Analysis to Support Proposed Dredge Cell Repair

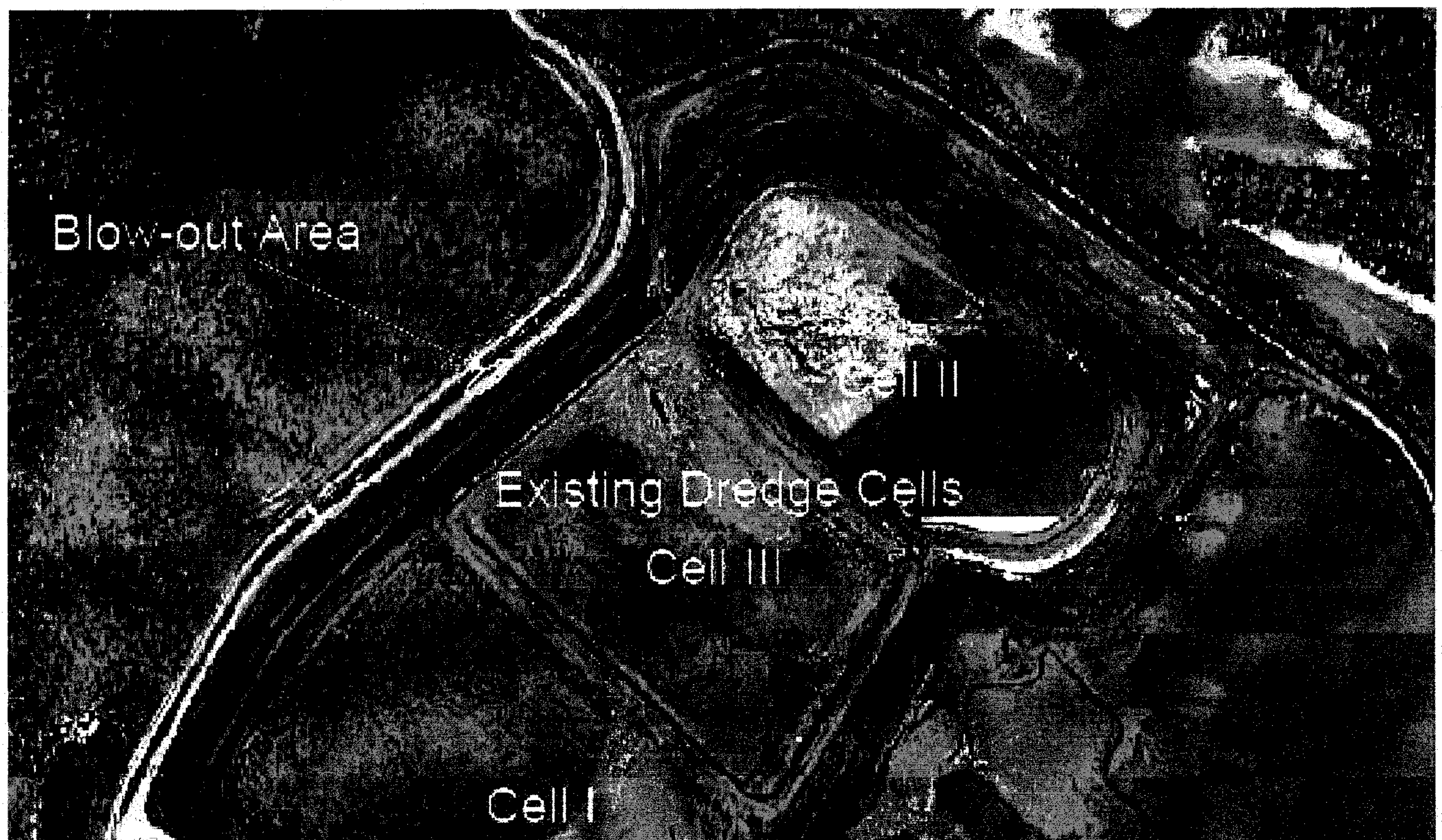
Prepared For Tennessee Valley Authority
Kingston Fossil Plant

PREPARED BY PARSONS E & C
April 2005

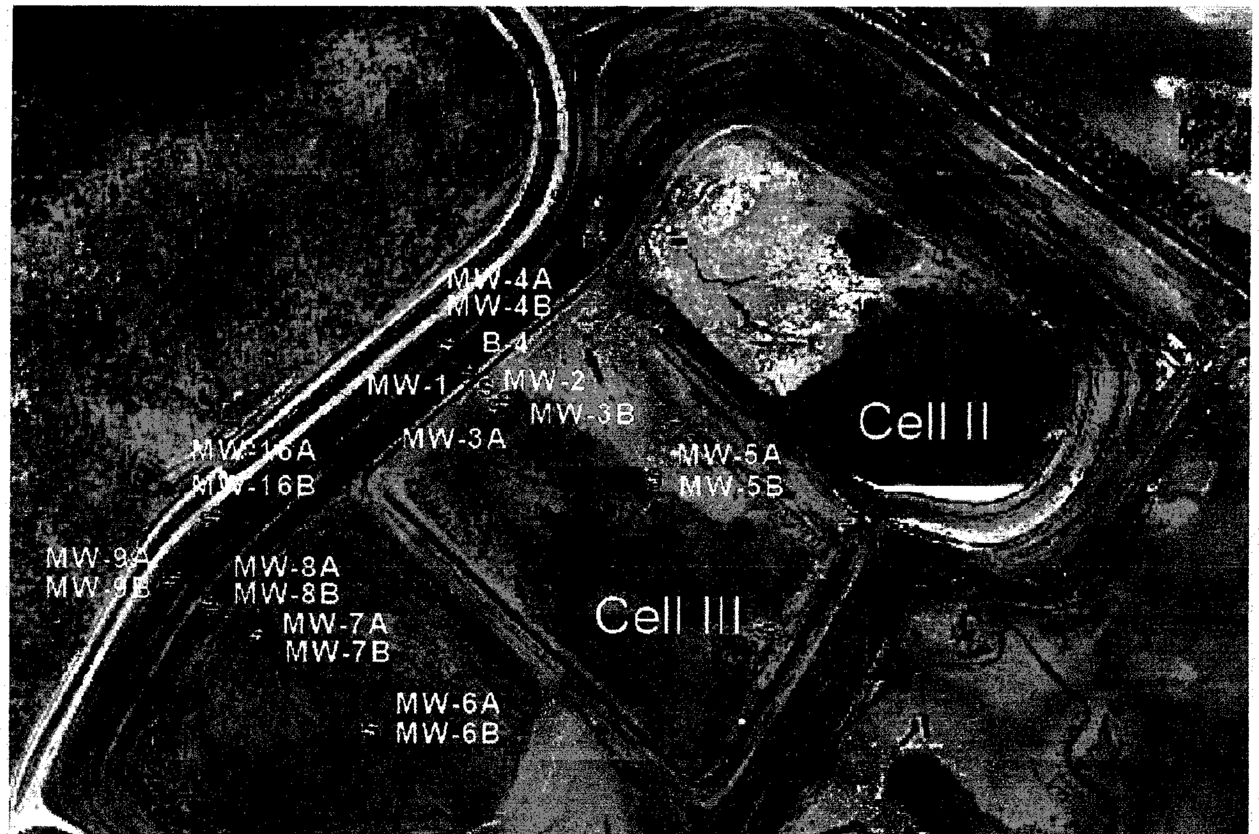
Outline of Presentation

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

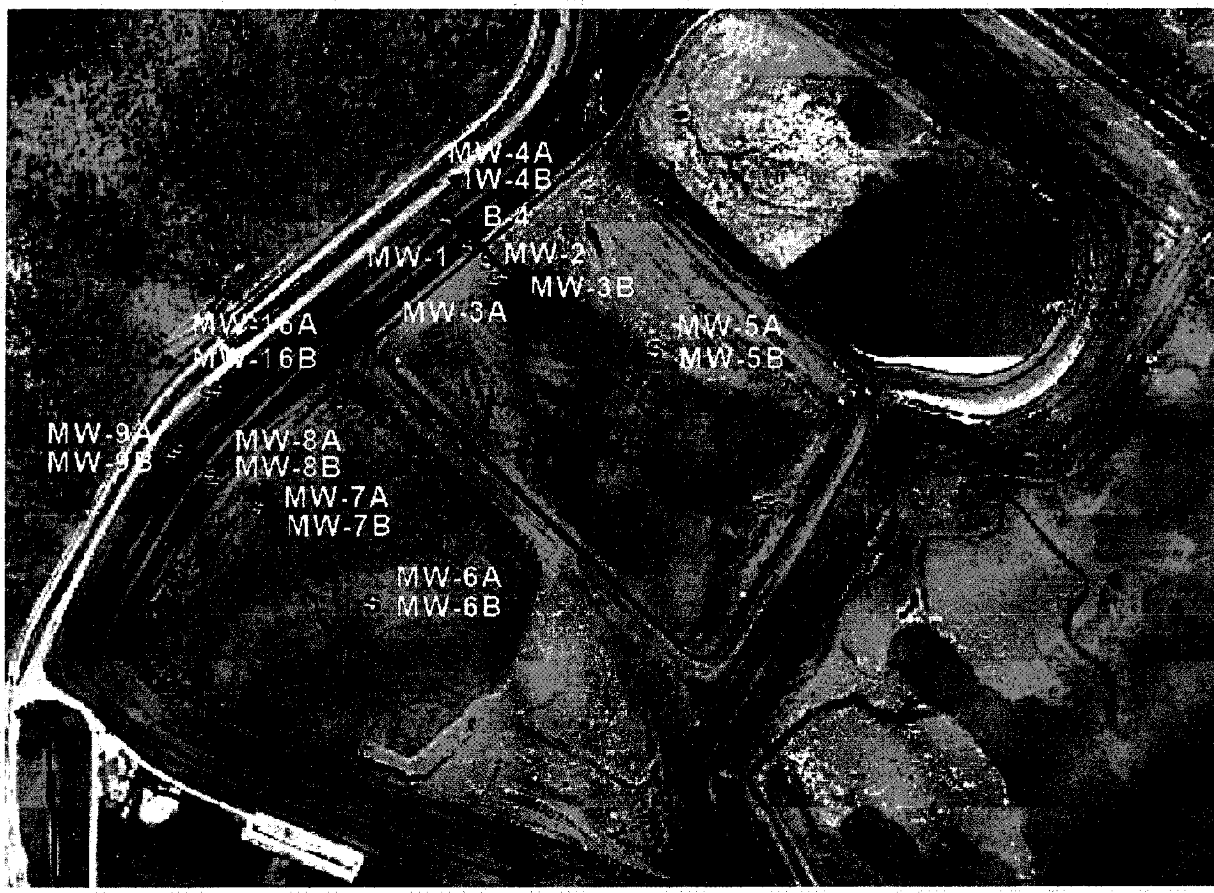
Site and Blow-Out Area



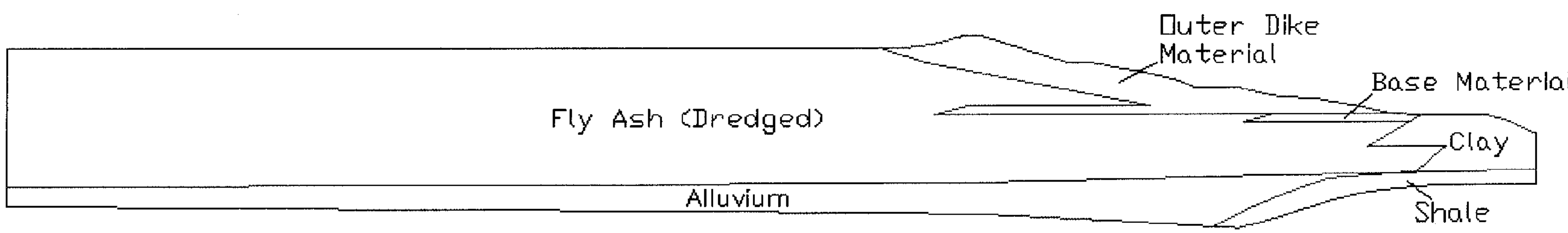
Focused Investigation Borings And Monitoring Wells



Cross Section for Cell III Analyses



Dredge Cell III Cross Section Existing Conditions



SECTION A73 - CELL III

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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

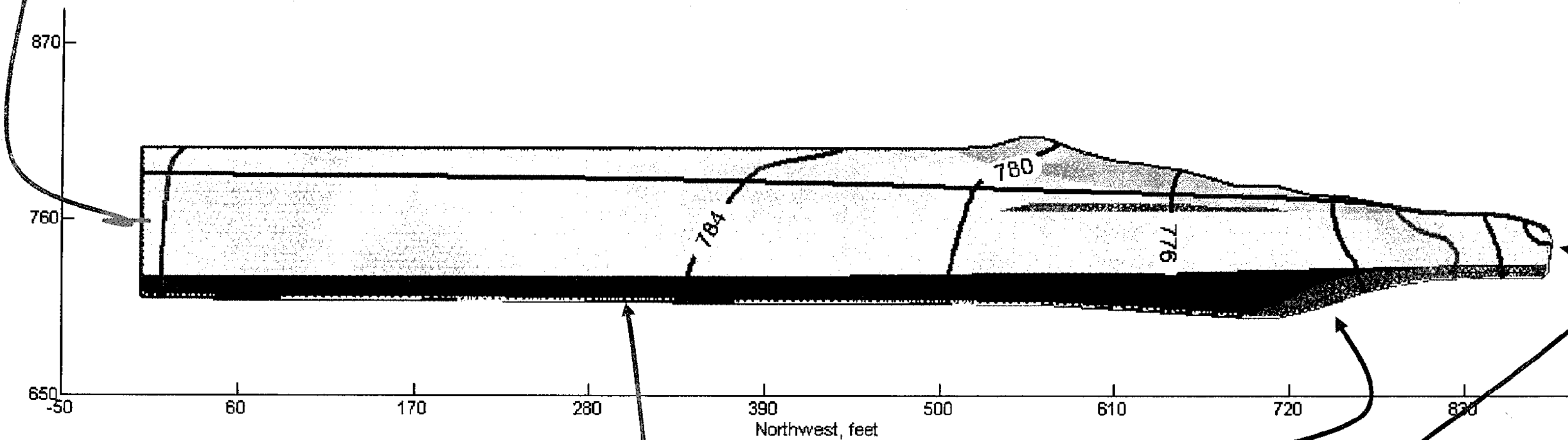
Zone	Material	Porosity	Residual Saturation	Specific Gravity	Wet Unit Weight pcf
1	Bottom Ash- Mactec (2003) Bull Run	0.589	0.104	2.37	97.6
2	Firm FA / BA Base- Mactec (2003) Bull Run	0.560	0.104	2.37	100.0
3	Fly Ash Mactec (2003) Bull Run	0.560	0.104	2.37	100.0
4	Alluvium Singleton (1994, US-9, T-1)	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

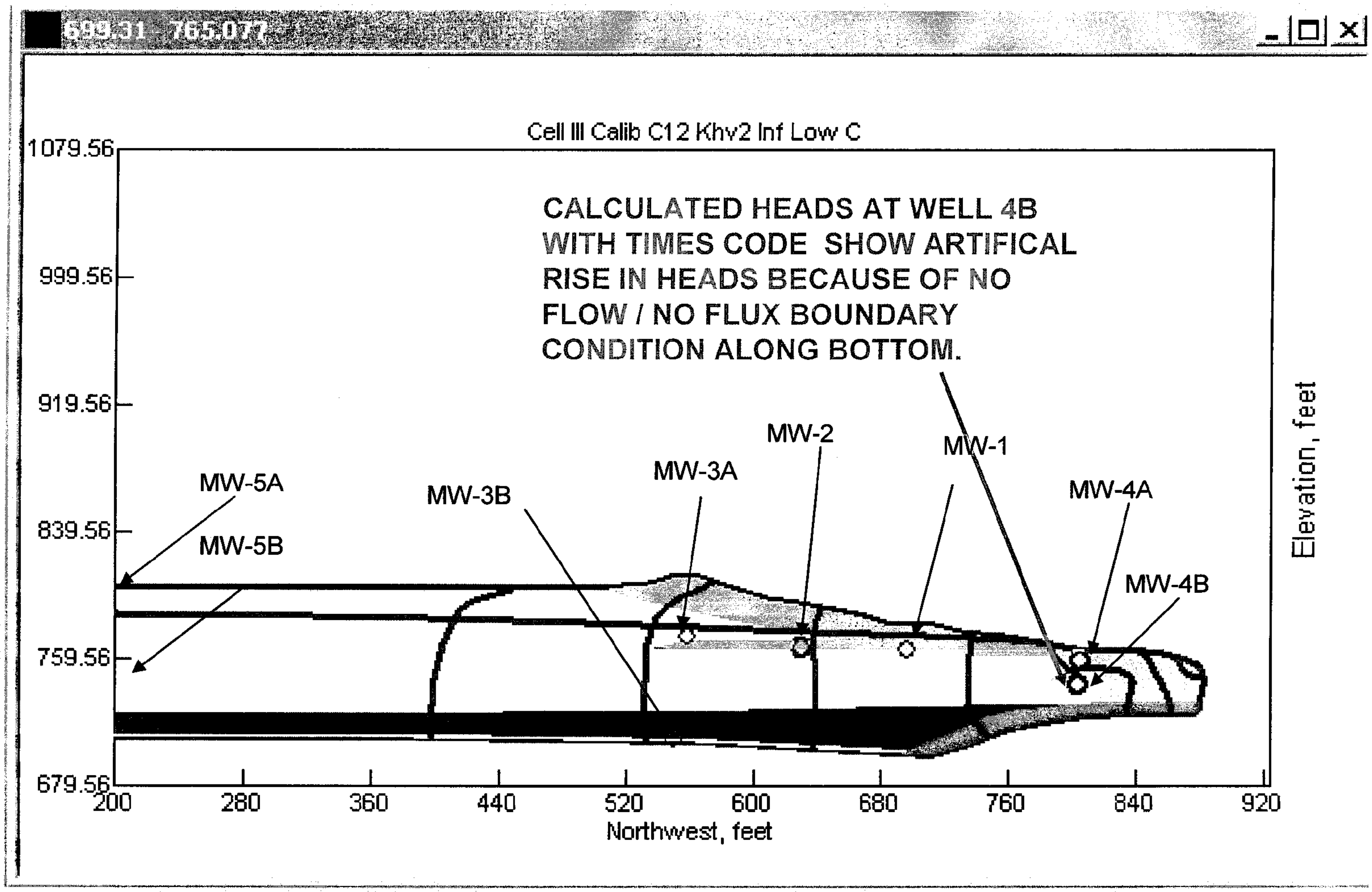
NO HEAD CHANGE PERIMETER
BOUNDARY CONDITION – DOES NOT HAVE
TO BE CONSTANT WITH ELEVATION



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

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

KINGSTON EXISTING DREDGE CELL III CASE 1 – CALIBRATION RUN



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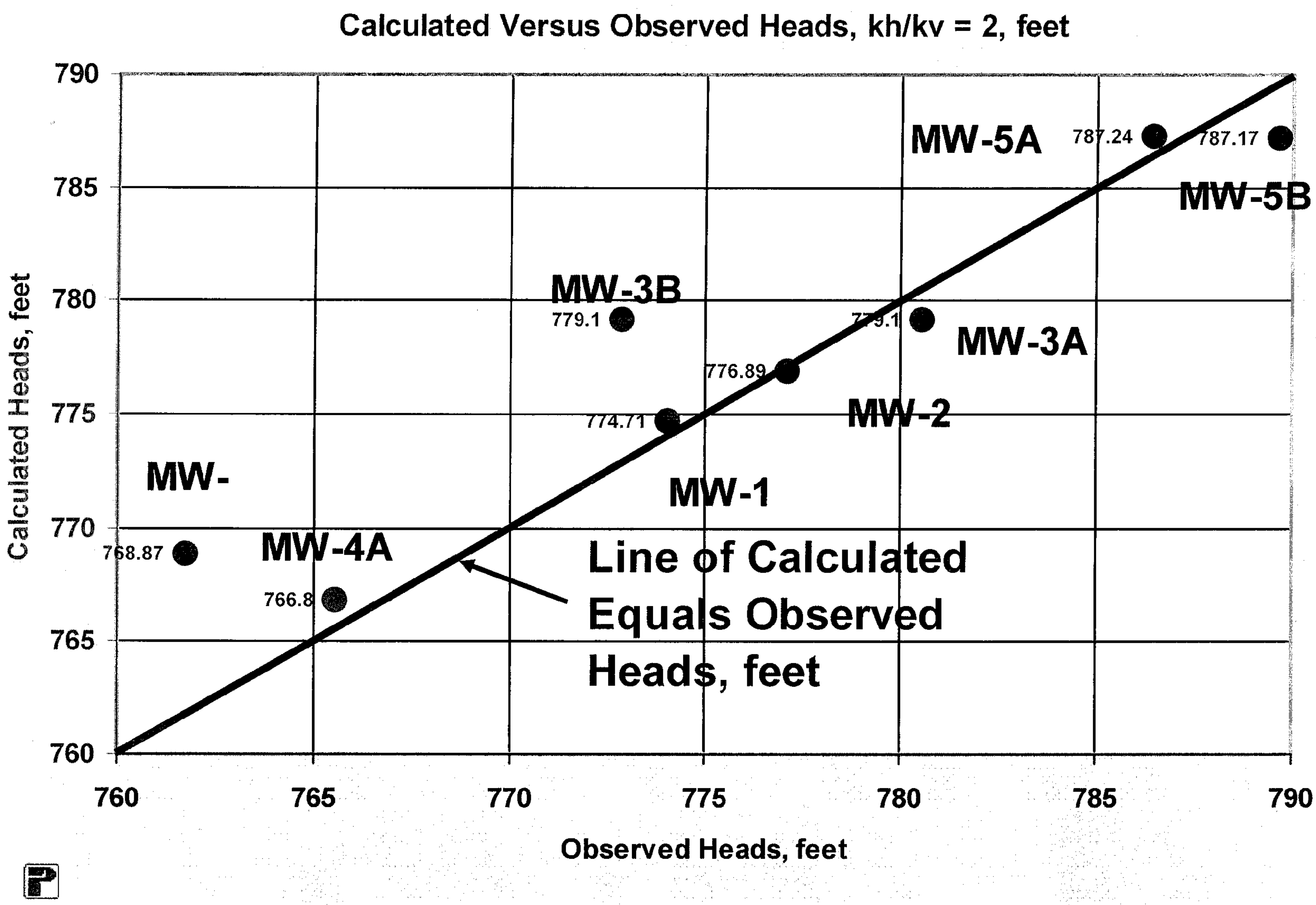

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The kh / kv = 2 for all soils gave the best calibration. The following monitoring wells show large calculated differences with the observed field heads because:

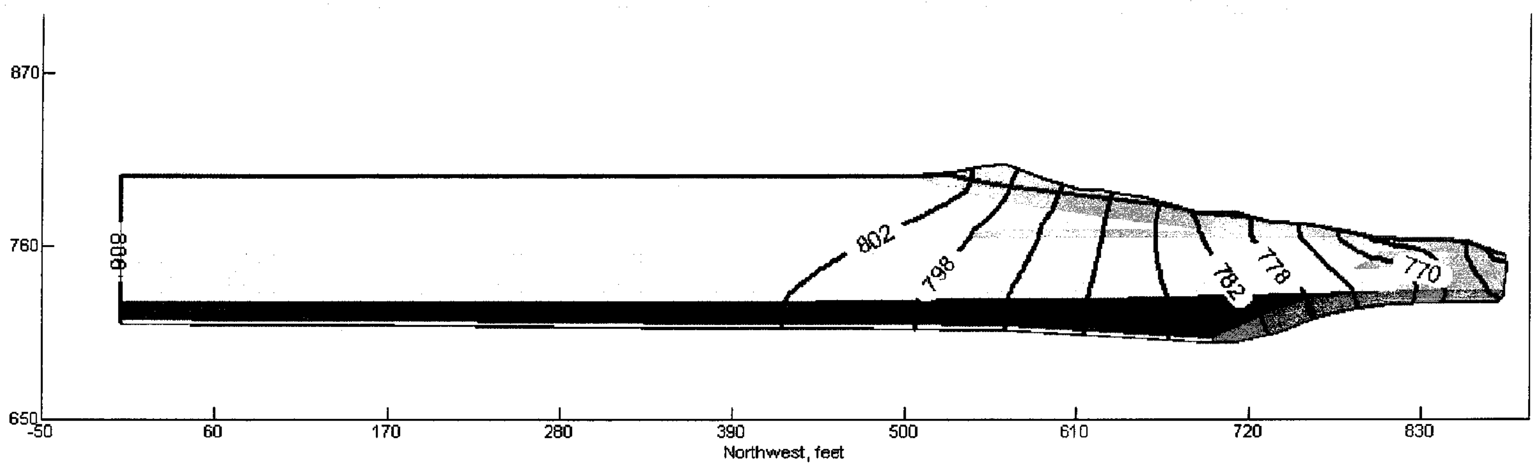
- MW – 3B measures lower heads than calculated because no flow boundary on the bottom increases heads. The downward head gradient reduces heads near the bottom in the field.
- MW - 4B measures lower heads than calculated because the no flow boundary increases the calculated heads where as the downward 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



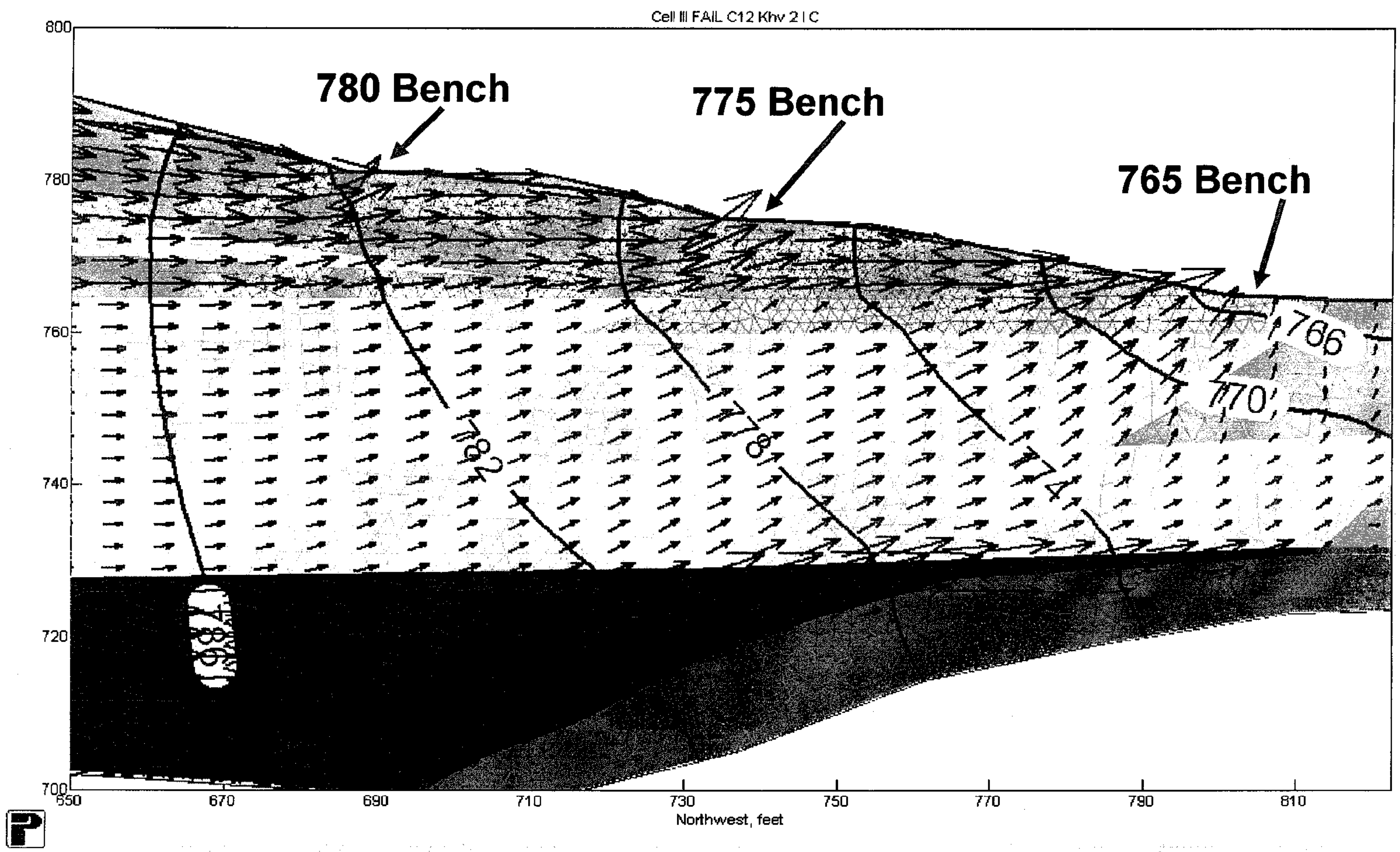
Calculated Flow Rates at Seepage Faces Along Selected Benches

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



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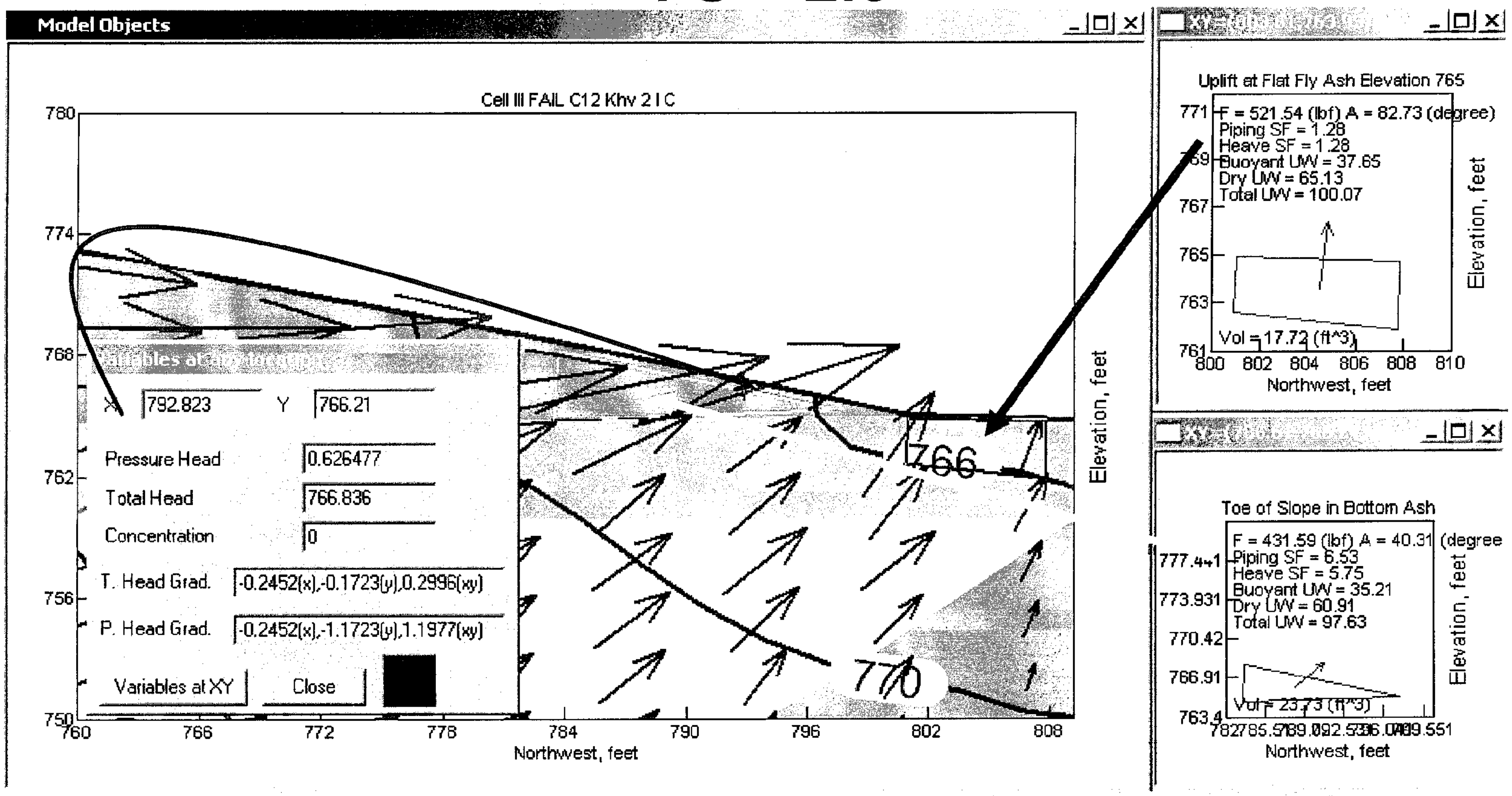
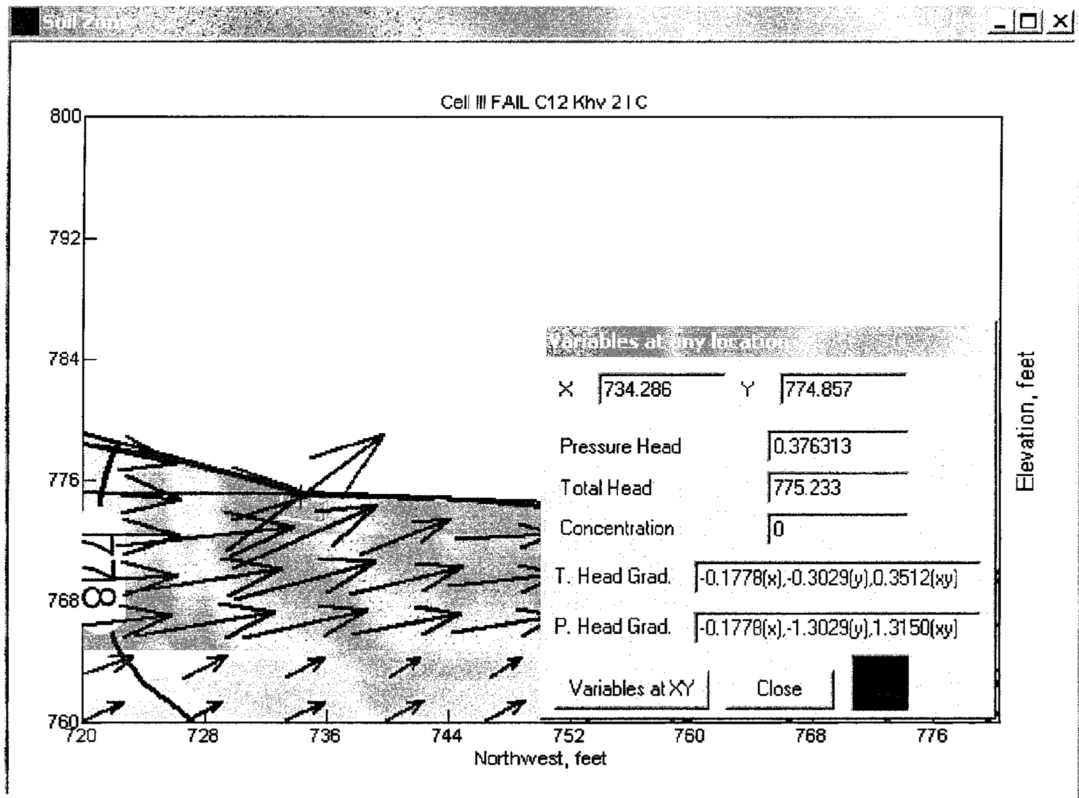
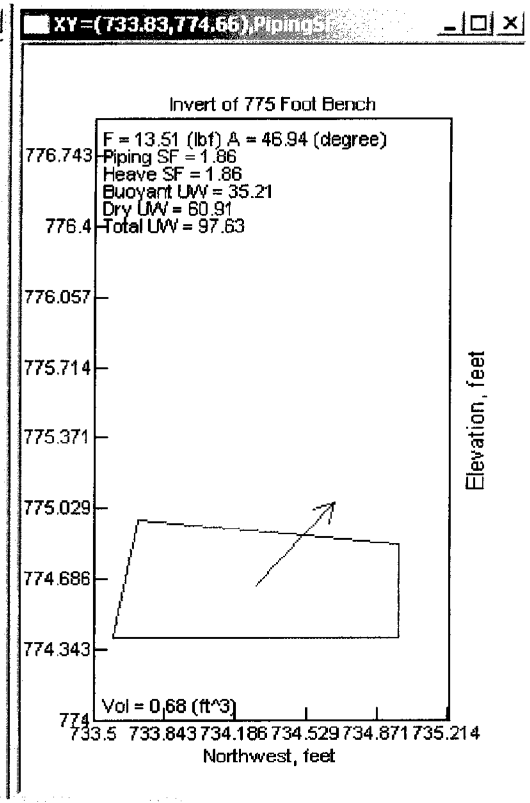
Uplift Factors of Safety at 765 ft Bench Flat in Fly Ash Fall Below 2.0 (= 1.28) – But BA Slope FS > 2.0



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





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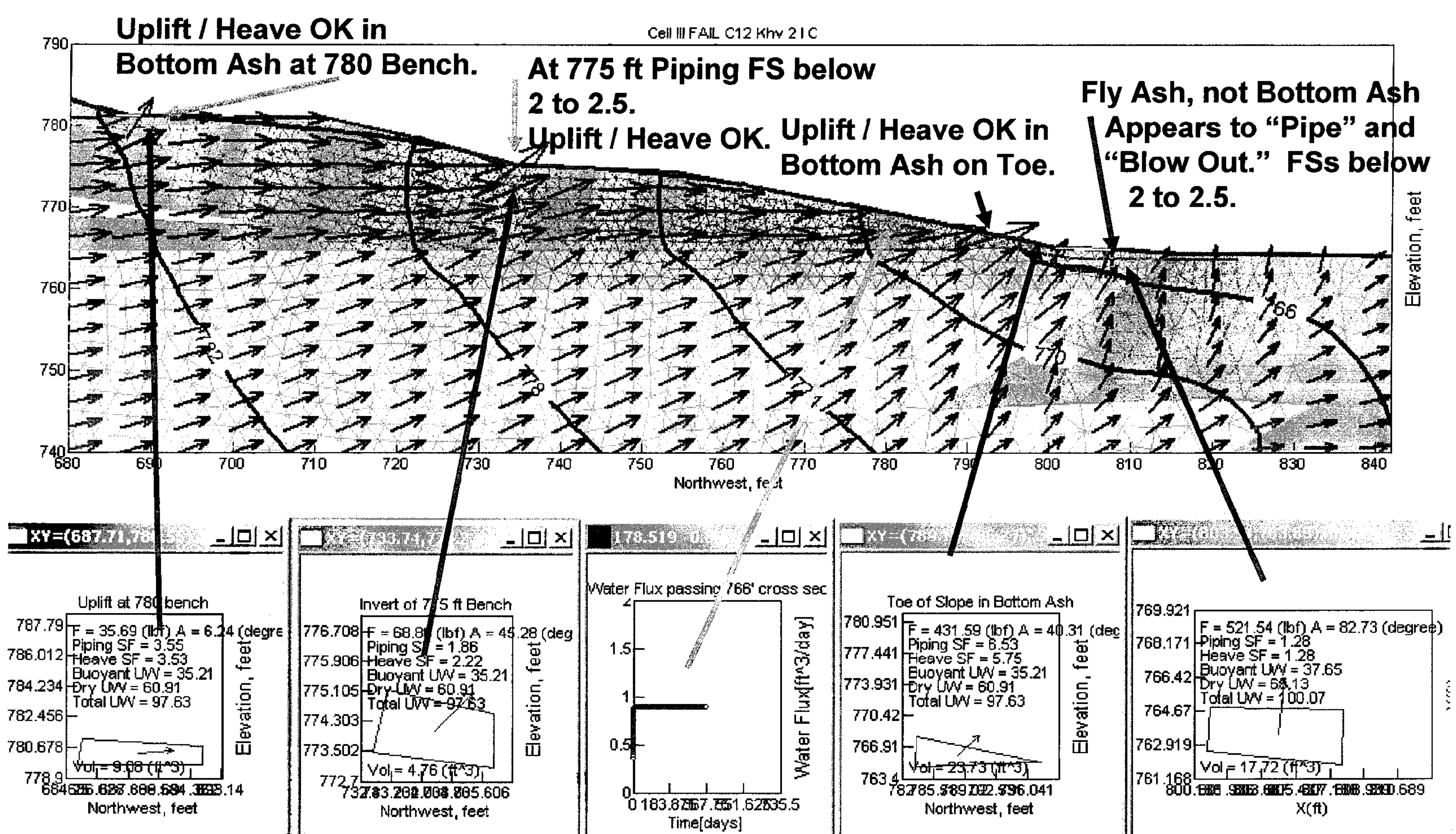
UPLIFT FS AND FLOW VECTORS



CASE 2 – SEEPAGE FAILURE RESULTS

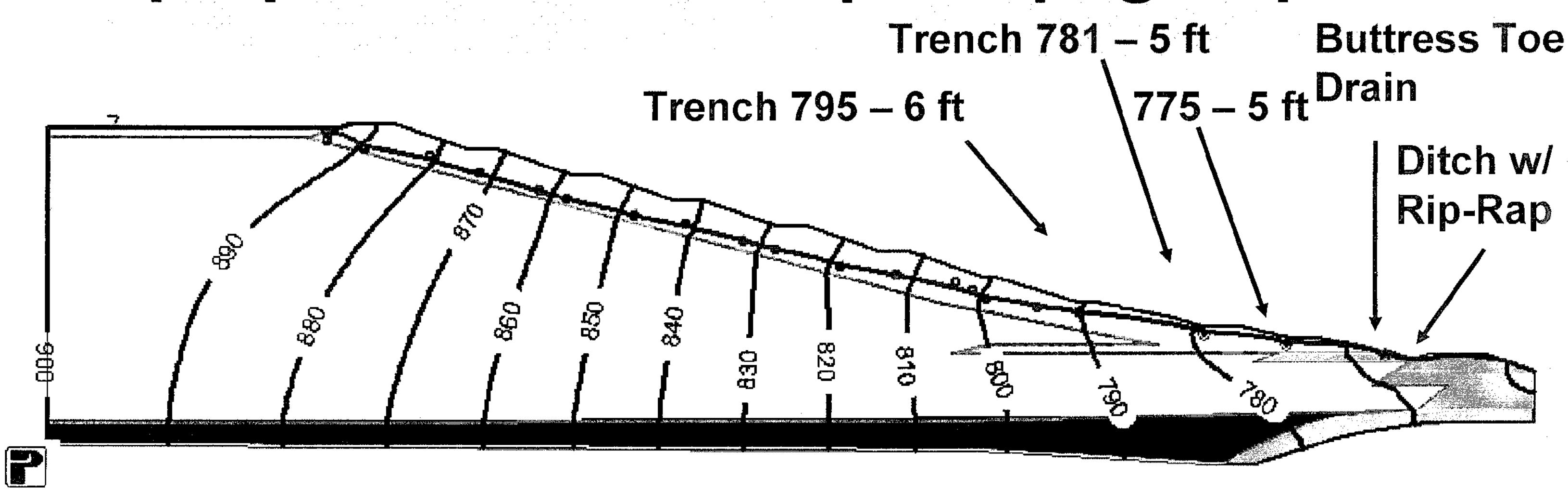
- Uplift FS is **1.28 < 2.0** at bottom of toe in the fly ash flat at Elevation 765 feet, approximately at the elevation observed in the field for the blowout.
- The slope above this point appears stable from seepage forces **except** the bench at the **775 foot elevation**. At this bench the factors 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

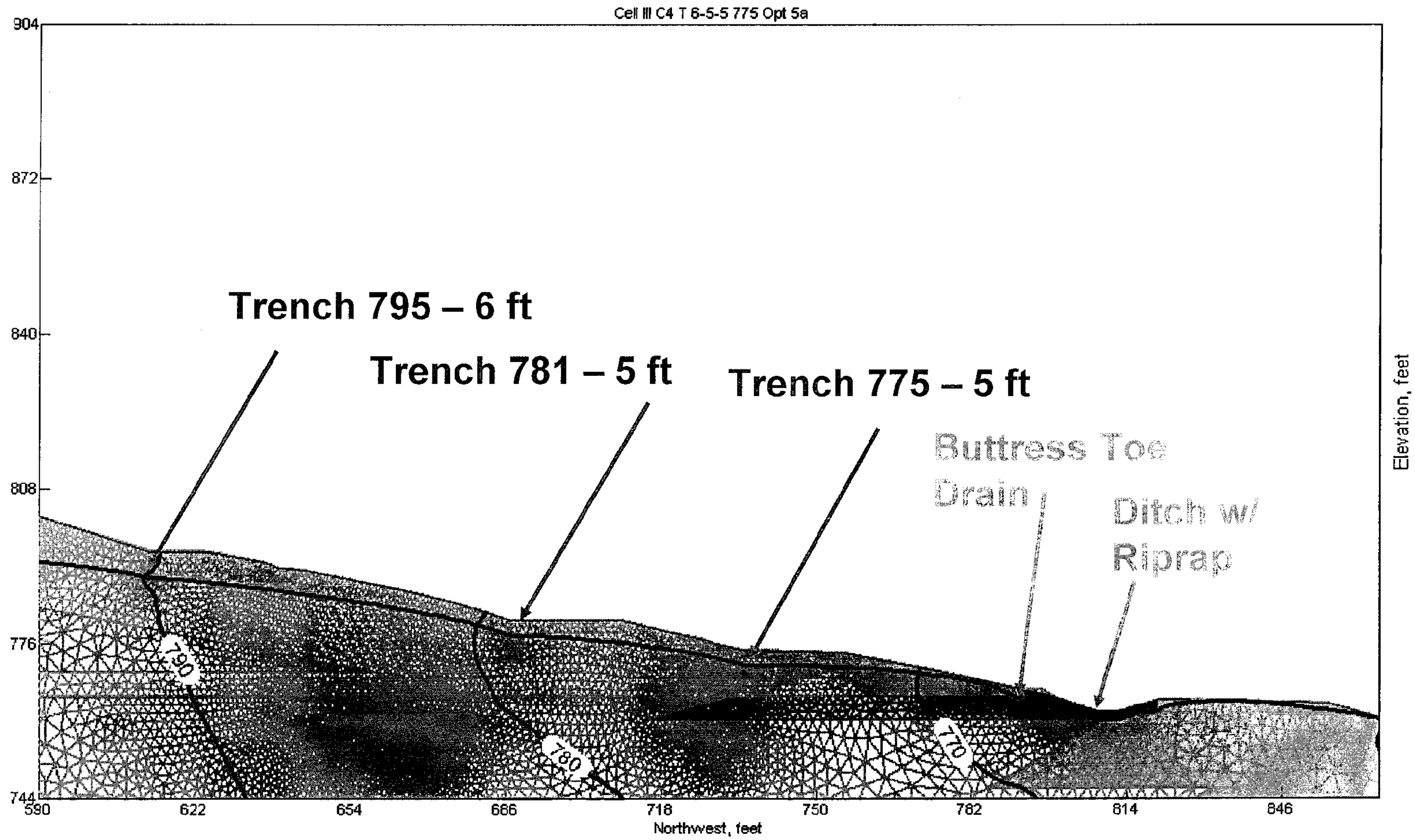
1. Evaluate a postulated future vertical expansion of the dredge cells to El 900.
2. Analyze alternatives to arrive at the most efficient solution to reducing seepage forces to requisite factors of safety of 2 to 2.5.
3. These alternatives include trench and buttress drains at various locations and depths 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

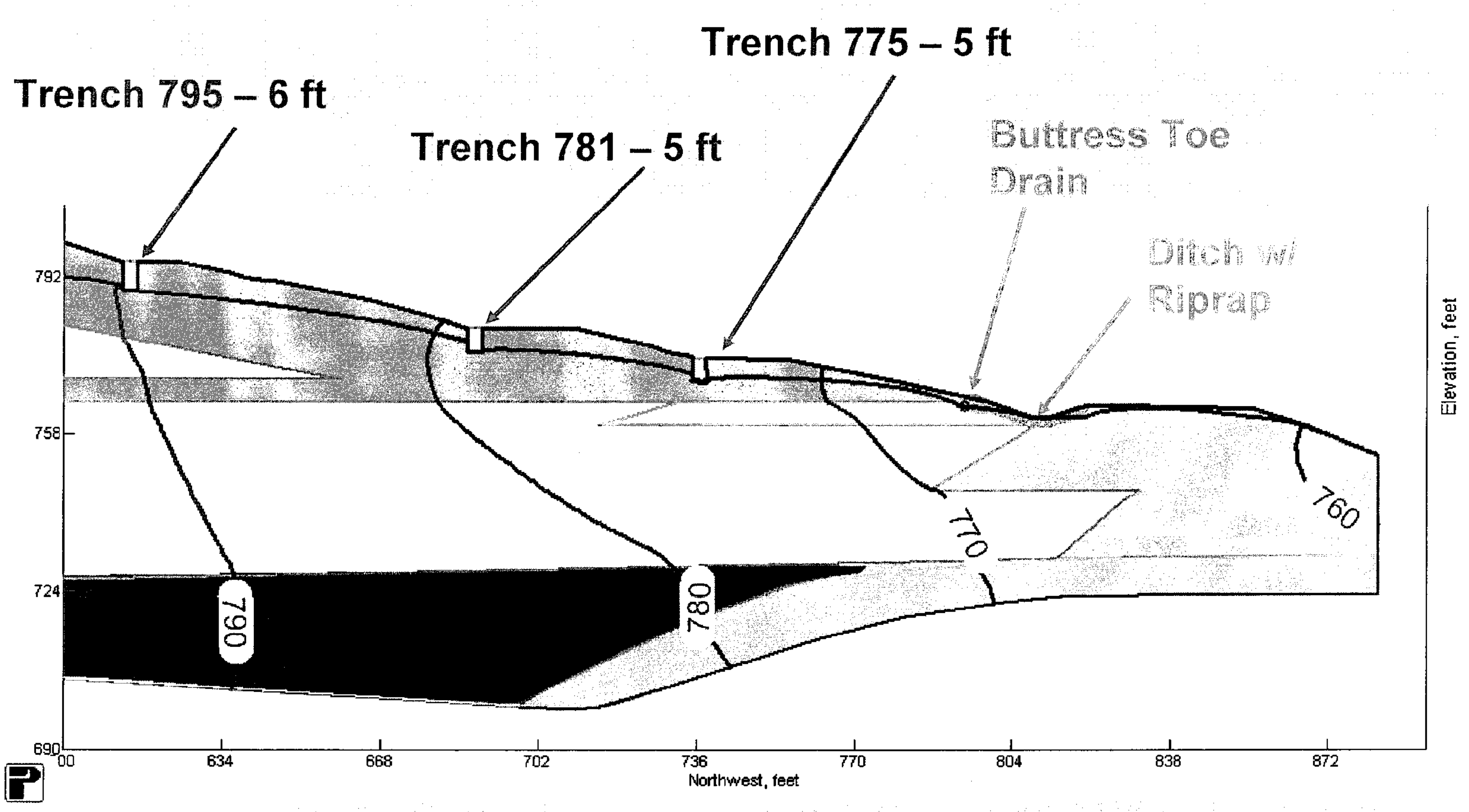
- One 6-foot Trench at 795 feet, Two 5-foot Trenches at 781, and 775 feet
- Buttress Toe Drain for Seepage Uplift
- Riprap Channel to Stop Seepage Uplift



FINITE ELEMENT MESH NEAR TRENCH, BUTTRESS, AND DITCH AREAS



CASE 3 – CLOSEUP ON TRENCHES



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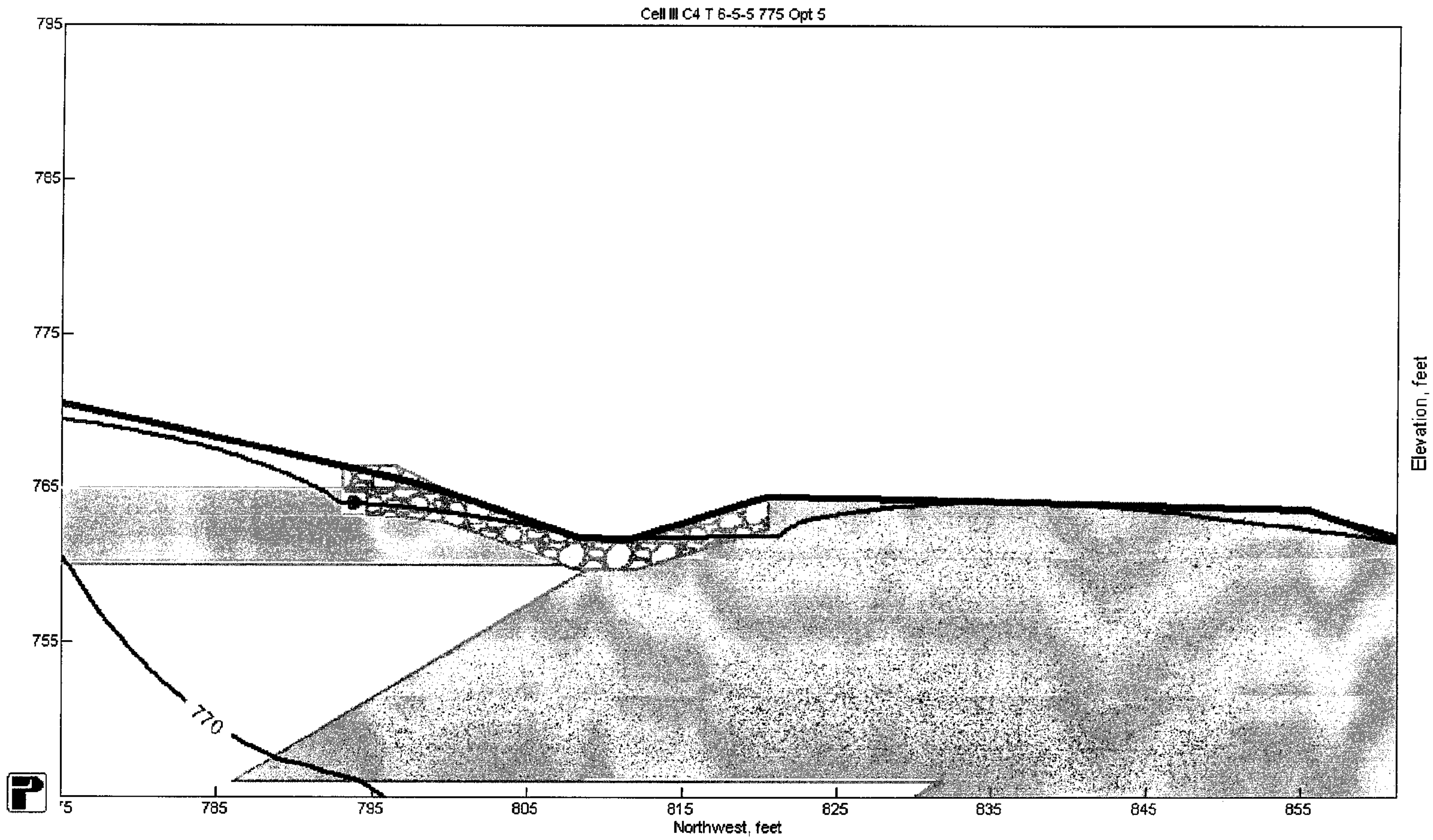
Calculated Flows for Future 900 ft Dredge Cell

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

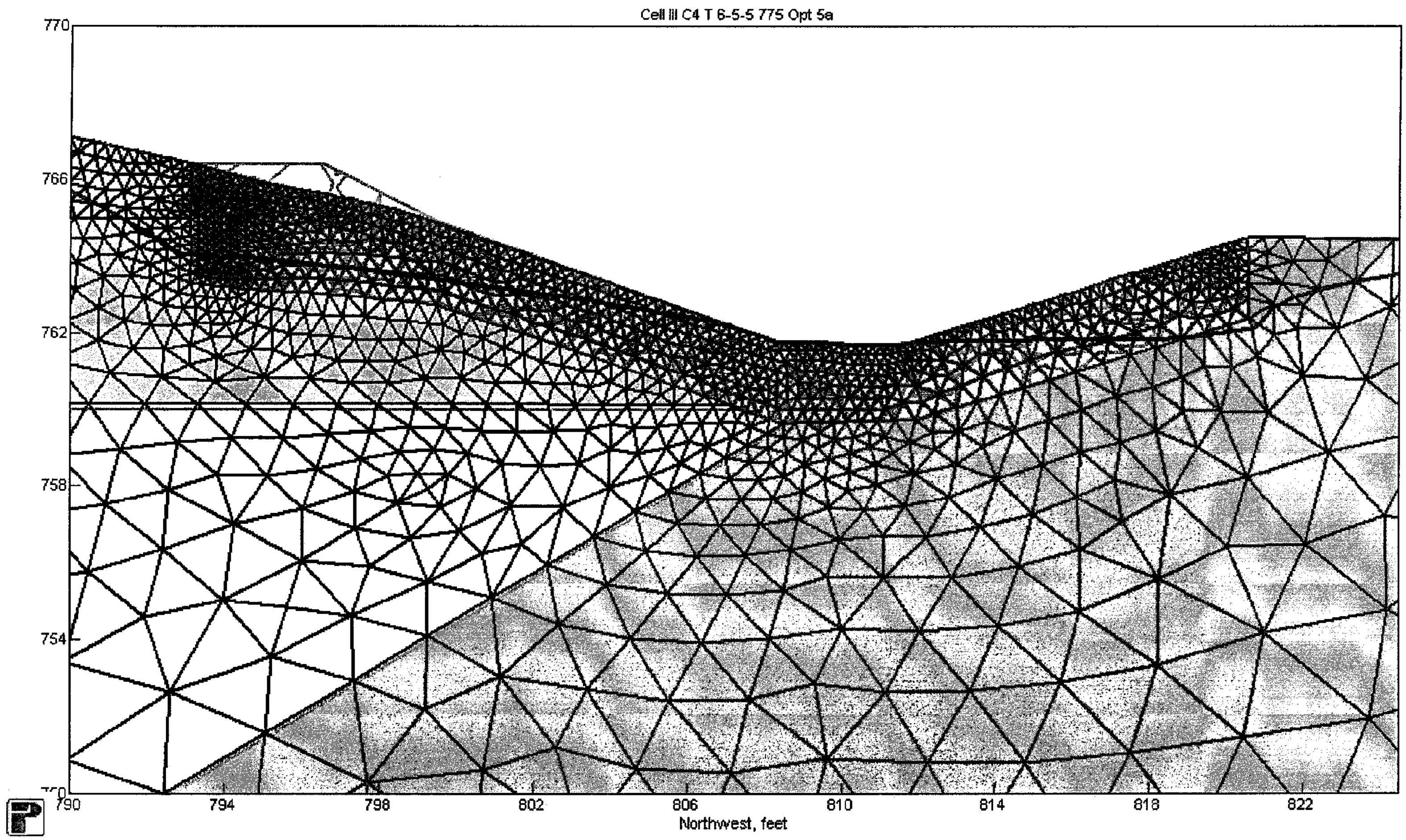
Riprap Design for Buttress and Ditch



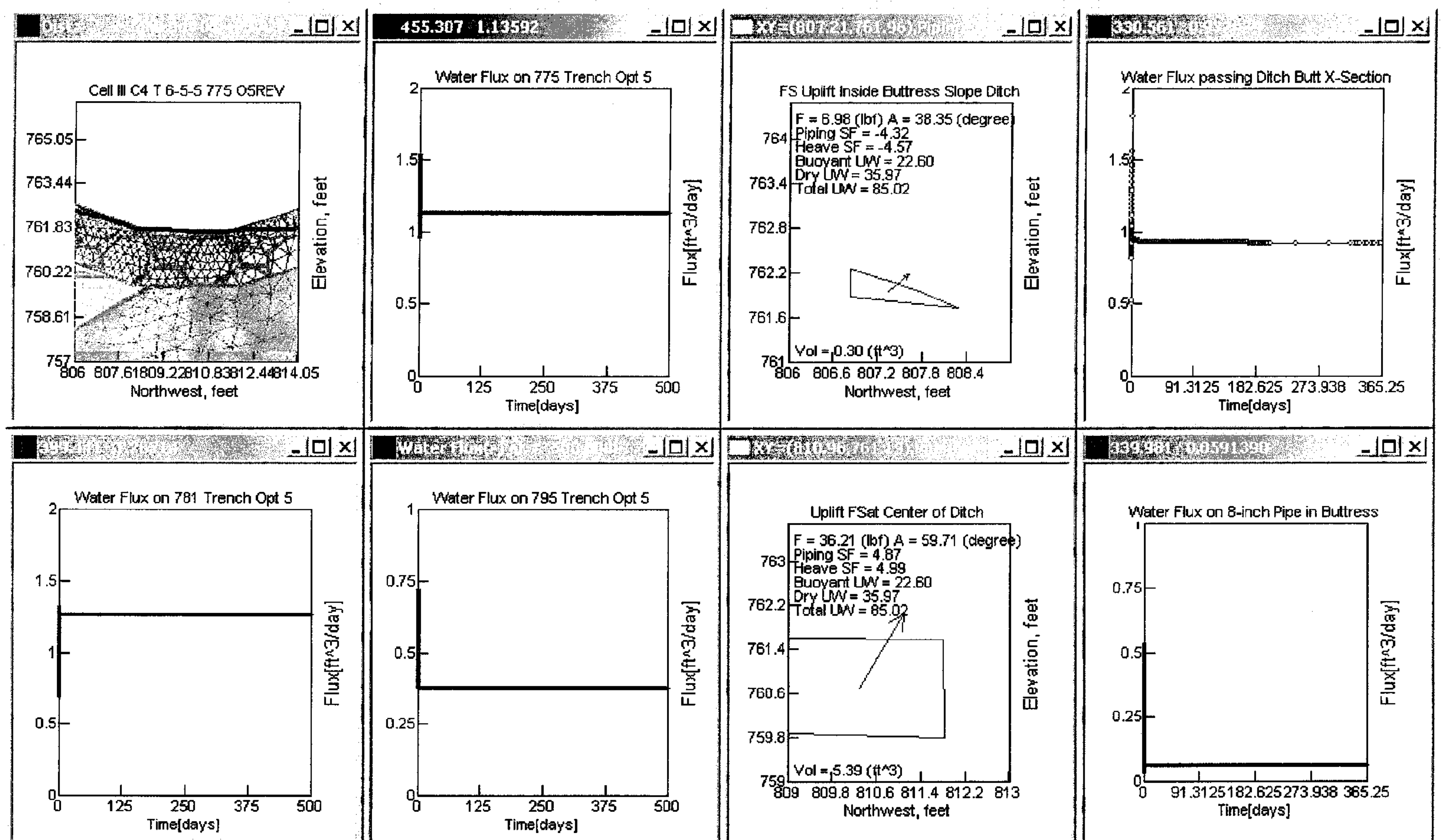
Buttress and Ditch Rip-Rap Design Assumptions

- 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



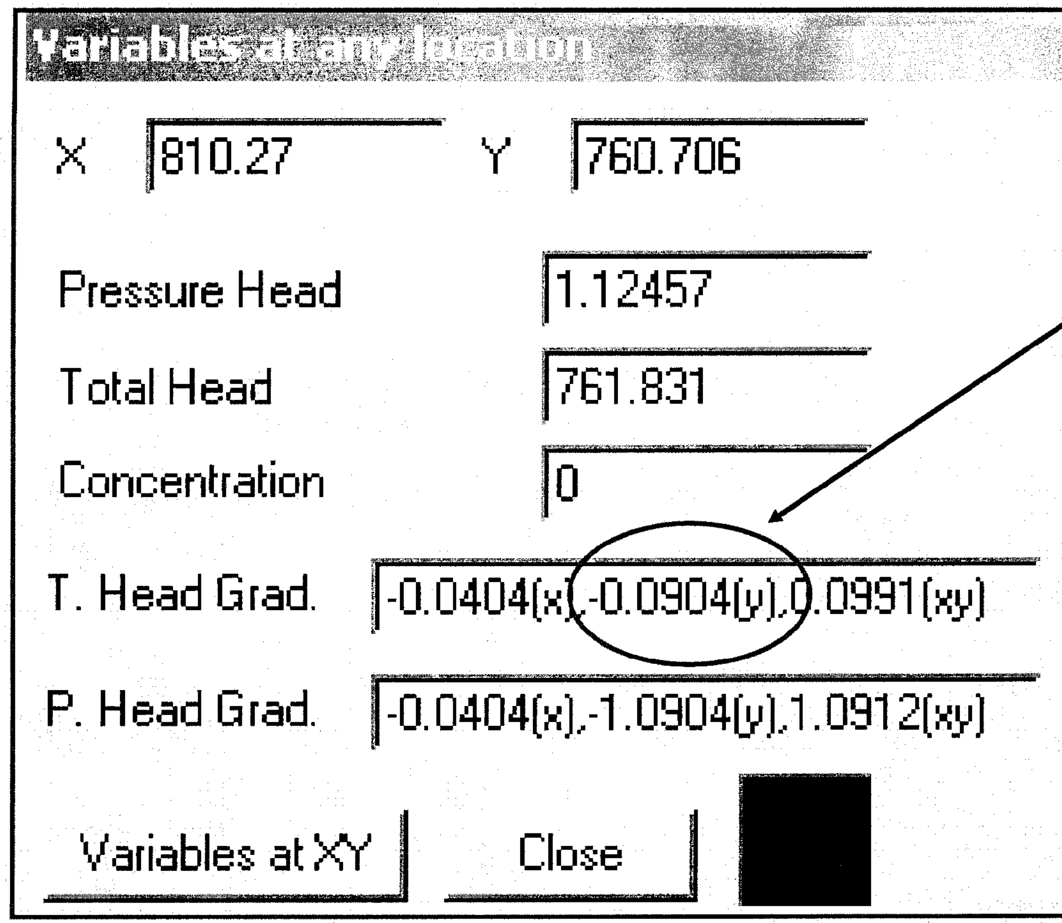
UPLIFT FS AND FLUXES



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.