CORPORATE EHS SERVICES

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Via E-Mail and Overnight Courier

February 4, 2011

Mr. Stephen Hoffman
US Environmental Protection Agency
Two Potomac Yard
2733 S. Crystal Drive
5th Floor, N-237
Arlington, VA 22202-2733

Re: Response to EPA letter regarding Dam Safety Assessment Report
Wabash River Generating Station, Vigo County, Indiana

Dear Mr. Hoffman:

Duke Energy Indiana (DEI) received the letter from Suzanne Rudzinski, Director of the Office of RCRA of the United States Environmental Protection Agency (EPA) dated January 7, 2011 and the final report from O'Brien & Gere titled "Dam Safety Assessments for CCW Impoundments for Wabash River Generating Station." The site assessment of the Primary Ash Pond (Pond A and Pond B), Secondary Ash Pond, and South Ash Pond was conducted by the EPA's engineering contractors on May 11, 2010.

DEI supports EPA's objective to ensure the safe operation and maintenance of coal combustion residue (CCR) impoundments and is committed to meeting all state and federal requirements. Based on ongoing monitoring, maintenance and inspections, DEI is confident that the CCR impoundments have the structural integrity necessary to protect the public and the environment. The O'Brien and Gere report on the Wabash River Generating Station supports this conclusion and found that acceptable performance is expected in accordance with the applicable safety regulatory criteria.

Today's submittal is in response to the above referenced letter from EPA dated January 7, 2011. As outlined in EPA's letter the contractor made several recommendations addressing minor deficiencies and secondary studies/investigations. The DEI response to each of these recommendations can be found in the first attachment. If you have any questions regarding the responses, comments, or need additional information, please contact Richard Meiers at 317-838-1955.

Sincerely,
Duke Energy Indiana

R. F. Klopfstein

R. F. Klopfstein
General Manager
Wabash River Station

Attachment (2)

- DEI Responses to EPA Recommendations
- Addendum to Sargent and Lundy Pond Examination Report – additional information

Attachment - DEI Responses to EPA Recommendations

6.1. URGENT ACTION ITEMS

None of the recommendations are considered to be urgent, since the issues noted above do not appear to threaten the structural integrity of the impoundments in the near term.

DEI Response

DEI agrees.

6.2. LONG TERM IMPROVEMENT

Primary and Secondary Ash Ponds

The soil strength data and other basic data used in the stability analysis completed by Sargent & Lundy were not presented in their report; therefore, we cannot comment on the validity of the analysis. We recommend that an addendum to the report be prepared that presents the basis of the analysis. If the data used in the analysis cannot be substantiated with a reasonable degree of confidence, additional investigation of the east dike may be required to provide valid data for the slope stability analysis.

DEI Response

The additional information referenced above was not provided to the contract inspectors during the site visit but was provided by DEI as an attachment to our comments on the draft report. The attachment included the additional information used as the basis for the slope stability analysis for the Sargent and Lundy Pond Examination Report. The attachment is again included with these responses. This recommendation is considered complete.

A hydrologic and hydraulic analysis should be performed to evaluate the potential for overtopping of the embankments during a 100-year to 50 percent PMP flood event and to identify a maximum surcharge pool elevation for slope stability analysis of that loading case.

DEI Response

DEI will have a hydrologic and hydraulic analysis for the Primary and Secondary Ash Ponds conducted by an independent engineering firm. This analysis will be completed by December 31, 2011.

Large trees growing in the outboard slope of the east dike and within five feet of the toe of the outboard slope of Primary Pond A should be removed along with other woody vegetation in accordance with standard dam safety practice. The primary reason behind the standard practice to remove trees from embankment dams is due to the potential for an uprooted tree to jeopardize the stability of the embankment and shorten seepage paths through the dike. Given that the Primary Pond A is nearly full of ash and does not retain a significant quantity of surface water (or liquid wastes) and no evidence of seepage was observed at the toe of this dike, the argument that the trees provide a measure of stability against rising and falling Wabash River levels may have merit, but only if it can be shown through investigation and analysis that the embankment will retain adequate stability should trees be uprooted, and if there is no future intent to remove the impounded ash and return Primary Ash Pond A to retaining large volumes of surface water or liquid wastes. If a decision is made to leave the trees in place, we recommend that underbrush and new tree growth be maintained to allow foot access for future visual inspections of the slope.

DEI Response

> *DEI will remove the underbrush and have this completed as soon as practical but no later than October 1, 2011. Any new tree growth will be noted during inspections and removed as necessary as soon as practical. DEI will have an independent engineering firm evaluate the impact of uprooted trees and have that completed by December 31, 2011.*

The trees growing along the outboard slope and within 5 feet of the toe of the Secondary Ash Pond dike should be removed. Additional maintenance recommendations are provided below:

- Remove trees/control heavy vegetation along freeboard of upstream slopes
- Place additional gravel road base in low areas on crest and re-grade to maintain positive drainage
- Monitor outboard slopes for erosion and repair if conditions worsen

DEI Response

> *DEI will remove trees growing along the outboard slope along the toe of the Secondary Ash pond dike and additional gravel will be placed in low areas on the crest. DEI will re-grade the road to maintain positive drainage. This will be completed as soon as practical but no later than October 1, 2011. Outboard slopes will be inspected in accordance with the DEI inspection program.*

South Ash Pond

In general, the South Pond appeared to be in good condition. No major improvements to the South Pond are recommended at this time. Some minor maintenance recommendations are provided below:

- Place and compact additional gravel road base to provide minimum 6-inches of cover over non-woven geotextile along crest roads and secondary roads.
- Mow vegetated slopes at least twice annually to control vegetation
- Repair erosion along groin on outboard northwest corner of the South Pond

DEI Response

> *DEI will place and compact additional gravel to maintain 6" of cover on areas where geotextile is exposed on the access road for the South Pond and will have that completed as soon as practical but no later than December 31, 2011. DEI agrees to mow the vegetation at least twice a year on the South Ash Pond berms beginning in the*

year 2011. Erosion along the groin on the NW corner of the South Pond will be repaired as soon as practical but no later than October 1, 2011.

6.3. MONITORING AND FUTURE INSPECTION

The quarterly internal inspections should continue as planned; however, we recommend that the inspections be documented on a standard dam safety inspection checklist similar to the one provide by IDNR. Consideration should be given to inspections by licensed dam safety engineers on a regular basis to document the continued proper maintenance and operation of the CCW impoundments.

DEI Response

DEI has developed and implemented a formal ash pond dike inspection program with scheduled inspections performed by internal and third party personnel that meet the criteria listed above. Written records of the inspections will be created and maintained. This recommendation is considered complete.

6.4. TIME FRAME FOR COMPLETION OF REPAIRS/IMPROVEMENTS

We recommend that the addendum or additional investigations needed to substantiate the stability analysis of the east dike of the Primary Pond A and Secondary Pond be completed within one year of this inspection. Other recommended maintenance items should be completed as soon as practical within one year of this inspection.

DEI Response

As noted above in each response, DEI has identified when each task will be completed.

Attachment - Addendum to Sargent and Lundy Pond Examination Report – additional information

ISSUE SUMMARY
Form SOP-0402-07, Revision 7B

DESIGN CONTROL SUMMARY			
CLIENT:	Duke Energy Indiana, Inc.	UNIT NO.:	Page No.: 1
PROJECT NAME:	**Wabash River Pond Examination Program**		
PROJECT NO.:	10444-806	☐ NUCLEAR SAFETY- RELATED	
CALC. NO.:	WRC-F-002S	☒ NOT NUCLEAR SAFETY-RELATED	
TITLE:	Ash Pond Slope Stability Analyses		
EQUIPMENT NO.:			

IDENTIFICATION OF PAGES ADDED/REVISED/SUPERSEDED/VOIDED & REVIEW METHOD

Calculation starts on this page. Added pages 2 through 19, Attachment A (2 pages) and Attachment B (8 pages).

INPUTS/ ASSUMPTIONS
☒ VERIFIED
☐ UNVERIFIED

REVIEW METHOD:	Detailed	REV.	0
STATUS:	Approved	DATE FOR REV.:	11/23/09
PREPARER	E. Sabri Motan/ E. Sabri Motan	DATE:	11/12/2009
REVIEWER	W. ROGER WU / [signature]	DATE:	11/23/09
APPROVER	D.L. Kocunik / Daniel G. Kocunik	DATE:	11/23/09

IDENTIFICATION OF PAGES ADDED/REVISED/SUPERSEDED/VOIDED & REVIEW METHOD

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NOTE: PRINT AND SIGN IN THE SIGNATURE AREAS

Total Number of Pages: 29

TABLE OF CONTENTS

1.0 Purpose

The purpose of this calculation is to determine the factors of safety of the existing exterior slopes of the Fly Ash Pond A dike, Pond B dike, and the Secondary Settling Pond Dike for the static and seismic conditions at the Wabash River Generating Station near Terre Haute, Indiana.

2.0 Design Input

- The subsoil profile, the geotechnical laboratory test results, and the recommended in-situ and embankment fill soil parameters were obtained from Ref. 1. The available borings nearest the pond location are B-11 and B-14 in Ref.1 (See also Fig. 1).
- Dike cross-sections and the cross-section locations were obtained from Refs. 2, 3, 4, 5.
- Top elevation of all pond dikes was considered at approximately El. 484' per Refs. 3 and 5.
- The approximate ground elevation is 464 feet at Pond A, Secondary Settling Pond, and Pond B areas (Refs. 2, 4).
- The top elevation of the ash fill is approximately 15 feet higher than the top of the Pond A dike as noted during the pond examination performed by S&L on 10/28/2009. The ash slopes down toward the top of the dike around the edges. This slope was considered as 3 Horizontal: 1 Vertical.
- The ash deposited in Pond A is estimated to have substantially drained and reached a condition where an angle of internal friction as well as a water table elevation can be associated with it. There are no test results available for the in-situ shear strength parameters of the ash deposited in Pond A. Ref. 6 contains triaxial compression test results on compacted samples of the ash from the existing ponds. The shear strength parameters obtained from these tests were discounted to some extent for use in the stability analyses to account for the uncompacted state of the ash inside the ponds. The Secondary Settling Pond contains water only.

3.0 Assumptions

None.

4.0 Methodology

The slope stability analyses were performed using SLOPE/W program Version 5.11 (Ref. 10). This program has been verified and validated in accordance with S&L SOP 0204 procedures. The S&L program number is 03.7.747-5.11. The runs were performed on Computer # ZD 2638. For static and seismic slope stability analyses, a large number of slip planes were generated and the factor of safety against sliding was determined for each plane. The slip planes were represented by circular arcs. The potential slip circles were analyzed using the Simplified Bishop Method which is routinely used by engineers for slope stability evaluations (See pages A-1 and A-2 for an overview of the method). Figure 4 shows the rectangular grid that forms the center points of the potential slip circles.

At each grid point, a number of circles tangent to each of the closely-spaced horizontal lines in the bottom portion of the figure are generated. The minimum factor of safety for each grid point is determined and registered by the software for each grid point. Once all grid points are covered in this manner, the minimum of all the FS values, the center of the most critical slip circle with the lowest FS, and the slip surface are displayed by the software.

The slope stability analyses in clayey embankments often include the effect of a crack that may open up during the service life of the earth structure as a combined result of the repeated wetting/drying repeated freeze/thaw, and gradual lateral deformation (particularly on clayey foundation soils) of the compacted dike soil over a period of several years. The shear strength available along this crack is assumed to be nonexistent, and the potential slip planes are started at the bottom of the crack. However, the dikes considered in this calculation have not shown such a condition over a period of approximately 30 years, and therefore, the slope stability analyses performed for this calculation do not consider this effect.

The slope stability analyses were also performed for the seismic conditions using a horizontal acceleration coefficient. For seismic stability, two separate analyses ("effective stress" and "total strength") are normally performed, and the smaller of the two values obtained is considered as the minimum slope factor of safety against seismic failure (Ref. 7). Generally, for small seismic events that do not significantly alter the porewater pressures in the fill and the in-situ soils, an effective stress analysis would be appropriate. If the porewater distribution is significantly altered as a result of ground shaking during a strong earthquake, the total stress analysis would be appropriate.

5.0 Calculations

Subsoil Conditions

The soil conditions shown in borings B-11 and B-14 (Ref.1) were considered as generally representative of the pond embankment area. B-11 is 45 feet deep, and B-14 is 10 feet deep.

The soils encountered consist of, from top to bottom:

1. Medium stiff to very soft silty clay (approximately 14 feet thick),
2. Loose to medium-dense to dense sand to the bottom of the boring (45 feet).

Bedrock was not encountered at 45-ft depth in B-11 although other borings (such as B-1 and B-2) further west encountered shale bedrock at depths as shallow as 18 feet. This indicates an overall downslope gradient from west to east at the top of the rock toward the Wabash River.

Approximately upper six (6) feet of the in-situ clay was described as medium stiff to very stiff (Standard Penetration Blow Counts 5 to 11 blows/ft), whereas the remaining 8 feet was described as soft to very soft (Standard Penetration Blow Counts 2 to 5 blows/ft). However, the slope stability analyses consider the same set of unit weight, friction angle, and cohesion values for both layers.

The **effective-stress** embankment and in-situ soil parameters used in the static and seismic analyses are shown below:

TABLE 1

Material	Unit Weight (lb/ft^3)	Friction Angle, φ'_{cu}	Cohesion, c'_{cu} (lb/ft^2)
Riprap	110	40	0
Pond Ash	90	25	0
Embankment Fill	120 (*)	22 (*)	250 (*)
In-situ Silty Clay	122 (*)	30 (*)	0 (*)
In-situ Sand	118 (*)	30 (*)	0 (*)

(*) Data from Ref. 1.

The **total-stress** parameters used in the seismic analyses are as follows:

TABLE 2

Material	Unit Weight (lb/ft^3)	Friction Angle, φ_{cu}	Cohesion, c_{cu} (lb/ft^2)
Riprap	110	40	0
Pond Ash	90	10	250
Embankment Fill	120 (*)	0 (*)	1500 (*)
In-situ Silty Clay	122 (*)	16 (*)	200 (*)
In-situ Sand	118 (*)	30 (*)	0 (*)

(*) Data from Ref. 1.

Many of the parameters in Tables 1 and 2 are provided in Ref. 1 for the design of the south ash pond. The unit weight and shear strength parameters of the riprap were estimated using typical values for rock fills. Also, as indicated above, the shear strength parameters of the compacted ash (Ref. 6) were reduced to adjust for the uncompacted condition of the ash in Pond A. Laboratory test data on the total stress shear strength parameters of the compacted dike fill were not available. The total strength shear strength of the compacted dike fill was represented with a cohesion of 1500 lb/ft^2 and a friction angle of zero degrees. This is considered as a conservative assumption as the shear strength of compacted fills generally increases over time as a result of gradual drying and consolidation of the fill soil which is usually compacted on the wet side of the optimum compaction moisture content.

Slope Stability Analyses

Pond B dike construction is essentially identical to that of the Secondary Settling Pond Dike. Also the South pond constructed in 2005 is being filled against the exterior slope of Pond B to eventually achieve an equilibrium condition on both sides of the dike. Therefore, Pond B dike stability was not evaluated in this calculation. The locations of the sections analyzed are shown on Fig. 3.

The seismic slope stability analyses were performed for a horizontal ground acceleration value of 0.05g. This value was obtained from the USGS map of 10-percent exceedance level Peak Ground Acceleration (PGA) values within a 50-year period (Ref. 9). The original seismic slope stability analyses were also performed with 0.05g horizontal acceleration (Ref. 1).

For the static stability analyses in terms of effective stresses, a groundwater surface profile was used. The groundwater surface was approximated in the form of three straight lines shown in Figures 4 and 5. Since no toe seepage along the pond slopes was observed during a recent pond examination (Ref. 8), the groundwater surface was considered to drop within the body of the dikes to the level of the groundwater table observed in the soil borings (Approximately El. 456). The water level within the ash in Pond A is not known, and was considered at about two (2) feet below the top of the berm.

Pond A Dike

The perimeter dike has an exterior slope of 2H:1V and an interior slope of 1-1/2H:1V (Section D-D on Fig. 2). The main body of the dike consists of compacted clayey soil. The dike is approximately 20 feet high.

Secondary Settling Pond Dike

The perimeter dike has an exterior slope of approximately 3H:1V and an interior slope of 3H:1V (Section 1-1 on Fig. 2). The main body of the dike also consists of compacted clayey soil. The dike is approximately 20 feet high. A layer of riprap was placed over the exterior slope of the dike (Fig. 2). The riprap placed over the interior slope above and below the water line was considered part of the embankment fill as its effect on the overall dike stability is very minor.

Sargent & Lundy LLC	Ash Pond Slope Stability Analyses			Calc. No. WRC-F-002S	
				Rev. 0	Date
		Safety-Related	X	Non Safety-Related	Page 7 of

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Project	Wabash River Pond Examination Program	Reviewed by	Date
Proj. No.	10444-806	Approved by	Date

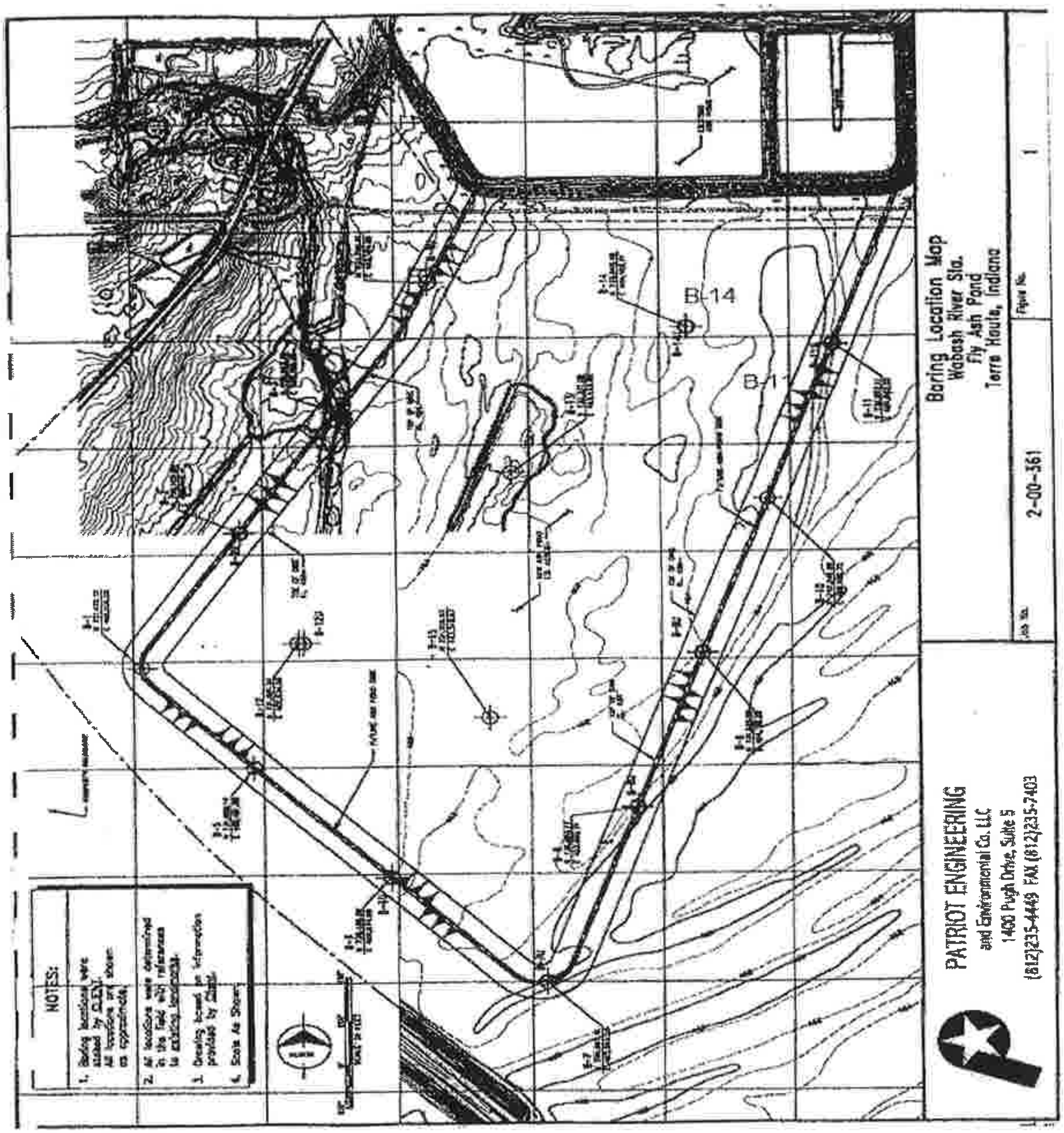

FIGURE 1 (From Ref. 1)

Client	Duke Energy Indiana, Inc.	Prepared by: E.S. Motan	Date 11/12/2009
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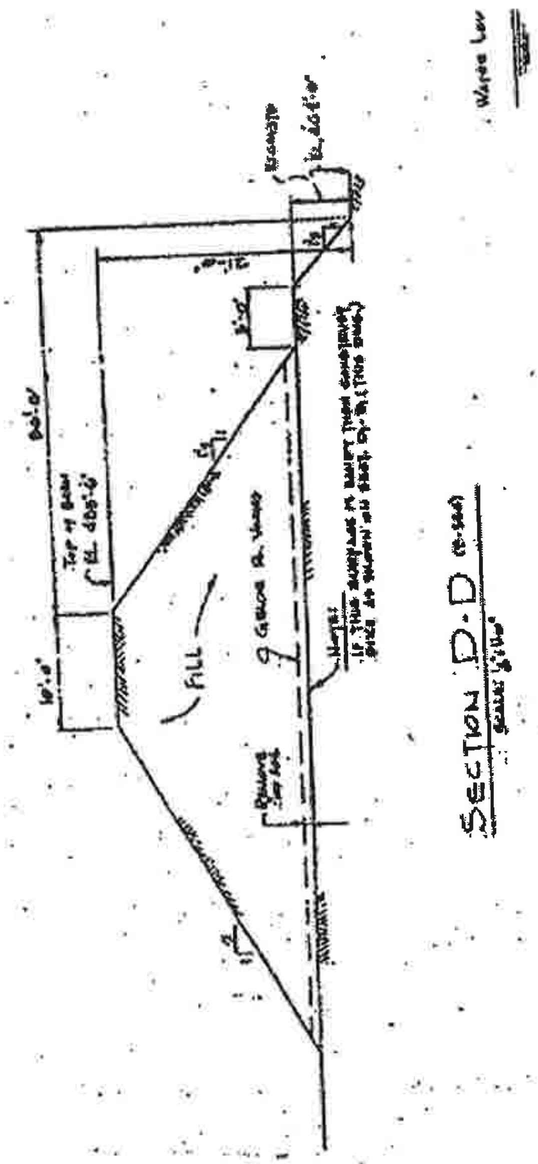
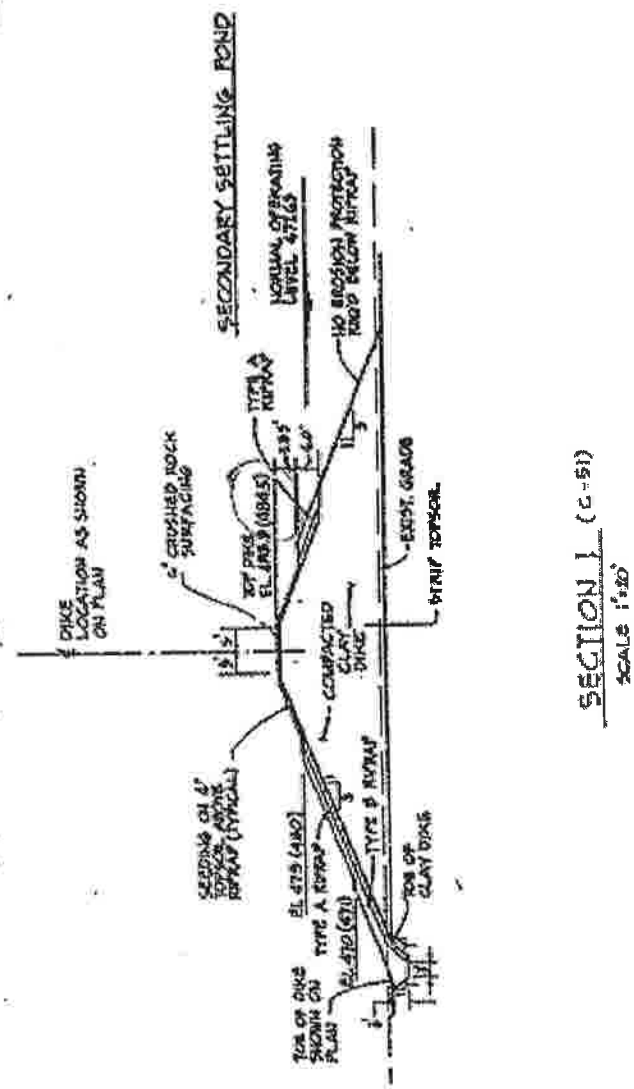
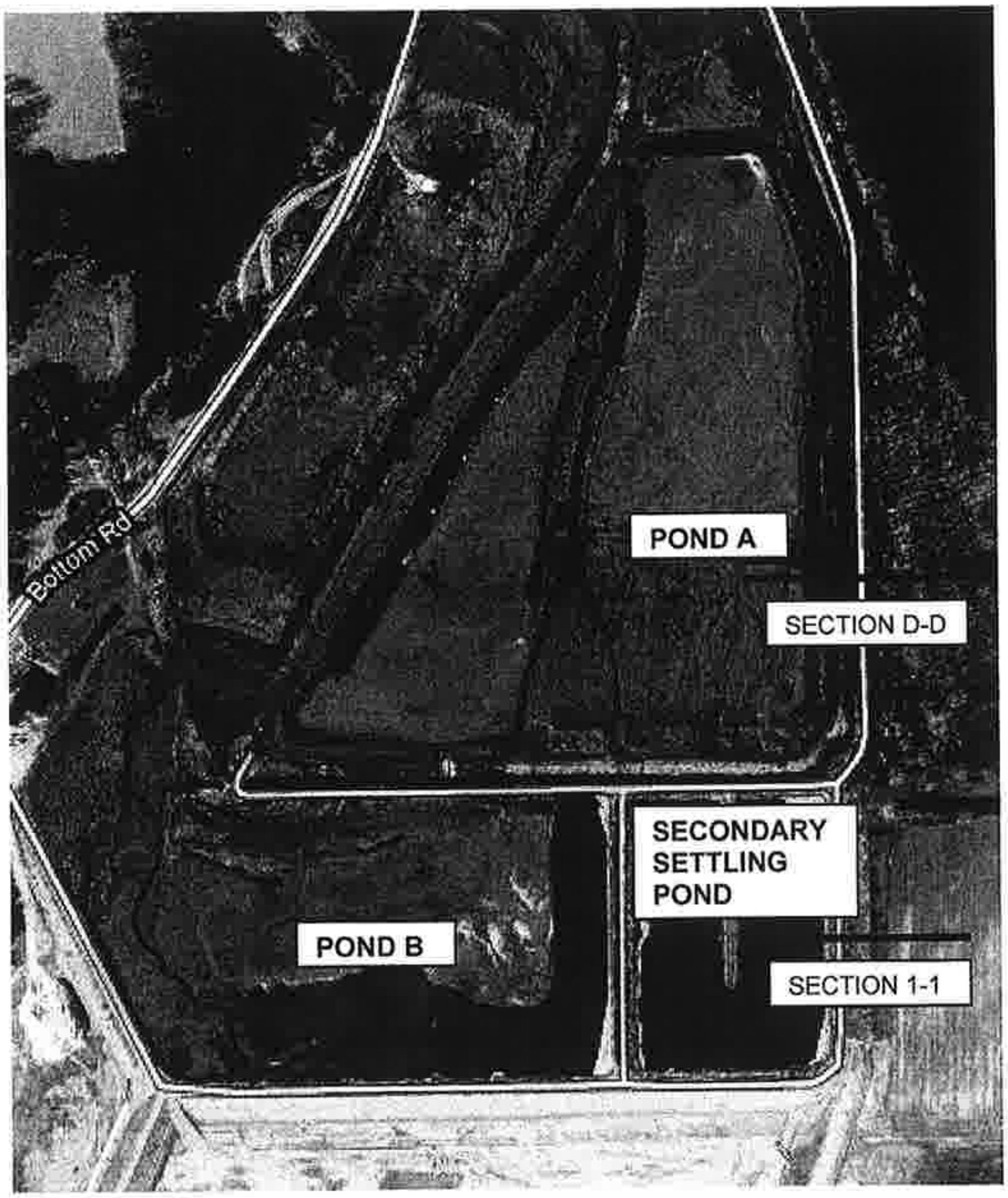


POND A DIKE (From Ref. 5)



SECONDARY SETTLING POND DIKE (From Ref. 3)

FIGURE 2



Bottom Rd
POND A
SECTION D-D
SECONDARY SETTLING POND
POND B
SECTION 1-1

FIGURE 3

Ash Pond Slope Stability Analyses			Calc. No. WRC-F-002S	
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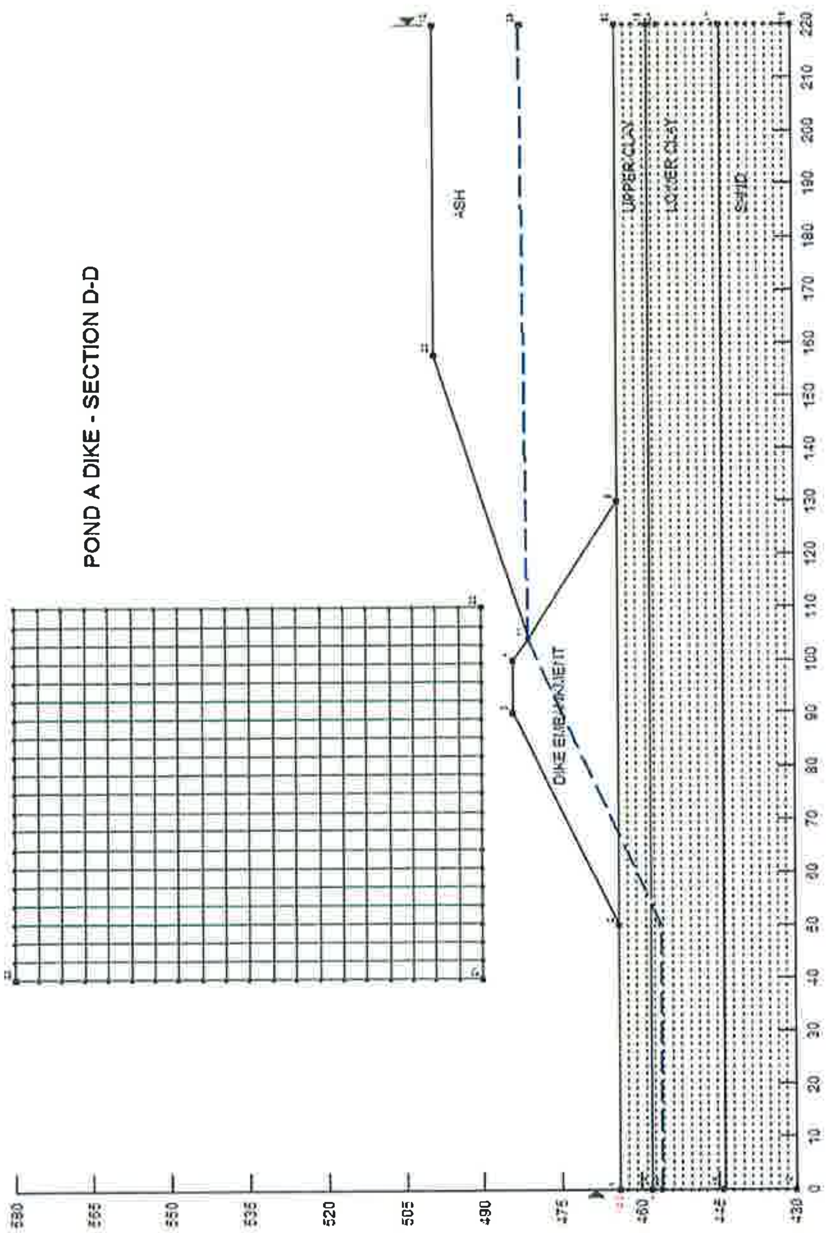

FIGURE 4

Sargent & Lundy LLC

Ash Pond Slope Stability Analyses			Calc. No. WRC-F-002S	
			Rev. 0	Date
	Safety-Related	X Non Safety-Related	Page 11 of	

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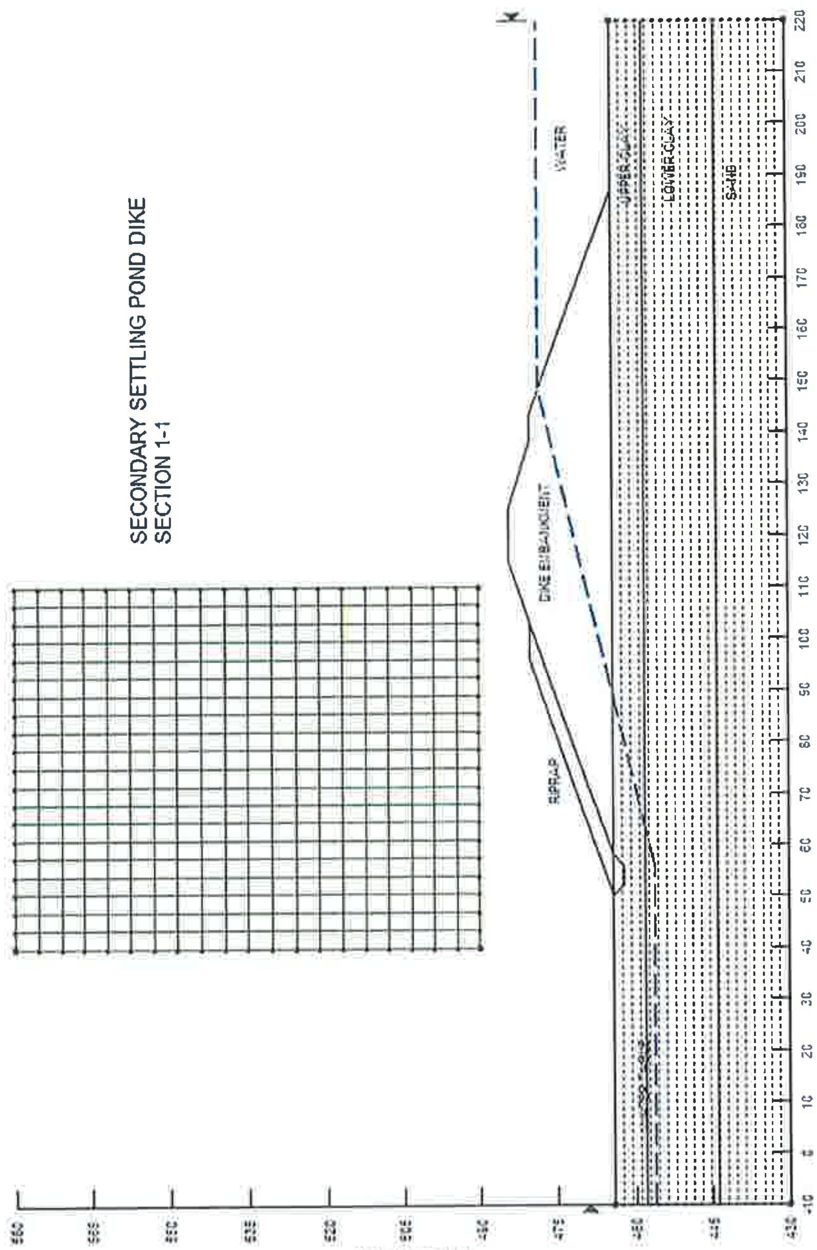
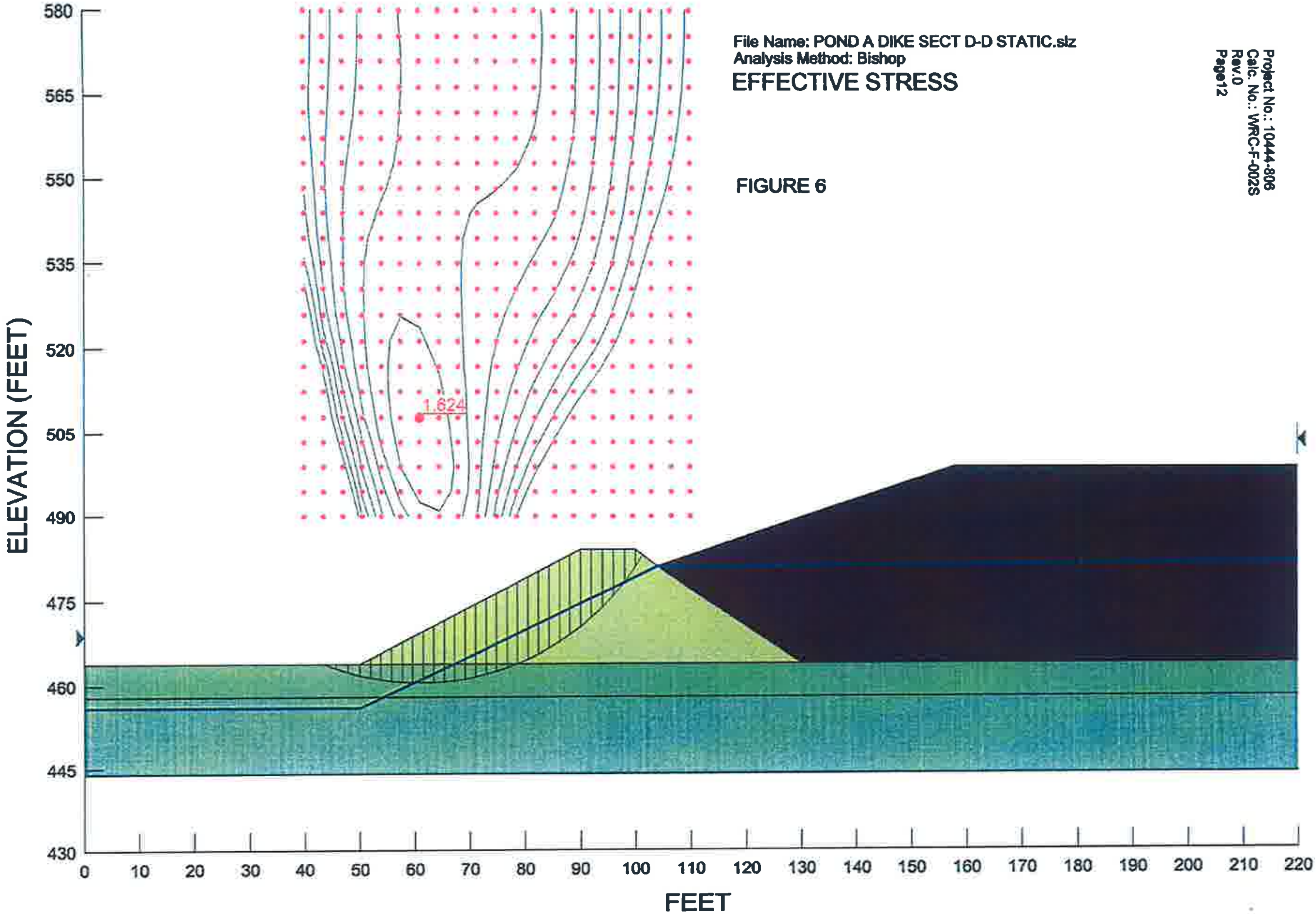


FIGURE 5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Analysis Method: Bishop
EFFECTIVE STRESS
FIGURE 6
1.624
ELEVATION (FEET)
580
565
550
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475
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430
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170
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190
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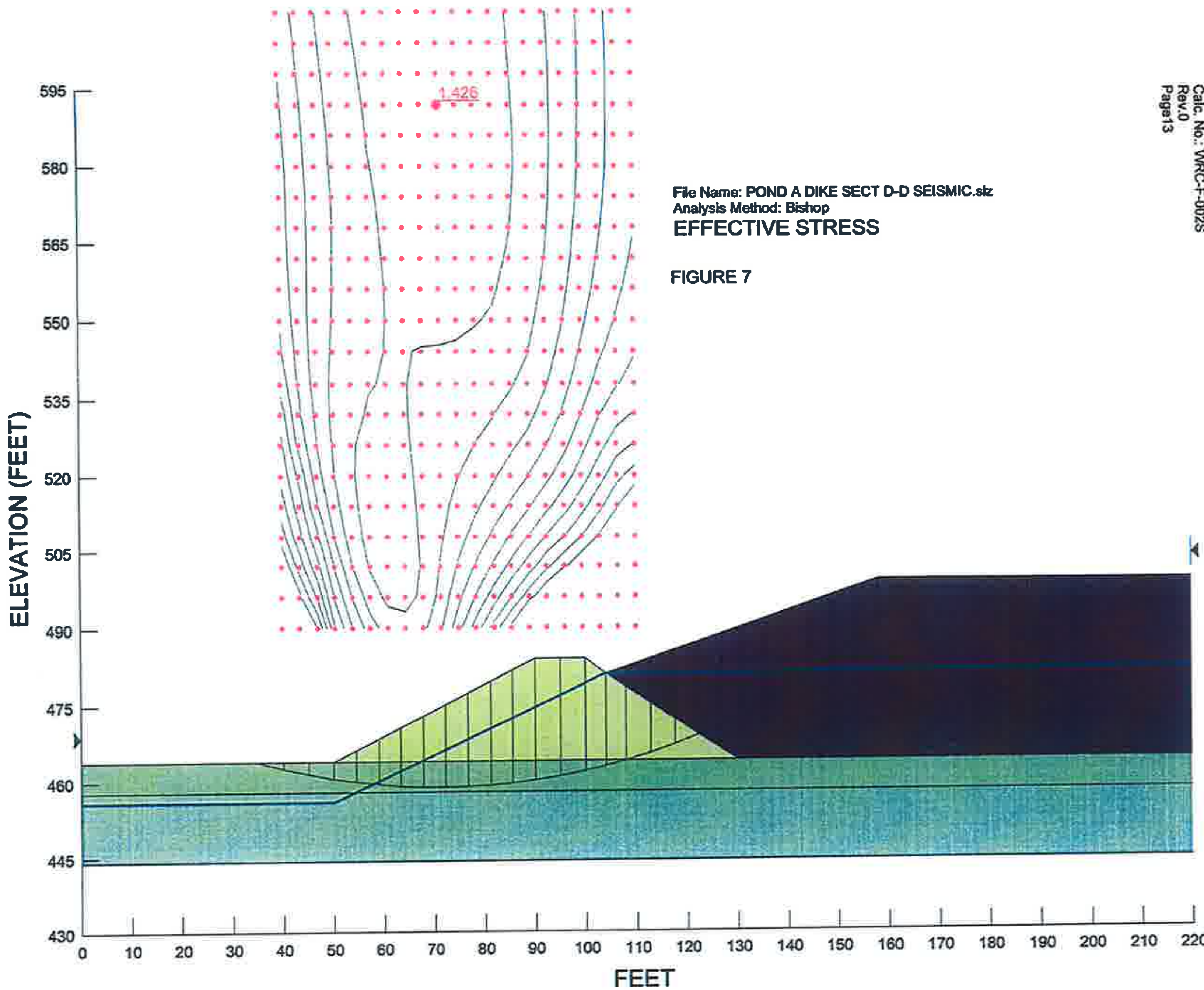
220
FEET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EFFECTIVE STRESS
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ELEVATION (FEET)
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520
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490
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430
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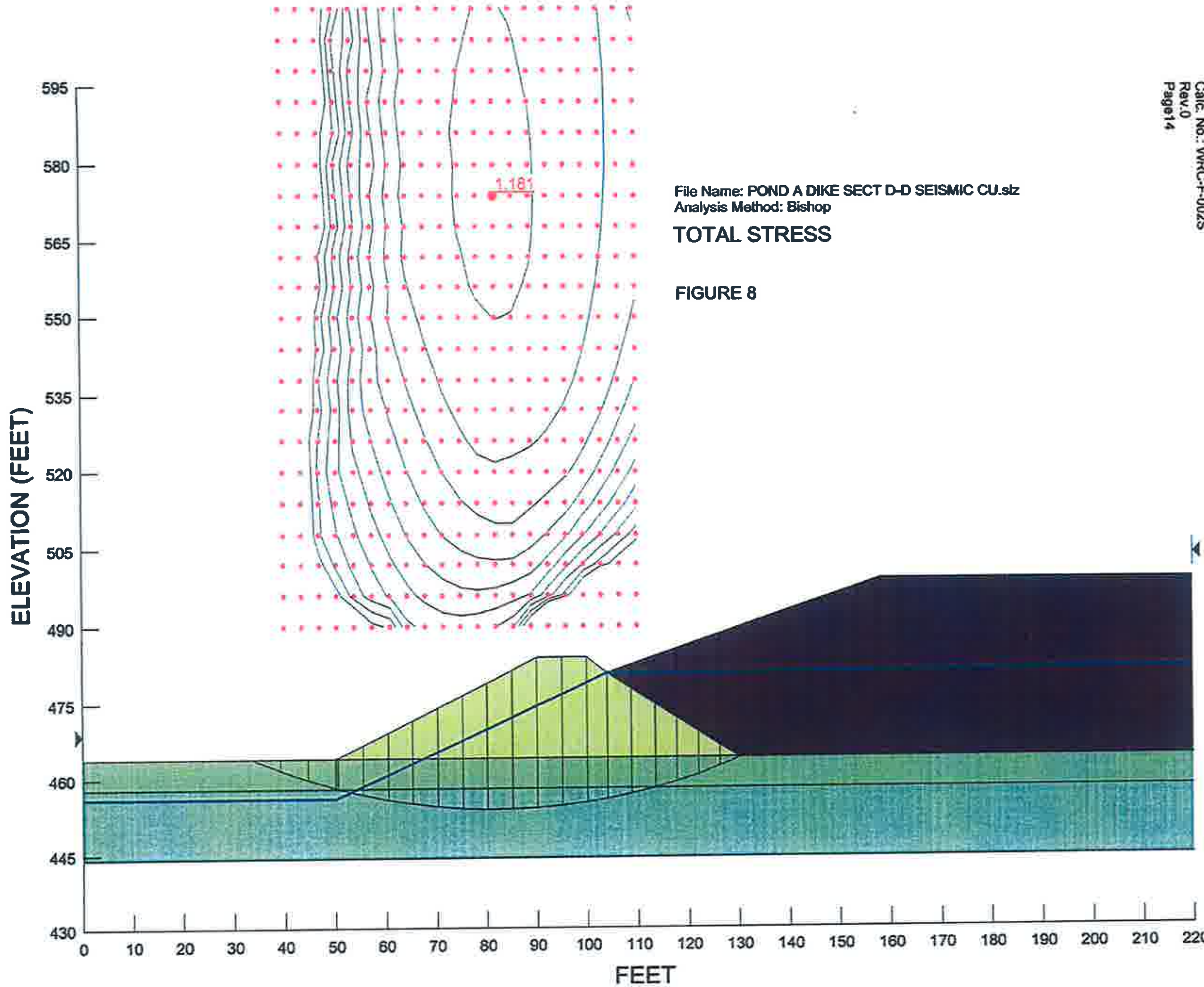
180
190
200
210
220
FEET

FIGURE 7

File Name: POND A DIKE SECT D-D SEISMIC CU.slz
Analysis Method: Bishop

TOTAL STRESS

FIGURE 8



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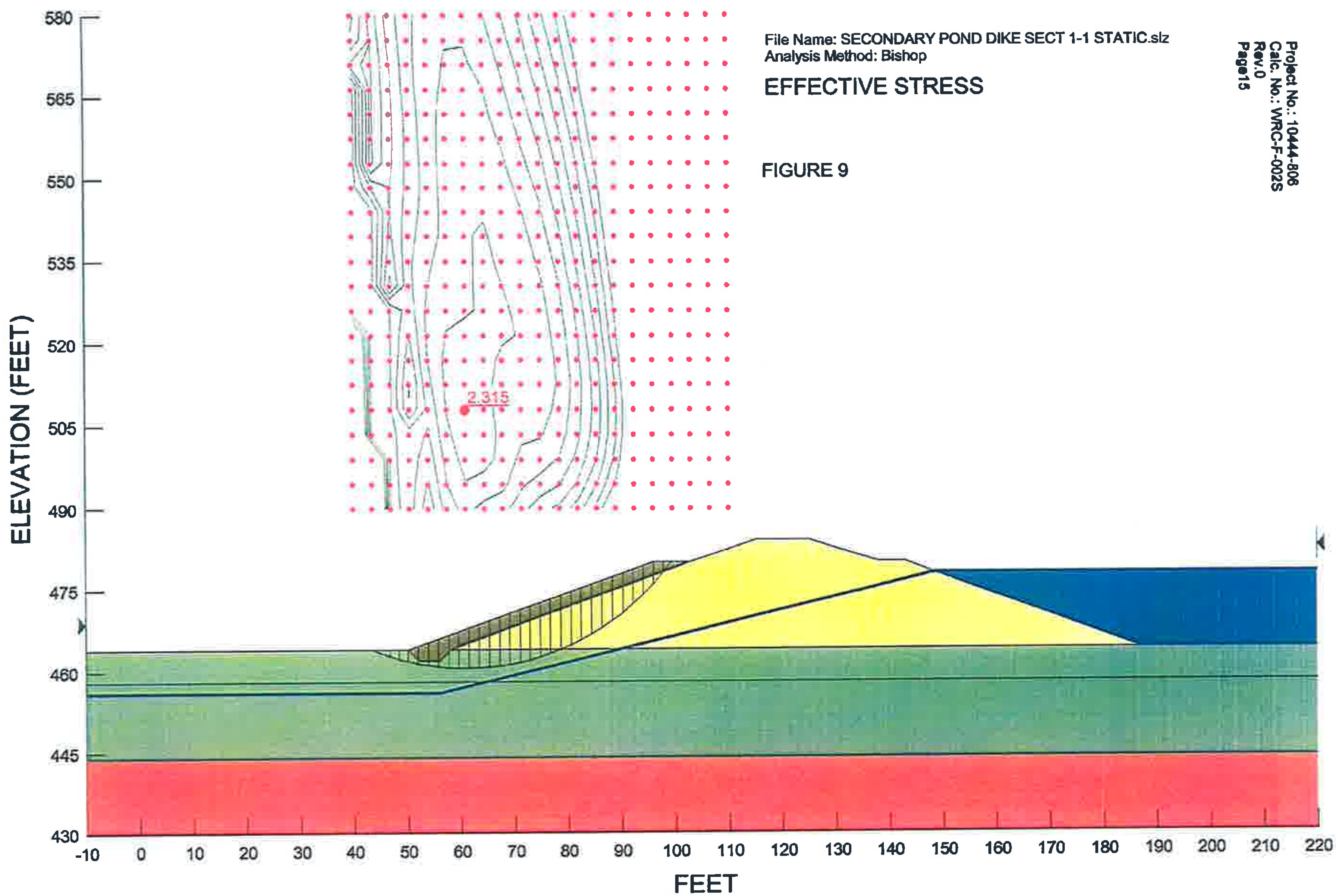
Analysis Method: Bishop

EFFECTIVE STRESS

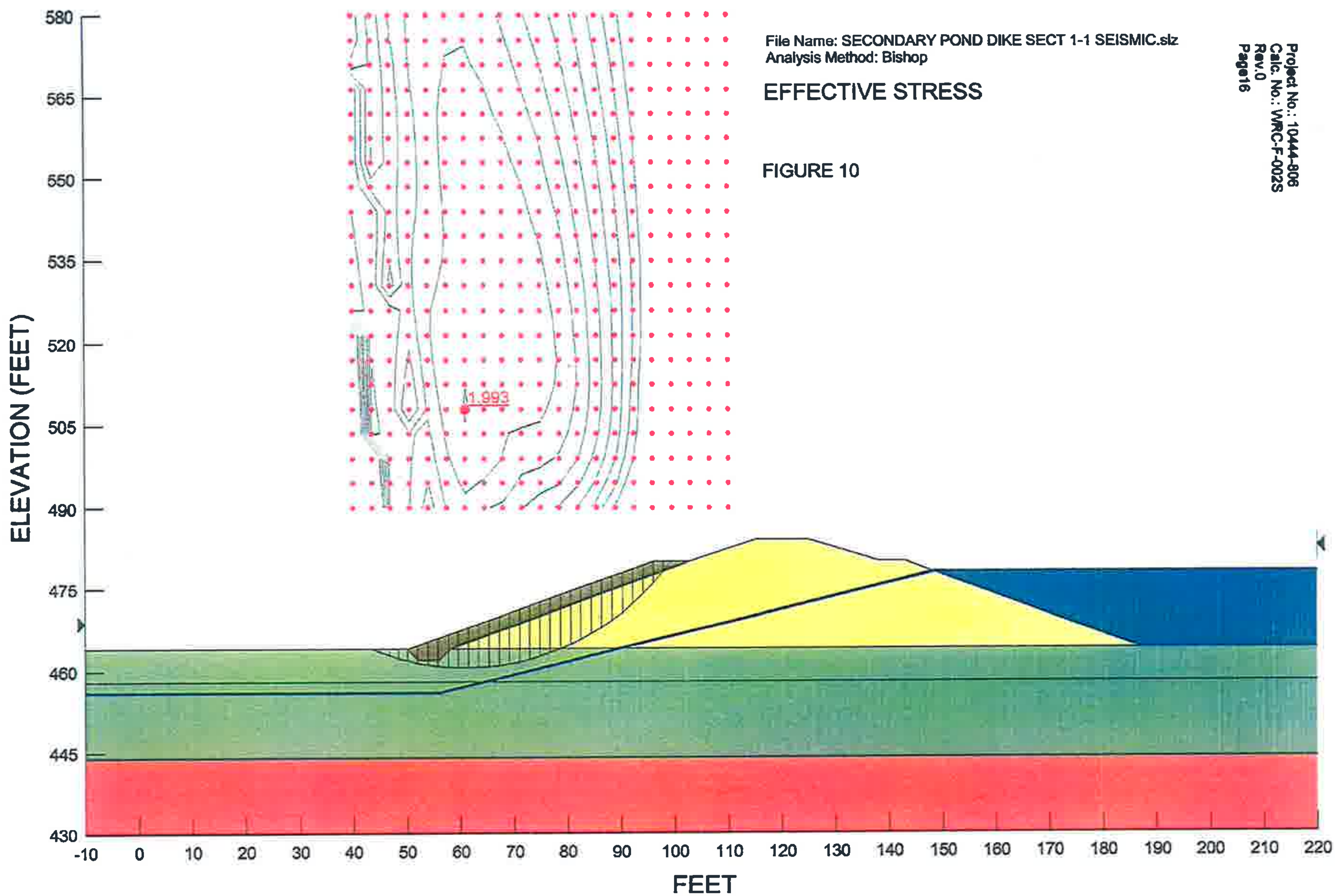
FIGURE 9

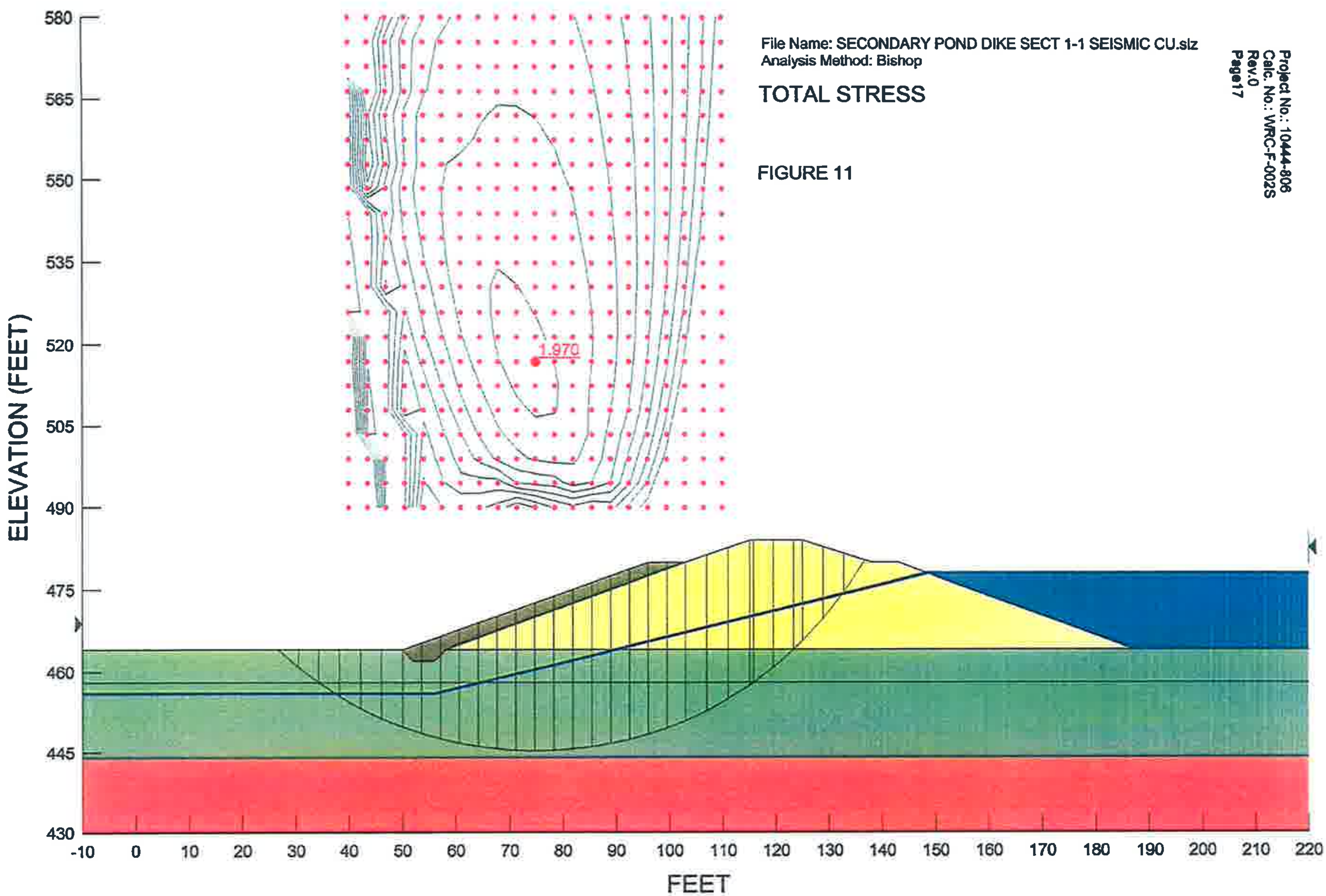


File Name: SECONDARY POND DIKE SECT 1-1 SEISMIC.slz
Analysis Method: Bishop

EFFECTIVE STRESS

FIGURE 10




File Name: SECONDARY POND DIKE SECT 1-1 SEISMIC CU.slz
Analysis Method: Bishop
TOTAL STRESS
FIGURE 11
1.970
ELEVATION (FEET)
580
565
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Results

Figures 6 through 11 contain the results of the runs with the minimum factors of safety indicated. The computer analysis printout of the static analysis for Section D-D is also provided as an example (Attachment B).

The results of the static and seismic stability analyses for both ponds are summarized in Table 3. The cross-sections analyzed are shown in Figs. 4 and 5.

TABLE 3

Section Analyzed	Static FS_{min} (Min FS = 1.5)	Seismic FS_{min} (Min FS = 1.1)
Pond A Dike (Section D-D) (Figs. 6, 7, 8)	1.624	1.426 (Effective Stress) 1.181 (Total Stress)
Secondary Settling Pond (Section 1-1) (Figs. 9, 10, 11)	2.315	1.993 (Effective Stress) 1.970 (Total Stress)

6.0 Summary

The stability analyses of the Pond A and the Secondary Settling Pond dikes at the Wabash River Generating Station indicated acceptable factors of safety for the existing exterior slopes of the dikes against a mass slope instability under the weight of the dikes as well as the external forces acting on the dikes (hydrostatic, ash fill retained). The minimum acceptable static factor of safety is 1.5 per Ref. 7 for the "downstream" slope of embankment dams.

Acceptable slope factors of safety were also obtained from the seismic analyses performed with a lateral seismic load coefficient of 0.05g (10-percent exceedance level in 50-year period). The minimum acceptable seismic factor of safety is 1.1 per Ref. 7 for the "downstream" slope of embankment dams, which was exceeded in the calculations.

Stability analyses were not performed for Pond B dike since ash is being gradually deposited against the exterior face of this dike as the new ash disposal area south of the Pond B is filled.

7.0 References

1. Patriot Engineering (2000) "Revised Report of Geotechnical Investigation – Proposed New Fly Ash Pond West Terre Haute, Indiana".
2. Sargent & Lundy Drawing C-51, "Ash and Secondary Ash Ponds – Sheet 1, Wabash River Station, Public Service Indiana, Terre Haute, Indiana" Rev. D, dated 1/22/87.

3. Sargent & Lundy Drawing C-53, "Ash and Secondary Ash Ponds Section & Details – Sheet 1, Wabash River Station, Public Service Indiana, Terre Haute, Indiana" Rev. C, dated 1/22/87.
4. Sargent & Lundy Drawing B-554, "Ash Disposal Area Plan South Portion - Units 1 to 6, Wabash River Station, Public Service Indiana, Terre Haute, Indiana" Rev. H, dated 1/22/87.
5. Sargent & Lundy Drawing B-555, "Ash Disposal Area Sections Units 1 to 6, Wabash River Station, Public Service Indiana, Terre Haute, Indiana" Rev. G, dated 1/22/87.
6. Burns & McDonnell (2002) "Addendum No. 2 to Slope Stability Analysis – South Ash Pond Extension, Wabash Generating Station, West Terre Haute, Indiana".
7. USDA (1990) "Earth Dams and Reservoirs", Technical Release No. 60, U.S. Department of Agriculture, Soil Conservation Service, Engineering Division.
8. SL-010066, "Wabash River Pond Examination Program – Pond Examination Report", Rev. 0, November 2009.
9. USGS (2008) "Documentation for the 2008 Update of the United States National Seismic Hazard Maps", Open File Report 2008-1128.
10. GEO-SLOPE International Ltd. (2002) "SLOPE/W for Slope Stability Analysis", Version 5.11.

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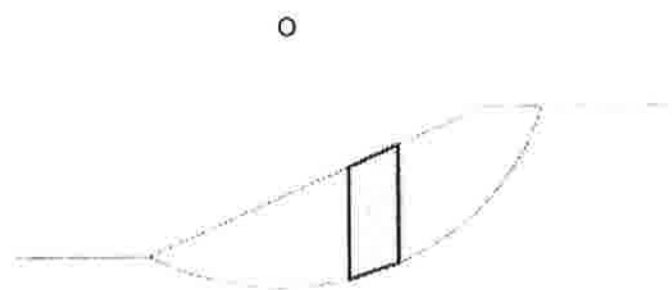
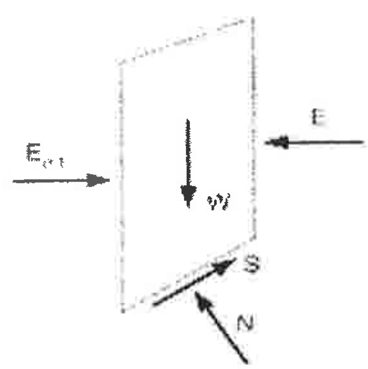
The Simplified Bishop Method

The Simplified Bishop Method used in slope stability analyses in this calculation was developed by Bishop (1955). The potential slip surfaces that can cause slope stability concern are assumed to be circular (See Figure 1.a below) or a combination of straight lines (blocks). The soil mass bounded by the slope face and the slip circle is normally divided into a series of vertical slices. One such slice is shown on Figure 1.a. The forces acting on each slice are shown on Figure 1.b. These are:

1. Weight of the slice (W),
2. Shear Resistance Force along the base of the slice (S),
3. Normal Force along the base of the slice (N), and
4. Lateral inter-slice forces (E_i and E_{i+1}).



a. Slope and trial slip surface



b. Typical slice

Figure 1

The Shear Force along the base of the slice (S) may be due to friction (cohesionless soils) or both cohesion and friction (cohesive soils). In cohesionless soil, the relationship between S and N is expressed as S = N tanφ where φ is the internal friction angle of the soil. In cohesive soil, the corresponding equation is S = cL + Ntanφ where c is the cohesive component of the shear strength and L is the length of the slice along the base (Mohr-Coulomb Equation). The two lateral force components (E_i and E_{i+1}) are assumed to be equal in magnitude and do not figure in the overall stability of the slices.

During the stability analysis, the total moments (about point O in Figure 1) resisting failure (M_r) and the total moments that tend to mobilize the soil mass due to the weight of the soil or the external forces that act on the soil (M_m) are calculated. Both moments are calculated relative to the center of the circular slip surface and are summations of the contributions from each slice. M_r is the summation of the shear resistance force (S) for each slice along the base of the slice multiplied by the moment arm (radius of the circle).

At the start of the analysis, the maximum values of soil strength parameters (c, φ) can be assigned to calculate S for each slice and a factor of safety (FS) can be calculated using M_r/M_m ratio. However, the vertical equilibrium of each slice may not necessarily be satisfied. Therefore, the analysis actually starts with an assumed FS value on c and φ (actually tan φ) and the value of FS is varied until vertical equilibrium is satisfied for each slice within a prescribed margin of tolerance. At this point, the M_r/M_m ratio calculated is the FS for the particular slip circle considered. Therefore, the Simplified Bishop Analysis is a successive approximation type procedure that requires a number of iterations on FS for each slip circle.

This same procedure is repeated for a large number of potential slip circles to determine the location of the circle with the lowest FS. The available computer programs perform this analysis methodically by using an imaginary grid above the slope. At each grid point, several slip circles with different radii are generated using the grid point as the center of the circles. The lowest FS for all circles at each grid point is registered by the software. Once all grid points are processed, the software marks the grid point with the lowest FS and draws the slip circle corresponding to the lowest FS. If desired, other grid points can be clicked on to obtain FS values for other slip circles that might be of interest.

Due to a number of simplifications (i.e., lateral slice forces, as well as horizontal and moment equilibrium for each slice are not considered) inherent in it, this method has been named the "Simplified Bishop Method". Incorporating all forces affecting the slices would have made the analysis statically indeterminate (i.e., can not be solved by using lateral force, vertical force, and moment equilibrium conditions in two-dimensional space) and would have required substantially more elaborate analyses.

Reference:

1. Bishop, A.W. (1955) "The Use of the Slip Circle in the Stability Analysis of Slopes", Geotechnique, Vol. 5, No. 1, pp. 7-17.

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CALC# WRC-F-0025
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PONDAD~1.SLP

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FILEINFO
SLOPEW 5.11
TITLE

DATESTAMP 11/12/2009
TIMESTAMP 11:23:55 AM
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SIDE
    2
LAMBDA
0 999 0 0 0 0 0 0 0 0 0
SOIL         5
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      +0.0000e+000 +0.0000e+000 +0.0000e+000 +0.0000e+000    0    0
      +0.0000e+000 +0.0000e+000 +0.0000e+000 +0.0000e+000 +0.0000e+000 +0.0000e+000
      +0.0000e+000 +0.0000e+000 +0.0000e+000 +0.0000e+000 +0.0000e+000 +0.0000e+000
PONDED ASH
    2 +1.2000e+002 +2.5000e+002 +2.2000e+001 +0.0000e+000 +0.0000e+000 +0.0000e+000   1  0
      +0.0000e+000 +0.0000e+000 +0.0000e+000 +0.0000e+000    0    0
      +0.0000e+000 +0.0000e+000 +0.0000e+000 +0.0000e+000 +0.0000e+000 +0.0000e+000
      +0.0000e+000 +0.0000e+000 +0.0000e+000 +0.0000e+000 +0.0000e+000 +0.0000e+000
DIKE EMBANKMENT
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      +0.0000e+000 +0.0000e+000 +0.0000e+000 +0.0000e+000    0    0
      +0.0000e+000 +0.0000e+000 +0.0000e+000 +0.0000e+000 +0.0000e+000 +0.0000e+000
      +0.0000e+000 +0.0000e+000 +0.0000e+000 +0.0000e+000 +0.0000e+000 +0.0000e+000
UPPER CLAY
    4 +1.2200e+002 +0.0000e+000 +3.0000e+001 +0.0000e+000 +0.0000e+000 +0.0000e+000   1  0
      +0.0000e+000 +0.0000e+000 +0.0000e+000 +0.0000e+000    0    0
      +0.0000e+000 +0.0000e+000 +0.0000e+000 +0.0000e+000 +0.0000e+000 +0.0000e+000
      +0.0000e+000 +0.0000e+000 +0.0000e+000 +0.0000e+000 +0.0000e+000 +0.0000e+000
LOWER CLAY
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      +0.0000e+000 +0.0000e+000 +0.0000e+000 +0.0000e+000    0    0
      +0.0000e+000 +0.0000e+000 +0.0000e+000 +0.0000e+000 +0.0000e+000 +0.0000e+000
      +0.0000e+000 +0.0000e+000 +0.0000e+000 +0.0000e+000 +0.0000e+000 +0.0000e+000
SAND
SFUNCTION       0
AFUNCTION       0
POINT          29
    1 +0.0000e+000 +4.6400e+002
    2 +5.0000e+001 +4.6400e+002
    3 +9.0000e+001 +4.8400e+002
    4 +1.0000e+002 +4.8400e+002
    5 +1.3000e+002 +4.6400e+002
    6 +2.2000e+002 +4.6400e+002
   10 +2.2000e+002 +4.6400e+002
   11 +1.0400e+002 +4.8100e+002
   12 +2.2000e+002 +4.9900e+002
   14 +0.0000e+000 +4.5800e+002
   15 +2.2000e+002 +4.5800e+002
   16 +0.0000e+000 +4.4400e+002
   17 +2.2000e+002 +4.4400e+002
   18 +0.0000e+000 +4.3000e+002
   19 +2.2000e+002 +4.3000e+002
   20 +4.0000e+001 +5.8000e+002
   21 +4.0000e+001 +4.9000e+002
   22 +1.1000e+002 +4.9000e+002
   23 +0.0000e+000 +4.5600e+002
   24 +2.2000e+002 +4.5600e+002
   27 +5.0000e+001 +4.5600e+002
   28 +1.5800e+002 +4.9900e+002
   29 +2.2000e+002 +4.8200e+002
LINE        5
   1     7
   1
   2
   3
   4
   11
   28
   12
   2     7
   1
   2
```

- UNIT WEIGHT
- COHESION (LB/FT²)
- FRICTION ANGLE (DEGREES)
- (OTHER DATA ITEMS NOT USED)
- SOIL DATA
- TOTAL # OF POINTS USED (SOME POINTS DELETED FOR THIS ANALYSIS AS THEY WERE NOT NEEDED)
- POINTS THAT DEFINE SLOPE GEOMETRY AND SOIL BOUNDARIES
- 7,8,9 DELETED
- 13 DELETED
- 25,26 DELETED
- POINTS ALONG EACH LINE DEFINING SLOPE GEOMETRY
- NO OF POINTS ALONG EACH LINE

CONT'D ON P B-2

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   4
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   5
   6
   3     3
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   2
  10
   4     2
  14
  15
   5     2
  16
  17
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GRID
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RADIUS
   1    10    18    19    20     1    10
AXIS
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LIMIT
0 +0.0000e+000 +2.2000e+002
SLIP             0
BLOCK
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   0     0     0     0     0 +4.5000e+001 +4.5000e+001 0 0
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   3 +0.0000e+000     0 +0.0000e+000
   4 +0.0000e+000     0 +0.0000e+000
   5 +0.0000e+000     0 +0.0000e+000
PBBAR            5
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   2 +0.0000e+000     0 +0.0000e+000
   3 +0.0000e+000     0 +0.0000e+000
   4 +0.0000e+000     0 +0.0000e+000
   5 +0.0000e+000     0 +0.0000e+000
PIEZ             5 +0.0000e+000     0
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  23
  27
  11
  29
   2     4     1
  23
  27
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  29
   3     4     1
  23
  27
  11
  29
   4     4     1
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  11
  29
   5     4     1
  23
  27
  11
  29
PCON             0
POGH             0
POGP             0
POGR             0
PORA             5
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   2 +0.0000e+000
   3 +0.0000e+000
   4 +0.0000e+000
   5 +0.0000e+000
LOAD             0
ANCHOR           0
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POINTS ALONG
WATER TABLE ASSOCIATED WITH EACH SOIL TYPE

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CALC # WRC-F-002S
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PBOUNDARY        0
SEISMIC
+0.0000e+000 +0.0000e+000 +0.0000e+000 +0.0000e+000
INTEGRATION

  -1


  -1
ENGINEERING
FT
MATLCOLOR        5
     1    128     0    64
     2    191   255   128
     3    128   255   128
     4    128   255   191
     5    128   255   255
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REV. 0
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POND A DIKE SECT D-D STATIC

ANALYSIS RESULTS FOR CRITICAL CIRCLE

DATESTAMP 11/12/2009
TIMESTAMP 11:35:11 AM

Center_X	Center_Y	Radius	Slip_Surface	Method
6.100000e+001	5.080000e+002	4.740000e+001	1893	3

← CENTER COORDINATES + RADIUS OF CRITICAL CIRCLE

SLICE GEOMETRY DATA & INTER-SLICE FORCES

SL#	X_Left	Y_L_Top	Y_L_Bottom	X_Right	Y_R_Top	Y_R_Bottom	Mid_Height
1	4.337161e+001	4.640000e+002	4.640000e+002	4.558108e+001	4.640000e+002	4.631779e+002	4.266679e-001
2	4.558108e+001	4.640000e+002	4.631779e+002	4.779054e+001	4.640000e+002	4.624778e+002	1.186988e+000
3	4.779054e+001	4.640000e+002	4.624778e+002	5.000000e+001	4.640000e+002	4.618940e+002	1.828326e+000
4	5.000000e+001	4.640000e+002	4.618940e+002	5.190856e+001	4.649543e+002	4.614801e+002	2.800390e+000
5	5.190856e+001	4.649543e+002	4.614801e+002	5.381712e+001	4.659086e+002	4.611474e+002	4.127743e+000
6	5.381712e+001	4.659086e+002	4.611474e+002	5.572568e+001	4.668628e+002	4.608944e+002	5.374682e+000
7	5.572568e+001	4.668628e+002	4.608944e+002	5.763424e+001	4.678171e+002	4.607196e+002	6.542703e+000
8	5.763424e+001	4.678171e+002	4.607196e+002	5.954280e+001	4.687714e+002	4.606224e+002	7.632876e+000
9	5.954280e+001	4.687714e+002	4.606224e+002	6.145135e+001	4.697257e+002	4.606021e+002	8.645869e+000
10	6.145135e+001	4.697257e+002	4.606021e+002	6.335991e+001	4.706800e+002	4.606588e+002	9.581971e+000
11	6.335991e+001	4.706800e+002	4.606588e+002	6.526847e+001	4.716342e+002	4.607926e+002	1.044109e+001
12	6.526847e+001	4.716342e+002	4.607926e+002	6.717703e+001	4.725885e+002	4.610042e+002	1.122276e+001
13	6.717703e+001	4.725885e+002	4.610042e+002	6.908559e+001	4.735428e+002	4.612947e+002	1.192613e+001
14	6.908559e+001	4.735428e+002	4.612947e+002	7.099415e+001	4.744971e+002	4.616656e+002	1.254993e+001
15	7.099415e+001	4.744971e+002	4.616656e+002	7.290271e+001	4.754514e+002	4.621188e+002	1.309245e+001
16	7.290271e+001	4.754514e+002	4.621188e+002	7.481127e+001	4.764056e+002	4.626568e+002	1.355149e+001
17	7.481127e+001	4.764056e+002	4.626568e+002	7.671983e+001	4.773599e+002	4.632826e+002	1.392429e+001
18	7.671983e+001	4.773599e+002	4.632826e+002	7.862839e+001	4.783142e+002	4.640000e+002	1.420747e+001
19	7.862839e+001	4.783142e+002	4.640000e+002	8.052366e+001	4.792618e+002	4.648076e+002	1.439640e+001
20	8.052366e+001	4.792618e+002	4.648076e+002	8.241892e+001	4.802095e+002	4.657154e+002	1.448709e+001
21	8.241892e+001	4.802095e+002	4.657154e+002	8.431419e+001	4.811571e+002	4.667301e+002	1.447439e+001
22	8.431419e+001	4.811571e+002	4.667301e+002	8.620946e+001	4.821047e+002	4.678597e+002	1.435098e+001
23	8.620946e+001	4.821047e+002	4.678597e+002	8.810473e+001	4.830524e+002	4.691144e+002	1.410786e+001
24	8.810473e+001	4.830524e+002	4.691144e+002	9.000000e+001	4.840000e+002	4.705065e+002	1.373384e+001
25	9.000000e+001	4.840000e+002	4.705065e+002	9.200000e+001	4.840000e+002	4.721425e+002	1.269823e+001
26	9.200000e+001	4.840000e+002	4.721425e+002	9.400000e+001	4.840000e+002	4.739741e+002	1.096799e+001
27	9.400000e+001	4.840000e+002	4.739741e+002	9.600000e+001	4.840000e+002	4.760350e+002	9.026656e+000
28	9.600000e+001	4.840000e+002	4.760350e+002	9.800000e+001	4.840000e+002	4.783730e+002	6.834396e+000
29	9.800000e+001	4.840000e+002	4.783730e+002	1.000000e+002	4.840000e+002	4.810601e+002	4.333020e+000
30	1.000000e+002	4.840000e+002	4.810601e+002	1.012908e+002	4.830319e+002	4.830319e+002	1.496703e+000

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2	0.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000	1.0000e+000	0.0000e+000	0.0000e+000
3	0.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000	1.0000e+000	0.0000e+000	0.0000e+000
4	0.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000	1.0000e+000	0.0000e+000	0.0000e+000
5	0.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000	1.0000e+000	0.0000e+000	0.0000e+000
6	0.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000	1.0000e+000	0.0000e+000	0.0000e+000
7	0.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000	1.0000e+000	0.0000e+000	0.0000e+000
8	0.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000	1.0000e+000	0.0000e+000	0.0000e+000
9	0.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000	1.0000e+000	0.0000e+000	0.0000e+000
10	0.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000	1.0000e+000	0.0000e+000	0.0000e+000
11	0.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000	1.0000e+000	0.0000e+000	0.0000e+000
12	0.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000	1.0000e+000	0.0000e+000	0.0000e+000

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13	0.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000	1.0000e+000	0.0000e+000	0.0000e+000
14	0.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000	1.0000e+000	0.0000e+000	0.0000e+000
15	0.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000	1.0000e+000	0.0000e+000	0.0000e+000
16	0.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000	1.0000e+000	0.0000e+000	0.0000e+000
17	0.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000	1.0000e+000	0.0000e+000	0.0000e+000
18	0.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000	1.0000e+000	0.0000e+000	0.0000e+000
19	0.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000	1.0000e+000	0.0000e+000	0.0000e+000
20	0.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000	1.0000e+000	0.0000e+000	0.0000e+000
21	0.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000	1.0000e+000	0.0000e+000	0.0000e+000
22	0.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000	1.0000e+000	0.0000e+000	0.0000e+000
23	0.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000	1.0000e+000	0.0000e+000	0.0000e+000
24	0.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000	1.0000e+000	0.0000e+000	0.0000e+000
25	0.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000	1.0000e+000	0.0000e+000	0.0000e+000
26	0.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000	1.0000e+000	0.0000e+000	0.0000e+000
27	0.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000	1.0000e+000	0.0000e+000	0.0000e+000
28	0.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000	1.0000e+000	0.0000e+000	0.0000e+000
29	0.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000	1.0000e+000	0.0000e+000	0.0000e+000
30	0.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000	1.0000e+000	0.0000e+000	0.0000e+000

SL#	Weight	Pore_Water	Alpha	Force Fn.	Seismic_F	Seismic_Y	Pore_Air	Phi_B	Liquified
1	1.1501e+002	0.0000e+000	-2.0408e+001	1.1956e-001	0.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000	0
2	3.1996e+002	0.0000e+000	-1.7582e+001	2.3740e-001	0.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000	0
3	4.9283e+002	0.0000e+000	-1.4800e+001	3.5183e-001	0.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000	0
4	6.5023e+002	0.0000e+000	-1.2238e+001	4.4668e-001	0.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000	0
5	9.5566e+002	0.0000e+000	-9.8870e+000	5.3674e-001	0.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000	0
6	1.2424e+003	0.0000e+000	-7.5524e+000	6.2106e-001	0.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000	0
7	1.5107e+003	0.0000e+000	-5.2303e+000	6.9873e-001	0.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000	0
8	1.7609e+003	0.0000e+000	-2.9168e+000	7.6891e-001	0.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000	0
9	1.9931e+003	3.0622e+001	-6.0806e-001	8.3087e-001	0.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000	0
10	2.2074e+003	1.3375e+002	1.6997e+000	8.8392e-001	0.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000	0
11	2.4038e+003	2.2816e+002	4.0102e+000	9.2751e-001	0.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000	0
12	2.5822e+003	3.1419e+002	6.3273e+000	9.6117e-001	0.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000	0
13	2.7423e+003	3.9210e+002	8.6548e+000	9.8454e-001	0.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000	0
14	2.8839e+003	4.6199e+002	1.0997e+001	9.9737e-001	0.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000	0
15	3.0066e+003	5.2388e+002	1.3358e+001	9.9952e-001	0.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000	0
16	3.1099e+003	5.7762e+002	1.5742e+001	9.9097e-001	0.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000	0
17	3.1930e+003	6.2295e+002	1.8154e+001	9.7180e-001	0.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000	0
18	3.2553e+003	6.5942e+002	2.0601e+001	9.4223e-001	0.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000	0
19	3.2742e+003	6.8151e+002	2.3078e+001	9.0288e-001	0.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000	0
20	3.2948e+003	6.9787e+002	2.5594e+001	8.5400e-001	0.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000	0
21	3.2919e+003	7.0280e+002	2.8164e+001	7.9610e-001	0.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000	0
22	3.2639e+003	6.9465e+002	3.0797e+001	7.2980e-001	0.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000	0
23	3.2086e+003	6.7116e+002	3.3504e+001	6.5579e-001	0.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000	0
24	3.1235e+003	6.2922e+002	3.6299e+001	5.7485e-001	0.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000	0
25	3.0476e+003	5.9337e+002	3.9283e+001	4.8288e-001	0.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000	0
26	2.6323e+003	4.8666e+002	4.2484e+001	3.8523e-001	0.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000	0
27	2.1664e+003	3.3336e+002	4.5859e+001	2.8306e-001	0.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000	0
28	1.6403e+003	1.1399e+002	4.9455e+001	1.7755e-001	0.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000	0
29	1.0399e+003	0.0000e+000	5.3340e+001	6.9960e-002	0.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000	0
30	2.3184e+002	0.0000e+000	5.6789e+001	2.6698e-008	0.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000	0

Ordinary_Method_Fm= 1.5198991 Applied_Lambda= 0.0000

SL#	Normal_M	ShearMob	Phi_Angle	Cohesion
1	1.0779e+002	4.0946e+001	3.0000e+001	0.0000e+000
2	3.0501e+002	1.1586e+002	3.0000e+001	0.0000e+000

3	4.7648e+002	1.8100e+002	3.0000e+001	0.0000e+000
4	6.3546e+002	2.4138e+002	3.0000e+001	0.0000e+000
5	9.4146e+002	3.5763e+002	3.0000e+001	0.0000e+000
6	1.2316e+003	4.6783e+002	3.0000e+001	0.0000e+000
7	1.5044e+003	5.7146e+002	3.0000e+001	0.0000e+000
8	1.7586e+003	6.6802e+002	3.0000e+001	0.0000e+000
9	1.9930e+003	7.4543e+002	3.0000e+001	0.0000e+000
10	2.2065e+003	7.8734e+002	3.0000e+001	0.0000e+000
11	2.3979e+003	8.2422e+002	3.0000e+001	0.0000e+000
12	2.5665e+003	8.5555e+002	3.0000e+001	0.0000e+000
13	2.7111e+003	8.8090e+002	3.0000e+001	0.0000e+000
14	2.8310e+003	8.9988e+002	3.0000e+001	0.0000e+000
15	2.9253e+003	9.1220e+002	3.0000e+001	0.0000e+000
16	2.9932e+003	9.1759e+002	3.0000e+001	0.0000e+000
17	3.0341e+003	9.1589e+002	3.0000e+001	0.0000e+000
18	3.0471e+003	9.0700e+002	3.0000e+001	0.0000e+000
19	3.0122e+003	9.5843e+002	2.2000e+001	2.5000e+002
20	2.9715e+003	9.5008e+002	2.2000e+001	2.5000e+002
21	2.9022e+003	9.3829e+002	2.2000e+001	2.5000e+002
22	2.8036e+003	9.2357e+002	2.2000e+001	2.5000e+002
23	2.6755e+003	9.0669e+002	2.2000e+001	2.5000e+002
24	2.5174e+003	8.8876e+002	2.2000e+001	2.5000e+002
25	2.3589e+003	8.9439e+002	2.2000e+001	2.5000e+002
26	1.9412e+003	8.3280e+002	2.2000e+001	2.5000e+002
27	1.5087e+003	7.8488e+002	2.2000e+001	2.5000e+002
28	1.0662e+003	7.5929e+002	2.2000e+001	2.5000e+002
29	6.2091e+002	7.1614e+002	2.2000e+001	2.5000e+002
30	1.2698e+002	4.2144e+002	2.2000e+001	2.5000e+002

Bishop_Method_Fm= 1.6241460 Applied_Lambda= 0.0000

SL#	Normal_M	ShearMob	Phi_Angle	Cohesion	SideLeft	ShearLeft	SideRight	ShearRight
1	1.4140e+002	5.0266e+001	3.0000e+001	0.0000e+000	0.0000e+000	0.0000e+000	-1.0137e+002	0.0000e+000
2	3.7822e+002	1.3445e+002	3.0000e+001	0.0000e+000	1.0137e+002	0.0000e+000	-3.5620e+002	0.0000e+000
3	5.6255e+002	1.9997e+002	3.0000e+001	0.0000e+000	3.5620e+002	0.0000e+000	-7.1064e+002	0.0000e+000
4	7.2091e+002	2.5627e+002	3.0000e+001	0.0000e+000	7.1064e+002	0.0000e+000	-1.1351e+003	0.0000e+000
5	1.0341e+003	3.6760e+002	3.0000e+001	0.0000e+000	1.1351e+003	0.0000e+000	-1.7040e+003	0.0000e+000
6	1.3152e+003	4.6752e+002	3.0000e+001	0.0000e+000	1.7040e+003	0.0000e+000	-2.3760e+003	0.0000e+000
7	1.5680e+003	5.5739e+002	3.0000e+001	0.0000e+000	2.3760e+003	0.0000e+000	-3.1151e+003	0.0000e+000
8	1.7957e+003	6.3832e+002	3.0000e+001	0.0000e+000	3.1151e+003	0.0000e+000	-3.8896e+003	0.0000e+000
9	2.0006e+003	7.0030e+002	3.0000e+001	0.0000e+000	3.8896e+003	0.0000e+000	-4.6599e+003	0.0000e+000
10	2.1868e+003	7.2980e+002	3.0000e+001	0.0000e+000	4.6599e+003	0.0000e+000	-5.3741e+003	0.0000e+000
11	2.3567e+003	7.5666e+002	3.0000e+001	0.0000e+000	5.3741e+003	0.0000e+000	-6.0145e+003	0.0000e+000
12	2.5115e+003	7.8108e+002	3.0000e+001	0.0000e+000	6.0145e+003	0.0000e+000	-6.5653e+003	0.0000e+000
13	2.6517e+003	8.0325e+002	3.0000e+001	0.0000e+000	6.5653e+003	0.0000e+000	-7.0125e+003	0.0000e+000
14	2.7780e+003	8.2329e+002	3.0000e+001	0.0000e+000	7.0125e+003	0.0000e+000	-7.3436e+003	0.0000e+000
15	2.8906e+003	8.4131e+002	3.0000e+001	0.0000e+000	7.3436e+003	0.0000e+000	-7.5482e+003	0.0000e+000
16	2.9895e+003	8.5738e+002	3.0000e+001	0.0000e+000	7.5482e+003	0.0000e+000	-7.6172e+003	0.0000e+000
17	3.0747e+003	8.7154e+002	3.0000e+001	0.0000e+000	7.6172e+003	0.0000e+000	-7.5432e+003	0.0000e+000
18	3.1457e+003	8.8381e+002	3.0000e+001	0.0000e+000	7.5432e+003	0.0000e+000	-7.3208e+003	0.0000e+000
19	3.1613e+003	9.3402e+002	2.2000e+001	2.5000e+002	7.3208e+003	0.0000e+000	-7.0060e+003	0.0000e+000
20	3.2004e+003	9.4604e+002	2.2000e+001	2.5000e+002	7.0060e+003	0.0000e+000	-6.5441e+003	0.0000e+000
21	3.2217e+003	9.5755e+002	2.2000e+001	2.5000e+002	6.5441e+003	0.0000e+000	-5.9377e+003	0.0000e+000
22	3.2227e+003	9.6854e+002	2.2000e+001	2.5000e+002	5.9377e+003	0.0000e+000	-5.1926e+003	0.0000e+000
23	3.2002e+003	9.7903e+002	2.2000e+001	2.5000e+002	5.1926e+003	0.0000e+000	-4.3188e+003	0.0000e+000
24	3.1496e+003	9.8900e+002	2.2000e+001	2.5000e+002	4.3188e+003	0.0000e+000	-3.3314e+003	0.0000e+000
25	3.1019e+003	1.0218e+003	2.2000e+001	2.5000e+002	3.3314e+003	0.0000e+000	-2.2450e+003	0.0000e+000

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26	2.6864e+003	9.6472e+002	2.2000e+001	2.5000e+002	2.2450e+003	0.0000e+000	-1.2283e+003	0.0000e+000
27	2.1819e+003	9.0196e+002	2.2000e+001	2.5000e+002	1.2283e+003	0.0000e+000	-3.7638e+002	0.0000e+000
28	1.5520e+003	8.3139e+002	2.2000e+001	2.5000e+002	3.7638e+002	0.0000e+000	1.7785e+002	0.0000e+000
29	7.8653e+002	7.1137e+002	2.2000e+001	2.5000e+002	-1.7785e+002	0.0000e+000	3.0548e+002	0.0000e+000
30	-9.4638e+001	3.3926e+002	2.2000e+001	2.5000e+002	-3.0548e+002	0.0000e+000	-8.0000e-005	0.0000e+000

Janbu_Method_Ff= 1.5101325 Applied_Lambda= 0.0000

SL#	Normal_F	ShearMob	Phi_Angle	Cohesion	SideLeft	ShearLeft	SideRight	ShearRight
1	1.4292e+002	5.4642e+001	3.0000e+001	0.0000e+000	0.0000e+000	0.0000e+000	-1.0137e+002	0.0000e+000
2	3.8159e+002	1.4589e+002	3.0000e+001	0.0000e+000	1.0137e+002	0.0000e+000	-3.5620e+002	0.0000e+000
3	5.6665e+002	2.1664e+002	3.0000e+001	0.0000e+000	3.5620e+002	0.0000e+000	-7.1064e+002	0.0000e+000
4	7.2513e+002	2.7723e+002	3.0000e+001	0.0000e+000	7.1064e+002	0.0000e+000	-1.1351e+003	0.0000e+000
5	1.0389e+003	3.9718e+002	3.0000e+001	0.0000e+000	1.1351e+003	0.0000e+000	-1.7040e+003	0.0000e+000
6	1.3197e+003	5.0456e+002	3.0000e+001	0.0000e+000	1.7040e+003	0.0000e+000	-2.3760e+003	0.0000e+000
7	1.5717e+003	6.0088e+002	3.0000e+001	0.0000e+000	2.3760e+003	0.0000e+000	-3.1151e+003	0.0000e+000
8	1.7980e+003	6.8740e+002	3.0000e+001	0.0000e+000	3.1151e+003	0.0000e+000	-3.8896e+003	0.0000e+000
9	2.0012e+003	7.5337e+002	3.0000e+001	0.0000e+000	3.8896e+003	0.0000e+000	-4.6599e+003	0.0000e+000
10	2.1853e+003	7.8433e+002	3.0000e+001	0.0000e+000	4.6599e+003	0.0000e+000	-5.3741e+003	0.0000e+000
11	2.3531e+003	8.1241e+002	3.0000e+001	0.0000e+000	5.3741e+003	0.0000e+000	-6.0145e+003	0.0000e+000
12	2.5057e+003	8.3784e+002	3.0000e+001	0.0000e+000	6.0145e+003	0.0000e+000	-6.5653e+003	0.0000e+000
13	2.6437e+003	8.6081e+002	3.0000e+001	0.0000e+000	6.5653e+003	0.0000e+000	-7.0125e+003	0.0000e+000
14	2.7676e+003	8.8147e+002	3.0000e+001	0.0000e+000	7.0125e+003	0.0000e+000	-7.3436e+003	0.0000e+000
15	2.8778e+003	8.9994e+002	3.0000e+001	0.0000e+000	7.3436e+003	0.0000e+000	-7.5482e+003	0.0000e+000
16	2.9743e+003	9.1628e+002	3.0000e+001	0.0000e+000	7.5482e+003	0.0000e+000	-7.6172e+003	0.0000e+000
17	3.0570e+003	9.3056e+002	3.0000e+001	0.0000e+000	7.6172e+003	0.0000e+000	-7.5432e+003	0.0000e+000
18	3.1254e+003	9.4279e+002	3.0000e+001	0.0000e+000	7.5432e+003	0.0000e+000	-7.3208e+003	0.0000e+000
19	3.1364e+003	9.9786e+002	2.2000e+001	2.5000e+002	7.3208e+003	0.0000e+000	-7.0060e+003	0.0000e+000
20	3.1724e+003	1.0100e+003	2.2000e+001	2.5000e+002	7.0060e+003	0.0000e+000	-6.5441e+003	0.0000e+000
21	3.1904e+003	1.0215e+003	2.2000e+001	2.5000e+002	6.5441e+003	0.0000e+000	-5.9377e+003	0.0000e+000
22	3.1880e+003	1.0324e+003	2.2000e+001	2.5000e+002	5.9377e+003	0.0000e+000	-5.1926e+003	0.0000e+000
23	3.1618e+003	1.0427e+003	2.2000e+001	2.5000e+002	5.1926e+003	0.0000e+000	-4.3188e+003	0.0000e+000
24	3.1072e+003	1.0523e+003	2.2000e+001	2.5000e+002	4.3188e+003	0.0000e+000	-3.3314e+003	0.0000e+000
25	3.0541e+003	1.0862e+003	2.2000e+001	2.5000e+002	3.3314e+003	0.0000e+000	-2.2450e+003	0.0000e+000
26	2.6369e+003	1.0243e+003	2.2000e+001	2.5000e+002	2.2450e+003	0.0000e+000	-1.2283e+003	0.0000e+000
27	2.1310e+003	9.5644e+002	2.2000e+001	2.5000e+002	1.2283e+003	0.0000e+000	-3.7638e+002	0.0000e+000
28	1.5003e+003	8.8032e+002	2.2000e+001	2.5000e+002	3.7638e+002	0.0000e+000	1.7785e+002	0.0000e+000
29	7.3741e+002	7.5194e+002	2.2000e+001	2.5000e+002	-1.7785e+002	0.0000e+000	3.0548e+002	0.0000e+000
30	-1.2034e+002	3.5800e+002	2.2000e+001	2.5000e+002	-3.0548e+002	0.0000e+000	-8.0000e-005	0.0000e+000

M-P_Method_Fm= 1.6463010 Applied_Lambda= -0.3631

SL#	Normal_M	ShearMob	Phi_Angle	Cohesion	SideLeft	ShearLeft	SideRight	ShearRight
1	1.4641e+002	5.1344e+001	3.0000e+001	0.0000e+000	0.0000e+000	0.0000e+000	-9.9049e+001	-4.2993e+000
2	4.0906e+002	1.4345e+002	3.0000e+001	0.0000e+000	9.9049e+001	4.2993e+000	-3.5909e+002	-3.0949e+001
3	6.3360e+002	2.2220e+002	3.0000e+001	0.0000e+000	3.5909e+002	3.0949e+001	-7.3533e+002	-9.3928e+001
4	8.3085e+002	2.9138e+002	3.0000e+001	0.0000e+000	7.3533e+002	9.3928e+001	-1.1956e+003	-1.9389e+002
5	1.2068e+003	4.2322e+002	3.0000e+001	0.0000e+000	1.1956e+003	1.9389e+002	-1.8188e+003	-3.5442e+002
6	1.5501e+003	5.4361e+002	3.0000e+001	0.0000e+000	1.8188e+003	3.5442e+002	-2.5601e+003	-5.7726e+002
7	1.8571e+003	6.5126e+002	3.0000e+001	0.0000e+000	2.5601e+003	5.7726e+002	-3.3765e+003	-8.5653e+002
8	2.1251e+003	7.4527e+002	3.0000e+001	0.0000e+000	3.3765e+003	8.5653e+002	-4.2273e+003	-1.1801e+003
9	2.3493e+003	8.1313e+002	3.0000e+001	0.0000e+000	4.2273e+003	1.1801e+003	-5.0637e+003	-1.5275e+003
10	2.5258e+003	8.3887e+002	3.0000e+001	0.0000e+000	5.0637e+003	1.5275e+003	-5.8258e+003	-1.8696e+003
11	2.6668e+003	8.5523e+002	3.0000e+001	0.0000e+000	5.8258e+003	1.8696e+003	-6.4912e+003	-2.1859e+003
12	2.7756e+003	8.6320e+002	3.0000e+001	0.0000e+000	6.4912e+003	2.1859e+003	-7.0423e+003	-2.4575e+003
13	2.8560e+003	8.6407e+002	3.0000e+001	0.0000e+000	7.0423e+003	2.4575e+003	-7.4659e+003	-2.6687e+003
14	2.9123e+003	8.5930e+002	3.0000e+001	0.0000e+000	7.4659e+003	2.6687e+003	-7.7532e+003	-2.8075e+003

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POND A DIKE SECT D-D STATIC

15	2.9488e+003	8.5040e+002	3.0000e+001	0.0000e+000	7.7532e+003	2.8075e+003	-7.8988e+003	-2.8663e+003
16	2.9695e+003	8.3883e+002	3.0000e+001	0.0000e+000	7.8988e+003	2.8663e+003	-7.9000e+003	-2.8422e+003
17	2.9783e+003	8.2599e+002	3.0000e+001	0.0000e+000	7.9000e+003	2.8422e+003	-7.7565e+003	-2.7366e+003
18	2.9781e+003	8.1314e+002	3.0000e+001	0.0000e+000	7.7565e+003	2.7366e+003	-7.4692e+003	-2.5551e+003
19	2.9458e+003	8.6857e+002	2.2000e+001	2.5000e+002	7.4692e+003	2.5551e+003	-7.1126e+003	-2.3315e+003
20	2.9311e+003	8.6720e+002	2.2000e+001	2.5000e+002	7.1126e+003	2.3315e+003	-6.6273e+003	-2.0548e+003
21	2.9110e+003	8.6841e+002	2.2000e+001	2.5000e+002	6.6273e+003	2.0548e+003	-6.0172e+003	-1.7392e+003
22	2.8856e+003	8.7277e+002	2.2000e+001	2.5000e+002	6.0172e+003	1.7392e+003	-5.2872e+003	-1.4009e+003
23	2.8535e+003	8.8077e+002	2.2000e+001	2.5000e+002	5.2872e+003	1.4009e+003	-4.4436e+003	-1.0580e+003
24	2.8120e+003	8.9283e+002	2.2000e+001	2.5000e+002	4.4436e+003	1.0580e+003	-3.4948e+003	-7.2937e+002
25	2.7874e+003	9.3087e+002	2.2000e+001	2.5000e+002	3.4948e+003	7.2937e+002	-2.4459e+003	-4.2881e+002
26	2.4450e+003	8.9250e+002	2.2000e+001	2.5000e+002	2.4459e+003	4.2881e+002	-1.4479e+003	-2.0251e+002
27	2.0277e+003	8.5197e+002	2.2000e+001	2.5000e+002	1.4479e+003	2.0251e+002	-5.8099e+002	-5.9706e+001
28	1.4878e+003	8.0444e+002	2.2000e+001	2.5000e+002	5.8099e+002	5.9706e+001	3.1853e+001	2.0533e+000
29	7.9022e+002	7.0271e+002	2.2000e+001	2.5000e+002	-3.1853e+001	-2.0533e+000	2.5095e+002	6.3741e+000
30	-8.1383e+001	3.3795e+002	2.2000e+001	2.5000e+002	-2.5095e+002	-6.3741e+000	-8.0000e-005	-7.7544e-013

Slip_Surface_Summary

Analysis	Volume	Weight	Res_Moment	Act_Moment	Res_Force	Act_Force	FOS
Ordinary Method	5.3733e+002	6.4640e+004	1.5320e+006	1.0080e+006			1.5198991
$\boxed{\text{Bishop Method}}$	5.3733e+002	6.4640e+004	1.6371e+006	1.0080e+006			1.6241460 ← Minimum F.S.
~~Janbu Method~~	5.3733e+002	6.4640e+004			3.0325e+004	2.0081e+004	1.5101325
M-P Method	5.3733e+002	6.4640e+004	1.6594e+006	1.0080e+006	3.1157e+004	1.8873e+004	1.6463010

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REVIEW COMMENT
Form SOP-0402-03, Revision 7B

Project:	Duke Energy Indiana, Inc.		Unit:
Project No.:	10444-806	Calc. No. WRC-F-002S	Calc. Rev. 0
Calc. Title:	Ash Pond Slope Stability Analyses		

#	Comment	Resolution
	NONE	

Reviewed by: W. ROGER WU / [signature] Date: 11/23/09