DUSEL Beamline Working Group
NuMI Underground

Lessons Learned

Laughton & Lackowski

Greg's Summary (5/5/06)..

- After years of specific designs and reviews and approval of baseline:
  - Cost was higher than originally baselined
    - $139M -> ~$168M
  - It took longer
    - 50%
  - The Interface between facilities and experiment is costly and often not well understood. **Underground work is harder to predict than above ground work.**
- All that aside, the facilities turned-out nicely and are performing well.
  - **ES&H concerns are paramount. Always.**

Underground Works.. $ & Time Overruns

- Took Longer..
  - Design completed ~ Aug'99.
  - Contract proposals originally returned ~ Nov'99.
  - Contract let ~ Mar'00.
  - Underground excavation complete ~ Dec'02 ~ 1 Year Late.
- Cost More (numbers are approx.)..
  - As-Estimated ('99) ~ $25M
  - As-Bid ~ $34M
  - As-Settled* ~ $41M

  [*includes negotiated Scope Changes e.g. ~ $1.3M (+17 days) for the Decay Tunnel Cooling pipes]

Underground Work IS Hard to Predict

- Harder to predict than surface building.. High risk..
  - Cost Overruns
  - Late Completions
  - Disputes/Litigation
  - Problematic Operation
- Based on NuMI Experience..
  - What we might do next time
  - Design criteria issues for the new beamline..
    - Cost Drivers
    - Risks

3. Récapitulation

La comparaison, qui figure ci-dessous, entre le montant total prévisible des postes de dépenses et le budget correspondant constitué par le montant du Contrat, établit le constat du bouleversement total de l'économie du marché.

Les sommes portées sur le tableau comparatif sont calculées en francs suisses "stabilisés".

POSTES DE DEPENSES	EVALUATION GLOBALE DU COUT DE L'OUVRAGE	BUDGET (ou "dotation")
Main-d'oeuvre	133.566.142	58.509.737
Appointements	29.997.556	20.099.583
Matériel	91.833.840	25.058.509
Fournitures, frais divers, prestations	155.168.825	98.150.526
Travaux sous-traités	72.767.488	72.767.488
Travaux sous-traités imprévus	25.850.762	0
Frais proportionnels (et marge)	26.142.036	16.154.839
Frais financiers	24.661.175	3.274.318
Sous-total	559.987.824	294.015.000
Avenant n° 5	Dépenses	20.000.000
Avenant n° 8	incluses	11.000.000
Prime contractuelle d'exactitude (8 %)	ci-dessus	22.100.635
TOTAL	559.987.824	347.115.635
Demandes des sous-traitants et fournisseurs	27.605.000	
TOTAL GENERAL	587.592.824	347.115.635
MONTANT DE LA DIFFERENCE	240.477.189 FS	

LEP Plaine.. Total Cost Claim!

General Discussion Format..

- NuMI Underground Works
  - Geological Hydrological Setting
  - Underground Design/Safety Criteria
  - Design & Construction Process
    - 1 Site Investigation/Alignment
    - 2 Rock Mass Characterization
    - 3 Methods & Means
    - 4 Detailed Design
    - 5 Contracting (risk assessment)
    - 6 Construction
  - Contract Close-Out

    (Notes on Long Baseline Geo-Differences..)
- Improved underground design and construction practices for a new beamline..

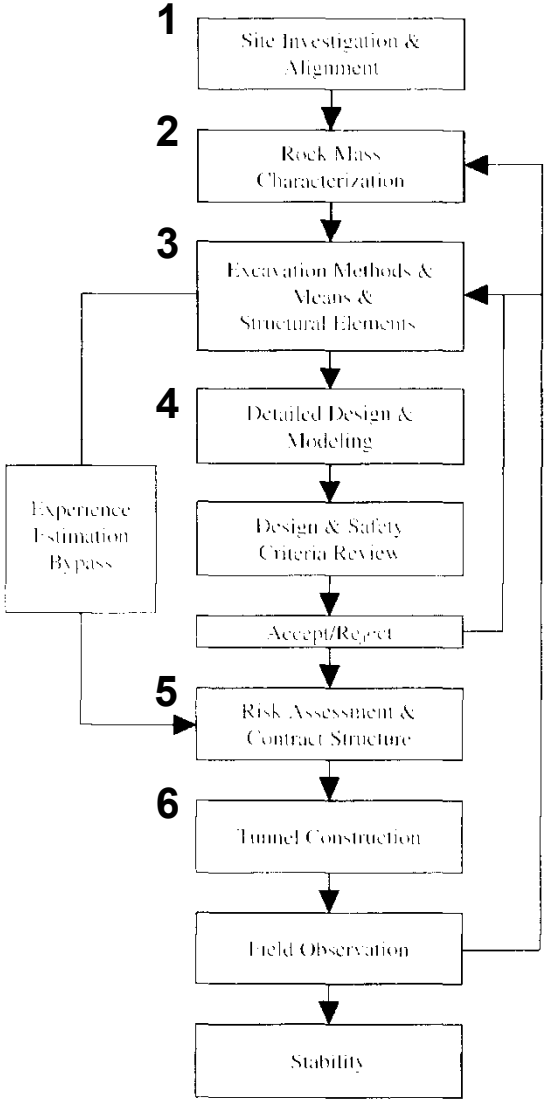
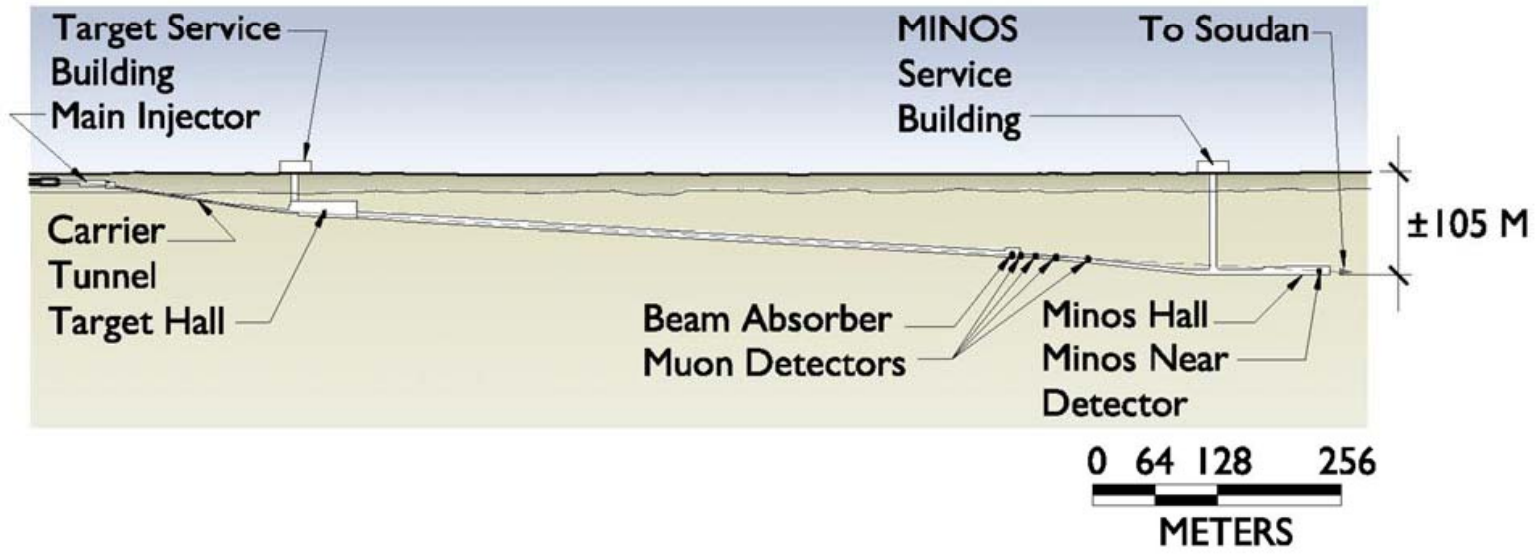


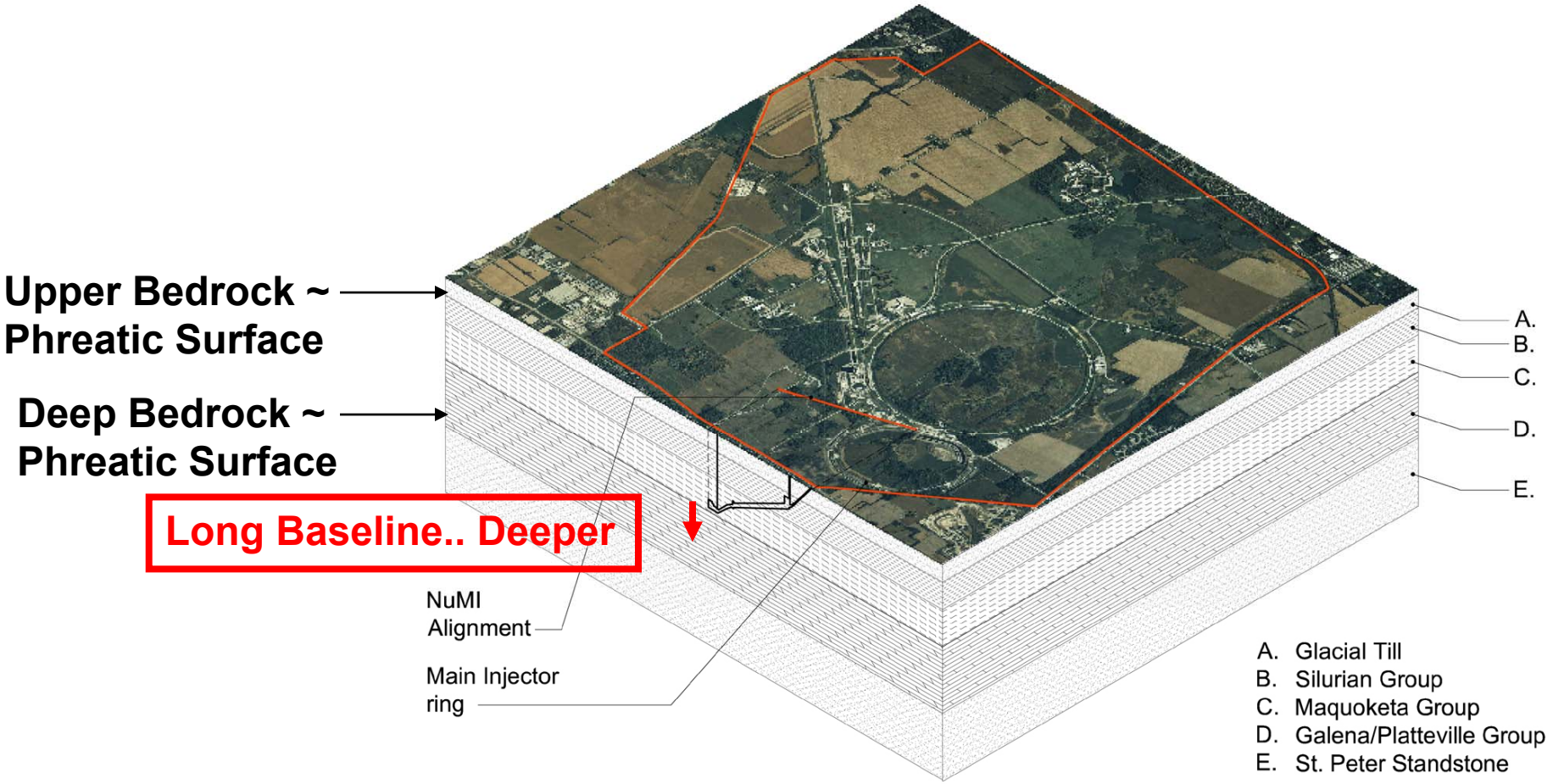
Figure 1. Tunnel design process flowchart.

NuMI Underground Works..

- **Carrier Tunnel:** 415-LF at 15% grade in soil, mixed-face and rock; pre-cast concrete and reinforced shotcrete linings, minimum 6-ft ID.
- **Construction Shaft:** 26-ft ID temporary shaft.
- **Target Shaft:** 22-ft ID, 120-ft-deep; cast-in-place concrete lining.
- **Support Rooms, Access Passageways and Labyrinth:** various dimensions; with reinforced shotcrete composite lining systems.
- **Target Hall:** 225-LF, 45 to 60-ft height by 27-ft width; reinforced shotcrete composite lining system.
- **Decay Tunnel:** 2100-LF TBM excavation at 5.8% grade, 21.5-ft ID with drill-and-blast enlargements; 78-in steel Decay Pipe with drainage membrane and Cementitious/Low Strength backfill (TBM on ~10% slope between Absorber & MINOS Shaft).
- **Absorber Hall:** 60-LF, 20-ft height by 27-ft width; reinforced shotcrete composite lining system.
- **Muon Alcoves (3):** 45-LF ea, 8 to 12-ft height by 8-ft width; reinforced shotcrete composite lining system.
- **Absorber Access Tunnel:** 700-LF TBM excavation at 10%grade, 21.5-ft ID.
- **MINOS Access Shaft:** 22-ft ID, 340-ft-deep; cast-in-place concrete lining.
- **MINOS Hall:** 235-LF, 32-ft height by 36-ft width; reinforced shotcrete composite lining system.



Regional Geology - Host Units



Long Baseline.. Reference Tomski's sections

Regional Hydrology - Host Units

- NuMI
  - Upper Bedrock Aquifer (~fractured dolostones) from base of glacial till to top of Maquoketa Scales Shale
- Long Baseline.. deeper
  - Deep Bedrock Aquifer(s)
    - Fractured Dolostones (G-P)
    - Porous Sandstones (St Peter/Ironton)

Fractured Dolostones

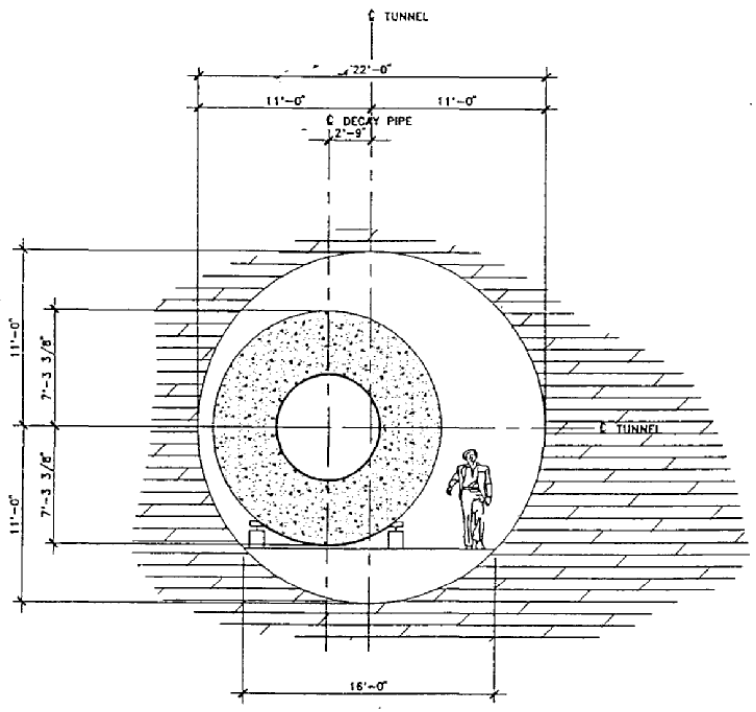
Source: http://www.sws.uiuc.edu/iswsdocs/wsp/ppt/GW_Occur_Move_NE.pdf

Early Concepts.. ’93 through ’97

- Per Gina’s Timeline
- Project Definition Reports
  - Nov.’93 (Rev.0)
  - Jun. ’94 (Rev.1)
  - Jun. ’95 (Rev.2)
- Cost Study
  - Oct. ‘95
- CDR… June 1997

Summer ’97: NuMI TBM-Based Concept

TBM or Drill & Blast?..



CROSS SECTION THRU DECAY PIPE
(LOOKING UPSTREAM)
SK–2

P.1, Price Report for TBM Tunneling. Ram D. , 13-Jun-96, Ck HHM

NuMI PROJECT

TBM Vs. D & B TUNNELING
COST COMPARISON
FOR A 4,271-FT TUNNEL LENGTH

COST SUMMARY FOR TUNNELING

Item	TBM Tunnel	D & B Tunnel
Excavation	$6,608,491	$6,953,268
Rock Anchors	$973,655	$1,029,149
Steel Spiling Bars	$48,960	$137,700
Steel Fiber Reinf. Shotcrete - 4"	$610,363	$656,333
Weep Holes	$11,830	$44,520
Concrete Invert Slab	$613,214	$738,724
Ch. Link Mesh Protection	$144,048	$111,518
Rockfill Under Slab	$37,250	N/A
Tunnel Grouting	$109,815	$126,420
Total Cost, June 1996 Level	**$9,157,626**	**$9,807,632**
Total Price per CY	$152.35	$187.60
Total Price per LF of Tunnel	$2,144	$2,300
Price per CY, Excavation Only	$109.94	$133.00

..TBM ~ a bit cheaper than Drill & Blast

Underground Engineering Input.. Conroy/Laughton/Lemley/McPherson - August 20-21 1997

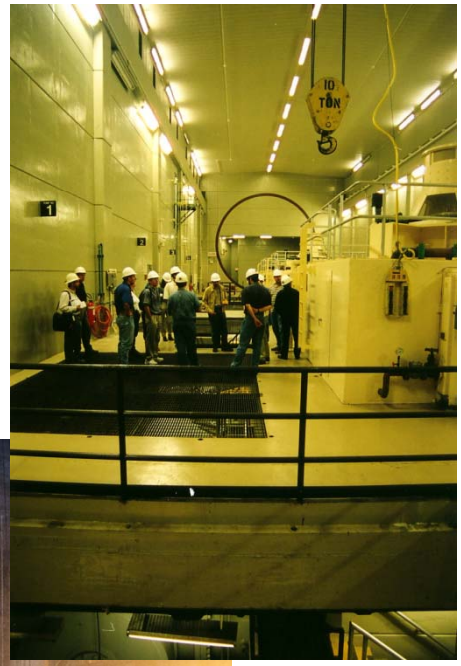
Summer ’97: CDR Review Feedback

- Few Comments from Director’s Review Write-Up..
  - Project as presented viable
  - Requirements Comments..
    - Concentrate on setting.. needs
    - This is a national lab and not a mine
    - Prioritize criteria – tell A/E what is important to Fermi
  - Design/Construction Comments..
    - Could Target Hall be mined instead of open cut?
    - If multiple shafts would reduce cost, can we offer it as option..?
    - Give the contractor the flexibility to do it either way (TBM or D&B)
  - Risk Comments..
    - Public Relations is very important
    - Prequalification of contractors is very important
    - Safety training at all levels is essential

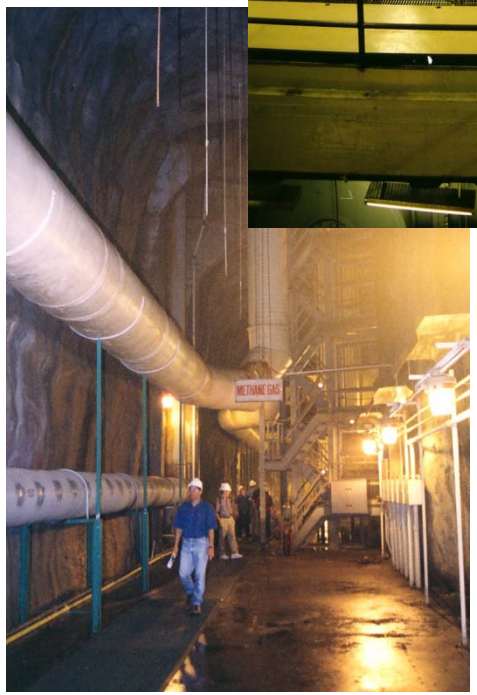
Spring ’98: Design Criteria/Site Visits

- Informed Discussion between..
  - Designers
  - Operators
  - Prospective Owner

~ Sewer Criteria?
~ Wine Cave Criteria?
~ Subway Criteria?



- Align Owner-Designer Expectations for Design
  - Stability, Watertightness, Alignment…
  - Life Safety (egress, refuge..)
  - Elec/Mech. etc.



Next time.. More visits to a wider variety of facilities and more upfront discussion on cost differences between different types of facilities/safety egress/finish-outs

Spring ’98: Criteria/Constructability

- Probable Methods & Means.. Drill and Blast
- Alignment.. Super-Low (mined Target Hall)

CONTRACTOR WORKSHOPS

CONSTRUCTABILITY WORKSHOPS

- March 27, 1998 J.F. SHEA COMPANY, INC.
- April 9, 1998 FRONTIER KEMPER CONSTRUCTORS, INC.
- April 17, 1998 KENNY CONSTRUCTION COMPANY

HIGHLIGHTS OF WORKSHOPS

Drill & Blast →

- Drill & Blast most probable method of construction
- Drill & Blast more flexible & adaptable to phased funding approach
- Prefer working 3 – 8 hour shifts, 5 days/week
- Work two headings from the MINOS Access Shaft
- Work one heading from the Target Access Shaft
- Minimum shaft size recommended is 20 to 24 feet
- 3 to 4 acre site required at surface for construction facilities and muck pile

Super-Low →

- Recommend lowering the Target Hall into the rock sufficiently to allow it to be constructed by mining rather than open-cut methods.
- Recommend having one soil/rock boring at each shaft location, at the MINOS Enclosure, at the Target Hall Enclosure and at the Carrier Tunnel soil/rock interface.
- Keep specifications open and flexible, don’t specify means and methods.
- Recommend Geotechnical Baseline Report (GBR) to provide clear guidance for resolution of changed conditions.
- Lump sum for well defined fixed portion of work and fixed unit prices for the variable portions of the work such as rock bolting and grouting.

VENDOR INPUT

Ref. Dave’s Talk

DECAY PIPE

Pipe material quotes from:

- Standard-Hayes Boiler & Tank
- Chicago Bridge & Iron
- Advance Tank & Construction Co.
- Van Leeuwen Pipe and Tube

Installation input from:

- Chicago Bridge & Iron
- J.F. Shea Company, Inc.
- Fluor Constructors – Northwest

CONCRETE: Prairie Group

- Structural concrete, 4000 psi & 5000 psi
- Lean concrete, 2000 psi
- Controlled Low Strength Mix (CLSM), Fly Ash/Cement Mix

AGGREGATE MATERIALS: Vulcan Materials

BRIDGE CRANES: Zenar Corp.

ELEVATORS

- Target Access Shaft: Alimak Elevator Co.
- MINOS Access Shaft : Montgomery Elevator Co.
  Dover Elevator Co.

BUILDING ARCHITECTURAL MATERIALS: G & L Associates

Next Time.. Develop a Better Early Understanding of Cost/Time Trade-Offs

Summer ’98: Criteria/Layout & Finish-Out

- Excavation Envelopes
  - Alignment ~ tolerances
  - Safe Egress ~ configuration
  - Occupancy Limits
- Electrical/Mechanical
- Radiation Shielding
- Water “Control” ..some areas dry/required residual inflow..

	Rock Tunnel Areas - Water Control Requirements				
Water Control Measures	1 DT	2 AT	3 CT	4 TH	e.g.
Grouting	●	●	●	●	
Drainage Mat & Shotcrete		●	●	●	
Drip Ceilings			●	●	
Dessicated Air Inlets				●	

Next Time.. Increased Drain Sizing Improved Access for Cleaning/Sampling

Summer '98: Criteria/Tunnel Stability

How Much Support Should Permanent NuMI Housings Receive?
(no temporary mine openings here!)

For NuMI..

~ Decay Tunnel *

~ Access Shafts/Tunnels Auxiliary Structures

~ Target & MINOS Halls & Beamline Tunnels

Instability.. has increased impact (FOS increased ESR decreased)

***Next Time… 100% Shotcrete Lined**

ESR*..

The excavation support ratio is related to the use for which the excavation is intended and the extent to which some degree of instability is acceptable. Barton[2] gives the following suggested values for ESR :

		ESR
A.	Temporary mine openings	3 - 5
B.	Permanent mine openings, water tunnels for hydro power (excluding high pressure penstocks) pilot tunnels, drifts and headings for large excavations.	1.6
C.	Storage rooms, water treatment plants, minor road and railway tunnels, surge chambers, access tunnels.	1.3
D.	Power stations, major road and railway tunnels, civil defence chambers, portals, intersections.	1.0
E.	Underground nuclear power stations, railway stations, sports and public facilities, factories.	0.8

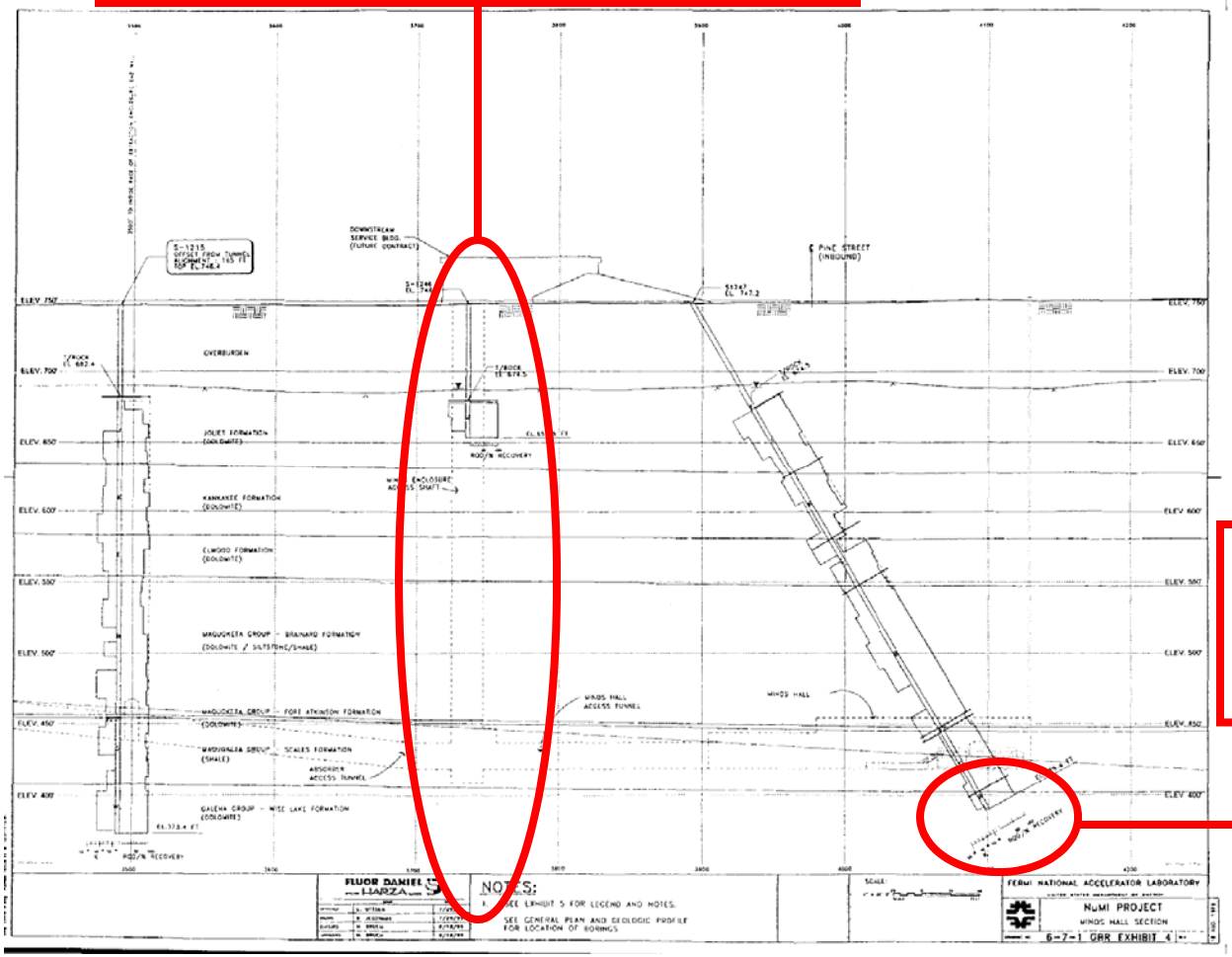
The ESR is roughly analogous to the inverse of the factor of safety used in the design of rock slopes[2].

* Lower ESR.. Higher ~ Factor of Safety

Source: NGI/Hoek & Brown, 1980

Summer/Fall ’98: Site Investigation

Next Time.. we’d put a hole all the way down at MINOS!

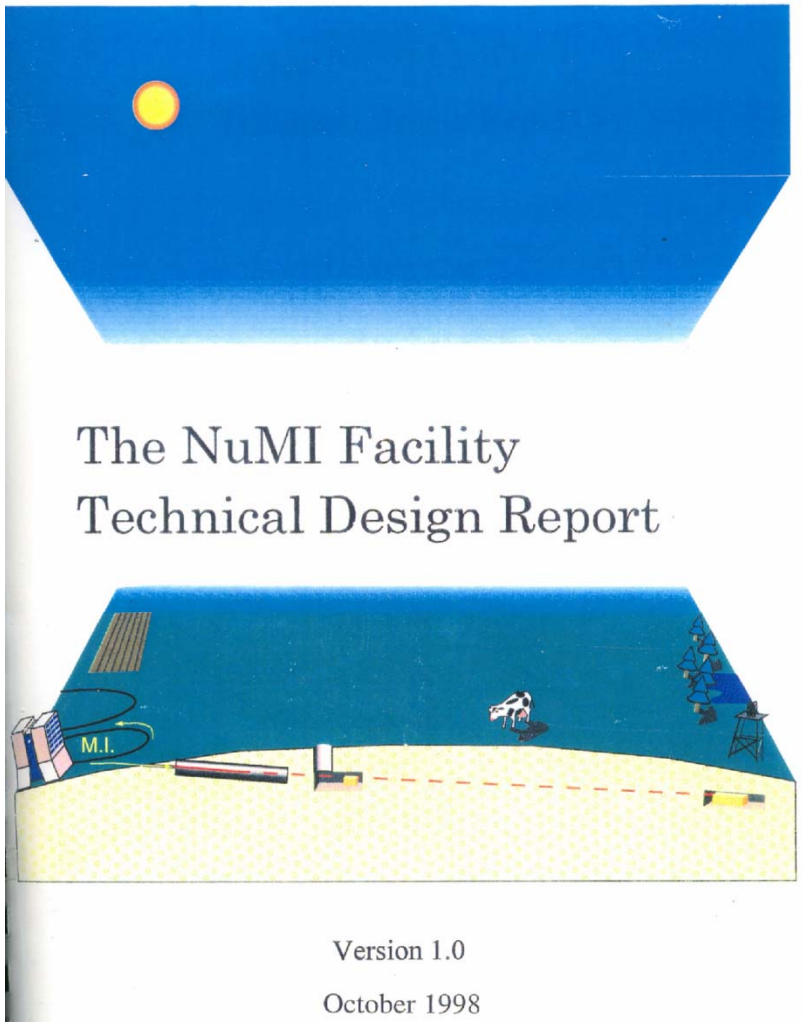


- Field Work
  - Boreholes
  - D-T-H
  - Seismics
  - Lab Tests
- Interpretation..

Loss of Water Circulation Noted in the Wise Lake top of G-P? ~ unsaturated

Fall '98: NuMI TDR Version 1.0

- Table of Contents
  - Executive Summary
  - Neutrino Beam Requirements & Conceptual Design
  - Radiation Safety
  - Civil Construction
  - Cost & Schedule
  - Project Management Summary
- Appendix
  - A - Beamsheet
  - B - Glossary



Next Time.. ~ a risk management/contingency section is important

‘97-’98: Rock Mass Characterization

- Understanding the Ground Masses/Predicting Behaviors
  - Cut-and-cover, soft ground, “mixed face”, and hard rock excavations
  - Large caverns up to 60-ft high and 34-ft wide with less than 30-ft of rock cover
  - Large-diameter shafts up to 340-ft deep
  - Tunnels on steep declines of up to 15% grade
  - Excavations in rock materials susceptible to deterioration upon exposure to air

Next Time ~ probably a similar process

97-98: Groundwater Characterization

- Inflow Estimates..
  - Max./Min. per region
- Other Studies by..
  - Earth Tec
  - Frank Breen
- Piezometer Nests Installed/Monitored (ES&H)
  - Water table fluctuations

TABLE 8.1

Groundwater Inflow Estimates

Project Feature	Length (approx.) LF	Maximum Anticipated Steady-State Inflow[1] (gpm)	Maximum Allowable Steady-State Inflow[2] (gpm)
Carrier Tunnel (soil)	100	20	< 15
Carrier Tunnel (mixed face)	155	50	
Carrier Tunnel (rock)	160		
Pre-Target and Target Hall	400	50	< 15
Decay Tunnel (Silurian dolomite)	800	70	< 20
Decay Tunnel (Maquoketa siltstone/shale); Absorber Hall and Absorber Access Tunnel; MINOS Access Tunnel	2250	220	< 70
MINOS Enclosure	230	80	< 10
Target Access Shaft	30	30	< 10
MINOS Access Shaft	250	80	< 10
TOTAL		**600**	**<150**

[1] Maximum anticipated steady-state inflow before grouting. Based on Heuer (1995) method of estimating tunnel inflows.

[2] Maximum allowable steady-state inflow after grouting. Based on an approximate a reduction in inflow due to grouting and water control measures (i.e. waterproofing membranes and shotcrete lining).

Next Time ~ Better Integration.. Site Modeling –> Operational Monitoring

Winter ’98: Value Engineering

VALUE ENGINEERING TEAM STUDY

SUMMARY OF RECOMMENDATIONS

One-hundred-fourteen ideas to improve the project or reduce costs were generated during the Speculation Phase of this study. The Analysis Phase of the study reduced the number of ideas to 27 for development and 35 ideas designated as design comments and are included in this report.

Of all the ideas from the Analysis and Development Phases, 21 ideas became proposals which can result in maximum potential cumulative savings of $7,124,940 for the approximately $50,000,0000 project.

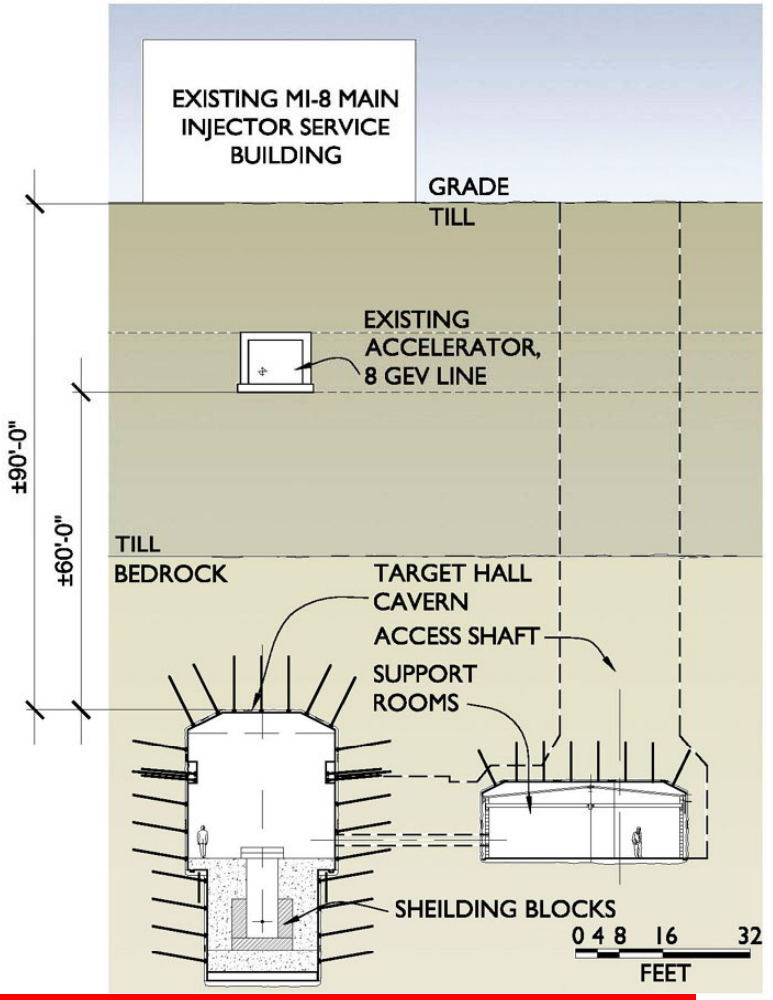
PROPOSAL NO.	DESCRIPTION	POTENTIAL SAVINGS
	ALIGNMENT	
1.	Move Proton Beam Bend Point in Extraction Enclosure 40’ Downstream to Eliminate Floor Penetration	$235,000
	CAVERN DESIGN	
2.	Lower Roof of MINOS Enclosure	$129,000
3.	Eliminate CIP Concrete Liner in Bottom of Target Hall Access Shaft	$797,000
4.	Raise Working Floor Level From the Base to the Top of The Target Pile	$227,500
5.	Eliminate Sump at the Target Shaft	$149,000
6.	(Proposal Deleted)	
	CRANE	
7.	Revise Bridge Crane Hook Height Within Absorber Building	$ 69,040
	DECAY TUNNEL	
8.	Use Excavated Material in Shielding Concrete Mix, Keeping Specification Open	$2,532,000
	GENERAL TUNNEL DESIGN	
9.	Reduce Width of Pre-Target Tunnel	$ 42,000
10.	Use Alternative Waterproofing Materials in Tunnels	$413,000
11.	Use Selective Waterproofing as a Function of Rock/Ground Water Mechanics	$571,000
12.	Change Muno Alcover Intersection Angle	$270,400
13.	Reduce Size of Beam Access Absorber Tunnel, Also Taper	$588,000
14.	Use Fiber Reinforced Shotcrete Versus Wire Mesh	$146,000
15.	Eliminate Waterproofing in the Downstream Access Tunnel	$304,000
16.	If Stairs Remain in Target Shaft, Eliminate Elevator Walls	$ 46,000
17.	Vary Slope of Beam Absorber Access Tunnel (Mirror Beam Line)	$ 5,000
	UTILITIES	
18.	Reduce Lighting to Emergency Lighting in Decay Tunnel and Other Restricted Areas	$ 59,000
19.	Eliminate or Reduce Utilities in Decay Tunnel	$384,000
20.	Put Electrical Feeders in Duct Bank Versus Direct Bury	($ 66,000)
	MISCELLANEOUS	
21.	Build to Function in the MINOS Service Building and Not to a Set Cost	$224,000
	MAXIMUM POTENTIAL ADDITIVE SAVINGS	**$7,124,940**

- “Relative” cost savings!
- Base estimate elements were generally low.. more later

Next Time.. A More Robust Cost, Schedule and Contingency before VE Work
(Note to Self.. Curb that Enthusiam.. More Devil’s Advocates/Critical Reviews)

Spring ’99: Detailed Design

- Using the rock’s strength.. minimizing lining costs
  - General Stability Considerations
    - Variable rock conditions
    - Classification-based rock supports
  - Special considerations
    - Stress/deformation modeling..
      - Low rock cover excavations
      - Larger-span excavations
    - Optimize the sequence of excavations and support installation
    - Swell potential of certain rock units
    - Multiple openings in close-proximity
- Site-wide water inflow models



Next Time ~ probably a similar process

Summer ’99: Contract Preparation

- Prequalification.. (experience/safety/financial)
  - 13 Requests for Prequalification
  - 10 Pre-qualified to Bid
  - 8 Attended Mandatory Pre-Bid Meeting
- Key Documents and Clauses..
  - Geotechnical Baseline Report ← **Next Time - TBM Method?**
  - Geotechnical Data Reports
  - Disputes Resolution ← **Next Time - Find a Better/Faster Way!**
  - Phased Construction
  - Unit Pricing ← **Next Time - ?On/Off Critical Path?**

Fall ’99: 5 Responsive Bidders..

- Fairly Good Response..
  - Few clarification requests during period
  - 6 Bids Received
  - Fairly Narrow Range
  - 5 Responsive/Detailed
- However, all exceeded Engineer’s Estimate.. By Large Margins (40%+)

		FD/H	Atkinson	Healy	Kenny	Kiewit	Obayashi	Shea
	Phase I		27,363,043	28,580,576		29,773,110	30,422,000	28,310,170
	Phase 2		6,840,761	7,145,144		8,692,890	7,630,000	6,689,830
	Total	24,844,809	34,203,803	35,725,720	46,483,770	38,466,000	38,052,000	35,000,000
	Score	108.31	70.00	63.77	19.74	52.55	54.25	66.74
	Lump Sum Items							
1a	Mobilization and Site Prep	886,337	597,618	3,500,000		2,443,000	2,000,000	3,489,320
1b	Demob	269,414	778,893	100,000		350,000	100,000	200,000
2	Extraction Enclosure	340,678	361,144	805,000		500,000	700,000	300,000
3d	Carrier Pipe						250,000	100,000
4	Pretarget	277,537	438,689	480,000		409,000	370,000	420,000
5a	Target Access Shaft	1,042,537	1,902,514	1,600,000		1,694,000	1,900,000	3,600,000
5b	Target Access Shaft Base	361,628	323,897	1,125,000		919,000	924,000	700,000
6a	Target Enclosure	3,231,805	2,708,603	3,200,000		3,721,250	3,880,000	4,750,000
6b	Target Hall Support Rooms	400,204	473,940	575,000		853,000	616,000	600,000
6c	Target Hall Exit and Utility	155,656	466,545	880,000		292,800	532,500	200,000
7	Decay Tunnel	9,626,552	9,076,364	8,582,153		8,585,200	9,900,000	4,834,830
7a	Decay Pipe Shielding		2,590,612	2,197,167		3,621,890	3,000,000	2,000,000
7b	Steel Decay Pipe		2,283,790	1,750,000		1,500,000	2,000,000	1,250,000
8a	Absorber Enclosure and Muon	610,425	470,589	475,000		494,200	752,000	400,000
8b	Absorber Access Tunnel	1,387,538	1,758,509	1,600,000		2,258,960	2,400,000	1,750,000
9	MINOS Access Shaft	2,222,476	3,547,572	2,800,000		3,751,000	3,939,035	5,900,000
10a	MINOS Enclosure and Data Acq	1,221,306	1,509,098	1,250,000		2,197,300	1,200,000	1,125,000
10b	MINOS Access Tunnel	814,494	985,115	1,243,950		1,941,800	662,000	600,000
11	Four Ventilation Shafts and Two	88,386	477,907	550,000		320,000	160,000	700,000
12	Furnish, Install and Main Instru	272,876	54,600	125,000		300,000	140,000	100,000
14	Furnish, Install and Main Oper	30,105	26,775	55,000		100,000	105,000	50,000
15	Grade and finish Kautz Rd.		40,133	260,000		25,000	75,000	80,000
16	Rehabilitate and Leave Temp Uti	96,336	284,728	75,000		30,000	514,000	300,000
	Lump Sum Total	23,336,490	31,157,655	33,228,270		36,307,400	36,119,535	33,449,150
	Check Column		31,157,655	33,228,270		36,307,400	36,119,535	33,449,150
	Unit Price Items							
3a	Carrier Tunnel - Earth	163,039	470,270	430,500		287,000	240,875	184,500
3b	Carrier Tunnel - Mixed Face	699,011	835,441	748,800		436,800	429,000	280,800
3c	Carrier Tunnel - Rock	217,630	781,637	660,100		450,800	273,700	241,500
17	Additional Shaft Concrete Lining	62,098	83,000	50,000		45,000	105,000	131,250
18a	Addl Drainage Membrane Inr	3,875	24,000	4,050		12,000	4,800	3,000
18b	Addl Geocom Drainage Strips	15,897	80,000	15,500		50,000	52,000	20,000
18c	Addl Metal Drip Ceiling	47,691	36,000	11,100		24,000	19,200	30,000
18d	Panning	2,111	10,000	6,250		17,500	6,250	7,500
19a	Grout Hole Drilling	16,095	40,000	50,000		24,000	40,000	110,000
19b	Portland Cement for Grouting	34,973	44,000	23,100		22,000	26,400	44,000
19c	Placement of Cement	27,820	280,000	175,000		245,000	350,000	210,000
19d	Grout Connections	4,372	11,000	19,250		6,600	24,750	22,000
19e	Standby Time for Pre-Excava	161,844	182,000	168,000		210,000	280,000	189,000
20a	Rock Dowels	18,282	73,600	73,600		73,600	9,200	36,800
20b	Rock Bolts, Resin Anchored	5,564	5,600	5,600		5,600	4,340	4,200
20c	Rock Bolts, Mech Anchored	4,769	4,800	4,800		12,000	3,840	3,600
20d	Steel Mine Straps	1,292	13,000	9,750		97,500	34,450	6,500
20e	Welded Wire Fabric	894	18,000	11,250		27,000	4,500	2,700
20f	Rebar Spiders	3,179	4,800	4,800		67,200	6,560	4,000
21a	Shotcrete, Steel Fiber	7,949	15,000	15,000		15,000	10,000	15,000
22	Addl Multi Position Tunnel Inst	9,936	24,000	10,000		30,000	7,600	4,500
	Unit Price Total	1,508,322	3,046,148	2,497,450		2,158,600	1,932,465	1,550,850
	Contract =	24,416,170	33,255,003	35,067,670	0	37,482,000	37,063,110	34,155,950
	Pay to Measure =	428,642	948,800	658,050	0	984,000	988,890	844,050

Next Time.. Again more attention to setting realistic numbers from the start..
~ desktop scoping studies
~ estimates/simulate bid conditions
Would be able to be more selective!

Fall ’99: Underground Underestimated

- Project Optimism meets Industry Reality..
  - Market Conditions* - maybe a few %
  - Mark-up (risk/overhead/profit)* - few more %
  - Production Rates/Crew Sizes* - main factor..

  (Engineer’s Estimate = “Construction in Heaven”)
- Necessary to further reduce costs thru negotiation with individual contractors..

Next Time.. Reduce potential that we design something we can’t afford
Seek out expert, independent verification of cost/schedule.. early/often

*** No reason that these issues could not be identified BEFORE bidding..**
Next time.. all estimating by those most intimately familiar with..
..rates/markets/mark-ups

Winter '99 More "Value" Engineering!

Next time.. More time to evaluate/trade-off installation/operation impacts

NuMI TUNNEL AND ENCLOSURES ACTION ITEMS

COST REDUCTION OPTIONS	FERMI DESIGN	FERMI APPROVAL	ATKINSON SUGGESTED DESIGN	ATKINSON ESTIMATE	ACTION DATE
1.) NO CRUSHING OF ROCK					
A.) NO CRUSHING OF ROCK		X			
B.) CRUSH ROCK/ FERMI SELL		X			
C.) CRUSH ROCK/ ATKINSON SELL		X			
D.) PRICE OPTION SELECTED				X	
2.) DECAY TUNNEL SHIELDING & PANNING					
A.) DESIGN CONCEPT	X	X			
B.) SHIELDING & PANNING	X				
C.) ESTIMATE COST EFFECT					
* SELECT FORMING METHOD		X	X		
* REVISE PLACEMENT COST				X	
3.) MINOS SHAFT WATER RING DELETION		X		X	
4.) BLAST RESTRICTION LIMITATIONS					
A.) 115 DBA VARIATION		X			
B.) VIBRATION LIMTATION VARIATION		X			
C.) ESTIMATE COST EFFECT				X	
5.) DRIP CEILING ALTERNATIVE					
A.) LATTICE GIRDER/ HDPE LINER		X	X		11/9/99 -A
B.) ALTERNATIVE CEILING SYSTEM	X			X	
7.) PHASE FACILITY HAND OVER					
A.) HAND OVER SCHEDULE		X			
B.) ESTIMATE COST EFFECT				X	
9.) MINE RESCUE REQUIREMENT					
A.) PROVIDE SUBCONTRACTOR REQ.		X			
B.) ESTIMATE COST EFFECT				X	
10.) QC ENGR. REQUIREMENT					
A.) SUBCONTRACTOR DELETION		X		X	
11.) INSTRUMENTATION REQUIREMENT					
A.) SUBCONTRACTOR DELETION		X		X	
12.) DRILLED SHAFT ALIGNMENT REQ'S		X			
A.) ESTIMATE COST EFFECT				X	

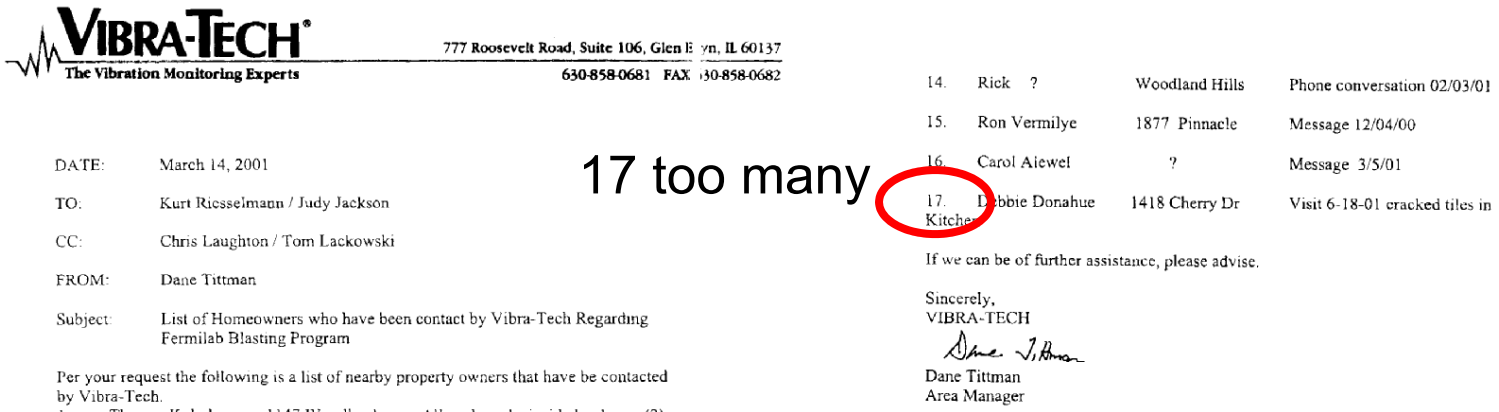
Telescoped/"Snug to Rock" Tunnel

COST REDUCTION OPTIONS	FERMI DESIGN	FERMI APPROVAL	ATKINSON SUGGESTED DESIGN	ATKINSON ESTIMATE	ACTION DATE
13.) DECAY TUNNEL X-SECTION					
A.) DESIGN CONCEPT	X	X			
B.) TUNNEL SIZE REDUCTION					
* EXCAVATION				X	
* INVERT CONCRETE				X	
* GROUND SUPPORT				X	
14.) STOCKPILE & HAUL ROUTES					
A.) STOCKPILE LOCATIONS	X	X			
B.) HAUL ROUTE STIPULATIONS	X	X			
C.) ESTIMATE COST EFFECT				X	
15.) ELECTRICAL DUPLICATIONS					
A.) PROVIDE DESIGN		X			
B.) ESTIMATE COST EFFECT				X	
16.) WATER PUMPING PLANT					
A.) PROVIDE DESIGN		X			
B.) ESTIMATE COST EFFECT				X	
17.) [illegible]					
A.) DESIGN CONCEPT		X	X		
B.) TUNNEL SIZE REDUCTION					
* EXCAVATION				X	
* INVERT CONCRETE				X	
* GROUND SUPPORT				X	
18.) CAST-IN-SHAFT CURTAIN PANEL				X	
19.) SHOTCRETE PLACEMENT TIMING		X			
A.) ESTIMATE COST EFFECT				X	
20.) REVIEW SIZE OF CARRIER TUNNEL					
A.) DESIGN CHANGE TO 4 FT OF ROCK		X			
B.) TUNNEL LENGTH REVISION					
* EXCAVATION				X	
* INVERT CONCRETE				X	
* GROUND SUPPORT				X	
* BACKFILL CONCRETE				X	
21.) OTHER OPTIONS					
22.) SCHEDULE MODIFICATIONS					
A.) INCORPORATE ITEM 7 CHANGE S AS WELL AS SCOPE ADJUSTMENTS		X		X	

Crane Eliminated.. Ref: Jim's talk

- Contract Let – March '00

’00-’01: Neighborhood Concerns



VIBRA-TECH®
The Vibration Monitoring Experts

777 Roosevelt Road, Suite 106, Glen E yn, IL 60137
630-858-0681 FAX 30-858-0682

DATE: March 14, 2001

TO: Kurt Riesselmann / Judy Jackson

CC: Chris Laughton / Tom Lackowski

FROM: Dane Tittman

Subject: List of Homeowners who have been contact by Vibra-Tech Regarding Fermilab Blasting Program

Per your request the following is a list of nearby property owners that have be contacted by Vibra-Tech.

1.	Theresa Kolody	1147 Woodland	Alleged cracks inside her home (2) visits
2.	Mary McNabb	3150 Sawgrass	Alleged cracks in her home
3.	Mindy Stoffeo	3158 Sawgrass	Tape seam cracks
4.	Tom Weiglien	3149 Savannah	Cracked window
5.	Marsha Jenkins	1092 Woodland Hills	Seismograph installed 12/00
6.	Iris Ware removed 01/01	1110 Woodland Hills	Seismograph installed 12/00
7.	Jeane Pritchett	1321 Scheidler Park	Seismograph installed 12/00
8.	Al Paskewicz removed 01/01.	3181 Savannah	Seismograph installed 12/00
9.	Chris Lirot	Kirkland Farms	Seismograph 08/00
10.	Peter Garbincius	709 Woodland Hills	Phone conversation 12/28/00
11.	Mary Ann O’Connor	1949 Pinnacle	Phone conversation 02/06/01
12.	Linda Seikel	20920 Compton	Phone conversation 02/06/01
13.	Janet Niemiec	3128 Savannah	Phone conversation 02/06/01
14.	Rick ?	Woodland Hills	Phone conversation 02/03/01
15.	Ron Vermilye	1877 Pinnacle	Message 12/04/00
16.	Carol Alewel	?	Message 3/5/01
17.	Debbie Donahue	1418 Cherry Dr	Visit 6-18-01 cracked tiles in Kitche

If we can be of further assistance, please advise.

Sincerely,
VIBRA-TECH

Dane Tittman
Area Manager

17 too many

- Concerns ~ mostly blast-related
  - Vibrations measured, but generally below instrument threshold
  - Air Overpressures likely culprit
- Other Project Experiences..
  - LEP-Crozet.. moratorium on NTB’s
  - SPS-Meyrin.. court injunction on TBM
- Ref. Judy’s talk

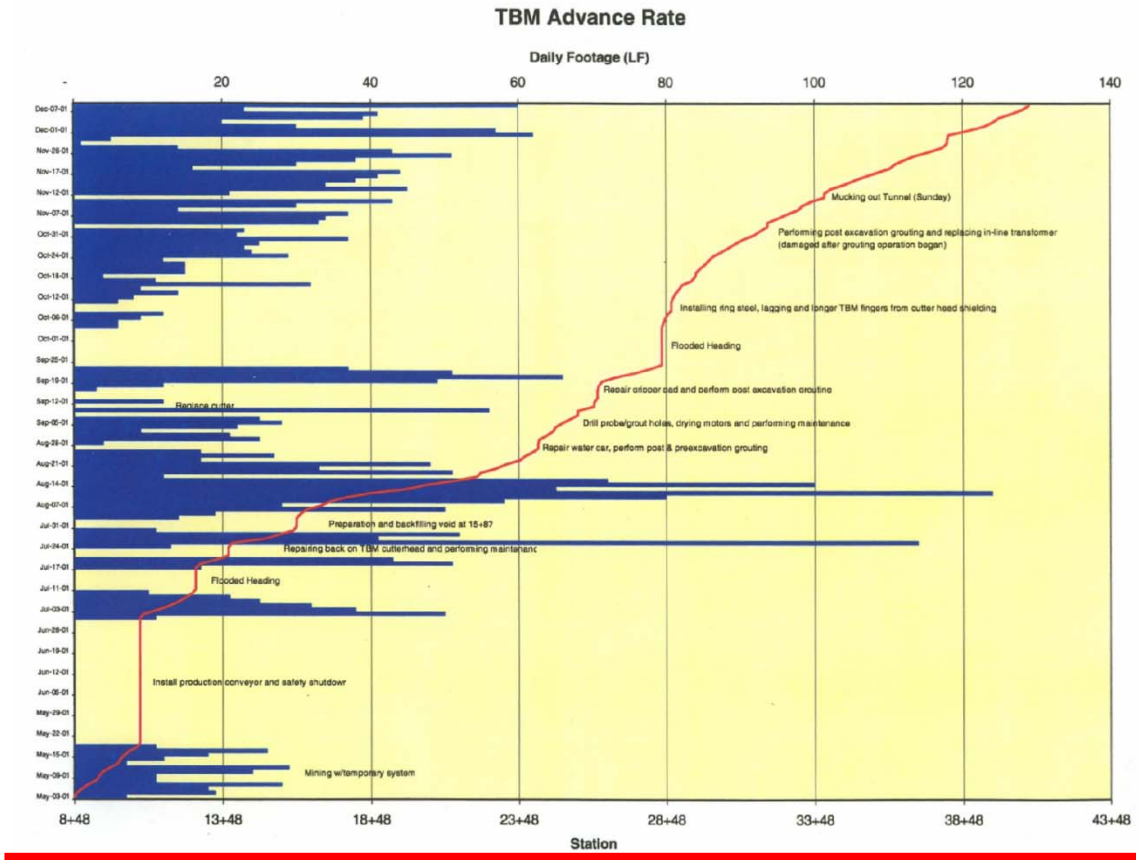
Next Time.. “Zero Complaints” is the goal ..reference other sites/other practices

’01: Mining Performance Deteriorates

- Accidents, Poor Water Quality (at Target & MINOS sites, ref talk by Don & Mike), Other Delays.. Many Requests for Equitable Adjustment (REA’s)..

- **TBM failed to perform..**
  - **Ground Failures..**
    - **Blocks/Wedges, Slabbing, Slaking, Swelling**
  - **Grouting..**
  - **Flooding..**
- **Alleged Differing Site Conditions (DSC’s)**
  - **C’s Consultants’ reports substantiated claims..**
  - **FNAL’s consultants reports rebutted claims..**
  - **So many experts so little consensus!**

..Prime Area for Dispute!



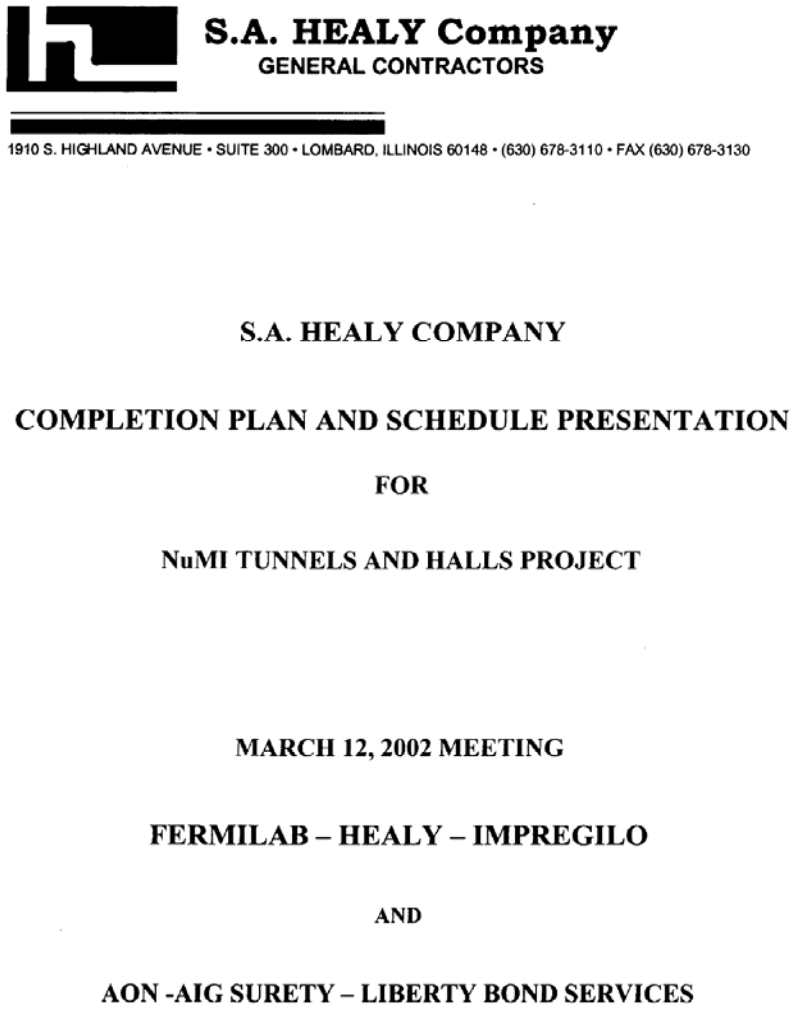
Next Time.. Better risk planning anticipate, identify & respond more quickly..

Summer/Fall ’01: Oversight Reinforced

- Increase in safety/construction oversight
- Claims support added
- Contractor poor performance documented (Wightman)..
  - Contractor ~ well-respected with a history of successfully completed underground projects (including TBM work)
  - However, at NuMI Contractor performing badly..
    - Poor Planning
    - Poor Water Handling
    - Poor Emergency Management
    - Poor Equipment Maintenance
    - Poor Roof Support Strategies Selected
  - Site Conditions.. no excuse for poor performance
- Opportunities Identified to Improve Future Work.. with an injection of resources…

Winter ’01-’02: Completion Plan Proposed

- Contractor’s parent company recommits to getting the job done..
  - Added Labor
  - Added Supervision
  - Added Engineering
  - Added Equipment
  - Added Formwork (DT)
  - Added Overtime Work
  - Increased Concurrency
  - Introduced Incentives Program



S.A. HEALY Company
GENERAL CONTRACTORS

1910 S. HIGHLAND AVENUE • SUITE 300 • LOMBARD, ILLINOIS 60148 • (630) 678-3110 • FAX (630) 678-3130

S.A. HEALY COMPANY

COMPLETION PLAN AND SCHEDULE PRESENTATION

FOR

NuMI TUNNELS AND HALLS PROJECT

MARCH 12, 2002 MEETING

FERMILAB – HEALY – IMPREGILO

AND

AON -AIG SURETY – LIBERTY BOND SERVICES

Facilities "Turned-Out Nicely"..

- Fall '02 - Beneficial Occupancy..
- Since Completion..
  - NuMI 2005 Honor Award from the American Council of Engineering Companies (ACEC) of Illinois
  - NuMI - MINOS Project - National Finalist for the 2005 ACEC Engineering Excellence Awards.

Next time.. Greater attention to condition of all left-in-place utilities

Compared to many underground facilities.. We did a lot with a little!
..the Contractor's site staff deserves a lot of credit for turning it around

Next Time.. Anticipate additional design mitigations (added $ and time) to improve water control in Target Hall and Decay Tunnel areas..

Project-long FNAL Survey Support

- FNAL surveyors provided survey stations, data and checked Contractor survey work **during** Construction.

Next time.. Coordination of survey work with mining activities will again be key… seemed to work better when surveyors came-in at quiet times? .. Can adjust contract language ..others to comment..

Ref. talks by Don & Mike & Virgil

‘04 NuMI: Disputes Resolved

- Disputes arose during the contract
  - ~ 100 Change Orders/Requests for Equitable Adjustments..
  - – Successful negotiation was rare ..mostly reached impasse
  - – Number of issues referred to the Disputes Review Board..
    - Six hearing held on a range of topics (DSC’s, safety stand-down, water treatment etc..)..
    - Major delays between hearings and recommendations (1 vs. 5 mths+)
    - Significant resources expended.. dysfunctional DRB/broken process
    - Parties loss of trust in the DRB..
    - Chairperson resigned from DRB Dec-03 ..DRB never reformed
- Global Settlement Achieved July 04
- Gary Leonard to provide the Legal Perspective

Next time.. Find a more cost-effective, timely way of resolving disputes, or ideally avoid them altogether.. risk management practices

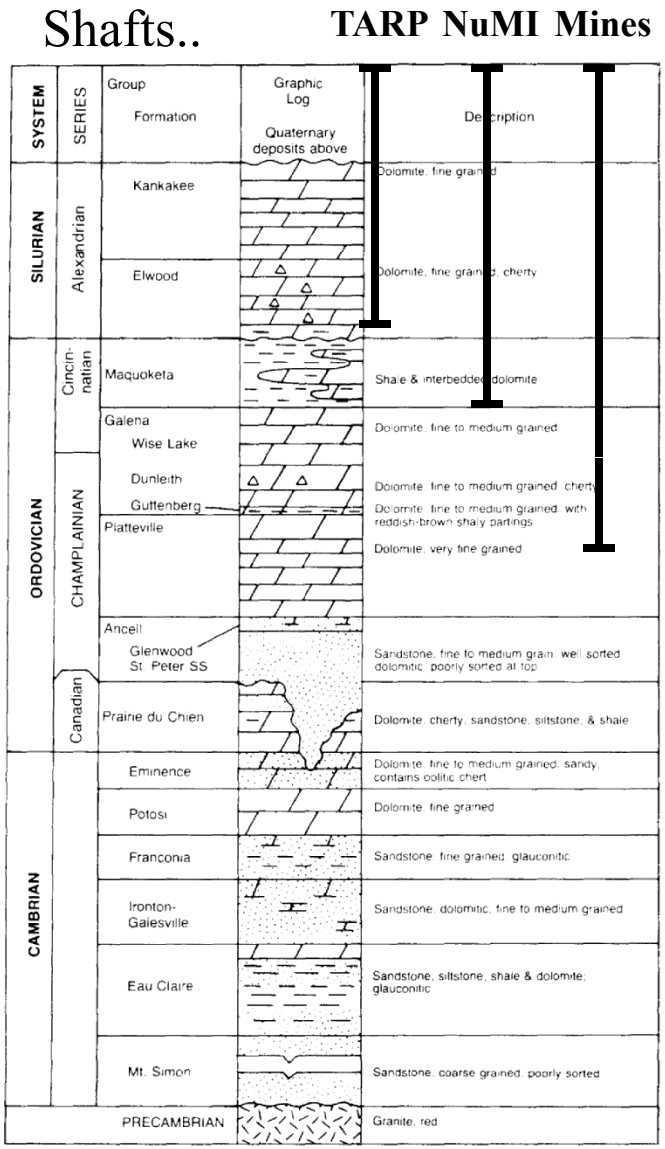
Lessons for the Long Baseline

"Those that fail to learn from history are doomed to repeat it."
Winston Churchill

Long Baseline - Some Geo-Design Issues

- What can we expect for a Long Baseline set of excavations in..
  - Glacial Tills
  - Bedrock Units
    - Silurian Dolomites,
    - Ordovician Units
    - Maquoketa Units
      - Brainard
      - Scales
    - Galena-Platteville Units
- Pending Site-specific investigation..

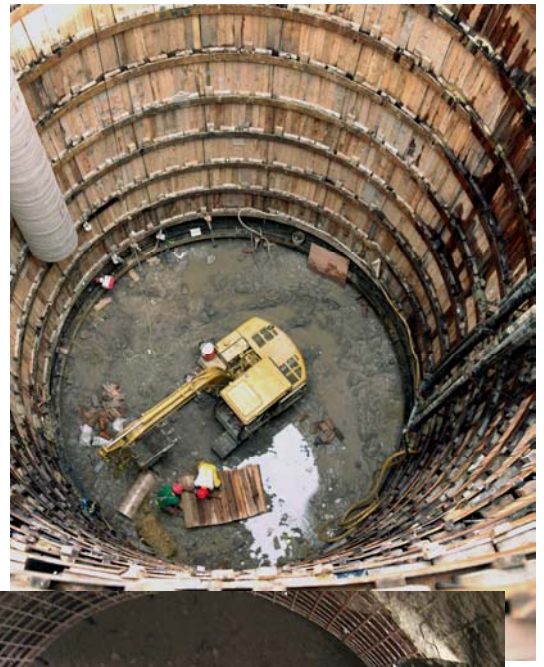
Shafts..



Source; ISGS/Harza 1988

Glacial Tills

- Glacial Tills at Fermilab
  - Mainly stiff clays, outwash sands and gravels to 20m depth
  - Wider range of conditions likely over a wider area..
- NuMI Construction Issues..
  - Carrier Tunnel dewatering across soil/rock contact ~ OK
  - Shaft pre-grouting ~ ineffectual..
  - Shaft mining..
    - Alleged DSC at MINOS Shaft
- Significant long-term draw-downs observed around the Target Hall and Construction Shafts (ref. Geoff Eargle's water level plots)

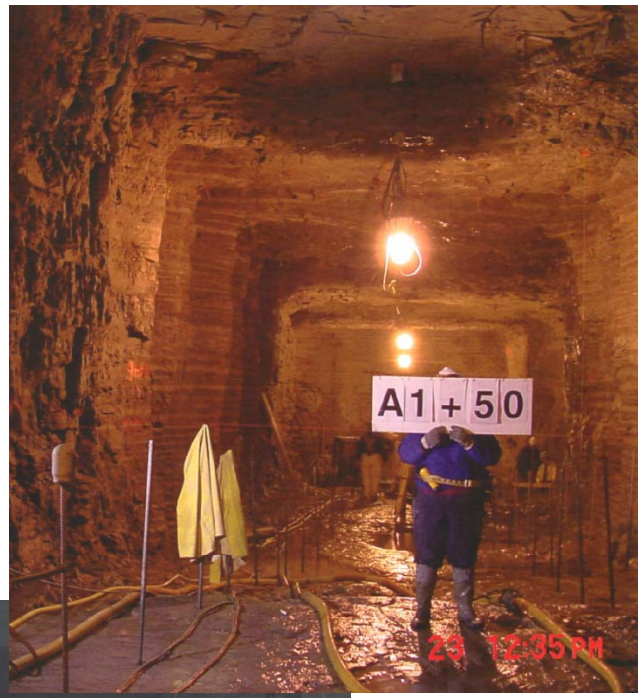


Silurian Dolostones..

- Silurian Rock Mass..
  - Dolostones with vuggy/shaley beds & partings
  - Support with dowels and reinforced shotcrete
  - Water inflows encountered ~ on bedding (TARP ~ on-jointing)
- Construction Issues..
  - Block/wedge and on-bed failures
  - Larger clay-filled solution pockets encountered (acknowledged DSC's)
  - Water infiltrations - limited connectivity.. (alleged DSC's)
  - Some clay beds/layers (alleged DSC's too ~ TH)
- TBM flooding - pump failures

Maquoketa by Drill & Blast

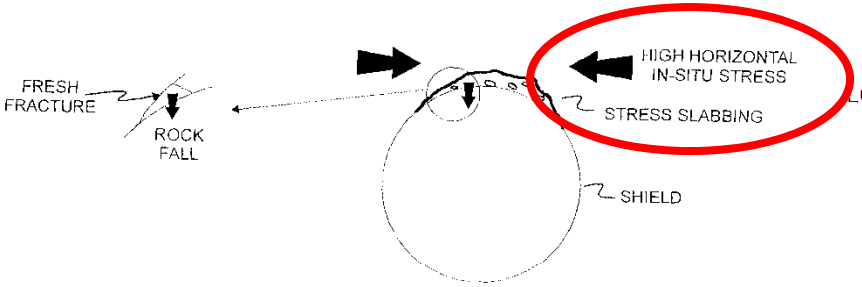
- Maquoketa Rock Mass..
  - Intermediate strength dolo-siltstone (Brainard) overlying weaker, relatively massive claystone (Scales)
  - Rock Support by dowels and reinforced shotcrete
- Construction Issues..
  - Slake-sensitive materials
  - Shotcrete applied within given time frame on all excavation surfaces
  - Overbreak



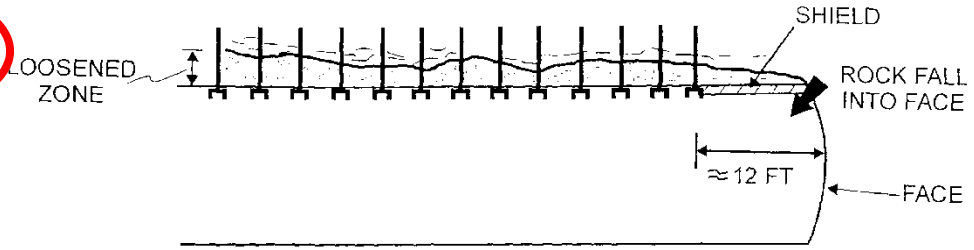
Maquoketa Mechanically Mined

- Delays due to..
  - Rock Falls (Slabbing)
  - Floor Heave
  - Floor Deterioration
- Extra Work..
  - Support Installed
  - Clean-up
- Large Claims Filed..
  - Excess Overstress Fall-Out
  - Excess Invert Deterioration
  - Constructive Acceleration

Behavior had been anticipated by the Contractor's consultant.. C. claimed there was "more" than anticipated!



Cross-Section



Longitudinal Section

Galena Platteville Adverse Behaviors?

- **NOT** perfect.. reference SSCL Reports
  - Slaking/Slabbing Potential ~ as in Maquoketa
  - Open Fracture System ~ as in Silurian (mainly filled)

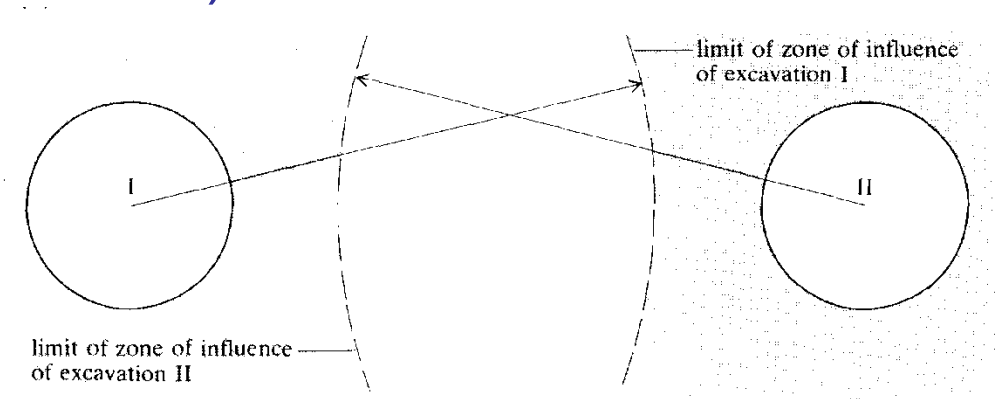
An Ekberg "Whopper"
Norht Aurora Mine

Optimizing Surface Stability - 100% Lining

- Even if just for egress/inspection purposes.. e.g. DT passage

Optimizing Geo-Stability

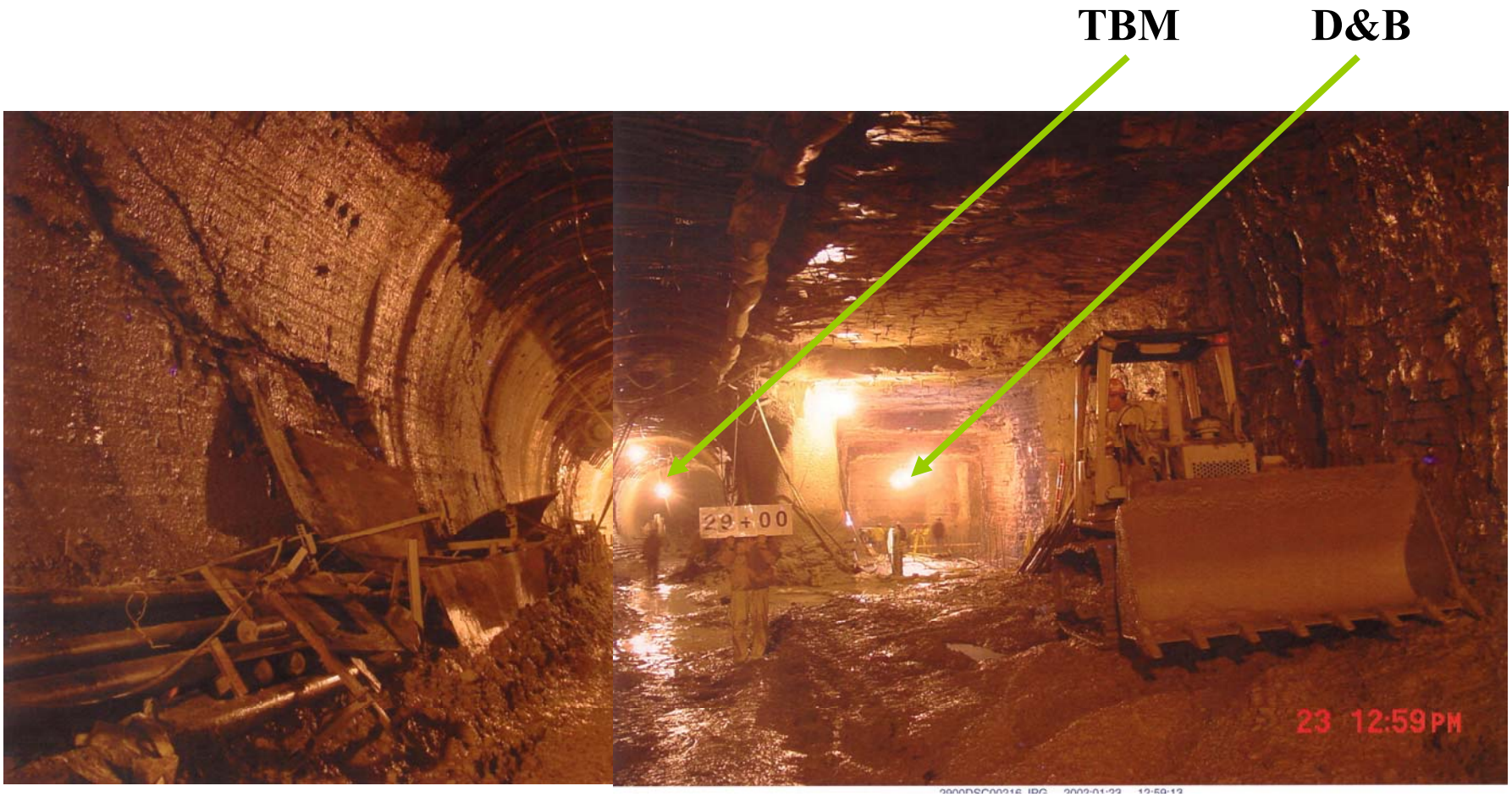
- Strength:stress ratios reduced in narrow pillars..
  - Site-specific layout studies
  - Attention to the stress regime in weaker/deeper strata (e.g. NOvA Near)



Overlapping Zones of Influence.. Stress Superposition

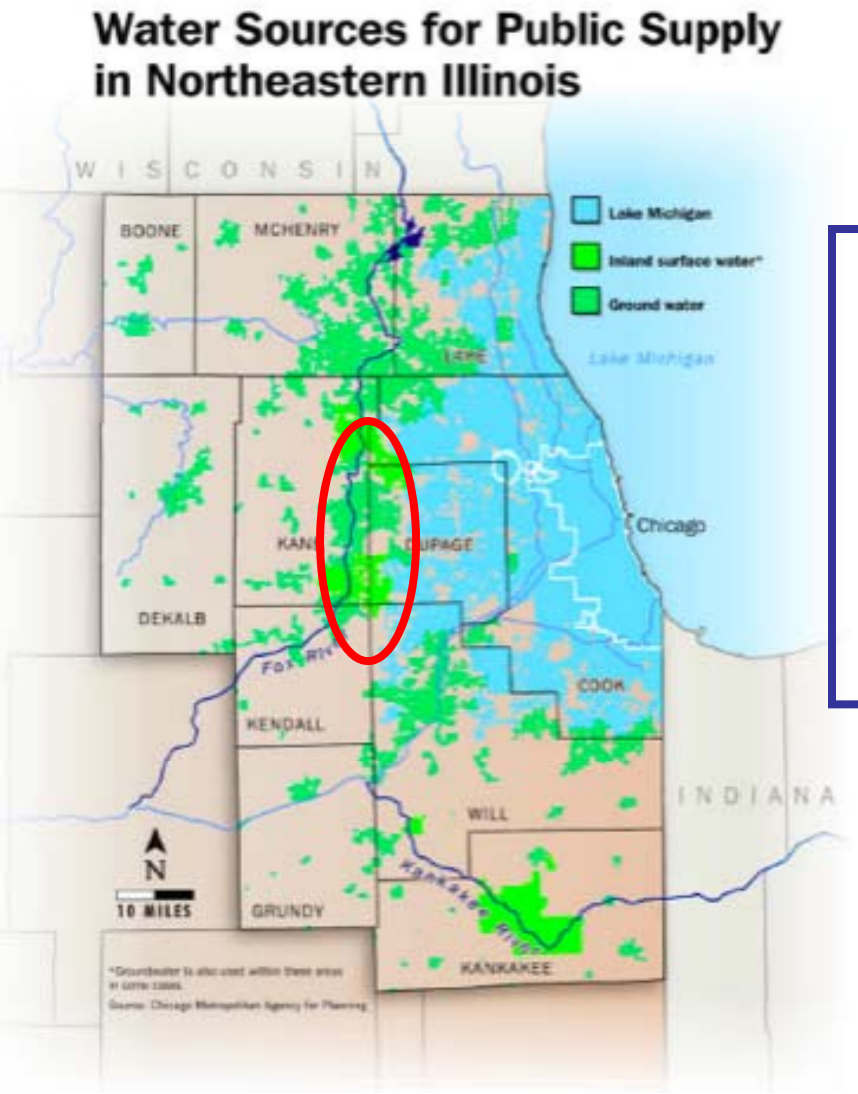
Optimizing Stability - Method Choices

- Ensure advantages of mechanical excavation are not lost by needs for additional support..

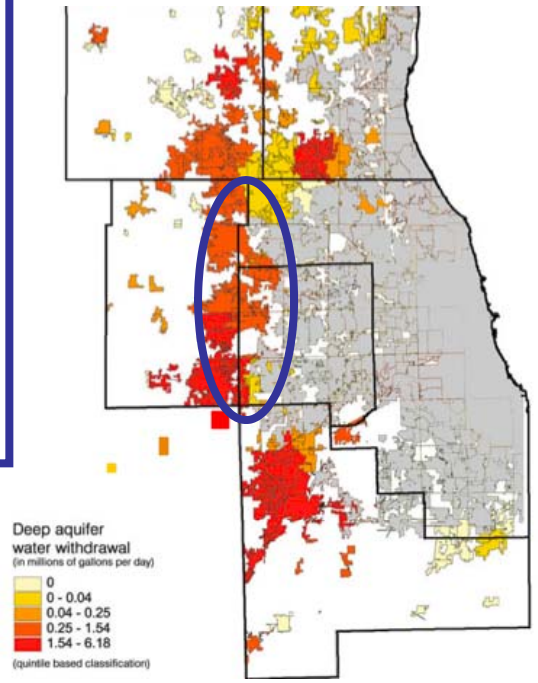


Improving Groundwater Modeling

- Groundwater.. Critical Resource
  - Integrated, Long-Term Modeling
    - Site Investigation/Field Monitoring



Understanding the impact of our excavations on the shallow & deep water resources.. now and in the future



Deep Aquifer Pumping

Improving In-Tunnel Water Control

- NuMI Underground Designs to be Revisited..
  - Increased provisions for watertightness, inspection, sampling, drainage, maintenance/clean-out....
  - **Expect to Pay Additional $'s..**

Improving Public Relations - Less Blasting

- Minimize/Eliminate need to Blast
- Reduce Damage to the Rock Mass
- Less Cost-Effective in Harder, More Abrasive Rocks
- Overstress potential in Wise Lake & Dunleith (orientation)

South Elgin

Improving Early Estimating Accuracy..

- Can we afford to build it?.. Setting more Realistic Budgets (Braidwood/Diablo Canyon Underground)
- Desktop Scoping Study, based on available data
- Professional underground estimate with Balanced-Bid Estimate/Schedule and Back-Up
- Independent critical reviews of work products – with feedback on construction risk/contingency

(memo to self.. pre-investigation we're all geo-optimists)

Improving Early Contingency Setting

- Early whole project risk analysis not just excavation work.. identify all threats/opportunities..
- Reviews by multidisciplinary team(s) a necessity..

Contract documents and company relations
- client – past working relationship
- customer's expectations
- sub-contractor/suppliers – competence, past working relationship
- contract conditions
- payment terms
- scope of works
- risk allocation – (e.g. ground risk)
- past design and build working relationship
- responsibility/authority boundaries
- communication lines
- handling information
- sensitivity to change (cost and time, alternative approaches)

Staffing
- staffing requirements
- relevant experience
- expertise involved at appropriate stage
- limitation of knowledge/expertise
- use of in-house specialists

Third parties and sensitivity
- Third party involvement
- reliance on other parties
- adjacent structures and services
- public involvement/concern
- location
- environmental issues
- aesthetics of finished work
- noise
- vibration

Approvals
- access
- regulations – environment, safety
- planning consents, licences
- client approvals
- waste management/minimisation

Ground conditions
- assessment of desk study, site investigation, interpretative report (are they adequate?)
- geological environment – potential variability, potential hazards
- hydrogeology – seasonal changes, long-term changes
- groundwater control
- contamination
- soil/structure interaction issues
- ground/structure movement
- earthworks

Design
- clear, unambiguous design brief
- serviceability criteria
- innovations or proven technology/methods/materials
- design interfaces
- adequacy and reliability of incoming data
- unforeseen mechanisms
- robustness of solution – design, workmanship, assumptions

Construction
- past experience with proposed methodology
- on-site verification/problem identification
- buildability
- maintenance
- innovations or proven technology/methods/materials
- instrumentation/monitoring
- construction interfaces
- feedback to verify design assumptions
- potential for observational method
- influence of changes to ground conditions
- temporary works

Programme
- sequencing of works
- time available
- access constraints
- availability of staff/specialist plan

What can go wrong?

Reviews by teams that knows what can go wrong!

generic prompt list
BTS '04

The sooner the better ..redesigns avoided ..opportunities for innovation created.

Improving Design/Construction Practices

- Precedent/experience often best guide.. Seek Projects
  - Similar ground condition
  - Similar design criteria (safety/enviro/durability/stability)
    - Materials/Methods/Means (ref. contractors' pool of best practices)
    - Diverse perspectives (owners/operators, designers, CM's, builders, vendors, manufacturers, end-users..)
    - Facilitate interaction between Estimating/Design/CM contactors
  - For outside help.. objectively assess performance on similar projects.. Use the best we can reasonably afford..
    - Project References (contacts)
    - Published Papers
    - Work Product Reviews
    - CM/Design Contractors ~ Quality Based Selection /CERN Surveys

NuMI Underground - More Info..

- For those who would like to read more on geotech aspects of NuMI..
  - Featured Project.. UCA of SME website..
  - “Drawing from past experience to improve the management of future underground projects.” (FERMILAB-CONF-04-536, 2004. 6pp)
  - “Construction of the NuMI underground laboratory facilities.” (FERMILAB-CONF-03-497, 2003. 9pp.)