DONNA

Title: Proposed Dredge Cell Restoration Supporting Information				DCN # KIF-05-1090
				Plant/Unit: KINGSTON FOSSIL PLANT
Vendor	Contract No.	Key Nouns: Minor Modification, Permit, Dredge Cell		
Applicable Design Documents	REV	EDMS NUMBER		DESCRIPTION
	R0	**B65 050426 ???**		April, 2005 IDL 73-0094
References	R1	B65 050426 254		

TENNESSEE VALLEY AUTHORITY
FOSSIL POWER GROUP
FOSSIL ENGINEERING SERVICES
SITE AND ENVIRONMENTAL ENGINEERING

	Revision 0	R1
Date	April, 2005	
Prepared	KIF Seep Team	
Checked	Larry C. Bowers	
Supervised	Harold L. Petty	

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Summary of Approach and Conclusion:

Approach:

In November of 2003 a blowout occurred in the Dredge Cells at Kingston Fossil Plant. Dredging operations were immediately suspended. With the approval of TDEC an interim dredge cell operation was commenced on the ash pond side of the dredge cells. The purpose of this interim operation was to allow TVA time to analyze the cause of the blowout and develop a solution to allow resumption of the original operation.

Many alternatives were considered and rejected during the early phase of our study period. These included vibratory beam slurry wall, liner installation, dewatering wells, rock armoring, and dry fly ash conversion. Effectiveness, constructability, economics, and practical experience led TVA to focus its efforts on trench drains as the preferred fix.

Since elevated dredge cells are an important tool in maximizing the onsite ash storage capacity at several of our plants, TVA formed a project team consisting of both TVA personnel and two separate consultants (Parsons E&C; GeoSyntec) to analyze and determine the detailed design of the trench drain and to insure the functionality of the drainage system. Mactec was also employed for additional site investigation.

The team took the following approach to the problem:

1. Reviewed all existing data including previous drillings and laboratory testing.
2. Performed additional site investigation (Mactec - January 2005) to get site specific data.
3. Performed seepage modeling. (Laplace Equation/Flow Net Analysis) TVA tasked Parsons E&C to perform TIMES finite element modeling. To confirm the output TVA tasked GeoSyntec to perform SEEP/W finite element modeling. The following conditions were modeled.

Case	Parsons (TIMES model)	GeoSyntec (SEEP/W)
Case 1. Existing Condition January 2005 – Purpose was to calibrate the models making sure that the permabilities used in the analyses matched those measured	X	X
Case 2. Conditions at the time of the November 2003 blowout. Purpose was to confirm the model capable of "predicting" the failure that actually occurred.	X	X
Case 3. Analyses conducted to a simulated dredge cell height of EL 900*. Modeled alternative locations of trench drains and buttress drains to arrive at the most efficient solution.	X	X

* EL 900 for conservatism and for speculative modeling purposes only. We are only proposing to return to the permitted dredge cell elevation of 841/842 at this tome. However, in the future a vertical expansion may be pursued.

The above modeling efforts resulted in a proposed "fix" consisting of 6 ft deep trench drains at the 795 bench, a 5 ft deep trenches at the 781 and 775 benches; and a buttress toe drain and a riprap channel to stop seepage uplift. (See Figure1).

As a part of this process a test excavation was performed to confirm the trench drains could in fact be constructed to the depth designed without extensive construction techniques required. This test confirmed that the drains could be constructed as proposed.

As further insurance against piping, TVA is proposing the installation of a Geonet membrane to elevation 775 in the vicinity of the failure. It should also be noted that the 5 ft trench drain in the bench at elevation 795 overlaps the exiting interior drain near that elevation. This redundancy was not modeled (conservative); only the shallower (new) drain was modeled.

Conclusion:

The extensive analysis performed by TVA and its contractors confirmed the cause of the failure was piping and excessive seepage. The proposed fix will lower the phreatic surface away from the face of the side slope, significantly reducing the future potential for piping. The calculated uplift factor of safety in the toe ditch is 4.005 for the postulated 900 FT elevation (Parsons E&C).

To insure that the proposed fix is successful TVA will install piezometers on the north, south and western faces of the dredge cells. To monitor performance of the drainage system, the phreatic surface measured in these piezometers will be compared with that predicted in the models.

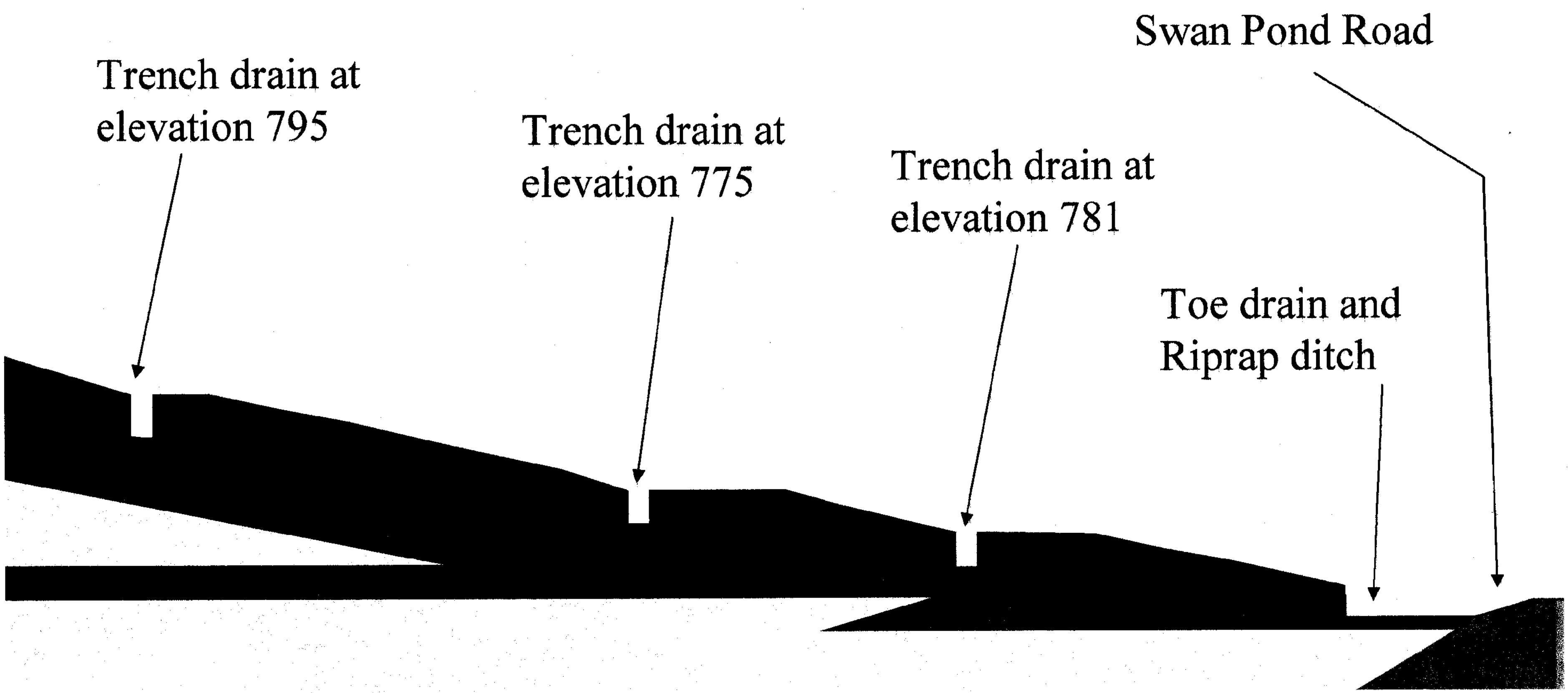


Figure 1 – Generalized Section Along Swan Pond Road

Description of Principle Design features

The proposed design is depicted on TVA drawings 81W--- thru 81W--- which are listed in Appendix D and are included as part of this minor modification request.

The drawings depict the installation of a 6 ft deep trench drain in the 795 bench, 5 ft deep trenches on the 781 and 775 benches; and a buttress toe drain and a riprap channel at the toe drain. The trench drains will outlet into the existing perimeter bench drains on 200 ft intervals. Each trench drain is constructed in a __ ft wide trench, __ inch diameter perforated tubing surrounded by an open graded limestone in a filter fabric envelope. A toe buttress and riprap channel will form the drainage ditch along Swan Pond Road. A high point will be in the ditch near Swan Pond Road at a point approx ________ft north of the intersection with the plant access road. From that point north the runoff and leachate collected will drain into a new sump pond. South of the high point the ditch will drain south and then east to the ash pond.

The new sump pond will be pumped to the ash pond. This pond is sized to contain a 25 year storm event. Emergency overflow from the pond is to the Swan Pond Embayment. The pond will be surrounded with a chain link fence. The pumps will be electric powered.

Output from the TIMES model was used to size the trench drains and in the hydraulic analysis of the sump pond. The Seep/W model confirmed the adequacy of the proposed design.

The riprap lined ditch and toe buttress is detailed on 10W???. All construction work will be behind the guardrail along Swan Pond Road.

Work is scheduled to begin June 1st, pending TDEC approval of the minor modification and storm water permit requests. There is a need to perform this work in the dry summer months to facilitate construction. In addition there is a need to return to dredging in these cells to maintain the NPDES permit required Free Water Volume (FWV) in the main ash pond.

Analysis to Support Proposed Dredge Cell Repair

Prepared For Tennessee Valley Authority
Kingston Fossil Plant

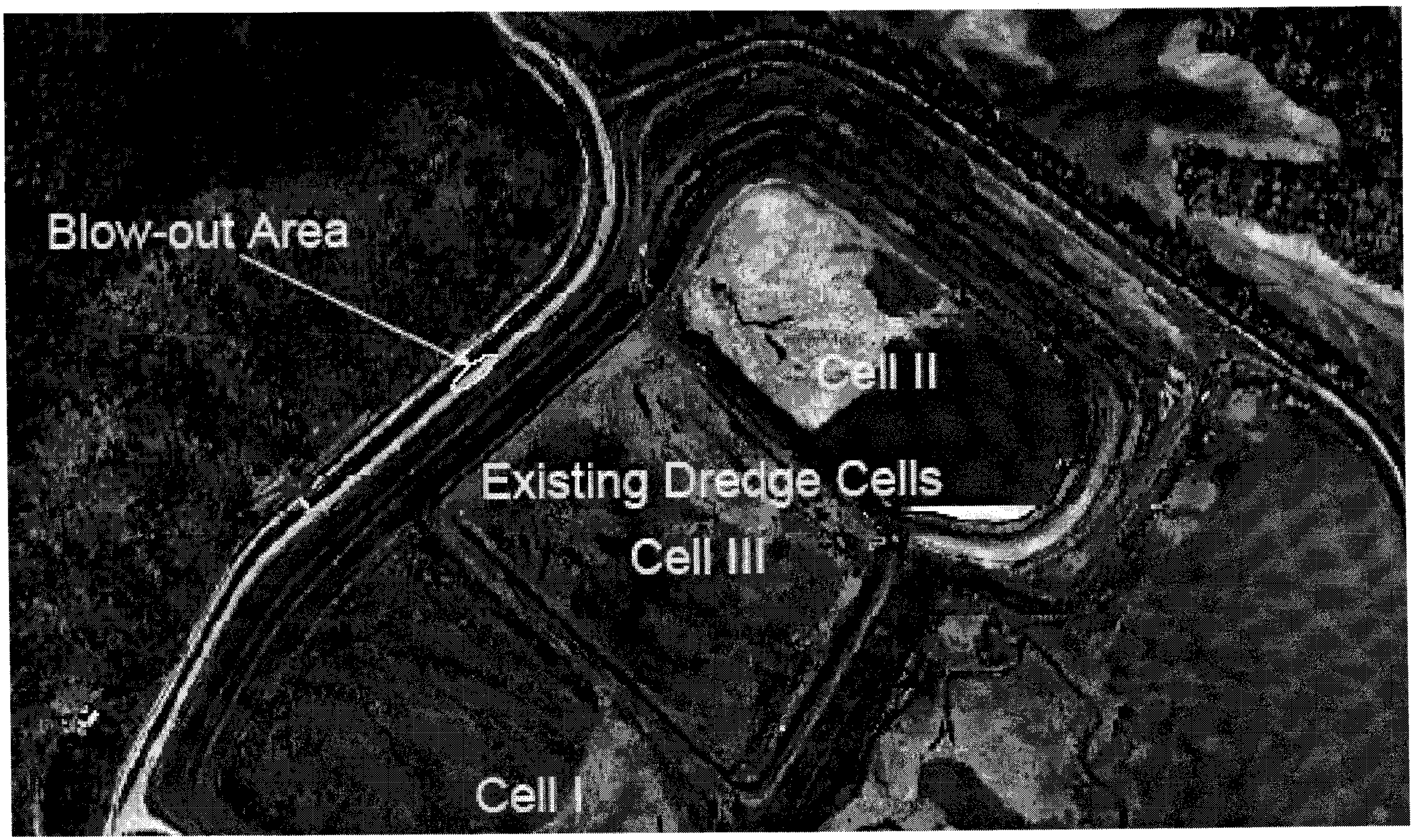
PREPARED BY PARSONS E & C

April 2005

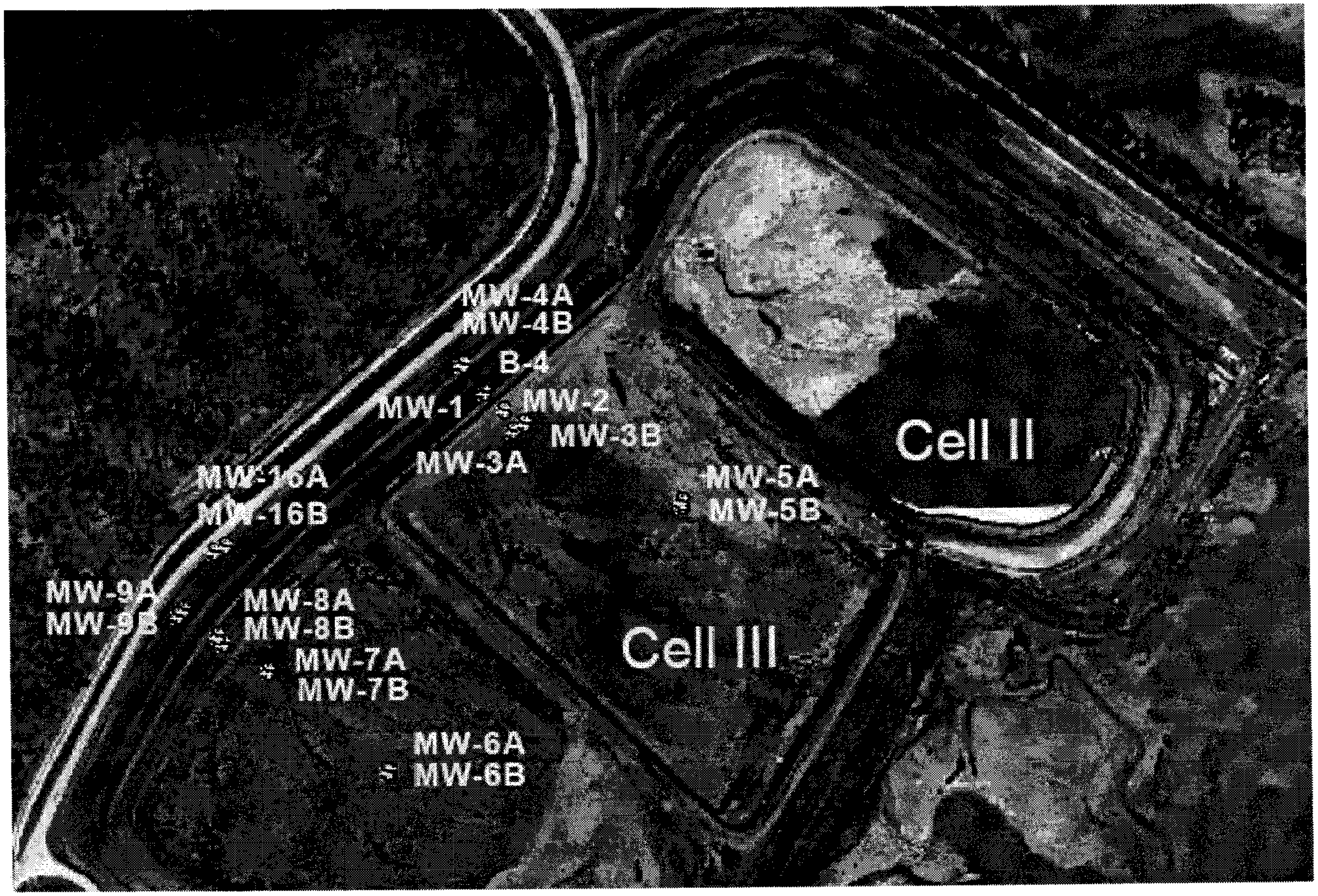
Outline of Presentation

1. Introduction – Focused Investigation
2. Case 1 – Calibration to Existing Conditions and The Limitations of Calibration
3. Case 2 – Analysis of Seepage Conditions at Pool Elevation 806 feet for Blowout in November, 2003.
4. Case 3 – Analysis of Seepage Conditions at a Postulated Future Projected Elevation of 900 feet.
5. Summary and Conclusions

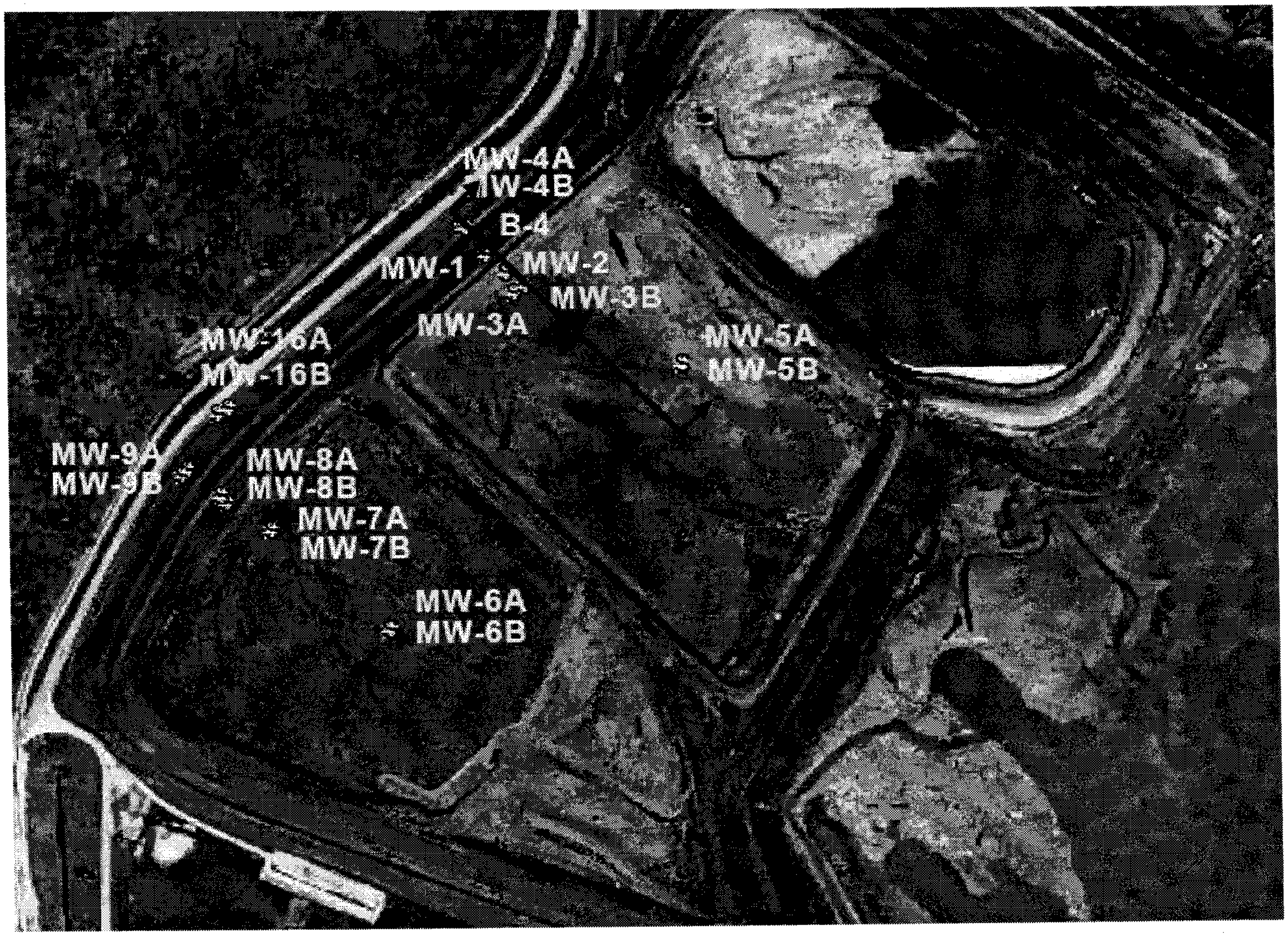
Site and Blow-Out Area



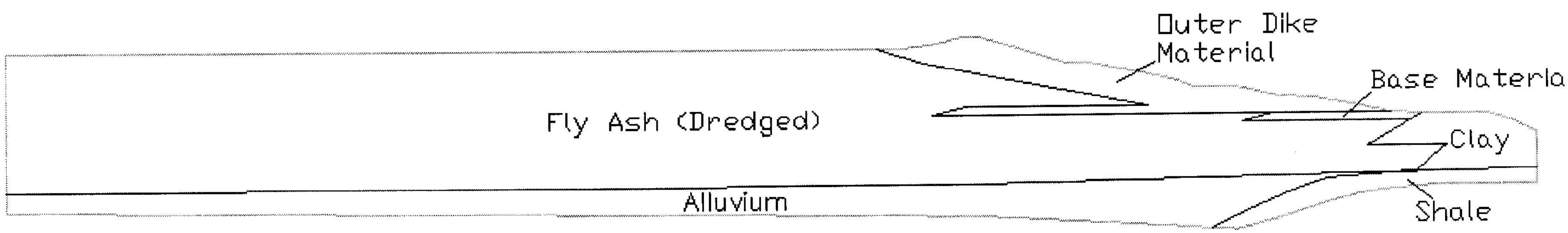
Focused Investigation Borings And Monitoring Wells



Cross Section for Cell III Analyses



Dredge Cell III Cross Section
Existing Conditions



SECTION A73 - CELL III

Aquifer Properties Each Layer –

Agreed to by Parsons E & C and Geosyntec

		Hydraulic Conductivity		Max/Min
Zone	Material	cm/sec	ft/day	K_h/K_v
1	Bottom Ash	1.0E-04	0.283	2
2	Firm Fly Ash Bottom Ash Base Material	1.73E-05	0.0490	2
3	Fly Ash	3.74E-05	0.106	2
4	Alluvium	1.29E-04	0.366	2
5	Clay	5.0E-06	0.0142	2
6	Shale	1.0E-06	0.00283	2

Unsaturated Zone Properties
Fly Ash and Bottom Ash

- VG alpha = 0.01944/ft = 0.0030/cm
- VG n = 2.68
- θ_r = 0.104 (% Volume) (residual moisture)

Hydraulic Properties Used By TIMES To Calculate Seepage Forces, Piping and Uplift Factors of Safety

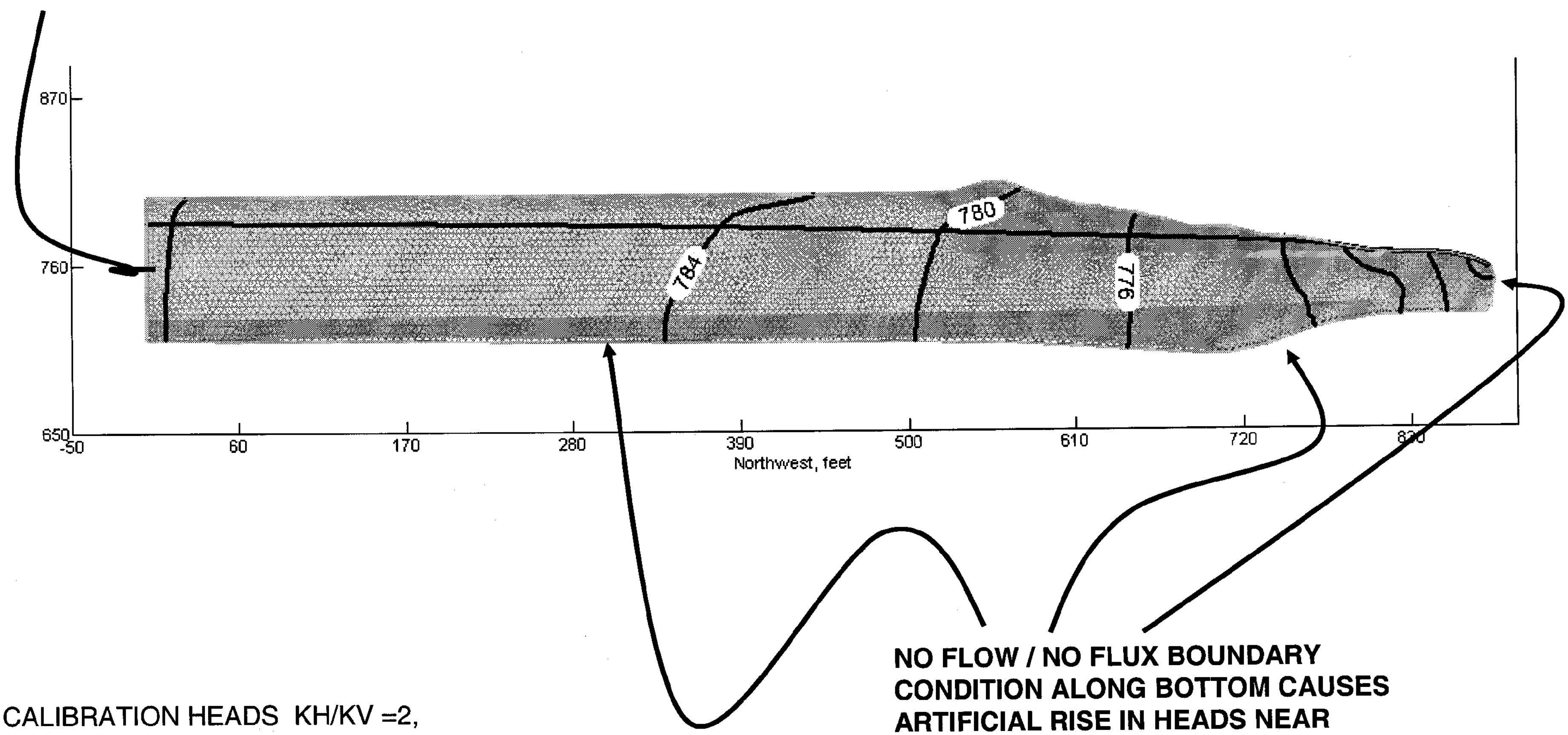
Zone	Material	Porosity	Residual Saturation	Specific Gravity	Wet Unit Weight pcf
1	Bottom Ash- Mactec (2003) Bull Run	0.589	0.104	2.37	97.6
2	Firm FA / BA Base- Mactec (2003) Bull Run	0.560	0.104	2.37	100.0
3	Fly Ash Mactec (2003) Bull Run	0.560	0.104	2.37	100.0
4	Alluvium Singleton (1994, US-9, T-1)	0.357	0.2	2.69	129.06
5	Clay Singleton (1994, US-1, T-1)	0.338	0.2	2.60	126.35
6	Shale Mactec (2003, Conf. Client)	0.169	0.14	2.69	150.0

Case 1 – Existing Conditions

- Existing conditions used for Calibration Exercise.

CASE 1 – CALIBRATION RUN - KINGSTON EXISTING DREDGE CELL III

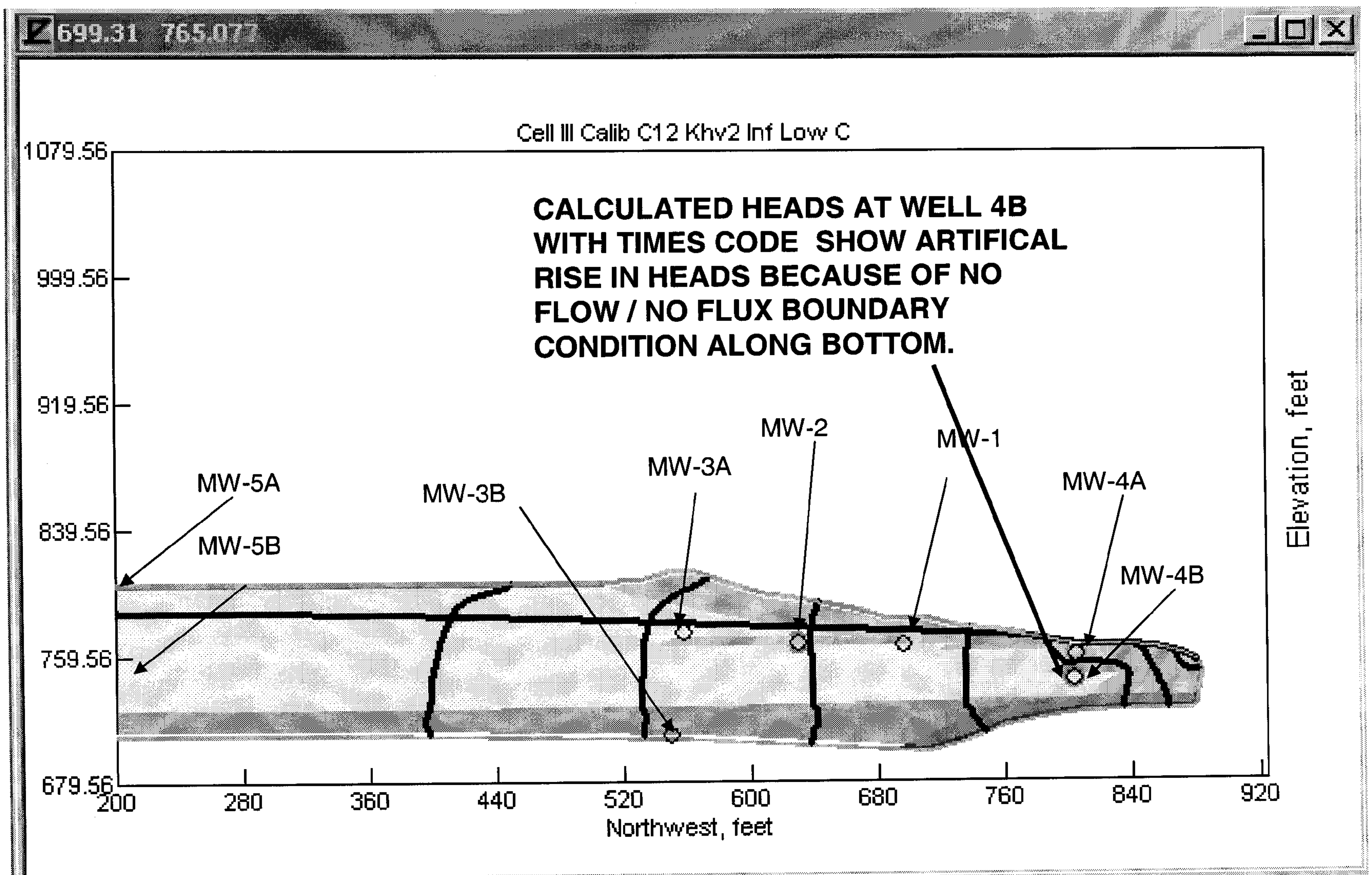
NO HEAD CHANGE PERIMETER
BOUNDARY CONDITION – DOES NOT HAVE
TO BE CONSTANT WITH ELEVATION



NO FLOW / NO FLUX BOUNDARY
CONDITION ALONG BOTTOM CAUSES
ARTIFICIAL RISE IN HEADS NEAR
ROAD THAT DO NOT EXIST IN FIELD.

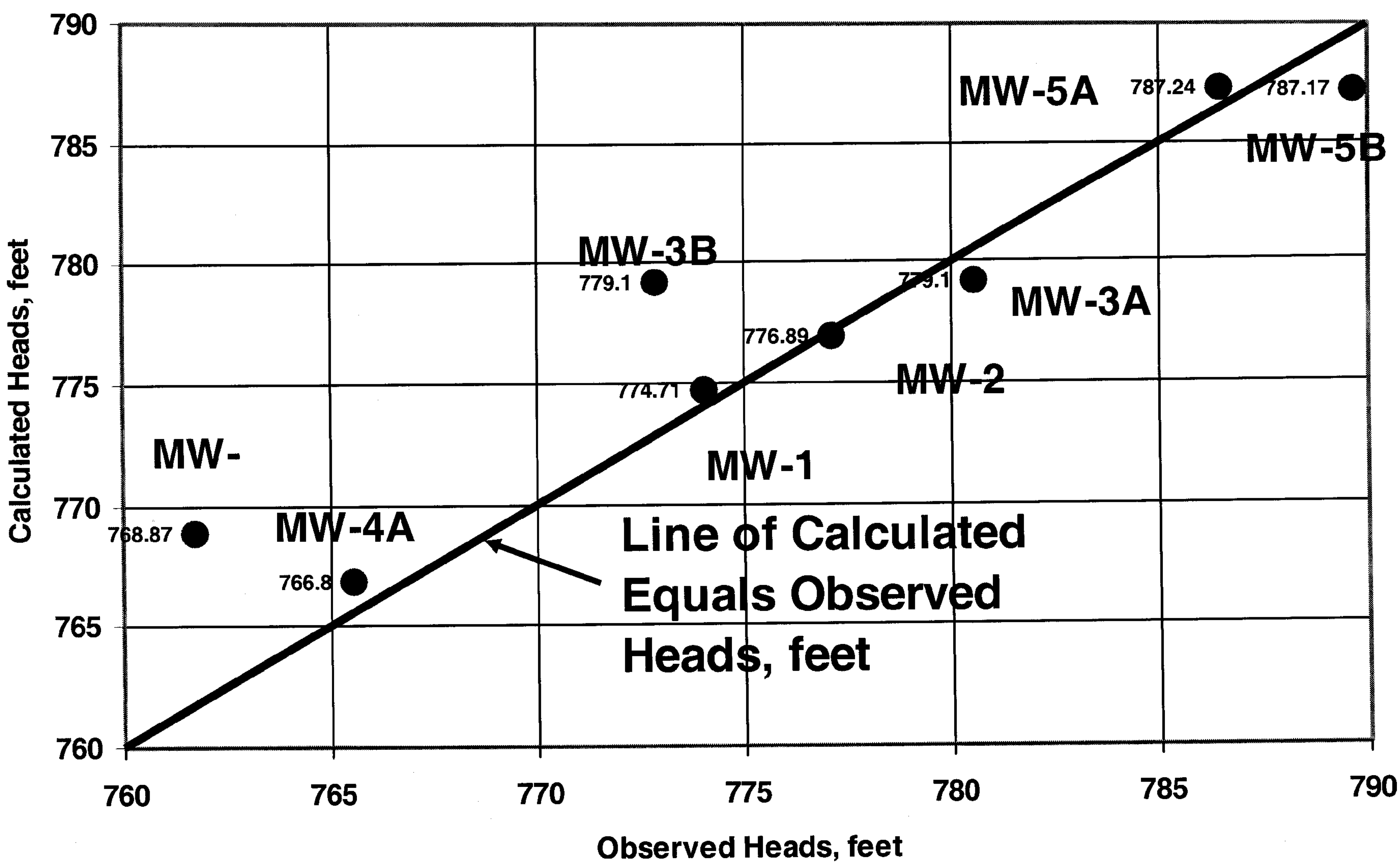
CALIBRATION HEADS KH/KV =2,
INFILTRATION = 12% SURFACE, 17% SLOPE,
USED MARK BOGGS VAN G. PARAMETERS FOR KINGSTON ASH

KINGSTON EXISTING DREDGE CELL III CASE 1 – CALIBRATION RUN



CALIBRATION HEADS KH/KV =2,
INFILTRATION = 12% SURFACE, 17% SLOPE,
USED MARK BOGGS VAN G. PARAMETERS FOR KINGSTON ASH

Calculated Versus Observed Heads, kh/kv = 2, feet



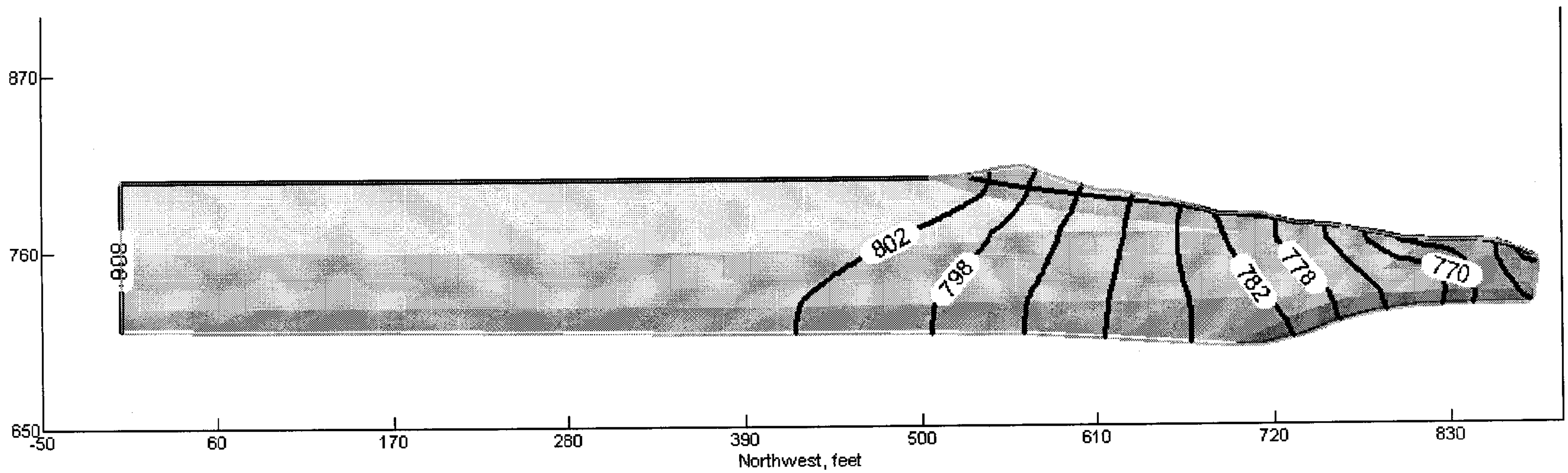
The kh / kv = 2 for all soils gave the best calibration. The following monitoring wells show large calculated differences with the observed field heads because:

- MW – 3B measures lower heads than calculated because no flow boundary on the bottom increases heads. The downward head gradient reduces heads near the bottom in the field.
- MW - 4B measures lower heads than calculated because the no flow boundary increases the calculated heads where as the downward gradient in field reduces them.
- MW – 5B, by contrast, shows no increase in head with depth even though there is an upward gradient near MW – 5B.

Ignoring downward gradients near toe will
1. over predict uplift and seepage forces
2. under predict factors of safety for uplift / heave at toe and on benches of slope
3. under predict factor of safety for slope stability.

Thus the modeling approach is "conservative" results in a safer design.

CASE 2 – "BLOWOUT CONDITION" - KINGSTON DREDGE CELL III



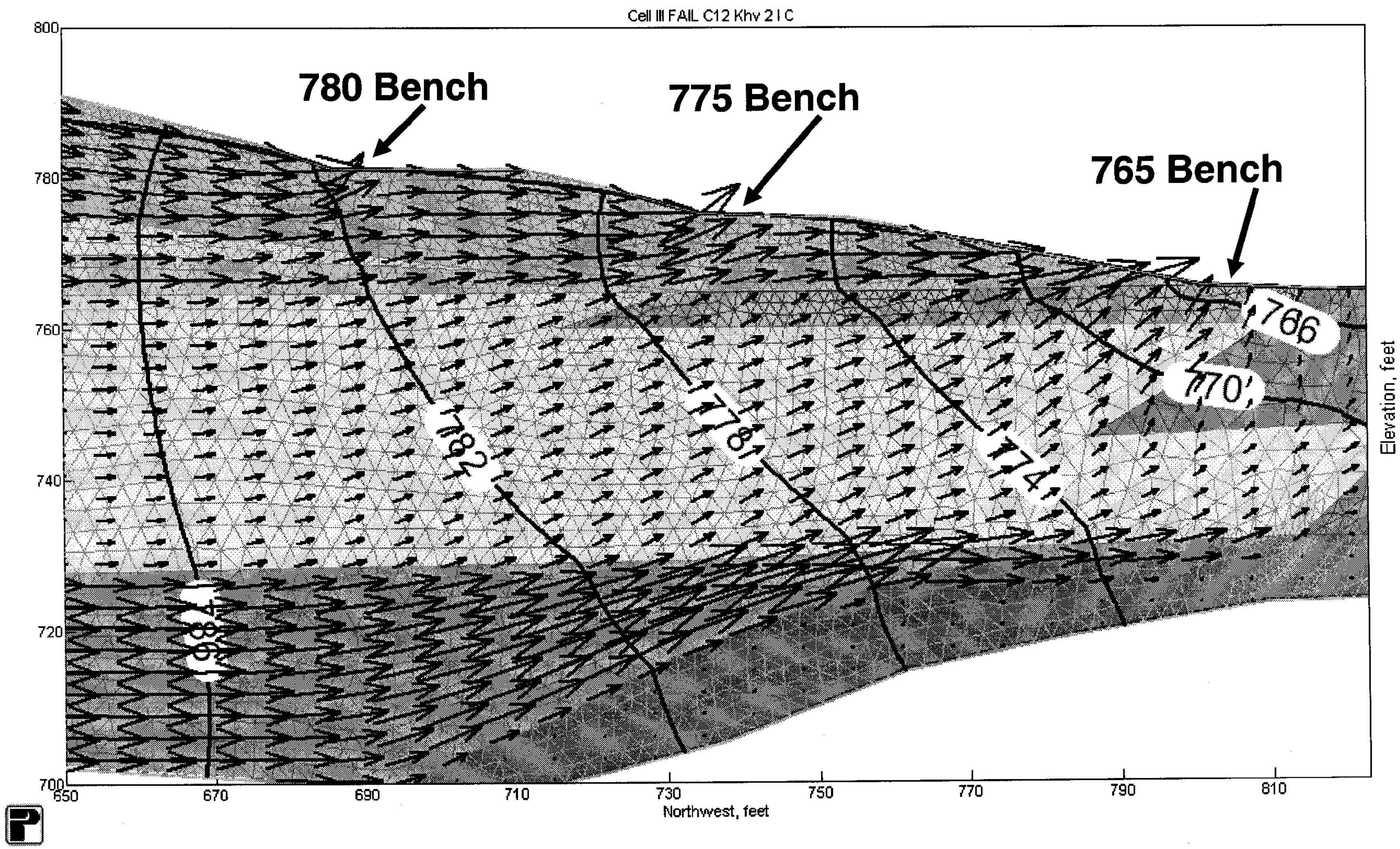
Calculated Flow Rates at Seepage Faces Along Selected Benches

Seepage Face	Calculated Flow Rate	
	ft^3/day/ft	ft^3/sec/ft
765 to 775 Bench	0.884	1.026E-05
775 to 780 Bench	0.550	6.360E-06
781 to 784 Bench	0.440	5.089E-06

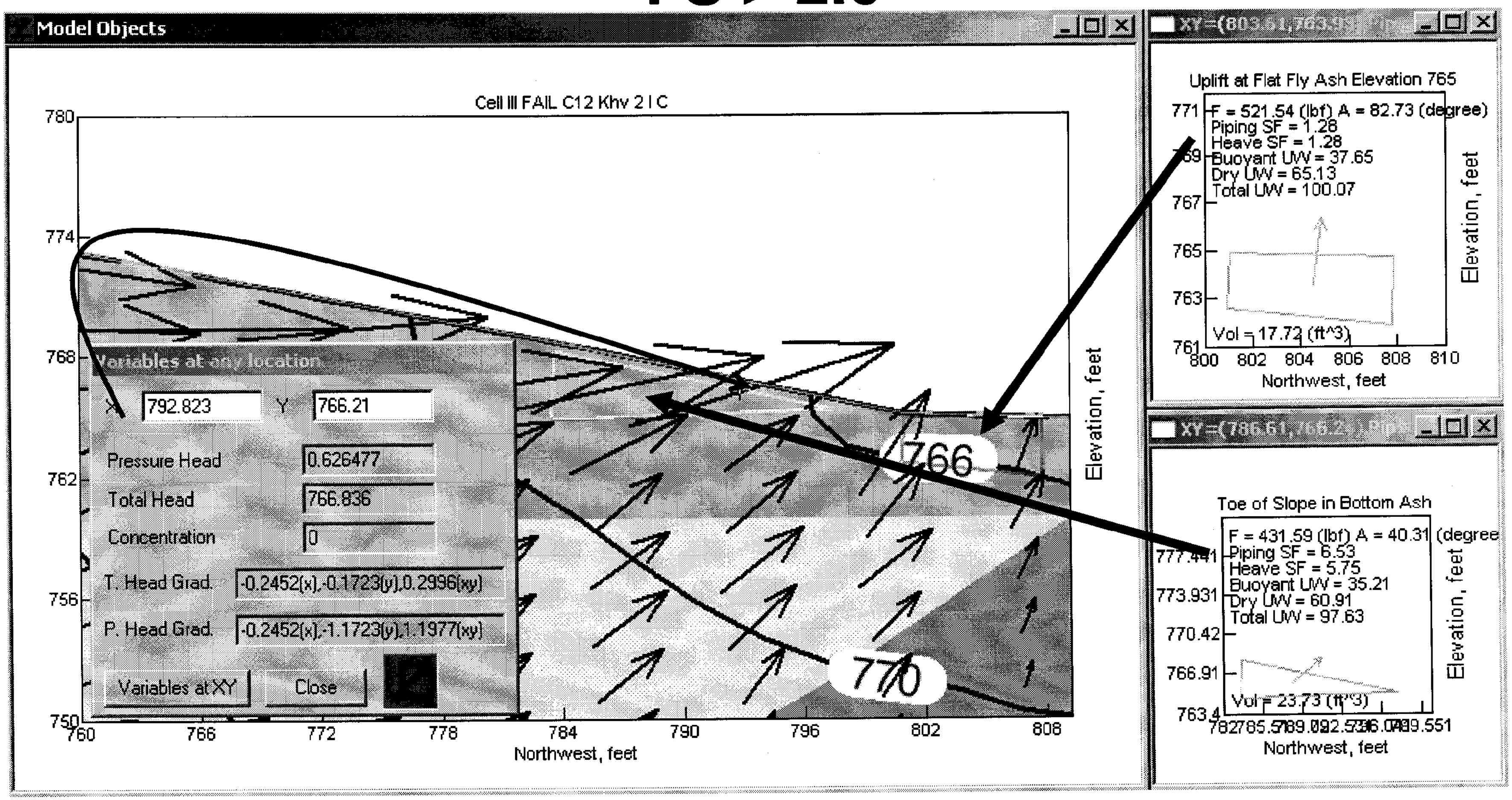
A NOTE ON FACTORS OF SAFETY

- Cedergren states that Uplift FS for these calculations should be 2 to 2.5 for boils (Pg. 227, Cedergren, 1967) AND 2.5 to 3.0 for uplift (Cedergren, Page 107, 1989, 3rd Edition).
- For this modeling exercise the above Factors of Safety were considered the minimum acceptable.

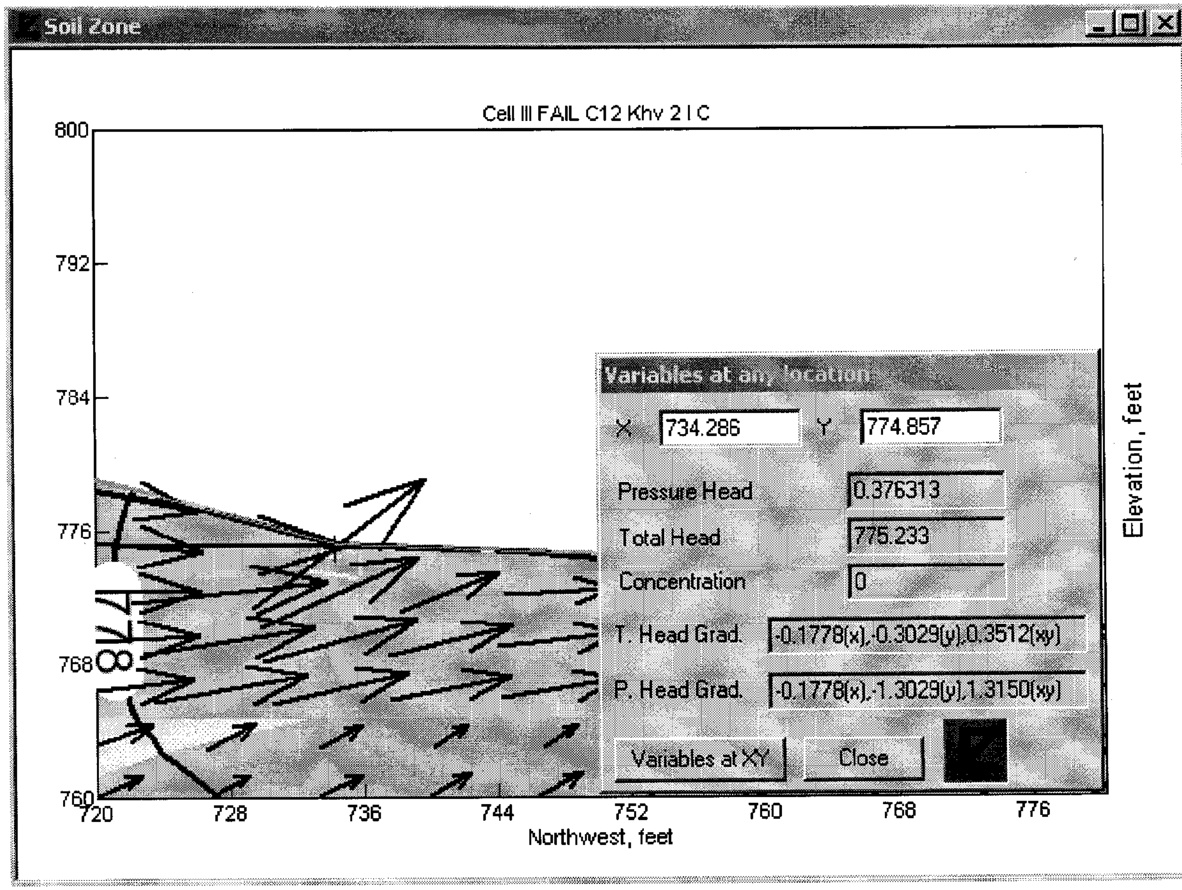
Pore Water Velocity Vectors Shown on Close Up View of Lower Slope

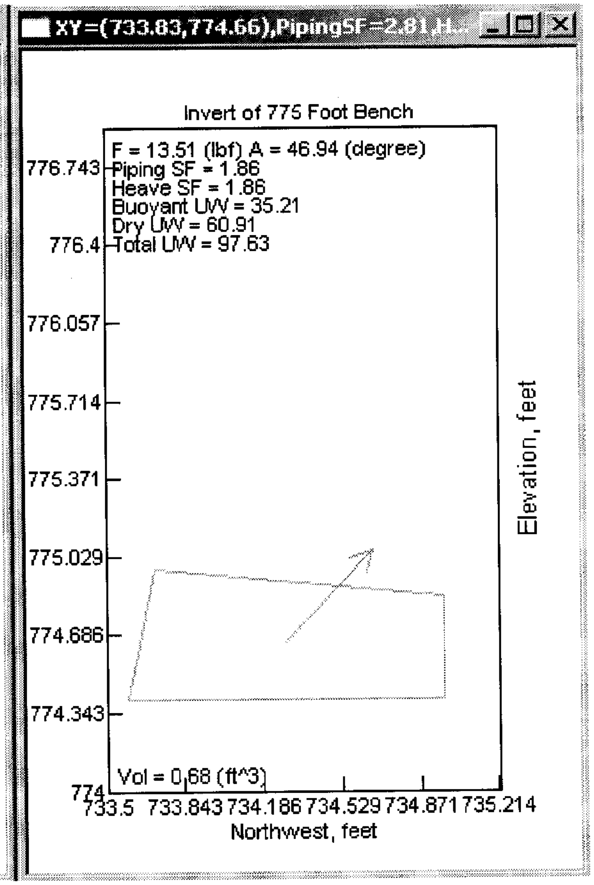


Uplift Factors of Safety at 765 ft Bench Flat in Fly Ash Fall Below 2.0 (= 1.28) – But BA Slope FS > 2.0

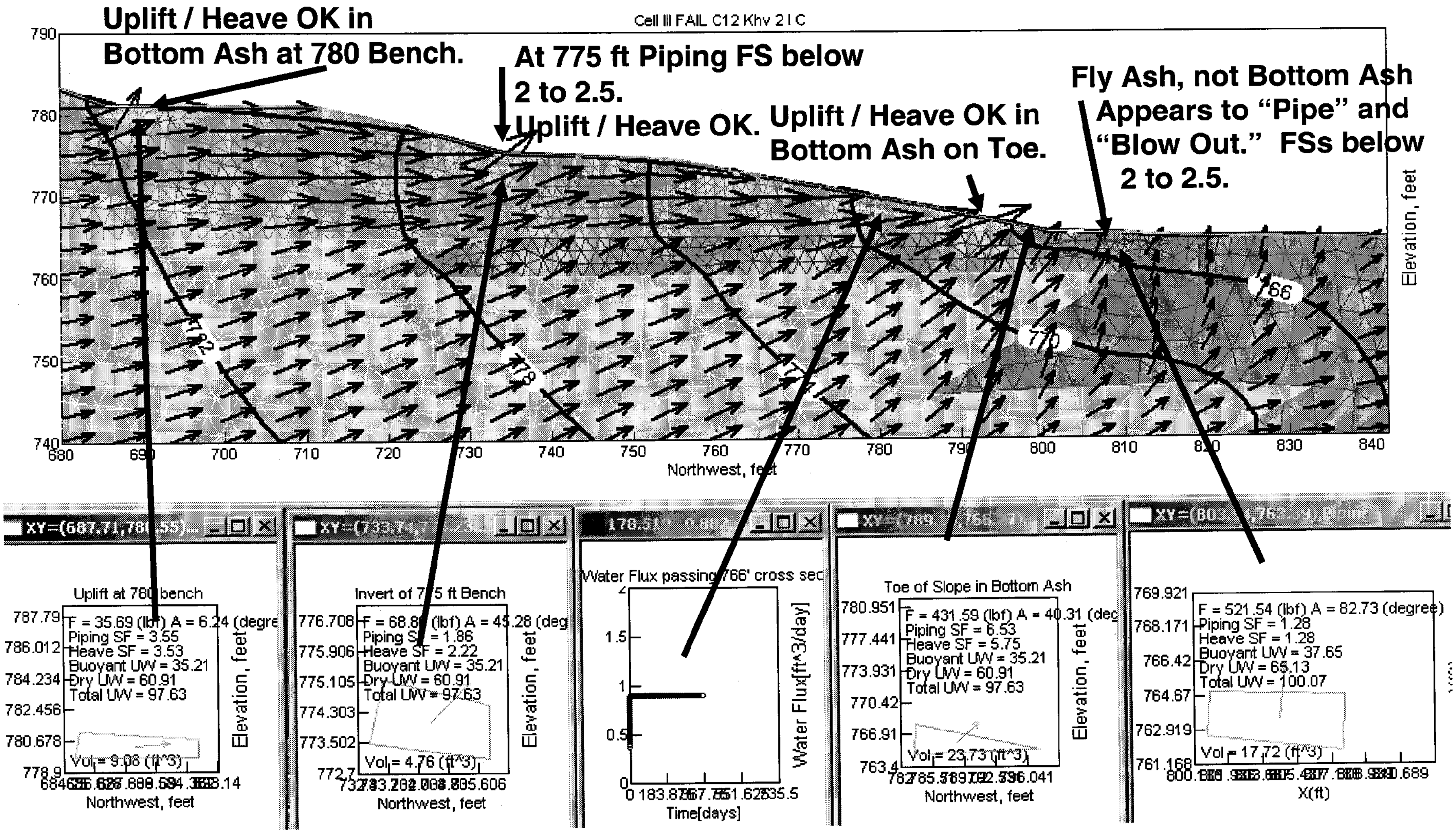


Toe of 775 ft Bench in BA – Piping and Uplift FS = 1.86; Below Requisite 2.0





UPLIFT FS AND FLOW VECTORS



CASE 2 – SEEPAGE FAILURE RESULTS

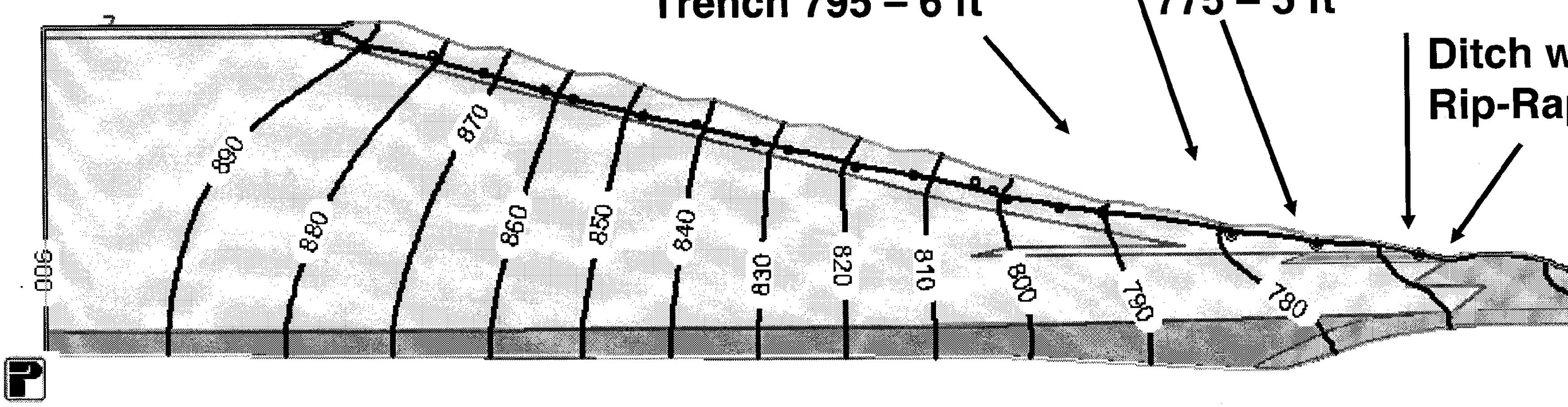
- Uplift FS is **1.28 < 2.0** at bottom of toe in the fly ash flat at Elevation 765 feet, approximately at the elevation observed in the field for the blowout.
- The slope above this point appears stable from seepage forces **except** the bench at the **775 foot elevation**. At this bench the factors of safety (**1.86**) fall below the requisite 2.0 (Boiling) to 2.5 to 3.0 (Uplift) required by Cedergren.

Case 3 – Looks at Future if Dredge Cell Raised to as High as El 900

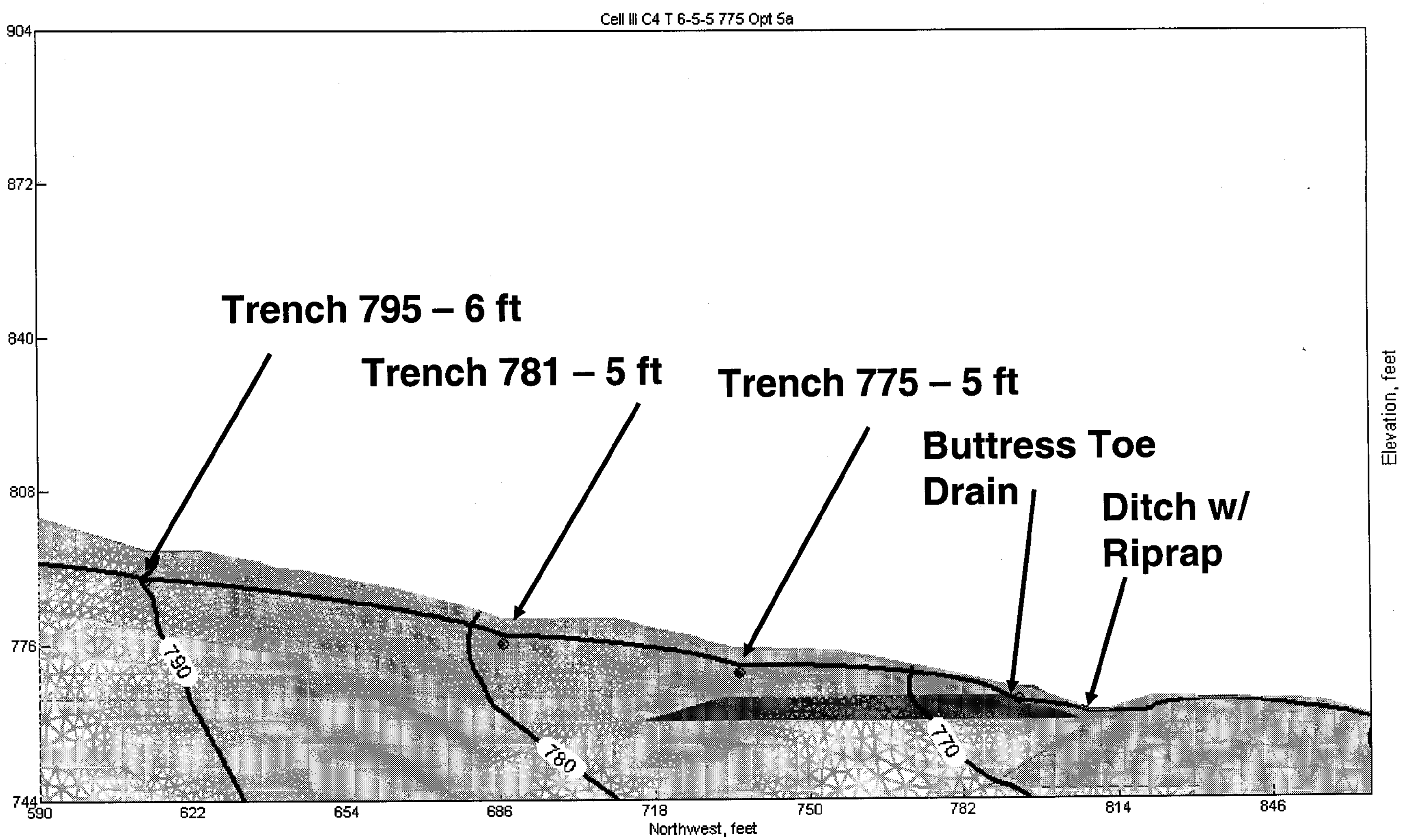
1. Evaluate a postulated future vertical expansion of the dredge cells to El 900.
2. Analyze alternatives to arrive at the most efficient solution to reducing seepage forces to requisite factors of safety of 2 to 2.5.
3. These alternatives include trench and buttress drains at various locations and depths parallel to the slope.
4. Note that the permit currently sets the maximum height of the dredge cells to an elevation of 841/842 feet. TVA is not proposing a vertical expansion at this time. However, TVA desires the fix to allow that expansion if needed in the future.

CASE 3 - 900 Foot Pool Proposed Design

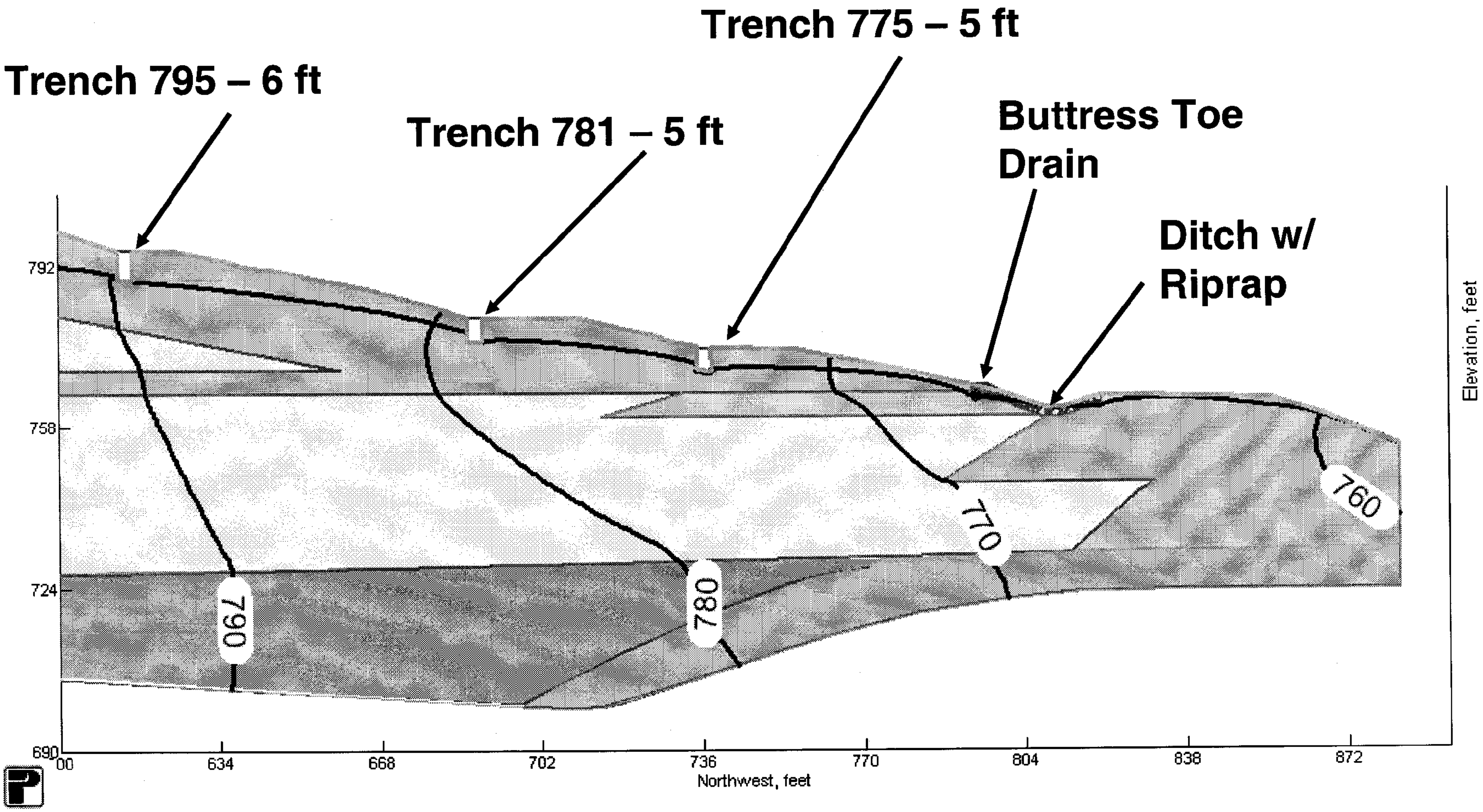
- One 6-foot Trench at 795 feet, Two 5-foot Trenches at 781, and 775 feet
- Buttress Toe Drain for Seepage Uplift
- Riprap Channel to Stop Seepage Uplift



FINITE ELEMENT MESH NEAR TRENCH, BUTTRESS, AND DITCH AREAS



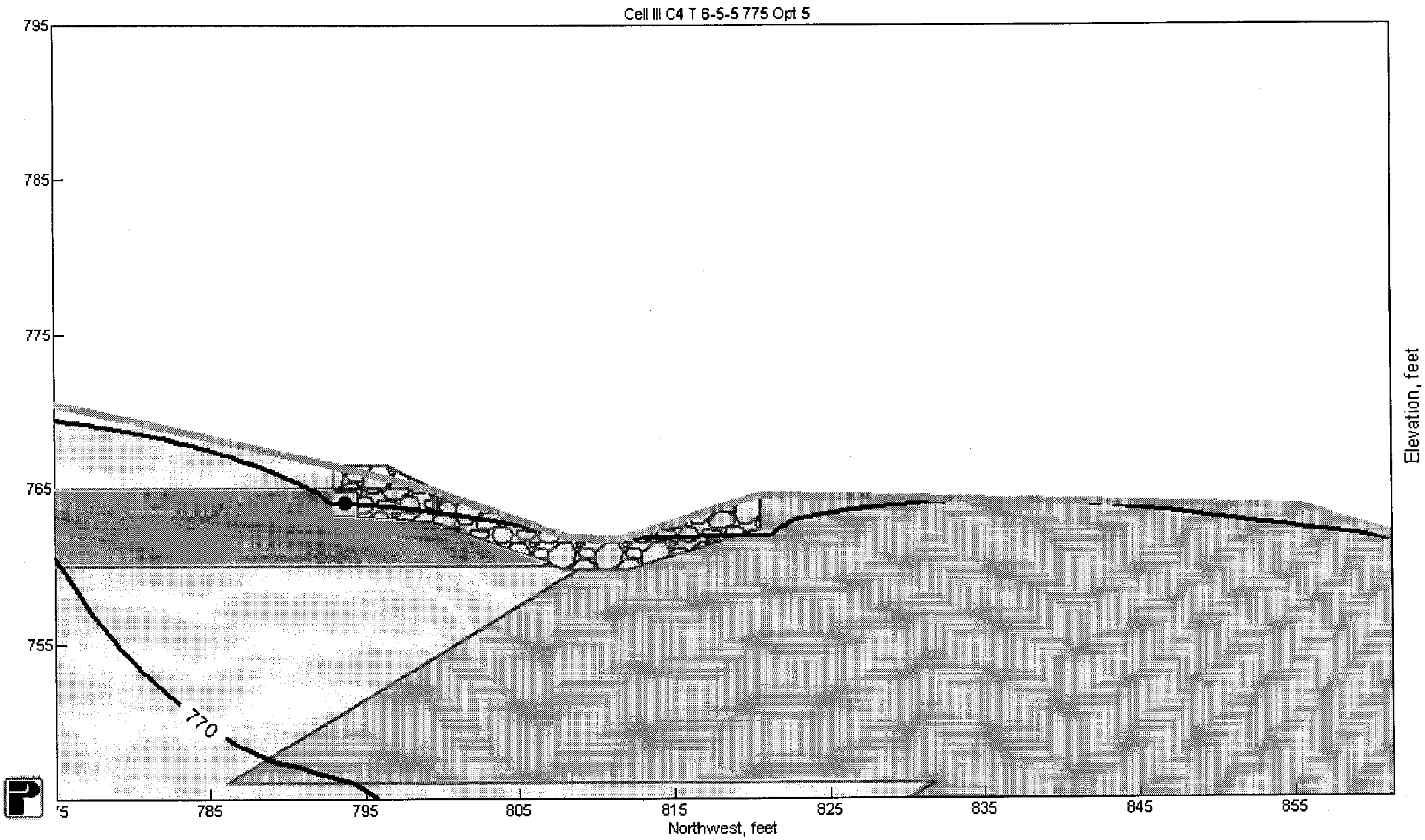
CASE 3 – CLOSEUP ON TRENCHES



Calculated Flows for Future 900 ft Dredge Cell

Well /Trench	ft^3/day/ft	ft^3/sec/ft
Buttress Ditch	0.921	1.066E-05
Geocomposite Drainage	5.1	5.903E-05
8-Inch Pipe	0.592	6.852E-07
775 ft Elevation Bench 5-Foot Trench	1.13	1.308E-05
781 ft Elevation Bench 5-Foot Trench	1.26	1.458E-05
795 ft Elevation Bench 6-Foot Trench	0.38	4.398E-06
797 foot Elevation Pipe Drain	0.93	1.076E-05
802 foot “	0	0
807 foot “	0	0
812 foot “	0.0058	6.713E-08
817 foot “	0.59	6.829E-06
827 foot “	0.29	3.356E-06
832 foot “	0.29	3.356E-06
842 foot “	0	0
847 foot “	0.259	2.998E-06
857 foot “	0.172	1.991E-06
862 foot “	0.0269	3.090E-07
872 foot “	0	0
882 foot “	0	0
887 foot “	0.804	9.306E-06
892 foot “	1.21	1.400E-05

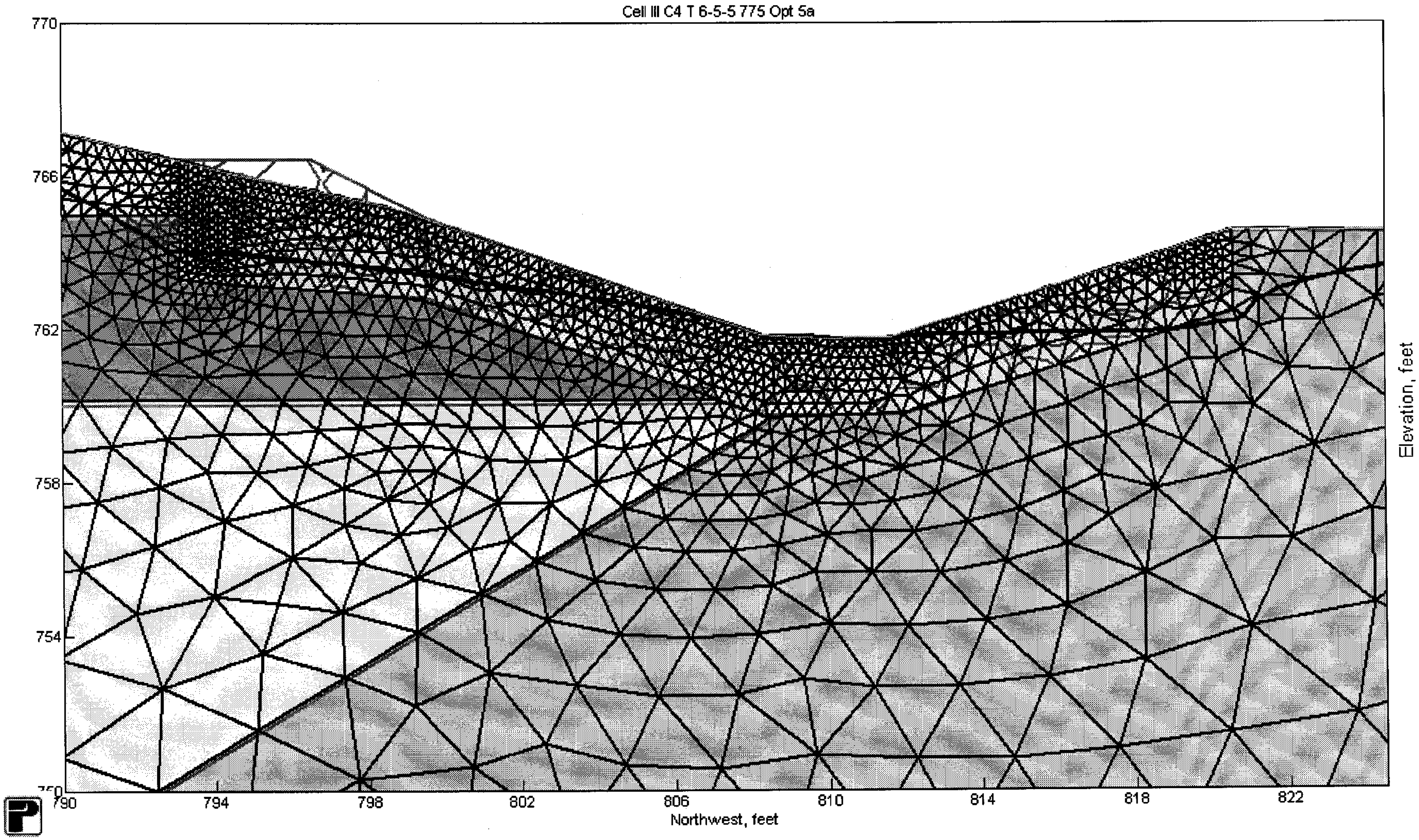
Riprap Design for Buttress and Ditch



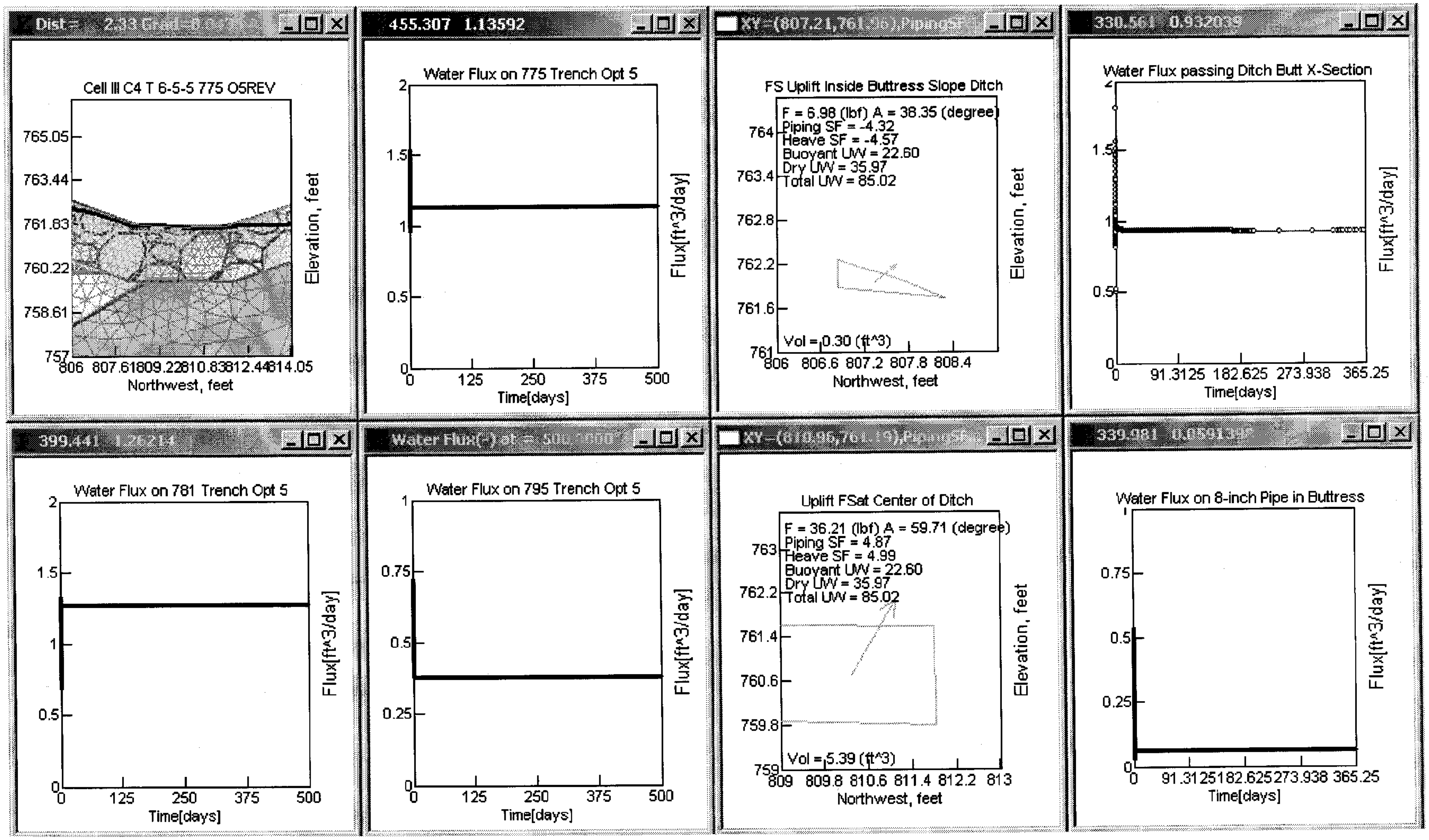
Buttress and Ditch Rip-Rap Design Assumptions

- To assess uplift seepage forces on riprap under clogged conditions, a minimum hydraulic conductivity, k = 1.42 ft/day or 5.0E-04 cm/sec was used; Actual k should be > 120,000 ft/day (Cedergren, 1989)
- VG alpha = 0.01944/ft
- VG n = 2.68
- Geotextile is assumed underneath the riprap.
- Bulk Unit Weight of Riprap equals 80 to 85 pcf (Source Red and Blue Steel Manuals, and the Pocket Reference (Glover,2001))

Finite Element Mesh At Buttress And Riprap Ditch



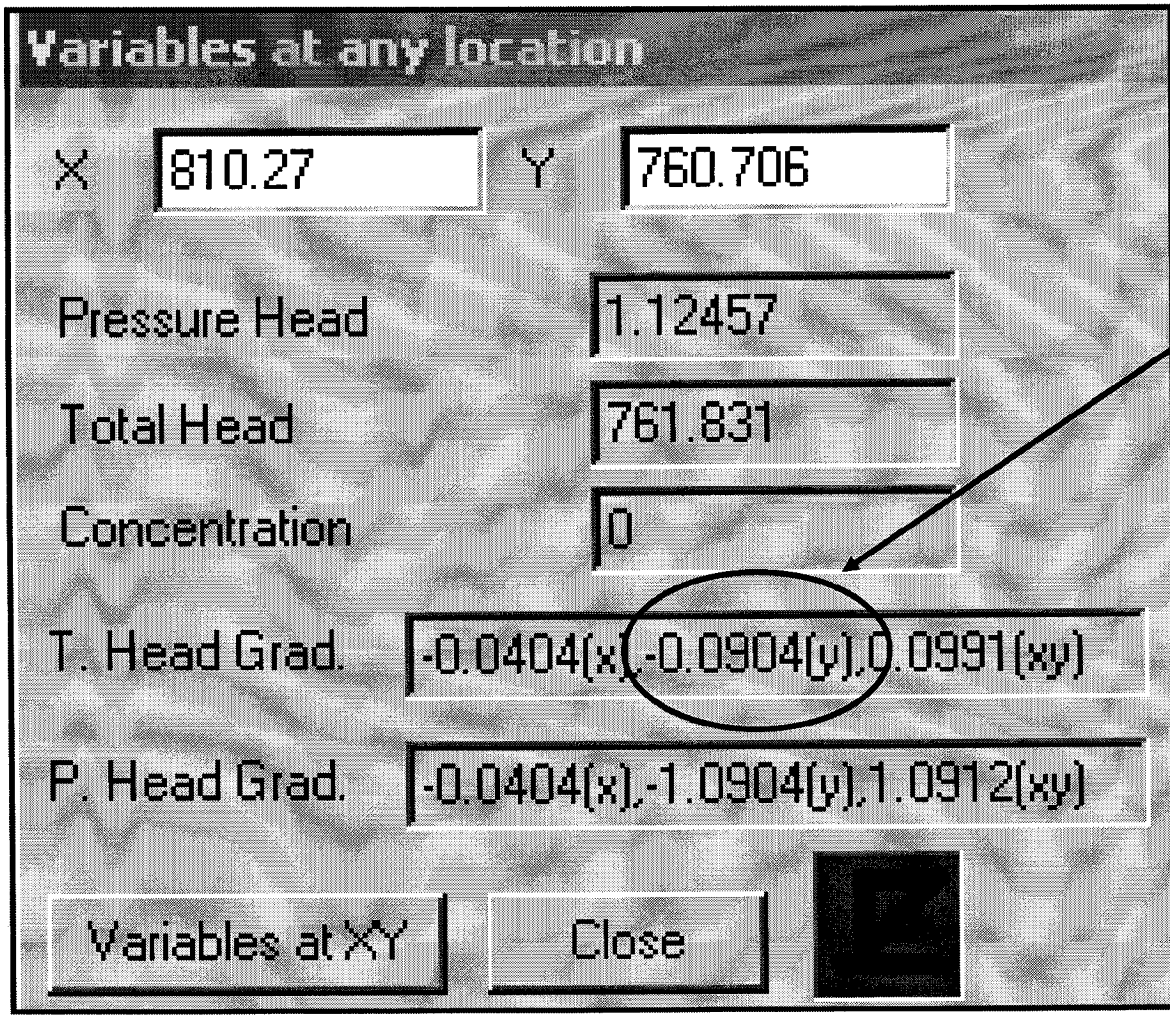
UPLIFT FS AND FLUXES



Another Note on Factor of Safety

- All Uplift Factors of Safety (FS) are calculated for below the water table at the seepage face. They do not take into account soil overburden.
- Addition of the weight of soil above the water table will increase the calculated uplift FSs.

Variables at Any Location



Total Head Gradient in Y Direction,

Note Negative Sign Means UPWARD.

Positive Y direction is <u>DOWNWARD, as in water moving down hill is + Y.</u>

Calculation of "Riprap"* for Three 5- foot Trench Option Thickness for Ditch Area Beyond Toe. * -

$$\text{Uplift FS} = \frac{(Gs - 1)\,(n - 1)}{\text{gradient } i}$$

Where Gs equals the specific gravity and n equals the porosity.

Given that Gs equals 2.69 for the riprap and n=0.78585, and assume a Note that *i* in y direction at centroid of the polygon and equals -0.0904

$$\text{Uplift FS} = \frac{(2.69-1.0)*(0.7858-1)}{(-0.0904)}$$

= 4.005, Factor of Safety satisfies Cedergren's 2.0 to 2.5

Case 3 - Results

1. Use 3 Trenches – 795 trench 6 feet deep, the 781 and 775 trench 5 feet deep.
2. Use the Toe Drain and Riprap Buttress as shown.
3. Use a Ditch with Riprap and Geotextile on the Bottom.
4. Uplift Factors of Safety satisfy the 2 to 2.5 required (Average FS = 4.005).

SUMMARY AND CONCLUSIONS

✓ Analysis confirms that the proposed trench drains, riprap buttress and ditch system as configured more than adequately handles the anticipated seepage.

Model Input Parameters

1. Saturated hydraulic conductivities

Material	Horizontal hydraulic conductivity (K_h)		K_h/K_v
	cm/sec	ft/sec	
Fly Ash [(1)]	3.74×10^{-5}	1.24×10^{-6}	2
Outer Dike [(1)]	1.00×10^{-4}	3.28×10^{-6}	2
Clay at the toe [(2)]	5.00×10^{-6}	1.64×10^{-7}	1
Shale [(2)]	1.00×10^{-6}	3.28×10^{-8}	1
Base material [(1)]	1.70×10^{-5}	5.58×10^{-7}	2
Alluvium [(1)]	1.29×10^{-4}	4.23×10^{-6}	2

(1) Saturated hydraulic conductivity data presented in the above table was estimated from in-situ hydraulic conductivity test performed during the January 2005 site investigation.

(2) Saturated hydraulic conductivity were estimated based on typical values available in the literature.

GeoSyntec Consultants

Model Input Parameters (cont.)

2. Soil water characteristic curves

- Flow in unsaturated zone requires information on soil water characteristic curves for the unsaturated zone materials, specifically, fly ash and outer dike material.

- The soil water characteristic curve for Kingston fly ash and outer dike material was obtained from the February 1993 report titled "*Physical and Hydraulic Properties of Fly ash and Other By-products from Coal Combustion*" prepared by TVA.

Analyses Cases

***Case 1* - Existing Condition**

- Analysis was performed for existing condition to ensure that the seepage model could represent groundwater elevations recorded in the field. This case was used as a means of calibrating the model. A calibrated model is needed to provide an acceptable level of confidence to proceed with the analysis of future conditions.

***Case 2* - Conditions at the time of Blow out ("Blow-out" Condition)**

- Analysis was performed for the conditions that were observed at the time of blow-out to identify/confirm blow-out triggering mechansim(s).

***Case 3* - Future condition and proposed improvement features**

- This case was analyzed to: (i) evaluate seepage conditions in the the dredge cells under future conditions (i.e., 2 possible vertical expansion) and (ii) evaluate the effectiveness of proposed improvements in terms of providing an adequate factor of safety against seepage failure under future conditions.

GEOSYNTEC CONSULTANTS

PRESENTATION ON PEER REVIEW, SUPPLEMENTAL INVESTIGATION AND SEEPAGE ANALYSIS FOR KINGSTON FOSSIL PLANT, DREDGE CELL KINGSTON, TENNESSEE

Prepared for
Tennessee Valley Authority

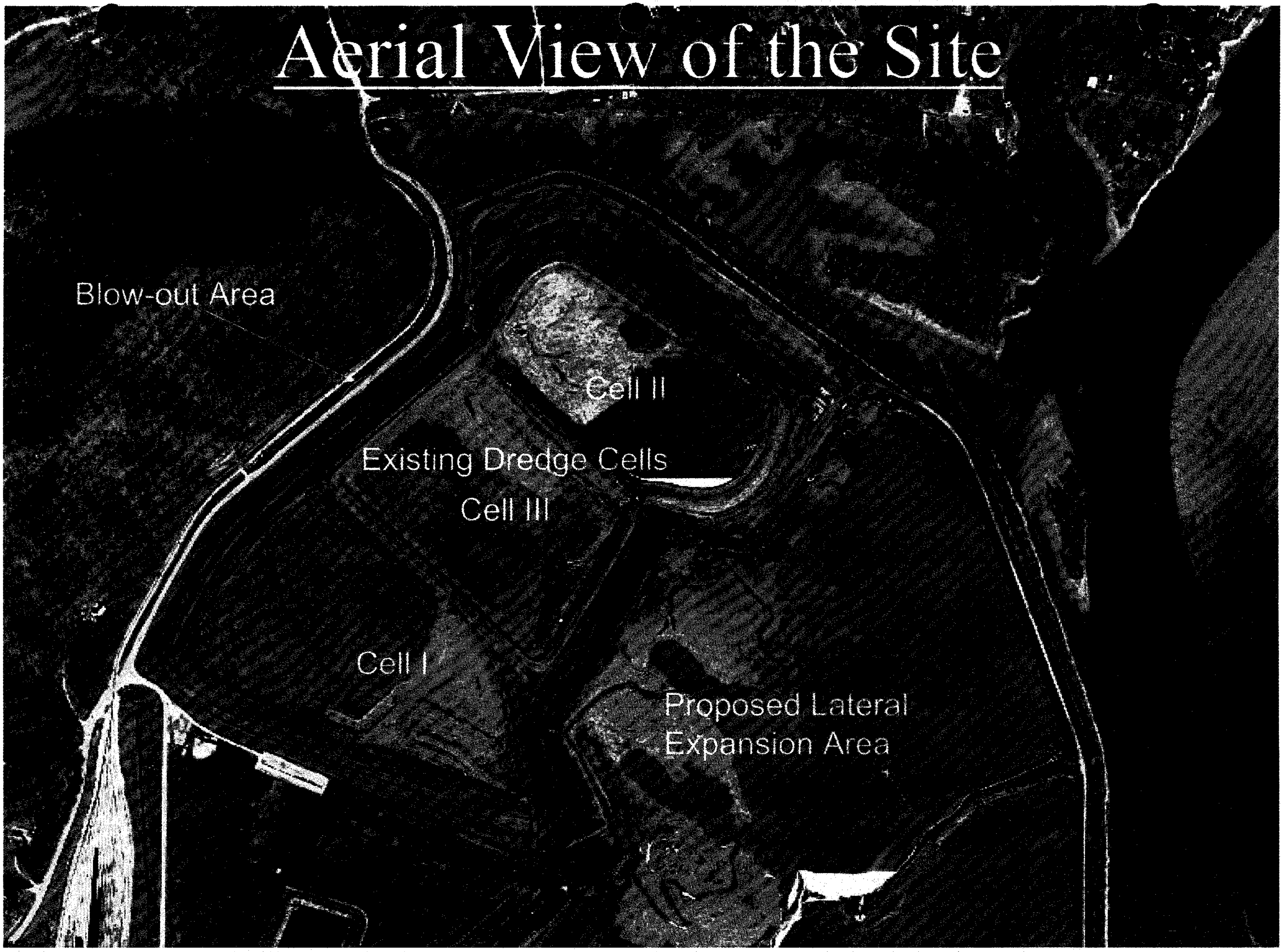
Prepared by
GeoSyntec Consultants

April 2005

GEOSYNTEC CONSULTANTS

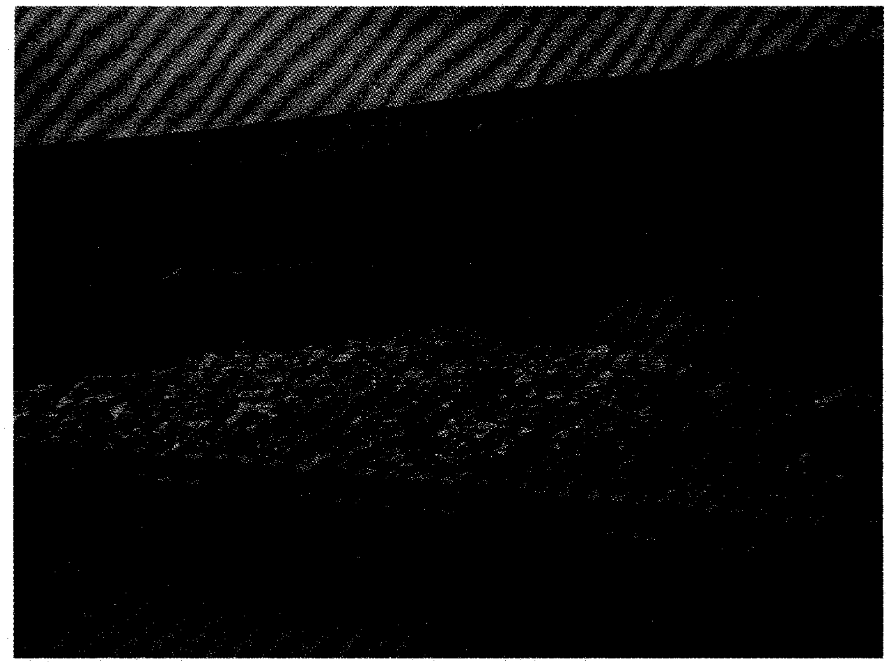
INTRODUCTION

- Plans are presently under development to construct a lateral ~~and vertical~~ expansion ~~over~~ the existing dredge cells of the Kingston Fossil Plant. adjacent to
- Prior to implementation of the planned expansion, excessive seepage (blow-out) occurred near the base of Dredge Cell III perimeter dike adjacent to Swan Pond Road.
- Fly-ash was reported to "flow" along the perimeter ditch and across Swan Pond Road.
- Due to the importance of this project, Tennessee Valley Authority (TVA) requested GeoSyntec Consultants (GeoSyntec) perform a peer review of the proposed expansion and an independent analysis of the seepage-related issues.
- This presentation presents the findings and recommendations relative to seepage conditions near the base of Dredge Cell III perimeter dike.


Aerial View of the Site
Blow-out Area
Cell II
Existing Dredge Cells
Cell III
Cell I
Proposed Lateral
Expansion Area

Site Reconnaissance

- GeoSyntec conducted a one-day site reconnaissance to observe and evaluate the cause of failure.



- Based on the site reconnaissance, piping and excessive seepage was hypothesized to be the triggering mechanisms for the “blow-out”.

GeoSyntec Consultants

Overview of the Approach

- The Project Team (TVA, Parsons and GeoSyntec) reviewed the findings of previous site investigation conducted at the site, in particular, for the dredge cell area to define cause of blow-out.

- Based on this review, the Project Team decided that additional investigations would be beneficial.

- A supplemental site investigation was performed to complement existing data and fill data gaps regarding the hydrogeology and stratigraphy within the dredge cell.

- Seepage analysis was used as a tool to: (i) evaluate the cause of blow-out; and (ii) develop potential remedies for both existing and future conditions for the dredge cells. (note: Project Team developed and agreed upon the model geometry and material properties; Parsons and GeoSyntec then performed independent seppage analyses.)

Sp Seepage

GeoSyntec Consultants

• Review of Previous Site Investigation •

Performed by MACTEC Engineering and Consulting, Inc.

Report Date: May 2004

Purpose:

- Evaluate subsurface stratigraphy within the footprint of existing dredge cells and proposed lateral expansion area.

Field activities performed within the Dredge cells consisted of:

- Drilling Six (6) boreholes for the characterization of subsurface stratigraphy
- Installing Three (3) piezometers within the vicinity of the failure cross section.
- Conducting six (6) Cone Penetration Test with pressure dissipation tests at selected locations within the dredge cells.
- Performing two (2) in-situ hydraulic conductivity tests.

Laboratory tests preformed on disturbed and undisturbed samples involved grain size analysis, specific gravity, Atterberg limits, permeability tests, consolidation tests, and triaxial tests.

Data Gaps Identified from Review of Site Investigation

- Review of previous site investigation indicated that:
  - Stratigraphy within the dredge cells is not well defined.
  - Water levels under existing conditions needed to be established.
  - In-situ hydraulic conductivity of construction materials and fly ash needed to be evaluated.
- Available information was not sufficient to identify the cause of blow-out and additional information was needed to perform seepage analysis with meaningful data.
- GeoSyntec recommended supplemental site investigation to be conducted within the Dredge Cells.
- The Project Team developed and agreed upon the scope of the supplemental site investigation.

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Supplemental Site Investigation

Performed by MACTEC Engineering and Consulting, Inc.

Date: January 2005

Purpose:

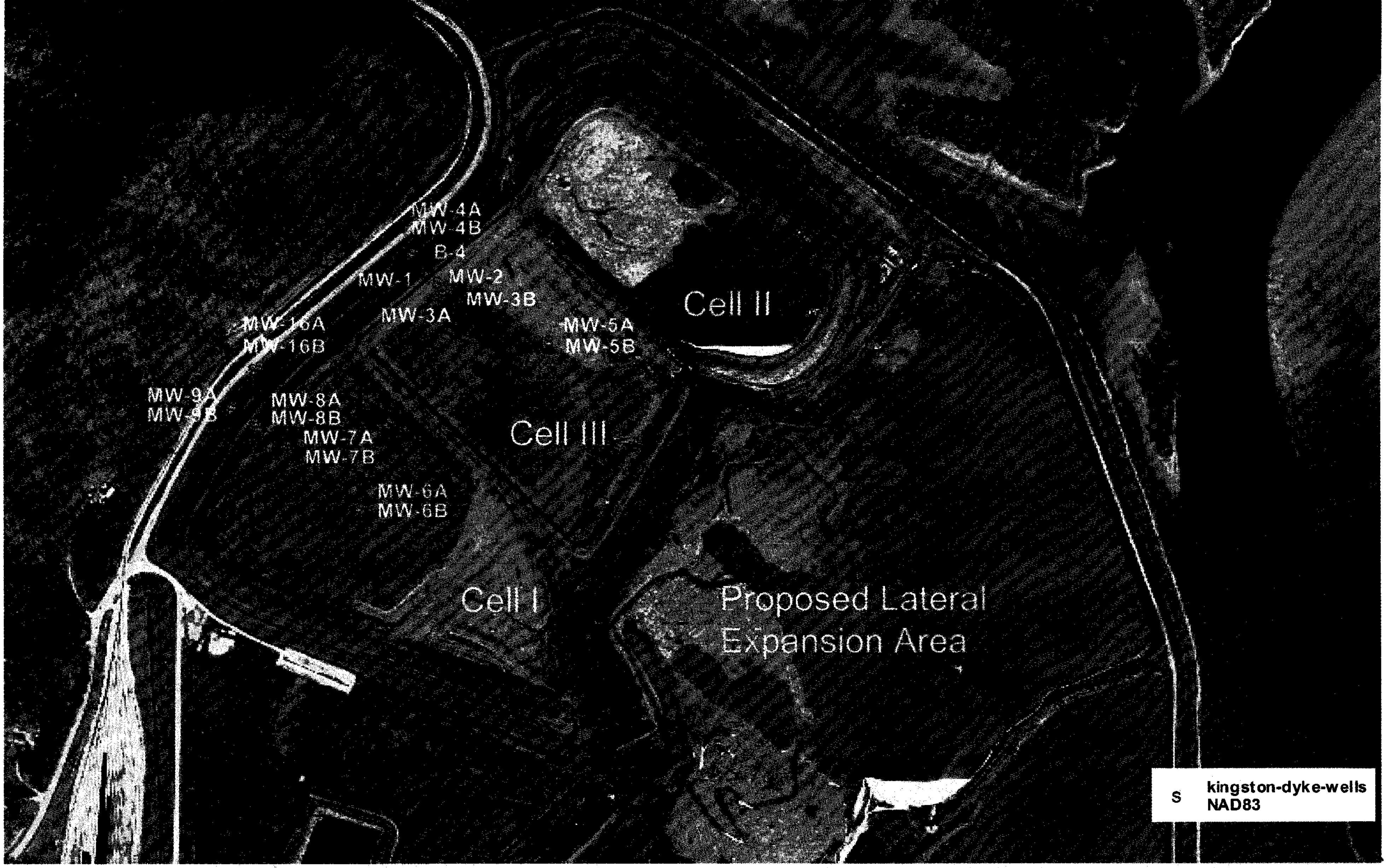
- Characterize subsurface stratigraphy within the dredge cells, in the vicinity of the blow-out area (Dredge Cell III) and in adjoining Dredge Cell I.
- Establish current groundwater elevations within the dredge cells.
- Estimate the in-situ hydraulic conductivity of subsurface materials encountered within the dredge cells

Field activities performed as part of this investigation consisted of:

- Drilling of seven (7) boreholes
- Installation of additional 13 piezometers within the dredge cells
- Performing in-situ hydraulic conductivity tests (13 slug tests, and 3 constant rate pumping test).

Laboratory tests preformed on samples included grain size analysis, Atterberg limits, natural moisture content, specific gravity.

Supplemental Site Investigation (cont.)
Piezometer Locations



Supplemental Site Investigation (cont.)
Summary of Results

- Findings of the supplemental site investigation revealed that subsurface stratigraphy within dredge cells is a complex layered system with subtle but important hydraulic conductivity differences. The stratigraphy consists of mainly (from top to bottom) fly ash, alluvium, and bedrock. Other subsurface layers encountered within the dredge cells include clay, shale and fly ash/bottom ash mixture (outer dike material).

- Groundwater measurements were used to estimate the phreatic surface and pore water pressures at key points along the section used for analysis.

- In-situ hydraulic conductivities for subsurface materials were estimated to be:

Fly ash	From 1.14×10^{-6} to 5.96×10^{-5}
Fly ash/Bottom ash	From 1.29×10^{-4} to 1.56×10^{-4}
Bottom ash	From 1.21×10^{-5} to 1.32×10^{-3}
Alluvium	From 1.29×10^{-4}

JS

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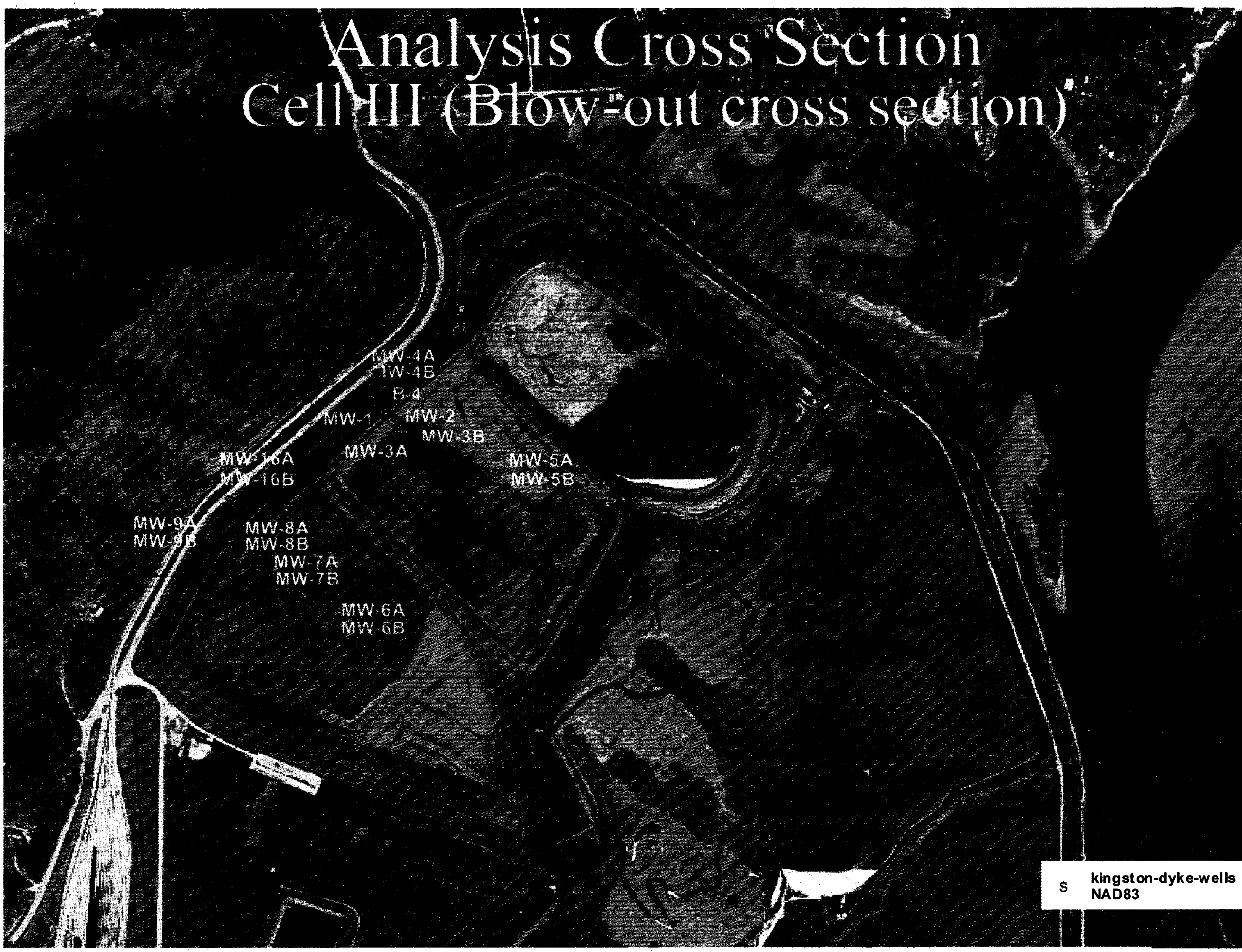
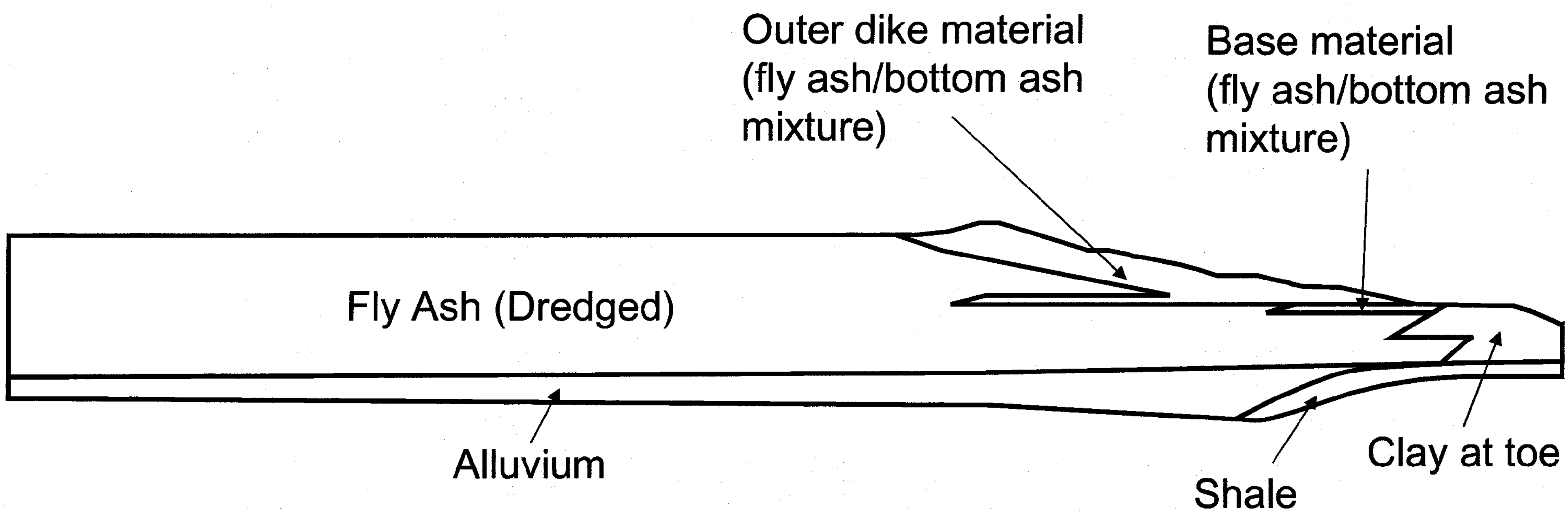
Seepage Analysis

- Parsons performed seepage analysis using TIMES Software.
- To validate the TIMES analytical results, GeoSyntec performed independent seepage analysis using SEEP/W® software.
- SEEP/W® is a finite element program that can be used to model flow of water in saturated and unsaturated zones under steady and unsteady state conditions.
- The remaining slides provide information on analysis cross section, analyses cases, input parameters, and sample output of SEEP/W results.
- For the sake of comparison, excerpts of TIMES graphical output, provided by Parsons, are also presented.


Analysis Cross Section
Cell III (Blow-out cross section)
MW-4A
MW-4B
B-4
MW-1
MW-2
MW-3B
MW-3A
MW-16A
MW-16B
MW-5A
MW-5B
MW-9A
MW-9B
MW-8A
MW-8B
MW-7A
MW-7B
MW-6A
MW-6B
S kingston-dyke-wells
NAD83

Model Stratigraphy and Existing Geometry



- Vertical and horizontal extent of subsurface stratigraphy were estimated based on visual field identification, SPT data, knowledge of the likely construction sequence, and in-situ hydraulic conductivity obtained during the January 2005 site investigation.
- Model geometry and subsurface stratigraphy were agreed on by the Project Team during the meeting that took place on 31st January 2005.

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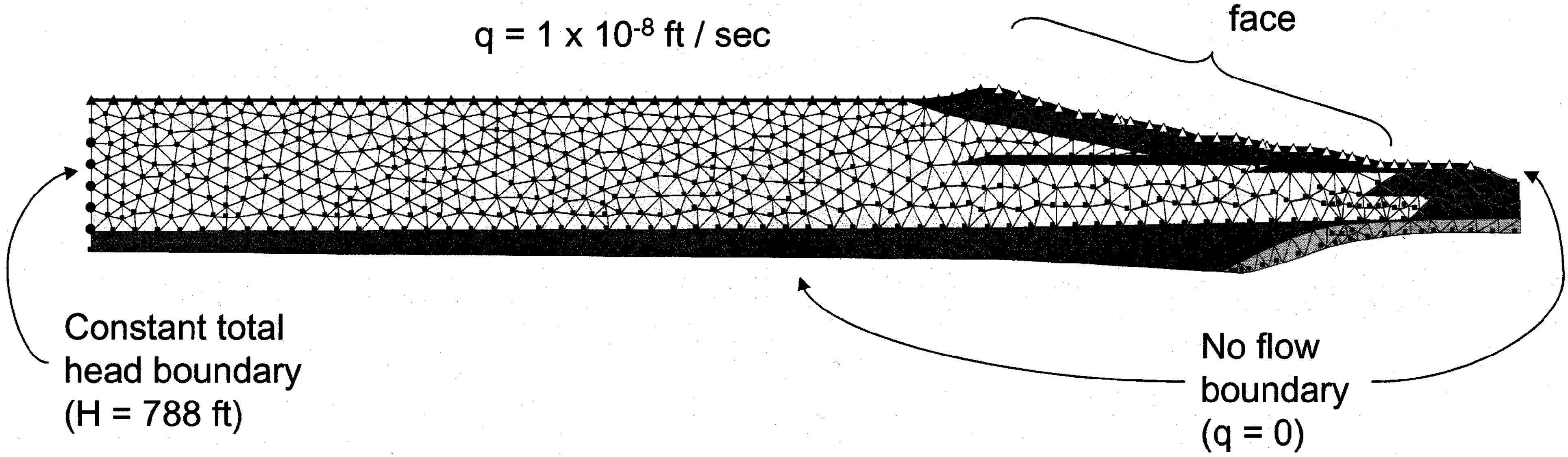
Case 1 (Existing Condition)

Mesh and Boundary Conditions



- The total head value assigned along the constant head boundary (left-hand side boundary) is the average total head recorded in piezometer MW-5A and MW-5B.
- The bottom boundary of the model was considered the top of the competent and impervious bedrock; therefore, no flow was assumed along this boundary.
- A no flow boundary was assumed along the model's right-hand side boundary.
- Infiltration, q, on the top and sideslope of the dredge cell represent the portion of rainfall that is anticipated to infiltrate into the cell. This portion is mainly rainfall minus runoff, evaporation and evapotranspiration. HELP model performed indicated that this portion is approximately 7 percent of total rainfall.

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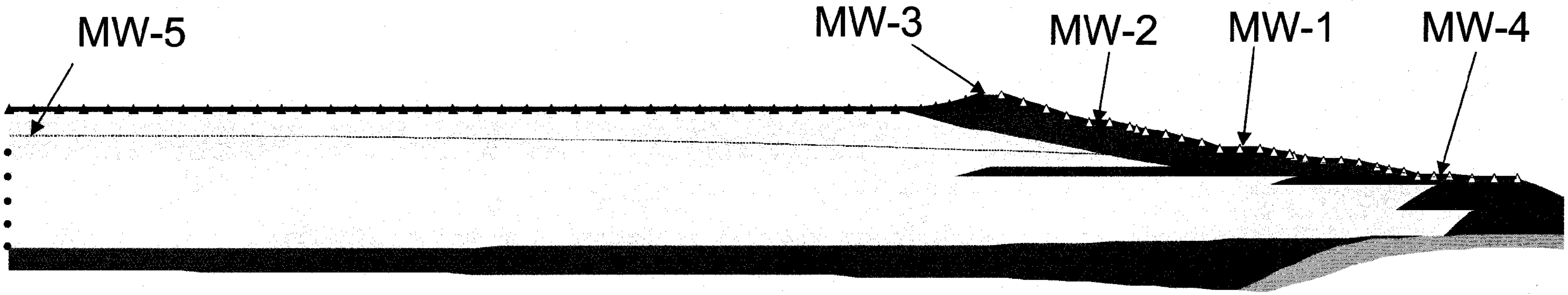
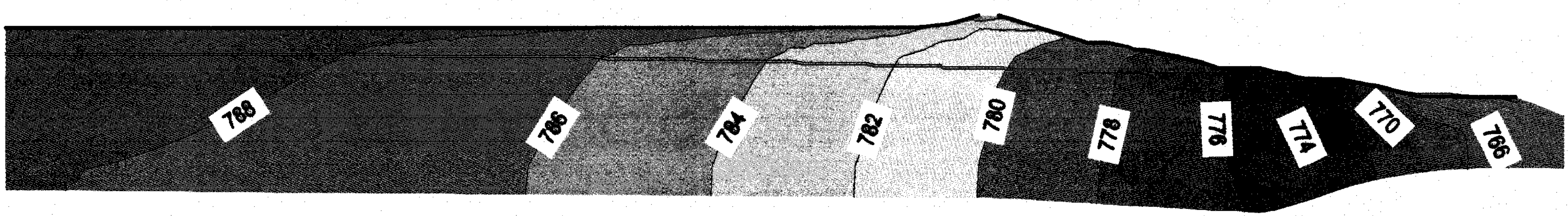
Case 1 (Existing condition)
SEEP/W Output Summary

- Model-predicted Phreatic Surface



- Model-predicted Total Head Distribution (equipotential lines)



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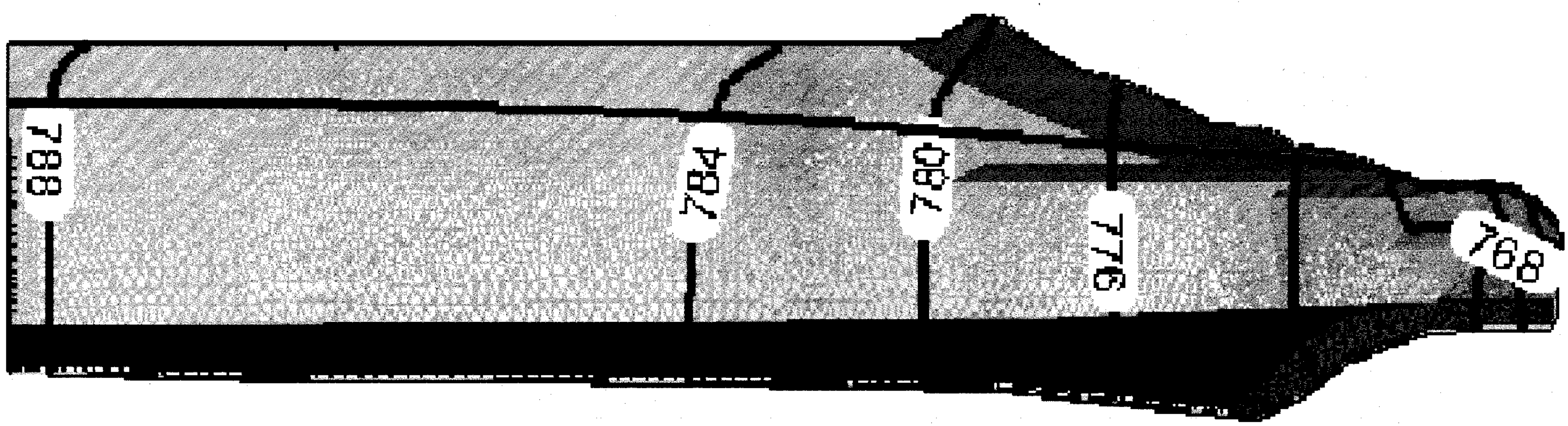
Case 1 (Existing condition)
TIMES Output



Note: Please note that the above figure has Vertical exaggeration

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Case 1 (Existing condition)

SEEP/W Output Summary (Cont.)

Comparison Table of Total Heads

Well ID	Field-measured Total Head[1] at screen interval A [2] (ft, MSL)	Model-predicted Total Head[1] at screen interval A [2] (ft, MSL)	Field-measured Total Head[1] at screen interval B [2] (ft, MSL)	Model-predicted Total Head[1] at screen interval B [2] (ft, MSL)
MW-1	774.1	775.42	N/A	N/A
MW-2	777.1	778.24	N/A	N/A
MW-3	780.6	780.32	772.9	779.84
MW-4	765.6	766.16	761.8	768.94
MW-5	786.5	788.06	789.70	788.02

Notes:

(1) Field–measured total head correspond to water levels elevations recorded on 21 January 2005.

(2) For piezometer locations with two screen intervals, ‘A‘ represent screen interval at a shallow depth and ‘B’ represent screen interval at a deep depth.

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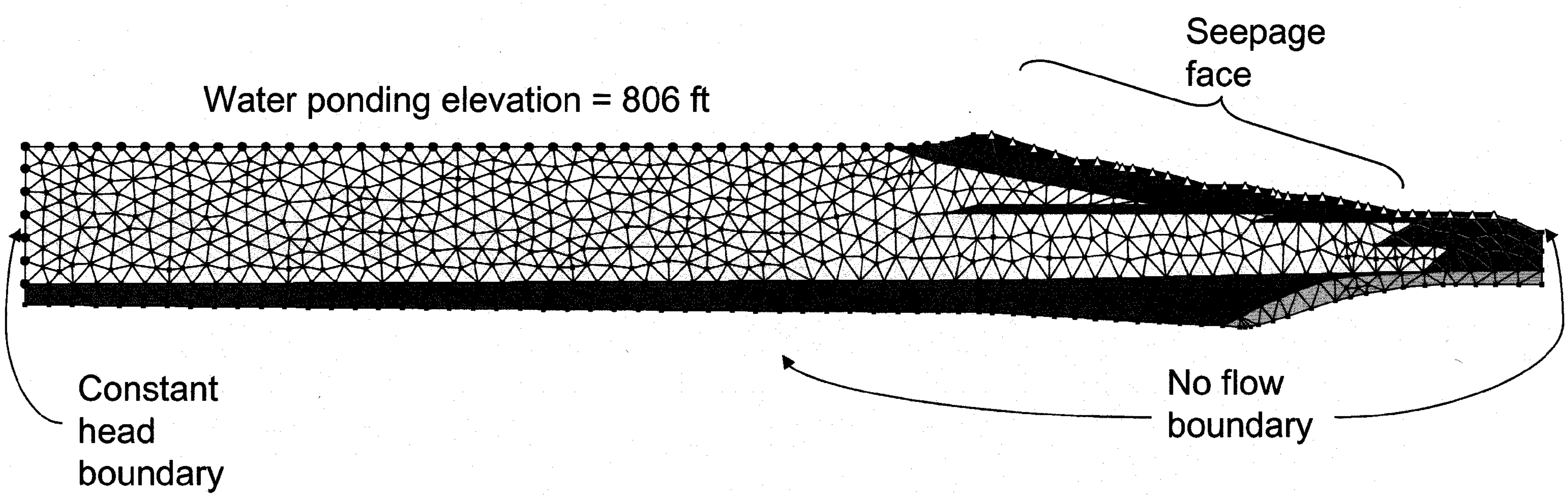
Observations and Conclusions

- Analytical results of Case 1 are in close agreement with total head measurements recorded in the field during the January 2005 site investigation.
- This analysis provides a good calibration for model input parameters (e.g., hydraulic conductivity). Close agreement between model-predicted and field observations provides an appropriate level of confidence in input parameters used.
- Input parameters specified in this analysis (i.e., material properties) were therefore used in subsequent analyses cases.

Case 2 (Blow-out condition)

Mesh and Boundary Conditions



Information regarding the depth of water in the dredge cells at the time of blow-out was estimated based on field observations and was provided by TVA personnel during the January 2005 meeting. Water depth in the dredge cell was observed to be 4 feet below the elevation of the top dike (i.e., elevation 810 ft MSL).

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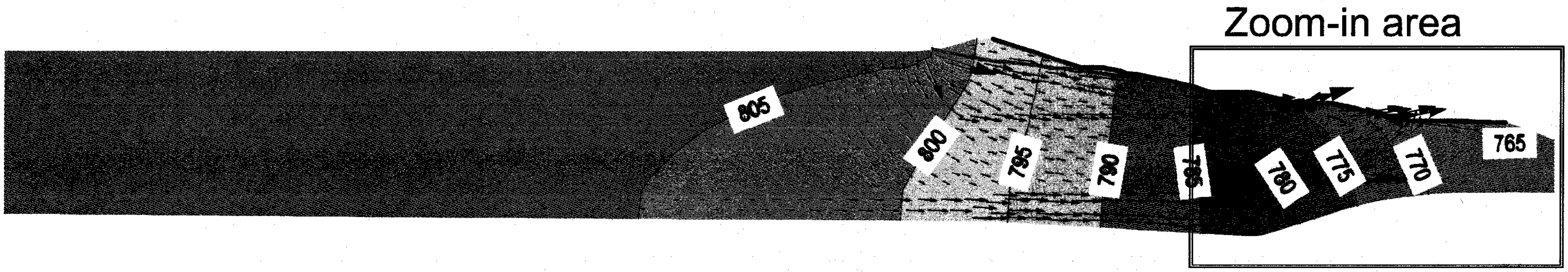
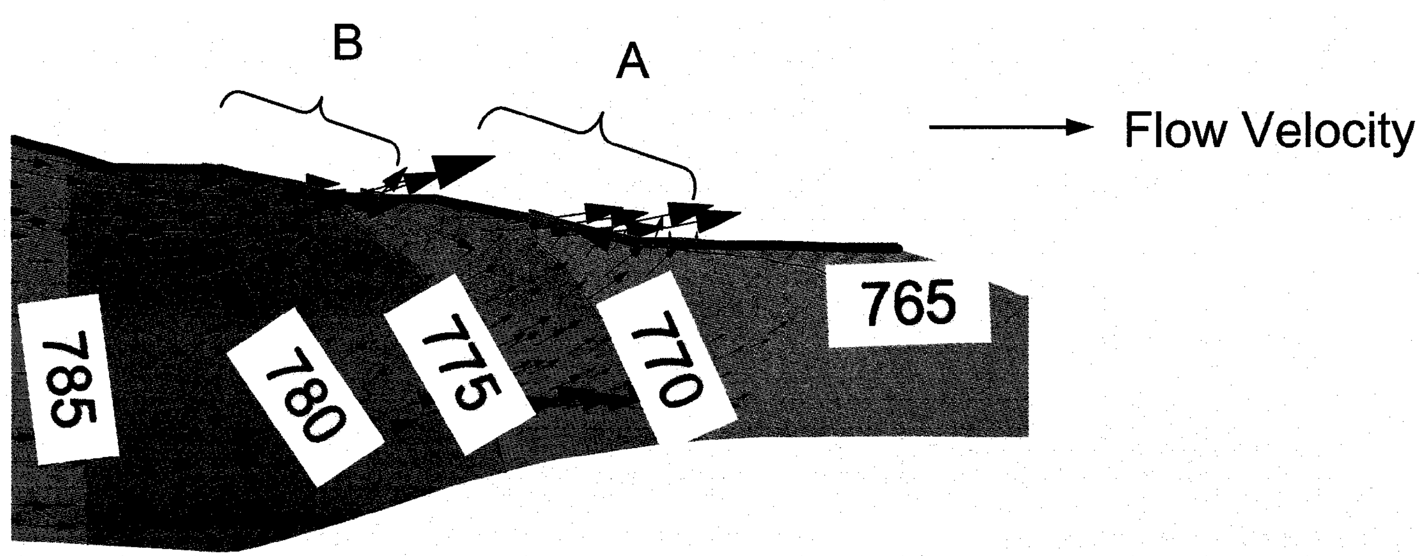
Case 2 (Blow-out condition)
SEEP/W Output Summary

Model-predicted Total Head Distribution (equipotential lines)





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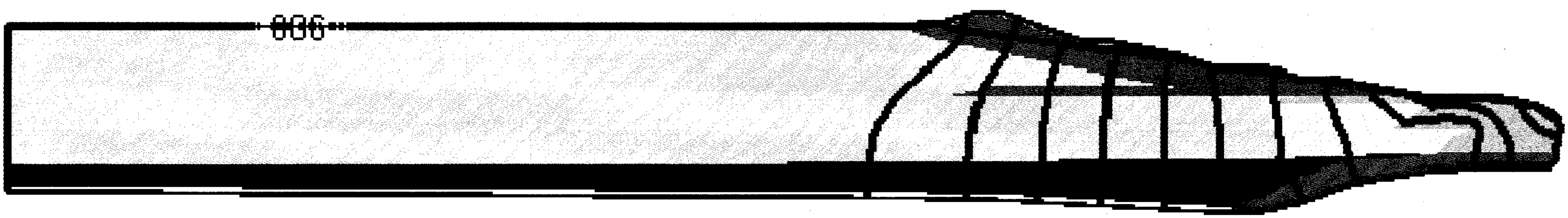
Case 2 (Blow-out condition)
TIMES Output



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Case 2 (Blow-out condition)
SEEP/W Output Summary (cont.)

Model-predicted Exit Hydraulic Gradients

	Model-predicted Hydraulic Gradient, i	Critical Hydraulic Gradient, i_c	Piping will occur? (Y/N)	Factor of safety against piping F.S. = i_c / i
Slope face A	**0.25 – 0.31**	**0.28**	**Y**	**0.90 – 1.12**
Slope face B	**0.14 - 0.25**	**0.28**	**N**	**1.12 – 2.00**
Base of slope	**0.21-0.24**	**0.28**	**N**	**1.17 -- 1.33**

Critical hydraulic gradient = $i_c = \gamma_{sub} / \gamma_w$

Where: γ_{sub} = submerged unit weight of fly ash; and γ_w = unit weight of water

Considering the unit weight of fly ash to be 80 pcf, the critical hydraulic gradient = (80-62.4)/62.4 = 0.28.

Acceptable factor of safety against piping is 1.50.

Case 2 (Blow-out condition)
SEEP/W Output Summary (cont.)

Model-predicted Flow Rates

	Flow rate	
	(ft^3/day/ft)	gpd/ft
Slope face A	**0.85**	**6.36**
Slope face B	**0.57**	**3.63**

Observations

- The computed hydraulic gradient at the lower portions along exit face 'A' is greater than the critical hydraulic gradient, confirming the likelihood that piping and blow-out will occur consistent with that observed in field.

- Model-predicted location of blow-out (i.e., exit face 'A') coincides with blow-out location observed in the field (i.e., at elevation 766 ft MSL).

- Qualitative assessment of analysis results performed for blow-out condition (Case 2) are consistent with visual observations reported in the field (e.g. wet spots on slope, vegetation on downstream slope and estimated quantity of seepage through the blow-out area).

Case 3 (Future conditions)

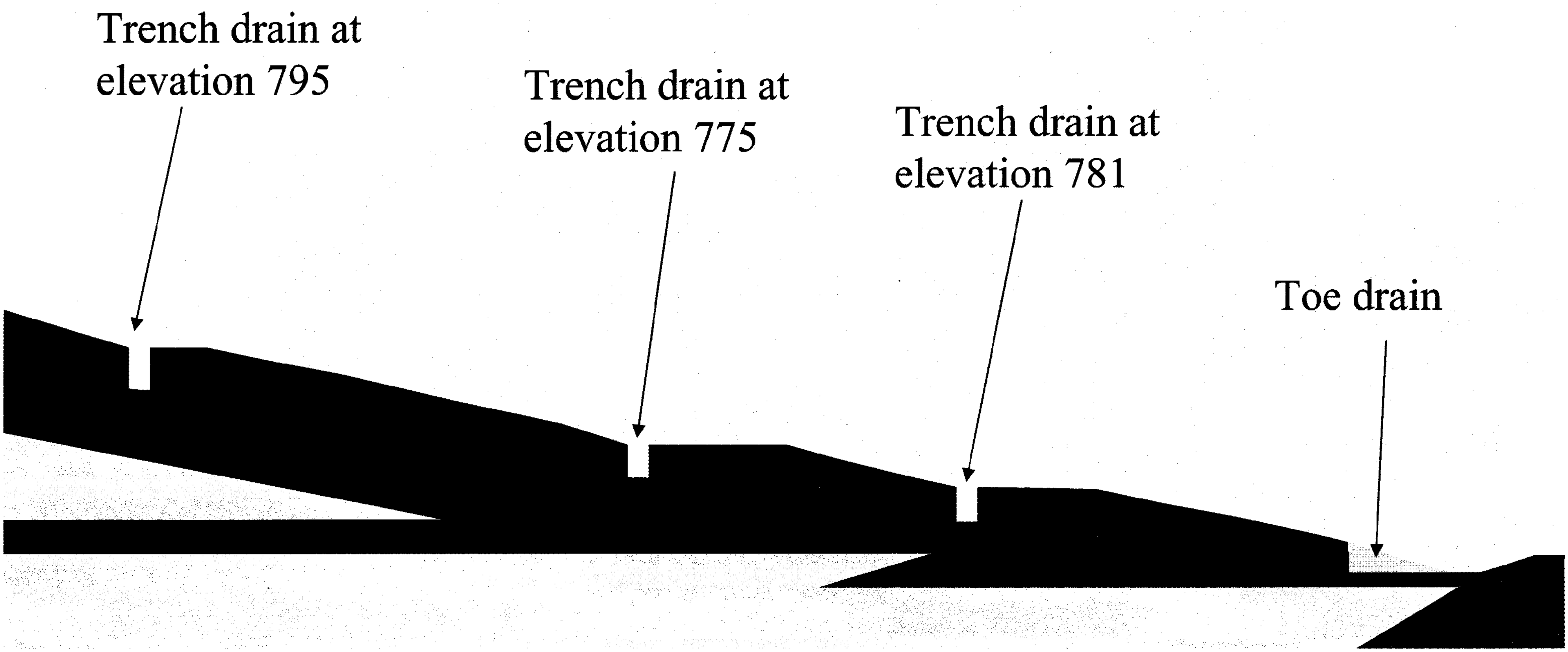
- As indicated from the analytical results of Case 2 (blow-out condition), blow-out resulted from the development of internal pore water pressure on the face of the slope that caused piping to occur that led eventually to excessive seepage.

- To prevent further piping action and to maintain the stability of the outer slopes, several improvement features need to be incorporated in the future design.

- The design ~~of the proposed vertical and lateral expansion~~ prepared by Parsons will incorporate a series of underdrains located at successive elevations within the outer dike. ~~Notwithstanding these measures, additional measures are needed to assure long-term stability of the lower portion of the side slopes.~~

- The Project Team have considered several improvement options. These options were evaluated on the basis of: (i) effectiveness to reduce pore pressure at the downstream slope; and (ii) ability to reliably construct/implement.

Proposed Improvement



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Case 3 (Future conditions)

Proposed Improvement

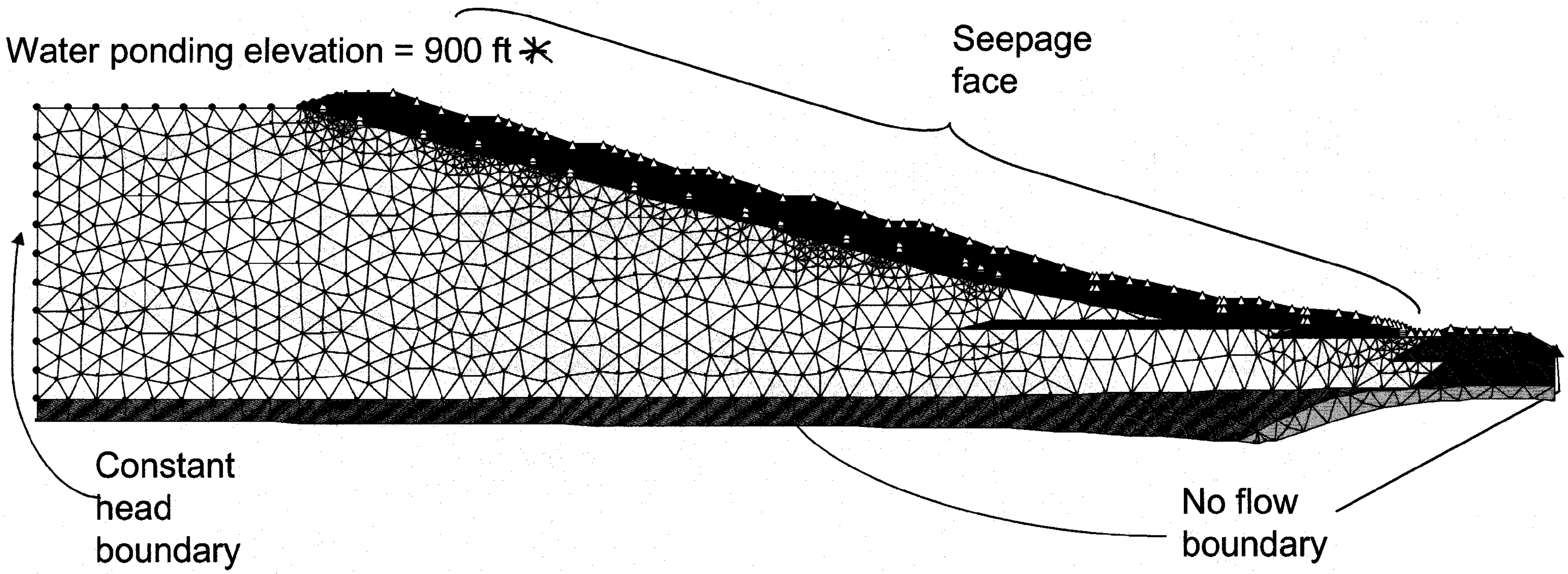
The proposed improvements for the lower portion of the dredge cell side slope consists of the following major items:

- A trench drain constructed to a minimum depth of 6 feet deep from the existing bench at EL 795 feet
- A trench drain constructed to a minimum depth of 5 feet deep from the existing bench at EL 781 feet
- A trench drain constructed to a minimum depth of 5 feet deep from the existing bench at EL 775 feet
- A buttress type toe drain pipe with minimum rip rap lining to the existing drainage channel adjacent to Swan Pond Road.

All trench drains have an assumed width of 3.0 feet.

Case 3 (Future condition)

Mesh and Boundary Conditions



* SPECULATIVE ELEVATION

ONLY PROPOSING TO RETURN TO THE PERMITTED DREDGE CELL ELEVATION OF 841/842. (CONSERVATIVE)

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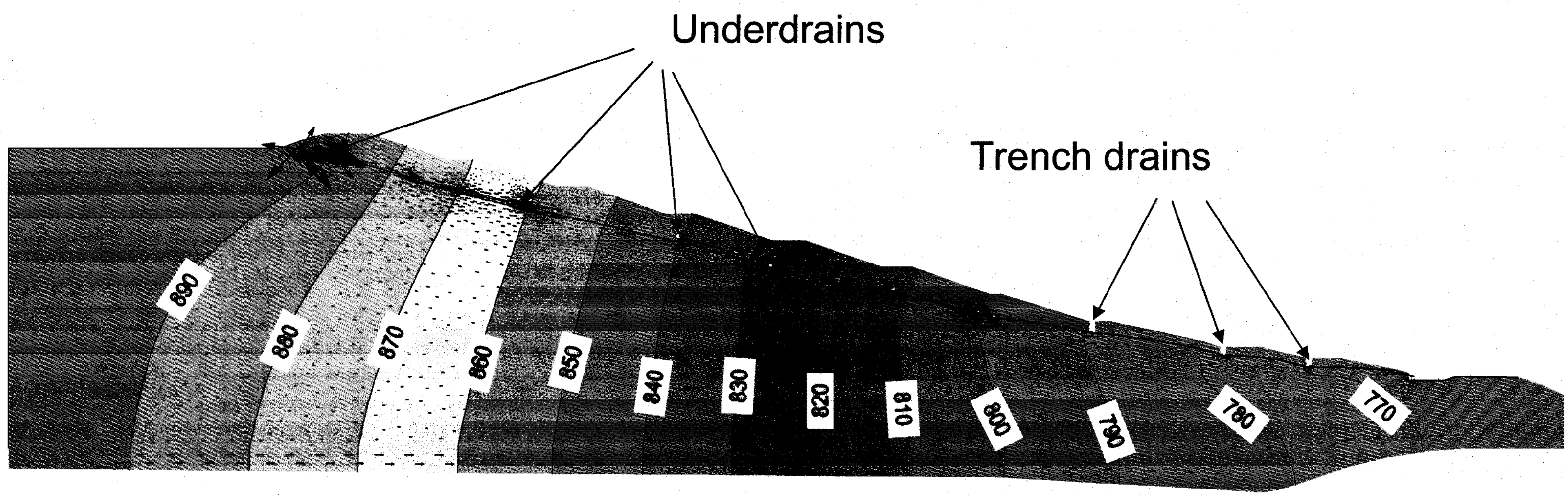
Case 3 (Future condition)

Mesh and Boundary Conditions (cont.)

- Dredge cell configuration under future condition (i.e., Case 3) represents the point in time after which operations in the cell will switch from wet disposal to dry disposal of fly ash.
- Change in disposal operations will take place when the dredge cell disposal area becomes considerably small resulting in a short disposal life.
- Future dredge cell configuration and underdrain locations presented in the previous slide are considered approximate. Configuration for Case 3 based on design drawings shall be considered in the final seepage analysis. (CONDUCTED BY PARSONS)
- Water depth in the dredge cell was assumed to be 2.0 feet below the elevation of the top dike (i.e., elevation 902 ft MSL).

Case 3 (Future condition)
SEEP/W Output Summary

Model-predicted Total Head Distribution (equipotential lines)



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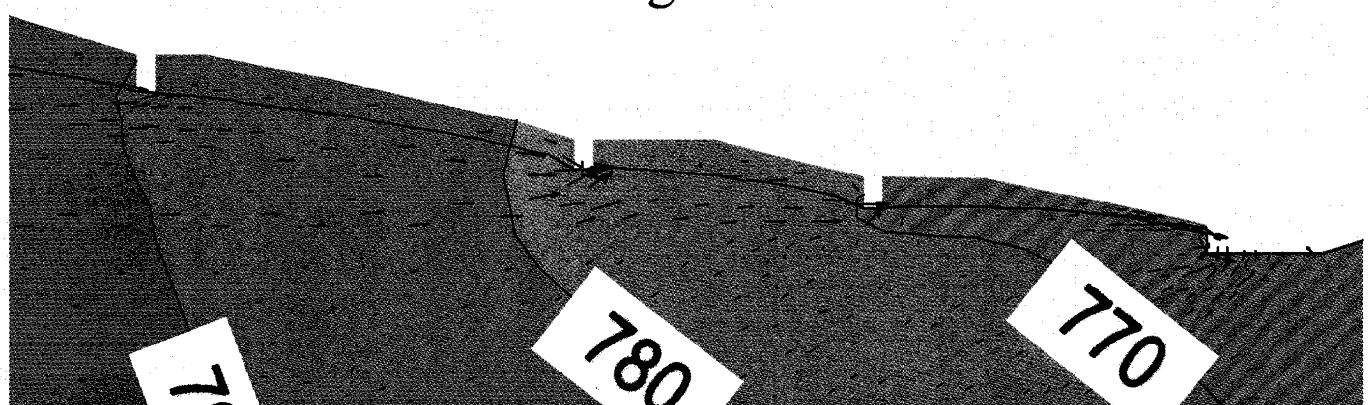
Case 3 (Future condition)
SEEP/W Output Summary (cont.)

Model-predicted Flow rates

	Elevation	Flow rate into drains	
		ft^3/day/ft	gpd/ft
Trench drain	795	0.33	2.43
Trench drain	781	0.98	7.33
Trench drain	775	0.90	6.74
Toe Drain		0.68	5.08

Flow rates estimated from the analytical model are used for trench drain design and perimeter ditch cross section design.



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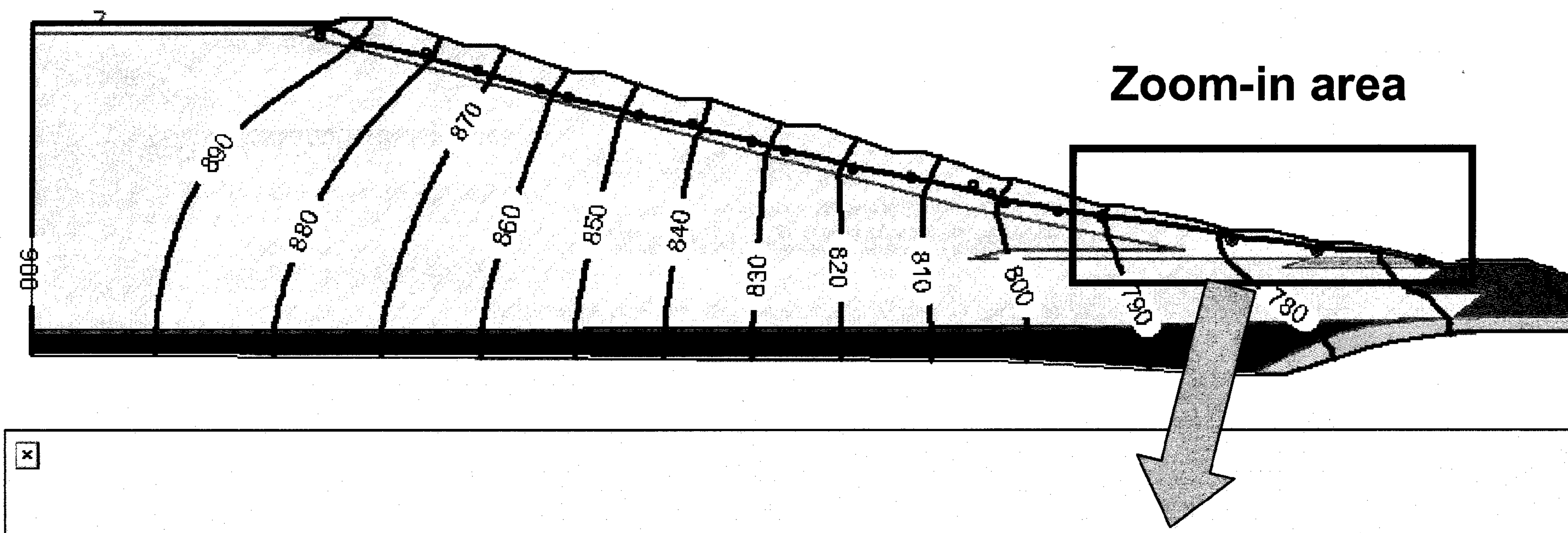
Case 3 (Future condition)
TIMES Output



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Conclusions and Final Recommendations

- Based on analytical results for Case 3, the proposed improvements are expected to lower the phreatic surface away from the face of the lower portion of the side slope significantly reducing the future potential for piping and providing an acceptable factor of safety.
- An alternative to the proposed improvement include relocating the toe drain is shown in the following figure

- In addition to the seepage analyses presented herein, GeoSyntec recommends that Parsons review/re-evaluate the slope stability analysis to assess the factor of safety against global stability under future conditions.
- The independent seepage analyses prepared by GeoSyntec are in general agreement with the analyses prepared by Parsons.

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