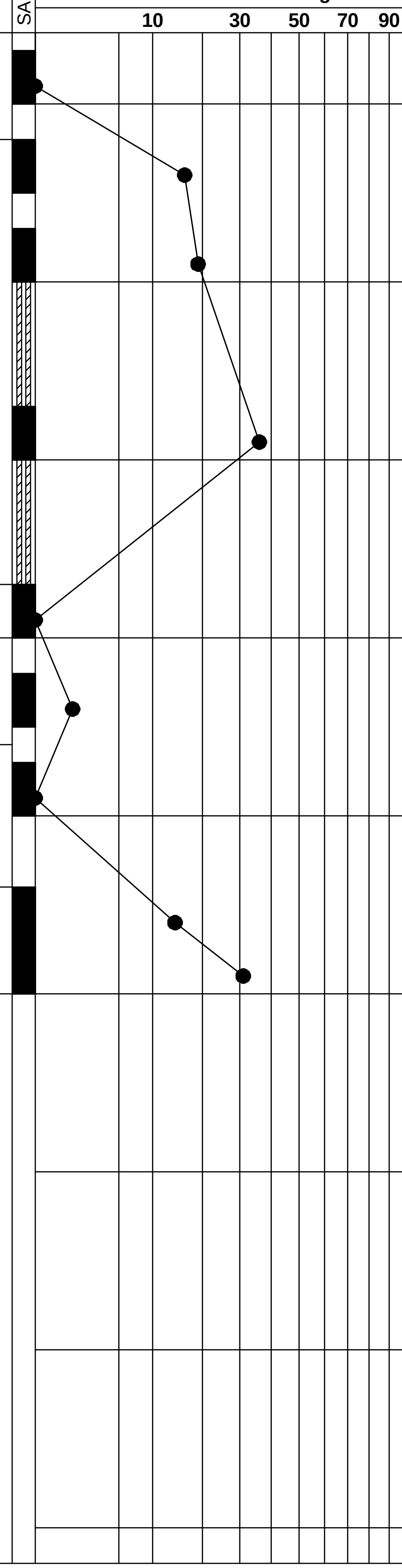
WILLIAMS EARTH SCIENCES, INC.

Project: **Crystal River, FGD Borings 1-6**

Boring No. **B-2**
Sheet **2** of **2**
Job No. **1307-011-07**

DEPTH FEET	CLASSIFICATION	BLOWS ON SAMPLER PER 6"
	No recovery (Possible Void)	WOR=18" REC 0"
45	Soft cream colored LIMESTONE	2/6/10 REC 13"
		12/9/10 REC 16"
50	CR 7, Cream dense to porous weakly cemented LIMESTONE Rockcore from 48.5' to 53.5' Rec 100% RQD 71% Gear 2nd PSI 120 RPM 78 Drill Time - Min:Sec 0:33, 1:12, 3:50, 2:46, 2:07	
		19/15/21 REC 15"
55	CR 8, Tan soft weakly cemented LIMESTONE Rockcore from 53.5' to 58.5' Rec 38% RQD 0% Gear 2nd PSI 120 RPM 78 Drill Time - Min:Sec 0:43, 0:21, 0:29, 0;03, 0:05	
	No recovery (Possible Void)	REC 0" WOR=18"
60	VERY LOOSE brown calcareous SAND (Limestone Formation)	4/WOH/1 REC 12"
	No recovery (Possible Void)	WOR=18" REC 0 "
65	SOFT to HARD gray calcareous sandy SILT (Limestone Formation)	WOH=12"/14 REC 18" 22/17/14 REC 18"
70	Boring Terminated @ 70.0'	
75		
80		
85		

STANDARD PENETRATION TEST
Blows per foot on 2" O.D. Sampler with 140 lb. hammer falling 30"



Notes:
Borehole Chipped

Percent Recovery and RQD based on portions of Core Run not including SPT.

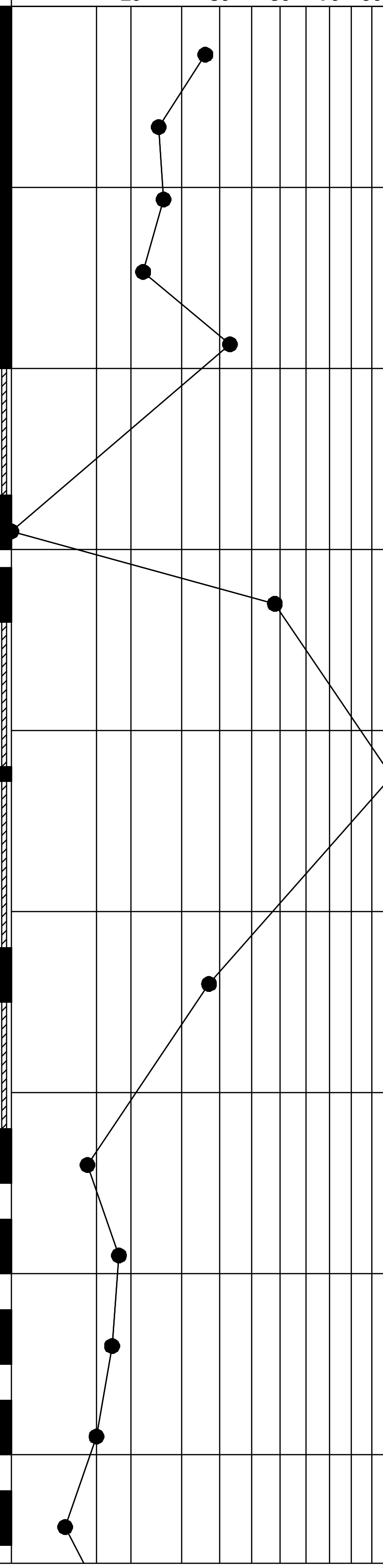
Drill times per foot include total Core Run.

TEST BORING LOG

WILLIAMS
EARTH SCIENCES, INC.

Project	Crystal River, FGD Borings 1-6	Boring No.	B-3
Boring Location	ERI Line 1, Station 135	Sheet	1 of 2
Ground Elevation	92.5 92.54'	Job No.	1307-011-07
Groundwater Depth ⊻	4'	Boring Completed	10/30/2008
Length of Casing Set	60'	Driller	CARNEY
		Drill Rig	CME 75 AUTOMATIC

STANDARD PENETRATION TEST
Blows per foot on 2" O.D. Sampler with 140 lb. hammer falling 30"



DEPTH FEET	CLASSIFICATION	BLOWS ON SAMPLER PER 6"
0	DENSE brown silty fine SAND with trace limestone (SM)	6/9/17/44 REC 24"
2	VERY STIFF dark brown SILT with trace organics (ML)	10/5/10/12 REC 14"
5	Soft gray LIMESTONE	11/10/6/7 REC 22"
		8/8/4/5 REC 16"
	100% Loss of circulation @ 8'	7/18/15/16 REC 24"
10	CR 1, Cream dense medium hard LIMESTONE Rockcore from 8.5' to 13.5' Rec 100% RQD 25% Gear 2nd PSI 120 RPM 78 Drill Time - Min:Sec 0:16, 3:25, 14:45, 21:25, 15:22	
15		2/WOH=12" REC 0"
		4/14/34 REC 18"
	CR 2, Cream dense medium hard LIMESTONE Rockcore from 16' to 21' Rec 94% RQD 43% Gear 2nd PSI 120 RPM 78 Drill Time - Min:Sec 0:12, 1;03, 5;36, 8;58, 21:20	
20		REC 5" 50=5"
	CR 3, Cream dense medium hard LIMESTONE Rockcore from 21' to 26' Rec 90 RQD 36% Gear 2nd PSI 120 RPM 78 Drill Time - Min:Sec 1:50, 1:43, 1:15, 1:07, 0:56	
25		11/12/15 REC 11"
	CR 4, Cream dense medium hard LIMESTONE Rockcore from 26' to 31' Rec 78% RQD 47% Gear 2nd PSI 120 RPM 78 Drill Time - Min:Sec 0"55, 0:48, 1:49, 2:35, 2:10	
30	with brown sandy silt seam from 31' to 32.5'	2/1/3 REC 9"
	Very Soft cream LIMESTONE	1/6/2 REC 5"
35		5/3/4 REC 4"
		4/3/2 REC 10"
40	No recovery (Possible Void)	WOR=12"/2 REC 0"

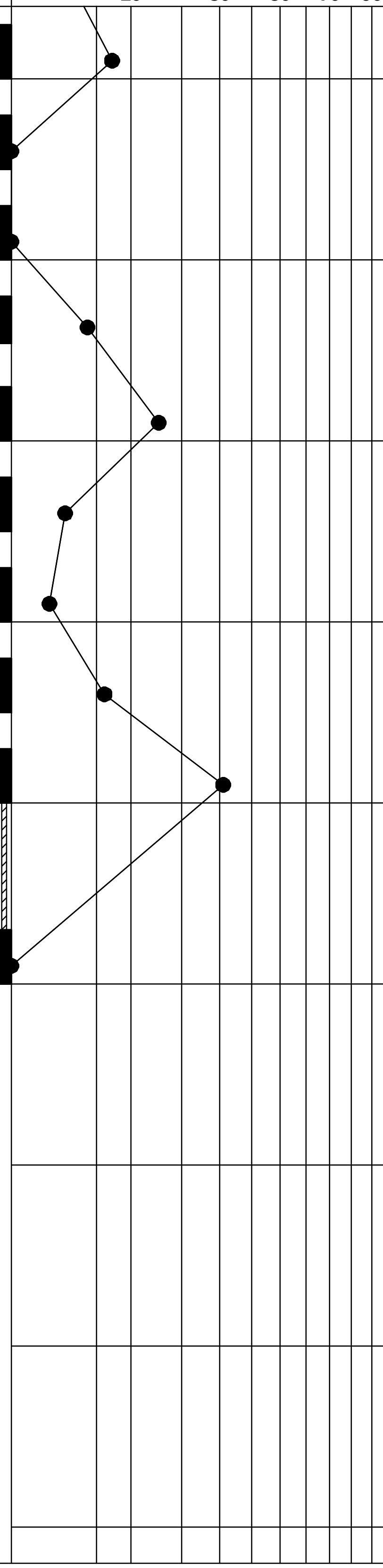
TEST BORING LOG

WILLIAMS
EARTH SCIENCES, INC.

Project: Crystal River, FGD Borings 1-6

Boring No. B-3
Sheet 2 of 2
Job No. 1307-011-07

DEPTH FEET	LITH-OLOGY	CLASSIFICATION	SAMPLE	STANDARD PENETRATION TEST Blows per foot on 2" O.D. Sampler with 140 lb. hammer falling 30" (10 30 50 70 90)	BLOWS ON SAMPLER PER 6"
		Very Soft cream LIMESTONE			WOR=12"/7 REC 5"
45					
		No recovery (Possible Void)			WOR=18" REC 0"
					WOR=18" REC 0"
50					
		Soft to very soft cream colored LIMESTONE			WOH/3/1 REC 3"
					WOR/8/7 REC 12"
55					
					2/1/1 REC 12"
					1=12"/1 REC 0"
60					
					3=12"/6 REC 6"
					27/13/18 REC 16"
65		CR 5, Tan dense medium hard LIMESTONE Rockcore from 63.5' to 68.5' Rec 35% RQD 27% Gear 2nd PSI 120 RPM 78 Drill Time - Min:Sec 1:14, 2:34, 0:36, 1;13, 0:06			
		No recovery (Possible Void)			WOR=18" REC 0"
70		Boring Terminated @ 70.0'			
75					
80					
85					



Boring Terminated @ 70.0'

Notes:
Borehole Chipped

Percent Recovery and RQD based on portions of Core Run not including SPT.

Drill times per foot include total Core Run.

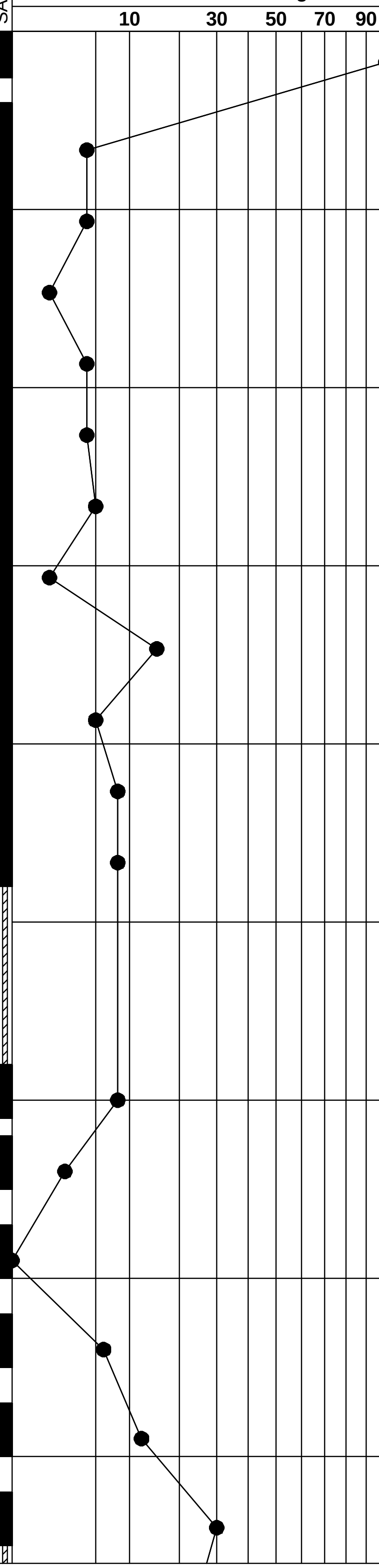
TEST BORING LOG

WILLIAMS EARTH SCIENCES, INC.

Project	Crystal River, FGD Borings 1-6
Boring Location	ERI Line 3, Station 115
Ground Elevation	92.5 92.48'
Groundwater Depth	4'
Length of Casing Set	65'
Boring No.	B-4
Sheet	1 of 2
Job No.	1307-011-07
Boring Completed	10/27/2008
Driller	CARNEY
Drill Rig	CME 75 AUTOMATIC

DEPTH FEET	CLASSIFICATION	BLOWS ON SAMPLER PER 6"
0	VERY DENSE brown fine SAND with trace gravel (SP)	4/8/50=3" REC 15"
2	LOOSE brown silty fine SAND (SM)	4/2/2/2 REC
4	SOFT black PEAT mixed with sand (PT)	1/2/2/2 REC 24"
		WOH=18"/1 REC 24 "
		3/2/2/2 REC 20"
9.5	Very soft to soft gray LIMESTONE	3/2/2/3 REC 18"
	100% Loss of circulation @ 13'	1/2/3/1 REC 10"
		2/1=12"/2 REC 2"
		6/4/11/12 REC 8"
		6/2/3/8 REC 10"
		11/5/3/2 REC 14"
		1=12"/8/9 REC 14"
24	100% Loss of circulation for the full run CR 1, Cream weakly cemented LIMESTONE Rockcore from 24' to 29' Rec 10% RQD 0% Gear 2nd PSI 120 RPM 78 Drill Time - Min:Sec 2:07, 0:10, 0:05, 0:06, 0:06	
	Soft to very soft cream LIMESTONE	
30	100% Loss of circulation @ 30'	1/4/4 REC 16"
		WOH=12"/2 REC 1"
		WOH=18" REC 1"
		6/3/3 REC 16"
		21/7/5 REC 16"
		10/11/19 REC 16"

STANDARD PENETRATION TEST
Blows per foot on 2" O.D. Sampler with 140 lb. hammer falling 30"



TEST BORING LOG

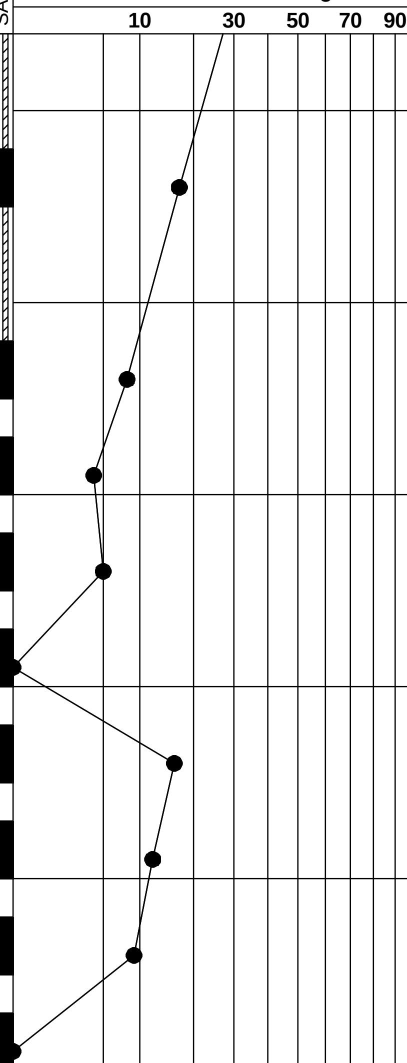
WILLIAMS
EARTH SCIENCES, INC.

Project: **Crystal River, FGD Borings 1-6**

Boring No. **B-4**
Sheet **2** of **2**
Job No. **1307-011-07**

DEPTH FEET	CLASSIFICATION	BLOWS ON SAMPLER PER 6"
45	CR 2, Cream weakly cemented LIMESTONE Rockcore from 46' to 51' Rec 34% RQD 0% Gear 2nd PSI 150 RPM 78 Drill Time - Min:Sec 0:03, 0:23, 3:15, 23:15, 0:42	6/7/10 REC 13"
50	CR 3, Cream weakly cemented LIMESTONE Rockcore from 46' to 51' Rec 75% RQD 43% Gear 2nd PSI 120 RPM 78 Drill Time - Min:Sec 0:37, 1:32, 0:40, 1;10, 2:22	13/5/3 REC 5"
	Soft cream LIMESTONE	3/2/2 REC 9"
55		2/1/4 REC 9"
	VERY SOFT brown clayey SILT with a thin lens of black clay (ML)	1=18" REC 13"
60	Medium soft cream colored LIMESTONE	5/9/7 REC 9"
65		5/9/3 REC 8"
	STIFF to VERY STIFF gray calcareous sandy SILT (Limestone Formation)	4/5/4 REC 18"
	With a lens of dark gray clay from 68.5' to 70.0'	WOR=18" REC 10"
70	Boring Terminated @ 70.0'	
75		
80		
85		

STANDARD PENETRATION TEST
Blows per foot on 2" O.D. Sampler
with 140 lb. hammer falling 30"



Notes:
Borehole Chipped

Percent Recovery and RQD based on portions of Core Run not including SPT.

Drill times per foot include total Core Run.

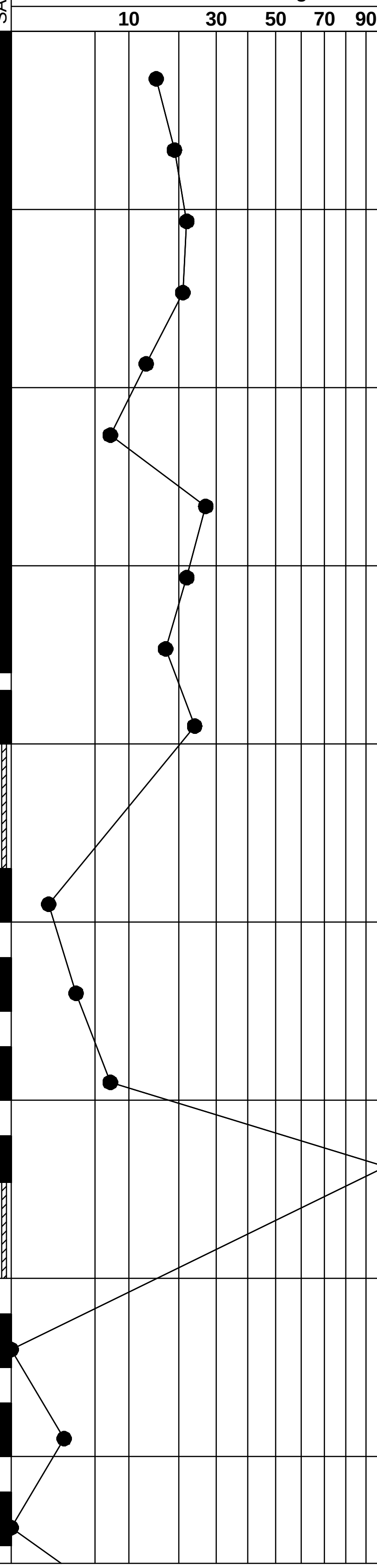
TEST BORING LOG

WILLIAMS
EARTH SCIENCES, INC.

Project	Crystal River, FGD Borings 1-6	Boring No.	B-5
Boring Location	ERI Line 3, Station 130	Sheet	1 of 2
Ground Elevation	92.4 92.35'	Job No.	1307-011-07
Groundwater Depth	⊻ 4'	Boring Completed	10/28/2008
Length of Casing Set	65'	Driller	CARNEY
		Drill Rig	CME 75 AUTOMATIC

DEPTH FEET	CLASSIFICATION	BLOWS ON SAMPLER PER 6"
0	MEDIUM DENSE brown silty fine SAND (SM)	
1.5		5/7/8/5 REC 22"
2	With clay nodules from 2' to 4'	
3.5		4/8/11/12 REC 24"
4	⊻	
5.5		9/10/12/11 REC 20"
6	SOFT gray sandy LIMESTONE	
7.5		8/11/10/11 REC 17"
8	MEDIUM DENSE gray silty fine SAND with trace limestone (SM)	
9.5		7/7/6/7 REC 19"
10	SOFT light gray LIMESTONE	
11.5		3/4/3/8 REC 17"
13.5		3/11/16/7 REC 12"
15.5		9/11/11/13 REC 16"
17.5		5/7/10 REC 15"
19.5		8/6/18 REC 12"
20	CR 1, Gray soft weakly cemented LIMESTONE Rockcore from 18.5' to 23.5' Rec 86% RQD 31% Gear 2nd PSI 120 RPM 78 Drill Time - Min:Sec 0:58, 3:36, 1:33, 2:15, 1:20	
23.5	VERY SOFT gray to brown sandy LIMESTONE	
24.5		1=12"/1 REC 10"
27		2/1/2 REC 14"
29.5		WOH/2/5 REC 8"
30	100% Loss of circulation @ 30'	
31.5		20/38/50=4" REC 16"
32	CR 2, Tan dense weakly cemented LIMESTONE Rockcore from 31' to 36' Rec 27% RQD 0% Gear 2nd PSI 120 RPM 78 Drill Time - Min:Sec 1:14, 4:28, 4:58, 0:06, 0:02	
36	No recovery	
37		WOH=18" REC 0"
39.5		WOH/1/1 REC 3"
41	VERY SOFT tan LIMESTONE	
42		1=18" REC 2"

STANDARD PENETRATION TEST
Blows per foot on 2" O.D. Sampler
with 140 lb. hammer falling 30"



TEST BORING LOG

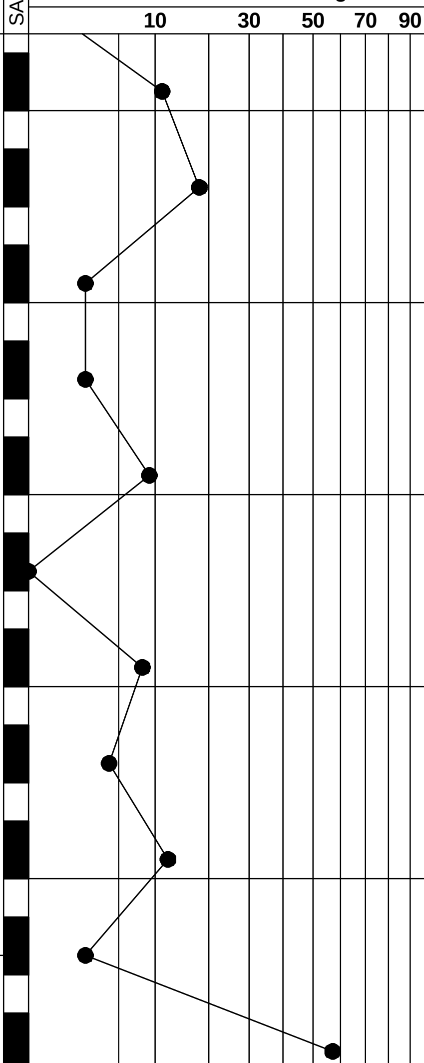
WILLIAMS
EARTH SCIENCES, INC.

Project: **Crystal River, FGD Borings 1-6**

Boring No. **B-5**
Sheet **2** of **2**
Job No. **1307-011-07**

DEPTH FEET	CLASSIFICATION
43–44.5	SOFT gray to brown sandy LIMESTONE
44.5–67	MEDIUM to VERY STIFF cream colored LIMESTONE
67–70	VERY SOFT to HARD cream to gray calcareous clayey SILT with a lens of soft dark gray clay
70	Boring Terminated @ 70.0'

STANDARD PENETRATION TEST
Blows per foot on 2" O.D. Sampler
with 140 lb. hammer falling 30"



BLOWS ON SAMPLER PER 6"
4/4/7 REC 8"
11/11/7 REC 11"
WOH=12"/2 REC 2"
1/1/1 REC 5"
3/4/5 REC 14
5/WOH=12" REC 12"
10/7/1 REC 14"
2/2/2 REC 7"
8/6/6 REC 18"
8/1/1 REC 14"
WOR/36/21 REC 18'

Notes:
Borehole Chipped

Percent Recovery and RQD based on portions of Core Run not affected by SPT.

Drill times per foot include total Core Run.

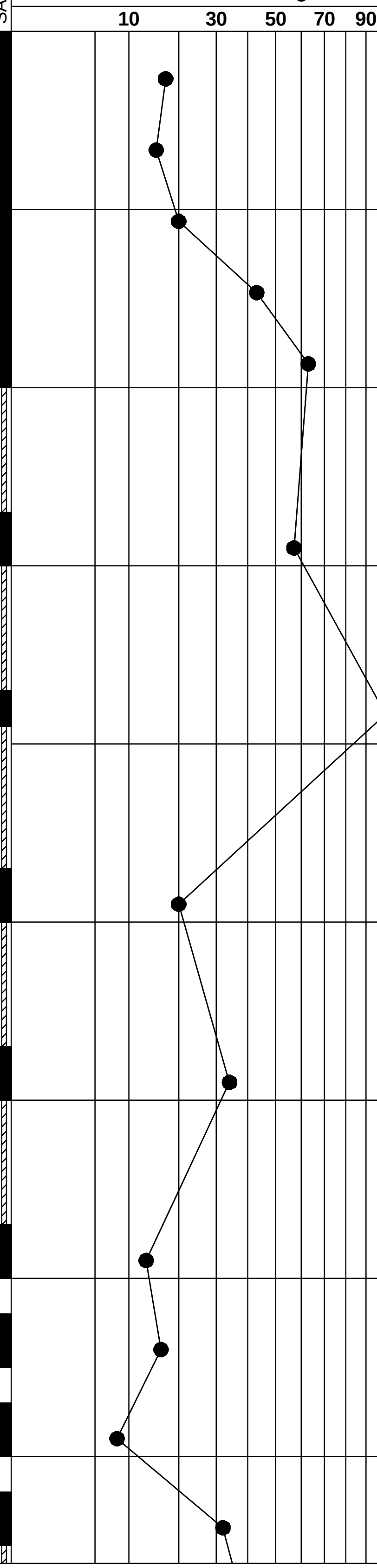
TEST BORING LOG

WILLIAMS
EARTH SCIENCES, INC.

Project	Crystal River, FGD Borings 1-6	Boring No.	B-6
Boring Location	ERI Line 2, Station 170	Sheet	1 of 2
Ground Elevation	92.4 92.44'	Job No.	1307-011-07
Groundwater Depth ⊻	4'	Boring Completed	11/30/2008
Length of Casing Set	50'	Driller	CARNEY
		Drill Rig	CME 75 AUTOMATIC

DEPTH FEET	CLASSIFICATION	BLOWS ON SAMPLER PER 6"
0	MEDIUM DENSE brown silty fine SAND with trace roots (SM)	
		5/8/9/6 REC 24"
⊻	MEDIUM SOFT to MEDIUM HARD gray to light gray LIMESTONE	2/6/9/22 REC 24"
5		12/10/10/14 REC 24"
		21/23/20/22 REC 24"
	Note: Inner barrel liner destroyed by root - RQD is suspect	
10	CR 1, Cream dense fine grained medium hard LIMESTONE Rockcore from 8.5' to 13.5' Rec 100% RQD 47% Gear 2nd PSI 120 RPM 78 Drill Time - Min:Sec 2:19, 4:34, 7:59, 20:06, 4;57	13/26/37/48 REC 24"
	Hard cream colored LIMESTONE	
15	CR 2, Hard cream colored LIMESTONE with small vugs Rockcore from 13.5' to 18.5' Rec 100% RQD 97% Gear 2nd PSI 120 RPM 78 Drill Time - Min:Sec 3:11, 6:05, 10:08, 1;56, 1:34	43/27/30 REC 18"
20	CR 3, Hard cream colored LIMESTONE with small vugs Rockcore from 18.5' to 23.5' Rec 100% RQD 77% Gear 2nd PSI 120 RPM 78 Drill Time - Min:Sec 4:01, 2:10, 9:47, 9:05, 7:13	33/50=6" REC 11"
25	CR 4, Cream dense fine grained weakly cemented LIMESTONE Rockcore from 23.5' to 28.5' Rec 81% RQD 0% Gear 2nd PSI 120 RPM 78 Drill Time - Min:Sec 0:39, 2:07, 4:45, 1:14, 0:03	7/9/11 REC 14"
30	CR 5, Cream dense fine grained weakly cemented LIMESTONE Rockcore from 28.5' to 33.5' Rec 53% RQD 0% Gear 2nd PSI 120 RPM 78 Drill Time - Min:Sec 0:10, 0:28, 2:39, 7;00, 0:37	4/14/20 REC 15"
35	Soft cream LIMESTONE	9/4/9 REC 15"
		7/6/10 REC 18"
40		3/3/5 REC 8"
	Medium hard cream LIMESTONE	12/10/22 REC 18"

STANDARD PENETRATION TEST
Blows per foot on 2" O.D. Sampler with 140 lb. hammer falling 30"



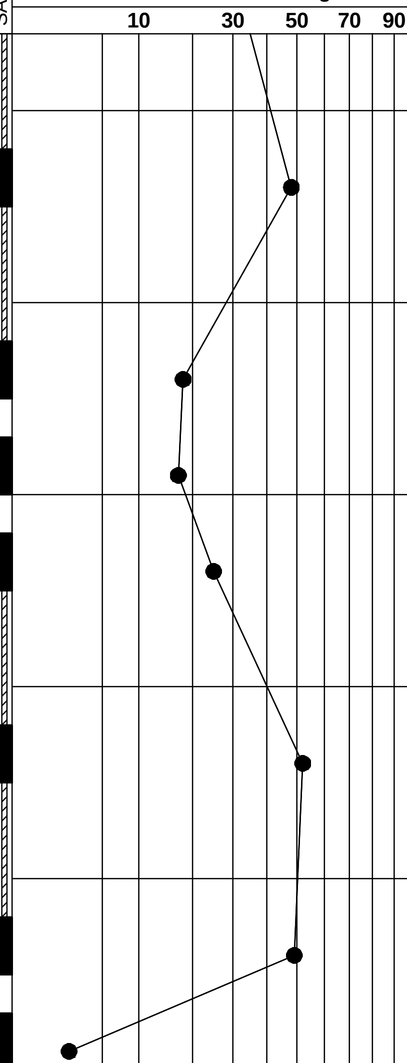
TEST BORING LOG

WILLIAMS
EARTH SCIENCES, INC.

Project: **Crystal River, FGD Borings 1-6**

Boring No. **B-6**
Sheet **2** of **2**
Job No. **1307-011-07**

DEPTH FEET	CLASSIFICATION	SAMPLE / STANDARD PENETRATION TEST (Blows per foot on 2" O.D. Sampler with 140 lb. hammer falling 30")	BLOWS ON SAMPLER PER 6"
45	CR 6, Cream silghtly porous weakly cemented LIMESTONE Rockcore from 41' to 46' Rec 76% RQD 33% Gear 2nd PSI 120 RPM 78 Drill Time - Min:Sec 0:21, 0:24, 2:46, 3:03, 1:20		
	CR 7, Cream soft weakly cemented LIMESTONE Rockcore from 46' to 51' Rec 36% RQD 0% Gear 2nd PSI 120 RPM 78 Drill Time - Min:Sec 0:21, 1:53, 4:29, 3:08, 1:27		12/24/24 REC 16"
50	Soft cream LIMESTONE		12/7/11 REC 16"
55			5/7/10 REC 14"
			3/8/17 REC 11"
60	CR 8, Cream porous weakly cemented LIMESTONE Rockcore from 56' to 61' Rec 57% RQD 26% Gear 2nd PSI 120 RPM 7 Drill Time - Min:Sec 0:06, 0:24, 1:29, 3:08, 1:58		13/23/29 REC 14'
65	CR 9, Cream porous weakly cemented LIMESTONE Rockcore from 61' to 66' Rec 38% RQD 0% Gear 2nd PSI 120 RPM 78 Drill Time - Min:Sec 0:27, 1:18, 3:20, 0:48, 3:40		
	Medium hard tan LIMESTONE		32/28/21 REC 17"
70	Very soft tan LIMESTONE		7/1/1



Boring Terminated @ 70.0'

Notes:
Borehole Chipped

Percent Recovery and RQD based on portions of Core Run not affected by SPT.

Drill times per foot include total Core Run.

75
80
85

GOLDER BORING LOGS

RECORD OF BOREHOLE G-1

PROJECT: PEF/FGD Blowdown Pond	DRILL METHOD: Sonic	DATUM: plant coordinates; ft NAVD 88	INCLINATION: -90
PROJECT NUMBER: 093-82538	DRILL RIG: Sonic 150	COORDS: N: 8,041.8 E: 14,723.5	DEPTH W.L.: 6
DRILLED DEPTH: 88.0 ft	DATE STARTED: 2/25/2009	GS ELEVATION: 95.89 (Approx.)	ELEVATION W.L.: N/A
AZIMUTH: N/A	DATE COMPLETED: 2/26/2009	TOC ELEVATION: N/A	DATE W.L.: 2/26/09
LOCATION: Crystal River, FL	WEATHER: cloudy	TEMPERATURE: 55°	TIME W.L.: N/A

SOIL PROFILE

DESCRIPTION	ELEV. / DEPTH (ft)
0.0 - 6.0 Brown to gray-brown, fine SAND; trace-little fines, trace-little limestone gravel (FILL)	89.9
6.0 - 6.5 Dark gray, fine SAND; little-some fines	89.4
6.5 - 7.0 Olive to tan, silty SAND	88.9 7.0
7.0 - 14.0 Tan LIMESTONE; and calcareous sand, weathered	81.9 14.0
14.0 - 25.0 Very light tan LIMESTONE and calcareous, silty SAND	70.9 25.0
25.0 - 28.0 Very light tan, highly weathered limestone sampled as calcareous SAND; little weathered limestone gravel	67.9
28.0 - 28.5 Light tan, competent LIMESTONE	67.4 28.5
28.5 - 46.0 Very light tan, highly weathered limestone sampled as consolidated, calcareous SAND; little-some fines; trace limestone gravel/cobbles	

SAMPLES

RUN	DRILL TIME (min)	REC / ATT
1	1	8.0 / 8.0
2	7	10.0 / 10.0
3	8	10.0 / 10.0
4	5	9.0 / 10.0

COMMENTS

Log continued on next page

LOG SCALE: 1 in = 4 ft
DRILLING COMPANY: Boart Longyear
DRILLER: Bear

INSPECTOR: J. King
CHECKED BY: J. King/TDA
DATE: 3/31/09

Golder Associates

RECORD OF BOREHOLE G-1

PROJECT: PEF/FGD Blowdown Pond
PROJECT NUMBER: 093-82538
DRILLED DEPTH: 88.0 ft
AZIMUTH: N/A
LOCATION: Crystal River, FL

DRILL METHOD: Sonic
DRILL RIG: Sonic 150
DATE STARTED: 2/25/2009
DATE COMPLETED: 2/26/2009
WEATHER: cloudy

DATUM: plant coordinates; ft NAVD 88
COORDS: N: 8,041.8 E: 14,723.5
GS ELEVATION: 95.89 (Approx.)
TOC ELEVATION: N/A
TEMPERATURE: 55°

INCLINATION: -90
DEPTH W.L.: 6
ELEVATION W.L.: N/A
DATE W.L.: 2/26/09
TIME W.L.: N/A

DEPTH (ft)	ELEVATION (ft)	SOIL PROFILE: DESCRIPTION	GRAPHIC LOG	ELEV. / DEPTH (ft)	SAMPLES: RUN	DRILL TIME (min)	REC / ATT	COMMENTS
		28.5 - 46.0 Very light tan, highly weathered limestone sampled as consolidated, calcareous SAND; little-some fines; trace limestone gravel/cobbles *(Continued)*						
35	60				4	5	9.0 / 10.0	
40	55				5	<1	9.0 / 10.0	
45	50			49.9 / 46.0				
		46.0 - 58.0 Light tan, highly weathered limestone sampled as calcareous, fine SAND; little-some fines, trace cemented limestone gravel/cobbles						
50	45				6	1	10.0 / 10.0	
55	40			37.9 / 58.0				Driller encountered no resistance at 58' bgs using fast feed on rig
		58.0 - 70.0 Possible VOID (may be soft, unconsolidated sand and fines)						
60	35				7	<1	5.0 / 20.0	

Log continued on next page

LOG SCALE: 1 in = 4 ft
DRILLING COMPANY: Boart Longyear
DRILLER: Bear

INSPECTOR: J. King
CHECKED BY: J. King/TDA
DATE: 3/31/09

Golder Associates

RECORD OF BOREHOLE G-1

PROJECT: PEF/FGD Blowdown Pond
PROJECT NUMBER: 093-82538
DRILLED DEPTH: 88.0 ft
AZIMUTH: N/A
LOCATION: Crystal River, FL

DRILL METHOD: Sonic
DRILL RIG: Sonic 150
DATE STARTED: 2/25/2009
DATE COMPLETED: 2/26/2009
WEATHER: cloudy

DATUM: plant coordinates; ft NAVD 88
COORDS: N: 8,041.8 E: 14,723.5
GS ELEVATION: 95.89 (Approx.)
TOC ELEVATION: N/A
TEMPERATURE: 55°

INCLINATION: -90
DEPTH W.L.: 6
ELEVATION W.L.: N/A
DATE W.L.: 2/26/09
TIME W.L.: N/A

DEPTH (ft)	SOIL PROFILE: DESCRIPTION	ELEV. / DEPTH (ft)	SAMPLES: RUN	DRILL TIME (min)	REC / ATT	COMMENTS
58.0 - 70.0	Possible VOID (may be soft, unconsolidated sand and fines) *(Continued)*					
70.0 - 71.0	Tan, highly weathered limestone sampled as calcareous SAND; little-some fines	25.9 / 70.0	7	<1	5.0 / 20.0	
71.0 - 72.0	Tan, highly weathered limestone sampled as calcareous, coarse SAND with shells	24.9 / 71.0				
72.0 - 76.0	Light tan LIMESTONE	23.9 / 72.0				
76.0 - 84.0	Tan-gray-light gray SILT	19.9 / 76.0	8	1	6.0 / 10.0	
84.0 - 85.0	Tan, highly weathered limestone sampled as calcareous, medium-coarse SAND with shells	11.9 / 84.0				Driller encounters greater resistance at 84' bgs Completed drilling of G-1 at 15:45
85.0 - 88.0	Light tan, competent LIMESTONE; and coarse sand with shells, little fines	10.9 / 85.0				Flushed hole with water at 225 gallons water in 10 minutes at 17:05 in attempt to improve camera visibility; aquifer absorbed all water introduced
	Boring completed at 88.0 ft	7.9				Drillers pump 200 gallons (4 drums) grout into hole through tremie pipe at 9:30 on 2/26/09- 12 bags Amerimix Portland Cement - installed 60' of 4-inch PVC casing VIDEO NOTES (2/29/05 - 17:20): very turbid - little to be seen - darker from 58.5 - 60' bgs - darkness could be thicker sediment or void opening - camera refusal at 60' bgs

LOG SCALE: 1 in = 4 ft
DRILLING COMPANY: Boart Longyear
DRILLER: Bear

INSPECTOR: J. King
CHECKED BY: J. King/TDA
DATE: 3/31/09

Golder Associates

RECORD OF BOREHOLE G-10

PROJECT: PEF/FGD Blowdown Pond
PROJECT NUMBER: 093-82538
DRILLED DEPTH: 73.0 ft
AZIMUTH: N/A
LOCATION: Crystal River, FL

DRILL METHOD: Sonic
DRILL RIG: Sonic 150
DATE STARTED: 3/5/2009
DATE COMPLETED: 3/5/2009
WEATHER: clear

DATUM: plant coordinates; ft NAVD 88
COORDS: N: 7,890.0 E: 14,522.6
GS ELEVATION: 91.39 (Approx.)
TOC ELEVATION: N/A
TEMPERATURE: 60°

INCLINATION: -90
DEPTH W.L.: 3.5
ELEVATION W.L.: N/A
DATE W.L.: 3/5/09
TIME W.L.: N/A

DEPTH (ft)	SOIL PROFILE – DESCRIPTION	ELEV. / DEPTH (ft)	RUN	DRILL TIME (min)	REC / ATT	COMMENTS
0.0 - 5.0	Brown, fine SAND; little fines, trace limestone gravel (FILL)	86.4 / 5.0	1	<1	8.0 / 8.0	
5.0 - 7.0	Dark brown-gray, fine SAND; trace-little fines	84.4 / 7.0				
7.0 - 8.0	Tan-brownish green, fine SAND; trace-little fines	83.4 / 8.0				
8.0 - 14.5	Brownish green, fine SAND; little-some fines, trace organics	76.9 / 14.5	2	<1	10.0 / 10.0	
14.5 - 16.5	Gray, sandy SILT; trace limestone gravel	74.9				
16.5 - 17.0	Gray, fine SAND with shells; some dark brown silt	74.4 / 17.0				
17.0 - 19.5	Light gray, highly weathered limestone sampled as calcareous, fine SAND with shells; trace limestone gravel, poorly cemented, trace-little fines, inclusions of dark greenish silty sand	71.9 / 19.5	3	<1	10.0 / 10.0	
19.5 - 40.0	Light gray-tan to very light tan, weathered LIMESTONE GRAVEL; and poorly sorted sand, little-some fines (greenish tinge on gravel may indicate small void at 23' bgs)		4	<1	10.0 / 10.0	

Log continued on next page

LOG SCALE: 1 in = 4 ft
DRILLING COMPANY: Boart Longyear
DRILLER: Bear

INSPECTOR: J. King
CHECKED BY: J. King/TDA
DATE: 3/31/09

Golder Associates

RECORD OF BOREHOLE G-10

PROJECT: PEF/FGD Blowdown Pond	DRILL METHOD: Sonic	DATUM: plant coordinates; ft NAVD 88	INCLINATION: -90
PROJECT NUMBER: 093-82538	DRILL RIG: Sonic 150	COORDS: N: 7,890.0 E: 14,522.6	DEPTH W.L.: 3.5
DRILLED DEPTH: 73.0 ft	DATE STARTED: 3/5/2009	GS ELEVATION: 91.39 (Approx.)	ELEVATION W.L.: N/A
AZIMUTH: N/A	DATE COMPLETED: 3/5/2009	TOC ELEVATION: N/A	DATE W.L.: 3/5/09
LOCATION: Crystal River, FL	WEATHER: clear	TEMPERATURE: 60°	TIME W.L.: N/A

SOIL PROFILE / SAMPLES

DESCRIPTION	ELEV. / DEPTH (ft)	RUN	DRILL TIME (min)	REC / ATT	COMMENTS
19.5 - 40.0 Light gray-tan to very light tan, weathered LIMESTONE GRAVEL; and poorly sorted sand, little-some fines (greenish tinge on gravel may indicate small void at 23' bgs) *(Continued)*	51.4 40.0	4	<1	10.0/10.0	
40.0 - 41.0 Tan, highly weathered limestone sampled as calcareous, fine SAND; trace-little fines, trace shells	50.4 41.0				Installed 6-inch casing to 40' bgs in G-10: drillers reported that casing was chasing the augers or dropping as the boring was being drilled (due to very soft material at the top of the boring)
41.0 - 43.0 Light tan-light gray, highly weathered limestone sampled as calcareous, fine SAND; little coarse calcareous sand, little fines, greenish streaks from 42 - 43' bgs	48.4 43.0	5	<1	10.0/10.0	
43.0 - 48.0 Tan to light gray, weathered LIMESTONE GRAVEL; and poorly sorted sand, little fines, greenish staining from 43.5-44' bgs	43.4 48.0				
48.0 - 56.3 Light brown, highly weathered limestone sampled as calcareous, fine SAND; little poorly cemented limestone gravel, trace fines	35.1	6	<1	9.0/10.0	
56.3 - 56.5 Gray to dark brown-gray SILT; little sand, little angular limestone gravel	34.4 57.0				
56.5 - 57.0 Light to dark gray SILT	33.4 58.0				
57.0 - 58.0 Very light tan SILT; little sand, little-some limestone gravel					
58.0 - 63.0 Light gray to very light brown LIMESTONE; little sandy silt	28.4 63.0	7	3	10.0/10.0	
63.0 - 64.0 Very light tan LIMESTONE; little sand in gray silt matrix, 1.5 in layer of dark brown silt	27.4				

Log continued on next page

LOG SCALE: 1 in = 4 ft
DRILLING COMPANY: Boart Longyear
DRILLER: Bear

INSPECTOR: J. King
CHECKED BY: J. King/TDA
DATE: 3/31/09

Golder Associates

RECORD OF BOREHOLE G-10

PROJECT: PEF/FGD Blowdown Pond
PROJECT NUMBER: 093-82538
DRILLED DEPTH: 73.0 ft
AZIMUTH: N/A
LOCATION: Crystal River, FL

DRILL METHOD: Sonic
DRILL RIG: Sonic 150
DATE STARTED: 3/5/2009
DATE COMPLETED: 3/5/2009
WEATHER: clear

DATUM: plant coordinates; ft NAVD 88
COORDS: N: 7,890.0 E: 14,522.6
GS ELEVATION: 91.39 (Approx.)
TOC ELEVATION: N/A
TEMPERATURE: 60°

INCLINATION: -90
DEPTH W.L.: 3.5
ELEVATION W.L.: N/A
DATE W.L.: 3/5/09
TIME W.L.: N/A

DEPTH (ft)	ELEVATION (ft)	SOIL PROFILE: DESCRIPTION	ELEV. / DEPTH (ft)	SAMPLES: RUN	DRILL TIME (min)	REC / ATT	COMMENTS
		at 63.5' bgs					
65		64.0 - 66.0 Very light tan LIMESTONE; trace sandy silt	64.0 25.4	7	3	10.0 / 10.0	
	25	66.0 - 67.0 Very light tan highly weathered limestone sampled as SILT; little-some limestone gravel	66.0 24.4				
		67.0 - 68.0 Very light tan LIMESTONE GRAVEL; little light gray to brown silty matrix	67.0 23.4				Completed drilling of G-10 at 13:15 at 73' bgs - total depth after extracting rods is 42' bgs due to sidewall collapse - able to clean out to 43' bgs with auger bit - set up to flush with 300 gallons water
		68.0 - 70.0 Very light tan LIMESTONE; fractured, competent, small vugs < 1 in	68.0 21.4				Pumped 160 gallons grout from 14:10 to 14:30 (3 - 55 gallon drums) - 9 total bags of Amerimix Portland Cement used - installed 50' of 4-inch PVC casing
70		70.0 - 71.8 Very light tan LIMESTONE; some silt, little sand	70.0 19.6	8	2	5.0 / 5.0	
	20	71.8 - 72.3 Very light blue, SILT; little-some coarse gravel, little sand	19.1 72.3				
		72.3 - 73.0 Very light tan LIMESTONE; little-some very light blue silt, little sand	18.4				
		Boring completed at 73.0 ft					
75	15						VIDEO NOTES (3/05/09 - 13:54): below 37.5' bgs (casing), no visibility - camera refusal at 43', no visibility
80	10						
85	5						
90	0						
95							

LOG SCALE: 1 in = 4 ft
DRILLING COMPANY: Boart Longyear
DRILLER: Bear

INSPECTOR: J. King
CHECKED BY: J. King/TDA
DATE: 3/31/09

Golder Associates

RECORD OF BOREHOLE G-11

PROJECT: PEF/FGD Blowdown Pond
PROJECT NUMBER: 093-82538
DRILLED DEPTH: 73.0 ft
AZIMUTH: N/A
LOCATION: Crystal River, FL

DRILL METHOD: Sonic
DRILL RIG: Sonic 150
DATE STARTED: 3/5/2009
DATE COMPLETED: 3/6/2009
WEATHER: clear

DATUM: plant coordinates; ft NAVD 88
COORDS: N: 8,037.9 E: 14,382.2
GS ELEVATION: 95.99 (Approx.)
TOC ELEVATION: N/A
TEMPERATURE: 70°

INCLINATION: -90
DEPTH W.L.: 6.25
ELEVATION W.L.: N/A
DATE W.L.: 3/6/09
TIME W.L.: N/A

DEPTH (ft)	ELEVATION (ft)	SOIL PROFILE: DESCRIPTION	ELEV. / DEPTH (ft)	SAMPLES: RUN	DRILL TIME (min)	REC / ATT	COMMENTS
0	95	0.0 - 3.5 Brown (light gray-brown from 3 - 3.5'), fine SAND; trace-little fines, trace limestone gravel (FILL)	92.5 / 3.5				
		3.5 - 5.0 Orange-brown, fine SAND; trace limestone gravel, trace light red fine sand, some fines	91.0	1	4	8.0 / 8.0	
5		5.0 - 5.5 Dark orange-dark brown, fine SAND; little-some fines	90.5 / 5.5				
	90	5.5 - 6.5 Light brown-brown, fine SAND; trace fines	89.5				
		6.5 - 7.0 Very dark gray, fine SAND; little-some fines	89.0 / 7.0				
		7.0 - 8.0 Light brown, weathered LIMESTONE GRAVEL; little calcareous sand, little fines	88.0 / 8.0				
		8.0 - 10.5 Very light gray to very light tan, weathered LIMESTONE; trace-little sandy silt	85.5 / 10.5				
10	85	10.5 - 11.5 Very light tan, highly weathered limestone sampled as poorly cemented SILT; and limestone gravel	84.5 / 11.5				
		11.5 - 17.8 Very light tan LIMESTONE; little calcareous, silty, medium-coarse sand, trace-some fines	78.2	2	8	10.0 / 10.0	Installed 6-inch casing to 17.5' bgs
15	80						
		17.8 - 18.0 Light brown, weathered LIMESTONE; trace fines, trace calcareous sand	18.0				
		18.0 - 26.0 Very light tan, poorly cemented, weathered LIMESTONE; poorly sorted sand, little fines, trace shell fragments	70.0 / 26.0	3	3	10.0 / 10.0	
20	75						
25	70	26.0 - 33.0 Very light tan, highly weathered limestone sampled as calcareous, silty SAND; trace limestone gravel					
30	65			4	1	10.0 / 10.0	

Log continued on next page

LOG SCALE: 1 in = 4 ft
DRILLING COMPANY: Boart Longyear
DRILLER: Bear

INSPECTOR: J. King
CHECKED BY: J. King/TDA
DATE: 3/31/09

Golder Associates

RECORD OF BOREHOLE G-11

PROJECT: PEF/FGD Blowdown Pond
PROJECT NUMBER: 093-82538
DRILLED DEPTH: 73.0 ft
AZIMUTH: N/A
LOCATION: Crystal River, FL

DRILL METHOD: Sonic
DRILL RIG: Sonic 150
DATE STARTED: 3/5/2009
DATE COMPLETED: 3/6/2009
WEATHER: clear

DATUM: plant coordinates; ft NAVD 88
COORDS: N: 8,037.9 E: 14,382.2
GS ELEVATION: 95.99 (Approx.)
TOC ELEVATION: N/A
TEMPERATURE: 70°

INCLINATION: -90
DEPTH W.L.: 6.25
ELEVATION W.L.: N/A
DATE W.L.: 3/6/09
TIME W.L.: N/A

DESCRIPTION (SOIL PROFILE)	ELEV. / DEPTH (ft)	RUN	DRILL TIME (min)	REC / ATT	COMMENTS
	63.0				
33.0 - 34.3 Very light tan, LIMESTONE GRAVEL; and very light tan, silty sand	33.0 61.7				
34.3 - 38.0 Very light tan, highly weathered limestone sampled as calcareous, silty SAND; trace-little limestone gravel	34.3 58.0	4	1	10.0 / 10.0	
38.0 - 46.0 Very light tan LIMESTONE GRAVEL; and poorly sorted sand, little-some fines (<1 cm thick layer of light brown, calcareous, fine sand with little fines at 43' bgs)	38.0 50.0	5	3	10.0 / 10.0	
46.0 - 48.0 Very light tan, LIMESTONE GRAVEL; little poorly sorted sand, trace-little fines	46.0 48.0				From 48 - 58' bgs, material fell out of auger while drawing up; placed auger bit on to go down again
48.0 - 50.0 Very light tan, highly weathered limestone sampled as calcareous, medium-coarse SAND; little shells, little fines	48.0 46.0				
50.0 - 52.0 Light tan, weathered LIMESTONE GRAVEL	50.0 44.0				
52.0 - 57.0 Light tan, highly weathered limestone sampled as calcareous, medium-coarse SAND with shells	52.0 39.0	6	2	6.0 / 10.0	
57.0 - 60.5 Light tan to very light tan, LIMESTONE GRAVEL; trace-some sandy silt	57.0 35.5				
60.5 - 61.0 Very light tan, highly weathered limestone sampled as SILT; trace sand, trace limestone gravel	35.0	7	2	10.0 / 10.0	
61.0 - 69.5 Light tan to very light tan LIMESTONE GRAVEL; and poorly sorted, calcareous sand, little-some fines	61.0				

Depth scale (ft): 35, 40, 45, 50, 55, 60. Elevation scale (ft): 60, 55, 50, 45, 40, 35.

Log continued on next page

LOG SCALE: 1 in = 4 ft
DRILLING COMPANY: Boart Longyear
DRILLER: Bear

INSPECTOR: J. King
CHECKED BY: J. King/TDA
DATE: 3/31/09

Golder Associates

RECORD OF BOREHOLE G-11

PROJECT: PEF/FGD Blowdown Pond
PROJECT NUMBER: 093-82538
DRILLED DEPTH: 73.0 ft
AZIMUTH: N/A
LOCATION: Crystal River, FL

DRILL METHOD: Sonic
DRILL RIG: Sonic 150
DATE STARTED: 3/5/2009
DATE COMPLETED: 3/6/2009
WEATHER: clear

DATUM: plant coordinates; ft NAVD 88
COORDS: N: 8,037.9 E: 14,382.2
GS ELEVATION: 95.99 (Approx.)
TOC ELEVATION: N/A
TEMPERATURE: 70°

INCLINATION: -90
DEPTH W.L.: 6.25
ELEVATION W.L.: N/A
DATE W.L.: 3/6/09
TIME W.L.: N/A

DEPTH (ft)	ELEVATION (ft)	SOIL PROFILE: DESCRIPTION	ELEV. / DEPTH (ft)	SAMPLES: RUN	DRILL TIME (min)	REC / ATT	COMMENTS
65	30	61.0 - 69.5 Light tan to very light tan LIMESTONE GRAVEL; and poorly sorted, calcareous sand, little-some fines *(Continued)*	26.5	7	2	10.0 / 10.0	After augers extracted and hole flushed with 300 gallons water, hole open to 68' bgs
70		69.5 - 70.0 Highly weathered limestone sampled as calcareous SAND; little-some fines	26.0 / 70.0	8	<1	5.0 / 5.0	Pumped 160 gallons grout (3 - 55 gallon drums) on 3/06/09 from 08:20 to 08:45 - 9 bags Amerimix Portland Cement used - installed 70' of 4-inch PVC casing
	25	70.0 - 71.0 Light tan to tan, weathered LIMESTONE GRAVEL; and poorly sorted sand, little fines	25.0				
		71.0 - 71.5 Light brown SILT	24.5 / 71.5				
		71.5 - 73.0 Light brown to light gray SILT	23.0				
		Boring completed at 73.0 ft					
75	20						VIDEO NOTES: small dissolution hole (<1 inch diameter) at 19' bgs - fractured limestone and cave in of walls from 25 - 32' bgs - large collapse area at 35' bgs - poor visibility below 36' bgs - camera refusal at 67.5' bgs
80	15						
85	10						
90	5						
95	0						

LOG SCALE: 1 in = 4 ft
DRILLING COMPANY: Boart Longyear
DRILLER: Bear

INSPECTOR: J. King
CHECKED BY: J. King/TDA
DATE: 3/31/09

Golder Associates

RECORD OF BOREHOLE G-12

PROJECT: PEF/FGD Blowdown Pond	DRILL METHOD: Sonic	DATUM: plant coordinates; ft NAVD 88	INCLINATION: -90
PROJECT NUMBER: 093-82538	DRILL RIG: Sonic 150	COORDS: N: 7,483.7 E: 14,408.5	DEPTH W.L.: 3.5
DRILLED DEPTH: 78.0 ft	DATE STARTED: 3/6/2009	GS ELEVATION: 90.59 (Approx.)	ELEVATION W.L.: N/A
AZIMUTH: N/A	DATE COMPLETED: 3/6/2009	TOC ELEVATION: N/A	DATE W.L.: 3/6/09
LOCATION: Crystal River, FL	WEATHER: clear	TEMPERATURE: 65°	TIME W.L.: N/A

DEPTH (ft)	SOIL PROFILE: DESCRIPTION	ELEV. / DEPTH (ft)	SAMPLES: RUN	DRILL TIME (min)	REC / ATT	COMMENTS
0.0 - 6.5	Brown, fine SAND; trace-little fines, trace gravel, inclusions of very light brown silty material from 4 - 6.5' bgs (FILL)	84.1 / 6.5	1	3	8.0 / 8.0	
6.5 - 8.0	Light gray, weathered LIMESTONE; and poorly sorted sand/gravel, little fines	82.6 / 8.0				
8.0 - 10.0	Light gray, competent LIMESTONE; trace-little fine sand, little silt	80.6 / 10.0	2	4	10.0 / 10.0	
10.0 - 12.0	Light gray, weathered LIMESTONE; little sandy silt	78.6 / 12.0				
12.0 - 13.0	Very light tan, highly weathered limestone sampled as calcareous SILT	77.6 / 13.0				
13.0 - 18.0	Very light tan to gray, fractured LIMESTONE; little-some sandy silt	72.6 / 18.0				Very soft drilling (rotation only by driller) from 14 - 16' bgs Installed 6-inch casing to 17.5' bgs
18.0 - 23.0	Light gray LIMESTONE; fractured, angular, coarse limestone gravel	67.6 / 23.0	3	3	8.0 / 10.0	
23.0 - 23.5	Light gray, highly weathered limestone sampled as calcareous, silty SAND; little-some shells	67.1 / 23.5				
23.5 - 25.0	Dark brown, sandy SILT; trace clay, little-some shells	65.6 / 25.0				
25.0 - 28.0	Brown-gray, weathered LIMESTONE; little limestone gravel, little sand	62.6 / 28.0				
28.0 - 33.0	Light gray to very light tan LIMESTONE; little calcareous, poorly sorted sandy gravel, little fines		4	<1	10.0 / 10.0	

Log continued on next page

LOG SCALE: 1 in = 4 ft
DRILLING COMPANY: Boart Longyear
DRILLER: Bear

INSPECTOR: J. King
CHECKED BY: J. King/TDA
DATE: 3/31/09

Golder Associates

RECORD OF BOREHOLE G-12

PROJECT: PEF/FGD Blowdown Pond
PROJECT NUMBER: 093-82538
DRILLED DEPTH: 78.0 ft
AZIMUTH: N/A
LOCATION: Crystal River, FL

DRILL METHOD: Sonic
DRILL RIG: Sonic 150
DATE STARTED: 3/6/2009
DATE COMPLETED: 3/6/2009
WEATHER: clear

DATUM: plant coordinates; ft NAVD 88
COORDS: N: 7,483.7 E: 14,408.5
GS ELEVATION: 90.59 (Approx.)
TOC ELEVATION: N/A
TEMPERATURE: 65°

INCLINATION: -90
DEPTH W.L.: 3.5
ELEVATION W.L.: N/A
DATE W.L.: 3/6/09
TIME W.L.: N/A

DEPTH (ft)	ELEVATION (ft)	SOIL PROFILE: DESCRIPTION	ELEV. / DEPTH (ft)	SAMPLES: RUN	DRILL TIME (min)	REC / ATT	COMMENTS
			57.6 / 33.0				
35	55	33.0 - 36.5 Very light tan, highly weathered limestone sampled as calcareous, fine SAND; little-some fines, little-trace limestone gravel	54.1 / 36.5	4	<1	10.0 / 10.0	
		36.5 - 40.5 Light tan LIMESTONE; little-some calcareous, poorly sorted sand	50.1 / 40.5				
40, 45	50, 45	40.5 - 47.5 Light tan, weathered LIMESTONE GRAVEL; and calcareous, fine sand, trace-little fines	43.1 / 47.5	5	<1	10.0 / 10.0	
		47.5 - 48.3 Very light tan, highly weathered limestone sampled as calcareous SAND; trace weathered limestone gravel	42.3 / 48.3				Driller notes very soft (little to no resistance) from 48 - 58' bgs Little recovery from 48 - 58' bgs (mostly slough)
50	40	48.3 - 52.0 Greenish grey to tan, poorly sorted SAND with shells	38.6 / 52.0				
55	35	52.0 - 58.0 Tan LIMESTONE GRAVEL; little fine sand, trace-little fines, little shells	32.6 / 58.0	6	<1	7.0 / 10.0	
60	30	58.0 - 66.0 POOR RECOVERY		7	<1	1.0 / 10.0	Poor recovery from 58 - 68' bgs (mostly slough); driller reports very soft drilling

Log continued on next page

LOG SCALE: 1 in = 4 ft
DRILLING COMPANY: Boart Longyear
DRILLER: Bear

INSPECTOR: J. King
CHECKED BY: J. King/TDA
DATE: 3/31/09

Golder Associates

RECORD OF BOREHOLE G-12

PROJECT: PEF/FGD Blowdown Pond	DRILL METHOD: Sonic	DATUM: plant coordinates; ft NAVD 88	INCLINATION: -90
PROJECT NUMBER: 093-82538	DRILL RIG: Sonic 150	COORDS: N: 7,483.7 E: 14,408.5	DEPTH W.L.: 3.5
DRILLED DEPTH: 78.0 ft	DATE STARTED: 3/6/2009	GS ELEVATION: 90.59 (Approx.)	ELEVATION W.L.: N/A
AZIMUTH: N/A	DATE COMPLETED: 3/6/2009	TOC ELEVATION: N/A	DATE W.L.: 3/6/09
LOCATION: Crystal River, FL	WEATHER: clear	TEMPERATURE: 65°	TIME W.L.: N/A

DEPTH (ft)	ELEVATION (ft)	SOIL PROFILE: DESCRIPTION	GRAPHIC LOG	ELEV. / DEPTH (ft)	SAMPLES: RUN	DRILL TIME (min)	REC / ATT	COMMENTS
65	25	58.0 - 66.0 POOR RECOVERY *(Continued)*		24.6 / 66.0	7	<1	1.0 / 10.0	
		66.0 - 67.0 Very dark brown, organic SILT		23.6 / 67.0				
		67.0 - 68.0 Gray-light gray SILT		22.6 / 68.0				Pushed from 68 - 73' bgs with no recovery, so used flapper bit to 78' bgs
70, 75	20, 15	68.0 - 76.0 POOR RECOVERY		14.6 / 76.0	8	<1	2.0 / 10.0	Drilling completed at 10:45; hole flushed with 300 gallons water. Pumped approximately 200 gallons grout - 12 bags of Amerimix Portland Cement used - installed 30' of 4-inch Schedule 40 PVC casing
		76.0 - 78.0 Gray-light gray SILT; little angular limestone gravel, little cemented light brown silt		12.6				
80, 85, 90, 95	10, 5, 0, -5	Boring completed at 78.0 ft						VIDEO NOTES (3/06/09 - 11:02): at 20.2' bgs, small dissolution crevice just above silt bottom - camera refusal at 22' bgs due to collapse of sidewalls

LOG SCALE: 1 in = 4 ft	INSPECTOR: J. King
DRILLING COMPANY: Boart Longyear	CHECKED BY: J. King/TDA
DRILLER: Bear	DATE: 3/31/09

Golder Associates

RECORD OF BOREHOLE G-13

PROJECT: PEF/FGD Blowdown Pond
PROJECT NUMBER: 093-82538
DRILLED DEPTH: 73.0 ft
AZIMUTH: N/A
LOCATION: Crystal River, FL

DRILL METHOD: Sonic
DRILL RIG: Sonic 150
DATE STARTED: 3/3/2009
DATE COMPLETED: 3/3/2009
WEATHER: clear

DATUM: plant coordinates; ft NAVD 88
COORDS: N: 7,726.8 E: 14,708.2
GS ELEVATION: 91.49 (Approx.)
TOC ELEVATION: N/A
TEMPERATURE: 50°

INCLINATION: -90
DEPTH W.L.: 2.5
ELEVATION W.L.: N/A
DATE W.L.: 3/3/09
TIME W.L.: N/A

DEPTH (ft)	ELEVATION (ft)	SOIL PROFILE: DESCRIPTION	GRAPHIC LOG	ELEV. / DEPTH (ft)	SAMPLES: RUN	DRILL TIME (min)	REC / ATT	COMMENTS
0		0.0 - 3.0 Brown, fine SAND; little fines, trace limestone gravel (FILL)		88.5 / 3.0				
	90	3.0 - 8.0 Gray to light gray, weathered LIMESTONE; little-some fine sand, little fines, trace-little calcareous, coarse sand		83.5 / 8.0	1	4	8.0 / 8.0	Installed 6-inch steel casing to 7.5' bgs
5	85	8.0 - 13.0 Very light gray to very light tan LIMESTONE; little calcareous, silty sand		78.5 / 13.0				
10	80	13.0 - 14.0 Very light tan, highly weathered limestone sampled as poorly cemented, calcareous SILT		77.5 / 14.0	2	13	10.0 / 10.0	
15	75	14.0 - 18.0 Very light tan, competent LIMESTONE; trace-little silty sand		73.5 / 18.0				
		18.0 - 19.0 Brown to light tan, highly weathered limestone sampled as calcareous, fine SAND; little-some fines		72.5 / 19.0				
20	70	19.0 - 26.5 Very light tan to very light gray, competent LIMESTONE; little-some calcaerous sand, trace fines		65.0 / 26.5	3	7	8.0 / 10.0	Driller notes much softer material below 24' bgs
25	65	26.5 - 28.0 Tan to light brown, weathered LIMESTONE GRAVEL; little-some, calcareous, coarse sand, little fines		63.5 / 28.0				
		28.0 - 30.5 Yellow-brown, highly weathered limestone sampled as calcareous, poorly sorted SAND; and gravel with shells, little fines		61.0 / 30.5	4	1	10.0 / 10.0	
30	60	30.5 - 38.0 Tan to light tan, highly weathered limestone sampled as calcareous, fine SAND; little-some fines, trace-little gravel						

Log continued on next page

LOG SCALE: 1 in = 4 ft
DRILLING COMPANY: Boart Longyear
DRILLER: Bear

INSPECTOR: J. King
CHECKED BY: J. King/TDA
DATE: 3/31/09

Golder Associates

RECORD OF BOREHOLE G-13

PROJECT: PEF/FGD Blowdown Pond
PROJECT NUMBER: 093-82538
DRILLED DEPTH: 73.0 ft
AZIMUTH: N/A
LOCATION: Crystal River, FL

DRILL METHOD: Sonic
DRILL RIG: Sonic 150
DATE STARTED: 3/3/2009
DATE COMPLETED: 3/3/2009
WEATHER: clear

DATUM: plant coordinates; ft NAVD 88
COORDS: N: 7,726.8 E: 14,708.2
GS ELEVATION: 91.49 (Approx.)
TOC ELEVATION: N/A
TEMPERATURE: 50°

INCLINATION: -90
DEPTH W.L.: 2.5
ELEVATION W.L.: N/A
DATE W.L.: 3/3/09
TIME W.L.: N/A

DEPTH (ft)	ELEVATION (ft)	SOIL PROFILE: DESCRIPTION	ELEV. / DEPTH (ft)	SAMPLES: RUN	DRILL TIME (min)	REC / ATT	COMMENTS
		30.5 - 38.0 Tan to light tan, highly weathered limestone sampled as calcareous, fine SAND; little-some fines, trace-little gravel *(Continued)*					
35	55			4	1	10.0 / 10.0	
		38.0 - 44.0 Light tan, weathered LIMESTONE; and calcareous, silty sand	53.5 / 38.0				
40	50			5	<1	10.0 / 10.0	
45	45	44.0 - 59.0 Light tan to tan (grayish tan from 53 - 55' bgs), highly weathered limestone sampled as calcareous, fine SAND; little-some fines, little-some limestone gravel	47.5 / 44.0				
50	40			6	<1	10.0 / 10.0	
55	35						
60	30	59.0 - 64.5 Tan LIMESTONE GRAVEL, little-some fine, silty sand, trace calcareous, coarse sand	32.5 / 59.0	7	2	10.0 / 10.0	

Log continued on next page

LOG SCALE: 1 in = 4 ft
DRILLING COMPANY: Boart Longyear
DRILLER: Bear

INSPECTOR: J. King
CHECKED BY: J. King/TDA
DATE: 3/31/09

Golder Associates

RECORD OF BOREHOLE G-13

PROJECT: PEF/FGD Blowdown Pond	DRILL METHOD: Sonic	DATUM: plant coordinates; ft NAVD 88	INCLINATION: -90
PROJECT NUMBER: 093-82538	DRILL RIG: Sonic 150	COORDS: N: 7,726.8 E: 14,708.2	DEPTH W.L.: 2.5
DRILLED DEPTH: 73.0 ft	DATE STARTED: 3/3/2009	GS ELEVATION: 91.49 (Approx.)	ELEVATION W.L.: N/A
AZIMUTH: N/A	DATE COMPLETED: 3/3/2009	TOC ELEVATION: N/A	DATE W.L.: 3/3/09
LOCATION: Crystal River, FL	WEATHER: clear	TEMPERATURE: 50°	TIME W.L.: N/A

DESCRIPTION (SOIL PROFILE)	ELEV. / DEPTH (ft)	RUN	DRILL TIME (min)	REC / ATT	COMMENTS
	27.0				
64.5 - 68.0 Tan, highly weathered limestone sampled as silty, calcareous, fine SAND; trace-little calcareous, coarse sand, trace limestone gravel	64.5 23.5	7	2	10.0 / 10.0	
68.0 - 71.0 Tan to light brown, highly weathered limestone sampled as calcareous, coarse SAND; and gravel with shells, little fines	68.0 20.5	8	<1	5.0 / 5.0	
71.0 - 72.0 Gray to very light gray, highly weathered limestone sampled as calcareous, silty, fine SAND, little-some coarse sand, trace limestone gravel	71.0 19.5				
72.0 - 73.0 Very light tan to light orange, SILT, trace fine sand	72.0 18.5				Drilling of G-13 complete (73' bgs)at 13:25 (some collapse after completion- tagged depth of ~33' bgs) - Added 300 gallons water to hole
Boring completed at 73.0 ft					Added 2 drums of grout via tremie pipe at 14:05 (6 bags Amerimix Portland Cement Type 1/11) - installed 30' of 4-inch PVC casing VIDEO NOTES (3/03/09 - 13:50): solid limestone below 8' bgs with vugs <1 inch - possible crack/void ~1 inch thick at 15.6' bgs - void at 23.7' bgs, weathered area where side walls have collapsed into hole to about 24.9' bgs - camera refusal at 29.6' bgs

DEPTH (ft): 65, 70, 75, 80, 85, 90, 95
ELEVATION (ft): 25, 20, 15, 10, 5, 0

LOG SCALE: 1 in = 4 ft
DRILLING COMPANY: Boart Longyear
DRILLER: Bear

INSPECTOR: J. King
CHECKED BY: J. King/TDA
DATE: 3/31/09

Golder Associates

RECORD OF BOREHOLE G-14

PROJECT: PEF/FGD Blowdown Pond
PROJECT NUMBER: 093-82538
DRILLED DEPTH: 68.0 ft
AZIMUTH: N/A
LOCATION: Crystal River, FL

DRILL METHOD: Sonic
DRILL RIG: Sonic 150
DATE STARTED: 3/3/2009
DATE COMPLETED: 3/3/2009
WEATHER: clear

DATUM: plant coordinates; ft NAVD 88
COORDS: N: 7,723.4 E: 14,975.8
GS ELEVATION: 92.29 (Approx.)
TOC ELEVATION: N/A
TEMPERATURE: 55°

INCLINATION: -90
DEPTH W.L.: 3.5
ELEVATION W.L.: N/A
DATE W.L.: 3/3/09
TIME W.L.: N/A

DESCRIPTION (SOIL PROFILE)	ELEV. / DEPTH (ft)	RUN	DRILL TIME (min)	REC / ATT	COMMENTS
0.0 - 3.0 Brown, fine SAND; little fines, trace limestone gravel (FILL)	89.3				
3.0 - 3.5 Tan-yellow, highly weathered limestone sampled as calcareous SAND; and weathered limestone gravel	88.8 / 3.5	1	3	8.0 / 8.0	
3.5 - 8.0 Light tan to very light tan, weathered LIMESTONE GRAVEL; and calcareous, fine sand, little-some fines	84.3 / 8.0				
8.0 - 11.0 Competent LIMESTONE; little silt, trace fine sand	81.3				
11.0 - 11.5 Very light tan, highly weathered limestone sampled as calcareous SILT	80.8 / 11.5	2	6	10.0 / 10.0	
11.5 - 18.0 Very light tan, competent LIMESTONE; little fines, trace-little sand	74.3 / 18.0				
18.0 - 19.0 Very light tan, highly weathered limestone sampled as calcareous, fine SAND; little-some fines	73.3 / 19.0				
19.0 - 25.8 Very light tan, competent LIMESTONE; some calcareous, fine sand, little-some fines	66.5 / 25.8	3	4	10.0 / 10.0	
25.8 - 26.5 Tan, weathered LIMESTONE GRAVEL	65.8 / 26.5				
26.5 - 28.0 Very light tan, weathered LIMESTONE GRAVEL; and silty, fine sand	64.3 / 28.0				
28.0 - 34.0 NO RECOVERY		4	PUSH	0.0 / 10.0	

Log continued on next page

LOG SCALE: 1 in = 4 ft
DRILLING COMPANY: Boart Longyear
DRILLER: Bear

INSPECTOR: J. King
CHECKED BY: J. King/TDA
DATE: 3/31/09

Golder Associates

RECORD OF BOREHOLE G-14

PROJECT: PEF/FGD Blowdown Pond	DRILL METHOD: Sonic	DATUM: plant coordinates; ft NAVD 88	INCLINATION: -90
PROJECT NUMBER: 093-82538	DRILL RIG: Sonic 150	COORDS: N: 7,723.4 E: 14,975.8	DEPTH W.L.: 3.5
DRILLED DEPTH: 68.0 ft	DATE STARTED: 3/3/2009	GS ELEVATION: 92.29 (Approx.)	ELEVATION W.L.: N/A
AZIMUTH: N/A	DATE COMPLETED: 3/3/2009	TOC ELEVATION: N/A	DATE W.L.: 3/3/09
LOCATION: Crystal River, FL	WEATHER: clear	TEMPERATURE: 55°	TIME W.L.: N/A

DEPTH (ft)	ELEVATION (ft)	SOIL PROFILE: DESCRIPTION	GRAPHIC LOG	ELEV. / DEPTH (ft)	SAMPLES: RUN	DRILL TIME (min)	REC / ATT	COMMENTS
	60	28.0 - 34.0 NO RECOVERY *(Continued)*		58.3 34.0				Soft drilling at 34' bgs (possible void or very soft material 28- 38' bgs)
35	55	34.0 - 48.0 Possible VOID			4	PUSH	0.0/10.0	
40	50				5	<1	0.0/10.0	Possible void floor at 43.6' bgs (tape measure stopped)
45	45			44.3 48.0				Driller pushed rods to 43.6' bgs and did not hit substantial resistance until 48' bgs
50	40	48.0 - 54.0 POOR RECOVERY		38.3 54.0	6	<1	4.0/10.0	
55		54.0 - 56.0 Light tan LIMESTONE; and limestone gravel, olive silty sand, trace shells		36.3 56.2				
	35	56.0 - 56.2 Light gray, highly weathered limestone sampled as calcareous, silty, fine SAND; and limestone gravel, trace shells 56.2 - 58.0 Light brown, weathered LIMESTONE GRAVEL/COBBLES; little shells, little-some fines		34.3 58.0				
60	30	58.0 - 63.5 POOR RECOVERY		28.8 63.5	7	NR	4.0/10.0	

Log continued on next page

LOG SCALE: 1 in = 4 ft
DRILLING COMPANY: Boart Longyear
DRILLER: Bear

INSPECTOR: J. King
CHECKED BY: J. King/TDA
DATE: 3/31/09

RECORD OF BOREHOLE G-14

PROJECT: PEF/FGD Blowdown Pond	DRILL METHOD: Sonic	DATUM: plant coordinates; ft NAVD 88	INCLINATION: -90
PROJECT NUMBER: 093-82538	DRILL RIG: Sonic 150	COORDS: N: 7,723.4 E: 14,975.8	DEPTH W.L.: 3.5
DRILLED DEPTH: 68.0 ft	DATE STARTED: 3/3/2009	GS ELEVATION: 92.29 (Approx.)	ELEVATION W.L.: N/A
AZIMUTH: N/A	DATE COMPLETED: 3/3/2009	TOC ELEVATION: N/A	DATE W.L.: 3/3/09
LOCATION: Crystal River, FL	WEATHER: clear	TEMPERATURE: 55°	TIME W.L.: N/A

DEPTH (ft)	ELEVATION (ft)	SOIL PROFILE: DESCRIPTION	GRAPHIC LOG	ELEV. / DEPTH (ft)	SAMPLES: RUN	DRILL TIME (min)	REC / ATT	COMMENTS
63.5 - 65.0		63.5 - 65.0 Tan, highly weathered limestone sampled as calcareous, fine-coarse SAND with shells *(Continued)*		27.3 / 65.0				Rock from 64 - 68' bgs is very light tan with weathered very dark gray/brown surfaces; matrix is light greenish-brown silt
65.0 - 67.5		65.0 - 67.5 Angular, coarse LIMESTONE GRAVEL/COBBLES; trace fines, little fine sand		24.8 / 67.5	7	NR	4.0 / 10.0	
67.5 - 68.0		67.5 - 68.0 Tan, LIMESTONE GRAVEL; little coarse sand, trace-little fines Boring completed at 68.0 ft		24.3 / 68.0				Total depth after pulling rods is 51.5' bgs due to cave in; flushed hole with 300 gallons water before filming Installed 60' of 4-inch PVC casing; no grout added to hole VIDEO NOTES (3/03/09): top of boring below casing appears to be solid and weathered limestone with small vugs - small void or (more likely) sidewall collapse - more sidewall collapse at 29.5' bgs - VOID from 34.5' bgs to approximately 49' bgs (bottom of visible cavern) - camera refusal at 51.3' bgs

Depth scale (ft): 65, 70, 75, 80, 85, 90, 95
Elevation scale (ft): 25, 20, 15, 10, 5, 0

LOG SCALE: 1 in = 4 ft
DRILLING COMPANY: Boart Longyear
DRILLER: Bear

INSPECTOR: J. King
CHECKED BY: J. King/TDA
DATE: 3/31/09

Golder Associates

RECORD OF BOREHOLE G-15

PROJECT: PEF/FGD Blowdown Pond	DRILL METHOD: Sonic	DATUM: plant coordinates; ft NAVD 88	INCLINATION: -90
PROJECT NUMBER: 093-82538	DRILL RIG: Sonic 150	COORDS: N: 7,894.2 E: 14,724.7	DEPTH W.L.: 3.5
DRILLED DEPTH: 48.0 ft	DATE STARTED: 3/4/2009	GS ELEVATION: 91.29 (Approx.)	ELEVATION W.L.: N/A
AZIMUTH: N/A	DATE COMPLETED: 3/4/2009	TOC ELEVATION: N/A	DATE W.L.: 3/4/09
LOCATION: Crystal River, FL	WEATHER: clear	TEMPERATURE: 60°	TIME W.L.: N/A

DEPTH (ft)	SOIL PROFILE: DESCRIPTION	ELEV. / DEPTH (ft)	SAMPLES: RUN	DRILL TIME (min)	REC / ATT	COMMENTS
0.0 - 5.5	Brown, fine SAND; trace fines, trace limestone gravel (FILL)	85.8	1	<1	8.0 / 8.0	Installed 6-inch casing to 7.5' bgs
5.5 - 6.0	Dark gray, highly weathered limestone sampled as calcareous, fine SAND	85.3 / 6.0				
6.0 - 10.0	Light gray to brownish gray (light brown from 8-10' bgs) weathered LIMESTONE; and calcareous, fine sand, little-some fines	81.3				
10.0 - 10.5	Greenish brown, weathered LIMESTONE GRAVEL, little fine sand, trace fines	80.8 / 10.5	2	5	10.0 / 10.0	
10.5 - 12.0	Tan to light tan, LIMESTONE GRAVEL; little-some fine sand, little fines	79.3 / 12.0				
12.0 - 15.0	Very light tan, fractured, competent, LIMESTONE; trace limestone gravel, trace-little silty sand	76.3 / 15.0				
15.0 - 16.0	Very light tan, weathered LIMESTONE; some silt, trace calcareous sand	75.3 / 16.0				
16.0 - 18.0	Light tan, fractured, weathered LIMESTONE; fine sand, little-some silt	73.3 / 18.0				Soft material from 18 - 28' bgs (only 5' of recovery)
18.0 - 23.0	Possible VOID	68.3 / 23.0	3	<1	5.0 / 10.0	
23.0 - 25.0	Brown, highly weathered limestone sampled as calcareous, silty SAND; and weathered limestone gravel	66.3 / 25.0				
25.0 - 26.0	Light tan to light brown-tan, LIMESTONE GRAVEL; and sandy silt	65.3 / 26.0				
26.0 - 28.0	Light tan to light gray, weathered LIMESTONE; poorly graded, calcareous sand, little fines	63.3 / 28.0				Very soft material from 28 - 38' bgs
28.0 - 33.0	Possible VOID		4	PUSH	5.0 / 10.0	

Log continued on next page

LOG SCALE: 1 in = 4 ft	INSPECTOR: J. King
DRILLING COMPANY: Boart Longyear	CHECKED BY: J. King/TDA
DRILLER: Bear	DATE: 3/31/09

Golder Associates

RECORD OF BOREHOLE G-15

PROJECT: PEF/FGD Blowdown Pond	DRILL METHOD: Sonic	DATUM: plant coordinates; ft NAVD 88	INCLINATION: -90
PROJECT NUMBER: 093-82538	DRILL RIG: Sonic 150	COORDS: N: 7,894.2 E: 14,724.7	DEPTH W.L.: 3.5
DRILLED DEPTH: 48.0 ft	DATE STARTED: 3/4/2009	GS ELEVATION: 91.29 (Approx.)	ELEVATION W.L.: N/A
AZIMUTH: N/A	DATE COMPLETED: 3/4/2009	TOC ELEVATION: N/A	DATE W.L.: 3/4/09
LOCATION: Crystal River, FL	WEATHER: clear	TEMPERATURE: 60°	TIME W.L.: N/A

DEPTH (ft)	ELEVATION (ft)	SOIL PROFILE: DESCRIPTION	ELEV. / DEPTH (ft)	SAMPLES: RUN	DRILL TIME (min)	REC / ATT	COMMENTS
		28.0 - 33.0 Possible VOID *(Continued)*	58.3				
35	55	33.0 - 44.0 Possible VOID (half of sample missing); Light gray to light tan (stained brown 33-35' bgs from silt above), weathered LIMESTONE GRAVEL; some poorly sorted sand, little fines	33.0	4	PUSH	5.0 / 10.0	Soft drilling from 38 - 41' bgs
40	50			5	PUSH	6.0 / 10.0	After drilling to 48' bgs, cave in to 19' bgs - cleaned out with augers: cave in to 19' bgs again - flushed with 60 gallons water
			47.3				
45	45	44.0 - 48.0 Very light tan, highly weathered limestone sampled as calcareous SAND; little-some fines, little-some limestone gravel	44.0				Pumped grout (2 - 55 gallon drums, used 6 bags Amerimix Portland Cement) and installed 20' of 4-inch PVC casing
			43.3				
		Boring completed at 48.0 ft					
50	40						VIDEO NOTES: little visibility below 15' bgs - very turbid
55	35						
60	30						

LOG SCALE: 1 in = 4 ft
DRILLING COMPANY: Boart Longyear
DRILLER: Bear

INSPECTOR: J. King
CHECKED BY: J. King/TDA
DATE: 3/31/09

Golder Associates

RECORD OF BOREHOLE G-16

PROJECT: PEF/FGD Blowdown Pond
PROJECT NUMBER: 093-82538
DRILLED DEPTH: 38.0 ft
AZIMUTH: N/A
LOCATION: Crystal River, FL

DRILL METHOD: Sonic
DRILL RIG: Sonic 150
DATE STARTED: 3/4/2009
DATE COMPLETED: 3/4/2009
WEATHER: clear

DATUM: plant coordinates; ft NAVD 88
COORDS: N: 7,927.2 E: 14,923.6
GS ELEVATION: 91.79 (Approx.)
TOC ELEVATION: N/A
TEMPERATURE: 60°

INCLINATION: -90
DEPTH W.L.: 3.5
ELEVATION W.L.: N/A
DATE W.L.: 3/4/09
TIME W.L.: N/A

DEPTH (ft)	ELEVATION (ft)	SOIL PROFILE: DESCRIPTION	ELEV. / DEPTH (ft)	SAMPLES: RUN	DRILL TIME (min)	REC / ATT	COMMENTS
0		0.0 - 3.0 Brown, fine SAND; little fines, trace limestone gravel (FILL)					
	90		88.8 / 3.0				
		3.0 - 4.0 Orange-tan, weathered LIMESTONE; and calcareous sand, little fines	87.8 / 4.0	1	NR	8.0 / 8.0	
5		4.0 - 8.5 Light tan to very light tan, very weathered LIMESTONE GRAVEL; and calcareous, fine sand, little-some fines					
	85						Installed 6-inch casing to 7' bgs
			83.3 / 8.5				
10		8.5 - 22.0 Light tan, competent LIMESTONE; little limestone gravel, little sandy silt					
	80			2	NR	10.0 / 10.0	
15	75						
20	70		69.8 / 22.0				
		22.0 - 27.5 Light tan, weathered LIMESTONE GRAVEL; and poorly sorted sand		3	NR	10.0 / 10.0	
25	65		64.3 / 27.5				
		27.5 - 38.0 Light tan to very light tan, highly weathered limestone sampled as calcareous, silty SAND; some limestone gravel, poorly to well cemented					
30				4	NR	10.0 / 10.0	
	60						

Log continued on next page

LOG SCALE: 1 in = 4 ft
DRILLING COMPANY: Boart Longyear
DRILLER: Bear

INSPECTOR: J. King
CHECKED BY: J. King/TDA
DATE: 3/31/09

Golder Associates

RECORD OF BOREHOLE G-16

PROJECT: PEF/FGD Blowdown Pond
PROJECT NUMBER: 093-82538
DRILLED DEPTH: 38.0 ft
AZIMUTH: N/A
LOCATION: Crystal River, FL

DRILL METHOD: Sonic
DRILL RIG: Sonic 150
DATE STARTED: 3/4/2009
DATE COMPLETED: 3/4/2009
WEATHER: clear

DATUM: plant coordinates; ft NAVD 88
COORDS: N: 7,927.2 E: 14,923.6
GS ELEVATION: 91.79 (Approx.)
TOC ELEVATION: N/A
TEMPERATURE: 60°

INCLINATION: -90
DEPTH W.L.: 3.5
ELEVATION W.L.: N/A
DATE W.L.: 3/4/09
TIME W.L.: N/A

DEPTH (ft)	ELEVATION (ft)	SOIL PROFILE: DESCRIPTION	GRAPHIC LOG	ELEV. / DEPTH (ft)	SAMPLES: RUN	DRILL TIME (min)	REC / ATT	COMMENTS
		27.5 - 38.0 Light tan to very light tan, highly weathered limestone sampled as calcareous, silty SAND; some limestone gravel, poorly to well cemented *(Continued)*						Drilling completed at 13:45; flushed with 180 gallons water
35					4	NR	10.0 / 10.0	Pumped 90 gallons grout (5 bags of Amerimix Portland Cement) - grout stays in hole; no PVC casing needed
	55			53.8				
		Boring completed at 38.0 ft						
40								
	50							VIDEO NOTES (3/04/09 - 14:00): limestone appears weathered and fractured - no noticable voids - turbid at 25' bgs
45								
	45							
50								
	40							
55								
	35							
60								
	30							

LOG SCALE: 1 in = 4 ft
DRILLING COMPANY: Boart Longyear
DRILLER: Bear

INSPECTOR: J. King
CHECKED BY: J. King/TDA
DATE: 3/31/09

RECORD OF BOREHOLE G-17

PROJECT: PEF/FGD Blowdown Pond	DRILL METHOD: Sonic	DATUM: plant coordinates; ft NAVD 88	INCLINATION: -90
PROJECT NUMBER: 093-82538	DRILL RIG: Sonic 150	COORDS: N: 7,720.0 E: 15,018.1	DEPTH W.L.: 3.5
DRILLED DEPTH: 68.0 ft	DATE STARTED: 3/4/2009	GS ELEVATION: 92.79 (Approx.)	ELEVATION W.L.: N/A
AZIMUTH: N/A	DATE COMPLETED: 3/4/2009	TOC ELEVATION: N/A	DATE W.L.: 3/4/09
LOCATION: Crystal River, FL	WEATHER: clear	TEMPERATURE: 45°	TIME W.L.: N/A

DEPTH (ft)	DESCRIPTION	ELEV. / DEPTH (ft)	RUN	DRILL TIME (min)	REC / ATT	COMMENTS
0.0 - 3.5	Brown to dark brown, fine SAND; little fines, trace limestone gravel (FILL)	89.3 / 3.5				
3.5 - 8.0	Light brown to tan to very light tan, weathered LIMESTONE GRAVEL; little fine sand, trace fines	84.8 / 8.0	1	3	8.0 / 8.0	Installed 6-inch casing to 7' bgs
8.0 - 10.0	Very light tan, competent LIMESTONE; little silt, trace calcareous sand	82.8 / 10.0				
10.0 - 13.0	Very light tan, poorly cemented LIMESTONE; and silt	79.8 / 13.0	2	9	10.0 / 10.0	
13.0 - 19.0	Light brown, weathered LIMESTONE; some calcareous sand, little silt	73.8 / 19.0				
19.0 - 20.0	Very light tan, poorly cemented LIMESTONE; and silt	72.8 / 20.0				
20.0 - 43.0	Very light tan, weathered LIMESTONE; some calcareous sand, little silt		3	5	10.0 / 10.0	
			4	4	10.0 / 10.0	

Depth scale (ft): 0, 5, 10, 15, 20, 25, 30. Elevation scale (ft): 90, 85, 80, 75, 70, 65.

Log continued on next page

LOG SCALE: 1 in = 4 ft	INSPECTOR: J. King
DRILLING COMPANY: Boart Longyear	CHECKED BY: J. King/TDA
DRILLER: Bear	DATE: 3/31/09

Golder Associates

RECORD OF BOREHOLE G-17

PROJECT: PEF/FGD Blowdown Pond	DRILL METHOD: Sonic	DATUM: plant coordinates; ft NAVD 88	INCLINATION: -90
PROJECT NUMBER: 093-82538	DRILL RIG: Sonic 150	COORDS: N: 7,720.0 E: 15,018.1	DEPTH W.L.: 3.5
DRILLED DEPTH: 68.0 ft	DATE STARTED: 3/4/2009	GS ELEVATION: 92.79 (Approx.)	ELEVATION W.L.: N/A
AZIMUTH: N/A	DATE COMPLETED: 3/4/2009	TOC ELEVATION: N/A	DATE W.L.: 3/4/09
LOCATION: Crystal River, FL	WEATHER: clear	TEMPERATURE: 45°	TIME W.L.: N/A

SOIL PROFILE

DESCRIPTION	ELEV. / DEPTH (ft)
20.0 - 43.0 Very light tan, weathered LIMESTONE; some calcareous sand, little silt *(Continued)*	49.8 / 43.0
43.0 - 47.0 Light gray-light brown, highly weathered limestone sampled as calcareous SAND; some limestone gravel	45.8 / 47.0
47.0 - 48.0 Tan LIMESTONE GRAVEL; and calcareous sand, little-some fines	44.8 / 48.0
48.0 - 50.0 Light tan, highly weathered limestone sampled as calcareous, fine SAND; trace limestone gravel, trace-little fines	42.8 / 50.0
50.0 - 56.0 Very light tan, highly weathered limestone sampled as calcareous, silty, fine SAND; little-some limestone gravel	36.8 / 56.0
56.0 - 60.0 Light tan to tan weathered LIMESTONE GRAVEL; little-some calcareous, fine sand, trace-some fines	32.8 / 60.0
60.0 - 64.0 Possible VOID	28.8

Log continued on next page

SAMPLES

RUN	DRILL TIME (min)	REC / ATT	COMMENTS
4	4	10.0 / 10.0	
5	<1	10.0 / 10.0	
6	<1	10.0 / 10.0	Only 5' of recovery from 58 - 68' bgs - possible dissolution features
7	<1	4.0 / 10.0	Possible VOID from 60 - 63.9' bgs

LOG SCALE: 1 in = 4 ft
DRILLING COMPANY: Boart Longyear
DRILLER: Bear

INSPECTOR: J. King
CHECKED BY: J. King/TDA
DATE: 3/31/09

Golder Associates

RECORD OF BOREHOLE G-17

PROJECT: PEF/FGD Blowdown Pond
PROJECT NUMBER: 093-82538
DRILLED DEPTH: 68.0 ft
AZIMUTH: N/A
LOCATION: Crystal River, FL

DRILL METHOD: Sonic
DRILL RIG: Sonic 150
DATE STARTED: 3/4/2009
DATE COMPLETED: 3/4/2009
WEATHER: clear

DATUM: plant coordinates; ft NAVD 88
COORDS: N: 7,720.0 E: 15,018.1
GS ELEVATION: 92.79 (Approx.)
TOC ELEVATION: N/A
TEMPERATURE: 45°

INCLINATION: -90
DEPTH W.L.: 3.5
ELEVATION W.L.: N/A
DATE W.L.: 3/4/09
TIME W.L.: N/A

DEPTH (ft)	ELEVATION (ft)	SOIL PROFILE: DESCRIPTION	ELEV. / DEPTH (ft)	SAMPLES: RUN	DRILL TIME (min)	REC / ATT	COMMENTS
65		64.0 - 65.0 Light brown, highly weathered limestone sampled as calcareous, medium-coarse SAND; trace-little fines	64.0 27.8				Hole open to 57.5' bgs - added 300 gallons water to hole
		65.0 - 67.0 Light brown, angular, LIMESTONE GRAVEL; little-some sandy silt	65.0 25.8	7	<1	4.0 / 10.0	Pumped 160 gallons grout (3 - 55 gallon drums) - 9 bags Amerimix Portland Cement used - installed 60' of Schedule 40 PVC casing
	25	67.0 - 68.0 Light gray, highly weathered limestone sampled as calcareous, silty SAND; trace limestone gravel	67.0 24.8				
		Boring completed at 68.0 ft					
70							VIDEO NOTES (3/04/09 - 11:48): Small dissolution crevice (no discoloration) at 26.75' bgs - large collapse area at 31.6' bgs of weathered limestone - water becomes turbid - camera refusal at 57' bgs
	20						
75							
	15						
80							
	10						
85							
	5						
90							
	0						
95							

LOG SCALE: 1 in = 4 ft
DRILLING COMPANY: Boart Longyear
DRILLER: Bear

INSPECTOR: J. King
CHECKED BY: J. King/TDA
DATE: 3/31/09

Golder Associates

RECORD OF BOREHOLE G-18

PROJECT: PEF/FGD Blowdown Pond	DRILL METHOD: Sonic	DATUM: plant coordinates; ft NAVD 88	INCLINATION: -90
PROJECT NUMBER: 093-82538	DRILL RIG: Sonic 150	COORDS: N: 7,675.2 E: 14,955.2	DEPTH W.L.: 3.5
DRILLED DEPTH: 43.0 ft	DATE STARTED: 3/6/2009	GS ELEVATION: 91.99 (Approx.)	ELEVATION W.L.: N/A
AZIMUTH: N/A	DATE COMPLETED: 3/6/2009	TOC ELEVATION: N/A	DATE W.L.: 3/6/09
LOCATION: Crystal River, FL	WEATHER: clear	TEMPERATURE: 75°	TIME W.L.: N/A

DESCRIPTION (SOIL PROFILE)	ELEV. / DEPTH (ft)	RUN	DRILL TIME (min)	REC / ATT	COMMENTS
0.0 - 2.0 Brown, fine SAND; little fines, trace limestone gravel (FILL)	90.0 / 2.0	1	3	8.0 / 8.0	
2.0 - 2.2 Gray, fine SAND, little fines, little limestone gravel	2.2				
2.2 - 8.0 Light tan, weathered LIMESTONE GRAVEL; and fine sand, little-some fines	84.0 / 8.0				
8.0 - 15.0 Very light tan, competent LIMESTONE; little fines, trace-some silt, trace sand	77.0 / 15.0	2	9	10.0 / 10.0	
15.0 - 18.0 Very light tan, weathered LIMESTONE; some sandy silt	74.0 / 18.0				Installed 6-inch steel casing to 17.5' bgs
18.0 - 28.0 Light tan, competent, weathered LIMESTONE; 0.5 - 1 inch vugs, and poorly sorted sand/gravel, trace fines, little shells	64.0 / 28.0	3	6	5.0 / 10.0	
28.0 - 30.0 Very light tan, highly weathered limestone sampled as calcareous, silty, fine SAND; trace-little limestone gravel	62.0 / 30.0	4	2	10.0 / 10.0	
30.0 - 43.0 Very light tan, poorly sorted LIMESTONE GRAVEL; little fines					

Log continued on next page

LOG SCALE: 1 in = 4 ft
DRILLING COMPANY: Boart Longyear
DRILLER: Bear

INSPECTOR: J. King
CHECKED BY: J. King/TDA
DATE: 3/31/09

Golder Associates

RECORD OF BOREHOLE G-18

PROJECT: PEF/FGD Blowdown Pond
PROJECT NUMBER: 093-82538
DRILLED DEPTH: 43.0 ft
AZIMUTH: N/A
LOCATION: Crystal River, FL

DRILL METHOD: Sonic
DRILL RIG: Sonic 150
DATE STARTED: 3/6/2009
DATE COMPLETED: 3/6/2009
WEATHER: clear

DATUM: plant coordinates; ft NAVD 88
COORDS: N: 7,675.2 E: 14,955.2
GS ELEVATION: 91.99 (Approx.)
TOC ELEVATION: N/A
TEMPERATURE: 75°

INCLINATION: -90
DEPTH W.L.: 3.5
ELEVATION W.L.: N/A
DATE W.L.: 3/6/09
TIME W.L.: N/A

DEPTH (ft)	ELEVATION (ft)	SOIL PROFILE: DESCRIPTION	GRAPHIC LOG	ELEV. / DEPTH (ft)	SAMPLES: RUN	DRILL TIME (min)	REC / ATT	COMMENTS
		30.0 - 43.0 Very light tan, poorly sorted LIMESTONE GRAVEL; little fines *(Continued)*						
35	55				4	2	10.0 / 10.0	
40	50			49.0	5	<1	5.0 / 5.0	Drilling completed at 12:30 at 43' bgs - flushed hole with 200 gallons water - hole open to 41.4' bgs Pumped 100 gallons grout to surface (6 bags Amerimix Portland Cement); no casing necessary
		Boring completed at 43.0 ft						
45	45							VIDEO NOTES (3/06/09: 13:49) - casing to 17.5' bgs, small cracks and vugs in weathered limestone - poor visibility at 30' bgs - small cracks near 30' bgs - top of muck ~36' bgs
50	40							
55	35							
60	30							

LOG SCALE: 1 in = 4 ft
DRILLING COMPANY: Boart Longyear
DRILLER: Bear

INSPECTOR: J. King
CHECKED BY: J. King/TDA
DATE: 3/31/09

Golder Associates

RECORD OF BOREHOLE G-19

PROJECT: PEF/FGD Blowdown Pond
PROJECT NUMBER: 093-82538
DRILLED DEPTH: 43.0 ft
AZIMUTH: N/A
LOCATION: Crystal River, FL

DRILL METHOD: Sonic
DRILL RIG: Sonic 150
DATE STARTED: 3/6/2009
DATE COMPLETED: 3/6/2009
WEATHER: clear

DATUM: plant coordinates; ft NAVD 88
COORDS: N: 7,935.9 E: 14,691.7
GS ELEVATION: 91.59 (Approx.)
TOC ELEVATION: N/A
TEMPERATURE: 70°

INCLINATION: -90
DEPTH W.L.: 4
ELEVATION W.L.: N/A
DATE W.L.: 3/6/09
TIME W.L.: N/A

DESCRIPTION (SOIL PROFILE)	ELEV. / DEPTH (ft)	RUN	DRILL TIME (min)	REC / ATT	COMMENTS
0.0 - 5.0 Brown, fine SAND; little fines, trace limestone gravel (FILL)	86.6	1	2	8.0 / 8.0	
5.0 - 5.3 Dark gray, fine SAND; little silt	5.3				
5.3 - 8.0 Light gray, weathered LIMESTONE; some calcareous, very fine sand, little fines, poorly sorted	83.6				Installed 6-inch casing to 7.5' bgs
8.0 - 15.0 Light gray, weathered LIMESTONE; little-some calcareous, poorly sorted sand/gravel, trace-little fines	8.0 76.6	2	1	10.0 / 10.0	Driller reports soft material at 11' bgs
15.0 - 16.5 Light brown, highly weathered limestone sampled as calcareous SILT; trace-little sand, hard, coarse limestone gravel	15.0 75.1				
16.5 - 17.0 Greenish brown, organic SILT; trace-little sand with shells	74.6 17.0				
17.0 - 18.0 Tan to very light tan LIMESTONE GRAVEL; and poorly sorted, calcareous sand, little fines	73.6 73.1				
18.0 - 18.5 Tan, highly weathered limestone sampled as calcareous, fine SAND; little fines	18.5				
18.5 - 24.0 Competent LIMESTONE; trace calcareous sand, trace-little fines	67.6	3	2	10.0 / 10.0	
24.0 - 28.0 Very light tan weathered LIMESTONE; little-some fines, trace-little poorly sorted, calcareous sand	24.0 63.6				Driller reports probable VOID from 26.5 - 27' bgs
28.0 - 31.0 Very light tan, highly weathered limestone sampled as calcareous, fine SAND; little fines, little limestone gravel	28.0 60.6	4	<1	10.0 / 10.0	
	31.0				

Log continued on next page

LOG SCALE: 1 in = 4 ft
DRILLING COMPANY: Boart Longyear
DRILLER: Bear

INSPECTOR: J. King
CHECKED BY: J. King/TDA
DATE: 3/31/09

Golder Associates

RECORD OF BOREHOLE G-19

PROJECT: PEF/FGD Blowdown Pond
PROJECT NUMBER: 093-82538
DRILLED DEPTH: 43.0 ft
AZIMUTH: N/A
LOCATION: Crystal River, FL

DRILL METHOD: Sonic
DRILL RIG: Sonic 150
DATE STARTED: 3/6/2009
DATE COMPLETED: 3/6/2009
WEATHER: clear

DATUM: plant coordinates; ft NAVD 88
COORDS: N: 7,935.9 E: 14,691.7
GS ELEVATION: 91.59 (Approx.)
TOC ELEVATION: N/A
TEMPERATURE: 70°

INCLINATION: -90
DEPTH W.L.: 4
ELEVATION W.L.: N/A
DATE W.L.: 3/6/09
TIME W.L.: N/A

DEPTH (ft)	ELEVATION (ft)	SOIL PROFILE: DESCRIPTION	GRAPHIC LOG	ELEV. / DEPTH (ft)	SAMPLES: RUN	DRILL TIME (min)	REC / ATT	COMMENTS
		31.0 - 39.0 Very light tan, highly weathered limestone sampled as poorly sorted, calcareous SAND; little-some fines, little-some gravel *(Continued)*						
35					4	<1	10.0 / 10.0	
	55							Pulled rods - hole open to 38.3' bgs due to sidewall collapse - flushed with 250 gallons water
				52.6 / 39.0				
		39.0 - 40.0 Very light tan, poorly sorted, calcareous sandy GRAVEL; trace-little shells, little fines		51.6 / 40.0				Pumped 160 gallons grout (3 - 55 gallon drums) - 9 bags Amerimix Portland Cement used - installed 36.25' of 4-inch Schedule 40 PVC
40		40.0 - 43.0 Very light tan, highly weathered limestone sampled as weathered, poorly sorted, calcareous SAND; and gravel, little-some fines			5	<1	5.0 / 5.0	
	50			48.6				
		Boring completed at 43.0 ft						
45	45							
50	40							VIDEO NOTES (3/06/09 - 16:20) - collapsed sidewalls at 26.5' bgs - camera refusal at 32' bgs
55	35							
60	30							

LOG SCALE: 1 in = 4 ft
DRILLING COMPANY: Boart Longyear
DRILLER: Bear

INSPECTOR: J. King
CHECKED BY: J. King/TDA
DATE: 3/31/09

Golder Associates

RECORD OF BOREHOLE G-2

PROJECT: PEF/FGD Blowdown Pond	DRILL METHOD: Sonic	DATUM: plant coordinates; ft NAVD 88	INCLINATION: -90
PROJECT NUMBER: 093-82538	DRILL RIG: Sonic 150	COORDS: N: 8,038.9 E: 15,008.5	DEPTH W.L.: 6
DRILLED DEPTH: 73.0 ft	DATE STARTED: 2/26/2009	GS ELEVATION: 97.09 (Approx.)	ELEVATION W.L.: N/A
AZIMUTH: N/A	DATE COMPLETED: 2/26/2009	TOC ELEVATION: N/A	DATE W.L.: 2/26/09
LOCATION: Crystal River, FL	WEATHER: clear	TEMPERATURE: 65°	TIME W.L.: N/A

SOIL PROFILE: DESCRIPTION	ELEV. / DEPTH (ft)	SAMPLES: RUN	DRILL TIME (min)	REC / ATT	COMMENTS
0.0 - 3.5 Brown, fine SAND; little limestone gravel, trace-little fines (FILL)	93.6				
3.5 - 4.0 Dark gray, fine SAND; trace-little fines, some limestone gravel	93.1 / 4.0	1	1	8.0 / 8.0	
4.0 - 6.0 Brown, fine SAND; little fines, little weathered limestone	91.1 / 6.0				
6.0 - 7.5 Dark gray-brown, fine SAND; trace-little fines	89.6 / 7.5				
7.5 - 8.5 Light gray LIMESTONE and calcareous sand	88.6 / 8.5				
8.5 - 18.0 Tan, weathered LIMESTONE GRAVEL; and coarse sand, some silt	79.1 / 18.0	2	7	10.0 / 10.0	
18.0 - 26.0 Very light tan, LIMESTONE; some calcareous sandy silt	71.1 / 26.0	3	4	10.0 / 10.0	
26.0 - 28.0 Very light tan, weathered LIMESTONE GRAVEL; and sandy silt	69.1 / 28.0				
28.0 - 39.0 Very light tan, highly weathered limestone sampled as calcareous, silty SAND; trace-little limestone gravel		4	2	10.0 / 10.0	

Log continued on next page

LOG SCALE: 1 in = 4 ft	INSPECTOR: J. King	
DRILLING COMPANY: Boart Longyear	CHECKED BY: J. King/TDA	Golder Associates
DRILLER: Bear	DATE: 3/31/09	

RECORD OF BOREHOLE G-2

PROJECT: PEF/FGD Blowdown Pond
PROJECT NUMBER: 093-82538
DRILLED DEPTH: 73.0 ft
AZIMUTH: N/A
LOCATION: Crystal River, FL

DRILL METHOD: Sonic
DRILL RIG: Sonic 150
DATE STARTED: 2/26/2009
DATE COMPLETED: 2/26/2009
WEATHER: clear

DATUM: plant coordinates; ft NAVD 88
COORDS: N: 8,038.9 E: 15,008.5
GS ELEVATION: 97.09 (Approx.)
TOC ELEVATION: N/A
TEMPERATURE: 65°

INCLINATION: -90
DEPTH W.L.: 6
ELEVATION W.L.: N/A
DATE W.L.: 2/26/09
TIME W.L.: N/A

DEPTH (ft)	ELEVATION (ft)	SOIL PROFILE: DESCRIPTION	GRAPHIC LOG	ELEV. / DEPTH (ft)	SAMPLES: RUN	DRILL TIME (min)	REC / ATT	COMMENTS
	65	28.0 - 39.0 Very light tan, highly weathered limestone sampled as calcareous, silty SAND; trace-little limestone gravel *(Continued)*						
35					4	2	10.0 / 10.0	
	60			58.1 / 39.0				
40		39.0 - 41.0 Light tan weathered LIMESTONE GRAVEL; some sandy silt		56.1 / 41.0				
	55	41.0 - 58.0 Light tan to tan, highly weathered limestone sampled as calcareous, silty SAND; trace-little limestone gravel			5	2	10.0 / 10.0	
45								
	50							
50								
	45				6	3	10.0 / 10.0	
55								
	40			39.1 / 58.0				
		58.0 - 60.0 Very light tan, highly weathered limestone sampled as calcareous, coarse SAND with shell fragments		37.1 / 60.0				
60		60.0 - 64.0 Very light tan, competent LIMESTONE; little-some calcareous sandy silt			7	4	5.0 / 10.0	
	35			33.1				

Log continued on next page

LOG SCALE: 1 in = 4 ft
DRILLING COMPANY: Boart Longyear
DRILLER: Bear

INSPECTOR: J. King
CHECKED BY: J. King/TDA
DATE: 3/31/09

Golder Associates

RECORD OF BOREHOLE G-2

PROJECT: PEF/FGD Blowdown Pond
PROJECT NUMBER: 093-82538
DRILLED DEPTH: 73.0 ft
AZIMUTH: N/A
LOCATION: Crystal River, FL

DRILL METHOD: Sonic
DRILL RIG: Sonic 150
DATE STARTED: 2/26/2009
DATE COMPLETED: 2/26/2009
WEATHER: clear

DATUM: plant coordinates; ft NAVD 88
COORDS: N: 8,038.9 E: 15,008.5
GS ELEVATION: 97.09 (Approx.)
TOC ELEVATION: N/A
TEMPERATURE: 65°

INCLINATION: -90
DEPTH W.L.: 6
ELEVATION W.L.: N/A
DATE W.L.: 2/26/09
TIME W.L.: N/A

DESCRIPTION (SOIL PROFILE)	ELEV. / DEPTH (ft)	RUN	DRILL TIME (min)	REC / ATT	COMMENTS
64.0 - 66.5 Possible VOID	64.0 30.6	7	4	5.0/10.0	
66.5 - 68.0 Very light tan, competent LIMESTONE GRAVEL; little-some calcareous sandy silt	66.5 29.1				
68.0 - 70.0 Light tan, highly weathered limestone sampled as calcareous SILT; trace sand	68.0 27.1	8	1	5.0/5.0	Completed drilling of G-2 at 13:50 - collapse to depth of 65' bgs; flushed with 300 gallons water
70.0 - 72.0 Tan to light gray-tan sandy SILT	70.0 25.1				Drillers pumped 165 gallons grout (9 bags Amerimix Portland Cement) through tremie pipe into hole - installed 40' of 4-inch PVC casing
72.0 - 73.0 Gray-brown-tan, very soft SILT	72.0 24.1				
Boring completed at 73.0 ft					VIDEO NOTES: very turbid - dark at bottom of hole (65.25' bgs) - possible void or thick sediment at 63.75' bgs

DEPTH (ft) scale: 65, 70, 75, 80, 85, 90, 95
ELEVATION (ft) scale: 30, 25, 20, 15, 10, 5

LOG SCALE: 1 in = 4 ft
DRILLING COMPANY: Boart Longyear
DRILLER: Bear

INSPECTOR: J. King
CHECKED BY: J. King/TDA
DATE: 3/31/09

Golder Associates

RECORD OF BOREHOLE G-3

PROJECT: PEF/FGD Blowdown Pond
PROJECT NUMBER: 093-82538
DRILLED DEPTH: 73.0 ft
AZIMUTH: N/A
LOCATION: Crystal River, FL

DRILL METHOD: Sonic
DRILL RIG: Sonic 150
DATE STARTED: 2/27/2009
DATE COMPLETED: 2/27/2009
WEATHER: clear

DATUM: plant coordinates; ft NAVD 88
COORDS: N: 7,509.2 E: 14,725.2
GS ELEVATION: 91.69 (Approx.)
TOC ELEVATION: N/A
TEMPERATURE: 75°

INCLINATION: -90
DEPTH W.L.: 3
ELEVATION W.L.: N/A
DATE W.L.: 2/27/09
TIME W.L.: N/A

DEPTH (ft)	SOIL PROFILE: DESCRIPTION	ELEV. / DEPTH (ft)	SAMPLES: RUN	DRILL TIME (min)	REC / ATT	COMMENTS
0.0 - 2.0	Brown to dark brown, fine SAND; trace-little fines, trace limestone gravel (FILL)	89.7 / 2.0				
2.0 - 3.0	Tan, weathered LIMESTONE GRAVEL; and coarse sand, little fines	88.7 / 3.0				
3.0 - 8.0	Light tan to very light tan, highly weathered limestone sampled as weathered, calcareous, coarse SAND; and limestone gravel, little silt	83.7 / 8.0	1	1	8.0 / 8.0	Casing installed to 7.5' bgs (water used when driving casing)
8.0 - 16.0	Very light tan, competent LIMESTONE; some sandy silt	75.7 / 16.0	2	6	10.0 / 10.0	
16.0 - 21.0	Very light tan, weathered LIMESTONE; some calcareous, silty sand	70.7 / 21.0				
21.0 - 26.0	Very light tan, weathered LIMESTONE GRAVEL; and poorly sorted calcareous sand, little fines	65.7 / 26.0	3	4	10.0 / 10.0	Driller reports easy drilling - little resistance from 21 - 27' bgs
26.0 - 46.0	Very light tan, highly weathered limestone sampled as weathered, calcareous, silty SAND; trace limestone gravel, trace limestone cobbles		4	2	10.0 / 10.0	

Log continued on next page

LOG SCALE: 1 in = 4 ft
DRILLING COMPANY: Boart Longyear
DRILLER: Bear

INSPECTOR: J. King
CHECKED BY: J. King/TDA
DATE: 3/31/09

Golder Associates

RECORD OF BOREHOLE G-3

PROJECT: PEF/FGD Blowdown Pond
PROJECT NUMBER: 093-82538
DRILLED DEPTH: 73.0 ft
AZIMUTH: N/A
LOCATION: Crystal River, FL

DRILL METHOD: Sonic
DRILL RIG: Sonic 150
DATE STARTED: 2/27/2009
DATE COMPLETED: 2/27/2009
WEATHER: clear

DATUM: plant coordinates; ft NAVD 88
COORDS: N: 7,509.2 E: 14,725.2
GS ELEVATION: 91.69 (Approx.)
TOC ELEVATION: N/A
TEMPERATURE: 75°

INCLINATION: -90
DEPTH W.L.: 3
ELEVATION W.L.: N/A
DATE W.L.: 2/27/09
TIME W.L.: N/A

DEPTH (ft)	ELEVATION (ft)	SOIL PROFILE: DESCRIPTION	ELEV. / DEPTH (ft)	SAMPLES: RUN	DRILL TIME (min)	REC / ATT	COMMENTS
		26.0 - 46.0 Very light tan, highly weathered limestone sampled as weathered, calcareous, silty SAND; trace limestone gravel, trace limestone cobbles *(Continued)*					
35				4	2	10.0 / 10.0	
	55						
40							
	50			5	3	10.0 / 10.0	
45			45.7 / 46.0				
	45	46.0 - 47.0 Very light tan, highly weathered limestone sampled as calcareous, coarse SAND; and gravel, little-some fines	44.7 / 47.0				
		47.0 - 52.0 Tan, highly weathered limestone sampled as calcareous, medium-coarse SAND; little-some fines, trace cemented limestone gravel					
50							
	40		39.7 / 52.0				
		52.0 - 69.0 Very light tan-tan-light brown, highly weathered limestone sampled as calcareous, medium-coarse SAND; little fines, trace-little limestone gravel (poorly sorted)		6	NR	9.0 / 10.0	No voids apparent - sample did not stay in core barrel on first attempt - collected sample on second attempt with auger bit (flights on interior of shoe)
55							
	35						
60							
	30			7	2	9.0 / 10.0	
							No void detected - rotation required, but minimal drilling resistance

Log continued on next page

LOG SCALE: 1 in = 4 ft
DRILLING COMPANY: Boart Longyear
DRILLER: Bear

INSPECTOR: J. King
CHECKED BY: J. King/TDA
DATE: 3/31/09

Golder Associates

RECORD OF BOREHOLE G-3

PROJECT: PEF/FGD Blowdown Pond	DRILL METHOD: Sonic	DATUM: plant coordinates; ft NAVD 88	INCLINATION: -90
PROJECT NUMBER: 093-82538	DRILL RIG: Sonic 150	COORDS: N: 7,509.2 E: 14,725.2	DEPTH W.L.: 3
DRILLED DEPTH: 73.0 ft	DATE STARTED: 2/27/2009	GS ELEVATION: 91.69 (Approx.)	ELEVATION W.L.: N/A
AZIMUTH: N/A	DATE COMPLETED: 2/27/2009	TOC ELEVATION: N/A	DATE W.L.: 2/27/09
LOCATION: Crystal River, FL	WEATHER: clear	TEMPERATURE: 75°	TIME W.L.: N/A

DEPTH (ft)	ELEVATION (ft)	SOIL PROFILE: DESCRIPTION	GRAPHIC LOG	ELEV. / DEPTH (ft)	SAMPLES: RUN	DRILL TIME (min)	REC / ATT	COMMENTS
65	25	52.0 - 69.0 Very light tan-tan-light brown, highly weathered limestone sampled as calcareous, medium-coarse SAND; little fines, trace-little limestone gravel (poorly sorted) *(Continued)*		22.7 / 69.0	7	2	9.0 / 10.0	
		69.0 - 70.0 Brown LIMESTONE GRAVEL to COBBLES; and dark gray-brown clayey silt		21.7 / 70.0	8	1	5.0 / 5.0	Drillers pumped 160 gallons grout (10 bags of Amerimix Portland Cement, Type 1/11) at 15:50 - added 70' casing to 63.9' bgs, trimmed to 29 inches of stick-up
70		70.0 - 71.0 Gray silty SAND; trace-little limestone gravel		20.7 / 71.0				
	20	71.0 - 73.0 Light gray-gray SILT		18.7				
		Boring completed at 73.0 ft						
75	15							VIDEO NOTES: did not flush for this hole - water is more turbid - dark at 63' bgs - camera refusal at 64.2' bgs - possible void from 63.2' - 64.2' bgs, but likely thick sediment blocking camera light
80	10							
85	5							
90	0							
95								

LOG SCALE: 1 in = 4 ft
DRILLING COMPANY: Boart Longyear
DRILLER: Bear

INSPECTOR: J. King
CHECKED BY: J. King/TDA
DATE: 3/31/09

Golder Associates

RECORD OF BOREHOLE G-4

PROJECT: PEF/FGD Blowdown Pond
PROJECT NUMBER: 093-82538
DRILLED DEPTH: 73.0 ft
AZIMUTH: N/A
LOCATION: Crystal River, FL

DRILL METHOD: Sonic
DRILL RIG: Sonic 150
DATE STARTED: 2/27/2009
DATE COMPLETED: 2/27/2009
WEATHER: partly cloudy

DATUM: plant coordinates; ft NAVD 88
COORDS: N: 7,514.3 E: 14,985.6
GS ELEVATION: 94.19 (Approx.)
TOC ELEVATION: N/A
TEMPERATURE: 60°

INCLINATION: -90
DEPTH W.L.: 3.5
ELEVATION W.L.: N/A
DATE W.L.: 2/27/09
TIME W.L.: N/A

DESCRIPTION (SOIL PROFILE)	ELEV. / DEPTH (ft)	RUN	DRILL TIME (min)	REC / ATT	COMMENTS
0.0 - 2.5 Light brown, fine SAND; little limestone gravel, trace-little fines (FILL)	91.7 / 2.5	1	3	8.0 / 8.0	Auger would not retract; driller installed 6-inch steel casing to 7.5' bgs.
2.5 - 3.5 Brown, fine SAND; trace limestone gravel, little fines (FILL)	90.7 / 3.5				
3.5 - 5.0 Light tan, highly weathered limestone sampled as calcareous, silty SAND; little limestone gravel	89.2 / 5.0				Driller reports rock at 4' bgs
5.0 - 10.0 Very light tan, weathered LIMESTONE; some calcareous, silty sand	84.2 / 10.0				
10.0 - 13.5 Very light tan, highly weathered limestone sampled as calcareous, sandy SILT; little limestone gravel	80.7 / 13.5	2	6	10.0 / 10.0	
13.5 - 18.0 Very light tan LIMESTONE GRAVEL and COBBLES; little calcareous, sandy silt	76.2 / 18.0				
18.0 - 28.0 Very light tan, weathered LIMESTONE; and calcareous, sandy silt	66.2 / 28.0	3	14	10.0 / 10.0	
28.0 - 47.0 Very light tan, highly weathered limestone sampled as calcareous, silty SAND; trace limestone gravel		4	2	10.0 / 10.0	

Log continued on next page

LOG SCALE: 1 in = 4 ft
DRILLING COMPANY: Boart Longyear
DRILLER: Bear

INSPECTOR: J. King
CHECKED BY: J. King/TDA
DATE: 3/31/09

Golder Associates

RECORD OF BOREHOLE G-4

PROJECT: PEF/FGD Blowdown Pond	DRILL METHOD: Sonic	DATUM: plant coordinates; ft NAVD 88	INCLINATION: -90
PROJECT NUMBER: 093-82538	DRILL RIG: Sonic 150	COORDS: N: 7,514.3 E: 14,985.6	DEPTH W.L.: 3.5
DRILLED DEPTH: 73.0 ft	DATE STARTED: 2/27/2009	GS ELEVATION: 94.19 (Approx.)	ELEVATION W.L.: N/A
AZIMUTH: N/A	DATE COMPLETED: 2/27/2009	TOC ELEVATION: N/A	DATE W.L.: 2/27/09
LOCATION: Crystal River, FL	WEATHER: partly cloudy	TEMPERATURE: 60°	TIME W.L.: N/A

SOIL PROFILE

DESCRIPTION	ELEV. / DEPTH (ft)
28.0 - 47.0 Very light tan, highly weathered limestone sampled as calcareous, silty SAND; trace limestone gravel *(Continued)*	47.2 / 47.0
47.0 - 48.0 Very light tan, weathered LIMESTONE GRAVEL; some silty sand	46.2 / 48.0
48.0 - 50.0 Very light tan, highly weathered limestone sampled as calcareous SAND; little fines	44.2 / 50.0
50.0 - 54.5 Very light tan, highly weathered limestone sampled as calcareous, medium-coarse SAND; little fines, trace limestone gravel 52 - 54.5' bgs	39.7 / 54.5
54.5 - 59.0 Possible VOID	35.2 / 59.0
59.0 - 61.0 Brown, highly weathered limestone sampled as calcareous SAND; and silt	33.2 / 61.0
61.0 - 63.0 Brown SILT; little calcareous sand, little angular limestone gravel/cobbles	31.2 / 63.0
63.0 - 73.0 Light brown SILT; lens of cobbles with trace shells at 70.75' bgs	

Log continued on next page

SAMPLES

RUN	DRILL TIME (min)	REC / ATT	COMMENTS
4	2	10.0 / 10.0	
5	2	8.0 / 10.0	
6	2	7.0 / 10.0	Driller suggests possible void detected at 54.5' bgs to 58' bgs - dropped straight down to 58' bgs (max depth for run) after hopping at 54.5' bgs
7	1	4.0 / 10.0	Drilling resistance at 59' bgs, then soft material Broken limestone cobbles at 59' overlying silt suggest collapsed material from dissolution feature ceiling

LOG SCALE: 1 in = 4 ft
DRILLING COMPANY: Boart Longyear
DRILLER: Bear

INSPECTOR: J. King
CHECKED BY: J. King/TDA
DATE: 3/31/09

Golder Associates

RECORD OF BOREHOLE G-4

PROJECT: PEF/FGD Blowdown Pond	DRILL METHOD: Sonic	DATUM: plant coordinates; ft NAVD 88	INCLINATION: -90
PROJECT NUMBER: 093-82538	DRILL RIG: Sonic 150	COORDS: N: 7,514.3 E: 14,985.6	DEPTH W.L.: 3.5
DRILLED DEPTH: 73.0 ft	DATE STARTED: 2/27/2009	GS ELEVATION: 94.19 (Approx.)	ELEVATION W.L.: N/A
AZIMUTH: N/A	DATE COMPLETED: 2/27/2009	TOC ELEVATION: N/A	DATE W.L.: 2/27/09
LOCATION: Crystal River, FL	WEATHER: partly cloudy	TEMPERATURE: 60°	TIME W.L.: N/A

DEPTH (ft)	ELEVATION (ft)	SOIL PROFILE: DESCRIPTION	GRAPHIC LOG	ELEV. / DEPTH (ft)	SAMPLES: RUN	DRILL TIME (min)	REC / ATT	COMMENTS
	30	63.0 - 73.0 Light brown SILT; lens of cobbles with trace shells at 70.75' bgs *(Continued)*						
65					7	1	4.0 / 10.0	Five feet of collapse after drilling to 68' bgs; drove next run from 63 - 73' bgs
70	25				8	2	5.0 / 5.0	Completed drilling of G-4 at 10:10; flushed hole with ~325 gallons water at 10:45
				21.2				
		Boring completed at 73.0 ft						Pumped ~165 gallons grout (3 drums, 12 bags Amerimix Portland Cement Type 1/11) - installed 60' of 4-inch PVC casing (TOC = 2 inches bgs)
75	20							VIDEO NOTES (2/27/09 - 11:12): better visibility - driller reports formation water is clearer - lost light at 55.5' bgs, possibly due to void or sediment blocking light to camera - camera refusal at 61.5' bgs
80	15							
85	10							
90	5							
95	0							

LOG SCALE: 1 in = 4 ft	INSPECTOR: J. King
DRILLING COMPANY: Boart Longyear	CHECKED BY: J. King/TDA
DRILLER: Bear	DATE: 3/31/09

Golder Associates

RECORD OF BOREHOLE G-5

PROJECT: PEF/FGD Blowdown Pond	DRILL METHOD: Sonic	DATUM: plant coordinates; ft NAVD 88	INCLINATION: -90
PROJECT NUMBER: 093-82538	DRILL RIG: Sonic 150	COORDS: N: 7,644.4 E: 14,889.7	DEPTH W.L.: 3
DRILLED DEPTH: 73.0 ft	DATE STARTED: 2/27/2009	GS ELEVATION: 91.89 (Approx.)	ELEVATION W.L.: N/A
AZIMUTH: N/A	DATE COMPLETED: 2/28/2009	TOC ELEVATION: N/A	DATE W.L.: 2/28/09
LOCATION: Crystal River, FL	WEATHER: clear	TEMPERATURE: 70°	TIME W.L.: N/A

DEPTH (ft)	ELEVATION (ft)	SOIL PROFILE: DESCRIPTION	GRAPHIC LOG	ELEV. / DEPTH (ft)	SAMPLES: RUN	DRILL TIME (min)	REC / ATT	COMMENTS
0		0.0 - 2.0 Brown, fine SAND; little fines, trace limestone gravel (FILL)		89.9 2.0				
	90	2.0 - 3.5 Tan, weathered LIMESTONE; and calcareous sand, little fines		88.4 3.5				
		3.5 - 5.0 Very light tan, weathered LIMESTONE; trace-little fines		86.9 5.0	1	4	8.0 / 8.0	
5	85	5.0 - 8.0 Very light tan, weathered LIMESTONE; and calcareous sand, little-some fines		83.9 8.0				Installed 6-inch steel casing to 7.5' bgs (water used when driving casing)
10	80	8.0 - 17.5 Very light tan, competent LIMESTONE; trace-little fines, trace calcareous, fine sand (1-inch weathered limestone gravel and coarse sand layer at 12' bgs)		74.4	2	8	10.0 / 10.0	
15	75	17.5 - 18.0 Very light tan, weathered LIMESTONE; and calcareous silty sand		73.9 18.0				
20	70	18.0 - 25.0 Very light tan LIMESTONE; trace-little calcareous, silty sand		66.9 25.0	3	7	10.0 / 10.0	
25	65	25.0 - 48.0 Very light tan, highly weathered limestone sampled as calcareous, silty, poorly graded SAND; trace limestone gravel						
30	60				4	2	10.0 / 10.0	

Log continued on next page

LOG SCALE: 1 in = 4 ft
DRILLING COMPANY: Boart Longyear
DRILLER: Bear

INSPECTOR: J. King
CHECKED BY: J. King/TDA
DATE: 3/31/09

Golder Associates

RECORD OF BOREHOLE G-5

PROJECT: PEF/FGD Blowdown Pond
PROJECT NUMBER: 093-82538
DRILLED DEPTH: 73.0 ft
AZIMUTH: N/A
LOCATION: Crystal River, FL

DRILL METHOD: Sonic
DRILL RIG: Sonic 150
DATE STARTED: 2/27/2009
DATE COMPLETED: 2/28/2009
WEATHER: clear

DATUM: plant coordinates; ft NAVD 88
COORDS: N: 7,644.4 E: 14,889.7
GS ELEVATION: 91.89 (Approx.)
TOC ELEVATION: N/A
TEMPERATURE: 70°

INCLINATION: -90
DEPTH W.L.: 3
ELEVATION W.L.: N/A
DATE W.L.: 2/28/09
TIME W.L.: N/A

DEPTH (ft)	ELEVATION (ft)	SOIL PROFILE: DESCRIPTION	ELEV. / DEPTH (ft)	SAMPLES: RUN	DRILL TIME (min)	REC / ATT	COMMENTS
		25.0 - 48.0 Very light tan, highly weathered limestone sampled as calcareous, silty, poorly graded SAND; trace limestone gravel *(Continued)*					
35				4	2	10.0 / 10.0	
	55						Completed drilling for the day at 17:30 on 2/27/09 at 38' bgs
							Resumed drilling at 08:50 on 2/28/09
40							
	50						
				5	4	10.0 / 10.0	
45							
	45		43.9 / 48.0				
		48.0 - 58.0 Very light tan-tan, highly weathered limestone sampled as silty, calcareous, coarse SAND; and weathered limestone					
50							
	40						
				6	1	8.0 / 10.0	
55							
	35		33.9 / 58.0				
		58.0 - 59.0 Material present but not recovered (lost when breaking through into void below)	32.9 / 59.0				Encountered very hard material at 59' bgs, then very soft at 59.5' bgs
		59.0 - 62.0 Possible VOID					
60				7	8	6.0 / 10.0	
	30		29.9 / 62.0				Encountered very hard material at 62' bgs
		62.0 - 63.0 Light brown, cemented LIMESTONE; little brown silty sand	28.9 / 63.0				
		63.0 - 68.0 Very light tan, weathered LIMESTONE GRAVEL; and sandy silt					

Log continued on next page

LOG SCALE: 1 in = 4 ft
DRILLING COMPANY: Boart Longyear
DRILLER: Bear

INSPECTOR: J. King
CHECKED BY: J. King/TDA
DATE: 3/31/09

Golder Associates

RECORD OF BOREHOLE G-5

PROJECT: PEF/FGD Blowdown Pond	DRILL METHOD: Sonic	DATUM: plant coordinates; ft NAVD 88	INCLINATION: -90
PROJECT NUMBER: 093-82538	DRILL RIG: Sonic 150	COORDS: N: 7,644.4 E: 14,889.7	DEPTH W.L.: 3
DRILLED DEPTH: 73.0 ft	DATE STARTED: 2/27/2009	GS ELEVATION: 91.89 (Approx.)	ELEVATION W.L.: N/A
AZIMUTH: N/A	DATE COMPLETED: 2/28/2009	TOC ELEVATION: N/A	DATE W.L.: 2/28/09
LOCATION: Crystal River, FL	WEATHER: clear	TEMPERATURE: 70°	TIME W.L.: N/A

DEPTH (ft)	ELEVATION (ft)	SOIL PROFILE: DESCRIPTION	GRAPHIC LOG	ELEV. / DEPTH (ft)	SAMPLES: RUN	DRILL TIME (min)	REC / ATT	COMMENTS
65	25	63.0 - 68.0 Very light tan, weathered LIMESTONE GRAVEL; and sandy silt *(Continued)*		23.9 / 68.0	7	8	6.0 / 10.0	Encountered soft material at 66' bgs
		68.0 - 69.0 Tan, highly weathered limestone sampled as calcareous, coarse SAND; and shells, trace-little fines		22.9 / 69.0	8	1	5.0 / 5.0	Drilling of G-5 complete at 9:44 (some collapse after completion- tagged depth of 62.6' bgs) - Added 300 gallons water to hole at 10:40
70		69.0 - 70.0 Tan, angular LIMESTONE GRAVEL; little fines		21.9 / 70.0				
	20	70.0 - 72.0 Tan, highly weathered limestone sampled as calcareous, fine SAND; and limestone gravel, trace silt, trace-some sand		19.9				Pumped 160 gallons grout (9 bags Amerimix Portland Cement Type 1/11) - added 60' of 4-inch PVC casing (21 inches of stick-up)
		72.0 - 72.5 Dark gray SILT; trace clay		19.4				
		72.5 - 73.0 Light brown SILT		18.9				
		Boring completed at 73.0 ft						
75	15							VIDEO NOTES: much better visibility - trace small (< 2-inch) vugs in top 40' - no large voids - some sidewall collapse features - large collapse at 48' bgs - visibility is poor below 50' - dark at 52.5', may be void - below 53' shows collapsed sidewalls of weathered material - camera refusal at 61.75'
80	10							
85	5							
90	0							
95								

LOG SCALE: 1 in = 4 ft
DRILLING COMPANY: Boart Longyear
DRILLER: Bear

INSPECTOR: J. King
CHECKED BY: J. King/TDA
DATE: 3/31/09

Golder Associates

RECORD OF BOREHOLE G-6

PROJECT: PEF/FGD Blowdown Pond
PROJECT NUMBER: 093-82538
DRILLED DEPTH: 73.0 ft
AZIMUTH: N/A
LOCATION: Crystal River, FL

DRILL METHOD: Sonic
DRILL RIG: Sonic 150
DATE STARTED: 2/28/2009
DATE COMPLETED: 2/28/2009
WEATHER: partly cloudy

DATUM: plant coordinates; ft NAVD 88
COORDS: N: 7,809.2 E: 14,877.9
GS ELEVATION: 91.49 (Approx.)
TOC ELEVATION: N/A
TEMPERATURE: 70°

INCLINATION: -90
DEPTH W.L.: 3
ELEVATION W.L.: N/A
DATE W.L.: 2/28/09
TIME W.L.: N/A

DESCRIPTION (SOIL PROFILE)	ELEV. / DEPTH (ft)	RUN	DRILL TIME (min)	REC / ATT	COMMENTS
0.0 - 6.5 Brown, fine SAND; trace-little fines, trace limestone gravel (FILL)	85.0 / 6.5	1	2	8.0 / 8.0	
6.5 - 8.0 Brown, fine SAND; little fines	83.5 / 8.0				
8.0 - 10.0 Light brown to very light tan, highly weathered limestone sampled as calcareous, medium-coarse SAND; and weathered limestone gravel	81.5 / 10.0	2	3	10.0 / 10.0	
10.0 - 14.0 Very light tan, weathered, cemented LIMESTONE; little silty, coarse sand	77.5				
14.0 - 14.4 Very light tan, highly weathered limestone sampled as calcareous SILT; and limestone gravel	77.1 / 14.4				
14.4 - 17.0 Very light tan, highly weathered limestone sampled as calcareous, sandy SILT; and limestone gravel	74.5 / 17.0				
17.0 - 18.0 Tan, weathered LIMESTONE; little calcareous, coarse sand, little fines	73.5 / 18.0				Installed 6-inch steel casing to 17.5' bgs
18.0 - 26.0 Very light tan, weathered LIMESTONE; trace shells, trace vugs up to 1.5 inches long, coarse sand/shell layer (1 inch thick) at 18.5'	65.5 / 26.0	3	4	10.0 / 10.0	
26.0 - 31.5 Very light tan to light gray-tan, highly weathered limestone sampled as calcareous, poorly sorted SAND; little-some fines, trace-little limestone gravel	60.0 / 31.5	4	NR	10.0 / 10.0	

Log continued on next page

LOG SCALE: 1 in = 4 ft
DRILLING COMPANY: Boart Longyear
DRILLER: Bear

INSPECTOR: J. King
CHECKED BY: J. King/TDA
DATE: 3/31/09

Golder Associates

RECORD OF BOREHOLE G-6

PROJECT: PEF/FGD Blowdown Pond
PROJECT NUMBER: 093-82538
DRILLED DEPTH: 73.0 ft
AZIMUTH: N/A
LOCATION: Crystal River, FL

DRILL METHOD: Sonic
DRILL RIG: Sonic 150
DATE STARTED: 2/28/2009
DATE COMPLETED: 2/28/2009
WEATHER: partly cloudy

DATUM: plant coordinates; ft NAVD 88
COORDS: N: 7,809.2 E: 14,877.9
GS ELEVATION: 91.49 (Approx.)
TOC ELEVATION: N/A
TEMPERATURE: 70°

INCLINATION: -90
DEPTH W.L.: 3
ELEVATION W.L.: N/A
DATE W.L.: 2/28/09
TIME W.L.: N/A

DEPTH (ft)	ELEVATION (ft)	SOIL PROFILE: DESCRIPTION	GRAPHIC LOG	ELEV. / DEPTH (ft)	SAMPLES: RUN	DRILL TIME (min)	REC / ATT	COMMENTS
		31.5 - 47.0 Light tan to very light tan, highly weathered limestone sampled as calcareous, silty, fine SAND; trace-little coarse limestone sand, trace limestone gravel *(Continued)*						
35					4	NR	10.0 / 10.0	
	55							
40								
	50							
					5	8	10.0 / 10.0	
45								
	45			44.5 / 47.0				
		47.0 - 48.0 Very light tan, highly weathered limestone sampled as calcareous, coarse SAND; trace-some limestone gravel		43.5 / 48.0				
		48.0 - 53.0 Light tan, weathered, competent LIMESTONE; little silty gravel						
50								
	40			38.5 / 53.0	6	NR	10.0 / 10.0	
		53.0 - 58.0 Light tan, highly weathered limestone sampled as calcareous, silty SAND; little limestone gravel						
55								
	35			33.5 / 58.0				
		58.0 - 63.0 Light tan, highly weathered limestone sampled as calcareous, medium-coarse SAND; trace-little fines, trace-little limestone gravel						
60					7	NR	10.0 / 10.0	
	30			28.5 / 63.0				

Log continued on next page

LOG SCALE: 1 in = 4 ft
DRILLING COMPANY: Boart Longyear
DRILLER: Bear

INSPECTOR: J. King
CHECKED BY: J. King/TDA
DATE: 3/31/09

Golder Associates

RECORD OF BOREHOLE G-6

PROJECT: PEF/FGD Blowdown Pond
PROJECT NUMBER: 093-82538
DRILLED DEPTH: 73.0 ft
AZIMUTH: N/A
LOCATION: Crystal River, FL

DRILL METHOD: Sonic
DRILL RIG: Sonic 150
DATE STARTED: 2/28/2009
DATE COMPLETED: 2/28/2009
WEATHER: partly cloudy

DATUM: plant coordinates; ft NAVD 88
COORDS: N: 7,809.2 E: 14,877.9
GS ELEVATION: 91.49 (Approx.)
TOC ELEVATION: N/A
TEMPERATURE: 70°

INCLINATION: -90
DEPTH W.L.: 3
ELEVATION W.L.: N/A
DATE W.L.: 2/28/09
TIME W.L.: N/A

DEPTH (ft)	ELEVATION (ft)	SOIL PROFILE: DESCRIPTION	GRAPHIC LOG	ELEV. / DEPTH (ft)	SAMPLES: RUN	DRILL TIME (min)	REC / ATT	COMMENTS
65	25	63.0 - 68.0 Very light tan, weathered LIMESTONE GRAVEL; trace-little silty, coarse sand grading to tan limestone, trace sandy silt *(Continued)*		23.5 / 68.0	7	NR	10.0 / 10.0	
		68.0 - 69.0 Light brown to brown, angular LIMESTONE; some sandy silt		22.5 / 69.0	8	NR	5.0 / 5.0	
70		69.0 - 71.0 Dark gray to dark brown SILT; trace sand, trace-little clay		20.5 / 71.0				
	20	71.0 - 72.0 Dark gray to gray-brown SILT		19.5 / 72.0				Drilling of G-6 complete at 15:45 - flushed hole with 300 gallons water (tagged depth at 60.5' bgs)
		72.0 - 73.0 Light brown-orange SILT		18.5				
		Boring completed at 73.0 ft						Pumped 160 gallons grout (9 bags Amerimix Portland Cement Type 1/11) - installed 65' of 4-inch PVC (25 inches of stick-up)
75	15							VIDEO NOTES: hole open to 64' bgs - little visibility beyond 30' bgs - boring gets dark at 62.5' bgs, likely due to accumulated sediment
80	10							
85	5							
90	0							
95								

LOG SCALE: 1 in = 4 ft
DRILLING COMPANY: Boart Longyear
DRILLER: Bear

INSPECTOR: J. King
CHECKED BY: J. King/TDA
DATE: 3/31/09

Golder Associates

RECORD OF BOREHOLE G-7

PROJECT: PEF/FGD Blowdown Pond	DRILL METHOD: Sonic	DATUM: plant coordinates; ft NAVD 88	INCLINATION: -90
PROJECT NUMBER: 093-82538	DRILL RIG: Sonic 150	COORDS: N: 7,689.4 E: 14,697.2	DEPTH W.L.: 3.5
DRILLED DEPTH: 73.0 ft	DATE STARTED: 3/2/2009	GS ELEVATION: 91.39 (Approx.)	ELEVATION W.L.: N/A
AZIMUTH: N/A	DATE COMPLETED: 3/2/2009	TOC ELEVATION: N/A	DATE W.L.: 3/2/09
LOCATION: Crystal River, FL	WEATHER: clear	TEMPERATURE: 50°	TIME W.L.: N/A

SOIL PROFILE

DESCRIPTION	ELEV. / DEPTH (ft)
0.0 - 2.0 Brown, fine SAND; trace-little fines, trace limestone gravel (FILL)	89.4 / 2.0
2.0 - 6.3 Tan, weathered LIMESTONE; and gray, fine SAND, little-some fines	85.1 / 6.3
6.3 - 8.0 Dark brown, soft SILT; trace clay	83.4 / 8.0
8.0 - 10.0 Brown-gray SAND; little-some fines	81.4 / 10.0
10.0 - 12.0 Dark gray, fine SAND; little-some fines	79.4 / 12.0
12.0 - 16.0 Light gray, weathered LIMESTONE; and silty, coarse sand	75.4 / 16.0
16.0 - 17.0 Greenish-gray, silty SAND; trace-little limestone gravel	74.4 / 17.0
17.0 - 19.0 Greenish-brown SILT; little limestone gravel, trace-little sand	72.4 / 19.0
19.0 - 20.0 Dark brown, silty SAND; trace limestone gravel	71.4 / 20.0
20.0 - 22.0 Light brown to tannish-gray, weathered LIMESTONE; and calcareous, silty sand	69.4 / 22.0
22.0 - 28.0 Light gray (tan from 24 - 28' bgs), weathered LIMESTONE; and coarse sand, little fines, trace rounded coarse sand	63.4 / 28.0
28.0 - 35.5 Light tan (light brown from 34.5 - 35.5' bgs), weathered LIMESTONE GRAVEL/COBBLES; little very light tan, fine sand, trace-little fines	

SAMPLES

RUN	DRILL TIME (min)	REC / ATT	Interval (ft)
1	3	8.0 / 8.0	0 - 8
2	1	10.0 / 10.0	8 - 18
3	2	6.0 / 10.0	18 - 28
4	2	10.0 / 10.0	28 -

COMMENTS

- (12.0 ft) Driller reports he is not encountering solid rock - appears weathered/fractured
- (17.5 ft) Installed 6-inch casing to 17.5' bgs

Log continued on next page

LOG SCALE: 1 in = 4 ft
DRILLING COMPANY: Boart Longyear
DRILLER: Bear

INSPECTOR: J. King
CHECKED BY: J. King/TDA
DATE: 3/31/09

Golder Associates

RECORD OF BOREHOLE G-7

PROJECT: PEF/FGD Blowdown Pond
PROJECT NUMBER: 093-82538
DRILLED DEPTH: 73.0 ft
AZIMUTH: N/A
LOCATION: Crystal River, FL

DRILL METHOD: Sonic
DRILL RIG: Sonic 150
DATE STARTED: 3/2/2009
DATE COMPLETED: 3/2/2009
WEATHER: clear

DATUM: plant coordinates; ft NAVD 88
COORDS: N: 7,689.4 E: 14,697.2
GS ELEVATION: 91.39 (Approx.)
TOC ELEVATION: N/A
TEMPERATURE: 50°

INCLINATION: -90
DEPTH W.L.: 3.5
ELEVATION W.L.: N/A
DATE W.L.: 3/2/09
TIME W.L.: N/A

DESCRIPTION (SOIL PROFILE)	ELEV. / DEPTH (ft)	RUN	DRILL TIME (min)	REC / ATT	COMMENTS
28.0 - 35.5 Light tan (light brown from 34.5 - 35.5' bgs), weathered LIMESTONE GRAVEL/COBBLES; little very light tan, fine sand, trace-little fines *(Continued)*	55.9 / 35.5	4	2	10.0 / 10.0	
35.5 - 36.0 Light brown to brown, highly weathered limestone sampled as calcareous, fine SAND with shells; trace-little fines	55.4 / 36.0				
36.0 - 38.0 Light brown to tan, highly weathered limestone sampled as calcareous, fine SAND with shells; trace-little limestone gravel	53.4 / 38.0				
38.0 - 43.5 LIMESTONE GRAVEL; little coarse sand with shells, trace-little fines	47.9 / 43.5	5	1	10.0 / 10.0	
43.5 - 50.0 Very light tan, highly weathered limestone sampled as calcareous, fine SAND; little-some fines, some limestone gravel	41.4 / 50.0				
50.0 - 53.0 Light tan, weathered LIMESTONE; little coarse sand with shell fragments, little fines	38.4 / 53.0	6	1	10.0 / 10.0	
53.0 - 55.0 Tan, highly weathered limestone sampled as calcareous, fine SAND; little fines, little limestone gravel	36.4 / 55.0				
55.0 - 55.4 Dark brown SILT	36.0 / 55.4				
55.4 - 60.5 Light brown to tan, weathered LIMESTONE; and calcareous, coarse sand with shells, trace-little fines	30.9 / 60.5				
60.5 - 62.5 Light tan, highly weathered limestone sampled as calcareous silty SAND; and limestone	28.9 / 62.5	7	4	10.0 / 10.0	
62.5 - 64.3 Tan, highly weathered limestone sampled as calcareous, poorly sorted SAND with shells; and limestone, little fines					

Depth scale (ft): 35, 40, 45, 50, 55, 60. Elevation scale (ft): 55, 50, 45, 40, 35, 30.

Log continued on next page

LOG SCALE: 1 in = 4 ft
DRILLING COMPANY: Boart Longyear
DRILLER: Bear

INSPECTOR: J. King
CHECKED BY: J. King/TDA
DATE: 3/31/09

Golder Associates

RECORD OF BOREHOLE G-7

PROJECT: PEF/FGD Blowdown Pond
PROJECT NUMBER: 093-82538
DRILLED DEPTH: 73.0 ft
AZIMUTH: N/A
LOCATION: Crystal River, FL

DRILL METHOD: Sonic
DRILL RIG: Sonic 150
DATE STARTED: 3/2/2009
DATE COMPLETED: 3/2/2009
WEATHER: clear

DATUM: plant coordinates; ft NAVD 88
COORDS: N: 7,689.4 E: 14,697.2
GS ELEVATION: 91.39 (Approx.)
TOC ELEVATION: N/A
TEMPERATURE: 50°

INCLINATION: -90
DEPTH W.L.: 3.5
ELEVATION W.L.: N/A
DATE W.L.: 3/2/09
TIME W.L.: N/A

DEPTH (ft)	ELEVATION (ft)	SOIL PROFILE: DESCRIPTION	GRAPHIC LOG	ELEV. / DEPTH (ft)	SAMPLES: RUN	DRILL TIME (min)	REC / ATT	COMMENTS
				27.1				
		64.3 - 65.0 Light to dark brown SILT		64.3 26.4				
65	25	65.0 - 68.0 Light tan, highly weathered limestone sampled as calcareous, silty SAND; some limestone gravel, AND LIMESTONE GRAVEL; little-some silty sand		65.0 23.4	7	4	10.0 / 10.0	
70	20	68.0 - 71.0 Tan, highly weathered limestone sampled as calcareous, poorly sorted SAND; and gravel, trace-little fines, little shell fragments		68.0 20.4	8	1	5.0 / 5.0	
		71.0 - 72.0 Light gray, sandy SILT; trace limestone gravel		71.0 19.4				
		72.0 - 73.0 Light gray-brown SILT		72.0 18.4				Drilling of G-7 complete at 16:10 (73' bgs)
		Boring completed at 73.0 ft						Pumped 165 gallons grout (9 bags Amerimix Portland Cement Type 1/11) - installed 20' of 4-inch PVC casing
75	15							VIDEO NOTES (3/02/09 - 16:40): first attempt - rock obstruction at 21' bgs - blockage to 60' bgs; second attempt (17:25) - poor visibility and more collapse within 1' of bottom of casing
80	10							
85	5							
90	0							
95								

LOG SCALE: 1 in = 4 ft
DRILLING COMPANY: Boart Longyear
DRILLER: Bear

INSPECTOR: J. King
CHECKED BY: J. King/TDA
DATE: 3/31/09

Golder Associates

RECORD OF BOREHOLE G-8

PROJECT: PEF/FGD Blowdown Pond	DRILL METHOD: Sonic	DATUM: plant coordinates; ft NAVD 88	INCLINATION: -90
PROJECT NUMBER: 093-82538	DRILL RIG: Sonic 150	COORDS: N: 7,683.5 E: 14,996.7	DEPTH W.L.: 3.5
DRILLED DEPTH: 73.0 ft	DATE STARTED: 2/28/2009	GS ELEVATION: 92.19 (Approx.)	ELEVATION W.L.: N/A
AZIMUTH: N/A	DATE COMPLETED: 3/2/2009	TOC ELEVATION: N/A	DATE W.L.: 3/2/09
LOCATION: Crystal River, FL	WEATHER: partly cloudy	TEMPERATURE: 70°	TIME W.L.: N/A

SOIL PROFILE

DEPTH (ft)	DESCRIPTION	ELEV. / DEPTH (ft)
0.0 - 2.8	Brown, fine SAND; little fines, trace limestone gravel (FILL)	89.4 / 2.8
2.8 - 8.0	Very light tan, highly weathered limestone sampled as calcareous, silty, coarse SAND; and limestone gravel	84.2 / 8.0
8.0 - 22.0	Very light tan, LIMESTONE; little calcareous, sandy silt	70.2 / 22.0
22.0 - 40.0	Light tan - very light tan, highly weathered limestone sampled as calcareous, silty SAND; trace-little limestone gravel	

Log continued on next page

SAMPLES

RUN	DRILL TIME (min)	REC / ATT
1	NR	8.0 / 8.0
2	8	10.0 / 10.0
3	5	7.0 / 10.0
4	1	10.0 / 10.0

COMMENTS

Installed 6-inch steel casing to 7.5' bgs

Completed drilling for the day on 2/28/09 at 15:50

Resumed drilling at 08:38 on 3/02/09

Driller encountered soft material from 22 - 28' bgs

LOG SCALE: 1 in = 4 ft	INSPECTOR: J. King
DRILLING COMPANY: Boart Longyear	CHECKED BY: J. King/TDA
DRILLER: Bear	DATE: 3/31/09

Golder Associates

RECORD OF BOREHOLE G-8

PROJECT: PEF/FGD Blowdown Pond	DRILL METHOD: Sonic	DATUM: plant coordinates; ft NAVD 88	INCLINATION: -90
PROJECT NUMBER: 093-82538	DRILL RIG: Sonic 150	COORDS: N: 7,683.5 E: 14,996.7	DEPTH W.L.: 3.5
DRILLED DEPTH: 73.0 ft	DATE STARTED: 2/28/2009	GS ELEVATION: 92.19 (Approx.)	ELEVATION W.L.: N/A
AZIMUTH: N/A	DATE COMPLETED: 3/2/2009	TOC ELEVATION: N/A	DATE W.L.: 3/2/09
LOCATION: Crystal River, FL	WEATHER: partly cloudy	TEMPERATURE: 70°	TIME W.L.: N/A

DEPTH (ft)	ELEVATION (ft)	SOIL PROFILE: DESCRIPTION	ELEV. / DEPTH (ft)	SAMPLES: RUN	DRILL TIME (min)	REC / ATT	COMMENTS
	60	22.0 - 40.0 Light tan - very light tan, highly weathered limestone sampled as calcareous, silty SAND; trace-little limestone gravel *(Continued)*					
35	55			4	1	10.0 / 10.0	
40		40.0 - 54.0 Possible VOID	52.2 / 40.0				From 40' - 48' bgs: little resistance - no vibration or rotation necessary No recovery with auger bit - dropped rods down to 48' bgs - ran tape down to 54' bgs - VOID LIKELY from 40 - 54' bgs
	50			5	1	0.0 / 10.0	
45	45						
50	40			6	1	4.0 / 10.0	
		54.0 - 55.0 Tan, weathered, angular LIMESTONE GRAVEL; and dark brown silt, trace calcareous sand	38.2 / 54.0				Driller encountered significant resistance (relative to above) at 54' bgs Interval from 54 - 58' bgs may be compressed to 3' of recovery in sleeve
55		55.0 - 64.0 Very light tan, weathered LIMESTONE; trace shells, little-some coarse sand, little fines	37.2 / 55.0				
	35						
60	30			7	5	6.0 / 10.0	
			28.2				

Log continued on next page

LOG SCALE: 1 in = 4 ft
DRILLING COMPANY: Boart Longyear
DRILLER: Bear

INSPECTOR: J. King
CHECKED BY: J. King/TDA
DATE: 3/31/09

Golder Associates

RECORD OF BOREHOLE G-8

PROJECT: PEF/FGD Blowdown Pond
PROJECT NUMBER: 093-82538
DRILLED DEPTH: 73.0 ft
AZIMUTH: N/A
LOCATION: Crystal River, FL

DRILL METHOD: Sonic
DRILL RIG: Sonic 150
DATE STARTED: 2/28/2009
DATE COMPLETED: 3/2/2009
WEATHER: partly cloudy

DATUM: plant coordinates; ft NAVD 88
COORDS: N: 7,683.5 E: 14,996.7
GS ELEVATION: 92.19 (Approx.)
TOC ELEVATION: N/A
TEMPERATURE: 70°

INCLINATION: -90
DEPTH W.L.: 3.5
ELEVATION W.L.: N/A
DATE W.L.: 3/2/09
TIME W.L.: N/A

DEPTH (ft)	ELEVATION (ft)	SOIL PROFILE: DESCRIPTION	GRAPHIC LOG	ELEV. / DEPTH (ft)	SAMPLES: RUN	DRILL TIME (min)	REC / ATT	COMMENTS
64.0		64.0 - 67.5 Tan, highly weathered limestone sampled as calcareous SILT; trace-little fine sand		64.0 24.7	7	5	6.0/10.0	
67.5	25	67.5 - 67.7 Cemented LIMESTONE						
67.7		67.7 - 68.0 Tan, highly weathered limestone sampled as calcareous SILT; little sand, little limestone gravel						
68.0		68.0 - 73.0 Light brown, weathered LIMESTONE; little silt		68.0 19.2	8	1	4.0/5.0	Drilling soft from 71 - 73' bgs Drilling of G-8 complete at 10:05 (73' bgs) - flushed hole with 300 gallons water Pumped 160 gallons grout (9 bags Amerimix Portland Cement Type 1/11) at 11:15
73.0		Boring completed at 73.0 ft						Installed 60' of 4-inch PVC casing at 8:35 on 3/3/09 VIDEO NOTES (3/02/09 -10:44): at 25.5' bgs, limestone darker and 3 - 6 inch void to 26' bgs, then softer limestone material - at 34' bgs, significant sidewall collapse, very soft weathered limestone - at 40.75' bgs, void ceiling - at 55' bgs, into brown colored suspended silt area, then floor collapse at 56' bgs

Depth scale: 65, 70, 75, 80, 85, 90, 95. Elevation scale: 25, 20, 15, 10, 5, 0.

LOG SCALE: 1 in = 4 ft
DRILLING COMPANY: Boart Longyear
DRILLER: Bear

INSPECTOR: J. King
CHECKED BY: J. King/TDA
DATE: 3/31/09

Golder Associates

RECORD OF BOREHOLE G-8A

PROJECT: PEF/FGD Blowdown Pond
PROJECT NUMBER: 093-82538
DRILLED DEPTH: 33.0 ft
AZIMUTH: N/A
LOCATION: Crystal River, FL

DRILL METHOD: Sonic
DRILL RIG: Sonic 150
DATE STARTED: 3/3/2009
DATE COMPLETED: 3/3/2009
WEATHER: clear

DATUM: plant coordinates; ft NAVD 88
COORDS: N: 7,700.9 E: 14,996.0
GS ELEVATION: 92.49 (Approx.)
TOC ELEVATION: N/A
TEMPERATURE: 38°

INCLINATION: -90
DEPTH W.L.: 3.5
ELEVATION W.L.: N/A
DATE W.L.: 3/3/09
TIME W.L.: N/A

DESCRIPTION (SOIL PROFILE)	ELEV. / DEPTH (ft)	RUN	DRILL TIME (min)	REC / ATT	COMMENTS
0.0 - 2.5 Brown, fine SAND; trace-little fines, trace limestone gravel (FILL)	90.0 / 2.5				
2.5 - 8.0 Light tan, weathered LIMESTONE GRAVEL; and coarse sand, little fines	84.5 / 8.0	1	4	8.0 / 8.0	Installed 6-inch steel casing to 7.5' bgs
8.0 - 9.0 Very light tan, competent LIMESTONE; little sandy silt	83.5 / 9.0				
9.0 - 10.0 Very light tan, weathered LIMESTONE GRAVEL; and calcareous, coarse sand, little fines	82.5 / 10.0				
10.0 - 14.0 Very light tan LIMESTONE; little sandy silt	78.5 / 14.0	2	8	10.0 / 10.0	
14.0 - 18.0 Very light tan to light yellow, weathered LIMESTONE GRAVEL; and silty, coarse sand	74.5 / 18.0				
18.0 - 20.0 Very light tan, competent LIMESTONE; little sandy silt	72.5 / 20.0				
20.0 - 26.0 Light tan, weathered LIMESTONE; some fine sand, little fines	66.5 / 26.0	3	3	10.0 / 10.0	
26.0 - 28.0 Tan to yellow-orange, highly weathered limestone sampled as calcareous, fine SAND; little fines, trace limestone gravel	64.5 / 28.0				
28.0 - 29.5 Green-brown, highly weathered limestone sampled as calcareous, coarse SAND; little fines	63.0 / 29.5				
29.5 - 33.0 Very light tan (with brownish-green stains from 29.5-30.5' bgs), weathered LIMESTONE; little-some fines		4	<1	5.0 / 5.0	

Log continued on next page

LOG SCALE: 1 in = 4 ft
DRILLING COMPANY: Boart Longyear
DRILLER: Bear

INSPECTOR: J. King
CHECKED BY: J. King/TDA
DATE: 3/31/09

Golder Associates

RECORD OF BOREHOLE G-8A

PROJECT: PEF/FGD Blowdown Pond
PROJECT NUMBER: 093-82538
DRILLED DEPTH: 33.0 ft
AZIMUTH: N/A
LOCATION: Crystal River, FL

DRILL METHOD: Sonic
DRILL RIG: Sonic 150
DATE STARTED: 3/3/2009
DATE COMPLETED: 3/3/2009
WEATHER: clear

DATUM: plant coordinates; ft NAVD 88
COORDS: N: 7,700.9 E: 14,996.0
GS ELEVATION: 92.49 (Approx.)
TOC ELEVATION: N/A
TEMPERATURE: 38°

INCLINATION: -90
DEPTH W.L.: 3.5
ELEVATION W.L.: N/A
DATE W.L.: 3/3/09
TIME W.L.: N/A

DEPTH (ft)	ELEVATION (ft)	SOIL PROFILE: DESCRIPTION	GRAPHIC LOG	ELEV. / DEPTH (ft)	SAMPLES: RUN	DRILL TIME (min)	REC / ATT	COMMENTS
	60			59.5	4	<1	5.0 / 5.0	Drilling of G-8A complete at 10:06 (33' bgs) - flushed hole with 160 gallons water Pumped 100 gallons grout (6 bags Amerimix Portland Cement Type 1/11) at 10:45 - installed 30' of 4-inch PVC casing
		Boring completed at 33.0 ft						
35	55							VIDEO NOTES (3/03/03 - 10:35) - limestone color change to yellow at 26' bgs - 2 - 3 inch void at 27' bgs - camera refusal at 28.6' bgs, dark from extensive sidewall collapse beyond or another small void
40	50							
45	45							
50	40							
55	35							
60	30							

LOG SCALE: 1 in = 4 ft
DRILLING COMPANY: Boart Longyear
DRILLER: Bear

INSPECTOR: J. King
CHECKED BY: J. King/TDA
DATE: 3/31/09

Golder Associates

RECORD OF BOREHOLE G-9

PROJECT: PEF/FGD Blowdown Pond
PROJECT NUMBER: 093-82538
DRILLED DEPTH: 73.0 ft
AZIMUTH: N/A
LOCATION: Crystal River, FL

DRILL METHOD: Sonic
DRILL RIG: Sonic 150
DATE STARTED: 3/4/2009
DATE COMPLETED: 3/5/2009
WEATHER: clear

DATUM: plant coordinates; ft NAVD 88
COORDS: N: 7,687.7 E: 14,473.7
GS ELEVATION: 90.79 (Approx.)
TOC ELEVATION: N/A
TEMPERATURE: 50°

INCLINATION: -90
DEPTH W.L.: 3.5
ELEVATION W.L.: N/A
DATE W.L.: 3/5/09
TIME W.L.: N/A

DEPTH (ft)	SOIL PROFILE – DESCRIPTION	ELEV. / DEPTH (ft)	RUN	DRILL TIME (min)	REC / ATT	COMMENTS
0	0.0 - 5.0 Brown, fine SAND; trace-little fines, trace limestone (FILL)	85.8 / 5.0	1	<1	8.0 / 8.0	
5	5.0 - 5.5 Dark brown, fine SAND; little-some fines	85.3 / 5.5				
	5.5 - 7.5 Light gray, weathered LIMESTONE; some calcareous sand, trace-little fines	83.3 / 7.5				
	7.5 - 9.0 Light gray to green-brown, highly weathered limestone sampled as calcareous, fine SAND; little-some fines, little limestone gravel	81.8 / 9.0	2	1	10.0 / 10.0	
	9.0 - 10.5 Green-brown to tan, weathered LIMESTONE; little fine sand, little-some fines	80.3 / 10.5				
10	10.5 - 27.0 Light gray to very light tan, weathered LIMESTONE; little-some fine sand, little silt	63.8 / 27.0	3	<1	9.0 / 10.0	Completed drilling for the day on 3/04/09 at 17:40 Resumed drilling at 08:18 on 3/05/09
	27.0 - 28.0 Tan, weathered LIMESTONE; trace fine sand, trace limestone gravel, trace coarse sand	62.8 / 28.0				
	28.0 - 30.5 Light grayish tan, weathered LIMESTONE GRAVEL; trace coarse sand, trace fine sand, trace fines	60.3 / 30.5	4	<1	9.0 / 10.0	
30	30.5 - 34.0 Light grayish tan LIMESTONE GRAVEL; little coarse sand, little-some fine sand, little fines					

Log continued on next page

LOG SCALE: 1 in = 4 ft
DRILLING COMPANY: Boart Longyear
DRILLER: Bear

INSPECTOR: J. King
CHECKED BY: J. King/TDA
DATE: 3/31/09

Golder Associates

RECORD OF BOREHOLE G-9

PROJECT: PEF/FGD Blowdown Pond	DRILL METHOD: Sonic	DATUM: plant coordinates; ft NAVD 88	INCLINATION: -90
PROJECT NUMBER: 093-82538	DRILL RIG: Sonic 150	COORDS: N: 7,687.7 E: 14,473.7	DEPTH W.L.: 3.5
DRILLED DEPTH: 73.0 ft	DATE STARTED: 3/4/2009	GS ELEVATION: 90.79 (Approx.)	ELEVATION W.L.: N/A
AZIMUTH: N/A	DATE COMPLETED: 3/5/2009	TOC ELEVATION: N/A	DATE W.L.: 3/5/09
LOCATION: Crystal River, FL	WEATHER: clear	TEMPERATURE: 50°	TIME W.L.: N/A

DESCRIPTION (SOIL PROFILE)	ELEV. / DEPTH (ft)	RUN	DRILL TIME (min)	REC / ATT	COMMENTS
30.5 - 34.0 Light grayish tan LIMESTONE GRAVEL; little coarse sand, little-some fine sand, little fines *(Continued)*	56.8				
34.0 - 38.5 Very light tan, fractured LIMESTONE; little silty sand	34.0 52.3	4	<1	9.0 / 10.0	
38.5 - 41.0 Tan to light tan, LIMESTONE GRAVEL; little calcareous, fine-coarse sand, trace fines	38.5 49.8				
41.0 - 45.0 Tan to very light tan, competent LIMESTONE; trace fines, trace sand	41.0 45.8	5	3	10.0 / 10.0	Very soft drilling from 44 - 52' bgs, resistance at 52' bgs, then soft again
45.0 - 47.0 Very light tan LIMESTONE; little fines, trace-little gravel, trace-little sand	45.0 43.8				
47.0 - 48.5 Light brown LIMESTONE; trace limestone gravel, trace-little calcareous, silty sand	47.0 42.3				
48.5 - 62.0 Light tan to light brown weathered LIMESTONE GRAVEL; little-some poorly sorted sand with shells, trace-little fines	48.5 28.8	6	<1	9.0 / 10.0	
62.0 - 62.5 LIMESTONE GRAVEL; and very dark brown silt, trace sand	28.3	7	PUSH	10.0 / 10.0	
62.5 - 69.0 Light tan to light gray LIMESTONE GRAVEL; little fines, little calcareous, fine sand (1in seam of very dark brown silt, trace-little shells at 66' bgs)	62.5				

DEPTH (ft): 35, 40, 45, 50, 55, 60
ELEVATION (ft): 55, 50, 45, 40, 35, 30

Log continued on next page

LOG SCALE: 1 in = 4 ft
DRILLING COMPANY: Boart Longyear
DRILLER: Bear

INSPECTOR: J. King
CHECKED BY: J. King/TDA
DATE: 3/31/09

Golder Associates

RECORD OF BOREHOLE G-9

PROJECT: PEF/FGD Blowdown Pond
PROJECT NUMBER: 093-82538
DRILLED DEPTH: 73.0 ft
AZIMUTH: N/A
LOCATION: Crystal River, FL

DRILL METHOD: Sonic
DRILL RIG: Sonic 150
DATE STARTED: 3/4/2009
DATE COMPLETED: 3/5/2009
WEATHER: clear

DATUM: plant coordinates; ft NAVD 88
COORDS: N: 7,687.7 E: 14,473.7
GS ELEVATION: 90.79 (Approx.)
TOC ELEVATION: N/A
TEMPERATURE: 50°

INCLINATION: -90
DEPTH W.L.: 3.5
ELEVATION W.L.: N/A
DATE W.L.: 3/5/09
TIME W.L.: N/A

DEPTH (ft)	ELEVATION (ft)	SOIL PROFILE: DESCRIPTION	GRAPHIC LOG	ELEV. / DEPTH (ft)	SAMPLES: RUN	DRILL TIME (min)	REC / ATT	COMMENTS
65	25	62.5 - 69.0 Light tan to light gray LIMESTONE GRAVEL; little fines, little calcareous, fine sand (1in seam of very dark brown silt, trace-little shells at 66' bgs) *(Continued)*		21.8 / 69.0	7	PUSH	10.0 / 10.0	Completed drilling of G-9 at 09:20 at 73' bgs - hole open to 34' bgs after removing rods - drillers attempt to clean out hole but encounter continuing collapse
70	20	69.0 - 71.0 Very dark brown SILT; trace-little fine sand, trace clay		19.8 / 71.0	8	PUSH	5.0 / 5.0	Pumped 160 gallons grout (3 - 55 gallon drums) - 9 total bags of Amerimix Portland Cement type 1/11 used - installed 30' of 4-inch PVC casing
		71.0 - 72.0 Tan LIMESTONE GRAVEL; little-some silty sand and very dark brown silt		18.8 / 72.0				
		72.0 - 73.0 Light gray LIMESTONE GRAVEL; little coarse sand, little-some fines		17.8				
		Boring completed at 73.0 ft						
75	15							VIDEO NOTES (3/05/09 - 10:05) - water turbid after 200 gallon flush; pulled out camera and added 100 gallons - water remained turbid with poor visibility - camera refusal due to sidewall collapse at 28' bgs
80	10							
85	5							
90	0							
95	-5							

LOG SCALE: 1 in = 4 ft
DRILLING COMPANY: Boart Longyear
DRILLER: Bear

INSPECTOR: J. King
CHECKED BY: J. King/TDA
DATE: 3/31/09

Golder Associates

Golder Associates Inc.

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Golder Associates

RE: DRAWINGS
FGD BLOWDOWN POND
CRYSTAL RIVER ENERGY COMPLEX – UNITS 4 AND 5
CRYSTAL RIVER, FLORIDA

The following Drawings for the Crystal River Energy Complex – Units 4 and 5, FGD Blowdown Ponds were prepared by Golder Associates Inc. (Florida Professional Engineering Certificate of Authorization #1670) and under the responsible charge of Kenneth B. Karably (Florida Professional Engineer License #42366):

Drawing No.	Title	Date
1	Cover Sheet – Site Location	06/02/09
2	Reserved for Future Use	---
3	Topographic Map of the Former Ash Pond/FGD Pond Area	06/02/09
4	Subsurface Boring and Remediation Locations	06/02/09
5	Initial Grading Plan and Limits of Reinforcing Geotextile	06/02/09
6	Plan View of Pond Layout	06/02/09
7	Cross Sections	06/02/09
8	Final Grading Plan	06/02/09
8A	Former Ash Pond Limits Relative to FGD Ponds Design	06/02/09
9	Final Grading System Details	06/02/09
10	Liner System Details	06/02/09
11	Inlet Piping Details (Sheet 1 of 2)	06/02/09
12	Inlet Piping Details (Sheet 2 of 2)	06/02/09
13	Outlet Piping Details	06/02/09
14	Process and Instrumentation Diagram	06/02/09
15	Electrical Service Routing and Details	06/02/09

GOLDER ASSOCIATES INC.

Kenneth B. Karably

Kenneth B. Karably
Florida P.E. 42366
6/2/2009

ISSUED FOR PERMIT

ELECTRONIC DRAWING SET

PROVIDED UNDER SEPARATE COVER

Golder Associates Inc.

9428 Baymeadows Road, Suite 400
Jacksonville, FL USA 32256
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Golder Associates

RE: CALCULATIONS
FGD BLOWDOWN POND
CRYSTAL RIVER ENERGY COMPLEX – UNITS 4 AND 5
CRYSTAL RIVER, FLORIDA

The following Calculations for the Crystal River Energy Complex – Units 4 and 5, FGD Blowdown Ponds were prepared by Golder Associates Inc. (Florida Professional Engineering Certificate of Authorization #1670) and under the responsible charge of Kenneth B. Karably (Florida Professional Engineer License #42366):

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GOLDER ASSOCIATES INC.

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6/2/2009

Primary Pond Volumes

Golder Associates	SUBJECT Crystal River FGD Blowdown Pond		
	Job No. 0838952001 Ref. Progress Energy	Made by PEF Checked CAB Reviewed KBK	Date 3-19-09 Sheet 1 of 2

Pond Volumes

Given: Full Pond Storage Vol. = 1,982,600 cf or 45.5 ac-ft

[2-18-09 Calc p2 of 3] 1,982,600 cf × 7.48 gal/cf = 14,830,000 gallons

[ibid] → Maximum Volume Sludge = 1,125,000 cf or 25.83 ac-ft

1,125,000 cf × 7.48 gal/cf = 8,415,000 gallons

Vol. Water above Max Sludge = 14,830,000
− 8,415,000
6,415,000 gal

Pond Detention (Settling) Time

Full Pond (no sludge) @ 300 gpm –

14,830,000 gal ÷ 300 gpm = 49,433 min
or 824 hours
or 34.3 days

Pond above full sludge layer @ 300 gpm

6,415,000 gal ÷ 300 gpm = 21,383 min
or 356 hours
or 14.85 days

~~Pond above full sludge layer @ 885 gpm (300 gpm + 585 gpm)~~ 100-yr storm vol. removal

~~[See DB text for 885 gpm derivation]~~

~~6,415,000 gal ÷ 885 gpm = 7248.6 min.~~

See p. 2

~~or 121 hours~~
~~or 5.0 days~~

Golder Associates	SUBJECT Crystal River FGD Blowdown Pond		
	Job No.	Made by PEP	Date 3-19-09
	Ref.	Checked	Sheet 2 of 2
		Reviewed KBK	

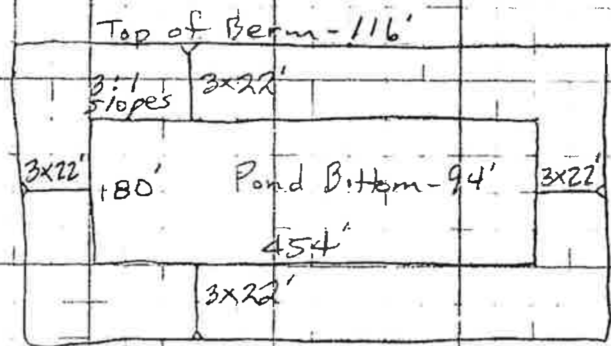
Sludge Volumes

1/2 Pond @ 11' Sludge Depth = 1/2 × 1,125,000 cf =
(from p.1)
562,500 c.f.

Pond Area (top of Berm)

Top Area – from 94 ft up to 116 ft = 22 ft

$$\text{Area} = ((454' + (22' \times 3 \times 2)) \times ((180' + (22' \times 3 \times 2)) = 182,832 \text{ ft}^2$$



Volume of Design Storm

Given: ① 100yr, 24-hr storm = 11" (EPCR Design Basis)

② Bottom Area = 454' × 180' = 81,720 ft²

$$\text{Vol.} = 182,832 \text{ ft}^2 \times \left(\frac{11}{12}\right) \text{ft} \times 7.48 \text{ gal/cf} = 1,253,618 \text{ gal}$$

or 1.25 million gal

Remove vol in 3 days

$$Q = \frac{1,253,618 \text{ gal}}{1440 \text{ min/day} \times 3 \text{ days}} = 290 \text{ gpm}$$

Total Max. Flow (required) = 300 + 290 = 590 gpm

Pond Settling Time (Storm flow - full sludge layer)

(see p.1) 6,415,000 gal ÷ 590 gpm = 10873 min or 181 hrs.

T. 1

FGD Blowdown Sludge Storage

Crystal River - Progress Energy

CASE	SLUDGE ACCUMULATION CONDITIONS	Settled Solids (%)	Influent TSS (mg/l)	Daily Sludge Production (lbs/day)	Annual Sludge Production (lbs/yr)	Dry Solids (lb/cf)	Annual Sludge Volume (cf/yr)	Total Sludge Storage (tons)	Years Capacity
1	All pond area filled 11ft[a]	40	20000	72058	21566840	32.3	667704	18169	1.68
2	All pond area filled 11ft[a]	60	20000	72058	21566840	56.84	379431	31973	2.96
3	1/2 Pond area filled 11 ft, 1/2 filled 5.5 ft[b]	40	6000	21617	6470052	32.3	200311	13169	4.07
4	1/2 Pond area filled 11 ft, 1/2 filled 5.5 ft[b]	60	6000	21617	6470052	56.84	113829	23174	7.16
5	1/2 Pond area filled 11 ft, 1/2 filled 5.5 ft[b]	40[c]		18073	5409173	32.3	167467	9084	
		20[c]		3545	1060879	14.09	75293	1782	
	Total for Case 5		6000	21617	6470052		242760	10866	3.36
6	1/2 Pond area filled 11 ft, 1/2 filled 5.5 ft[b]	60[c]		18340	5489211	56.84	96573	15986	
		30[c]		3277	980841	22.59	43419	2857	
	Total for Case 6		6000	21617	6470052		139992	18843	5.82

Constants		
Sludge Vol at 11 ft for entire pond area	1,125,000	cubic feet
Sludge Vol at 11 ft for half of pond	562,500	cubic feet
Sludge Vol at 5.5 ft for half of pond	252,900	cubic feet
Flow	300	gpm
Assumed Capacity Factor[d]	0.82	

[a/] Top 6.24 ft of pond depth left as open water column for settling surge and precipitation.

[b/] Southern part of pond nearer outlet will only fill to 1/2 depth of northern part before solids building up in northern part around inlet nozzles start to restrict influent distribution. 11 and 5.5 ft are average depths for north and south zones.

[c/] Same as Cases 3 and 4, except that settled solids content for the southern half half of the pond is only one-half the value for the northern.

[d/] Source: EPCR Design Basis Attachment 3, FGD Settling Pond Design, p. 2 of 2.

Golder Associates

Golder Associates	SUBJECT Alternative Pond 2 Sizing-Shallow		
	Job No. 09382538	Made by PEP	Date 5-7-09
	Ref. Progress Energy	Checked CAB Reviewed KBK	Sheet 1 of 2

Assume: Pond 2 to East of Pond 1 and sharing a N-S Berm; Ramp up to berm crest @ 116'

General will be displaced to N on outer slope of Pond 2 N Berm, which aligns with ℄ of Pond 1 N. Berm.

Specific 1. Elevations –

Berm Crest 116'

Spillway(E) 112'

O/F Invert 111.24'

2. Pond must achieve 6 months storage of solids under Table 2 cases 3, 4, 6, 7 & 8

3. Water column must be 6.24' minimum (105' Elev.)

4. There will be a maximum of 2 inlet points, fed from the inlet piping on the E Berm Pond 1 (ideally 1)

1st. Try – Bottom Elev. – 100' (vs. 94' for Pond 1)

Pond Area – 100' × 180' Bottom = 18,000 sf

Vol. @ 5' – Area = $[100+6(5)] \times [180+6(5)] = 27{,}300$ s.f

Vol. = $\frac{(18000+27{,}300)}{2} \times 5' = 113{,}250$ c.f.

– corners = 112,300 c.f.

Vol. @ 2.5' (1/2 of Pond) –

Area = $[100+6(2.5)] \times [180+6(2.5)] = 22{,}425$ s.f

Vol = $\frac{1}{2}\frac{(18000+22{,}425)}{2} \times 2.5 = 25{,}266$ c.f

– corners = 25,000 c.f.

Lowest = 0.41 yrs. (Case 3)

Golder Associates	SUBJECT Alternative Pond 2 Sizing - Shallow		
	Job No. 0938 2538	Made by PEB	Date 5-7-09
	Ref. Progress Energy	Checked CAB	Sheet 2 of 2
		Reviewed KBK	

2nd Try - $\boxed{100 \times 200}$ Area Bottom = 20,000 s.f.

@ 5' Area = $[100+6(5)] \times [200+6(5)] =$ 29,900 s.f.

Vol = $\left(\frac{20,000 + 29,900}{2}\right)5 =$ 124,750 c.f.

- corners = 123,500 c.f.

@ 2.5' Area = $[100+6(2.5)] \times [200+6(2.5)] =$ 24,725 s.f

½ Vol. = $\frac{1}{2}\left(\frac{20,000+24,725}{2}\right) \times 2.5' =$ 27,953 c.f.

- corners = 27,650 c.f.

Lowest = 0.45 yrs (Case 3)

3rd Try - 100 × 225 Bottom Area = 22,500 s.f.

@ 5' Area = $[100+6(5)] \times [225+6(5)] =$ 33,150 s.f.

Vol = $\left(\frac{22,500+33,150}{2}\right) \times 5 =$ 139,125 c.f.

- corners = 137,750 c.f.

@ 2.5' Area = $[100+6(2.5)] \times [225+6(2.5)] =$ 27,600 s.f.

½ Vol. = $\frac{1}{2}\left(\frac{22,500+27,600}{2}\right) \times 2.5 =$ 31,312.5 c.f.

- corners = 30,980 c.f.

Lowest = 0.50 yrs (Case 3) - OK

Table 2
FGD Blowdown Sludge Storage, Backup Pond 2
225x100 Feet
Progress Energy, Crystal River Plant

CASE	SLUDGE ACCUMULATION CONDITIONS	Settled Solids (%)	Influent TSS (mg/l)	Daily Sludge Production (lbs/day)	Annual Sludge Production (lbs/yr)	Dry Solids (lb/cf)	Annual Sludge Volume (cf/yr)	Total Sludge Storage (tons)	Years Capacity
1	All pond area filled 5ft[a/]	40	20000	72058	21566840	32.3	667704	2225	0.21
2	All pond area filled 5ft[a/]	60	20000	72058	21566840	56.84	379431	3915	0.36
3	1/2 Pond area filled 5 ft, 1/2 filled 2.5 ft[b/]	40	6000	21617	6470052	32.3	200311	1613	0.50
4	1/2 Pond area filled 5 ft, 1/2 filled 2.5 ft[b/]	60	6000	21617	6470052	56.84	113829	2838	0.88
5	1/2 Pond area filled 5 ft, 1/2 filled 2.5 ft[b/]	40[c/]		18071	5408778	32.3	167454	1112	
		20[c/]		3546	1061274	14.09	75321	218	
	Total for Case 5		6000	21617	6470052		242775	1331	0.41
6	1/2 Pond area filled 5 ft, 1/2 filled 2.5 ft[b/]	60[c/]		18339	5488841	56.84	96567	1957	
		30[c/]		3278	981211	22.59	43436	350	
	Total for Case 6		6000	21617	6470052		140002	2307	0.71
7	All pond area filled 5ft[a/]	40	6000	21617	6470052	32.3	200311	2225	0.69
8	All pond area filled 5ft[a/]	60	6000	21617	6470052	56.84	113829	3915	1.21

Constants		
Sludge Vol at 5 ft for entire pond area	137,750	cubic feet
Sludge Vol at 5 ft for half of pond	68,875	cubic feet
Sludge Vol at 2.5 ft for half of pond	30,980	cubic feet
Flow	300	gpm
Assumed Capacity Factor[d/]	0.82	

These quantities are for a pond with bottom dimensions of 225 ft N-S x 100 ft E-W

[a/] Top 6.24 ft of pond depth left as open water column for settling, surge and precipitation.

[b/] Southern part of pond nearer outlet will only fill to 1/2 depth of northern part before solids building up in northern part around inlet nozzles start to restrict influent distribution. 5 and 2.5 ft are average depths for north and south zones.

[c/] Same as Cases 3 and 4, except that settled solids content for the southern half of the pond is only one-half the value for the northern.

[d/] Source: EPCR Design Basis Attachment 3, FGD Settling Pond Design, p. 2 of 2.

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T 2
FGD Blowdown Sludg. .orage, Backup Pond 2
225x100 Feet
Progress Energy, Crystal River Plant

CASE	SLUDGE ACCUMULATION CONDITIONS	Settled Solids (%)	Influent TSS (mg/l)	Daily Sludge Production (lbs/day)	Annual Sludge Production (lbs/yr)	Dry Solids (lb/cf)	Annual Sludge Volume (cf/yr)	Total Sludge Storage (tons)	Years Capacity
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2	All pond area filled 5ft[a/]	60	20000	72058	21566840	56.84	379431	3915	0.36
3	1/2 Pond area filled 5 ft, 1/2 filled 2.5 ft[b/]	40	6000	21617	6470052	32.3	200311	1613	0.50
4	1/2 Pond area filled 5 ft, 1/2 filled 2.5 ft[b/]	60	6000	21617	6470052	56.84	113829	2838	0.88
5	1/2 Pond area filled 5 ft, 1/2 filled 2.5 ft[b/]	40[c/]		18071	5408778	32.3	167454	1112	
		20[c/]		3546	1061274	14.09	75321	218	
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Flow	300	gpm
Assumed Capacity Factor[d/]	0.82	

These quantities are for a pond with bottom dimensions of 225 ft N-S x 100 ft E-W

[a/] Top 6.24 ft of pond depth left as open water column for settling, surge and precipitation.

[b/] Southern part of pond nearer outlet will only fill to 1/2 depth of northern part before solids building up in northern part around inlet nozzles start to restrict influent distribution. 5 and 2.5 ft are average depths for north and south zones.

[c/] Same as Cases 3 and 4, except that settled solids content for the southern half of the pond is only one-half the value for the northern.

[d/] Source: EPCR Design Basis Attachment 3, FGD Settling Pond Design, p. 2 of 2.

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SUBJECT Progress Energy – Windspeed Calculations – WAVE HEIGH

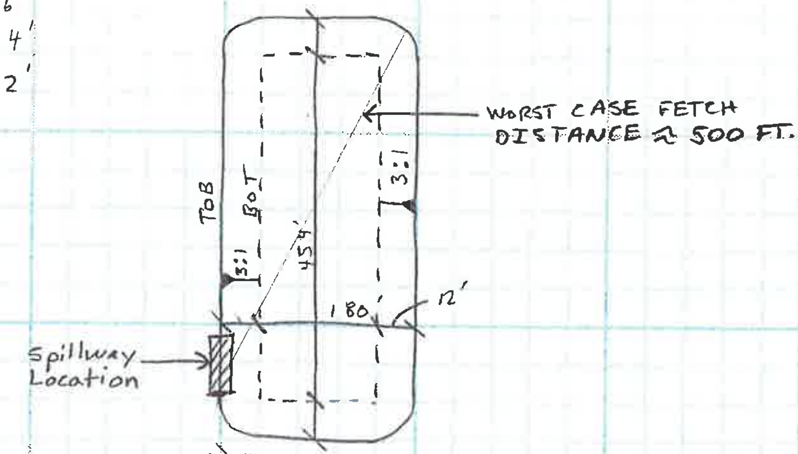
Job No. 093-82538.0002	Made by BTH	Date 4/6/09
Ref.	Checked SFS	Sheet 1 of 3
	Reviewed KBK	

KNOWN PARAMETERS:

POND TOB ELEV. = 116'

POND BOT ELEV. = 94'

SPILLWAY ELEV. = 112'



WIND SPEED (3-SECOND METHOD):

50-YR, 3-SECOND GUST (OVER LAND) = 110 MPH (FL. BUILDING CODE)

50-YR RETURN PERIOD TO 100-YR RETURN PERIOD CONVERSION FACTOR = 1.07 (USACOE, 2003)

∴ 100-YR, 3-SECOND GUST = 110 MPH * 1.07 = 117.7 MPH

CONVERT FROM 3-SECOND GUST TO 1-HOUR AVERAGE:

$$\frac{U_t}{U_{3600}} = 1.277 + 0.296 \tanh\left(0.9 * \log_{10}\left(\frac{45}{t}\right)\right)$$

U_{3600} = 1-HOUR WIND SPEED

U_t = WIND SPEED OF LESS THAN 1-HOUR = 117.7 MPH

t = DURATION OF LESS THAN 1-HOUR = 0.0008 HRS.

∴ 100-YR, 1-HOUR AVERAGE WIND SPEED (OVER LAND) = 74.83 MPH

OVER-LAND TO OVER-WATER ADJUSTMENT FACTOR = 1.2 (USACOE, 2005)

∴ 100-YR, 1-HOUR AVG. WIND SPEED (OVER-WATER) = 89.90 MPH

WAVE HEIGHT:

MOLITOR FORMULA FOR INLAND LAKES:

$$H = 0.17\sqrt{U \cdot F} + 2.5 - \sqrt[4]{F} \qquad \text{(TM-5-850-1)}$$

H = MAX. WAVE HEIGHT (FT.)
U = MAX. WIND VELOCITY (MPH) = 89.80 MPH
FETCH DISTANCE = 500 FT
FETCH DISTANCE (NMILE) = 0.082 NMILE

∴ 100-YR MAX WAVE HEIGHT = 2.42 FT.

MAX. WAVE RUN-UP HEIGHT FOR RIP-RAP:

$$\frac{R_{MAX}}{H_{MO}} = \frac{a \cdot \mathcal{E}}{1 + b \cdot \mathcal{E}} \qquad \text{(EM 1110-2-1614)}$$

R_{MAX} = MAX VERTICAL HEIGHT OF RUN-UP
H_{MO} = ENERGY BASED HEIGHT OF ZEROTH MOMENT
a = REGRESSION COEFFICIENT = 1.022
b = REGRESSION COEFFICIENT = 0.247
$\mathcal{E}$ = SURF PARAMETER

$$\mathcal{E} = \frac{\tan \theta}{\left[\dfrac{2\pi H_{MO}}{g \cdot T_p^2}\right]^{1/2}}$$

θ = ANGLE OF REVETMENT SLOPE (3H:1V) = 18.435 DEG
θ = 0.322 RADIANS
g = 32.2 FT/S²
T_p = PERIOD OF PEAK ENERGY DENSITY SPECTRUM

DETERMINE T_p FROM PIERSON-MOSKOWITZ (EM 1110-2-1614):

$$\frac{T_s}{T_p} = 0.88$$

T_s = SIGNIFICANT WAVE PERIOD = 2.1 SEC.
T_p = 2.38 SEC

Golder Associates	SUBJECT Progress Energy - Windspeed Calculations		
	Job No. 093-82538.0002 Ref.	Made by BTH Checked SFS Reviewed KBK	Date 4/6/09 Sheet 3 of 3

DETERMINE H_{MO} FROM EQUATION:

$$\frac{H_S}{H_{MO}} = \exp\left[C_0\left(\frac{d}{g \cdot T_P^2}\right)^{-C_1}\right]$$

H_S = SIG. WAVE HEIGHT = 2.42 FT.
C_0 = REG. COEFFICIENT = 0.00089
C_1 = REG. COEFFICIENT = 0.834
d = DEPTH AT POINT IN QUESTION = 4.0 FT

$\therefore H_{MO}$ = 2.37 FT.

$\therefore \mathcal{E}$ = 1.76 FT.

R_{MAX} = RIP-RAP MAX. WAVE RUN HEIGHT = 2.20 FT

SMOOTH-SLOPE WAVE RUN-UP HEIGHT = R_{MAX} / QUARRYSTONE CORRECTION FACTOR 3:1 SLOPE
(EM 1110-2-1614)

3:1 SLOPE, QUARRYSTONE CORRECTION FACTOR = 0.615

$\therefore$ SMOOTH-SLOPE MAX WAVE RUN-UP HEIGHT = 3.58 FT.

80% SMOOTH SLOPE RUN-UP HEIGHT = 2.86 FT.

95% SMOOTH SLOPE RUN-UP HEIGHT = 3.40 FT.

EROSION CONTROL DESIGN ALTERNATIVES

Wind Speed

50-year, 3-second gust wind speed (over-land) =	110 mph	(FL. Builing Code) -Attachment 1

Convert to 100-yr, 1-hour average wind speed

Convert from 50-year return period to 100-year return period

Conversion Factor =	1.07	(USASCE, 2003) - Attachment 2
100-year, 3-second gust wind speed (over-land) =	117.7 mph	

Convert from 3-second gust to 1-hour average

$$\frac{U_t}{U_{3600}} = 1.277 + 0.296 \tanh\left(0.9 \cdot \log_{10}\left(\frac{45}{t}\right)\right)$$

(USASCE, 2006) - Attachment 3

Where

U_{3600} = 1-hour wind speed

U_t = wind speed of less than 1-hour =	117.7 mph
t = duration of less than 1 hour =	0.0008 hours

100-year, 1-hour average wind speed (over-land)=	74.83 mph

Adjustment from over-land to over-water wind speed

Conversion Factor =	1.2	(USACE, 2005)
100-year, 1-hour average wind speed (over-water) =	**89.80 mph**	

Wave Height

Molitor Formula for Inland Lakes: (TM-5-850-1)

$$H = 0.17\sqrt{U \cdot F} + 2.5 - \sqrt[4]{F}$$

H = Maximum Wave Height (feet)		
U = Maximum Wind Velocity (mph) =	89.80 mph	
Fetch Distance =	500 feet	Attachment 4
F = Fetch Distance (nmile) =	0.082 nmile	
100-year Maximum Wave Height =	**2.43 feet**	

EROSION CONTROL DESIGN ALTERNATIVES

Wave Run-Up Height

Maximum Wave Run-Up Height for Rip-Rap:

$$\frac{R_{MAX}}{H_{mo}} = \frac{a \cdot \xi}{1 + b \cdot \xi}$$ (EM 1110-2-1614)

Where:

R_{MAX} = maximum vertical height of run-up
H_{mo} = energy based height of zeroth moment
a = regression coefficient = 1.022
b = regression coefficient = 0.247
ξ = surf parameter:

$$\xi = \frac{\tan \theta}{\left(\frac{2\pi H_{mo}}{g \cdot T_p^2}\right)^{1/2}}$$

θ = angle of revetment slope (3H:1V) =	18.435	degrees
θ =	0.322	radians
g = acceleration due to gravity =	32.2	ft/s^2
T_p = period of peak engergy density spectrum		

Determine T_p via relationship between significant wave period and peak energy density of the spectrum from Pierson-Moskowitz (EM 1110-2-1614):

$$\frac{T_s}{T_p} = 0.88$$ (EM 1110-2-1614) - Attachment 5

T_s = significant wave period =	2.1	sec	(TM 5-850-1) - Attachment 6
T_p =	2.39	sec	

Determine H_{mo} from following equation (EM 1110-2-1614):

$$\frac{H_s}{H_{mo}} = \exp\left[C_0\left(\frac{d}{g \cdot T_p^2}\right)^{-C_1}\right]$$

H_s = significant wave height =	2.43	feet
C_0 = regression coefficent =	0.00089	
C_1 = regression coefficent =	0.834	
d = depth at point in question =	4	feet
H_{mo} =	2.37	feet
Therefore, ξ = Surf Parameter =	1.17	

R_{MAX} = Rip-rap Maximum Wave Run-Up Height = 2.20 feet

Determine smooth-slope wave run-up height (soil cement) by dividing RMAX by the quarrystone rough slope correction factor, see Attachment 7 (EM 1110-2-1614)

3:1 Slope, Quarrystone Correction Factor = 0.615
Smooth-slope Maximum Wave Run-Up Height = 3.58 feet

Determine soil cement wave run-up height based on 80% of smooth-slope wave run-up height (EM 1110-2-1614)
Soil Cement Maximum Wave Run-Up Height = 2.86 feet

Determine fabriform wave run-up height based on 95% of smooth-slope wave run-up height (EM 1110-2-1614)
Fabriform Maximum Wave Run-Up Height = 3.40 feet

are assumed to be measured at an elevation of 33 ft and may be determined through linear interpolation of the isovels as necessary.

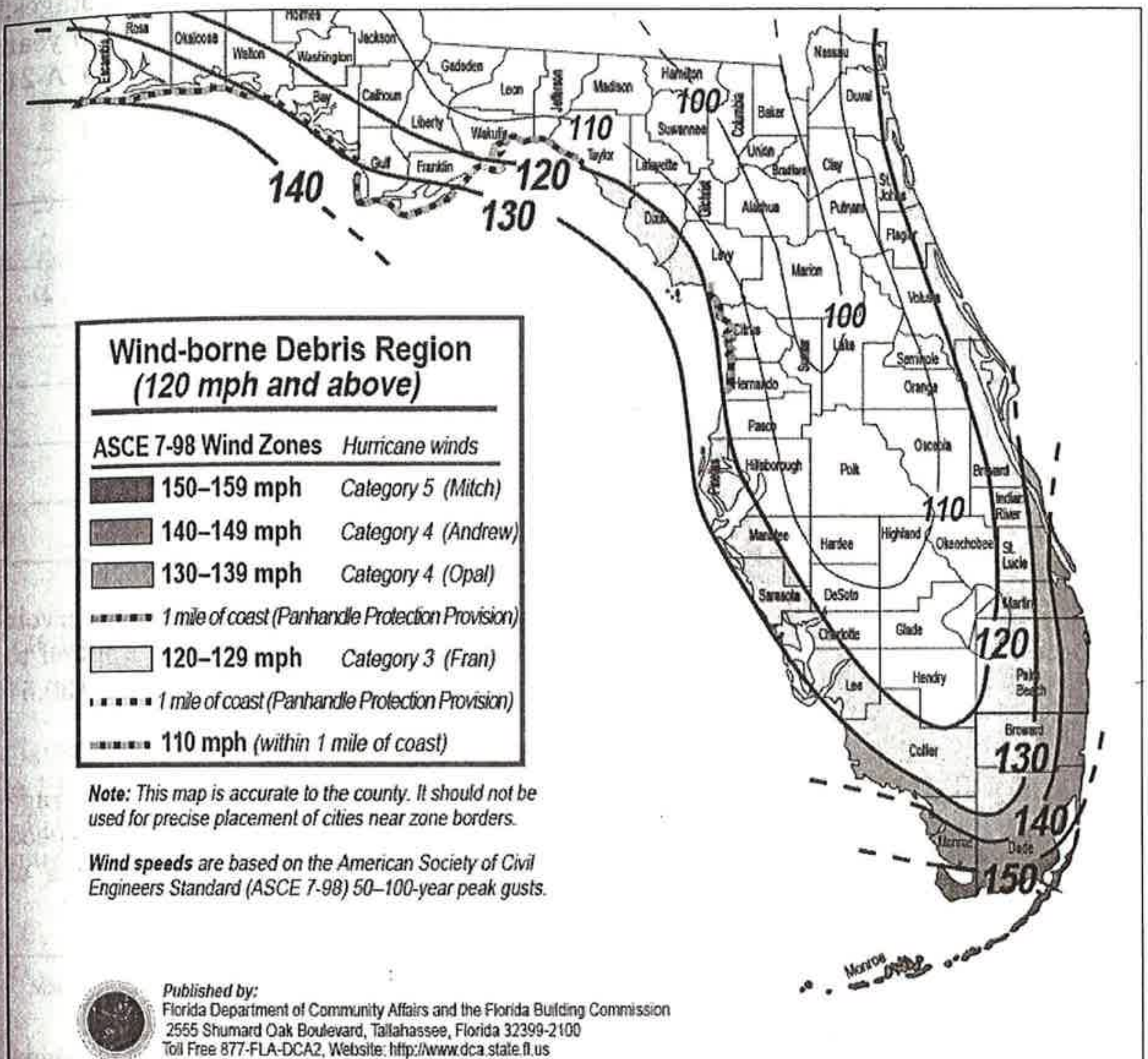


FIGURE A-17: 50 YEAR, 3-SECOND GUST WIND SPEED ISOVELS

The 3-second gusts provided by the Florida Building Code are used primarily in the evaluation of the structural stability of buildings and are not directly applicable to earthen embankments or wind-wave analyses. However, these conditions can be adjusted to wind speeds that are appropriate for such investigations. Three steps are required to convert a 3-second gust wind speed to an appropriate 100 year design wind speed: (1) conversion of the 50 year, 3-second gust to a 100 year, 1-hour average wind speed (2) adjustment from an over-land wind speed to an over-water wind speed, and (3) adjustment of over-water wind speed to fetch-limited wind speed.

Conversion of 50 year, 3-second gust to 100 year, 1-hour average wind speed

Conversion of the 50 year, 3 second gust wind speed takes place in two stages. The first stage is to convert the gust wind speed from a 50 year to a 100 year return period. This is done using conversion factors located in Table A-21 (ASCE, 2003).

TABLE A-21: RETURN PERIOD CONVERSION FACTORS

Return Period (years)	Conversion Factor
500	1.23
200	1.14
100	1.07
50	1.00
25	0.88

From Figure A-17, the 50 year, 3-second gust corresponding to the EAA reservoir location is 122 mph. Using Table A-21, a conversion factor of 1.07 is applied to this wind speed, resulting in a 100 year, 3-second gust wind speed of 130.54 mph.

The second stage is to convert the 3-second gust wind speed to a 1-hour average wind speed. Figure A-18 provides a means of converting extremal wind speed estimates from one averaging interval to another, using ratios of winds of various durations to 1-hour average wind speeds.

Attachment 2

Attachment 3

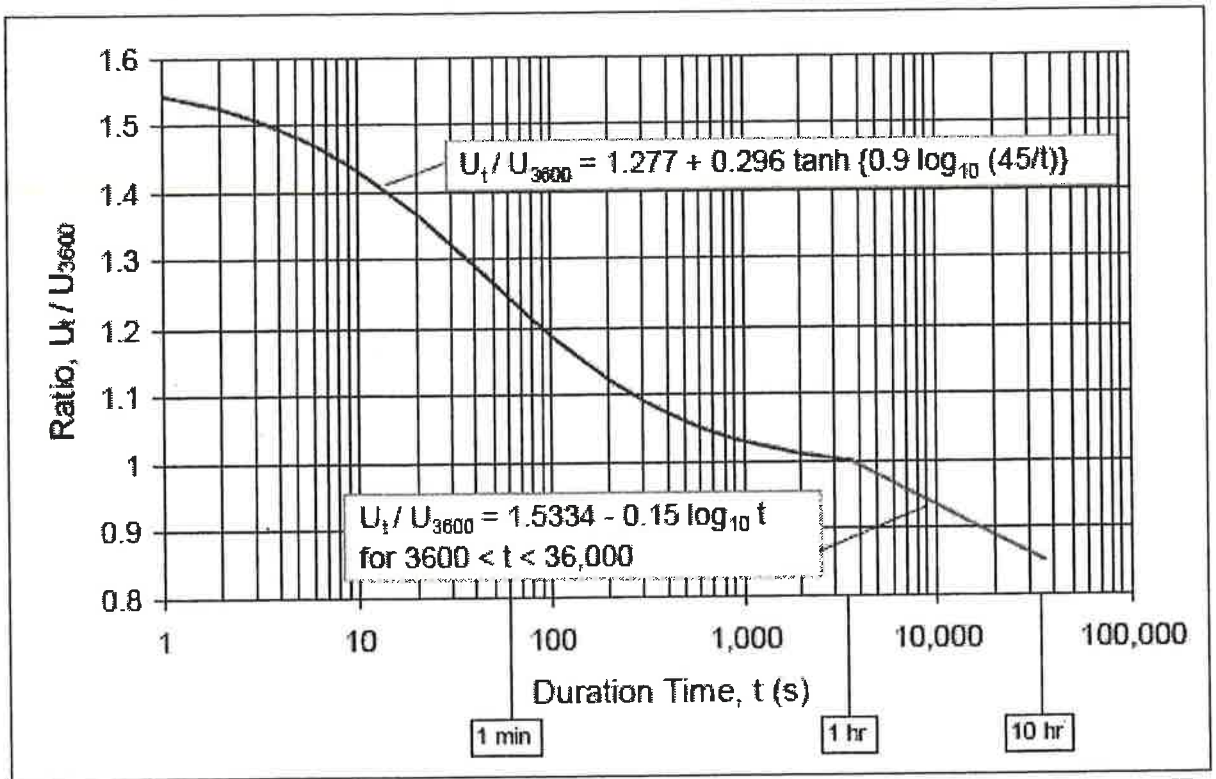


FIGURE A-18: RATIO OF WIND SPEED OF AND DURATION TO 1-HOUR WIND SPEED

Figure A-18 includes defining equations for wind durations of less than or equal to 1 hour (Ut < 3,600 seconds) and durations between 1 and 10 hours (3,600 < Ut <36,000 seconds). In this particular case, the duration (3 seconds) is less than 1 hour, resulting in the application of the following equation:

$$\frac{U_t}{U_{3600}} = 1.277 + 0.296 \tanh\left\{0.9 \log_{10}\left(\frac{45}{t}\right)\right\}$$

where,

Ut	= wind speed of duration less than 1 hour (130.45 mph)
U3600	= 1 hour wind speed
t	= duration less than 1 hour (3 sec)

Solving the above equations for U3600, results in a 100 year, 1 hour wind speed of 86.49 mph.

Adjustment from over-land wind speed to over-water wind speed

The next adjustment required to reach an appropriate design wind speed, is to account for land effects in the measured data. Wind observations over water are

Attachment 4

explosion-generated waves is extremely localized when compared with the several-hundred-mile-wide area affected by a tsunami. The periods of nuclear-explosion-generated waves can roughly be classified as being between that of wind waves and tsunami waves, i.e., they are in the long-period wave region but can have amplitudes considerably greater than those of normal long-period waves found in the open ocean.

d. Design wave calculation.

(1) For preliminary study and/or structures where occasional damage may be permissible. One of the following procedures may be used:

(a) Refer to local records and experiences of longtime residents.

(b) Make observations at the site of such physical features as wash and runup marks and debris.

(c) Use the following empirical relations for open seas and inland lakes.

Open seas (Stevenson formula)

$$H = 1.5\sqrt{F} \text{ for } F > 30 \text{ nautical miles} \quad (5\text{-}4)$$

or

$$H = 1.5\sqrt{F} + 2.5 - \sqrt[4]{F} \text{ for } F < 30 \text{ nautical miles} \quad (5\text{-}5)$$

Inland lakes (Molitor formula)

$$H = 01.17\sqrt{UF} \text{ For } F > 20 \text{ nautical miles} \quad (5\text{-}6)$$

or

$$H = 0.17\sqrt{UF} + 2.5 - \sqrt[4]{F} \text{ for } F < 20 \text{ nautical miles} \quad (5\text{-}7)$$

where

H = wave height, feet

F = fetch, nautical miles

U = maximum wind velocity, miles per hour

(*d*) Where the wind speed is known and an adequate fetch for full development of the waves is assumed, equation (5-8) may be used for waves of low to moderate amplitude. This formula is not applicable to very high waves (more than 25 to 30 feet).

$$H = 0.026U^2 \quad 5\text{-}8)$$

where U represents wind velocity in knots.

(*e*) When the maximum wind velocity, as well as the fetch, is known, a more accurate determination of the design wave is possible using figures 5-2 through 5-13.

(2) *For final design of structures of major importance.* For such design or where the extent of the development warrants more accurate determination of the wave characteristics, follow the procedures given below:

(*a*) Make an analysis of a comprehensive series of aerial photographs of the incident waves generated by severe storms.

(*b*) Hindcast (i.e., calculate from historic, synoptic weather charts) the characteristics of waves resulting from several of the more recurrent deepwater storms. Determine the shallow-water characteristics of these waves by use of refraction and diffraction diagrams. The determination of the characteristics of the incident waves by hindcasting is the most reliable method for determining the design wave. Detailed wave and water level predictions are given in "Shore Protection Manual," Vol. 1. (See app A.)

e. Wave pressure on vertical walls. Wave pressures due to breaking and nonbreaking waves differ widely. The first step in the evaluation of wave forces is to determine if the structure will be subjected to forces from nonbreaking waves, breaking waves, or broken waves. The determination of wave pressure on vertical walls is explained in "Shore Protection Manual," Vol. II. (See app A.)

f. Wave forces and movements on piles. Waves acting on piles exert pressures that are the result of drag and inertial forces. The determination of waves forces and movements on piles can be found in "Shore Protection Manual," Vol. II. (See app A.)

Attachment 5

Table 2-1
lationships among T_p, T_s, and T_z

T_z/T_p	T_s/T_p	Comments	γ
0.67	0.80	Severe surf zone conditions[1]	NA
0.74	0.88	Pierson-Moskowitz spectrum[2]	1.0
0.80	0.93	Typical JONSWAP spectrum[2]	3.3
0.87	0.96	Swell from distant storms[2]	10.0

[1] Developed from data in Ahrens (1987).
[2] Developed from Goda (1987).

and time constraints may prohibit the establishment of a viable gauging program that would provide sufficient digital data for reliable study. Visual observations from shoreline points are convenient and inexpensive, but they have questionable accuracy, are often skewed by the omission of extreme events, and are sometimes difficult to extrapolate to other sites along the coast. A visual wave observation program is described in Schneider (1981). Problems with shipboard observations are similar to shore observations.

2-9. Wave Hindcasts

Designers should use the simple hindcasting methods in CES (Leenknecht et al. 1989) and hindcasts developed by the U.S. Army Engineer Waterways Experiment Station (WES) (Resio and Vincent 1976-1978; Corson et al. 1981) for U.S. coastal waters using numerical models. These later results are presented in a series of tables for each of the U.S. coasts. They give wave heights and periods as a function of season, direction of wave approach, and return period; wave height as a function of return period and seasons combined; and wave period as a function of wave height and approach angle. Several other models exist for either shallow or deep water. Specific applications depend on available wind data as well as bathymetry and topography. Engineers should stay abreast of developments and choose the best method for a given analysis. Contact the Coastal Engineering Research Center (CERC) at WES for guidance in special cases.

2-10. Wave Forecasts

Wave forecasts can be performed using the same methodologies as those for the wave hindcasts. Normally, the Corps hindcasts waves for project design, and the Navy forecasts waves to plan naval operations.

2-11. Breaking Waves

a. Wave heights derived from a hindcast should be checked against the maximum breaking wave that can be supported at the site given the available depth at the design still-water level and the nearshore bottom slope. Figure 2-2 (Weggel 1972) gives the maximum breaker height, H_b, as a function of the depth at the structure, d_s, nearshore bottom slope, m, and wave period, T. Design wave heights, therefore, will be the *smaller* of the maximum breaker height or the hindcast wave height.

b. For the severe conditions commonly used for design, H_{mo} may be limited by breaking wave conditions. A reasonable upper bound for H_{mo} is given by

$$(H_{mo})_{\max} = 0.10\, L_p \tanh\left(\frac{2\pi d}{L_p}\right) \tag{2-5}$$

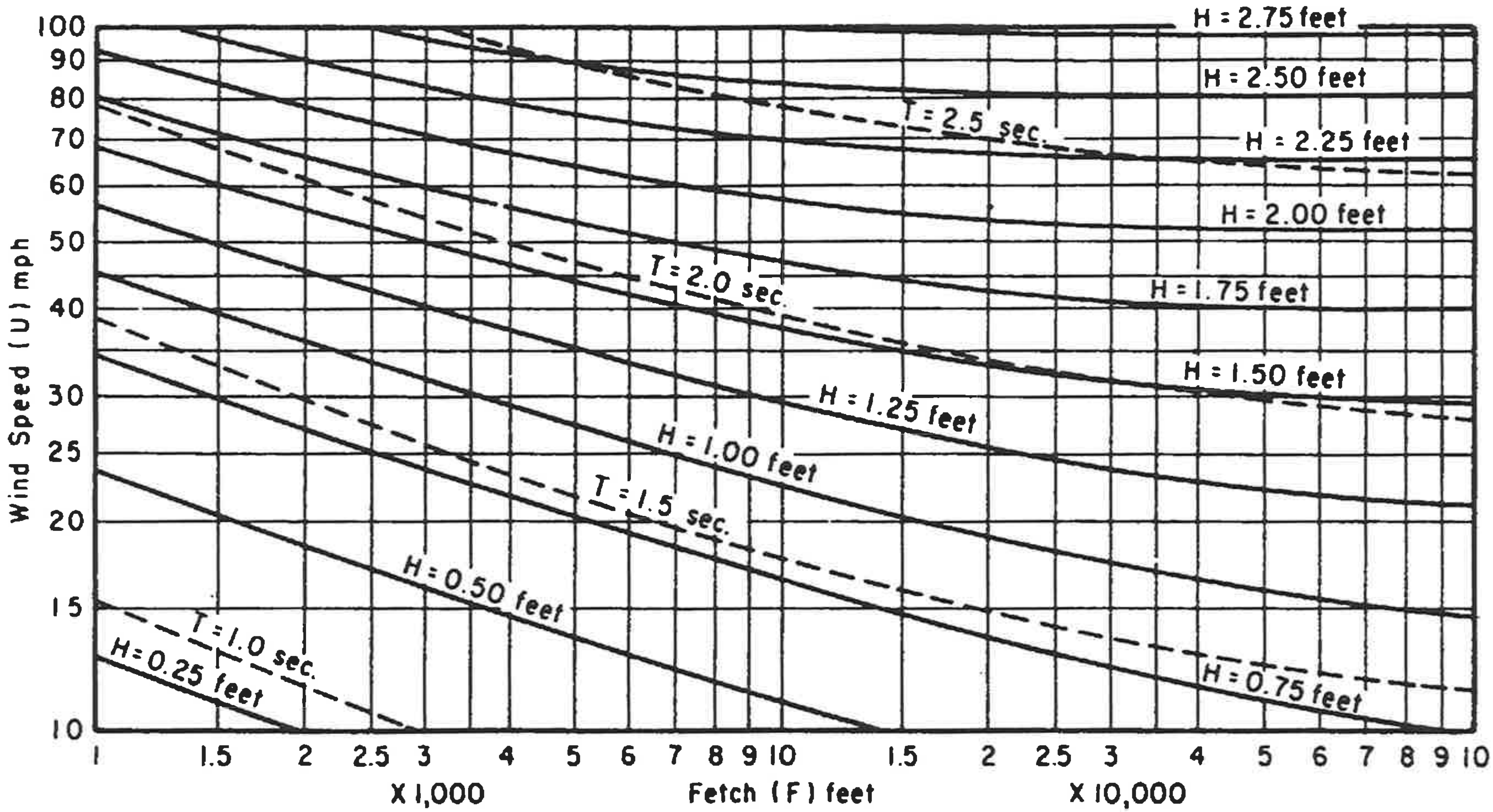
where L_p is wavelength calculated using T_p and d.

2-12. Height of Protection

When selecting the height of protection, one must consider the maximum water level, any anticipated structure settlement, freeboard, and wave runup and overtopping.

2-13. Wave Runup

Runup is the vertical height above the still-water level (swl) to which the uprush from a wave will rise on a structure. Note that it is not the distance measured along the inclined surface.



US Army Coastal Engineering Research Center

Figure 5-4. Forecasting curves for shallow-water waves (constant depth = 5 feet).

Attachment 7

Table 2-2
Rough Slope Runup Correction Factors (Carstea et al. 1975b)

Armor Type	Slope (cot θ)	Relative Size H / K_r[a,b]	Correction Factor r
Quarrystone	1.5	3 to 4	0.60
Quarrystone	2.5	3 to 4	0.63
Quarrystone	3.5	3 to 4	0.60
Quarrystone	5	3	0.60
Quarrystone	5	4	0.68
Quarrystone	5	5	0.72
Concrete Blocks[c]	Any	6[b]	0.93
Stepped slope with vertical risers	1.5	$1 \le H_o'/K_r$[d]	0.75
Stepped slope with vertical risers	2.0	$1 \le H_o'/K_r$[d]	0.75
Stepped slope with vertical risers	3.0	$1 \le H_o'/K_r$[d]	0.70
Stepped slope with rounded edges	3.0	$1 \le H_o'/K_r$[d]	0.86
Concrete Armor Units			
Tetrapods random two layers	1.3 to 3.0	-	0.45
Tetrapods uniform two layers	1.3 to 3.0	-	0.51
Tribars random two layers	1.3 to 3.0	-	0.45
Tribars uniform one layer	1.3 to 3.0	-	0.50

[a] K_r is the characteristic height of the armor unit perpendicular to the slope. For quarrystone, it is the nominal diameter; for armor units, the height above the slope.
[b] Use H_o' for $d_s/H_o' > 3$; and the local wave height, H_s for $d_s/H_o' \le 3$.
[c] Perforated surfaces of Gobi Blocks, Monoslaps, and concrete masonry units placed hollows up.
[d] K_r is the riser height.

$$F' = \frac{F}{\left(H_{mo}^2 L_o\right)^{1/3}} \tag{2-11}$$

where F is dimensional freeboard (vertical distance of crest above swl). The remaining terms in Equation 2-9 are m (cotangent of revetment slope) and the regression coefficients C_0, C_1, and C_2 defined as

$$\begin{aligned} C_0 &= 0.4578 \\ C_1 &= -29.45 \\ C_2 &= 0.8464 \end{aligned} \tag{2-12}$$

The coefficients listed above were determined for dimensionless freeboards in the range $0.25 < F' < 0.43$, and revetment slopes of 1:2 and 1:3.5.

c. Overtopping rates for seawalls are complicated by the numerous shapes found on the seawall face plus the variety of fronting berms, revetments, and steps. Information on overtopping rates for a range of configurations is available in Ward and Ahrens (1992). For bulkheads and simple vertical seawalls with no fronting revetment and a small parapet at the crest, the overtopping rate may be calculated from

$$Q' = C_0 \exp\left[C_1 F' + C_2\left(\frac{F}{d_s}\right)\right] \tag{2-13}$$

where Q' is defined in Equation 2-10, F' is defined in Equation 2-11, d_s is depth at structure toe, and the regression coefficients are defined by

$$\begin{aligned} C_0 &= 0.338 \\ C_1 &= -7.385 \\ C_2 &= -2.178 \end{aligned} \tag{2-14}$$

Golder Associates 44 Union Blvd Lakewood, Colorado 80228	Subject	FGD Pond Design and Permitting – INFLUENT PIPE SIZING						
	Job No.	093-82538	Made by	John Irvin	Date	05-14-09		
	Reference	Progress Energy-Crystal River	Checked by	C. Beck	Sheet	1	Of	8
			Reviewed by	KBK				

The following specifications and software package were used to calculate the Progress Energy Crystal River FGD Pond Design pressure loss and also to determine the necessary minimum pressure to be supplied at the point of connection.

Software used		
PIPE-FLO	**version 11.01**	**Generated on 5/13/2009**
System: File Name	Pipe Flow_Progress Energy_Proj 09382538_05-19-09_4 in Pipe.pipe	
Lineup: Case Study	**075,150, 300 gpm ZONE 2- B**	

Company:	Progress Energy - Crystal River
Project:	9382538
by:	John Irvin
Footer:	Pipe Flow Calc - 4 inch pipe

UNITS:			
Flow Rate:	US gpm	Volume:	gallons
Pressure:	psi a	Atm:	14.64
Temperature:	°F		
Viscosity:	cP		
Density:	lb/ft³		
Grade:	ft		
Length:	ft		
Size:	in		

Assumptions used to determine pipe sizing and calculations

- All pipe to be HDPE
- Water temperature of water in pipe – 140 deg F
- Pipe Flows: 75, 150, 300 gallons per minute
- Piping will be buried with the exception of drain pipe section over pond.
- FGD blowdown water has same properties of water
- Tie point elevation @ 93.2 msl, pond discharge elevation @ 115 ft msl
- Zone 2-B is from the tie point (TP) to the farthest discharge point (southwest) and considered to be the worst case for system pressure drop

Golder Associates	Subject	FGD Pond Design and Permitting						
	Job No.	093-82538	Made by	John Irvin	Date	05-14-09		
	Reference	Progress Energy-Crystal River	Checked by	C. Beck	Sheet	2	Of	8
44 Union Blvd Lakewood, Colorado 80228			Reviewed by					

CALCULATION SUMMARY

Flow Rate gpm	System Losses psi	Safety Factor 15% psi	Pressure Required @ TP psi
75	10.5	1.6	12.1
150	13.8	2.1	15.9
300	25.8	3.9	29.7

Software Used		
PIPE-FLO	ver 11.01	5/21/2009 0:00
System: File Name	Pipe Flow_Progress Energy_Proj 09382538_05-14-09_Butterfly Valves_4 in Pipe.pipe	
Lineup: Case Study	75 gpm, ZONE 2- B	

Company:	Progress Energy - Crystal River
Project:	9382538
by:	John Irvin
Footer:	Pipe Flow Calc - 4 inch pipe @ 300 gpm

UNITS:		
Flow Rate:	US gpm	Volume: gallons
Pressure:	psi a	Atm: 14.64 psi a
Temperature:	°F	
Viscosity:	cP	
Density:	lb/ft³	
Grade:	ft	
Length:	ft	
Size:	in	

CALCULATION:
Iteration: 1
Deviation percent: 0
Pressure drop calculations: Darcy-Weisbach method, laminar cutoff Re = 2100

Pipe List	Specification (HDPE)	Fluid Zone	Size (in)	Length (ft)	Only for valves & Fittings K	Status	Flow	Velocity	Pipe & Fitting (Elev + Pipeloss) dP	From Friction Only HL	Tagged	From	To	Inside Dia
Pipe(001)	DR-11	Water	4	0.001	0		75	2.262	9.282	0	N	Input	~N(001)	3.682
Pipe(002)	DR-11	Water	4	23	0.4981		75	2.262	0.059	0.14	N	~N(001)	~N(002)	3.682
Pipe(003)	DR-11	Water	4	61.5	0.4981		75	2.262	0.131	0.307	N	~N(002)	~N(003)	3.682
Pipe(004)	DR-11	Water	4	0.001	0.3321		75	2.262	0.011	0.026	N	~N(003)	~N(004)	3.682
Pipe(005)	DR-11	Water	4	146	2.325	X Closed	—	—	—	—	N	~N(004)	~N(0005)	3.682
Pipe(006)	DR-11	Water	4	146	1.66	X Closed	—	—	—	—	N	~N(0005)	~N(0006)	3.682
Pipe(007)	DR-11	Water	4	46	1.993	X Closed	—	—	—	—	N	~N(0005)	~N(007)	3.682
Pipe(008)	DR-11	Water	4	46	1.245	X Closed	—	—	—	—	N	~N(0006)	~N(008)	3.682
Pipe(009)	DR-11	Water	4	104.5	1.411		75	2.262	0.242	0.567	N	~N(004)	~N(009)	3.682
Pipe(010)	DR-11	Water	4	0.001	0.3321		75	2.262	0.011	0.026	N	~N(009)	~N(010)	3.682
Pipe(011)	DR-11	Water	4	146	2.325		75	2.262	0.349	0.821	N	~N(010)	~N(011)	3.682
Pipe(012)	DR-11	Water	4	146	1.411		75	2.262	0.319	0.748	N	~N(011)	~N(012)	3.682
Pipe(013)	DR-11	Water	4	46	1.993	X Closed	—	—	—	—	N	~N(011)	~N(013)	3.682
Pipe(014)	DR-11	Water	4	46	1.245		75	2.262	0.127	0.299	N	~N(012)	~N(014)	3.682
Pipe(015)	DR-11	Water	4	209	1.079	X Closed	—	—	—	—	N	~N(010)	~N(015)	3.682
Totals					18.3474				10.531	2.934				

Pipe List	Pipe Only Pipe HL	Valves & Fittings Only Minor HL	Reynolds Number Re	Friction Factor ffp	Valves/Fittings	K Value for each Component		K Value for each Component		K Value for each Component		K Value for each Component
Pipe(001)	0	0	137645	0.01684								
Pipe(002)	0.1	0.04	137645	0.01684	1 x Mitre Bend @ 45~	0.2491	1 x Mitre Bend @ 45~	0.2491				
Pipe(003)	0.267	0.04	137645	0.01684	1 x Mitre Bend @ 45~	0.2491	1 x Mitre Bend @ 45~	0.2491				
Pipe(004)	0	0.026	137645	0.01684	1 x Tee - Flow Thru Run	0.3321						
Pipe(005)	—	—	—	—	1 x Tee - Flow Thru Branch	0.9963	1 x Mitre Bend @ 45~	0.2491	1 x Butterfly	0.7472	1 x Tee - Flow Thru Run	0.3321
Pipe(006)	—	—	—	—	1 x Mitre Bend @ 45~	0.2491	1 x Butterfly	0.7472	1 x Tee - Flow Thru Run	0.3321	1 x Tee - Flow Thru Run	0.3321
Pipe(007)	—	—	—	—	1 x Tee - Flow Thru Branch	0.9963	1 x Butterfly	0.7472	1 x Mitre Bend @ 45~	0.2491		
Pipe(008)	—	—	—	—	1 x Tee - Flow Thru Branch	0.9963	1 x Mitre Bend @ 45~	0.2491				
Pipe(009)	0.455	0.112	137645	0.01684	1 x Tee - Flow Thru Run	0.3321	1 x Butterfly	0.7472	1 x Tee - Flow Thru Run	0.3321		
Pipe(010)	0	0.026	137645	0.01684	1 x Tee - Flow Thru Run	0.3321						
Pipe(011)	0.636	0.185	137645	0.01684	1 x Tee - Flow Thru Branch	0.9963	1 x Mitre Bend @ 45~	0.2491	1 x Butterfly	0.7472	1 x Tee - Flow Thru Run	0.3321
Pipe(012)	0.636	0.112	137645	0.01684	1 x Butterfly	0.7472	1 x Tee - Flow Thru Run	0.3321	1 x Tee - Flow Thru Run	0.3321		
Pipe(013)	—	—	—	—	1 x Tee - Flow Thru Branch	0.9963	1 x Butterfly	0.7472	1 x Mitre Bend @ 45~	0.2491		
Pipe(014)	0.2	0.099	137645	0.01684	1 x Tee - Flow Thru Branch	0.9963	1 x Mitre Bend @ 45~	0.2491				
Pipe(015)	—	—	—	—	1 x Butterfly	0.7472	1 x Tee - Flow Thru Run	0.3321				
Totals	2.294	0.64										

Node List	Status	Pressure (psia)	Potential Energy of Fluid + Elevation Change Hydraulic Grade (ft)	Elev
~N(0005)	Isolated	—	—	115
~N(0006)	Isolated	—	—	115
~N(001)		15.89	117.9	115
~N(002)		15.83	117.8	115
~N(003)		15.7	117.5	115
~N(004)		15.69	117.5	115
~N(009)		15.45	116.9	115
~N(010)		15.44	116.9	115
~N(011)		15.09	116	115
~N(012)		14.77	115.3	115
~N(015)	Isolated	—	—	115

Demand List	Demand Type	Flow	Pressure	Status	Grade	Elev
~N(007)	Boundary pressure	—	14.64	Isolated	—	115
~N(008)	Boundary pressure	—	14.64	Isolated	—	115
~N(013)	Boundary pressure	—	14.64	Isolated	—	115
~N(014)	Boundary pressure	75	14.64		115	115
Input	Flow in	75	25.17		117.9	93.2

Pipe Specification	Material	Schedule	Roughness	HW-C	Sizing	Vel Limits	Press Limit	Valve Table
DR-11	PE (IPS_Golder)	DR-11.0	6.00E-05	150	not specifi	—	—	standard

Fluid Zone	Fluid	Temperature	Pressure	Density	Viscosity	k	Pv	Pc	MW
Water	Water	140	14.7	61.35	0.4603	—	2.891	3198	18

Software Used		
PIPE-FLO	ver 11.01	5/21/2009 0:00
System: File Name	Pipe Flow_Progress Energy_Proj 00382538_05-14-09_Butterfly Valves_4 in Pipe.pipe	
Lineup: Case Study	150 gpm, ZONE 2- B	

Company:	Progress Energy - Crystal River
Project:	0382538
by:	John Ivan
Footer:	Pipe Flow Calc - 4 inch pipe @ 300 gpm

UNITS:		
Flow Rate:	US gpm	Volume: gallons
Pressure:	psi a	Atm. 14.64 psi a
Temperature:	°F	
Viscosity:	cP	
Density:	lb/ft³	
Grade:	ft	
Length:	ft	
Size:	in	

CALCULATION:
Iteration: 1
Deviation percent: 0
Pressure drop calculations: Darcy-Weisbach method, laminar cutoff Re = 2100

Pipe List	Specification (HDPE)	Fluid Zone	Size (in)	Length (ft)	Only for valves & Fittings K	Status	Flow	Velocity	Pipe & Fitting (Elev + Pipeloss) dP	From Friction Only HL	Tagged
Pipe(001)	DR-11	Water	4	0.001	0		150	4 524	9 282	0	N
Pipe(002)	DR-11	Water	4	23	0.4981		150	4 524	0 217	0,51	N
Pipe(003)	DR-11	Water	4	61 5	0 4981		150	4 524	0 468	1 099	N
Pipe(004)	DR-11	Water	4	0.001	0 3321		150	4 524	0 045	0.105	N
Pipe(005)	DR-11	Water	4	146	2.325	X Closed	---	---	---	---	N
Pipe(006)	DR-11	Water	4	146	1.66	X Closed	---	---	---	---	N
Pipe(007)	DR-11	Water	4	46	1 993	X Closed	---	---	---	---	N
Pipe(008)	DR-11	Water	4	46	1 245	X Closed	---	---	---	---	N
Pipe(009)	DR-11	Water	4	104 5	1 411		150	4 524	0 871	2 047	N
Pipe(010)	DR-11	Water	4	0 001	0.3321		150	4 524	0 045	0 105	N
Pipe(011)	DR 11	Water	4	146	2 325		150	4 524	1 265	2 971	N
Pipe(012)	DR-11	Water	4	146	1 411		150	4 524	1 142	2 681	N
Pipe(013)	DR-11	Water	4	46	1 993	X Closed	---	---	---	---	N
Pipe(014)	DR-11	Water	4	46	1 245		150	4 524	0 468	1 099	N
Pipe(015)	DR-11	Water	4	209	1.079	X Closed	---	---	---	---	N
Totals					18.3474				13.803	10.617	

Pipe List	From	To	Inside Dia	Pipe Only Pipe HL	Valves & Fittings Only Minor HL	Reynolds Number Re	Friction Factor ffp	Valves/Fittings	K Value for each Component		K Value for each Component		K Value for each Component		K Value for each Component
Pipe(001)	Input	~N(001)	3.682	0	0	275290	0.01478								
Pipe(002)	~N(001)	~N(002)	3 682	0 352	0 158	275290	0 01478	1 x Mitre Bend @ 45°	0 2491	1 x Mitre Bend @ 45°	0.2491				
Pipe(003)	~N(002)	~N(003)	3 682	0.941	0 158	275290	0 01478	1 x Mitre Bend @ 45°	0 2491	1 x Mitre Bend @ 45°	0 2491				
Pipe(004)	~N(003)	~N(004)	3 682	0	0 105	275290	0 01478	1 x Tee - Flow Thru Run	0 3321						
Pipe(005)	~N(004)	~N(0005)	3.682	---	---	---	---	1 x Tee - Flow Thru Branch	0 9963	1 x Mitre Bend @ 45°	0 2491	1 x Butterfly	0.7472	1 x Tee - Flow Thru Run	0 3321
Pipe(006)	~N(0005)	~N(0006)	3.682	---	---	---	---	1 x Mitre Bend @ 45°	0.2491	1 x Butterfly	0 7472	1 x Tee - Flow Thru Run	0 3321	1 x Tee - Flow Thru Run	0.3321
Pipe(007)	~N(0005)	~N(007)	3 682	---	---	---	---	1 x Tee - Flow Thru Branch	0,9963	1 x Butterfly	0 7472	1 x Mitre Bend @ 45°	0 2491		
Pipe(008)	~N(0006)	~N(008)	3 682	---	---	---	---	1 x Tee - Flow Thru Branch	0 9963	1 x Mitre Bend @ 45°	0.2491				
Pipe(009)	~N(004)	~N(009)	3 682	1 599	0 448	275290	0 01478	1 x Tee - Flow Thru Run	0 3321	1 x Butterfly	0 7472	1 x Tee - Flow Thru Run	0 3321		
Pipe(010)	~N(009)	~N(010)	3 682	0	0 105	275290	0 01478	1 x Tee - Flow Thru Run	0 3321						
Pipe(011)	~N(010)	~N(011)	3 682	2 233	0 738	275290	0 01478	1 x Tee - Flow Thru Branch	0 9963	1 x Mitre Bend @ 45°	0 2491	1 x Butterfly	0 7472	1 x Tee - Flow Thru Run	0 3321
Pipe(012)	~N(011)	~N(012)	3 682	2 233	0 448	275290	0 01478	1 x Butterfly	0 7472	1 x Tee - Flow Thru Run	0.3321	1 x Tee - Flow Thru Run	0 3321		
Pipe(013)	~N(011)	~N(013)	3 682	---	---	---	---	1 x Tee - Flow Thru Branch	0 9963	1 x Butterfly	0 7472	1 x Mitre Bend @ 45°	0 2491		
Pipe(014)	~N(012)	~N(014)	3 682	0 704	0 395	275290	0 01478	1 x Tee - Flow Thru Branch	0 9963	1 x Mitre Bend @ 45°	0 2491				
Pipe(015)	~N(010)	~N(015)	3.682	---	---	---	---	1 x Butterfly	0.7472	1 x Tee - Flow Thru Run	0.3321				
Totals				8.062	2.555										

Node List	Status	Pressure (psia)	Potential Energy of Fluid + Elevation Change Hydraulic Grade (ft)	Elev
~N(0005)	Isolated	---	---	115
~N(0006)	Isolated	---	---	115
~N(001)		19.21	125.8	115
~N(002)		19	125.2	115
~N(003)		18.54	124.2	115
~N(004)		18.49	124	115
~N(009)		17.62	122	115
~N(010)		17.57	121.9	115
~N(011)		16.31	118.9	115
~N(012)		15.17	116.2	115
~N(015)	Isolated	---	---	115

Demand List	Demand Type	Flow	Pressure	Status	Grade	Elev
~N(007)	Boundary pressure	---	14.7	Isolated	---	115
~N(008)	Boundary pressure	---	14.7	Isolated	---	115
~N(013)	Boundary pressure	---	14.7	Isolated	---	115
~N(014)	Boundary pressure	150	14.7		115.1	115
Input	Flow in	150	28.5		125.8	93.2

Pipe Specification	Material	Schedule	Roughness	HW-C	Sizing	Vel Limits	Press Limit	Valve Table
DR-11	PE (IPS_Golder)	DR-11.0	6.00E-05	150	not specifi	---	---	standard

Fluid Zone	Fluid	Temperature	Pressure	Density	Viscosity	k	Pv	Pc	MW
Water	Water	140	14.7	61.35	0.4603	---	2.891	3198	18

Software Used			
PIPE-FLO	ver 11.01	5/21/2009 0:00	
System: File Name	Pipe Flow_Progress Energy_Proj 09382538_05-14-09_Butterfly Valves_4 in Pipe.pipe		
Lineup: Case Study	300 gpm, ZONE 2- B		

Company:	Progress Energy - Crystal River
Project:	9382538
by:	John Irvin
Footer:	Pipe Flow Calc - 4 inch pipe @ 300 gpm

UNITS:		
Flow Rate:	US gpm	Volume: gallons
Pressure:	psi a	Atm. 14.64 psi a
Temperature:	°F	
Viscosity:	cP	
Density:	lb/ft³	
Grade:	ft	
Length:	ft	
Size:	in	

CALCULATION:
Iteration: 1
Deviation percent: 0
Pressure drop calculations: Darcy-Weisbach method, laminar cutoff Re = 2100

					Only for valves & Fittings				Pipe & Fitting (Elev + Pipeloss)	From Friction Only				
Pipe List	Specification (HDPE)	Fluid Zone	Size (in)	Length (ft)	K	Status	Flow	Velocity	dP	HL	Tagged	From	To	Inside Dia
Pipe(001)	DR-11	Water	4	0.001	0		300	9.048	9.282	0	N	Input	~N(001)	3.682
Pipe(002)	DR-11	Water	4	23	0.4981		300	9.048	0.802	1.883	N	~N(001)	~N(002)	3.682
Pipe(003)	DR-11	Water	4	61.5	0.4981		300	9.048	1.693	3.977	N	~N(002)	~N(003)	3.682
Pipe(004)	DR-11	Water	4	0.001	0.3321		300	9.048	0.18	0.422	N	~N(003)	~N(004)	3.682
Pipe(005)	DR-11	Water	4	146	2.325	X Closed	---	---	---	---	N	~N(004)	~N(0005)	3.682
Pipe(006)	DR-11	Water	4	146	1.66	X Closed	---	---	---	---	N	~N(0005)	~N(0006)	3.682
Pipe(007)	DR-11	Water	4	46	1.993	X Closed	---	---	---	---	N	~N(0005)	~N(007)	3.682
Pipe(008)	DR-11	Water	4	46	1.245	X Closed	---	---	---	---	N	~N(0006)	~N(008)	3.682
Pipe(009)	DR-11	Water	4	104.5	1.411		300	9.048	3.182	7.474	N	~N(004)	~N(009)	3.682
Pipe(010)	DR-11	Water	4	0.001	0.3321		300	9.048	0.18	0.422	N	~N(009)	~N(010)	3.682
Pipe(011)	DR-11	Water	4	146	2.325		300	9.048	4.637	10.89	N	~N(010)	~N(011)	3.682
Pipe(012)	DR-11	Water	4	146	1.411		300	9.048	4.143	9.731	N	~N(011)	~N(012)	3.682
Pipe(013)	DR-11	Water	4	46	1.993	X Closed	---	---	---	---	N	~N(011)	~N(013)	3.682
Pipe(014)	DR-11	Water	4	46	1.245		300	9.048	1.738	4.083	N	~N(012)	~N(014)	3.682
Pipe(015)	DR-11	Water	4	209	1.079	X Closed	---	---	---	---	N	~N(010)	~N(015)	3.682
Totals					18.3474				25.837	38.882				

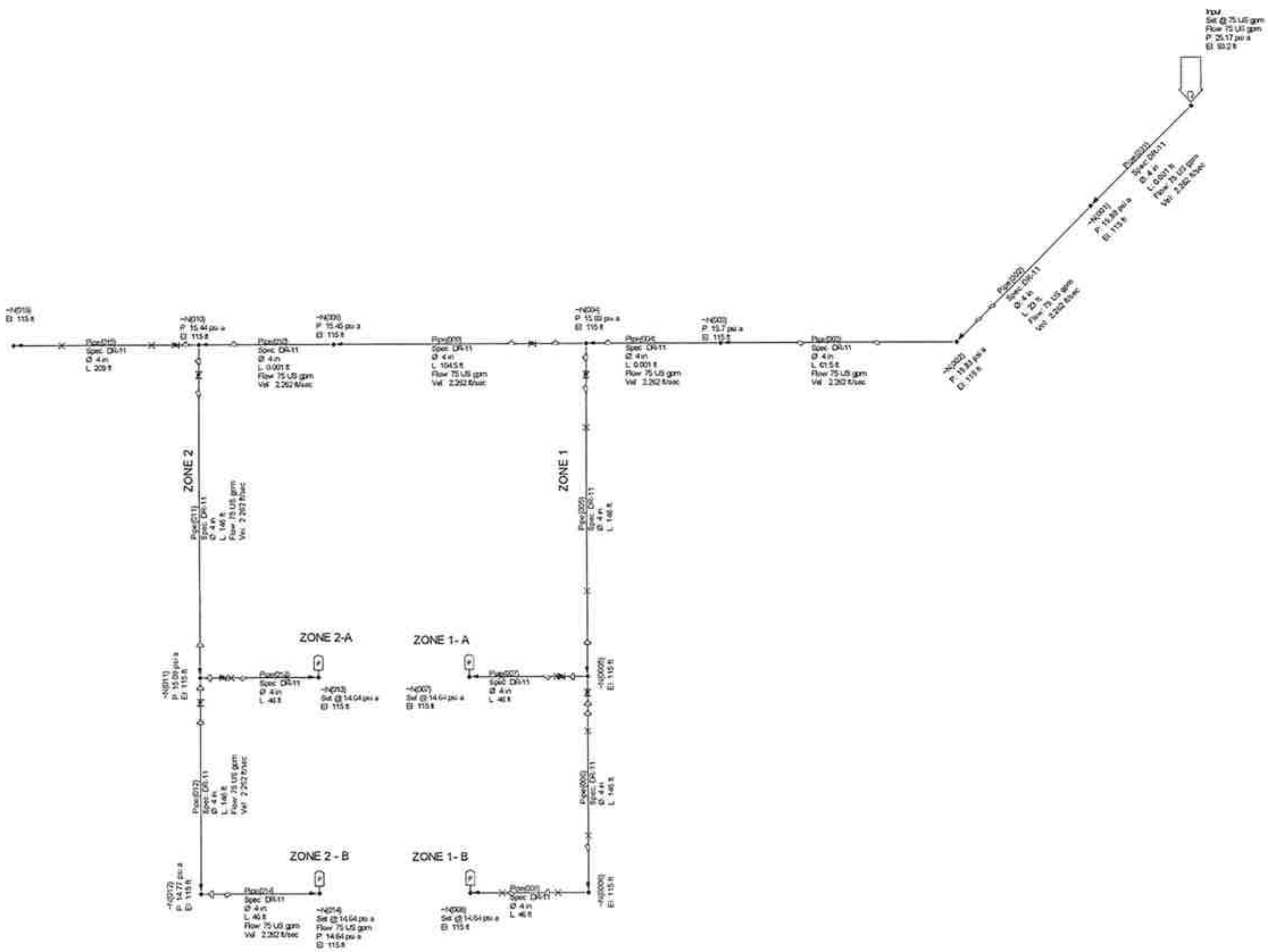
	Pipe Only	Valves & Fittings Only	Reynolds Number	Friction Factor		K Value for each Component		K Value for each Component		K Value for each Component		K Value for each Component
Pipe List	Pipe HL	Minor HL	Re	ffp	Valves/Fittings							
Pipe(001)	0	0	550581	0.01314								
Pipe(002)	1.25	0.633	550581	0.01314	1 x Mitre Bend @ 45~	0.2491	1 x Mitre Bend @ 45~	0.2491				
Pipe(003)	3.344	0.633	550581	0.01314	1 x Mitre Bend @ 45~	0.2491	1 x Mitre Bend @ 45~	0.2491				
Pipe(004)	0	0.422	550581	0.01314	1 x Tee - Flow Thru Run	0.3321						
Pipe(005)	---	---	---	---	1 x Tee - Flow Thru Branch	0.9963	1 x Mitre Bend @ 45~	0.2491	1 x Butterfly	0.7472	1 x Tee - Flow Thru Run	0.3321
Pipe(006)	---	---	---	---	1 x Mitre Bend @ 45~	0.2491	1 x Butterfly	0.7472	1 x Tee - Flow Thru Run	0.3321	1 x Tee - Flow Thru Run	0.3321
Pipe(007)	---	---	---	---	1 x Tee - Flow Thru Branch	0.9963	1 x Butterfly	0.7472	1 x Mitre Bend @ 45~	0.2491		
Pipe(008)	---	---	---	---	1 x Tee - Flow Thru Branch	0.9963	1 x Mitre Bend @ 45~	0.2491				
Pipe(009)	5.682	1.792	550581	0.01314	1 x Tee - Flow Thru Run	0.3321	1 x Butterfly	0.7472	1 x Tee - Flow Thru Run	0.3321		
Pipe(010)	0	0.422	550581	0.01314	1 x Tee - Flow Thru Run	0.3321						
Pipe(011)	7.938	2.952	550581	0.01314	1 x Tee - Flow Thru Branch	0.9963	1 x Mitre Bend @ 45~	0.2491	1 x Butterfly	0.7472	1 x Tee - Flow Thru Run	0.3321
Pipe(012)	7.939	1.792	550581	0.01314	1 x Butterfly	0.7472	1 x Tee - Flow Thru Run	0.3321	1 x Tee - Flow Thru Run	0.3321		
Pipe(013)	---	---	---	---	1 x Tee - Flow Thru Branch	0.9963	1 x Butterfly	0.7472	1 x Mitre Bend @ 45~	0.2491		
Pipe(014)	2.502	1.581	550581	0.01314	1 x Tee - Flow Thru Branch	0.9963	1 x Mitre Bend @ 45~	0.2491				
Pipe(015)	---	---	---	---	1 x Butterfly	0.7472	1 x Tee - Flow Thru Run	0.3321				
Totals	28.655	10.227										

			Potential Energy of Fluid + Elevation Change	
Node List	Status	Pressure (psia)	Hydraulic Grade (ft)	Elev
~N(0005)	Isolated	---	---	115
~N(0006)	Isolated	---	---	115
~N(001)		31.19	153.9	115
~N(002)		30.39	152	115
~N(003)		28.7	148	115
~N(004)		28.52	147.6	115
~N(009)		25.34	140.1	115
~N(010)		25.16	139.7	115
~N(011)		20.52	128.8	115
~N(012)		16.38	119.1	115
~N(015)	Isolated	---	---	115

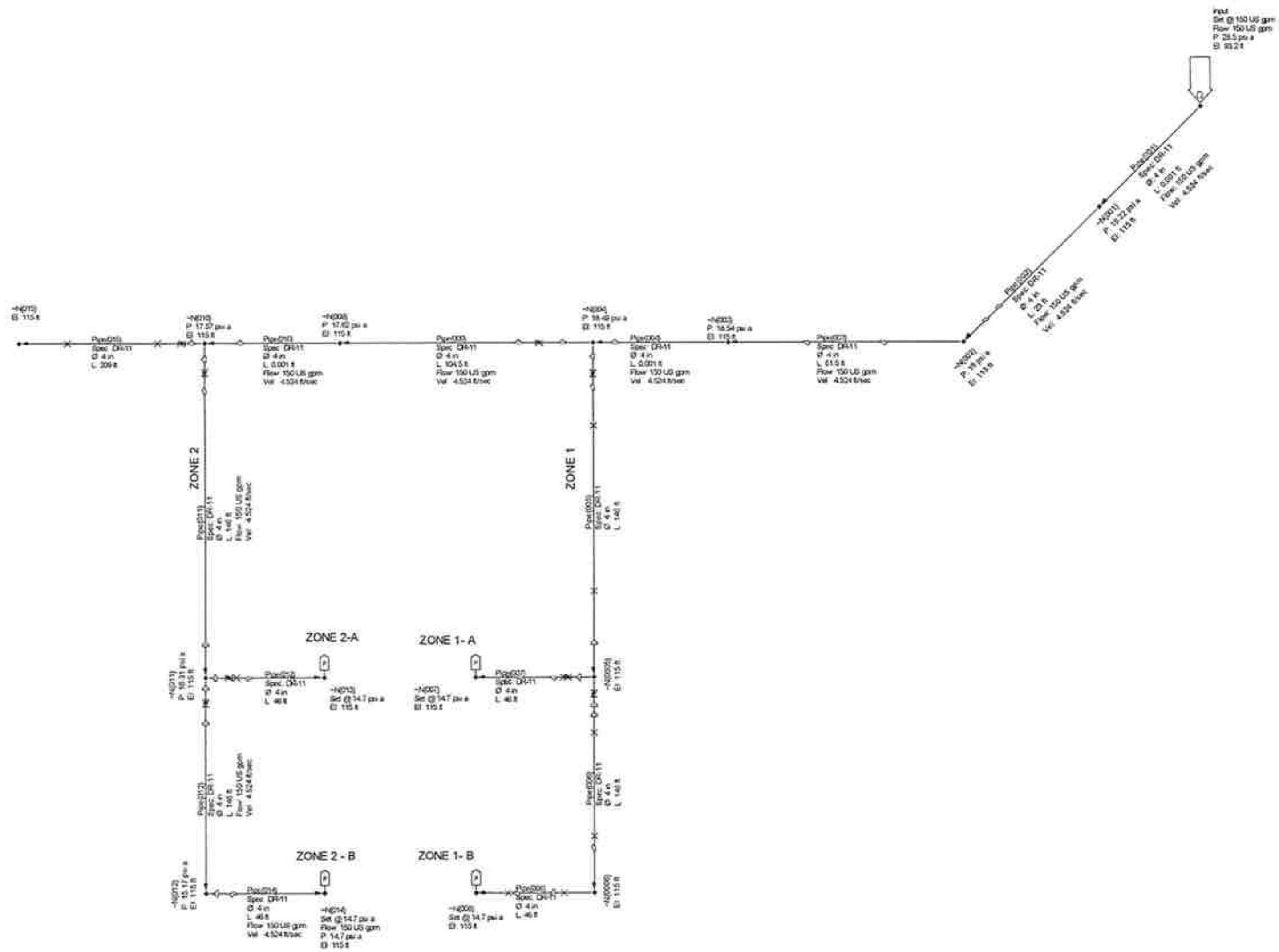
Demand List	Demand Type	Flow	Pressure	Status	Grade	Elev
~N(007)	Boundary pressure	---	14.64	Isolated	---	115
~N(008)	Boundary pressure	---	14.64	Isolated	---	115
~N(013)	Boundary pressure	---	14.64	Isolated	---	115
~N(014)	Boundary pressure	300	14.64		115	115
Input	Flow in	300	40.48		153.9	93.2

Pipe Specification	Material	Schedule	Roughness	HW-C	Sizing	Vel Limits	Press Limits	Valve Table
DR-11	PE (IPS_Golder)	DR-11.0	6.00E-05	150	not specifi	---	---	standard

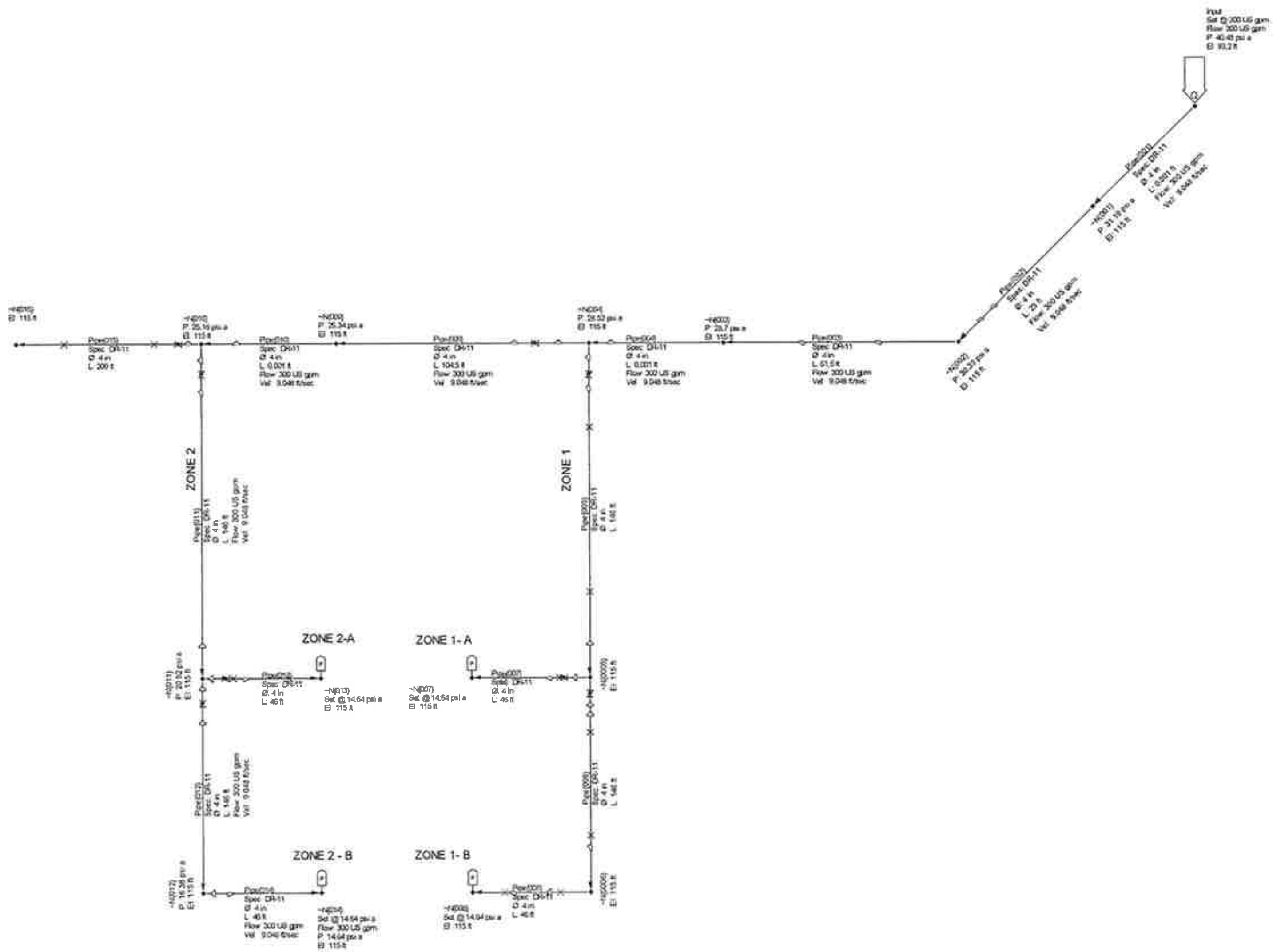
Fluid Zone	Fluid	Temperature	Pressure	Density	Viscosity	k	Pv	Pc	MW
Water	Water	140	14.7	61.35	0.4603	---	2.891	3198	18



Lineup: 075, ZONE 2- B	Darcy-Weisbach	PIPE-FLO 2009
System: Pipe Flow_Progress Energy_Proj 09382538_05-14-09_Butt... Date: 05/14/09 2:13 pm Company: Progress Energy - Crystal River Project: 09382538 by: John Irvin		Flow: US gpm Pressure: psi a Size: in Elevation: ft Velocity: ft/sec Length: ft Volume: gallons



Lineup:	150, ZONE 2- B	Darcy-Weisbach	PIPE-FLO 2009	
System:	Pipe Flow_Progress Energy_Proj 09382538_05-14-09_Butt...		Flow:	US gpm
Date:	05/14/09 2:12 pm		Pressure:	psi a
Company:	Progress Energy - Crystal River		Size:	in
Project:	09382538		Elevation:	ft
by:	John Irvin		Velocity:	ft/sec
			Length:	ft
			Volume:	gallons



Lineup:	300, ZONE 2 - B	Darcy-Weisbach	PIPE-FLO 2009
System:	Pipe Flow_Progress Energy_Proj 09382538_05-14-09_Butt...	Flow:	US gpm
Date:	05/14/09 2:11 pm	Pressure:	psi a
Company:	Progress Energy - Crystal River	Size:	in
Project:	09382538	Elevation:	ft
by:	John Irvin	Velocity:	ft/sec
		Length:	ft
		Volume:	gallons

Golder Associates	SUBJECT Small Pond Effluent Pipe Hydraulics		
	Job No. 09382538	Made by PEP	Date 5-19-09
	Ref. Progress Energy	Checked CAB	Sheet 1 of 3
		Reviewed KBK	

(PV)

Submerged Pump Vault Inlet

Given: PV has high level of 107' while pond effluent pipes enter at 102' (invert).

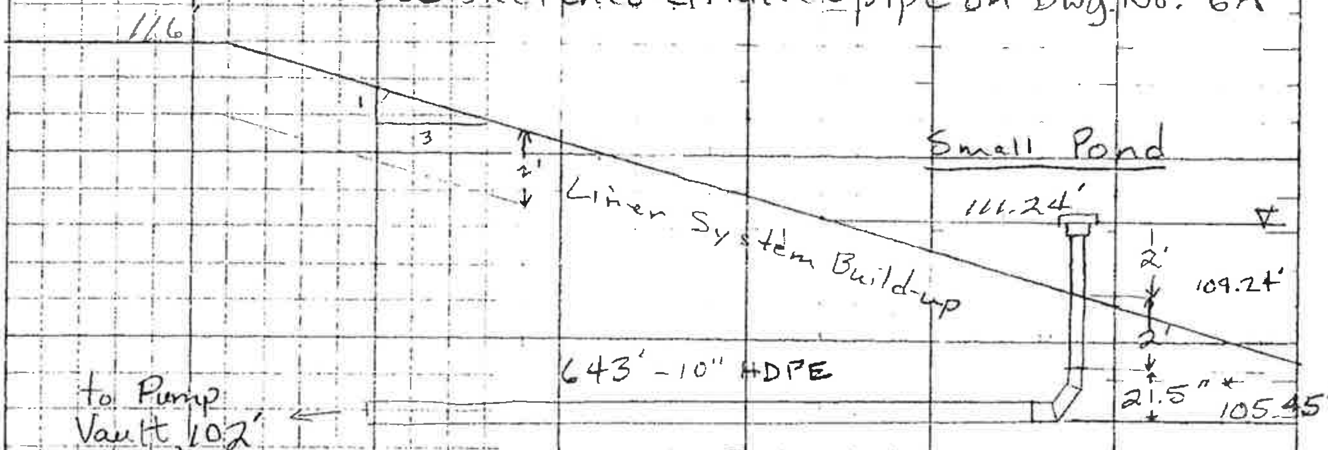
Calculate H_L in full 10" Small Pond effluent pipe

Given elevations: ℄ 10" @ PV $= 102' + \frac{5''}{12''/ft} = 102.42'$

Inlet to 10" from Sm. Pond = 111.24'

Invert bottom of 90° Elbow beneath pond inlet (see below) = 105.45'

see sketched effluent pipe on Dwg. No. 6A



10" pipe flows full; pump vault water surface rises to 107'; determine headloss in pipe to determine if H_L will cause backwater to pond inlet at 111.24', for 300 gpm

H_L Components

① Pipe - 643': $V = \frac{Q}{A} = \frac{300/448.8\,gpm/cfs}{\frac{\pi}{4}\left(\frac{10}{12}\right)^2} = \frac{.668}{.545} = 1.23\,fps$
(SDR 26)

$H_L = 0.05'/100'$ (Harrington Engrg. Manual)

$643 \times 0.05/100 = 0.32'$

② 90° Elbow, actually = 2 - 45° elbows

*ISCO 3-Segment Elbow - 10"

Golder Associates	SUBJECT Small Pond Effluent Pipe Hydraulics		
	Job No. 09382538 Ref. Progress Energy	Made by PEP Checked WB Reviewed KBK	Date 5-19-09 Sheet 2 of 3

③ 2 - 45° elbows along pipe route, K = 0.42*

$$H_L(90 + 2\text{-}45) = 4 \times 0.42 \times \frac{1.23^2}{2 \times 32.2} = 0.04\ ft$$

④ 2 - Butterfly Valves, K = 5*

$$H_L = 2 \times 5 \times \frac{1.23^2}{2 \times 32.2} = 0.23\ ft$$

Total H_L = 0.32 + 0.04 + 0.23 = .59 ft

∴ Back water in 10" pipe = 107' + .59' = <u>107.59 ft</u>

Pipe will not backwater to inlet @ 111.24 ft; there will still be a free overflow with PV @ its highest elevation

* Daugherty & Franzini, 1965. "Fluid Mechanics with Engrg. Applic."

Golder Associates	SUBJECT Small Pond Effluent Pipe Hydraulics		
	Job No. 09382538	Made by PEP	Date 5-19-09
	Ref. Progress Energy	Checked CAB	Sheet 3 of 3
		Reviewed KBK	

Gravity Flow in Pipe to Pump Vault @ < 102'

From Sheet 1, 10" pipe runs 643' from beneath Small Pond @ invert 105.45' to PV @ invert 102'

Use Manning Eq. to estimate depth of flow and gravity flow velocity.

Source: "Driscopipe Materials, Design and Engineering Guide for PE Pipe" [PolyPipe, 3/99]

$Q\,(gpm) = 449\,V \times A \times ID^2$ V in fps, A = dimensionless area factor, ID = inside diam, ft.

Use HDPE, 10" SDR 26, ∴ ID = 9.89 inches or 0.824 ft. (attached Source table A-5)

A (from table B-6) for $\frac{h}{ID} = 0.40$, 0.2934 [h = flow depth]

$\therefore\ V = \frac{300\,gpm\,(Q_{max})}{(A)\,0.2934 \times 449 \times (.824)^2} = \frac{0.984}{0.2934} = 3.35\ fps$

Compare direct V by Manning Eq.

$V = \frac{1.486}{n} \times R^{2/3} \times S^{1/2}$ where V = fps (same as above)

solve for R

$R = \left[\frac{V \times n}{1.486 \times S^{1/2}}\right]^{3/2}$

R (hydr. radius) = f × ID (ft)

f = fullness factor for same h/ID as A was obtained in Source table B-6

$R = \left(\frac{3.35 \times 0.010}{1.486 \times 0.7325}\right)^{1.5}$

S = slope, ft/ft (see above & sheet 1)

$\frac{105.45' - 102'}{643'} = 0.0054$ $S^{1/2} = 0.07325$

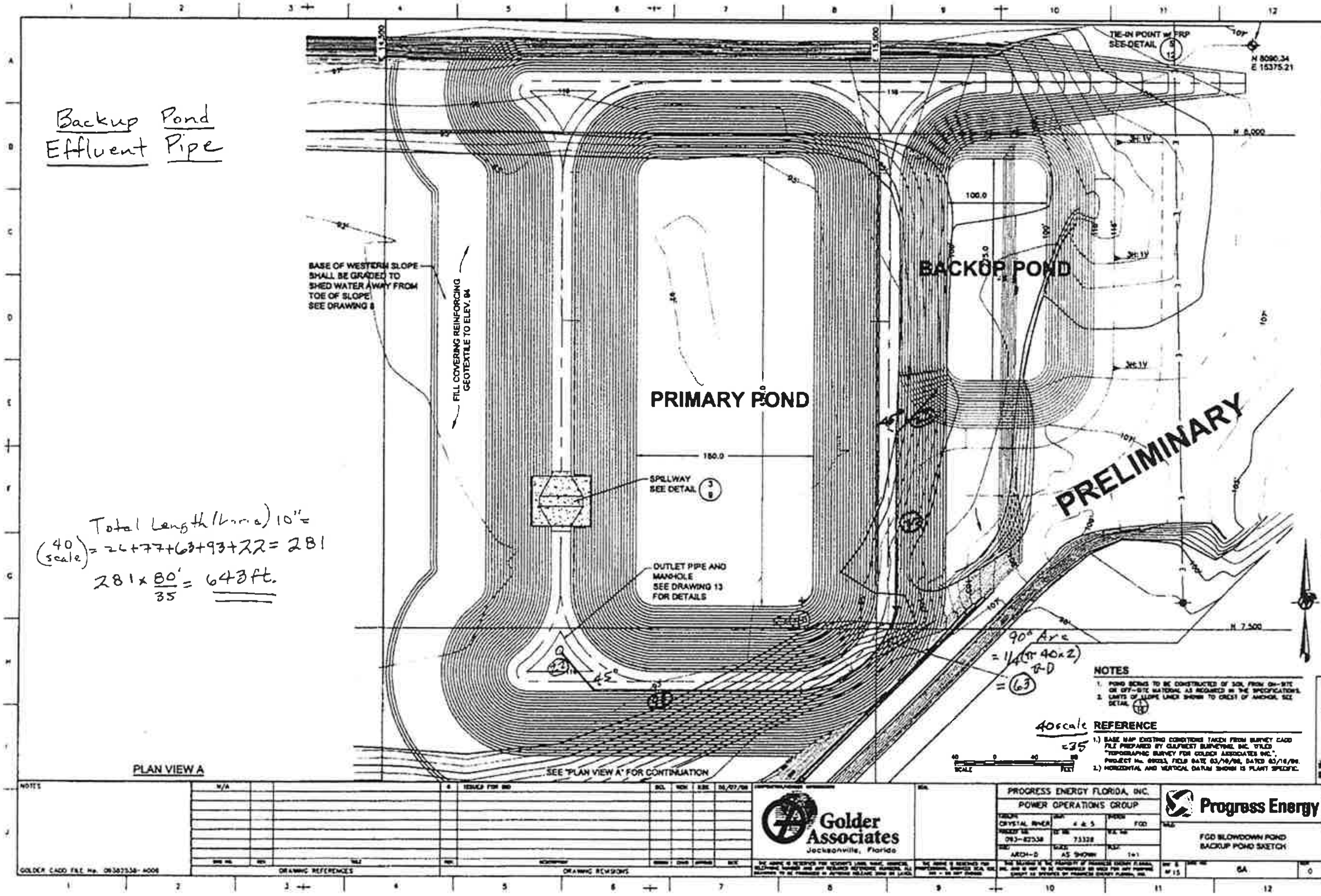
$R = 3.35^{1.5} \times 0.02785 = 0.1707$

$f = \frac{R}{ID} = \frac{0.1707}{0.824} = .2072$

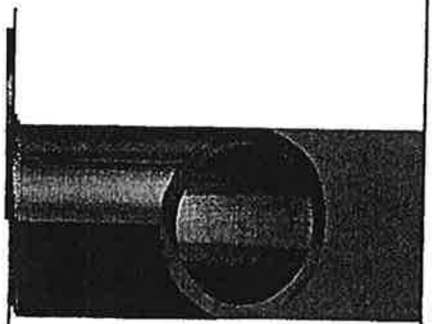
n = Manning Roughness coef. = 0.010 (Source B-6)

@ $\frac{h}{ID} = 0.4$, f (from Source table B-6) = .2143

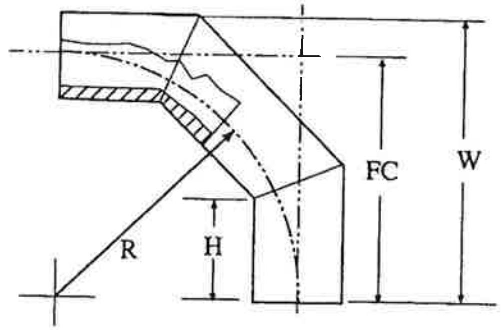
$.2072 \approx .2143$ ∴ depth of flow in 10" pipe SDR 26 = 9.89 inches × .4 = 3.96 inches ≈ 4"


Backup Pond
Effluent Pipe
BASE OF WESTERN SLOPE SHALL BE GRADED TO SHED WATER AWAY FROM TOE OF SLOPE SEE DRAWING 8
FILL COVERING REINFORCING GEOTEXTILE TO ELEV. 94
TIE-IN POINT w/ FRP SEE DETAIL
N 8090.34
E 15375.21
N 8,000
N 7,500
E 15,500
E 15,000
PRIMARY POND
BACKUP POND
100.0
150.0
3H:1V
SPILLWAY SEE DETAIL
OUTLET PIPE AND MANHOLE SEE DRAWING 13 FOR DETAILS
PRELIMINARY
Total Length (Lrma) 10" =
(40 scale) = 26+77+63+93+22 = 281
281 x 80'/35 = 643 ft.
90° Arc
= 1/4 (π 40 x 2)
π-D
= 63
45°
NOTES
1. POND BERMS TO BE CONSTRUCTED OF SOIL FROM ON-SITE OR OFF-SITE MATERIAL AS REQUIRED IN THE SPECIFICATIONS.
2. LIMITS OF SLOPE LINER SHOWN TO CREST OF ANCHOR. SEE DETAIL
40 scale
=35
REFERENCE
1.) BASE MAP EXISTING CONDITIONS TAKEN FROM SURVEY CADD FILE PREPARED BY GULFCREST SURVEYING, INC. TITLED "TOPOGRAPHIC SURVEY FOR GOLDER ASSOCIATES INC.", PROJECT No. 06023, FIELD DATE 03/10/06, DATED 03/16/06.
2.) HORIZONTAL AND VERTICAL DATUM SHOWN IS PLANT SPECIFIC.
40 0 40 80
SCALE FEET
PLAN VIEW A
SEE "PLAN VIEW A" FOR CONTINUATION
NOTES
DRAWING REFERENCES
DRAWING REVISIONS
ISSUED FOR BID
GOLDER CADD FILE No. 0638253B-A006
Golder Associates
Jacksonville, Florida
PROGRESS ENERGY FLORIDA, INC.
POWER OPERATIONS GROUP
CRYSTAL RIVER
4 & 5
FGD
063-82538
73328
ARCH-D
AS SHOWN
1=1
Progress Energy
FGD BLOWDOWN POND
BACKUP POND SKETCH
6A
0

IPS Fittings Fabricated 90° Ell - Three Segment



IPS
HDPE
Fittings



IPS Fittings Fabricated 90° Ell - Three Segment

Nominal Size(in)	Pipe OD(in)	DR	Pressure Rating	Part #	Dimensions R (in)	H (in)	FC (in)	W (in)	Weight Lbs.	Shipping Method
2	2.375	07	167	ISFF900207IPS3P	6.62	4.50	8.87	10.06	1	UPS
		09	125	ISFF900209IPS3P	"	"	"	"	1	"
		11	100	ISFF900211IPS3P	"	"	"	"	1	"
3	3.5	07	167	ISFF900307IPS3P	7.18	4.50	9.43	11.18	3	UPS
		09	125	ISFF900309IPS3P	"	"	"	"	2	"
		11	100	ISFF900311IPS3P	"	"	"	"	2	"
		17	63	ISFF900317IPS3P	"	"	"	"	1	"
4	4.5	07	167	ISFF900407IPS3P	7.68	4.50	9.93	12.18	5	UPS
		09	125	ISFF900409IPS3P	"	"	"	"	4	"
		11	100	ISFF900411IPS3P	"	"	"	"	3	"
		17	63	ISFF900417IPS3P	"	"	"	"	2	"
6	6.625	07	167	ISFF900607IPS3P	9.95	5.50	12.70	16.01	14	UPS
		09	125	ISFF900609IPS3P	"	"	"	"	11	"
		11	100	ISFF900611IPS3P	"	"	"	"	9	"
		17	63	ISFF900617IPS3P	"	"	"	"	6	"
		32.5	32	ISFF900632IPS3P	"	"	"	"	3	"
8	8.625	07	167	ISFF900807IPS3P	12.16	6.50	15.41	19.72	28	UPS
		09	125	ISFF900809IPS3P	"	"	"	"	23	"
		11	100	ISFF900811IPS3P	"	"	"	"	19	"
		17	63	ISFF900817IPS3P	"	"	"	"	17	"
		32.5	32	ISFF900832IPS3P	"	"	"	"	7	"
10	10.75	07	167	ISFF901007IPS3P	12.63	6.50	16.13	21.50	43	LTL
		09	125	ISFF901009IPS3P	"	"	"	"	37	"
		11	100	ISFF901011IPS3P	"	"	"	"	31	"
		17	63	ISFF901017IPS3P	"	"	"	"	21	"
		32.5	32	ISFF901032IPS3P	"	"	"	"	11	"
12	12.75	07	167	ISFF901207IPS3P	13.63	8.50	19.12	25.50	72	LTL
		09	125	ISFF901209IPS3P	"	"	"	"	61	"
		11	100	ISFF901211IPS3P	"	"	"	"	51	"
		17	63	ISFF901217IPS3P	"	"	"	"	34	"
		32.5	32	ISFF901232IPS3P	"	"	"	"	18	"
14	14	07	167	ISFF901407IPS3P	14.25	8.50	19.75	26.75	89	LTL
		09	125	ISFF901409IPS3P	"	"	"	"	75	"
		11	100	ISFF901411IPS3P	"	"	"	"	62	"
		17	63	ISFF901417IPS3P	"	"	"	"	42	"

CARRYING CAPACITY AND FRICTION LOSS 160 PSI AND SDR 26 THERMOPLASTIC PIPE

(Independent variables: Gallons per minute and nominal pipe size O.D.

Dependent variables: Velocity, friction head and pressure drop per 100 feet of pipe, interior smooth .)

GALLONS PER MINUTE	VELOCITY FEET PER SECOND	FRICTION HEAD FEET	FRICTION LOSS POUNDS PER SQUARE INCH	VELOCITY FEET PER SECOND	FRICTION HEAD FEET	FRICTION LOSS POUNDS PER SQUARE INCH	VELOCITY FEET PER SECOND	FRICTION HEAD FEET	FRICTION LOSS POUNDS PER SQUARE INCH	VELOCITY FEET PER SECOND	FRICTION HEAD FEET	FRICTION LOSS POUNDS PER SQUARE INCH
		1/2 IN.			3/4 IN.			1 IN.			1-1/4 IN.	
1	0.84	1.00	0.43	0.50	0.28	0.12						
2	1.67	2.00	0.86	0.99	0.56	0.24	0.59	0.29	0.13	0.36	0.085	0.037
5	4.17	11.25	4.87	2.47	3.14	1.36	1.48	0.91	0.39	0.90	0.27	0.117
7	5.84	20.66	8.95	3.46	5.76	2.49	2.08	1.66	0.72	1.25	0.49	0.21
10	8.34	39.34	17.03	4.94	10.96	4.74	2.96	3.16	1.37	1.79	0.92	0.40
15		4 IN.		7.40	23.23	10.06	4.44	6.69	2.90	2.68	1.96	0.85
20	0.48	0.02	0.009	9.87	39.57	17.13	5.92	11.40	4.94	3.58	3.34	1.45
25	0.60	0.04	0.017		5 IN.		7.40	17.23	7.46	4.47	5.04	2.18
30	0.72	0.05	0.022	0.47	0.02	0.009	8.88	24.15	10.46	5.36	7.07	3.06
35	0.84	0.07	0.030	0.55	0.03	0.013	10.36	32.13	13.91	6.26	9.41	4.07
40	0.96	0.09	0.039	0.63	0.03	0.013				7.15	12.05	5.22
45	1.08	0.11	0.048	0.71	0.04	0.017		6 IN.		8.04	14.98	6.49
50	1.20	0.14	0.061	0.78	0.05	0.022	0.55	0.02	0.009	8.94	18.21	7.88
60	1.44	0.19	0.082	0.94	0.07	0.030	0.66	0.03	0.013			
70	1.67	0.25	0.11	1.10	0.09	0.039	0.77	0.04	0.017			
75	1.79	0.29	0.13	1.18	0.10	0.043	0.83	0.04	0.017			
80	1.91	0.32	0.14	1.25	0.12	0.052	0.88	0.05	0.022			
90	2.15	0.40	0.17	1.41	0.14	0.061	0.99	0.06	0.026		8 IN.	
100	2.39	0.49	0.21	1.57	0.18	0.078	1.10	0.07	0.030	0.66	0.03	0.012
125	2.99	0.74	0.33	1.96	0.27	0.12	1.39	0.11	0.047	0.83	0.037	0.015
150	3.50	1.04	0.45	2.35	0.37	0.16	1.66	0.16	0.066	0.98	0.04	0.017
175	4.19	1.39	0.60	2.74	0.50	0.22	1.94	0.21	0.091	1.14	0.06	0.026
200	4.79	1.77	0.77	3.13	0.63	0.27	2.21	0.27	0.12	1.30	0.07	0.030
250	5.98	2.68	1.16	3.92	0.96	0.42	2.76	0.41	0.18	1.63	0.11	0.048
300	7.18	3.75	1.62	4.70	1.34	0.58	3.31	0.57	0.25	1.95	0.16	0.069
350	8.38	5.00	2.17	5.49	1.79	0.77	3.87	0.76	0.33	2.28	0.21	0.091
400	9.57	6.39	2.77	6.27	2.28	0.99	4.42	0.97	0.42	2.61	0.27	0.12
450	10.77	7.95	3.44	7.05	2.84	1.23	4.97	1.21	0.52	2.93	0.33	0.14
500	11.96	9.66	4.18	7.84	3.45	1.49	5.52	1.47	0.64	3.26	0.41	0.18
750				11.75	7.31	3.17	8.28	3.12	1.35	4.89	0.86	0.37
1000							11.05	5.31	2.30	6.51	1.47	0.64
1250										8.15	2.23	0.96
1500										9.77	3.11	1.35
2000										13.03	5.30	2.29
2500												
3000												
3500												
4000												
4500												

GALLONS PER MINUTE	VELOCITY FEET PER SECOND	FRICTION HEAD FEET	FRICTION LOSS POUNDS PER SQUARE INCH	VELOCITY FEET PER SECOND	FRICTION HEAD FEET	FRICTION LOSS POUNDS PER SQUARE INCH	VELOCITY FEET PER SECOND	FRICTION HEAD FEET	FRICTION LOSS POUNDS PER SQUARE INCH	VELOCITY FEET PER SECOND	FRICTION HEAD FEET	FRICTION LOSS POUNDS PER SQUARE INCH
		1-1/2 IN.			2 IN.			2-1/2 IN.			3 IN.	
1												
2	0.27	0.02	0.0087	0.17	0.01	0.004						
5	0.68	0.14	0.059	0.44	0.045	0.020	0.30	0.025	0.011	0.20	0.01	0.0045
7	0.96	0.25	0.104	0.61	0.08	0.035	0.42	0.035	0.015	0.28	0.014	0.0063
10	1.36	0.47	0.20	0.87	0.16	0.069	0.59	0.06	0.026	0.40	0.02	0.009
15	2.04	1.00	0.43	1.30	0.33	0.14	0.88	0.13	0.056	0.59	0.05	0.022
20	2.72	1.71	0.74	1.73	0.57	0.25	1.18	0.22	0.095	0.79	0.09	0.039
25	3.40	2.59	1.12	2.16	0.86	0.37	1.47	0.34	0.15	0.99	0.13	0.056
30	4.08	3.63	1.57	2.60	1.21	0.52	1.77	0.47	0.20	1.19	0.18	0.078
35	4.76	4.83	2.09	3.03	1.61	0.70	2.06	0.63	0.27	1.39	0.24	0.10
40	5.44	6.18	2.68	3.46	2.06	0.89	2.35	0.81	0.35	1.59	0.31	0.13
45	6.12	7.69	3.33	3.90	2.56	1.11	2.65	1.00	0.43	1.78	0.38	0.16
50	6.80	9.34	4.04	4.33	3.11	1.35	2.94	1.22	0.53	1.98	0.47	0.20
60	8.16	13.10	5.67	5.19	4.36	1.89	3.53	1.71	0.74	2.38	0.65	0.28
70	9.52	17.42	7.54	6.06	5.80	2.51	4.12	2.27	0.98	2.78	0.87	0.38
75	10.19	19.80	8.57	6.49	6.60	2.86	4.41	2.58	1.12	2.97	0.99	0.43
80	10.87	22.31	9.66	6.92	7.43	3.22	4.71	2.91	1.26	3.17	1.11	0.48
90	12.23	27.75	12.02	7.79	9.25	4.01	5.30	3.62	1.57	3.57	1.38	0.60
100	13.59	33.73	14.61	8.66	11.24	4.87	5.89	4.39	1.90	3.97	1.68	0.73
125							7.36	6.65	2.88	4.96	2.54	1.10
150							8.83	9.31	4.03	5.95	3.56	1.54
175		10 IN.					10.31	12.40	5.37	6.94	4.74	2.05
200	0.83	0.027	0.012							7.93	6.07	2.63
250	1.05	0.04	0.017		12 IN.					9.92	9.18	3.98
300	1.26	0.05	0.022									
350	1.47	0.075	0.033	1.04	0.04	0.017						
400	1.68	0.09	0.039	1.19	0.04	0.017						
450	1.89	0.11	0.048	1.34	0.05	0.022						
500	2.10	0.14	0.061	1.49	0.06	0.026						
750	3.14	0.29	0.13	2.23	0.13	0.056						
1000	4.19	0.50	0.22	2.98	0.22	0.095						
1250	5.27	0.76	0.33	3.73	0.34	0.15						
1500	6.29	1.06	0.46	4.47	0.46	0.20						
2000	8.38	1.81	0.78	5.96	0.79	0.34						
2500	10.48	2.74	1.19	7.45	1.20	0.52						
3000	12.58	3.84	1.66	8.94	1.67	0.72						
3500				10.43	2.22	0.96						
4000				11.92	2.86	1.24						
4500				13.41	3.54	1.53						

OD Nominal in.	OD Actual in.	OD Actual mm.	SDR	Nominal ID in.	Nominal ID mm.	Minimum Wall in.	Minimum Wall mm.	Weight lb. per foot	Weight kg. Per meter
			7	6.062	153.97	1.232	31.29	12.32	18.33
			7.3	6.167	156.64	1.182	30.02	11.90	17.71
			9	6.632	168.45	0.958	24.33	9.94	14.79
			9.3	6.696	170.08	0.927	23.55	9.66	14.37
			11	6.994	177.65	0.784	19.91	8.32	12.38
8	8.625	219.1	11.5	7.065	179.45	0.750	19.05	7.99	11.89
			13.5	7.296	185.32	0.639	16.23	6.90	10.27
			15.5	7.468	189.69	0.556	14.12	6.07	9.03
			17	7.570	192.28	0.507	12.88	5.57	8.29
			21	7.771	197.38	0.411	10.44	4.56	6.79
			26	7.935	201.55	0.332	8.43	3.72	5.54
			32.5	8.073	205.50	0.265	6.73	3.00	4.46
			7	7.556	191.92	1.536	39.01	19.14	28.48
			7.3	7.687	195.25	1.473	37.41	18.48	27.50
			9	8.266	209.96	1.194	30.25	15.44	22.97
			9.3	8.346	211.99	1.156	29.36	15.00	22.32
			11	8.717	221.41	0.977	24.82	12.92	19.22
10	10.75	273.1	11.5	8.806	223.67	0.935	23.75	12.41	18.47
			13.5	9.094	230.99	0.796	20.22	10.72	15.95
			15.5	9.307	236.40	0.694	17.63	9.43	14.03
			17	9.435	239.65	0.632	16.05	8.65	12.87
			21	9.685	246.00	0.512	13.00	7.09	10.55
			26	9.890	251.21	0.413	10.49	5.78	8.60
			32.5	10.062	255.57	0.331	8.41	4.66	6.93
			7	8.961	227.61	1.821	46.25	26.93	40.07
			7.3	9.117	231.57	1.747	44.37	26.00	38.69
			9	9.803	249.00	1.417	35.99	21.72	32.32
			9.3	9.898	251.41	1.371	34.82	21.10	31.40
			11	10.339	262.61	1.159	29.44	18.17	27.04
12	12.75	323.9	11.5	10.444	265.28	1.109	28.17	17.46	25.98
			13.5	10.786	273.96	0.944	23.98	15.08	22.44
			15.5	11.039	280.39	0.823	20.90	13.27	19.75
			17	11.190	284.23	0.750	19.05	12.17	18.11
			21	11.487	291.77	0.607	15.42	9.97	14.84
			26	11.730	297.94	0.490	2.45	8.13	12.10
			32.5	11.934	303.12	0.392	9.96	6.56	9.76
			7	9.840	249.94	2.000	50.80	32.46	48.30
			7.3	10.011	254.28	1.918	48.72	31.34	46.63
			9	10.764	273.41	1.556	39.52	26.19	38.97
			9.3	10.869	276.07	1.505	38.23	25.44	37.85
			11	11.353	288.37	1.273	32.33	21.91	32.60
14	14.00	356.6	11.5	11.468	291.29	1.217	30.91	21.05	31.32
			13.5	11.843	300.81	1.037	26.34	18.18	27.05
			15.5	12.121	307.87	0.903	22.94	16.00	23.81
			17	12.287	312.09	0.824	20.93	14.68	21.84
			21	12.613	320.37	0.667	16.94	12.02	17.89
			26	12.880	327.15	0.538	13.67	9.81	14.60
			32.5	13.104	332.84	0.431	10.95	7.91	11.77

GRAVITY FLOW

Commonly accepted approximation for gravity flow of **PolyPipe** is the Manning Equation.

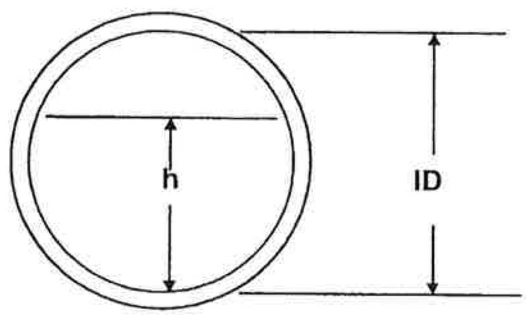
$$V = \frac{1.486 \bullet R^{0.667} S^{0..5}}{n}$$

Where	V	=	average flow velocity, feet per second (m • 0.3048/sec)
	R	=	hydraulic radius, feet (m • 0.3048)
	S	=	slope, feet per foot (m • 3.048)
	n	=	Manning flow coefficient

The Manning flow coefficient (n) for **PolyPipe** is approximately 0.009. However, a more conservative approximation generally utilized is 0.010. The hydraulic radius can be determined from the following formula:

$$R = f \bullet ID$$

Where	ID	=	inside diameter of pipe, feet (m • 0.003048)
	f	=	fullness factor (see table below)



h/ID	f	A	h/ID	f	A
0.05	0.0326	0.0147	0.55	0.2649	0.4426
0.10	0.0636	0.0409	0.60	0.2776	0.4920
0.15	0.0929	0.0739	0.65	0.2881	0.5404
0.20	0.1206	0.1118	0.70	0.2962	0.5872
0.25	0.1466	0.1535	0.75	0.3017	0.6319
0.30	0.1710	0.1982	0.80	0.3042	0.6736
0.35	0.1935	0.2450	0.85	0.3033	0.7115
0.40	0.2143	0.2934	0.90	0.2980	0.7445
0.45	0.2331	0.3428	0.95	0.2864	0.7707
0.50	0.2500	0.3927	1.00	0.2500	0.7854

Once the flow velocity has been determined, the volumetric flow rate can be calculated by use of the following formula:

$$Q = V \cdot A \cdot ID^{2} \qquad (09)$$

Where Q = flow rate, cfs ($2.831684659 \cdot 10^{-2}$ m^3/sec)
V = flow velocity
ID = inside diameter, feet (mm • .003048)
A = area factor from above table

or

$$Q = 449 \cdot V \cdot A \cdot ID^{2} \qquad (10)$$

Where Q = flow rate, gpm (0.000063 • m^3/sec)

For full flow application, the flow rate can be determined by use of the following formula:

$$Q = \frac{0.275}{n} \cdot d^{2.667} \cdot S^{0.5}$$

Q = flow rate, gpm (0.000063 m^3/sec)
n = Manning coefficient
d = inside diameter, inches (mm • .00394)
S = slope, feet per foot (m • 0.3048)

Golder Associates	SUBJECT FGD EXISTING BASIN SPILLWAY CALCULATIONS					
	Job No. 093-82538	Made by	BTH	Date	May 2009	
	Ref.	Checked	SFS	Sheet	1	of 2
		Reviewed	KBK			

PURPOSE

The purpose of this calculation package is to confirm that the installation of the east and west FDG ponds will not adversely affect the overall basin outfall location, storage capacity (25-year 24-hour and 100-year 24-hour storm events) and NPDES outfall at Crystal River Energy Complex (CREC).

AREAS

The watershed for the FGD existing basin (excluding the east and west FGD ponds) is approximately 22.90 acres. The watersheds are shown in Attachment 1.

The composite curve number (CN) for the basin is 88 (See Attachment 2).

STAGE-AREA-STORAGE

Stage-area information was determined for the basin, and the software package SMADA Version 6.43 for Windows written by Dr. R. D. Eaglin of the University of Central Florida was used to determine the storage capacities. The following table presents stage-area-storage data for the basin.

Stage (feet)	Area (acres)	Storage (ac-ft)
92.00	10.062	0
93.00	10.234	10.148
94.00	10.398	20.464
95.00	10.557	30.942

TIME OF CONCENTRATION

The time of concentration path for the basin is shown in Attachment 1. The time of concentration path begins in the northeastern portion of the watershed and flows in a southwesterly direction. The initial 264 feet was assumed to be overland flow, and Manning's equation for travel time was used to calculate travel times. The remaining time of concentration flow paths were assumed to be under shallow concentrated flow and slopes are shown in Attachment 2.

RAINFALL HYDROGRAPHS

Rainfall hydrographs for the watersheds were estimated using the software package SMADA Version 6.43 for Windows written by Dr. R. D. Eaglin of the University of Central Florida. The program uses procedures presented in the Soil Conservation Service's TR-55 (SCS TR-55, 1986).

Stormwater runoff was calculated for 25-yr, 24-hr and 100-yr, 24-hr design storms (Attachment 3).

The peak discharge for the watershed for the 25-yr, 24-hr and 100-yr, 24-hr hydrographs are 70.51 cubic feet per second (cfs) and 88.58 cfs, respectively (see Attachment 3).

EXISTING BASIN SPILLWAY ROUTING

The 25-year, 24-hour and 100-year, 24-hour hydrographs were routed through the existing basin area using the SMADA program.

There were no peak discharges for the 25-year, 24-hour and 100-year, 24-hour storm events, and therefore the existing basin area and weir are capable of managing the runoff and staging for these storm events. The following table presents peak rainfall and staging results for 25-year, 24-hour and 100-year, 24-hour storm events.

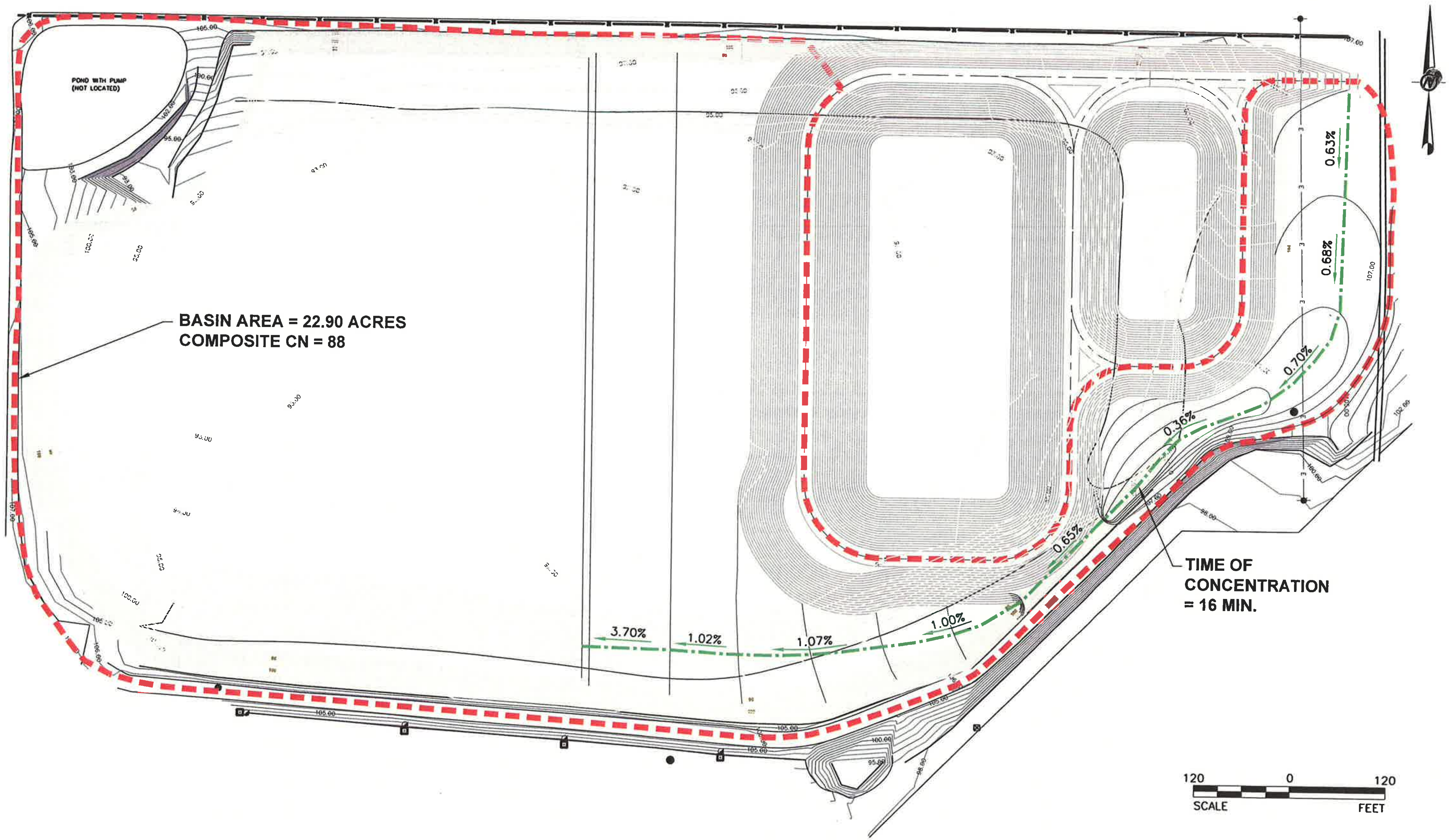
Return Period	Rainfall (inches)	Peak Elevation (feet)	Peak Discharge (cfs)
25-year, 24-hour	8.76	92.67	0
100-year, 24-hour	11.00	92.92	0

REFERENCES

Soil Conservation Service, 1986, Urban Hydrology for Small Watersheds - Technical Release 55

Hann, Barfield, Hayes, 1994; Design Hydrology and Sedimentology for Small Catchments; Academic Press, San Diego, CA.

ATTACHMENT 1


POND WITH PUMP (NOT LOCATED)
BASIN AREA = 22.90 ACRES
COMPOSITE CN = 88
TIME OF CONCENTRATION = 16 MIN.
3.70%
1.02%
1.07%
1.00%
0.65%
0.36%
0.70%
0.68%
0.63%
120
0
120
SCALE
FEET

ATTACHMENT 2

Time of Concentration

Project: **PEF CREC/Existing FGD Basin Design/FL**

Project No.: **093-82538**

Tc:

Dist. (ft)		Vel. (fps)	Time (min.)
120	Overland Flow (slope=0.0063, mannings formula)		1.80
144	Overland Flow (slope=0.0068, mannings formula)		2.00
132	Shallow Conc. Flow (slope=0.0070) @	1.25	1.76
276	Shallow Conc. Flow (slope=0.0036) @	1.15	4.00
156	Shallow Conc. Flow (slope=0.0065) @	2.50	1.04
144	Shallow Conc. Flow (slope=0.0100) @	1.60	1.50
192	Shallow Conc. Flow (slope=0.0107) @	1.60	2.00
84	Shallow Conc. Flow (slope=0.0102) @	1.60	0.88
108	Shallow Conc. Flow (slope=0.037) @	3.20	0.56
1356			

Time of Concentration = 16 min.

COMPOSITE CURVE NUMBER

Project ID: **PEF CREC/Exist FGD Basin Design/FL**

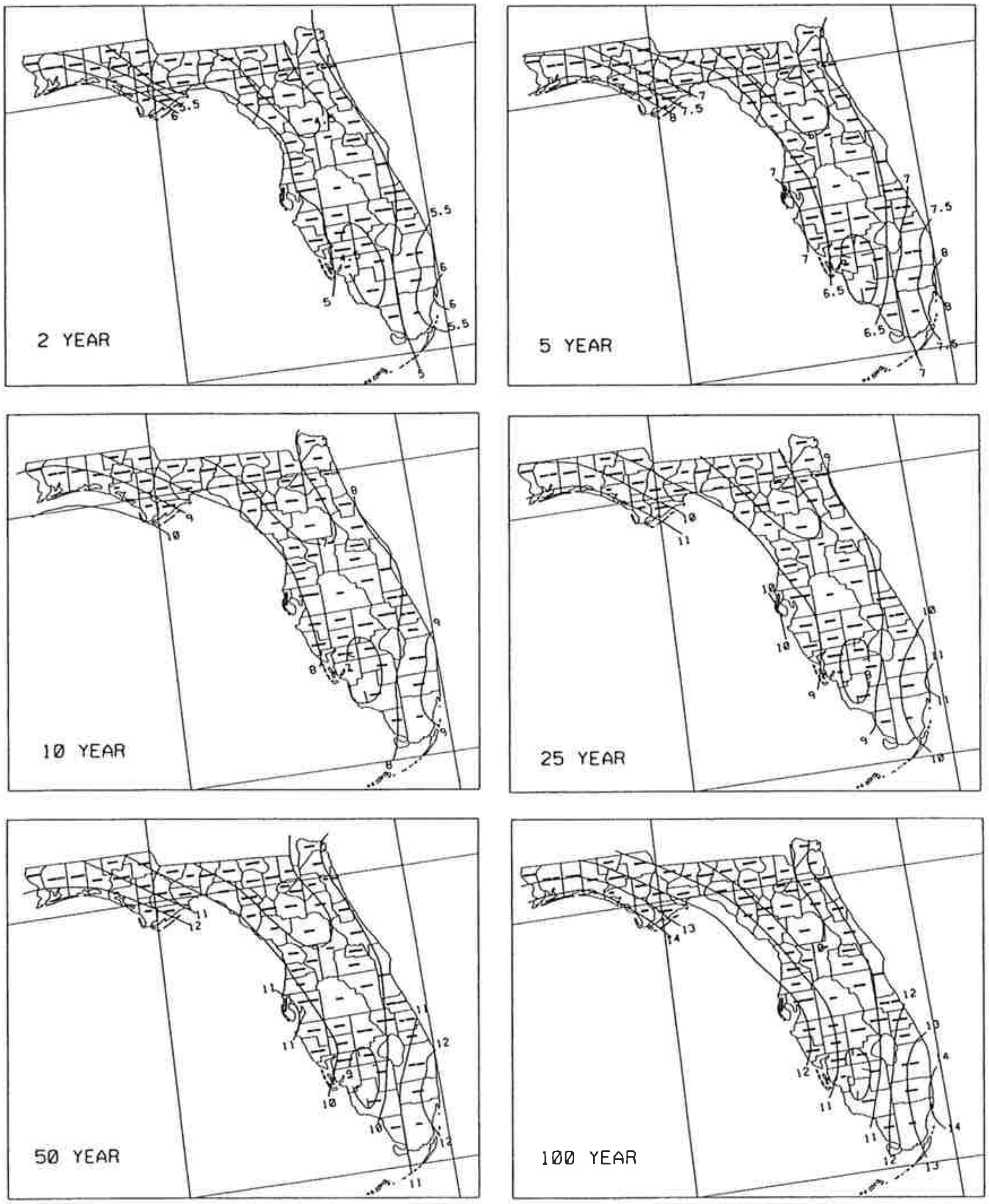
Project #: **093-82538**

DESCRIPTION: EXIST-FGD-BASIN, Total = 22.90 Ac.

CN:	Ac.	Land Cover	Soil Type	SCS CN	%	Weight %
	20.08	Dirt	D	89	87.7%	78
	2.82	Pasture/Rangeland (good condition)	D	80	12.3%	10
					100.0%	
Area:	22.90	**OK**		Weighted SCS CN =		$\boxed{88}$

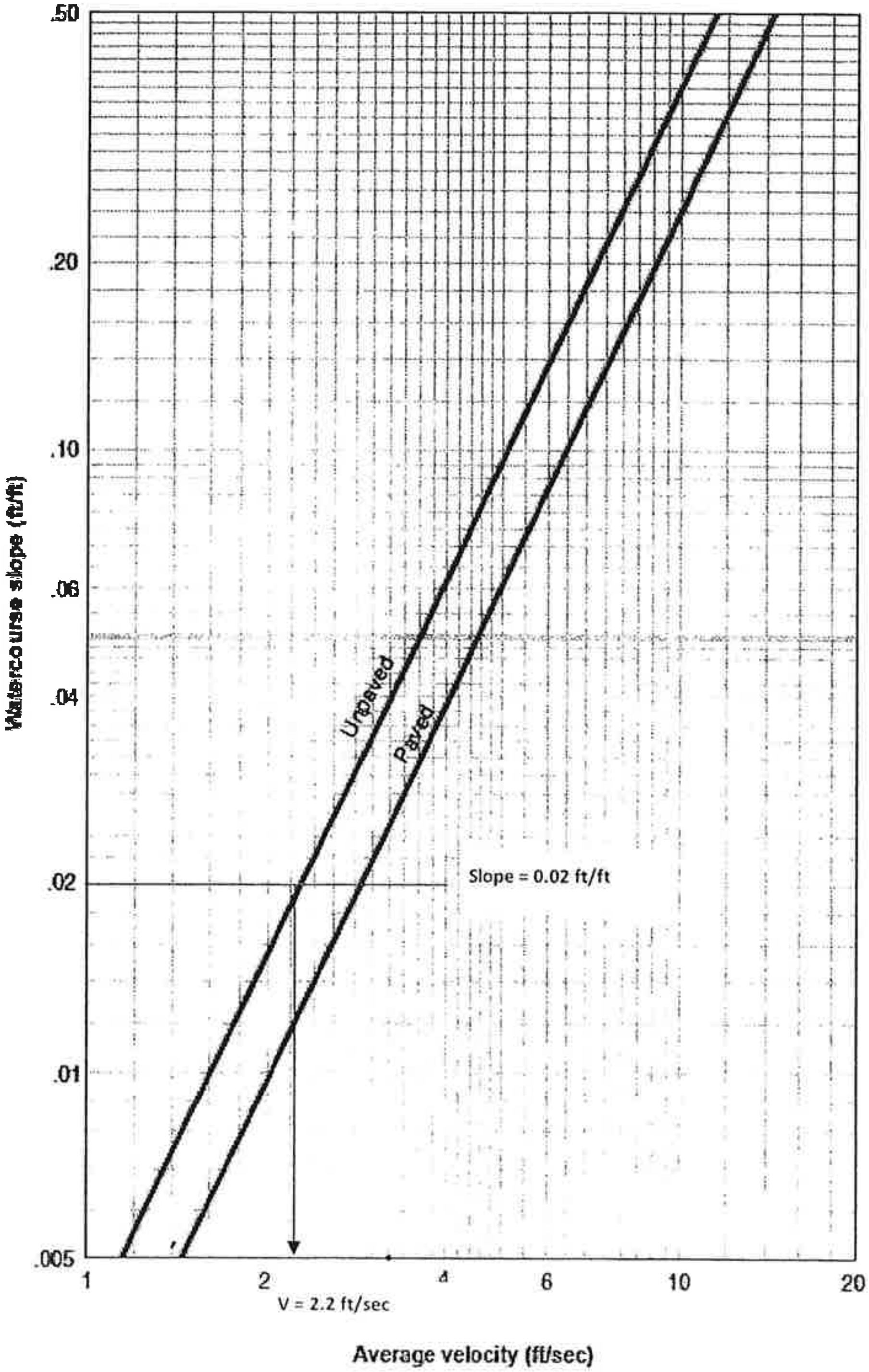
PRECIPITATION DEPTH DATA FOR 2-,5-,10-,25-, 50-, AND 100-YEAR FREQUENCIES

1 DAY



ALL DEPTH CONTOURS IN INCHES

Figure 3-1 **Average velocities for estimating travel time for shallow concentrated flow**



ATTACHMENT 3

SMADA RESULTS

Watershed Information

SMADA 6.0 for Windows

Watershed Information

Watershed Total Area (acres) :22.89

Impervious Area (acres) :0.00

Time of Concentration (min) :16.0

% Impervious Directly Connected :00.00

Additional Abstraction

Over Pervious Area (inches) :0.00

Over Impervious Area (inches) :0.00

Infiltration Characteristics:

Max Infiltration Capacity (in) :0.10

SCS Curve Number for Pervious :88

Initial Abstraction Factor :0.20

Rainfall 25-year, 24-hour Storm

Time (hr)	Time HHMM	Rain (in)	Cumulative (in)
1.000	00100	0.105	0.105
2.000	00200	0.114	0.219
3.000	00300	0.123	0.342
4.000	00400	0.131	0.473

5.000	00500	0.149	0.622
6.000	00600	0.158	0.780
7.000	00700	0.184	0.964
8.000	00800	0.210	1.174
9.000	00900	0.263	1.437
10.00	01000	0.324	1.761
11.00	01100	0.499	2.260
12.00	01200	3.057	5.317
13.00	01300	1.314	6.631
14.00	01400	0.438	7.069
15.00	01500	0.307	7.376
16.00	01600	0.245	7.621
17.00	01700	0.201	7.823
18.00	01800	0.175	7.998
19.00	01900	0.158	8.156
20.00	02000	0.149	8.304
21.00	02100	0.123	8.427
22.00	02200	0.123	8.550
23.00	02300	0.114	8.664
24.00	00000	0.096	8.760

8.76

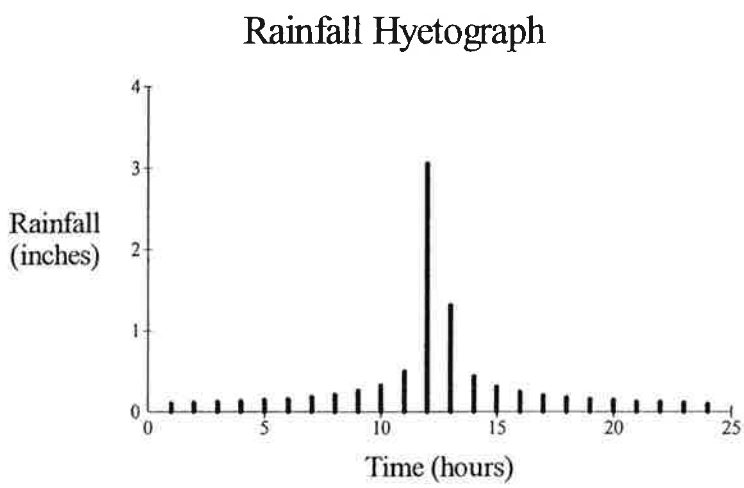
Rainfall 100-year, 24-hour Storm

Time (hr)	Time HHMM	Rain (in)	Cumulative (in)
1.000	00100	0.132	0.132
2.000	00200	0.143	0.275
3.000	00300	0.154	0.429
4.000	00400	0.165	0.594
5.000	00500	0.187	0.781
6.000	00600	0.198	0.979
7.000	00700	0.231	1.210
8.000	00800	0.264	1.474
9.000	00900	0.330	1.804
10.00	01000	0.407	2.211
11.00	01100	0.627	2.838
12.00	01200	3.839	6.677
13.00	01300	1.650	8.327
14.00	01400	0.550	8.877
15.00	01500	0.385	9.262
16.00	01600	0.308	9.570
17.00	01700	0.253	9.823
18.00	01800	0.220	10.043
19.00	01900	0.198	10.241
20.00	02000	0.187	10.428

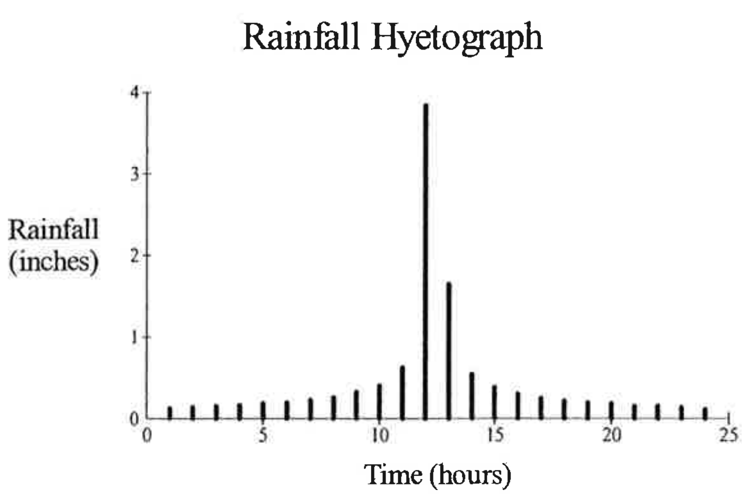
21.00	02100	0.154	10.582
22.00	02200	0.154	10.736
23.00	02300	0.143	10.879
24.00	00000	0.121	11.000

11.00

Rainfall Hyetograph 25-year, 24-hour Storm



Rainfall Hyetograph 100-year, 24-hour Storm



Hydrograph 25-year, 24-hour Storm

Hydrograph Type :SCS 484 Hydrograph

Time	Time	Rain	C Rain	Infiltration	Excess	Excess	Outflow
(hr)	HHMM	(in)	(in)	(in)	(in)	(cfs)	(cfs)
1.000	00100	0.105	0.105	0.105	0.000	0.000	0.000
2.000	00200	0.114	0.219	0.000	0.114	2.626	2.626
3.000	00300	0.123	0.341	0.000	0.123	2.828	2.828
4.000	00400	0.131	0.473	0.000	0.131	3.030	3.030
5.000	00500	0.149	0.622	0.000	0.149	3.434	3.434
6.000	00600	0.158	0.779	0.000	0.158	3.637	3.637
7.000	00700	0.184	0.963	0.000	0.184	4.243	4.243
8.000	00800	0.210	1.173	0.000	0.210	4.849	4.849
9.000	00900	0.263	1.436	0.000	0.263	6.061	6.061
10.00	01000	0.324	1.760	0.000	0.324	7.475	7.475
11.00	01100	0.499	2.259	0.000	0.499	11.516	11.516
12.00	01200	3.056	5.315	0.000	3.056	70.508	70.508
13.00	01300	1.313	6.628	0.000	1.313	30.304	30.304
14.00	01400	0.438	7.066	0.000	0.438	10.101	10.101
15.00	01500	0.306	7.373	0.000	0.306	7.071	7.071
16.00	01600	0.245	7.618	0.000	0.245	5.657	5.657
17.00	01700	0.201	7.819	0.000	0.201	4.647	4.647
18.00	01800	0.175	7.994	0.000	0.175	4.041	4.041
19.00	01900	0.158	8.152	0.000	0.158	3.637	3.637

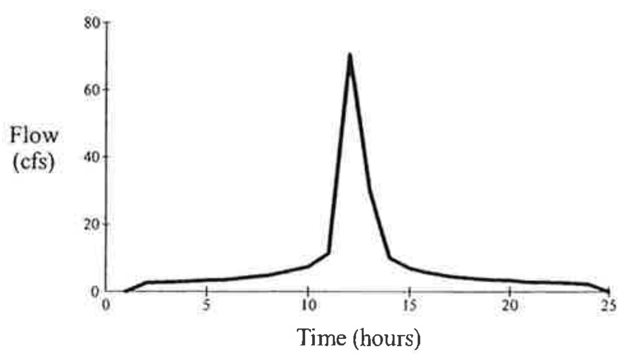
20.00	02000	0.149	8.301	0.000	0.149	3.434	3.434
21.00	02100	0.123	8.423	0.000	0.123	2.828	2.828
22.00	02200	0.123	8.546	0.000	0.123	2.828	2.828
23.00	02300	0.114	8.660	0.000	0.114	2.626	2.626
24.00	00000	0.096	8.756	0.000	0.096	2.222	2.222
25.00	00100	0.000	8.756	0.000	0.000	0.000	0.000

8.756 0.105 8.648 8.648

Totals for Watershed in inches over 22.89 acres

Rational Coefficient = 0.988 Peak Flow (cfs) = 70.51

Watershed Hydrograph



Hydrograph 100-year, 24-hour Storm

Hydrograph Type :SCS 484 Hydrograph

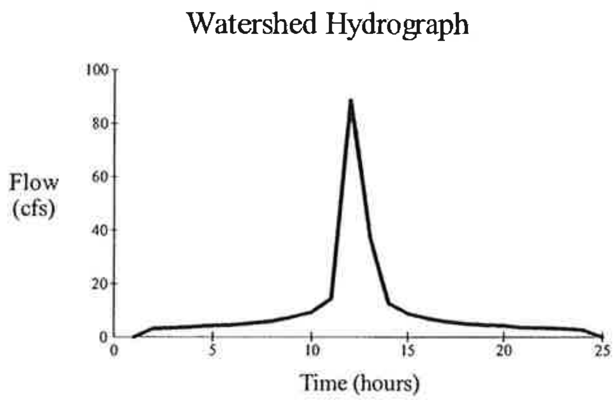
Time (hr)	Time HHMM	Rain (in)	C Rain (in)	Infiltration (in)	Excess (in)	Excess (cfs)	Outflow (cfs)
1.000	00100	0.132	0.132	0.132	0.000	0.000	0.000
2.000	00200	0.143	0.275	0.000	0.143	3.299	3.299
3.000	00300	0.154	0.429	0.000	0.154	3.553	3.553

4.000	00400	0.165	0.594	0.000	0.165	3.807	3.807
5.000	00500	0.187	0.781	0.000	0.187	4.315	4.315
6.000	00600	0.198	0.979	0.000	0.198	4.568	4.568
7.000	00700	0.231	1.210	0.000	0.231	5.330	5.330
8.000	00800	0.264	1.474	0.000	0.264	6.091	6.091
9.000	00900	0.330	1.804	0.000	0.330	7.614	7.614
10.00	01000	0.407	2.211	0.000	0.407	9.391	9.391
11.00	01100	0.627	2.838	0.000	0.627	14.467	14.467
12.00	01200	3.839	6.677	0.000	3.839	88.578	88.578
13.00	01300	1.650	8.327	0.000	1.650	38.071	38.071
14.00	01400	0.550	8.877	0.000	0.550	12.690	12.690
15.00	01500	0.385	9.262	0.000	0.385	8.883	8.883
16.00	01600	0.308	9.570	0.000	0.308	7.107	7.107
17.00	01700	0.253	9.823	0.000	0.253	5.837	5.837
18.00	01800	0.220	10.043	0.000	0.220	5.076	5.076
19.00	01900	0.198	10.241	0.000	0.198	4.568	4.568
20.00	02000	0.187	10.428	0.000	0.187	4.315	4.315
21.00	02100	0.154	10.582	0.000	0.154	3.553	3.553
22.00	02200	0.154	10.736	0.000	0.154	3.553	3.553
23.00	02300	0.143	10.879	0.000	0.143	3.299	3.299
24.00	00000	0.121	11.000	0.000	0.121	2.792	2.792
25.00	00100	0.000	11.000	0.000	0.000	0.000	0.000

11.000	0.132	10.864	10.86

Totals for Watershed in inches over 22.89 acres

Rational Coefficient = 0.988   Peak Flow (cfs) = 88.58



25-year, 24-hour Routing

Time (hr)	Inflow (cfs)	Outflow (cfs)	Stage (ft)	Storage (ac-ft)
1.00	0.00	0.00	92.00	0.00
2.00	2.63	0.00	92.00	0.00
3.00	2.83	0.00	92.00	0.01
4.00	3.03	0.00	92.00	0.01
5.00	3.44	0.00	92.00	0.00
6.00	3.64	0.00	92.00	0.00
7.00	4.24	0.00	92.00	0.01
8.00	4.85	0.00	92.00	0.00
9.00	6.06	0.00	92.00	0.00
10.00	7.48	0.00	92.00	0.00
11.00	11.52	0.00	92.02	0.16
12.00	70.52	0.00	92.46	4.66
13.00	30.31	0.00	92.66	6.65
14.00	10.10	0.00	92.67	6.80

15.00	7.07	0.00	92.65	6.56
16.00	5.66	0.00	92.61	6.20
17.00	4.65	0.00	92.57	5.74
18.00	4.04	0.00	92.52	5.23
19.00	3.64	0.00	92.46	4.69
20.00	3.44	0.00	92.41	4.13
21.00	2.83	0.00	92.35	3.53
22.00	2.83	0.00	92.29	2.92
23.00	2.63	0.00	92.23	2.30
24.00	2.22	0.00	92.16	1.64
25.00	0.00	0.00	92.08	0.82
26.00	0.00	0.00	92.00	0.00
27.00	0.00	0.00	92.00	0.00
28.00	0.00	0.00	92.00	0.00
29.00	0.00	0.00	92.00	0.00
30.00	0.00	0.00	92.00	0.00
31.00	0.00	0.00	92.00	0.00
Max:	70.52	0.00	92.67	6.80

Initial Pond Volume : 000.000 ac-ft

+

Total Inflow Volume : 016.500 ac-ft

-

Total Outflow Volume : 000.000 ac-ft

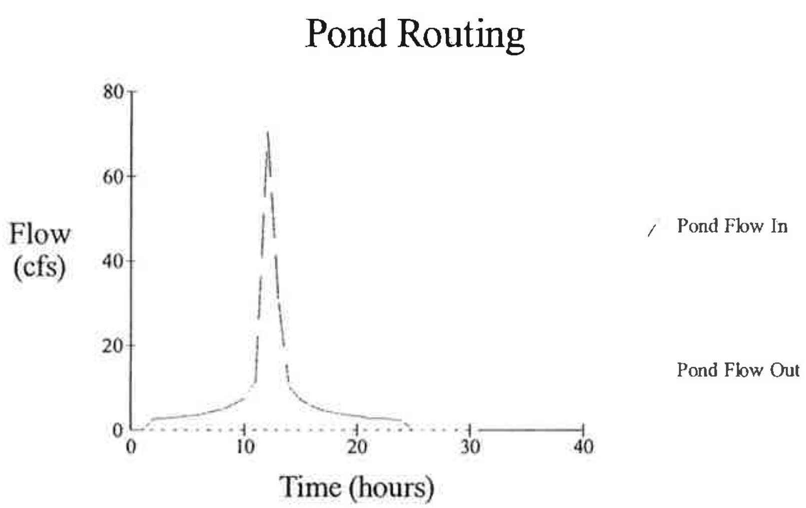
Total Percolation Volume : 016.517 ac-ft

=

Final Pond Volume (stage): 000.000 ac-ft

Final Pond Volume (calc) : -000.017 ac-ft

Difference (error) : 000.017 ac-ft



100-year, 24-hour Routing

Time (hr)	Inflow (cfs)	Outflow (cfs)	Stage (ft)	Storage (ac-ft)
1.00	0.00	0.00	92.00	0.00
2.00	3.30	0.00	92.00	0.00
3.00	3.55	0.00	92.00	0.00
4.00	3.81	0.00	92.00	0.01
5.00	4.31	0.00	92.00	0.03

6.00	4.57	0.00	92.00	0.00
7.00	5.33	0.00	92.00	0.00
8.00	6.09	0.00	92.00	0.00
9.00	7.61	0.00	92.00	0.02
10.00	9.39	0.00	92.00	0.03
11.00	14.47	0.00	92.03	0.35
12.00	88.58	0.00	92.61	6.21
13.00	38.07	0.00	92.88	8.93
14.00	12.69	0.00	92.92	9.33
15.00	8.88	0.00	92.91	9.25
16.00	7.11	0.00	92.89	9.00
17.00	5.84	0.00	92.85	8.64
18.00	5.08	0.00	92.81	8.22
19.00	4.57	0.00	92.76	7.75
20.00	4.31	0.00	92.72	7.26
21.00	3.55	0.00	92.66	6.71
22.00	3.55	0.00	92.61	6.16
23.00	3.30	0.00	92.55	5.59
24.00	2.79	0.00	92.49	4.97
25.00	0.00	0.00	92.41	4.15
26.00	0.00	0.00	92.33	3.31
27.00	0.00	0.00	92.24	2.47
28.00	0.00	0.00	92.16	1.63
29.00	0.00	0.00	92.08	0.79
30.00	0.00	0.00	92.00	0.00

31.00	0.00	0.00	92.00	0.00

Max:	88.58	0.00	92.92	9.33

Initial Pond Volume : 000.000 ac-ft

+

Total Inflow Volume : 020.724 ac-ft

-

Total Outflow Volume : 000.000 ac-ft

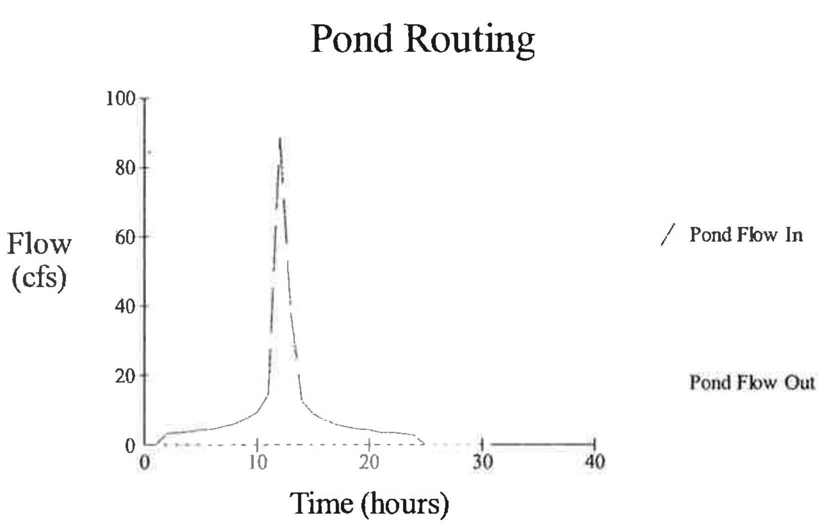
Total Percolation Volume : 020.777 ac-ft

=

Final Pond Volume (stage): 000.000 ac-ft

Final Pond Volume (calc) : -000.053 ac-ft

Difference (error) : 000.053 ac-ft



PURPOSE

The purpose of this calculation package is to design the culvert to convey runoff from area east of the FGD Pond to the area west of the FGD pond at Crystal River Energy Complex (CREC).

AREAS

The watershed east of the FGD Pond is approximately 2.6 acres. The watershed is shown in Attachment 1. The watershed was assumed to be impervious.

TIME OF CONCENTRATION

The flow path (750 feet) for the time of concentration has a slope of 0.67% (0.0067 ft/ft). It is assumed that the first 300 feet is under sheet flow regime and the remaining 450 feet is under shallow concentration flow. The Manning's roughness coefficient was estimated at n=0.011 (gravel) for sheet flow and the mid-point between paved and unpaved is used for shallow concentration flow conditions. The time of concentration is presented in Attachment 2. The time of concentration was calculated at 8.6 minutes.

STORMWATER DISCHARGE

Stormwater discharges are estimated using the software package SMADA Version 6.43 for Windows written by Dr. R. D. Eaglin of the University of Central Florida. The program uses procedures presented in the Soil Conservation Service's TR-55 (SCS TR-55, 1986).

Stormwater runoff was calculated for a 100-yr return period and 24-hr duration design storm.

The peak discharge for the stormwater discharge hydrograph is 18.81 cubic feet per second (cfs).

SMADA program inputs and outputs are presented in Attachment 3.

CULVERT SELECTION

A culvert will be installed to convey stormwater from the area east of the FGD pond to an area west of the pond. The culvert location is shown in Attachment 1. The length of the culvert is 154 feet and the slope is 0.65% (0.0065 ft/ft).

Hancor HDPE corrugated exterior and smooth interior pipe as selected for the culvert. Based on the design peak discharge of 19 cfs and the slope of 0.65%, a minimum 24-inch diameter pipe was selected (see Attachment 4).

The inlet and outlet controls were checked using the charts and table presented in Attachment 5.

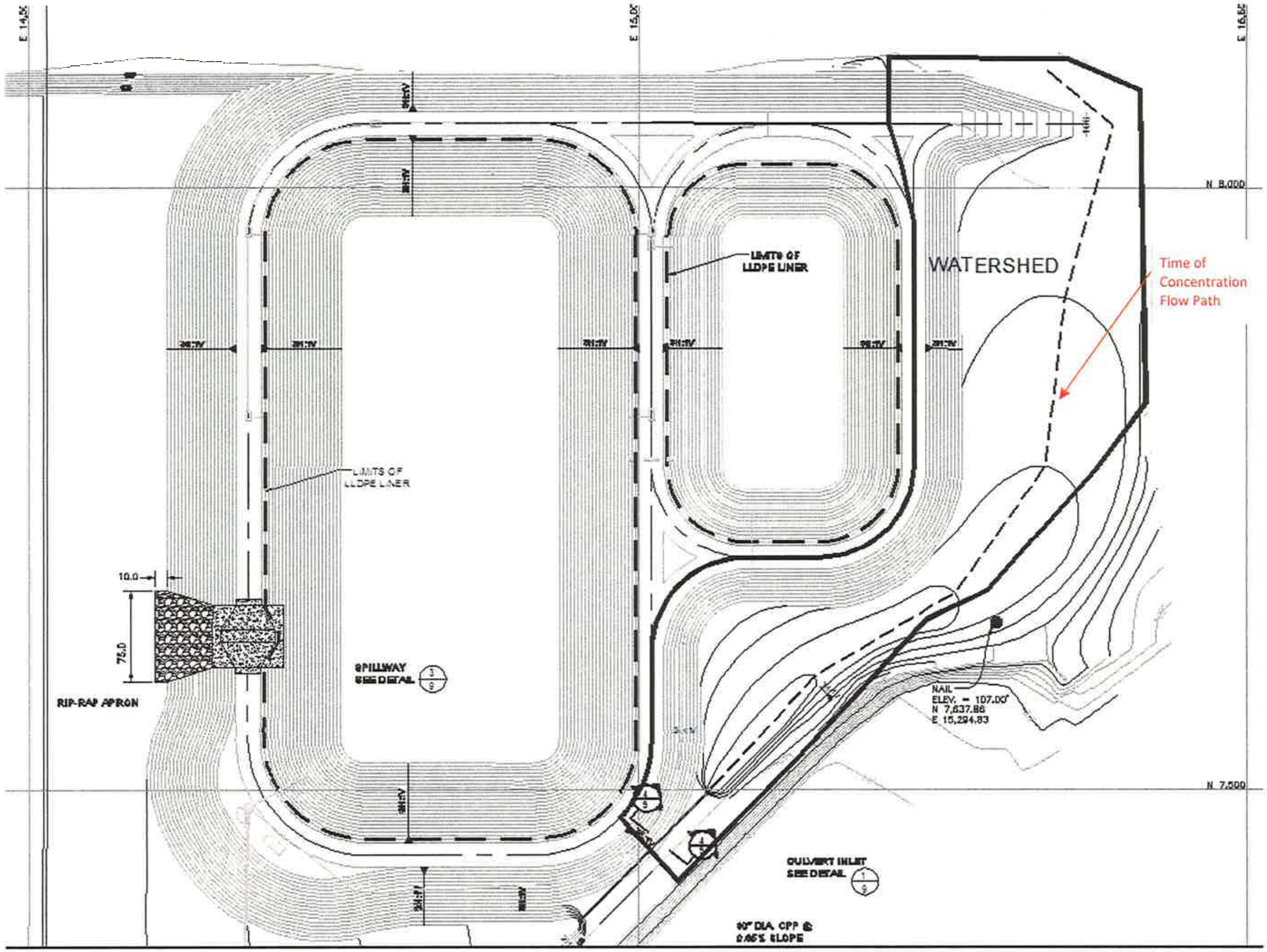
REFERENCES

Soil Conservation Service, 1986, Urban Hydrology for Small Watersheds - Technical Release 55

St. Johns River Water Management District, 2001, St. Johns Applicant's Handbook - Regulation of Stormwater Management Systems

Malcom, H. Rooney, 1989; Elements of Urban Stormwater Design; North Carolina State University, Raleigh, NC

ATTACHMENT 1



E 14,500
E 15,000
E 16,500
N 8,000
N 7,500
WATERSHED
Time of
Concentration
Flow Path
LIMITS OF
LLDPE LINER
LIMITS OF
LLDPE LINER
10.0
75.0
RIP-RAP APRON
SPILLWAY
SEE DETAIL
NAIL
ELEV. = 107.00'
N 7,637.86
E 15,294.83
CULVERT INLET
SEE DETAIL
10" DIA. CPP @
0.65% SLOPE

3/19

ATTACHMENT 2

Time of Concentration

Project:	PEF CREC FGD POND DESIGN	
Project No.:	093-82538	

Sheet flow (maximum 300 feet)

Flow length (ft)	L=	**300**
P for 2-year 24 hour storm (in)	P2=	**5**
Land slope (ft/ft)	s=	**0.0067**
Manning's roughness coefficient for sheet flow	n=	**0.011**
Tc sheet flow = 0.007*(n*L)^0.8/(P2^0.5*s^0.4)	Tc=	0.060 hour

Shallow concentrated flow

Flow length (ft)	L=	**450**
Water Course slope (ft/ft)	s=	**0.0067**
Average velocity (ft/s) from chart	v=	**1.5**
Tc shallow concentrated flow = L/(v*3600)	Tc=	0.083 hour

Tc total =	**Tc=**	**0.14** hour **8.6** minutes

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Figure 3-1 Average velocities for estimating travel time for shallow concentrated flow

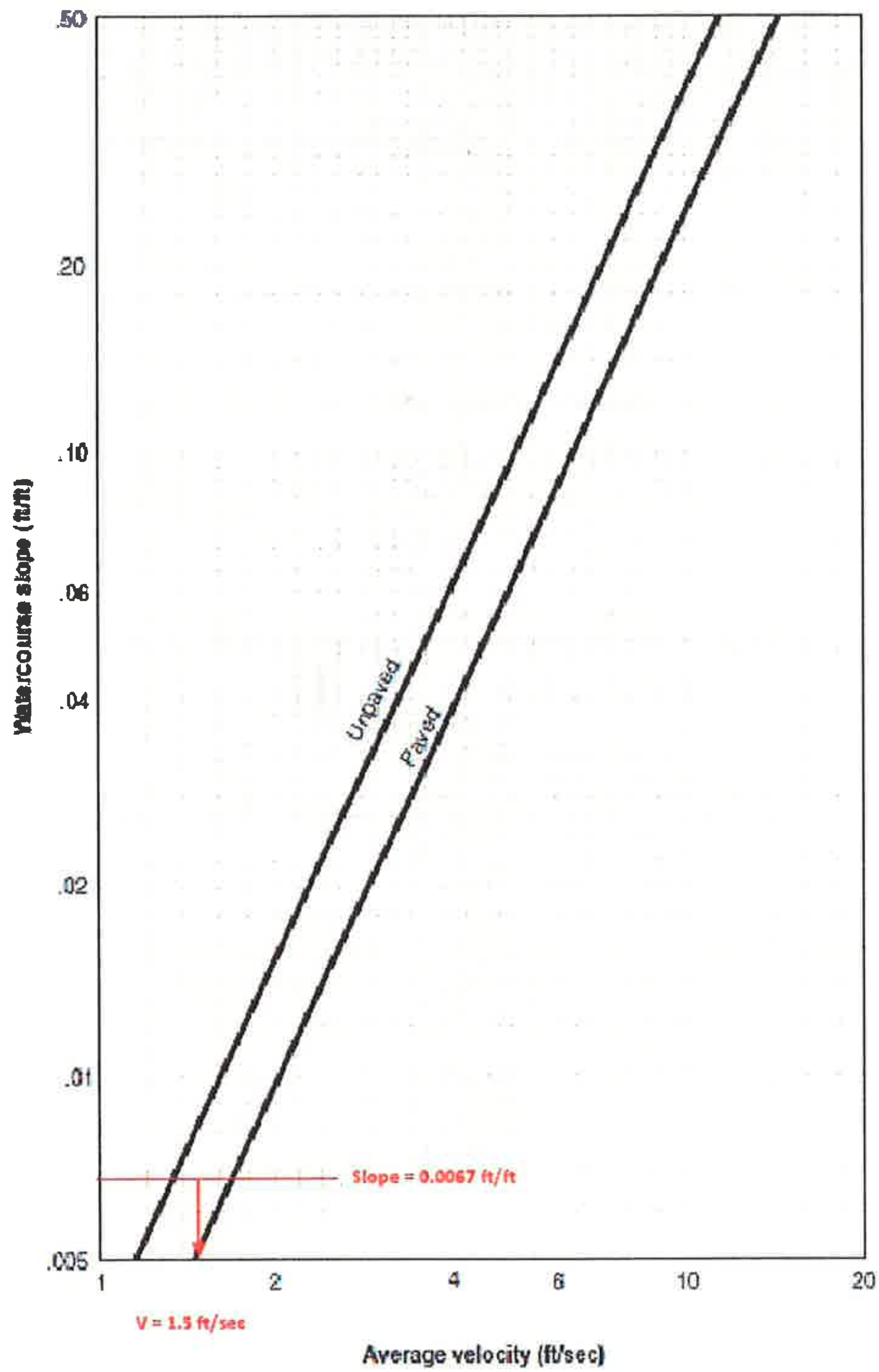
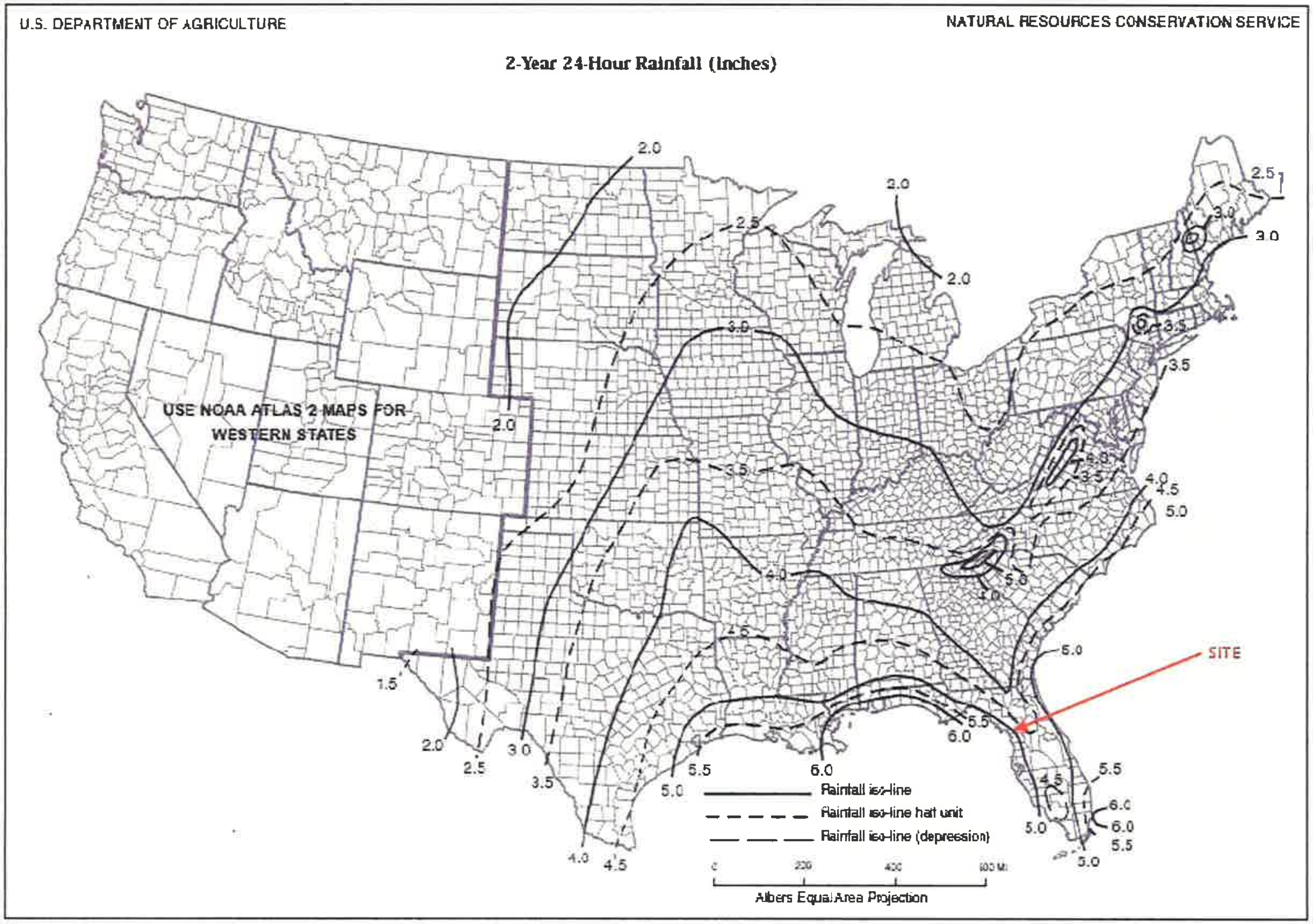


Figure B-3 2-year, 24-hr rainfall



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ATTACHMENT 3

SMADA PROGRAM OUTPUTS

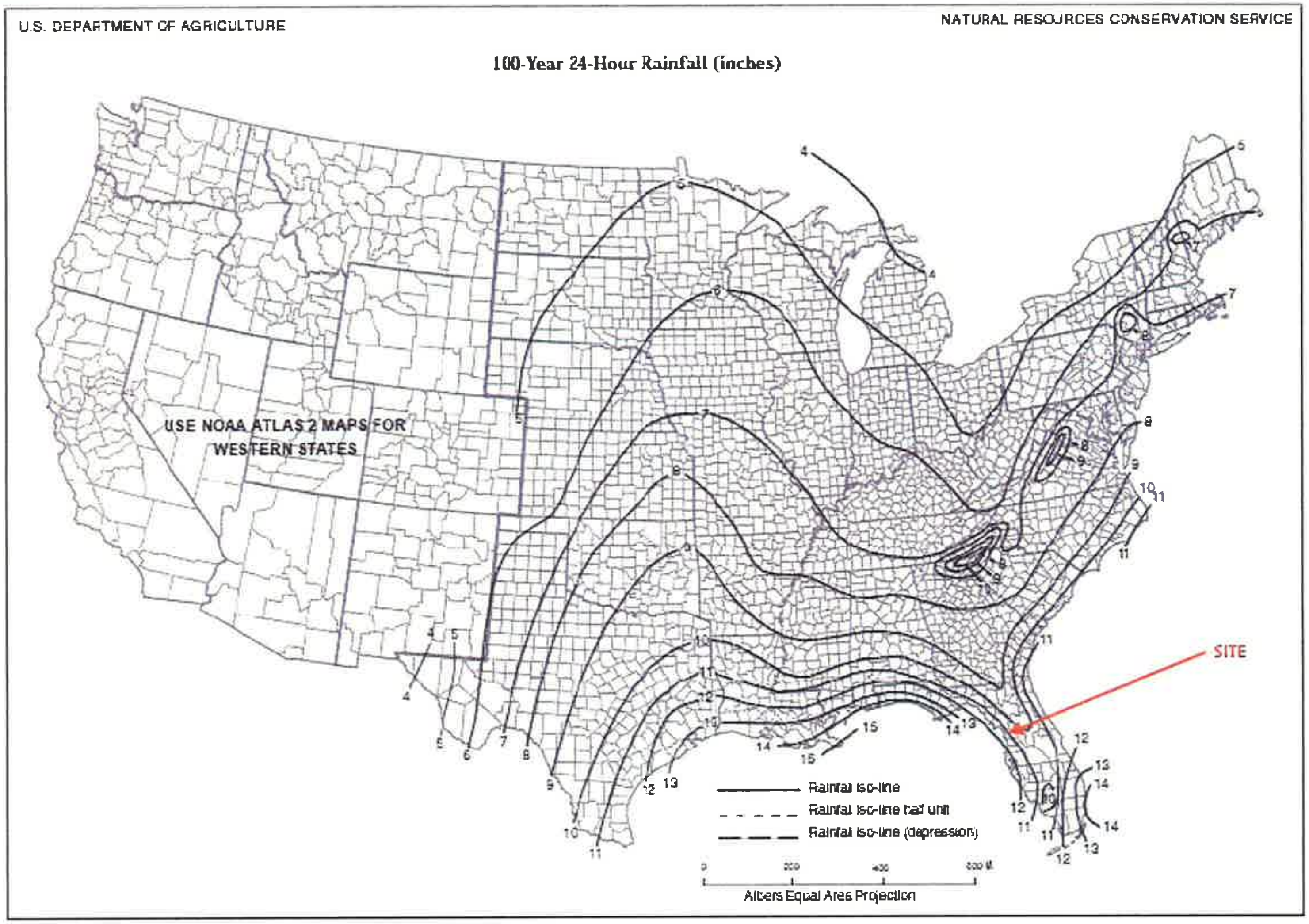
```
       SMADA 6.0 for Windows
          Watershed Information

Watershed Total Area (acres)      :2.60
Impervious Area (acres)           :2.60
Time of Concentration (min)       :8.6
% Impervious Directly Connected   :100.00

     Additional Abstraction
Over Pervious Area (inches)       :0.00
Over Impervious Area (inches)     :0.00

Infiltration Characteristics:
Max Infiltration Capacity (in)    :0.00
SCS Curve Number for Pervious     :98
Initial Abstraction Factor        :0.20
```

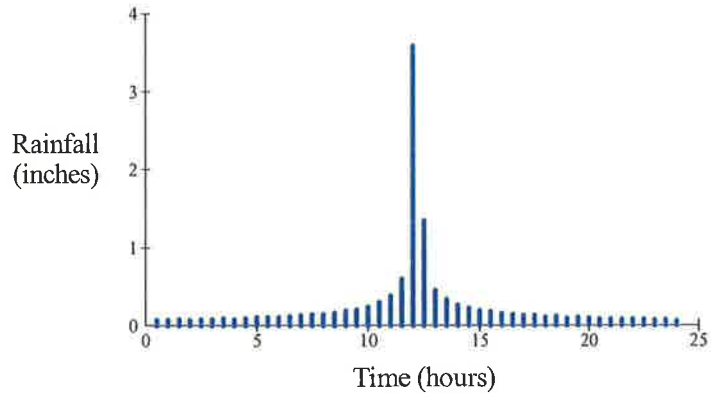
Figure B-8 100-year, 24-hour rainfall



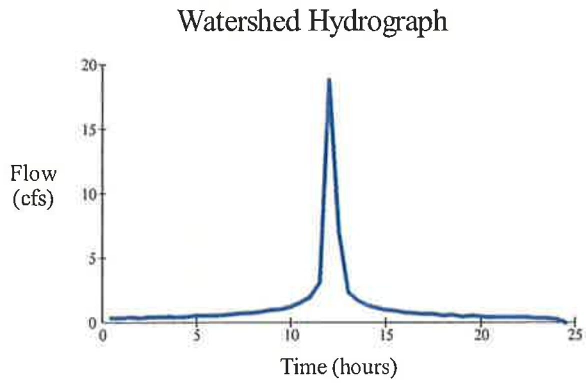
10/19

11/19

Rainfall Hyetograph



Time (hr)	Time HHMM	Rain (in)	Cumulative (in)
0.500	00030	0.072	0.072
1.000	00100	0.072	0.144
1.500	00130	0.084	0.228
2.000	00200	0.072	0.300
2.500	00230	0.084	0.384
3.000	00300	0.084	0.468
3.500	00330	0.096	0.564
4.000	00400	0.084	0.648
4.500	00430	0.096	0.744
5.000	00500	0.108	0.852
5.500	00530	0.108	0.960
6.000	00600	0.108	1.068
6.500	00630	0.120	1.188
7.000	00700	0.132	1.320
7.500	00730	0.144	1.464
8.000	00800	0.144	1.608
8.500	00830	0.168	1.776
9.000	00900	0.192	1.968
9.500	00930	0.204	2.172
10.00	01000	0.240	2.412
10.50	01030	0.300	2.712
11.00	01100	0.384	3.096
11.50	01130	0.600	3.696
12.00	01200	3.588	7.284
12.50	01230	1.344	8.628
13.00	01300	0.456	9.084
13.50	01330	0.336	9.420
14.00	01400	0.264	9.684
14.50	01430	0.228	9.912
15.00	01500	0.192	10.104
15.50	01530	0.180	10.284
16.00	01600	0.156	10.440
16.50	01630	0.144	10.584
17.00	01700	0.132	10.716
17.50	01730	0.132	10.848
18.00	01800	0.108	10.956
18.50	01830	0.120	11.076
19.00	01900	0.096	11.172
19.50	01930	0.108	11.280
20.00	02000	0.096	11.376
20.50	02030	0.084	11.460
21.00	02100	0.084	11.544
21.50	02130	0.084	11.628
22.00	02200	0.084	11.712
22.50	02230	0.084	11.796
23.00	02300	0.072	11.868
23.50	02330	0.072	11.940
24.00	00000	0.060	12.000
		12.00	



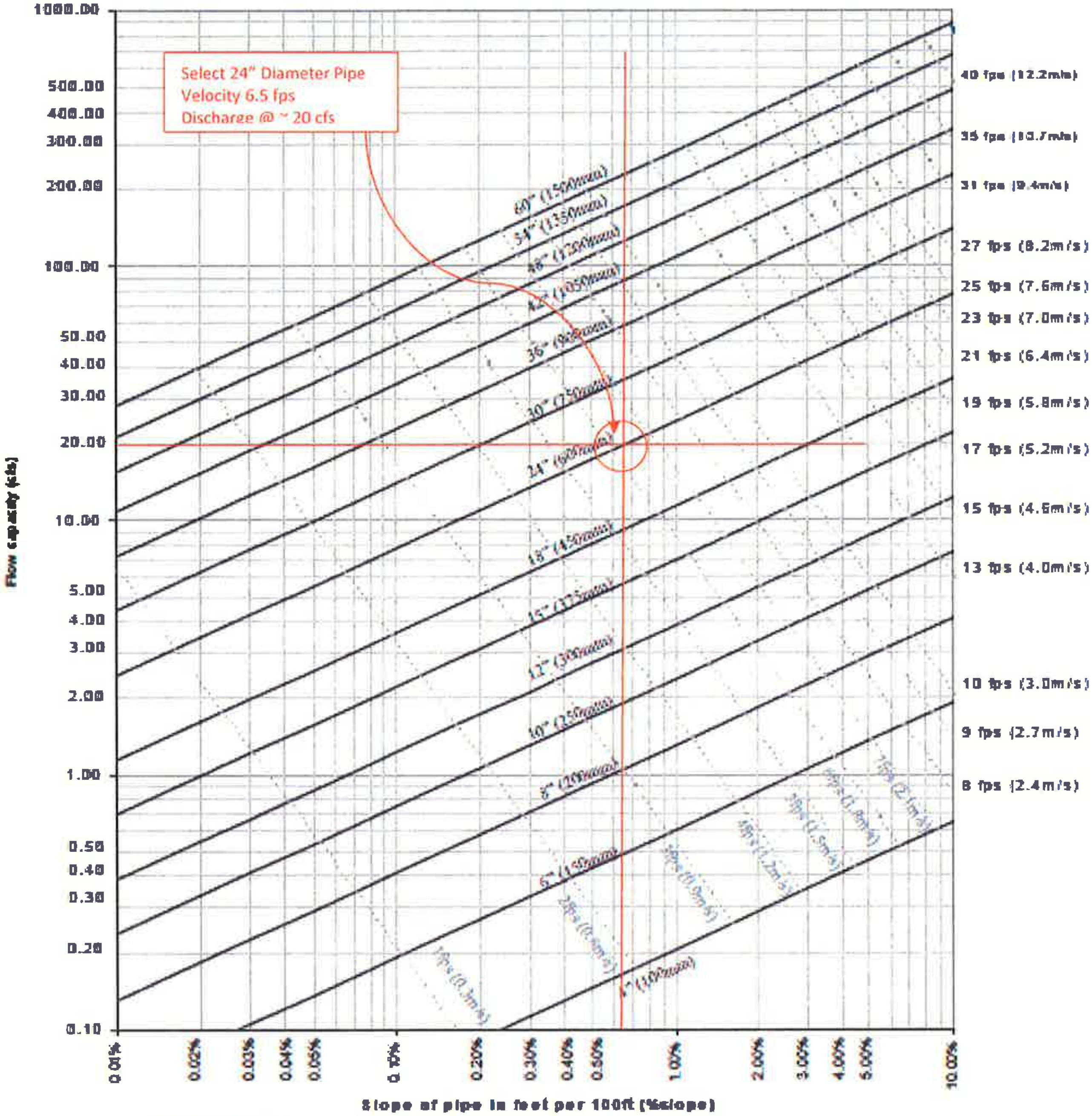
Hydrograph Type :SCS 484 Hydrograph

Time (hr)	Time HHMM	Rain (in)	C Rain (in)	Infiltration (in)	Excess (in)	Excess (cfs)	Outflow (cfs)
0.500	00030	0.072	0.072	0.000	0.072	0.377	0.377
1.000	00100	0.072	0.144	0.000	0.072	0.377	0.377
1.500	00130	0.084	0.228	0.000	0.084	0.440	0.440
2.000	00200	0.072	0.300	0.000	0.072	0.377	0.377
2.500	00230	0.084	0.384	0.000	0.084	0.440	0.440
3.000	00300	0.084	0.468	0.000	0.084	0.440	0.440
3.500	00330	0.096	0.564	0.000	0.096	0.503	0.503
4.000	00400	0.084	0.648	0.000	0.084	0.440	0.440
4.500	00430	0.096	0.744	0.000	0.096	0.503	0.503
5.000	00500	0.108	0.852	0.000	0.108	0.566	0.566
5.500	00530	0.108	0.960	0.000	0.108	0.566	0.566
6.000	00600	0.108	1.068	0.000	0.108	0.566	0.566
6.500	00630	0.120	1.188	0.000	0.120	0.629	0.629
7.000	00700	0.132	1.320	0.000	0.132	0.692	0.692
7.500	00730	0.144	1.464	0.000	0.144	0.755	0.755
8.000	00800	0.144	1.608	0.000	0.144	0.755	0.755
8.500	00830	0.168	1.776	0.000	0.168	0.881	0.881
9.000	00900	0.192	1.968	0.000	0.192	1.006	1.006
9.500	00930	0.204	2.172	0.000	0.204	1.069	1.069
10.00	01000	0.240	2.412	0.000	0.240	1.258	1.258
10.50	01030	0.300	2.712	0.000	0.300	1.572	1.572
11.00	01100	0.384	3.096	0.000	0.384	2.013	2.013
11.50	01130	0.600	3.696	0.000	0.600	3.145	3.145
12.00	01200	3.588	7.284	0.000	3.588	18.807	18.807
12.50	01230	1.344	8.628	0.000	1.344	7.045	7.045
13.00	01300	0.456	9.084	0.000	0.456	2.390	2.390
13.50	01330	0.336	9.420	0.000	0.336	1.761	1.761
14.00	01400	0.264	9.684	0.000	0.264	1.384	1.384
14.50	01430	0.228	9.912	0.000	0.228	1.195	1.195
15.00	01500	0.192	10.104	0.000	0.192	1.006	1.006
15.50	01530	0.180	10.284	0.000	0.180	0.943	0.943
16.00	01600	0.156	10.440	0.000	0.156	0.818	0.818
16.50	01630	0.144	10.584	0.000	0.144	0.755	0.755
17.00	01700	0.132	10.716	0.000	0.132	0.692	0.692
17.50	01730	0.132	10.848	0.000	0.132	0.692	0.692
18.00	01800	0.108	10.956	0.000	0.108	0.566	0.566
18.50	01830	0.120	11.076	0.000	0.120	0.629	0.629
19.00	01900	0.096	11.172	0.000	0.096	0.503	0.503
19.50	01930	0.108	11.280	0.000	0.108	0.566	0.566
20.00	02000	0.096	11.376	0.000	0.096	0.503	0.503
20.50	02030	0.084	11.460	0.000	0.084	0.440	0.440
21.00	02100	0.084	11.544	0.000	0.084	0.440	0.440
21.50	02130	0.084	11.628	0.000	0.084	0.440	0.440
22.00	02200	0.084	11.712	0.000	0.084	0.440	0.440
22.50	02230	0.084	11.796	0.000	0.084	0.440	0.440
23.00	02300	0.072	11.868	0.000	0.072	0.377	0.377
23.50	02330	0.072	11.940	0.000	0.072	0.377	0.377
24.00	00000	0.060	12.000	0.000	0.060	0.314	0.314
24.50	00030	0.000	12.000	0.000	0.000	0.000	0.000
			12.000	0.000	11.996	11.99	

Totals for Watershed in inches over 2.60 acres
Rational Coefficient = 1.000 Peak Flow (cfs) = 18.81

ATTACHMENT 4

Figure 3-1
Discharge Rates for Hancor Hi-Q®, Sure-Lok® ST, BLUE SEAL® Pipe Products



1cfs = 0.02832 m³/s
1ft/s = 0.30480 m/s
1% = 0.01 ft/ft

Note: Based on a design Manning's "n" of 0.012.
Solid lines indicate pipe diameters. Dashed lines indicate approximate flow velocity.
Redeveloped from FHWA HDS 3 – Design Charts for Open-Channel Flow[2]

ATTACHMENT 5

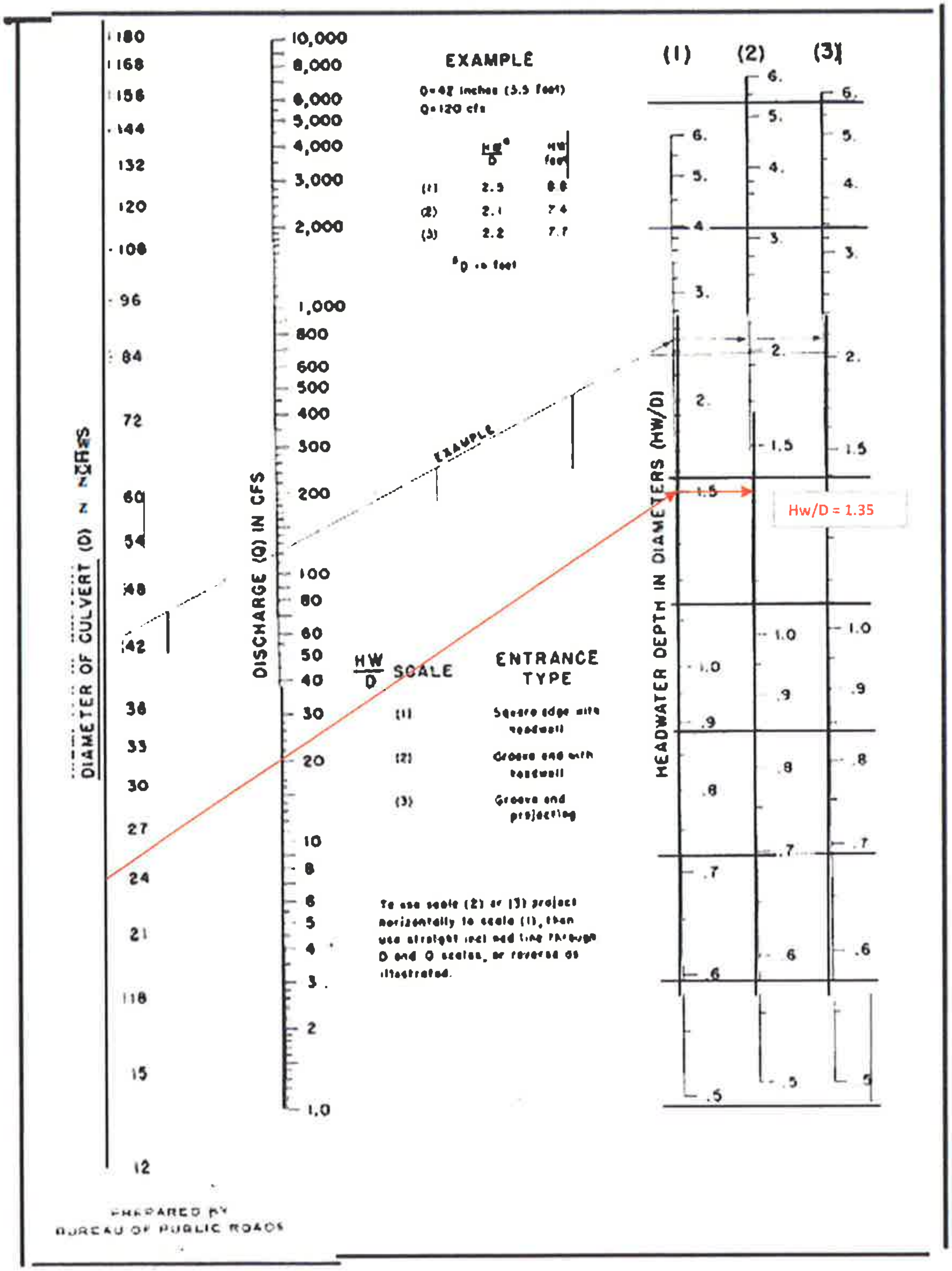


Figure B 2. Headwater depth for concrete pipe culverts with inlet control.

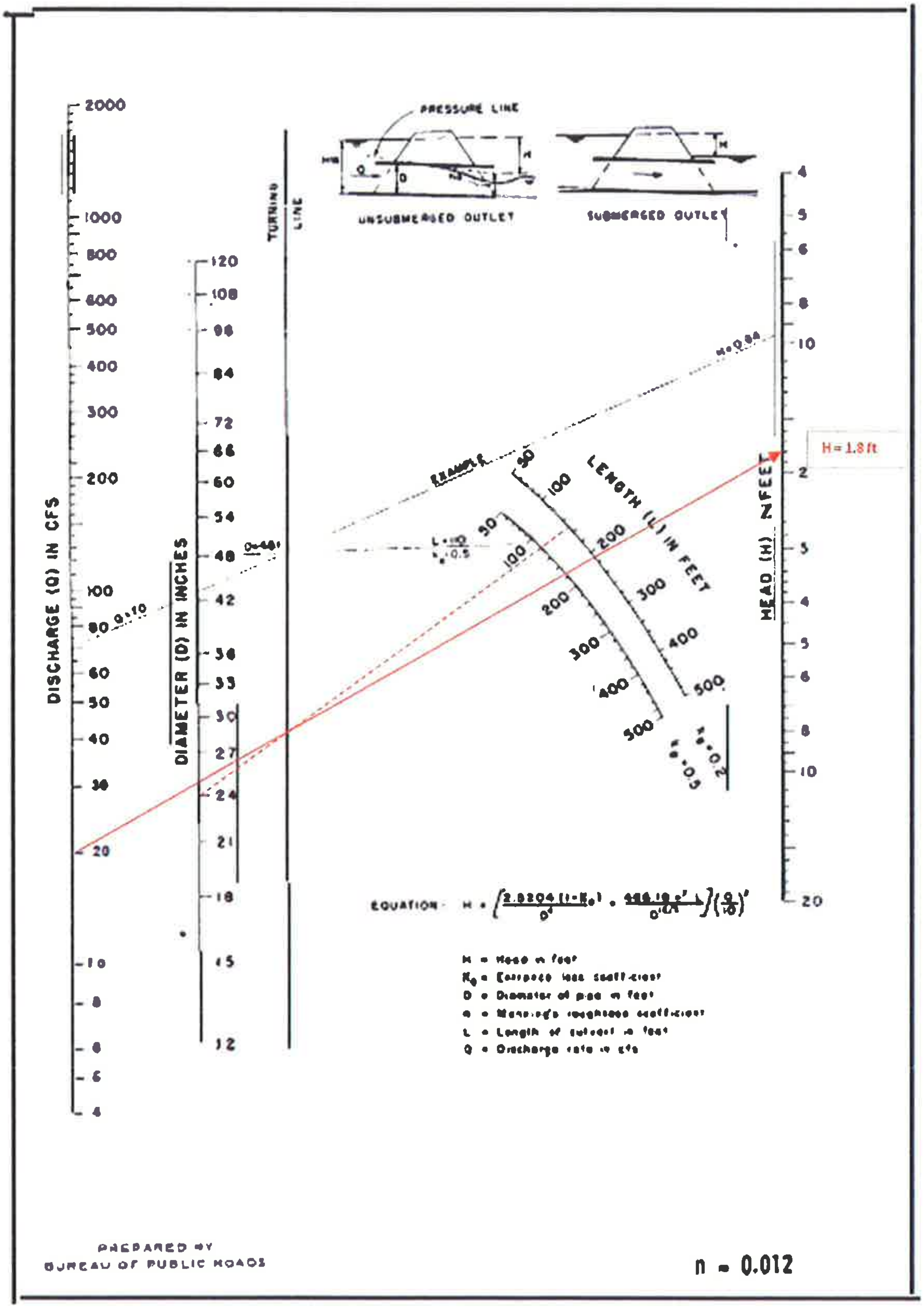


Figure B-11. Head for circular pipe culverts flowing full, n = 0.012.

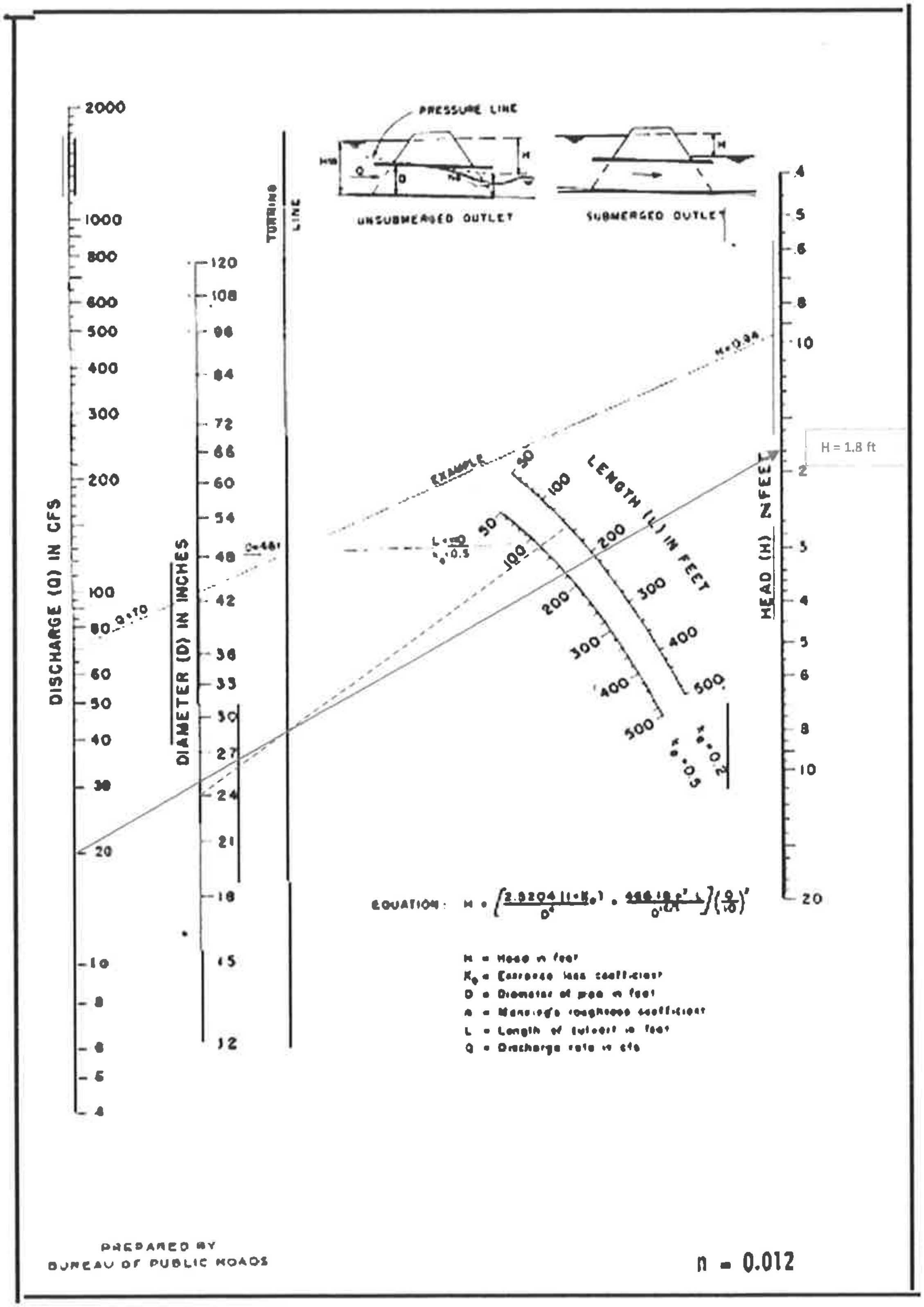


Figure B-11. Head for circular pipe culverts flowing full, n = 0.012.

CULVERT SIZING

													Inlet Control				Outlet Control						
Culvert ID	Inlet Invert Elevation (feet)	Inlet Berm Elevation (feet)	Outlet Invert Elevation (feet)	Outlet Berm Elevation (feet)	Tailwater Elevation (feet)	Peak Flow (cfs)	Number of Culverts	Culvert Size (B x D) (inches)	Design Flow each (cfs)	Total Design Flow (cfs)	Culvert Length (feet)	Culvert Slope	hw/D	D (ft)	Inlet Hw (ft)	Inlet Headwater Elevation	H (ft)	ho (ft)	Outlet Hw (ft)	Outlet Headwater Elevation	Type of Control	Freeboard (feet)	Check
E FGD	102.00	106.00	101.00	105.00	101.50	34.0	1	24	20	20	154	0.65%	1.35	2.00	2.70	104.70	1.80	0.50	1.30	103.30	Inlet	1.30	OK

Hw/D - from inlet control nomograph
Inlet Control Hw = Hw/D * D
H - from outlet control nomograph
Outlet Control Hw = H + ho - Length*slope

OBJECTIVE: To verify that the Factor of Safety (F.S.) of the embankment slope is greater than 1.5 given the assumptions and methodologies below:

METHOD: Bishop's simplified method using Slide 5.029.

REFERENCE: Slide version 5.029 by Rocscience Inc.

GEOMETRY: See Figures 1 and 2 for geometry during construction and after construction, respectively.

ASSUMPTIONS:

1) There is no water or waste in the pond during construction.
2) Groundwater is located at elevation 90 ft.
3) Berm has 3-foot horizontal to 1-foot vertical (3:1) slope on both sides of 20-foot wide access road.
4) Top of berm is located at elevation 116 ft.
5) Bottom of interior pond located at elevation 94 ft.
6) Reinforcing geotextile is located at elevation 92 ft over the entire footprint of the pond extending approximately 25-feet past the exterior toe of the berm. Interface shear strength is based on testing of site soils and a high-strength geotextile that is similar to that which will be used on the project.
7) Pond and interior slope of berm are lined with textured LLDPE 60-mil thick.
8) In-place material (above natural ground weathered limestone) is 4-feet thick.
9) Loadings on the access road at the top of the slope may not exceed 2,000 psf as shown on Figure 2.
10) Embankments of this type are typically analyzed for significant circular failure.
11) Vertical and horizontal datums are plant specific.
12) Shear testing results for the reinforcing geotextile is provided in Appendix B.
13) See Appendix A - "Slide Analysis Information (Surfaces A through D)" for material property assumptions, support properties and listing of boundary coordinates used in computations.

CALCULATIONS:

See Figures 1 and 2 for results, and Appendix A for computations.

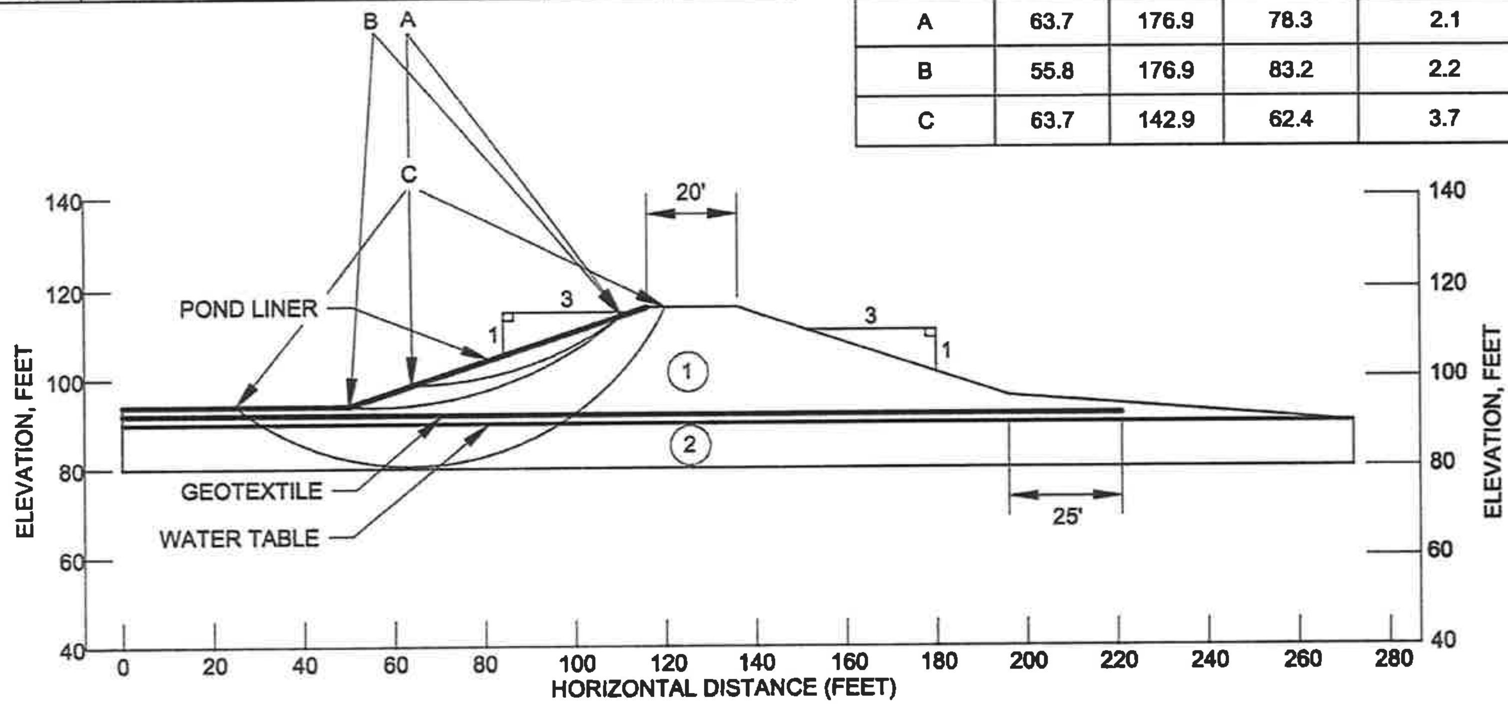
CONCLUSIONS:

Using the assumptions and methodologies provided above, it was determined that, under those conditions, the embankment slope has a minimum F.S. of 2.1 against a significant circular slope failure, which exceeds the 1.5 minimum.

FIGURES

MATERIAL PROPERTIES				
SOIL TYPE	DESCRIPTION	SOIL STRENGTH		UNIT WEIGHT (pcf)
		C (psf)	Phi	
1	COMPACTED FILL	0	34	110
2	WEATHERED LIMESTONE	102.5	36	120

RESULTS OF STABILITY ANALYSIS				
FAILURE SURFACE	CIRCLE CENTER		CIRCLE RADIUS	FACTOR OF SAFETY
	X	Y		
A	63.7	176.9	78.3	2.1
B	55.8	176.9	83.2	2.2
C	63.7	142.9	62.4	3.7



NOTES

1.) FACTORS OF SAFETY ARE CACLUATED USING BISHOP'S SIMPLIFIED METHOD IN SLIDE 5.029.

0 20 40
SCALE: 1" = 40'

PROJECT
CRYSTAL RIVER UNIT 4 AND 5
FGD BLOWDOWN POND
CRYSTAL RIVER, FLORIDA

TITLE
SLOPE STABILITY ANALYSES DURING CONSTRUCTION

Golder Associates
Tampa, Florida

PROJECT No.		093-82538
DESIGN	JJB	4/22/09
CADD	JJB	4/22/09
CHECK	JJB	4/23/09
REVIEW	TDA	4/23/09

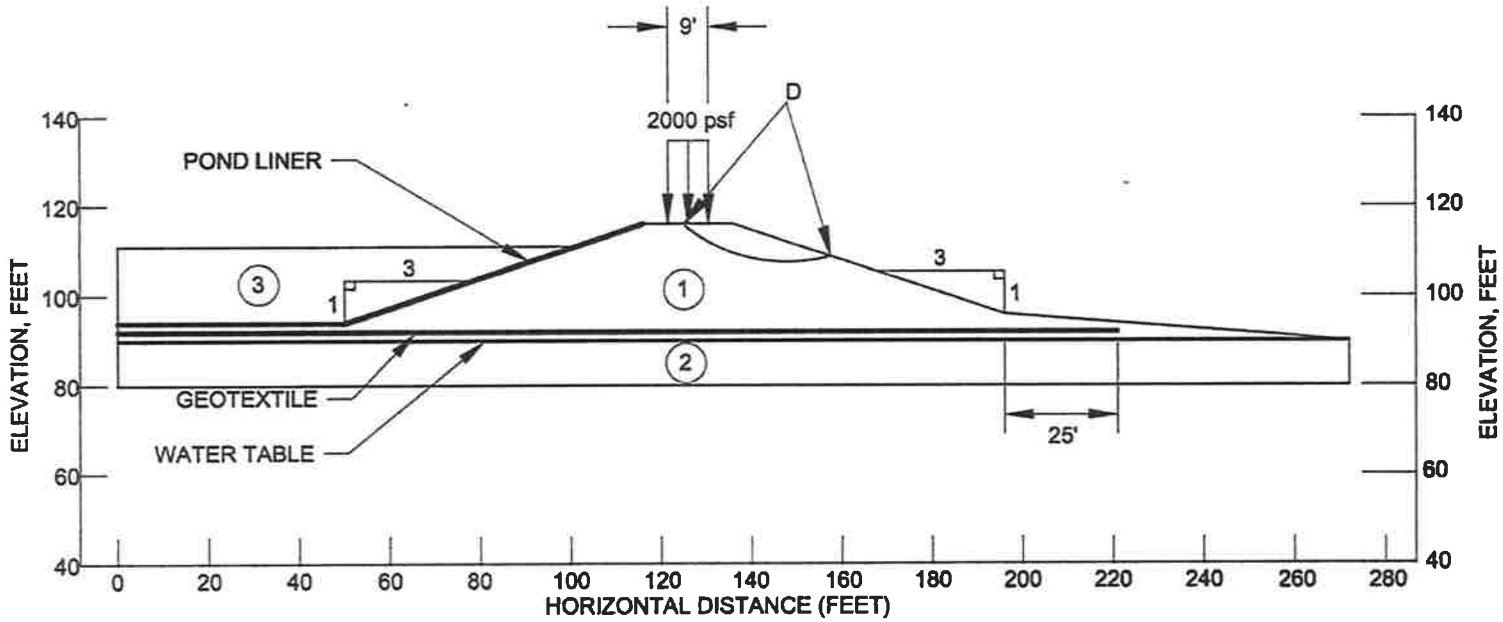
FILE No.
SCALE AS SHOWN REV. 0

FIGURE 1

Drawing file: 093-82538A002.dwg May 28, 2009 - 2:29pm

MATERIAL PROPERTIES				
SOIL TYPE	DESCRIPTION	SOIL STRENGTH		UNIT WEIGHT (pcf)
		C (psf)	Phi	
1	COMPACTED FILL	0	34	110
2	WEATHERED LIMESTONE	102.5	36	120
3	WASTE	0	0	100

RESULTS OF STABILITY ANALYSIS				
FAILURE SURFACE	CIRCLE CENTER		CIRCLE RADIUS	FACTOR OF SAFETY
	X	Y		
D	147.9	143.1	35.6	1.8



NOTES

1.) FACTORS OF SAFETY ARE CACLUATED USING BISHOP'S SIMPLIFIED METHOD IN SLIDE 5.029.

0 20 40
SCALE: 1" = 40'

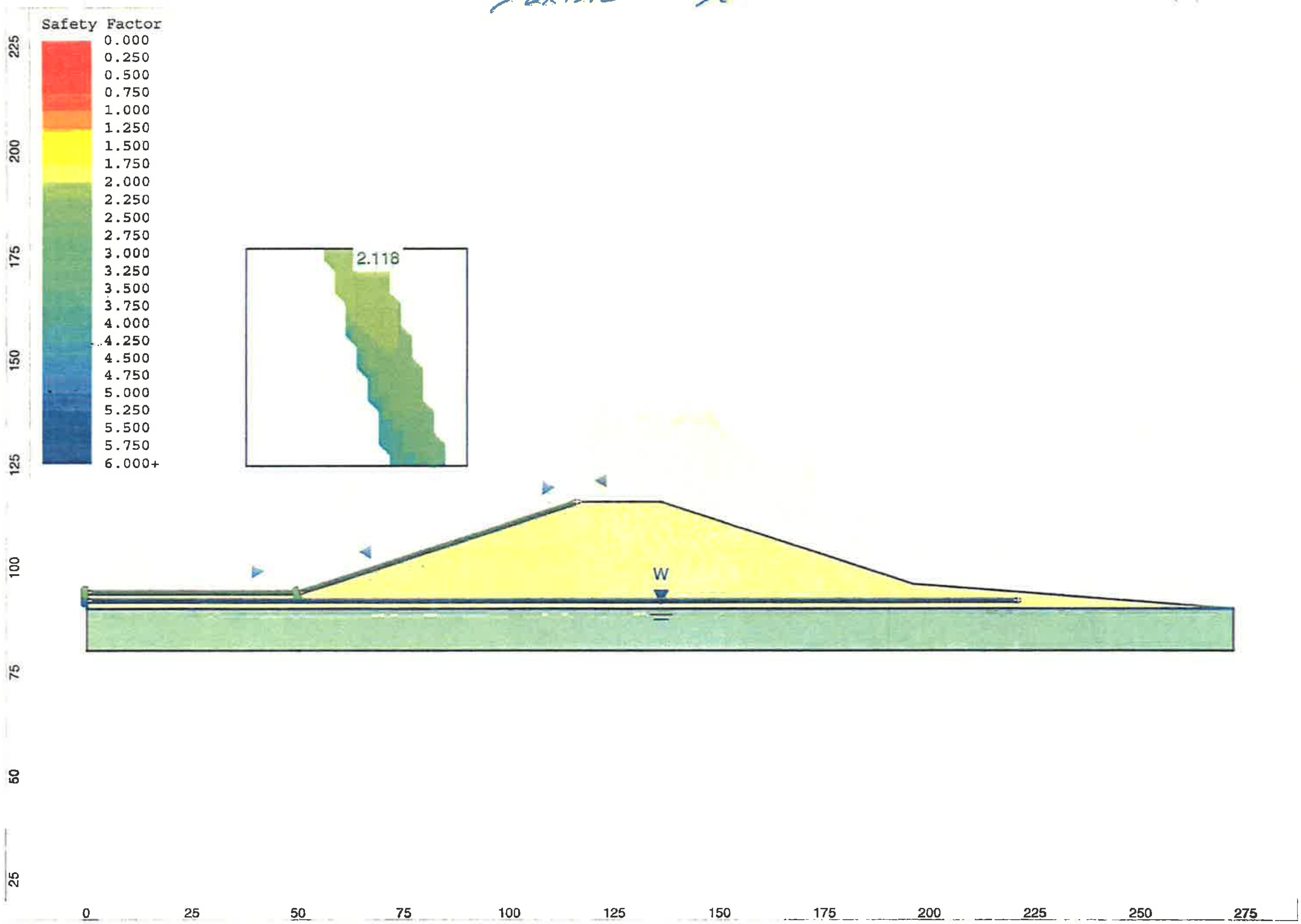
PROJECT	CRYSTAL RIVER UNIT 4 AND 5 FGD BLOWDOWN POND CRYSTAL RIVER, FLORIDA
TITLE	**SLOPE STABILITY ANALYSES POST CONSTRUCTION**

Golder Associates
Tampa, Florida

PROJECT No.		093-82538	FILE No.
DESIGN	JJB	4/22/09	SCALE AS SHOWN REV. 0
CADD	JJB	4/22/09	
CHECK	JJB	4/23/09	**FIGURE 2**
REVIEW	TDA	4/23/09	

APPENDIX A
SLIDE ANALYSIS INFORMATION
(SURFACES A THROUGH D)

Surfall - A



Safety Factor
0.000
0.250
0.500
0.750
1.000
1.250
1.500
1.750
2.000
2.250
2.500
2.750
3.000
3.250
3.500
3.750
4.000
4.250
4.500
4.750
5.000
5.250
5.500
5.750
6.000+
2.118
W
225
200
175
150
125
100
75
50
25
0
25
50
75
100
125
150
175
200
225
250
275

Slide Analysis Information

Document Name

File Name: 093-82538_Surface A.sli

Project Settings

Project Title: 093-82538 - Crystal River
Failure Direction: Right to Left
Units of Measurement: Imperial Units
Pore Fluid Unit Weight: 100 lb/ft3
Groundwater Method: Water Surfaces
Data Output: Standard
Calculate Excess Pore Pressure: Off
Allow Ru with Water Surfaces or Grids: Off
Random Numbers: Pseudo-random Seed
Random Number Seed: 10116
Random Number Generation Method: Park and Miller v.3

Analysis Methods

Analysis Methods used:
Bishop simplified
Janbu simplified

Number of slices: 25
Tolerance: 0.005
Maximum number of iterations: 50

Surface Options

Surface Type: Circular
Search Method: Grid Search
Radius increment: 10
Composite Surfaces: Disabled
Reverse Curvature: Create Tension Crack
Minimum Elevation: Not Defined
Minimum Depth: Not Defined

Material Properties

Material: Fill
Strength Type: Mohr-Coulomb
Unit Weight: 110 lb/ft3
Cohesion: 0 psf
Friction Angle: 34 degrees
Water Surface: Water Table
Custom Hu value: 1

Material: Natural Ground (Weathered Limestone)
Strength Type: Mohr-Coulomb
Unit Weight: 120 lb/ft3

Cohesion: 102.5 psf
Friction Angle: 36 degrees
Water Surface: Water Table
Custom Hu value: 1

Support Properties

Support: TENCATE PET 1000/100 WOVEN GEOTEXTILE
TENCATE PET 1000/100 WOVEN GEOTEXTILE
Support Type: GeoTextile
Force Application: Passive
Force Orientation: Bisector of Parallel and Tangent
Anchorage: Slope Face
Shear Strength Model: Linear
Strip Coverage: 100 percent
Tensile Strength: 33915 lb/ft
Pullout Strength Adhesion: 0 lb/ft2
Pullout Strength Friction Angle: 39 degrees

Support: AGRU - LLDPE 60-mil thick
AGRU - LLDPE 60-mil thick
Support Type: GeoTextile
Force Application: Passive
Force Orientation: Bisector of Parallel and Tangent
Anchorage: Slope Face
Shear Strength Model: Linear
Strip Coverage: 100 percent
Tensile Strength: 2016 lb/ft
Pullout Strength Adhesion: 0 lb/ft2
Pullout Strength Friction Angle: 0 degrees

Global Minimums

Method: bishop simplified
FS: 2.118420
Center: 63.683, 176.895
Radius: 78.311
Left Slip Surface Endpoint: 63.752, 98.584
Right Slip Surface Endpoint: 110.614, 114.205
Resisting Moment=738808 lb-ft
Driving Moment=348755 lb-ft

Method: janbu simplified
FS: 2.070670
Center: 63.683, 176.895
Radius: 78.311
Left Slip Surface Endpoint: 63.752, 98.584
Right Slip Surface Endpoint: 110.614, 114.205
Resisting Horizontal Force=8859.72 lb
Driving Horizontal Force=4278.67 lb

Valid / Invalid Surfaces

Method: bishop simplified
Number of Valid Surfaces: 1419

Number of Invalid Surfaces: 3432
Error Codes:
Error Code -1000 reported for 3432 surfaces

Method: janbu simplified
Number of Valid Surfaces: 1419
Number of Invalid Surfaces: 3432
Error Codes:
Error Code -1000 reported for 3432 surfaces

Error Codes

The following errors were encountered during the computation:

-1000 = No valid slip surfaces are generated
at a grid center. Unable to draw a surface.

List of All Coordinates

Water Table

0.000	90.000
272.000	90.000

Search Grid

37.565	124.659
89.801	124.659
89.801	176.895
37.565	176.895

Material Boundary

0.000	90.000
272.000	90.000

External Boundary

0.000	80.000
50.000	80.000
272.000	80.000
272.000	90.000
196.000	96.000
136.000	116.000
129.000	116.000
125.609	116.000
123.000	116.000
116.000	116.000
101.011	111.004
50.000	94.000
0.000	94.000
0.000	90.000

Support

0.000	92.000
221.000	92.000

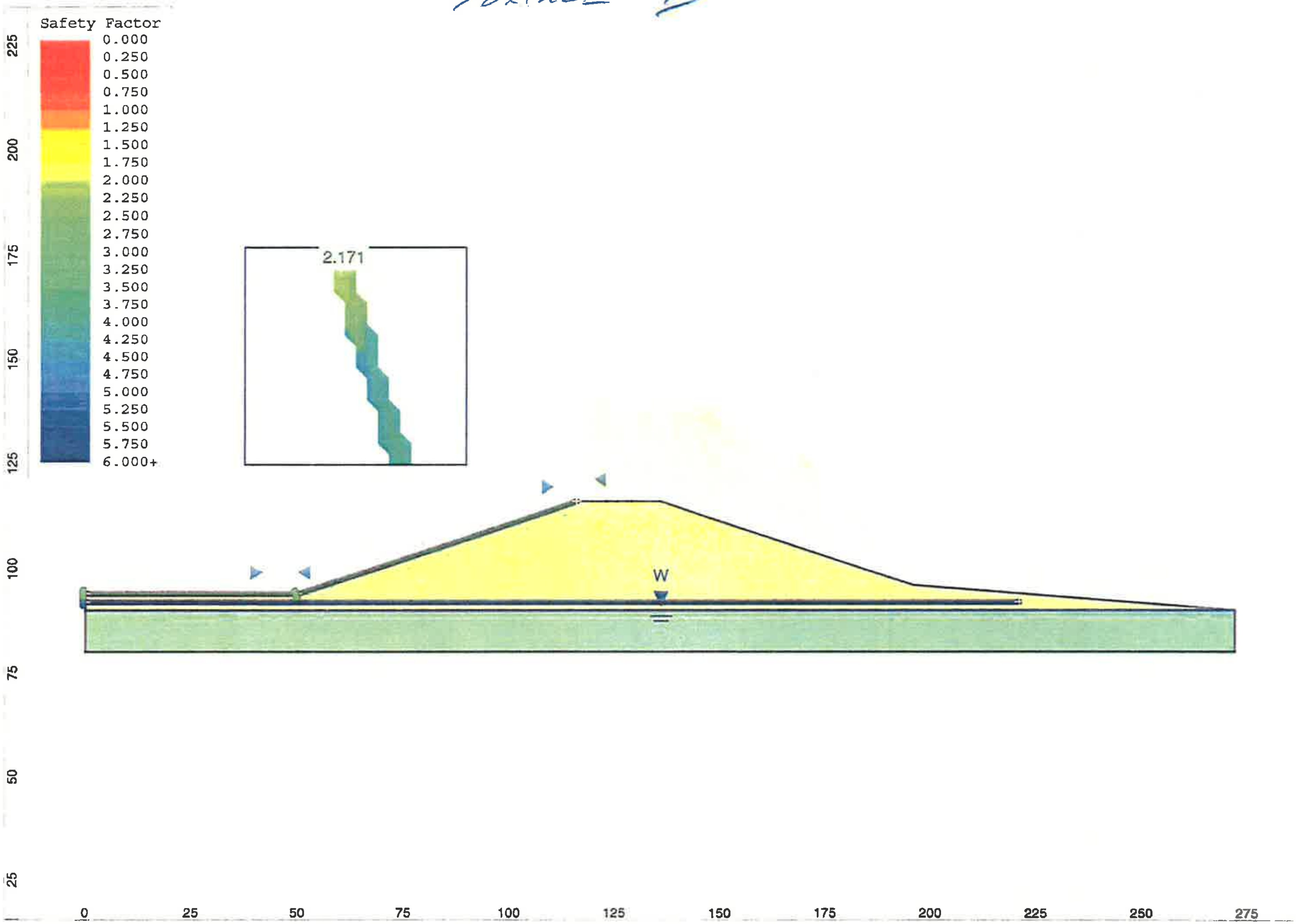
Support

0.000	94.000
50.000	94.000

<u>Support</u>

50.000	94.000
116.000	116.000

SURFACE B



Safety Factor
0.000
0.250
0.500
0.750
1.000
1.250
1.500
1.750
2.000
2.250
2.500
2.750
3.000
3.250
3.500
3.750
4.000
4.250
4.500
4.750
5.000
5.250
5.500
5.750
6.000+
2.171
W
225
200
175
150
125
100
75
50
25
0
25
50
75
100
125
150
175
200
225
250
275

Slide Analysis Information

Document Name

File Name: 093-82538_Surface B.sli

Project Settings

Project Title: 093-82538 - Crystal River
Failure Direction: Right to Left
Units of Measurement: Imperial Units
Pore Fluid Unit Weight: 100 lb/ft3
Groundwater Method: Water Surfaces
Data Output: Standard
Calculate Excess Pore Pressure: Off
Allow Ru with Water Surfaces or Grids: Off
Random Numbers: Pseudo-random Seed
Random Number Seed: 10116
Random Number Generation Method: Park and Miller v.3

Analysis Methods

Analysis Methods used:
Bishop simplified
Janbu simplified

Number of slices: 25
Tolerance: 0.005
Maximum number of iterations: 50

Surface Options

Surface Type: Circular
Search Method: Grid Search
Radius increment: 10
Composite Surfaces: Disabled
Reverse Curvature: Create Tension Crack
Minimum Elevation: Not Defined
Minimum Depth: Not Defined

Material Properties

Material: Fill
Strength Type: Mohr-Coulomb
Unit Weight: 110 lb/ft3
Cohesion: 0 psf
Friction Angle: 34 degrees
Water Surface: Water Table
Custom Hu value: 1

Material: Natural Ground (Weathered Limestone)
Strength Type: Mohr-Coulomb
Unit Weight: 120 lb/ft3

Cohesion: 102.5 psf
Friction Angle: 36 degrees
Water Surface: Water Table
Custom Hu value: 1

Support Properties

Support: TENCATE PET 1000/100 WOVEN GEOTEXTILE
TENCATE PET 1000/100 WOVEN GEOTEXTILE
Support Type: GeoTextile
Force Application: Passive
Force Orientation: Bisector of Parallel and Tangent
Anchorage: Slope Face
Shear Strength Model: Linear
Strip Coverage: 100 percent
Tensile Strength: 33915 lb/ft
Pullout Strength Adhesion: 0 lb/ft2
Pullout Strength Friction Angle: 39 degrees

Support: AGRU - LLDPE 60-mil thick
AGRU - LLDPE 60-mil thick
Support Type: GeoTextile
Force Application: Passive
Force Orientation: Bisector of Parallel and Tangent
Anchorage: Slope Face
Shear Strength Model: Linear
Strip Coverage: 100 percent
Tensile Strength: 2016 lb/ft
Pullout Strength Adhesion: 0 lb/ft2
Pullout Strength Friction Angle: 0 degrees

Global Minimums

Method: bishop simplified
FS: 2.171270
Center: 55.847, 176.895
Radius: 83.243
Left Slip Surface Endpoint: 48.240, 94.000
Right Slip Surface Endpoint: 110.614, 114.205
Resisting Moment=1.66687e+006 lb-ft
Driving Moment=767693 lb-ft

Method: janbu simplified
FS: 2.097100
Center: 55.847, 176.895
Radius: 83.243
Left Slip Surface Endpoint: 48.240, 94.000
Right Slip Surface Endpoint: 110.614, 114.205
Resisting Horizontal Force=18704.9 lb
Driving Horizontal Force=8919.41 lb

Valid / Invalid Surfaces

Method: bishop simplified
Number of Valid Surfaces: 710

Number of Invalid Surfaces: 4141
Error Codes:
Error Code -101 reported for 5 surfaces
Error Code -1000 reported for 4136 surfaces

Method: janbu simplified
Number of Valid Surfaces: 710
Number of Invalid Surfaces: 4141
Error Codes:
Error Code -101 reported for 5 surfaces
Error Code -1000 reported for 4136 surfaces

Error Codes

The following errors were encountered during the computation:

-101 = Only one (or zero)
surface / slope intersections.

-1000 = No valid slip surfaces are generated
at a grid center. Unable to draw a surface.

List of All Coordinates

Water Table

0.000	90.000
272.000	90.000

Search Grid

37.565	124.659
89.801	124.659
89.801	176.895
37.565	176.895

Material Boundary

0.000	90.000
272.000	90.000

External Boundary

0.000	80.000
50.000	80.000
272.000	80.000
272.000	90.000
196.000	96.000
136.000	116.000
129.000	116.000
125.609	116.000
123.000	116.000
116.000	116.000
101.011	111.004
50.000	94.000
0.000	94.000
0.000	90.000

Support

0.000	92.000
221.000	92.000

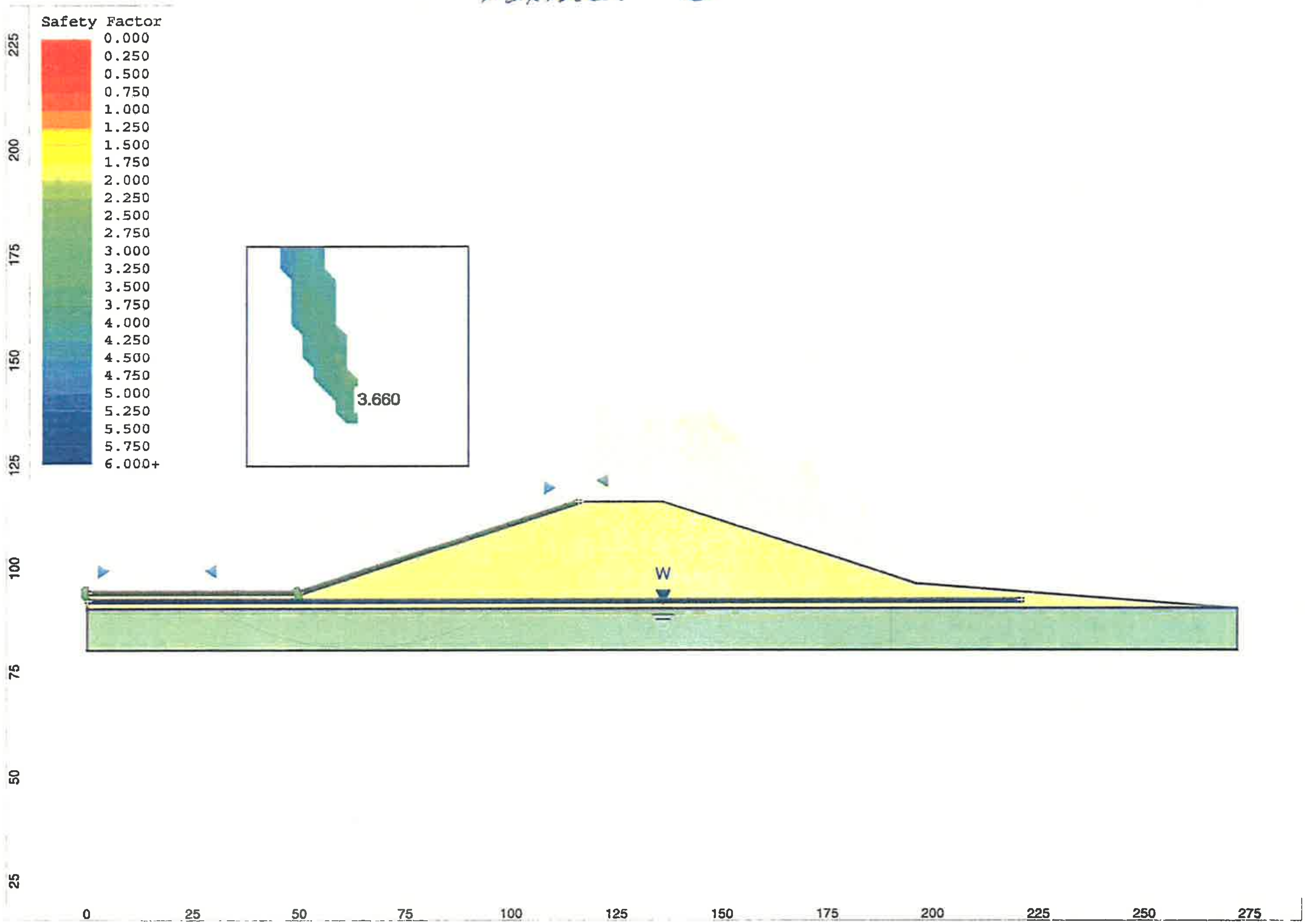
Support

0.000	94.000
50.000	94.000

Support

50.000	94.000
116.000	116.000

Surfac. C



Safety Factor
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0.250
0.500
0.750
1.000
1.250
1.500
1.750
2.000
2.250
2.500
2.750
3.000
3.250
3.500
3.750
4.000
4.250
4.500
4.750
5.000
5.250
5.500
5.750
6.000+
3.660
W
225
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175
150
125
100
75
50
25
0
25
50
75
100
125
150
175
200
225
250
275

Slide Analysis Information

Document Name

File Name: 093-82538_Surface C.sli

Project Settings

Project Title: 093-82538 - Crystal River
Failure Direction: Right to Left
Units of Measurement: Imperial Units
Pore Fluid Unit Weight: 100 lb/ft3
Groundwater Method: Water Surfaces
Data Output: Standard
Calculate Excess Pore Pressure: Off
Allow Ru with Water Surfaces or Grids: Off
Random Numbers: Pseudo-random Seed
Random Number Seed: 10116
Random Number Generation Method: Park and Miller v.3

Analysis Methods

Analysis Methods used:
Bishop simplified
Janbu simplified

Number of slices: 25
Tolerance: 0.005
Maximum number of iterations: 50

Surface Options

Surface Type: Circular
Search Method: Grid Search
Radius increment: 10
Composite Surfaces: Disabled
Reverse Curvature: Create Tension Crack
Minimum Elevation: Not Defined
Minimum Depth: Not Defined

Material Properties

Material: Fill
Strength Type: Mohr-Coulomb
Unit Weight: 110 lb/ft3
Cohesion: 0 psf
Friction Angle: 34 degrees
Water Surface: Water Table
Custom Hu value: 1

Material: Natural Ground (Weathered Limestone)
Strength Type: Mohr-Coulomb
Unit Weight: 120 lb/ft3

Cohesion: 102.5 psf
Friction Angle: 36 degrees
Water Surface: Water Table
Custom Hu value: 1

Support Properties

Support: TENCATE PET 1000/100 WOVEN GEOTEXTILE
TENCATE PET 1000/100 WOVEN GEOTEXTILE
Support Type: GeoTextile
Force Application: Passive
Force Orientation: Bisector of Parallel and Tangent
Anchorage: None
Shear Strength Model: Linear
Strip Coverage: 100 percent
Tensile Strength: 33915 lb/ft
Pullout Strength Adhesion: 0 lb/ft2
Pullout Strength Friction Angle: 39 degrees

Support: AGRU - LLDPE 60-mil thick
AGRU - LLDPE 60-mil thick
Support Type: GeoTextile
Force Application: Passive
Force Orientation: Bisector of Parallel and Tangent
Anchorage: Slope Face
Shear Strength Model: Linear
Strip Coverage: 100 percent
Tensile Strength: 2016 lb/ft
Pullout Strength Adhesion: 0 lb/ft2
Pullout Strength Friction Angle: 0 degrees

Global Minimums

Method: bishop simplified
FS: 3.659920
Center: 63.683, 142.941
Radius: 62.430
Left Slip Surface Endpoint: 24.924, 94.000
Right Slip Surface Endpoint: 120.000, 116.000
Resisting Moment=7.41575e+006 lb-ft
Driving Moment=2.0262e+006 lb-ft

Method: janbu simplified
FS: 3.667340
Center: 63.683, 142.941
Radius: 62.430
Left Slip Surface Endpoint: 24.924, 94.000
Right Slip Surface Endpoint: 120.000, 116.000
Resisting Horizontal Force=109024 lb
Driving Horizontal Force=29728.3 lb

Valid / Invalid Surfaces

Method: bishop simplified
Number of Valid Surfaces: 680

Number of Invalid Surfaces: 4171
Error Codes:
Error Code -103 reported for 541 surfaces
Error Code -1000 reported for 3630 surfaces

Method: janbu simplified
Number of Valid Surfaces: 680
Number of Invalid Surfaces: 4171
Error Codes:
Error Code -103 reported for 541 surfaces
Error Code -1000 reported for 3630 surfaces

Error Codes

The following errors were encountered during the computation:

-103 = Two surface / slope intersections,
but one or more surface / nonslope external polygon
intersections lie between them. This usually occurs
when the slip surface extends past the bottom of the
soil region, but may also occur on a benched
slope model with two sets of Slope Limits.

-1000 = No valid slip surfaces are generated
at a grid center. Unable to draw a surface.

List of All Coordinates

Water Table

0.000	90.000
272.000	90.000

Search Grid

37.565	124.659
89.801	124.659
89.801	176.895
37.565	176.895

Material Boundary

0.000	90.000
272.000	90.000

External Boundary

0.000	80.000
50.000	80.000
272.000	80.000
272.000	90.000
196.000	96.000
136.000	116.000
129.000	116.000
125.609	116.000
123.000	116.000
116.000	116.000
101.011	111.004

50.000	94.000
0.000	94.000
0.000	90.000

<u>Support</u>

0.000	92.000
221.000	92.000

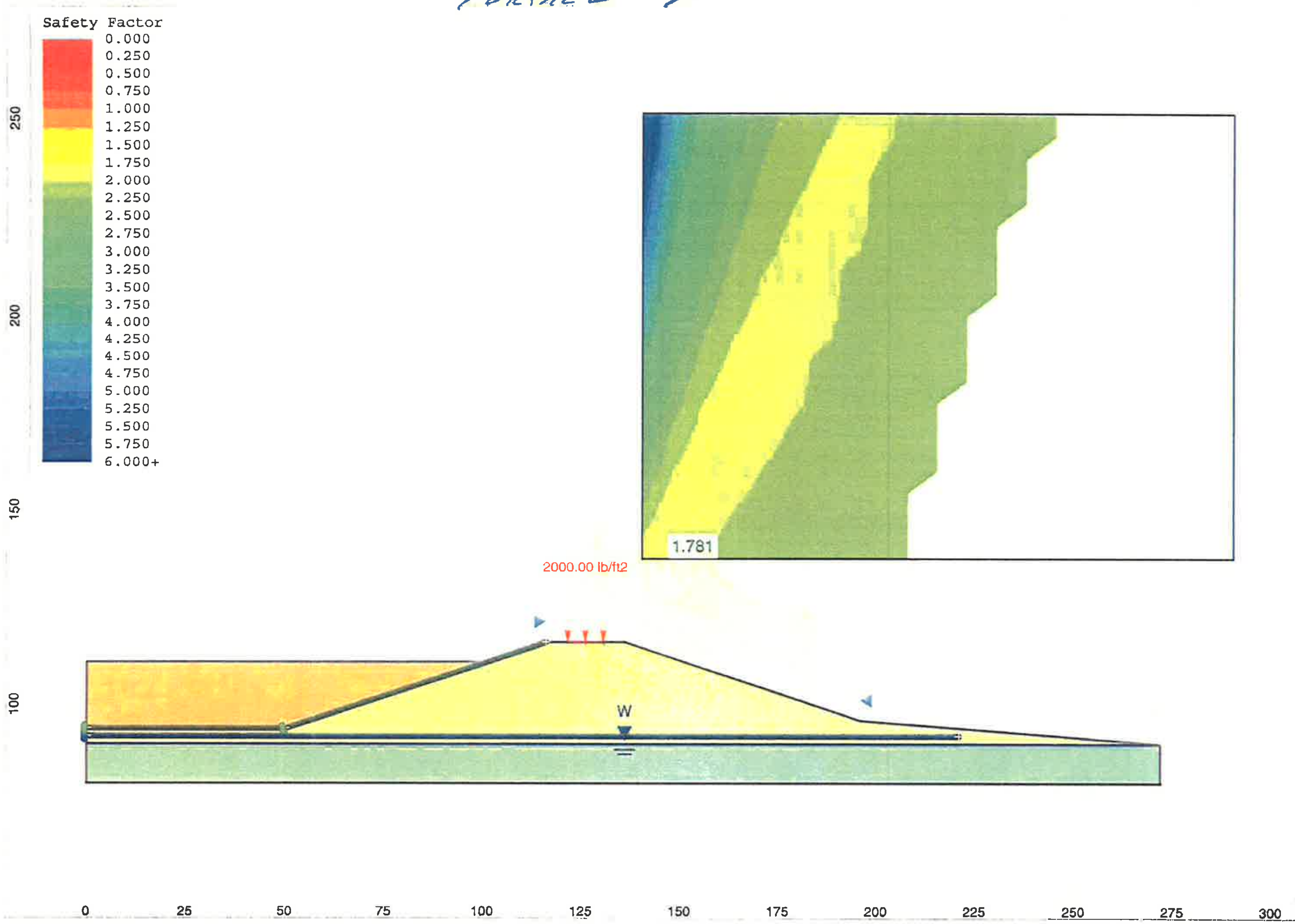
<u>Support</u>

0.000	94.000
50.000	94.000

<u>Support</u>

50.000	94.000
116.000	116.000

SURFACE D



Safety Factor
0.000
0.250
0.500
0.750
1.000
1.250
1.500
1.750
2.000
2.250
2.500
2.750
3.000
3.250
3.500
3.750
4.000
4.250
4.500
4.750
5.000
5.250
5.500
5.750
6.000+
1.781
2000.00 lb/ft2
W
250
200
150
100
0
25
50
75
100
125
150
175
200
225
250
275
300

Slide Analysis Information

Document Name

File Name: 093-82538_Surface D.sli

Project Settings

Project Title: 093-82538 - Crystal River
Failure Direction: Left to Right
Units of Measurement: Imperial Units
Pore Fluid Unit Weight: 100 lb/ft3
Groundwater Method: Water Surfaces
Data Output: Standard
Calculate Excess Pore Pressure: Off
Allow Ru with Water Surfaces or Grids: Off
Random Numbers: Pseudo-random Seed
Random Number Seed: 10116
Random Number Generation Method: Park and Miller v.3

Analysis Methods

Analysis Methods used:
Bishop simplified
Janbu simplified

Number of slices: 25
Tolerance: 0.005
Maximum number of iterations: 50

Surface Options

Surface Type: Circular
Search Method: Grid Search
Radius increment: 10
Composite Surfaces: Disabled
Reverse Curvature: Create Tension Crack
Minimum Elevation: Not Defined
Minimum Depth: Not Defined

Loading

1 Distributed Load present:
Distributed Load Constant Distribution, Orientation: Vertical, Magnitude: 2000 lb/ft2

Material Properties

Material: Fill
Strength Type: Mohr-Coulomb
Unit Weight: 110 lb/ft3
Cohesion: 0 psf
Friction Angle: 34 degrees
Water Surface: Water Table

Custom Hu value: 1

Material: Natural Ground (Weathered Limestone)
Strength Type: Mohr-Coulomb
Unit Weight: 120 lb/ft3
Cohesion: 102.5 psf
Friction Angle: 36 degrees
Water Surface: Water Table
Custom Hu value: 1

Material: Waste
Strength Type: Mohr-Coulomb
Unit Weight: 100 lb/ft3
Cohesion: 0 psf
Friction Angle: 0 degrees
Water Surface: Water Table
Custom Hu value: 1

Support Properties

Support: TENCATE PET 1000/100 WOVEN GEOTEXTILE
TENCATE PET 1000/100 WOVEN GEOTEXTILE
Support Type: GeoTextile
Force Application: Passive
Force Orientation: Bisector of Parallel and Tangent
Anchorage: Slope Face
Shear Strength Model: Linear
Strip Coverage: 100 percent
Tensile Strength: 33915 lb/ft
Pullout Strength Adhesion: 0 lb/ft2
Pullout Strength Friction Angle: 39 degrees

Support: AGRU - LLDPE 60-mil thick
AGRU - LLDPE 60-mil thick
Support Type: GeoTextile
Force Application: Passive
Force Orientation: Bisector of Parallel and Tangent
Anchorage: Slope Face
Shear Strength Model: Linear
Strip Coverage: 100 percent
Tensile Strength: 2016 lb/ft
Pullout Strength Adhesion: 0 lb/ft2
Pullout Strength Friction Angle: 0 degrees

Global Minimums

Method: bishop simplified
FS: 1.781390
Center: 147.875, 143.092
Radius: 35.645
Left Slip Surface Endpoint: 124.711, 116.000
Right Slip Surface Endpoint: 157.600, 108.800
Resisting Moment=618276 lb-ft
Driving Moment=347075 lb-ft

Method: janbu simplified
FS: 1.635680
Center: 147.875, 137.392
Radius: 31.219
Left Slip Surface Endpoint: 125.137, 116.000
Right Slip Surface Endpoint: 159.153, 108.282
Resisting Horizontal Force=16826.4 lb
Driving Horizontal Force=10287.1 lb

Valid / Invalid Surfaces

Method: bishop simplified
Number of Valid Surfaces: 2808
Number of Invalid Surfaces: 2043
Error Codes:
Error Code -104 reported for 7 surfaces
Error Code -106 reported for 45 surfaces
Error Code -1000 reported for 1991 surfaces

Method: janbu simplified
Number of Valid Surfaces: 2794
Number of Invalid Surfaces: 2057
Error Codes:
Error Code -104 reported for 7 surfaces
Error Code -106 reported for 45 surfaces
Error Code -108 reported for 14 surfaces
Error Code -1000 reported for 1991 surfaces

Error Codes

The following errors were encountered during the computation:

-104 = Same as -102. Surface / nonslope intersections also exist, but these points lie outside the arc defined by the two surface / slope intersections.

-106 = Average slice width is less than 0.0001 * (maximum horizontal extent of soil region). This limitation is imposed to avoid numerical errors which may result from too many slices, or too small a slip region.

-108 = Total driving moment or total driving force < 0.1. This is to limit the calculation of extremely high safety factors if the driving force is very small (0.1 is an arbitrary number).

-1000 = No valid slip surfaces are generated at a grid center. Unable to draw a surface.

List of All Coordinates

Water Table

0.000	90.000
272.000	90.000

Search Grid

140.369	137.392
290.480	137.392
290.480	251.381
140.369	251.381

Material Boundary

0.000	90.000
272.000	90.000

Material Boundary

0.000	94.000
50.000	94.000
101.011	111.004

Distributed Load

121.500	116.000
126.000	116.000
130.500	116.000

External Boundary

0.000	80.000
50.000	80.000
272.000	80.000
272.000	90.000
196.000	96.000
136.000	116.000
130.500	116.000
126.000	116.000
121.500	116.000
116.000	116.000
101.011	111.004
0.000	111.000
0.000	94.000
0.000	90.000

Support

0.000	92.000
221.000	92.000

Support

0.000	94.000
50.000	94.000

Support

50.000	94.000
116.000	116.000

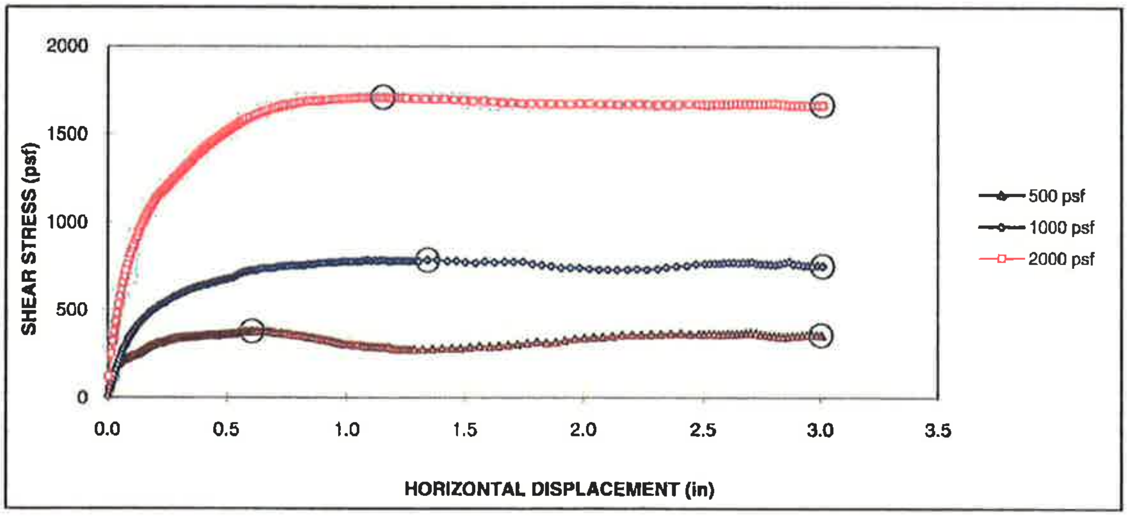
APPENDIX B
LABORATORY TESTING RESULTS FOR GEOTEXTILE REINFORCEMENT

DIRECT SHEAR TEST RESULTS

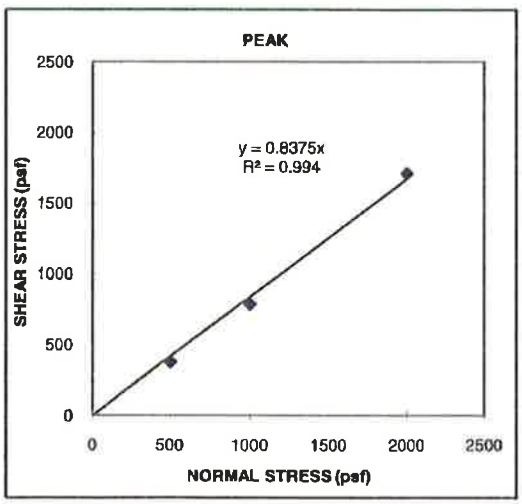
ASTM D5321

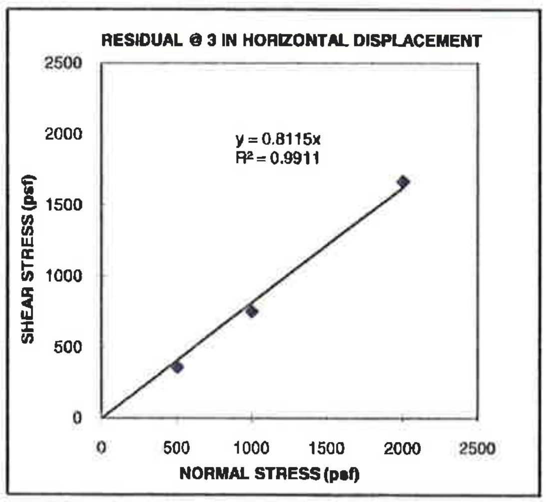
PROJECT NAME: PEF/FGD POND DESIGN & PERMIT/FL
SAMPLE NUMBER: SHEAR #2

INTERFACE TESTED: TENCATE PET 1000/100 WOVEN GEOTEXTILE (machine direction) vs SOIL (Floor Near G-5)
SOIL DESCRIPTION: Brown, (Limestone) FINE SAND, some clayey silt, little coarse to fine gravel. (SM)
SOIL CONDITIONS: REMOLDED TO 95% OF THE MAX DRY DENSITY OF 116.0 pcf AT A MOISTURE OF 11.5%
TEST CONDITIONS: SATURATED and CONSOLIDATED 24 hours AT THE NORMAL LOAD
SHEAR RATE: 0.04 in/min
SUBSTRATE: TEXTURED RIGID PLATES



Normal Stress (psf)	Shear Stress Peak[1] (psf)	Shear Stress Residual (psf)	Peak Friction Angle	Peak Adhesion[2] (psf)	Residual Friction Angle	Residual Adhesion[2] (psf)
500	380	357				
1000	785	750	39.9	0	39.1	0
2000	1711	1666				





Observations After Test
500 psf: Shearing occurred in the Soil
1000 psf: Shearing occurred in the Soil
2000 psf: Shearing occurred in the Soil

(1) The peak shear stresses for 500, 1000, and 2000 psf normal stresses were chosen at 0.605, 1.341, and 1.151 in horizontal displacements, respectively.
(2) The adhesion value is based on the "best-fit" line which may not show true adhesion.

Golder Associates Inc.

OBJECTIVE: Assess the geomembrane pond liner leakage rate based on assumptions of hole density and size.

METHOD: Using the methodology outlined in Reference 3 by Giroud and Bonaparte, determine the number of holes in a geomembrane liner based on installation construction quality assurance. After quantifying the number of holes, the rate of leakage on a per acre basis can be determined.

REFERENCES:

1) "The Hydrologic Evaluation of Landfill Performance (HELP) Model: Engineering Documentation for Version 3." USEPA, 1994.

2) Qian, X., Koerner, R., Gray, D. (2002). Geotechnical Aspects of Landfill Design and Construction. Prentice Hall, Upper Saddle River, New Jersey.

3) Giroud, J.P. and Bonaparte, R. (1989) "Leakage through liners constructed with geomembrane liners – parts I and II and technical note," *Geotextiles and Geomembranes*, 8(1), 27-67, 8(2), 71-111, 8(4), 337-340.

4) Agru America product information.

ASSUMPTIONS:

1) The pond will be constructed above-grade with a footprint of 3.81 acres. The pond berm will be 17 ft. high with 3H:1V side slopes.
2) The pond bottom is elevation 94.0 feet and the outlet elevation (to the pump station) is elevation 111.24 feet.
3) Pond will be lined with 60 mil Agru America liner low density polyethylene (LLDPE) "micro spike" geomembrane.
4) The unit weight of pond water is 62.4 pcf.
5) The soil underlying the geomembrane liner is high permeability and will allow for liquid to flow freely.
6) The construction quality assurance/ quality control will be intensively monitored and few installation defects will be allowed to occur. In addition, most defects in the liner will be identified and patched during the construction process.

CALCULATIONS:

1.) The design methodology used hereafter is based on a method outlined in the HELP Model (Reference 1). Reference 1 is used to determine the performance of geomembranes with standing head above them. It relies on and synthesizes various design aspects including those outlined in Reference 3.

Reference 3 defines installation defects to be sized equal to or larger than the geomembrane thickness. Reference 3 further states, based on several case studies with consistent results, that a 1 cm^2 is a conservatively high area per defect. This estimate is based on intensive quality assurance/ quality control monitoring during construction. However, Reference 2 states that most defects are small (< 0.1 cm^2), but that larger holes are occasionally observed.

For purposes of this calculation, a defect area of 0.5 cm^2 will be assumed.

Additionally, based on the level of quality assurance/ quality control flaw density can be estimated with 1 flaw/acre being used for intensively monitored projects and 10 flaws/acre being assigned to projects that employed only limited spot checks. Greater flaw densities could be assigned based on a number of issues, such as poor construction practices, poor material selection, and poor preparation of the subgrade.

For the purposes of this calculation, 1 flaw/ acre will be assumed.

2.) Since it was assumed the liner would be surrounded by highly permeable soil, the flow through a defect can be considered as flow through an orifice and Bernoulli's equation applies:

$$q = 0.0137\, C_B\, n\, a \sqrt{2\, g\, h_g}$$

Where,

q	=	leakage rate through defects, inches/day,
0.0137	=	units conversion, 0.0137 acre-seconds per day per inch^2,
C_B	=	head loss coefficient for sharp edged orifices, 0.6 for circular orifice,
n	=	installation defect density, #/ acre,
a	=	defect area, 0.0775 inches^2,
g	=	acceleration due to gravity, 386.4 inches/sec^2,
h_g	=	average hydraulic head on geomembrane liner, inches.

3.) The leakage rate determined in Step 2 is calculated on a per acre basis, so the result can be converted to cubic feet or gallons. The attached spreadsheet contains the calculations of leakage rate and conversions to cubic feet per day and gallons per day.

CONCLUSION:

From the assumptions stated in this calculation and the methodologies presented in the references the leakage rate of the geomembrane pond liner was evaluated. The leakage rate, as calculated here, is directly dependent on the installation quality assurance during the liner installation. The better the construction quality assurance during installation is the fewer defects or holes that can be expected in the geomembrane liner. An assumption of 1 defect/ acre was used in this analysis. Additionally, a conservative defect hole diameter of 0.0775 in^2 (0.5 cm^2) was used. An average head on the liner in the pond bottom of 17.24 feet was assumed and an average head on liner on the side slopes of 8.62 feet was assumed.

Using these parameters the leakage rate is **0.25 inch-acres/day**, which is **6,917 gallons/day/acre** in the pond bottom and **0.18 inch-acres/day**, which is **4,891 gallons/day/acre** on the pond side slopes. Over the entire footprint, the leakage rate would be **21,540 gallons/day**.

This leakage rate is comparable to general rates provided in Reference 2 based on one flaw per acre, and a defect area greater than 0.1 centimeters.

lder Associates

Pond Leaka e Calculation

q = leakage rate through defects, inches/day,
0.0137 = units conversion, 0.0137 acre-seconds per day per inch^2,
C_B = head loss coefficient for sharp edged orifices, 0.6 for circular orifice,
n = installation defect density, #/ acre,
a = defect area, 0.0775 inches^2,
g = acceleration due to gravity, 386.4 inches/sec^2,
h_g = average hydraulic head on geomembrane liner, inches

$$q = 0.0137\, C_B\, n\, a \sqrt{2\, g\, h_g}$$

Leakage rate from pond on per acre basis (Pond Bottom)

Head Loss Coefficient	Defect Area (in^2)	Number of Defects per Acre	Gravity (in/sec^2)	Average Hydraulic Head (in)	Leakage Rate (acre- inches/day)	Leakage Rate (ft^3/day)	Leakage Rate (gallons/day/acre)
0.6	0.0775	1	386.4	206.9	0.25	925	6,917

Leakage rate from pond on per acre basis (Side Slopes) - avg. head condition

Head Loss Coefficient	Defect Area (in^2)	Number of Defects per Acre	Gravity (in/sec^2)	Average Hydraulic Head (in)	Leakage Rate (acre- Inches/day)	Leakage Rate (ft^3/day)	Leakage Rate (gallons/day/acre)
0.6	0.0775	1	386.4	103.45	0.18	654	4,891

Pond Bottom Elevation = 94.0 ft.

Pond Area @ Elevation 94.0 ft. = 454 x 180 = 81.720 sq.ft.

Pond Area @ Elevation 111.24 ft. = (454 ft. + (2 x 3 x 17.24 ft.)) x (180 ft. = (2 x 3 x 17.24 ft.)) = 158,000 sq.ft.

Side Slope Area = 158,000 sq.ft. - 81,720 sq. ft. = 76,281 sq.ft.

Pond Leakage Rate (Pond Bottom) = 12,977 gallons/day

Pond Leakage Rate (Pond Bottom) = 8,563 gallons/day

Estimated Pond Leakage Rate (Total) = 21,540 gallons/day

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THE HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE (HELP) MODEL

ENGINEERING DOCUMENTATION FOR VERSION 3

by

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TABLE 8. GEOMEMBRANE DIFFUSIVITY PROPERTIES*

Geomembrane Material	Coefficient of Migration, cm^2/sec	Equivalent Hydraulic Conductivity, cm/sec
Butyl Rubber	$2x10^{-11}$	$1x10^{-12}$
Chlorinated Polyethylene (CPE)	$6x10^{-11}$	$4x10^{-12}$
Chlorosulfonated Polyethylene (CSPE) or Hypalon	$5x10^{-11}$	$3x10^{-12}$
Epichlorohydrin Rubber (CO)	$3x10^{-9}$	$2x10^{-10}$
Elasticized Polyolefin	$1x10^{-11}$	$8x10^{-13}$
Ethylene-Propylene Diene Monomer (EPDM)	$2x10^{-11}$	$2x10^{-12}$
Neoprene	$4x10^{-11}$	$3x10^{-12}$
Nitrile Rubber	$5x10^{-10}$	$3x10^{-11}$
Polybutylene	$7x10^{-12}$	$5x10^{-13}$
Polyester Elastomer	$2x10^{-10}$	$2x10^{-11}$
Low-Density Polyethylene (LDPE)	$5x10^{-12}$	$4x10^{-13}$
High-Density Polyethylene (HDPE)	$3x10^{-12}$	$2x10^{-13}$
Polyvinyl Chloride (PVC)	$2x10^{-10}$	$2x10^{-11}$
Saran Film	$9x10^{-13}$	$6x10^{-14}$

* From Giroud and Bonaparte (1985)

Geomembrane flaws can range in size from pinholes that are generally a result of manufacturing flaws such as polymerization deficiencies to larger defects resulting from seaming errors, abrasion, and punctures occurring during installation. Giroud and Bonaparte (1989) defines pinhole-sized flaws to be smaller than the thickness of the geomembrane. Since geomembrane liner thicknesses are typically 40 mils or greater, the HELP program assigns the diameter of pinholes to be 40 mils or 0.001 m (defect area = $7.84x10^{-7}$ m^2). Giroud and Bonaparte (1989) indicates that pinhole flaws are more commonly associated with the original, less sophisticated, geomembrane manufacturing

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techniques. Current manufacturing and polymerization techniques have made pinhole flaws less common. Giroud and Bonaparte (1989) defined installation defect flaws to be of a size equal to or larger than the thickness of the geomembrane. Based on 6 case studies that produced consistent results, Giroud and Bonaparte (1989) recommended using a defect area of 1 cm^2 (20 x 5 mm) for conservatively high predictions of liner leakage on projects with intensive quality assurance/quality control monitoring during liner construction. Therefore, the HELP program uses a defect area of 1 cm^2. Finally, the HELP program user must define the flaw density or frequency (pinholes or defects/acre) for each geomembrane liner. Giroud and Bonaparte (1989) recommended using a flaw density of 1 flaw/acre for intensively monitored projects. A flaw density of 10 flaws/acre or more is possible when quality assurance is limited to spot checks or when environmental difficulties are encountered during construction. Greater frequency of defects may also result from poor selection of materials, poor foundation preparation and inappropriate equipment as well as other design flaws and poor construction practices.

Geosyntec (1993) indicated that geomembranes may undergo deterioration due to aging or external elements such as chemicals, oxygen, micro-organisms, temperature, high-energy radiation, and mechanical action (i.e., foundation settlement, slope failure, etc.). Although geomembrane deterioration can create geomembrane flaws or increase the size of existing flaws, the HELP program does not account for this time-dependent deterioration in the liner.

The liquid that passes through a geomembrane hole will flow laterally between the geomembrane and the flow limiting (controlling) layer of material adjacent to the geomembrane, unless there is perfect contact between the geomembrane and the controlling soil or free flow from the hole. The space between the geomembrane and the soil is assumed to be uniform. The size of this space depends on the roughness of the soil surface, the soil particle size, the rugosity and stiffness of the geomembrane, and the magnitude of the normal stress (overburden pressure) that tends to press the geomembrane against the soil. The HELP program ranks the contact between a geomembrane and soil as perfect, excellent, good, poor, and worst case (free flow). The HELP program also permits designs where a geomembrane is separated from a low permeability soil by a geotextile. The leakage is controlled by the hydraulic transmissivity of the gap or geotextile between the geomembrane and the soil. This interfacial flow between the geomembrane and soil layer covers an area called the wetted area. The hole in the geomembrane is assumed to be circular and the interfacial flow is assumed to be radial; therefore, the wetted area is circular. Giroud and Bonaparte (1989); Bonaparte et al. (1989); and Giroud et al. (1992) examined steady-state leakage through a geomembrane liner for all of these qualitative levels of contact and provided either theoretical or empirical solutions for the leakage rate and the radius of interfacial flow. Leakage and wetted area are dependent on the static hydraulic head on the liner; the hydraulic conductivity and thickness of the surrounding soil, waste, or geotextile layers; the size of the flaw; and the contact (interface thickness) between the geomembrane and the controlling soil layer.

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The HELP program designates the controlling soil layer as either high, medium or low permeability. High is a saturated hydraulic conductivity greater than or equal to $1x10^{-1}$ cm/sec; medium is greater than or equal to $1x10^{-4}$ cm/sec and less than $1x10^{-1}$ cm/sec; and low is less than $1x10^{-4}$ cm/sec. The low permeability layers are assumed to remain saturated in the wetted area throughout the simulation. As mentioned earlier, geomembranes are geosynthetics with a very low cross-plane hydraulic conductivity (See Table 8). On the other hand, geotextiles are geosynthetics with a high cross-plane hydraulic conductivity and high in-plane transmissivity (See Table 9). The fabrics can help minimize damage to the membrane by the surrounding soil or waste layers. The in-plane transmissivity of geotextiles used as geomembrane cushions is used to compute the radius of interfacial flow and leakage through a geomembrane separated from the controlling soil by a geotextile.

Worst Case (Free Flow) Leakage

Giroud and Bonaparte (1989) theoretically examined free flow through a geomembrane surrounded by infinitely pervious media such as air or high permeability soil or waste layers (Brown et al., 1987). However, Giroud and Bonaparte (1989) cautioned that if the leachate head on the geomembrane liner is very small, surface tensions in the surrounding high permeability layers could prevent free flow through the geomembrane flaw. With time, leachate-entrained, fine-grained particles can clog the high permeability layers, greatly reducing the permeability of these layers and possibly preventing free flow. Free flow is assumed whenever the layers above and below the geomembrane have high permeability.

TABLE 9. NEEDLE-PUNCHED, NON-WOVEN GEOTEXTILE PROPERTIES *

Applied Compressive Stress, kPa	Resulting Geotextile Thickness, cm	In-Plane Flow		Cross-Plane Flow
		Geotextile Transmissivity, cm^2/sec **	Horizontal Hydraulic Conductivity, cm/sec	Vertical Hydraulic Conductivity, cm/sec
1 to 8	0.41	0.3	0.7	0.4
100	0.19	0.04	0.2	---
200	0.17	0.02	0.1	---

* Geotechnical Fabrics Report--1992 Specifiers Guide (Industrial Fabrics Association International, 1991), and Giroud and Bonaparte (1985).

** Transmissivity = horizontal hydraulic conductivity x thickness.

Pinholes. Giroud and Bonaparte (1989) concluded that percolation through pinholes surrounded by high permeability layers can be considered as flow through a pipe and recommended using Poiseuille's equation. Therefore, the HELP program uses the following form of Poiseuille's equation to predict free flow leakage through geomembrane pinholes:

$$q_{L_2}(k)_i = \frac{(86{,}400)\ \pi\ n_2(k)\ \rho_{15}\ g\ h_g(k)_i\ d_2^4}{(4{,}046.9)\ (128)\ \eta_{15}\ T_g(k)} \tag{142}$$

$$q_{L_2}(k)_i = \frac{1.775 \times 10^{-4}\ n_2(k)\ h_g(k)_i}{T_g(k)} \tag{143}$$

where

$q_{L_2}(k)_i$ = leakage rate through pinholes in subprofile k during time step i, inches/day

86,400 = units conversion, 86,400 seconds per day

$n_2(k)$ = pinhole density in subprofile k, #/acre

ρ_{15} = density of water at 15°C = 999 kg/m^3

g = gravitational constant, 386.1 inches/sec^2

d_2 = diameter of a pinhole, 0.001 meters

4,046.9 = units conversion, 4,046.9 m^2/acre

η_{15} = dynamic viscosity of water at 15°C = 0.00114 kg/m sec

$T_g(k)$ = thickness of geomembrane in subprofile k, inches

1.775 x 10^{-4} = constant, 1.775 x 10^{-4} inches acre/day

Installation Defects. Giroud and Bonaparte (1989) also concluded that leakage through defects in geomembranes surrounded by high permeability layers can be considered as flow through an orifice and recommended using Bernoulli's equation. Therefore, the HELP program uses the following form of Bernoulli's equation to predict free flow leakage through geomembrane defects:

$$q_{L_3}(k)_i = \frac{86{,}400\ C_B\ n_3(k)\ a_3\ \sqrt{2\ g\ h_g(k)_i}}{4046.9} \tag{144}$$

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$$q_{L_3}(k)_i = 0.0356 \; n_3(k) \sqrt{h_g(k)_i} \qquad (145)$$

where

$q_{L_3}(k)_i$ = leakage rate through defects in subprofile k during time step i, inches/day

C_B = head loss coefficient for sharp edged orifices, 0.6

$n_3(k)$ = installation defect density for subprofile k, #/acre

a_3 = defect area, 0.0001 m^2

$h_g(k)_i$ = average hydraulic head on geomembrane liner in subprofile k during time step i, inches

0.0356 = constant, 0.0356 $inches^{0.5}$ acre/day

Perfect Liner Contact

Perfect geomembrane liner contact means that there is no gap or interface between the geomembrane liner and controlling soil or waste layer. Perfect contact is not common but can be achieved if the geomembrane is sprayed directly onto a compacted, fine-grained soil or waste layer or if the geomembrane and controlling layers are manufactured together. Problems associated with the installation of spray-on liners (e.g. application, polymerization, etc.) has limited their use. Perfect liner contact results in only vertical percolation through the controlling layer below the liner flaw; however, both vertical and horizontal flow can occur in the layer opposite the controlling soil or waste layer.

Giroud and Bonaparte (1989) indicated that a lower bound estimate of leakage for perfect contact conditions can be estimated using Darcy's law assuming vertical flow through the controlling layer only in the area below the hole. An upper bound prediction can be obtained by assuming radial flow in the controlling layer and integrating Darcy's law in spherical coordinates to obtain the following equation:

$$Q_h = \frac{\pi \; K_s \; h_g \; d_o}{1 - \dfrac{0.5 \, d_o}{T_s}} \qquad (146)$$

where

Q_h = leakage rate through pinholes and installation defects, m^3/sec

K_s = saturated hydraulic conductivity of soil layer, m/sec

"GEOTECHNICAL ASPECTS OF LANDFILL DESIGN AND CONSTRUCTION"

X., Koerner, R., D. (2002)

ESTIMATION

TABLE 4.6 Calculated Flow Rates through Soil Liners with 1 foot (0.3 m) of Water Ponded on the Liner (USEPA, 1991)

Hydraulic Conductivity (cm/sec)	Rate of Flow	
	gallons/acre/day	liter/m²/day
1.0×10^{-6}	1,200	1.15
1.0×10^{-7}	120	0.115
1.0×10^{-8}	12	0.0115
1.0×10^{-9}	1.2	0.00115

4.8.2 Flow Rate through Geomembrane Liner

The second liner depicted in Figure 4.14 is a geomembrane liner. It was assumed (USEPA, 1991) that the geomembrane has one or more circular holes (defects) in the liner, that the holes are sufficiently widely spaced that leakage through each hole occurs independently from the other holes, that the head h of liquid ponded above the liner, is constant, and that the soil that underlies the geomembrane has a relatively large hydraulic conductivity (i.e., the subsoil offers no resistance to flow through a hole in the geomembrane). In this case, flow rates through holes in geomembranes can be estimated using the Bernoulii equation assuming the size and shape of the holes are known. The Bernoulii equation is

$$Q = C_b \cdot a \cdot (2 \cdot g \cdot h)^{0.5} \tag{4.51}$$

where Q = flow rate through geomembrane, cm³/sec;
C_b = flow coefficient with a value approximately 0.6 for a circular hole;
a = area of a circular hole in geomembrane, cm²;
g = acceleration due to gravity, 981 cm/sec²; and
h = liquid head above the liner, cm.

For example, if there is a single hole with an area of 1 cm² and the head is 30 cm (1 ft), the calculated rate of flow is 3,300 gallon/day (12,500 liter/day). If there is one hole per acre (2.5 holes per hectare), then the flow rate is 3,300 gallon/acre/day (3 liter/m²/day). Flow rate for other circumstances are calculated (USEPA, 1991) in Table 4.7. Giroud and Bonaparte (1989a) report that with good quality control, one hole per acre (2.5 holes per hectare) is typical. With poor quality control, 30 holes per acre (75 holes per hectare) is possible. They also note that most defects are small (< 0.1 cm²), but that larger holes are occasionally observed. In calculating the rate of flow for "No holes" in Table 4.7, it was assumed (USEPA, 1991) that any flux of liquid was controlled by water vapor transmission; flux of 0.01 gallon/acre/day (9.35×10^{-6} liter/m²/day) corresponds to a typical water vapor transmission rate for a 60-mil (1.5-mm) HDPE geomembrane. It is important to note that this information is based on the investigation of geomembrane installation prior to 1989. With wedge welders, certified technicians, and construction quality assurance, these estimates are generally very high.

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TABLE 4.7 Calculated Flow Rates through a Geomembrane with a Water Head of 1 foot (0.3 m) above Geomembrane (USEPA, 1991)

	Number of Holes		Flow Rate	
Size of Hole (cm^2)	hole/acre	hole/hectare	gallon/acre/day	liter/m^2/day
No holes	0	0	0.01	9.4×10^{-4}
0.1	1	2.5	330	0.31
0.1	30	75	10,000	9.4
1	1	2.5	3,300	3.1
1	30	75	100,000	94
10	1	2.5	33,000	31

4.8.3 Flow Rate through Composite Liner

The third type of liner depicted in Figure 4.14 is a *composite* geomembrane/compacted clay liner. A composite liner is a liner composed of a geomembrane layer and a layer of low-permeability soil placed in intimate contact with the geomembrane. Composite liners have been widely used in both hazardous and municipal solid waste landfills.

Leakage through a composite liner can result from flow through geomembrane defects or permeation through the geomembrane. In the case of a geomembrane defect, the rate of leakage through a composite liner is significantly less than the rate of leakage through a similar defect in a geomembrane placed on a high-permeability soil like sand or gravel (Giroud and Badu-Tweneboah, 1992).

The contained liquid is on the geomembrane side of the composite liner in landfills. If there is a defect in the geomembrane, the liquid flows first through the geomembrane defect, laterally some nominal distance between the geomembrane and the low-permeability soil, and finally, into and through the low-permeability soil layer, as shown in Figure 4.15. Flow in the space between the geomembrane and the soil, if there is such a space, is called *interface flow,* and the area covered by the interface flow is called the *wetted area.* The flow in the soil is assumed to be vertical and R is the radius of the wetted area.

The quality of the contact between the two components of a composite liner (i.e. the geomembrane and the low-permeability soil) is one of the key factors governing the rate of flow through the composite liner, because it governs the radius of the wetted area (Figure 4.15). Good and poor contact conditions have been characterized by Bonaparte et al. (1989) as follows:

(i) Good contact conditions correspond to a geomembrane installed, with as few waves or wrinkles as possible, on top of a low-permeability soil layer that has been adequately compacted and has a smooth surface.

(ii) Poor contact conditions correspond to a geomembrane that has been installed with a certain number of waves or wrinkles, and/or placed on a low-permeability soil that has not been well compacted and is not smooth.

Other factors affecting the rate of flow (Giroud and Badu-Tweneboah, 1992) through a composite liner are the size of the defect, the hydraulic conductivity of the low-permeability soil underlying the geomembrane, and the head of liquid on top of

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TABLE 4.9 Calculated Flow Rates for Soil Liners, Geomembrane Liners, and Composite Liners with Poor Contact (USEPA, 1991)

Type of Liner	Overall Quality of Liner	Assumed Values of Key Parameters	Flow Rate	
			gal/acre/day	liter/m²/day
Compacted Soil	Poor	$k_s = 1 \times 10^{-6}$ cm/sec	1,200	1.12
Geomembrane	Poor	30 hole/acre or 75 hole/hectare, $a = 0.1$ cm²	10,000	9.35
Composite	Poor	$k_s = 1 \times 10^{-6}$ cm/sec, 30 hole/acre or 75 hole/hectare, $a = 0.1$ cm²	100	9.35×10^{-2}
Compacted Soil	Good	$k_s = 1 \times 10^{-7}$ cm/sec	120	0.112
Geomembrane	Good	1 hole/acre or 2.5 hole/hectare, $a = 1$ cm²	3,300	3.09
Composite	Good	$k_s = 1 \times 10^{-7}$ cm/sec, 1 hole/acre or 2.5 hole/hectare, $a = 1$ cm²	0.8	7.48×10^{-4}
Compacted Soil	Excellent	$k_s = 1 \times 10^{-8}$ cm/sec	12	1.12×10^{-2}
Geomembrane	Excellent	$k_s = 1 \times 10^{-8}$ cm/sec, 1 hole/acre or 2.5 hole/hectare, $a = 0.1$ cm²	330	0.309
Composite	Excellent	$k_s = 1 \times 10^{-8}$ cm/sec, 1 hole/acre or 2.5 hole/hectare, $a = 0.1$ cm²	0.1	9.35×10^{-5}

defects would be expected only with minimal construction quality control and essentially no construction quality assurance. A *good* geomembrane liner was assumed to have been constructed with good quality control and quality assurance, and an *excellent* geomembrane liner was assumed to have one small hole per acre (or 2.5 small holes per hectare), with excellent quality control and quality assurance. For all of the flow rates computed for composite liners in Table 4.9, it was assumed that there was poor contact between the geomembrane and soil.

As Table 4.9 illustrates, a composite liner (even one built by a poor-to-mediocre standard) significantly outperforms a soil liner or a geomembrane liner alone. Even so, good quality control and quality assurance during construction is absolutely essential when using a composite liner; otherwise, leakage rates can increase several fold as either the total area of holes in the membrane or the hydraulic conductivity of the underlying soil increases. This increase in leakage rate can be observed by comparing the flow rate through an excellent composite liner (0.1 gal/acre/day or 9.35×10^{-5} liter/m²/day) versus a poor composite liner (100 gal/acre/day or 9.35×10^{-2} liter/m²/day) in Table 4.9.

To maximize the effectiveness of a composite liner, the geomembrane must be placed to achieve a good hydraulic contact (often called "intimate contact") with the underlying layer of low-permeability soil. As shown in Figure 1.12, the composite liner

	Subject	Evaluation of Geotextile and Pond Liner Tensile Strength	
Golder Associates	Job No. 093-82538.0002 Ref. PEF/Crystal River FGD Pond	Made by JPG Checked JB/KH Reviewed KBK KBK 6/1/09	Date 06/01/2009 Sheet 1 of 5

OBJECTIVE

Determine the largest void that can be spanned by the chosen geomembrane and geotextile products.

METHOD

Using the design methodology outlined in "Geotechnical Aspects of Landfill Design and Construction" for the spanning of circular depressions, determine the diameter of the circular depression that will cause failure of the overlying geosynthetic products.

REFERENCES

1. Qian, X., Koerner, R., Gray, D., "Geotechnical Aspects of Landfill Design and Construction"
2. Agru America Product Information
3. Huesker, Inc. Comtrac 600.100 Product Information
4. Koerner. "Designing with Geosynthetics," 5th ed.

ASSUMPTIONS

1. The pond will be constructed above grade.
2. Berm will be 25 ft high with 3:1 (H:V) slopes on each side.
3. Total footprint is 8 acres.
4. Geotextile reinforcement will extend over entire footprint.
5. Geomembrane liner will cover pond interior only.
6. Unit weight of berm soil is 120 pcf
7. Unit weight of pond water is 62.4 pcf
8. Unit weight of pond solids is 90 pcf
9. **Voids will be circular.**

CALCULATION

1. The geotextile strength will be verified first since it will serve as the reinforcement.
   (Comtrac 600.100 will be evaluated in this calculation.)

$$T_{allow} = \frac{T_{ult}}{RF_{cr} \times RF_{id} \times RF_{cbd}}$$

where:

T_{allow} = long-term allowable design tensile load

T_{ult} = short-term ultimate load from tensile tests

RF_{cr} = reduction factor which accounts for creep

RF_{id} = reduction factor which accounts for installation damage, intermediate with heavy equipment

RF_{cbd} = reduction factor for chemical/biological degradation

RF_{cr} = 4.0

RF_{id} = 1.4

RF_{cbd} = 1.2

Geotextile	T_{ult} (lbs/ft)	T_{allow} (lbs/ft)
Comtrac 600.100	41,112	6,118

Allowable Lining System Strain

$\varepsilon_l = \varepsilon_y/F_R$ where: ε_y = minimum yield strain of lining components
F_R = factor of safety against rupture. Generally>=1.5.

ε_y = 10%
F_R = 2.0

ε_l = 5.0%

Allowable reinforcement strain

ε_g = 10% From reference 1, ε_g y 10% for polyester geotextiles.

Allowable Design Strain

ε_d is lesser of ε_l and ε_g

ε_d = 5.0%

Average Unit weight of soil on geotextile:

$$\gamma_{avg} = \frac{\gamma_{soil}(H_{berm})}{6r}$$

γ_{soil} = 120 lbs/ft^3 Unit weight of soil in berm. Conservative approach since the unit weight of sludge and water in pond will be less.
H_{berm} = 25 ft

$$\gamma_{avg} = \frac{500}{r}$$

Normal pressure over depression

$$P = 2(\gamma_{avg})(r)(1-e^{-0.5(H_{berm})/r}) + q*e^{-0.5(H_{berm})/r}$$

Dimensionless factor

Ω = 0.97 from Reference 1 - for 5% strain

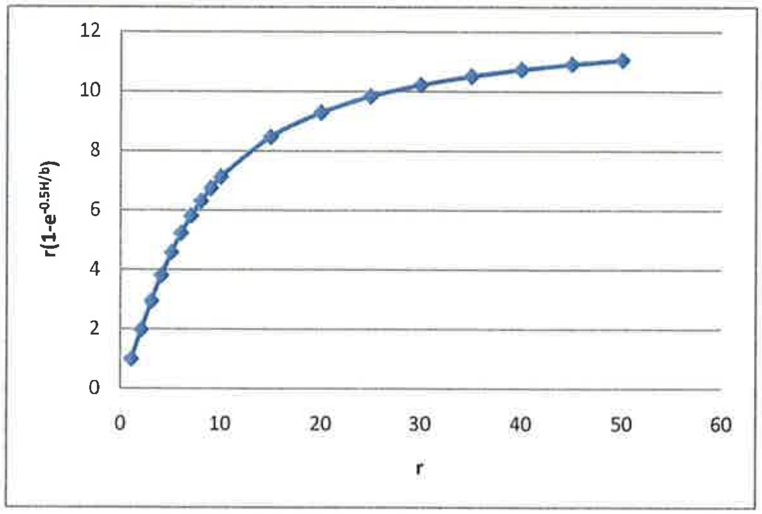
Calculate radius of depression

$$r = \frac{T_{allow}}{P\Omega}$$

where: r = radius of depression
T_{allow} = allowable tensile load
P = normal pressure
Ω = dimensionless factor

Geotextile	T_{allow} (lbs/ft)	r (ft)
Comtrac 600.100	6,118	8.0

Note: Equation appears nonlinear and will not be relied on for r>10 ft.



2. Evaluate the geomembrane strength

Geomembrane material properties from reference 2.

$$T_{allow} = \frac{T_{ult}}{RF_{cr} \times RF_{id} \times RF_{cbd}}$$

Reduction factors are not used for geomembranes. Instead use strength @ break listed in Reference 2.

Geomembrane	T_{break} (lbs/in)	T_{break} (lbs/ft)
60 mil LLDPE	168	2,016

Allowable strain

ε_r = rupture strain

F_r = factor of safety against rupture, generally >=1.5

$\varepsilon_g = \varepsilon_r / F_r$

ε_r = 400%

F_r = 2.5 — F_r was chosen to be 2.5 since the liner serves a critical function.

ε_g = 160% — Though the geotextile reinforcement was calculated for 10% allowable strain, the geomembrane will be evaluated to 160% allowable strain.

Average unit weight of solids and water on liner

$$\gamma_{avg} = \frac{\gamma_{water}(DEPTH_{water}) + \gamma_{solids}(THICKNESS_{solids})}{DEPTH_{water} + THICKNESS_{solids}}$$

$\gamma_{water} =$ 62.4

$DEPTH_{water} =$ 4

$\gamma_{solids} =$ 90

$THICKNESS_{solids} =$ 13

$\gamma_{avg} =$ 83.5 lb/ft^3

Normal pressure over depression

$$P = 2(\gamma_{avg})(r)(1-e^{-0.5(DEPTH)/r})$$

Dimensionless factor from Reference 1

y/r >= 0.5 y = allowable deflection into depression

This value was determined after having multiple solutions of the equation

$1+\varepsilon_d = 2\Omega\sin^{-1}[1/(2\Omega)]$ if y/r <=0.5 where: $\varepsilon_d =$ allowable design strain

y/r = 0.5

$\Omega = 0.25*(y/r + r/y)$

$\Omega =$ 0.625

Calculate the radius of depression

$$r = \frac{T_{break}}{P\Omega}$$

Geomembrane	r (ft)
60 mil LLDPE	4.8

CONCLUSION

After evaluation of the geotextile reinforcement and geomembrane liners, the void radii that these products can span were calculated.

The calculations were performed for each product independent of all others.

The results are summarized below:

Geotextile Reinforcement

Geotextile	T_{allow} (lbs/ft)	r (ft)
Comtrac 600.100	6,118	8.0

Geomembrane Liner

Geomembrane	T_{break} (lbs/ft)	r (ft)
60 mil LLDPE	2,016	4.8

Golder Associates	Subject	Anchor Trench Calculations - Reinforcing Geotextile		
	Job No. 093-82538.0002	Made by BTH	Date 06/01/2009	
	Ref. PEF/Crystal River FGD Pond	Checked SFS/KH	Sheet 1 of 3	
		Reviewed KBK KBK 6/1/09		

OBJECTIVE

To verify that the proposed anchor trench dimensions are adequate for the reinforcing geotextile.

METHOD

Using the methodology outlined in Reference 1 by Koerner, verify the proposed anchor trench dimensions for the geo-membrane pond liner.

REFERENCES

1. Koerner, R. (1999). Designing With Geosynthetics. Prentice Hall, Upper Saddle River, New Jersey.
2. Huesker Comtrac 600.100 Product Information

ASSUMPTIONS

1. The pond will be constructed above grade.			
2. Berm will be 2 ft. high with 100:0.1 (H:V) side slopes.	berm height =	2	feet
slope:	H:	100	
	V:	0.1	
The resulting side slope angle is:	β =	0.1	degrees
3. Pond will be underlain by a Woven High-Strength Geotextile (Comtrac 600.100 or equivalent).			
4. The unit weight of the cover soil:	γ_{AT} =	120	pcf
5. The depth of cover soil:	depth =	24	inches
6. The allowable force in the geo-membrane stress (based on Comtrac 600.100 and Golder calculations of allowable tensile strength - see Evaluation of Pond Liners.xlsx):	T_{allow} =	7,786	lbs/ft
7. The angle of shearing resistance between the reinforcing geotextile and adjacent material:	δ_L =	35	degrees
8. The frictional angle for the top of the geo-membrane under a soil-cracking assumption:	δ_U =	0	degrees
9. The angle of shearing resistance of the soil:	ϕ =	35	degrees
10. Length of geo-membrane runout:	L_{RO} =	20	feet
11. Proposed depth of anchor trench:	proposed d_{AT} =	3	feet

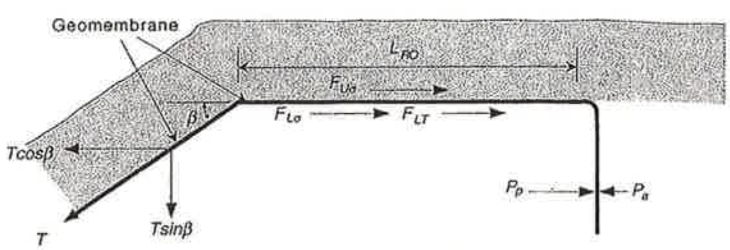
Notes: Interface shear data for Comtrac 600.100 and site soil = 39.3 degrees (residual)

Reinforcing layer actually deployed horizontally. "Runout" is assumed to be about one-third of the width of pond embankment width (66 feet x 0.33 ~ 20 feet). This indicates that the full allowable tensile strength of the geotextile will be mobilized outside the limits of the geomembrane which is the goal of the reinforcing layer.

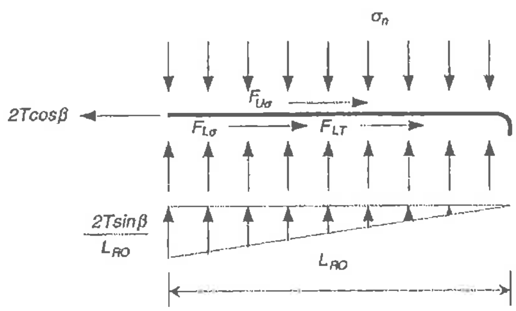
CALCULATION

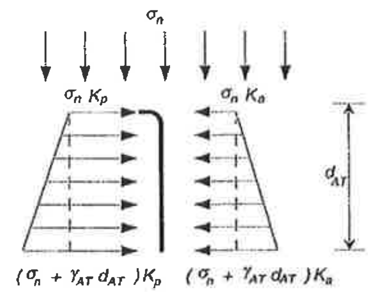
1. The design methodology used hereafter is based on a method outlined in Reference 1. Figures are from Reference 1.

Free-body diagram for geo-membrane profile:



Golder Associates	**Subject** Anchor Trench Calculations - Reinforcing Geotextile		
	Job No. 093-82538.0002 **Ref.** PEF/Crystal River FGD Pond	**Made by** BTH **Checked** SFS/KH **Reviewed** KBK	**Date** 06/01/2009 **Sheet** 2 of 3





$\Sigma Fx = 0$
Therefore,

$T_{ALLOW}\cos\beta = \quad F_{U\sigma} + F_{L\sigma} + F_{LT} - P_A + P_P$

where:

$T_{ALLOW} =$	allowable force in geomembrane
$\beta =$	side slope angle
$F_{U\sigma} =$	shear force above geomembrane due to cover soil
$F_{L\sigma} =$	shear force below geomembrane due to cover soil
$F_{LT} =$	shear force below geomembrane due to vertical component of T_{ALLOW}
$P_A =$	active earth pressure against the in-situ side of the anchor trench
$P_P =$	passive earth pressure against the in-situ side of the anchor trench
$L_{RO} =$	length of geo-membrane runout

$P_A = \quad 1/2(\gamma_{AT} d_{AT})\, K_A\, d_{AT} + (\sigma_n)\, K_A\, d_{AT}$

$P_A = \quad (0.5\gamma_{AT} d_{AT} + \sigma_n)\, K_A\, d_{AT}$

$P_P = \quad (0.5\gamma_{AT} d_{AT} + \sigma_n)\, K_P\, d_{AT}$

where:

$\gamma_{AT} =$	unit weight of soil in anchor trench
$d_{AT} =$	depth of anchor trench
$\sigma_n =$	applied normal stress from cover soil
$K_A =$	coefficient of active earth pressure = $\tan^2(45 - \phi/2)$
$K_P =$	coefficient of passive earth pressure = $\tan^2(45 + \phi/2)$
$\phi =$	angle of shearing resistance of respective soil
$\delta_L =$	angle of resistance between the geo-membrane liner and
$\delta_U =$	frictional angle for the top of the geo-membrane

Golder Associates	Subject	Anchor Trench Calculations - Reinforcing Geotextile	
	Job No. 093-82538.0002	**Made by** BTH	**Date** 06/01/2009
	Ref. PEF/Crystal River FGD Pond	**Checked** SFS/KH	**Sheet** 3 of 3
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From free-body diagram: $\Sigma Fx = 0$

$F_{U\sigma} = \sigma_n \tan\delta_U (L_{RO})$

$= 0$ lb/ft

$F_{L\sigma} = \sigma_n \tan\delta_L (L_{RO})$

$= 3361.00$ lb/ft

$F_{LT} = T_{ALLOW} \sin\beta \tan\delta_L$

$= 5.45$ lb/ft

$P_A = (0.5\gamma_{AT} d_{AT} + \sigma_n) K_A d_{AT}$

$= 350.28$

$P_P = (0.5\gamma_{AT} d_{AT} + \sigma_n) K_P d_{AT}$

$= 4769.83$

$T_{ALLOW}\cos\beta = F_{U\sigma} + F_{L\sigma} + F_{LT} - P_A + P_P$

$T_{ALLOW}\cos\beta = 7{,}786$

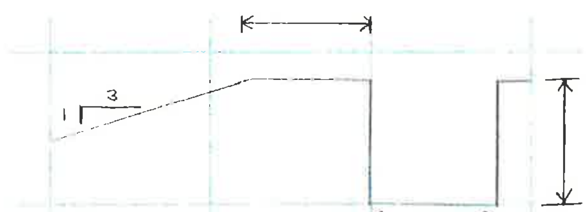
$T_{ALLOW}\cos\beta = 7{,}786$

$d_{AT} = 3$ ft   Use Excel solver to solve for d_{AT}

$d_{AT} < d_{AT\_proposed} = 3$ ft

Proposed Anchor Trench:

$L_{RO} = 20$ ft



$d_{AT} = 3$ ft

*not to scale

W=2.0 ft

CONCLUSION

From the assumptions stated in this calculation and the methodologies presented in the references, the proposed dimensions of the reinforcing geotextile were evaluated. The required depth of the anchor trench was calculated to be 3 feet, which is equivalent to the proposed anchor trench depth of 3 feet. Based on the calculations, the proposed anchor trench geometry is sufficient in providing stabilization for the reinforcing geotextile.

Golder Associates	Subject: Anchor Trench Calculations - Geomembrane Liner		
	Job No. 093-82538.0002 Ref. PEF/Crystal River FGD Pond	Made by BTH Checked SFS/KH Reviewed KBK KBK 6/1/09	Date 06/01/2009 Sheet 1 of 3

OBJECTIVE

To verify that the proposed anchor trench dimensions are adequate for reinforcing the geomembrane pond liner.

METHOD

Using the methodology outlined in Reference 1 by Koerner, verify the proposed anchor trench dimensions for the geomembrane pond liner.

REFERENCES

1. Koerner, R. (1999). Designing With Geosynthetics. Prentice Hall, Upper Saddle River, New Jersey.
2. Agru America Product Information

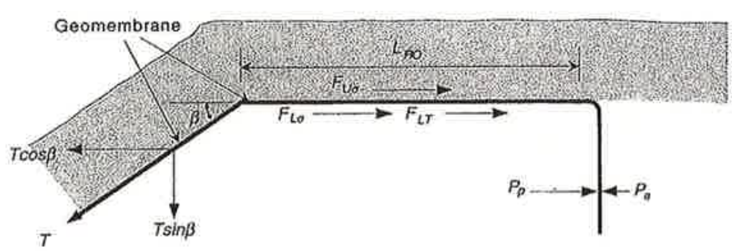
ASSUMPTIONS

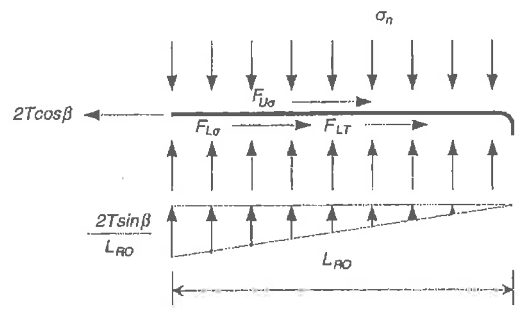
1. The pond will be constructed above grade.			
2. Berm will be 22 ft. high with 3:1 (H:V) side slopes.	berm height =	22	feet
	slope: H:	3	
	V:	1	
The resulting side slope angle is:	β =	18.4	degrees
3. Pond will be lined with 60 mil Agru America liner low density polyethylene "micro spike" geo-membrane.			
4. The unit weight of the cover soil:	γ_{AT} =	120	pcf
5. The depth of cover soil:	depth =	12	inches
6. The allowable force in the geo-membrane stress (based on Agru America "micro spike" geo-membranes):	T_{allow} =	2,016	lbs/ft
7. The angle of shearing resistance between the geo-membrane liner and adjacent material:	δ_L =	30	degrees
8. The frictional angle for the top of the geo-membrane under a soil-cracking assumption:	δ_U =	0	degrees
9. The angle of shearing resistance of the soil:	ϕ =	35	degrees
10. Length of geo-membrane runout:	L_{RO} =	2	feet
11. Proposed depth of anchor trench:	proposed d_{AT} =	2	feet

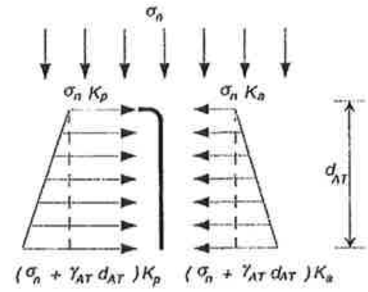
CALCULATION

1. The design methodology used hereafter is based on a method outlined in Reference 1. Figures are from Reference 1.

Free-body diagram for geo-membrane profile:







$\Sigma Fx = 0$

Therefore,

$T_{ALLOW}\cos\beta = \quad F_{U\sigma} + F_{L\sigma} + F_{LT} - P_A + P_P$

where:

- $T_{ALLOW} =$ allowable force in geomembrane
- $\beta =$ side slope angle
- $F_{U\sigma} =$ shear force above geomembrane due to cover soil
- $F_{L\sigma} =$ shear force below geomembrane due to cover soil
- $F_{LT} =$ shear force below geomembrane due to vertical component of T_{ALLOW}
- $P_A =$ active earth pressure against the in-situ side of the anchor trench
- $P_P =$ passive earth pressure against the in-situ side of the anchor trench
- $L_{RO} =$ length of geo-membrane runout

$P_A = \quad 1/2(\gamma_{AT} d_{AT})\, K_A\, d_{AT} + (\sigma_n)\, K_A\, d_{AT}$

$P_A = \quad (0.5\gamma_{AT} d_{AT} + \sigma_n)\, K_A\, d_{AT}$

$P_P = \quad (0.5\gamma_{AT} d_{AT} + \sigma_n)\, K_P\, d_{AT}$

where:

- $\gamma_{AT} =$ unit weight of soil in anchor trench
- $d_{AT} =$ depth of anchor trench
- $\sigma_n =$ applied normal stress from cover soil
- $K_A =$ coefficient of active earth pressure = $\tan^2(45 - \phi/2)$
- $K_P =$ coefficient of passive earth pressure = $\tan^2(45 + \phi/2)$
- $\phi =$ angle of shearing resistance of respective soil
- $\delta_L =$ angle of resistance between the geo-membrane liner and
- $\delta_U =$ frictional angle for the top of the geo-membrane

Golder Associates	Subject: Anchor Trench Calculations - Geomembrane Liner		
	Job No. 093-82538.0002	**Made by** BTH	**Date** 06/01/2009
	Ref. PEF/Crystal River FGD Pond	**Checked** SFS/KH	**Sheet** 3 of 3
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From free-body diagram: $\Sigma Fx = 0$

$F_{U\sigma} = \sigma_n \tan\delta_U (L_{RO})$

$= 0$ lb/ft

$F_{L\sigma} = \sigma_n \tan\delta_L (L_{RO})$

$= 138.56$ lb/ft

$F_{LT} = T_{ALLOW} \sin\beta \tan\delta_L$

$= 368.07$ lb/ft

$P_A = (0.5\gamma_{AT} d_{AT} + \sigma_n) K_A d_{AT}$

$= 111.43$

$P_P = (0.5\gamma_{AT} d_{AT} + \sigma_n) K_P d_{AT}$

$= 1517.34$

$T_{ALLOW}\cos\beta = F_{U\sigma} + F_{L\sigma} + F_{LT} - P_A + P_P$

$T_{ALLOW}\cos\beta = \boxed{1912.55}$

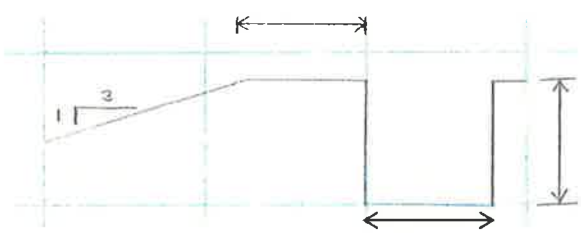
$T_{ALLOW}\cos\beta = \boxed{1912.55}$

$d_{AT} = \boxed{1.80}$ ft — Use Excel solver to solve for d_{AT}

$d_{AT} < d_{AT\_proposed} = 2$ ft

Proposed Anchor Trench:

$L_{RO} = 2$ ft



$d_{AT} = 2$ ft

*not to scale

W=2.0 ft

CONCLUSION

From the assumptions stated in this calculation and the methodologies presented in the references, the proposed dimensions of the geomembrane pond liner were evaluated. The required depth of the anchor trench was calculated to be 1.8 feet, which is less than the proposed anchor trench depth of 2 feet. Based on the calculations, the proposed anchor trench geometry is sufficient in providing stabilization for the geo-membrane liner.