

A topographic map of a region in Missouri, showing contour lines, roads, and a river. The map is oriented with the river flowing from the top right towards the bottom left. The text is overlaid on the map.

Construction and Quality Assurance – Quality Control  
High Capacity Micropiles in Mined Ground for Bridge Support

Route 249/171  
Joplin, Missouri

International Society for Micropiles  
8<sup>th</sup> International Workshop on Micropiles  
Toronto, Ontario, Canada

John Szturo R.G. Senior Geologist – HNTB Corporation  
Marcelo Chuaqui – Monir Precision Monitoring  
Tim Myers – Layne GeoConstruction  
Michael Middleton P.E. MoDOT

# ELEMENTS OF CONSTRUCTION RISK MANAGEMENT

- Issue a GBR – Geotechnical Baseline Report – all claims would be based on the GBR.
- Prequalification Process – Owner and Engineer Reviews Contractor Qualifications
- Real time Construction Monitoring
- Regular Team Meetings to Resolve Problems
  - Monthly Progress Meetings – All Parties
  - Weekly Construction Meetings between Resident Engineer and Contractor

# Contractor Prequalification

## WHY?

- **Site extremely complex with highly variable geology**
- **Methods proposed to investigate and treat the foundation rock would require interactive implementation during construction**
- **The ground conditions required a high level of construction expertise, flexibility, and responsiveness.**
- **The contractor would need to be able to react to variations in drilling and grouting conditions and highly variable quantities between adjacent hole locations**

# Contractor Prequalification Requirements

- Corporate
  - 5 similar projects in last 3 years
- Personnel
  - Superintendent with 5 years of similar job experience
- Specific Technical Experience
  - Drilling and grouting in similar conditions
  - Monitor While Drilling Experience
  - Ability to process, interpret, display and act upon data during construction
- Installation and Work Plan
  - Safety plan with special consideration to mine shafts
  - Operation sequence
  - Drilling Methods
  - Grout and reinforcement placement
  - Details of automated recording and reporting systems
  - Details of grout types
  - Details of micropile testing equipment and procedures
  - Understanding the scope of work and interaction with investigation, pretreatment, and practical operational interface with the Engineer.

# CRITICAL STEPS OF CONSTRUCTION INSPECTION

## CHARACTERIZE THE GROUND

- Site geology and subsurface conditions were deemed “chaotic”
- Subsurface conditions could change dramatically from boreholes drilled less than a meter apart

## CONSTRUCTION ENGINEERING AND INSPECTION

- Log each hole with subsurface conditions
- Verify ground conditions matched design assumptions
- Change design values based on conditions encountered

**\*Do all this with minimal delay**

# Real Time Monitoring During Construction

- Due to unpredictable nature of site, each treatment hole would be used to characterize the ground.
- Full time inspectors on each rig will log each hole.
- Contractor will furnish Monitor While Drilling (MWD) parameters to inspectors after each hole.
- Inspectors will interpret subsurface and prescribe treatment in real time.
- Avoid delays – Resolve conflicts. Resident Engineer charged with resolving most conflicts with contractor.

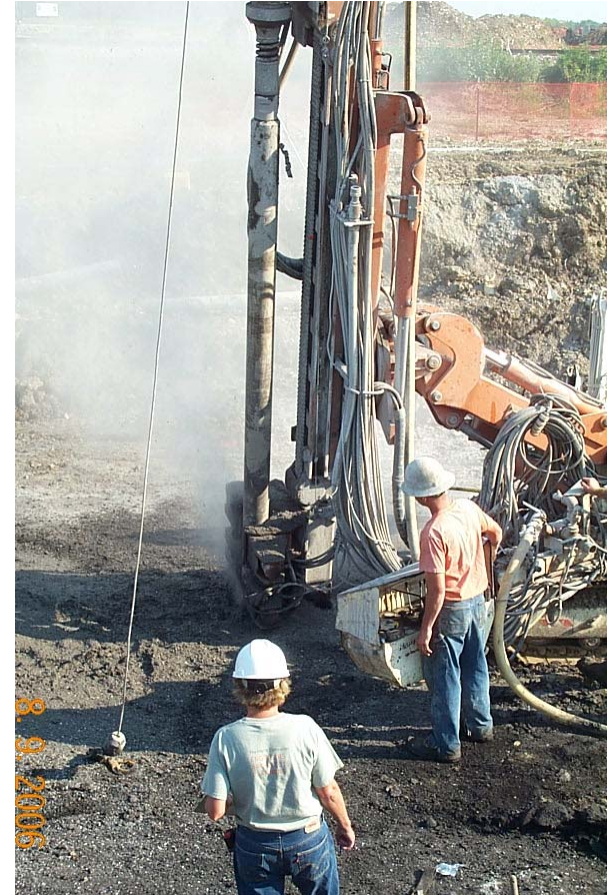
# Drill Rig Controls with Monitor While Drilling Instrumentation Drilling Rate- Thrust Pressure - Torque



## ■ Manual Monitoring

### – Rig Inspectors Recorded:

- o penetration rate
- o lithology
- o flush return characteristics (cuttings, volume)
- o drill “action”
- o interconnections between holes
- o hole stability
- o groundwater observations





# Inspectors Drill Log



## DRILLING LOG

Route 249 - Jasper County, MO  
 MoDOT Project No. J7U0436K HNTB Job No 42500-CN-001-001

Start Date and Time: 10-12-2006  
 Finish Date and Time: 10-12-2006  
 Hole Number: 49BT-94  
 Driller's Name: DAVID DEWITT  
 Elevation at 0.0 depth: 1  
 Logged By: SATH PAINTER

Drill Rig Type/#: RATCH / 1R 750  
 Casing and Hole: 130 mm  
 Inclination of Hole: 90°  
 Drilling system: DTN  
 Page 1 of 2

Time		Depth (m)		Penetr. Rate	Material Description Provide description min every 1meter.	Remarks
Start	Finish	From	To			
09:12	09:17	0	0.73		LIMESTONE - LITTLE WEATH	H <sub>2</sub> O ON
09:17	09:24	0.73	1.72		LIMESTONE - SOLID	H <sub>2</sub> O ON INT M.
09:24	09:31	1.72	3.31		LIMESTONE / TR. BROKEN / WEATH.	H <sub>2</sub> O ON INT M.
09:36	09:36	3.31	4.81		LIMESTONE - LITTLE BROKEN	ADD ROD / H <sub>2</sub> O OFF
09:41	09:47	4.81	7.95		LIMESTONE	H <sub>2</sub> O OFF
09:47	09:54	7.95	10.84		LIMESTONE - SOLID / DUSTY	H <sub>2</sub> O ON / ADD ROD
10:01	10:08	10.84	13.60		LIMESTONE - WEATHERED	GROUND H <sub>2</sub> O
10:08	10:11	13.60	14.72		RAKEN / WEATH LIMESTONE	FEW COBBLES - CHEAT
10:11	10:13	14.72	16.89		CHEAT / W LIMESTONE	ADD ROD
10:18	10:25	16.89	20.16		LIMESTONE / SOME CHEAT / LITTLE CLAY	STEADY GROUND H <sub>2</sub> O
10:25	10:29	20.16	21.85		LIMESTONE / SOME CHEAT / LITTLE CLAY	STEADY GROUND H <sub>2</sub> O
10:29	10:30	21.85	22.97		CLAY / ROCKS - FEW HITS	ADD ROD
10:34	10:34	22.97	23.15		LITTLE ROCKS - HITTING	CLAY / CHEAT SOLEM
10:34	10:37	23.15	27.80		CLAY / TR. ROCKS - FEW HITS	
10:37	10:38	27.80	28.52		VERY BROKEN ROCKS - HITS - PUSH THRU	
10:38	10:39	28.52	29.05		CLAY / TR. ROCKS - FEW HITS	ADD ROD
10:45	10:46	29.05	30.80		VERY BROKEN ROCKS	
10:48	10:48	30.80	31.05		CLAY / TR. ROCKS - FEW HITS	
10:48	10:48	31.05	31.72		VERY BROKEN ROCKS	
10:48	10:51	31.72	35.14		CLAY / ROCKS - FEW HITS	REAM / ADD ROD

Note: Indicate bottom of casing depth and final drill depth.

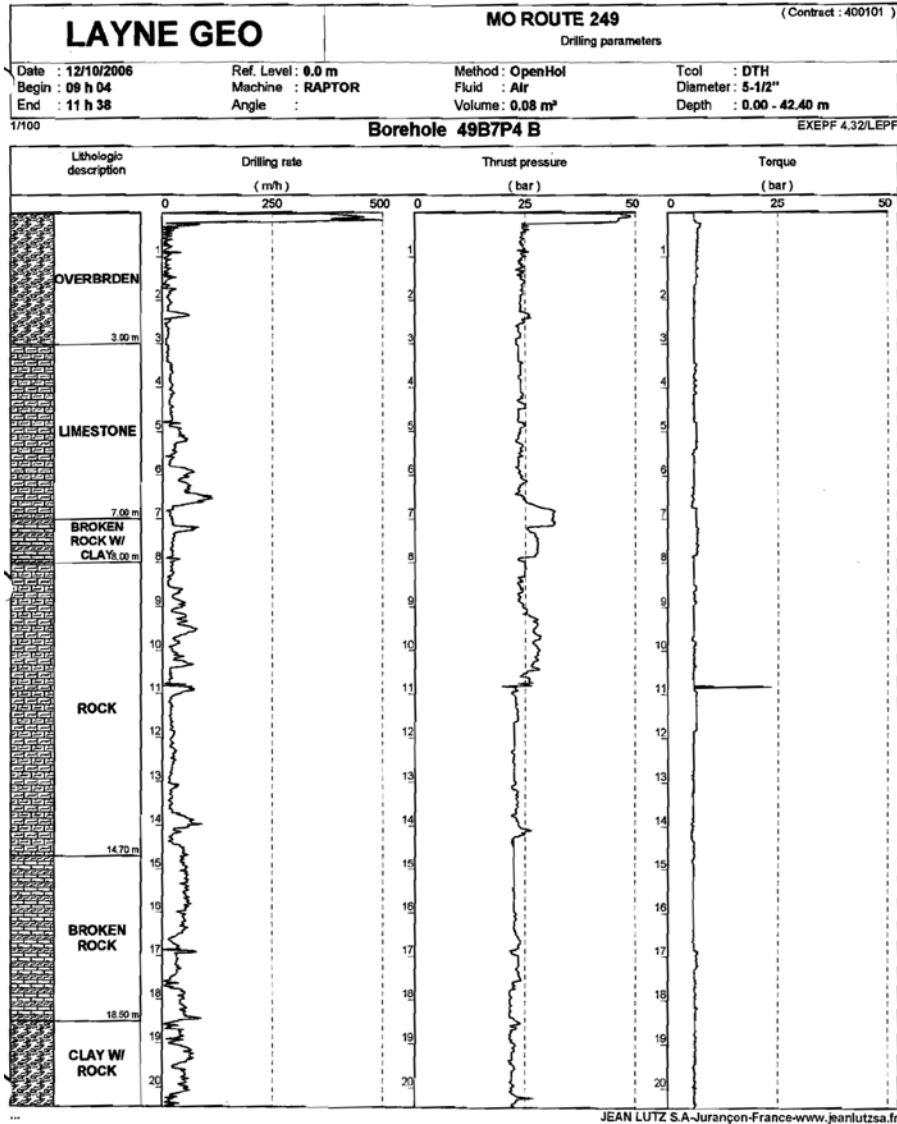
Contractor Representative: \_\_\_\_\_

Owner Representative: 

-LEAKS IN H<sub>2</sub>O LINE MAY BE FEEDING HOLE INDEPENDANT OF SWITCH



# Contractors MWD Drill Parameter Log



# Inspectors Low Mobility Grout Log



## LMG Grout Log Sample

Project: Route 249 - Jasper Co, MO

Page 1 of 2

Job#:

Hole: 49 B7-P5

Date: 10-18-06 / 10-19-06

Pump Type: Schwab WPS00X

Casing Diameter: 200

Slump: 6" Max

Casing Depth (meters)	Time		Maximum Gage Pressure (psi)	Grout Quantity		Reason for Stopping Injection	Comments
	Start	Stop		Strokes	Cubic Feet		
52	14:00	14:05	600	90		1	Truck 1 Stop 4"
50	14:03	14:05	600	95		1	
48	14:08	14:10	600	104		1	Remove Rod
46	14:10	14:35	200	378		4	8 yds
46	14:45	15:10	300	393		4	16 yds
46	15:10	15:40	250	375		4	Truck 3
46	15:45	16:10	400	385		4	Truck 4
46	16:10	16:35	300	338		4	Truck 5
46	16:40	17:00	300	272		4	Truck 6
44	17:00	17:08	350	358		4	48 yds
44	17:10	17:12	600	66		1	Truck 7
42	17:18	17:30	250	395		4	5 yds
42	17:30	17:35	500	130		1	Truck 8
40	17:25	17:45	480	335			rod sticks
38	17:45	17:50	400	388		4	64 yds
Refracted obtained			36 m depth				10-18-06
36	8:40	8:55	500	72			10-19-06
34	8:55	9:00	600			1	Truck 1 Slump 3 1/2"
32	8:56	8:57	600	85		1	
30	8:04	8:05	600+			1	Remove Rod
28	8:05	8:06	60+				
26	8:06	8:40	300	405		4	72 yds
26	8:45	9:00	600	110		1	Truck 2
24	9:00	9:01	600	112			Remove Rod

Reason for Stoppage: 1 = Refusal Pressure, 2 = Ground Heave, 3 = Grout Leak, 4 = Shift End/Breakdown/Grout Supply

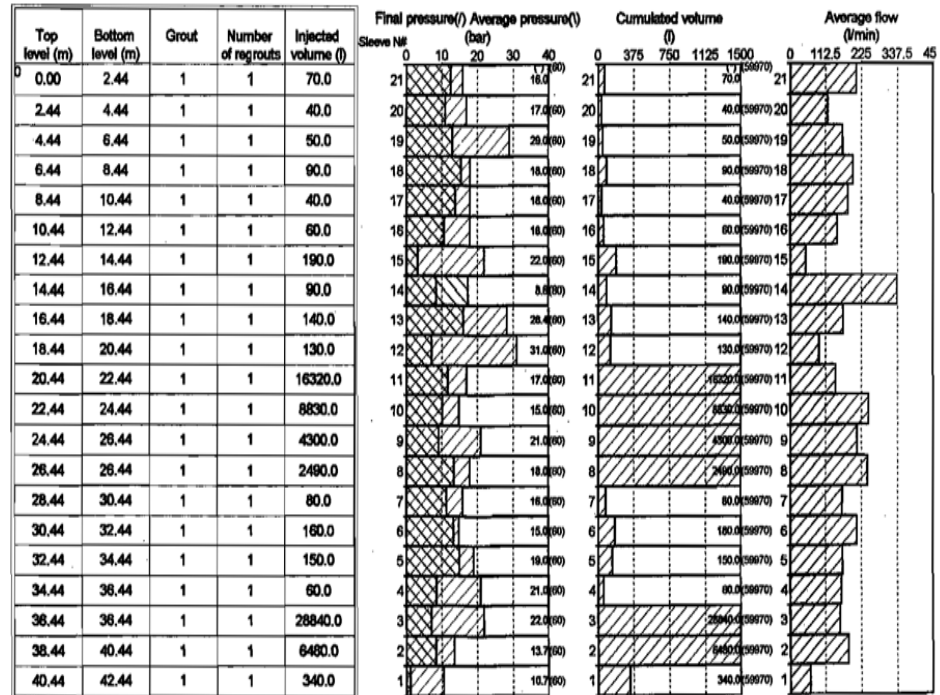
Total Volume Injected During This Operation: 34 cubic yards 64 on 10-18-06  
 Owner Representative: \_\_\_\_\_ 20 on 10-17-06  
 Contractor Representative: \_\_\_\_\_



# MWD Low Mobility Grout Log

<b>MO RT 249</b>	<b>LAYNE GEOCONST</b> (Contract N#: 400101)	
	COMPACTION GROUTING Pressure/Volume/Flow	
< site settings >		
Breaking pressure : 0 bar	Sleeve volume : 0 l	
Safety pressure : 60 bar	Delay time : 0 s	(current set of instructions)

Borehole 49B7P4 10/17/06



Cumulated volume (Gr.) : 68970l	Number of grouted sleeve(s): 21
Sampling (Gr.) : 2 s	(*) : measured values (*) : requested values

# Inspectors High Mobility Grout Log



## HMG Grout Log

Project: Route 249 – Jasper Co, MO

Page 1 of 6

Job#:

Hole: 4986-5-9

Date: 10-17-06

Grout Operation: \_\_\_\_\_

Date Hole Was Drilled: 10-11-06

Stage Depth Interval (Meters)	Time	Pressure (PSI)	Injection Rate (Gal/Min)	Total Volume Reading (Gallons)	Cumulative Take For Stage (Gallons)	Reason For Stopping Injection	Comments and QA/QC Data Marsh Cone, Specific Gravity
21	13:14	0	0	0			Mix A
	13:15	18 <sup>0</sup>	14 <sup>3</sup>	13			Air Pressure 110 PSI
	13:16	0	0	32		minitrend not working	
	13:17	0	0	32			
	13:18	11 <sup>20</sup>	18 <sup>45</sup>	46			
	13:19	0	0	55		Pump malfunctions	
	13:20	0	0	55			S.G. = 1.53 ; m.c = 45
	13:25	177 <sup>0</sup>	20 <sup>45</sup>	147		check packer	
	13:29	0	0	147			
	13:30	17 <sup>30</sup>	19 <sup>24</sup>	170			
	13:35	33 <sup>40</sup>	20 <sup>9</sup>	274			
	13:40	40 <sup>30</sup>	20 <sup>70</sup>	386		check packer replace Rt. Bottle	
	13:48	0	0	386			Air Pressure 110 PSI
	13:49	34 <sup>20</sup>	13 <sup>44</sup>	403			
	13:50	46 <sup>80</sup>	17 <sup>21</sup>	418			Mix B
	13:55	69 <sup>40</sup>	12 <sup>40</sup>	495			SG 1.62 m.c 64
	14:00	87 <sup>60</sup>	0 <sup>20</sup>	505			Start Reversal
↓	14:01	87 <sup>20</sup>	0 <sup>29</sup>	505			
21	14:02	87 <sup>30</sup>	0 <sup>29</sup>	505			

Reason for Stoppage: 1 = Refusal Pressure, 2 = Ground Heave, 3 = Grout Leak, 4 = Shift End/Breakdown/Grout Supply

Total Volume Injected During This Operation:  $3917 \text{ gals} = 31480 \text{ cu}$

Owner Representative:

Contractor Representative:



# MWD High Mobility Grout Log



**GeoConstruction**

**SPECIALTY FOUNDATION CONSTRUCTION**

*a Division of Layne Christensen Company*

Missouri Dept. of Transportation  
Rte. 249 Interchange

Ground Treatment and Microp  
40.0

## HMG APRD Data

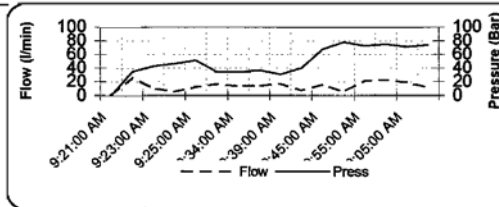
49B6S8

Grout Date: 10/10/06

**Stage 1** 24.0 m to 21.0 m

**Volume:** Mix A 242.0 gall  
Mix B 523.0 gall  
Mix C gall  
trimie 0.0 gall  
Stage Volume 765.0 gall

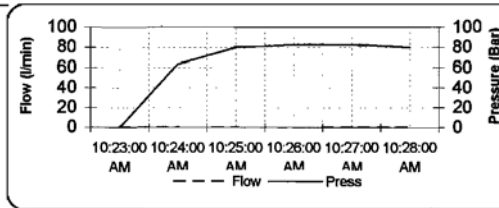
**Note:** REFUSAL



**Stage 2** 21.0 m to 18.0 m

**Volume:** Mix A 7.0 gall  
Mix B gall  
Mix C gall  
trimie 17 gall  
Stage Volume 24.0 gall

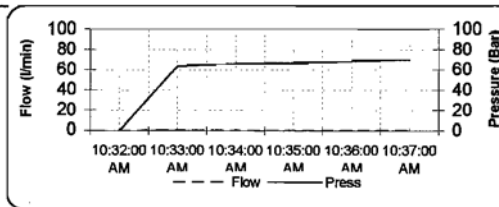
**Note:** REFUSAL



**Stage 3** 18.0 m to 15.0 m

**Volume:** Mix A 5.0 gall  
Mix B gall  
Mix C gall  
trimie 0.0 gall  
Stage Volume 5.0 gall

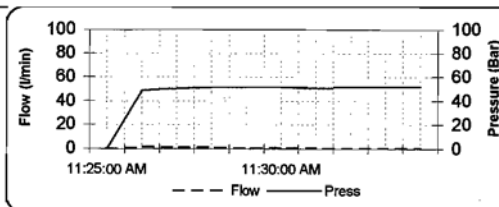
**Note:** PACKER STUCK



**Stage 4** 11.0 m to 9.0 m

**Volume:** Mix A 11.0 gall  
Mix B gall  
Mix C gall  
trimie 0.0 gall  
Stage Volume 11.0 gall

**Note:** REFUSAL



# Inspectors Micropile Installation Log

HNTB		FILE <input type="checkbox"/>																																																																																																																			
Project Name: <u>Route 249 - Jasper Co. MO</u>		Installed Date: <u>Casing 11-16-06 Bar 11-19-06</u>																																																																																																																			
Location/Area: <u>Bridge 6149, Bent 6</u>		Design Capacity: <u>1565 kN</u>																																																																																																																			
Weather/Temp: _____		Pile No.: <u>4906-MI-67</u>																																																																																																																			
Standard Micropile Installation Log and Report (Use Additional Pages as Needed)																																																																																																																					
<b>(A) Construction Dimensions (min U.N.C.)</b>		<b>(B) Reinforcing Steel Specifications</b>																																																																																																																			
Refer to Standard Drilling & Drive Log For Soil Description		Casing Diameter: 193.7 mm x 12.7 mm																																																																																																																			
Date Drilled (Complete): <u>11-19-06</u>		Bar Diameter: 63.5 mm - Epoxy Coated																																																																																																																			
Surface El: <u>296.80</u> (Bottom of Footing)		Comments: _____																																																																																																																			
Final Stick-Out: Casing <u>0.25 m</u> Bar <u>0.60 m</u>		<b>(C) Casing Grouting</b>																																																																																																																			
<table border="1"> <tr> <th>Depth (m)</th> <th>Casing Log Time</th> <th>Casing Profile</th> <th>Pile Installation</th> <th>Connection Description:</th> </tr> <tr> <td>0.00</td> <td></td> <td></td> <td></td> <td><b>THREADED COUPLER</b></td> </tr> <tr> <td>1.000</td> <td>Overburden</td> <td></td> <td></td> <td><b>337mm x 114mm OD</b></td> </tr> <tr> <td>2.000</td> <td>Limestone</td> <td></td> <td></td> <td><b>9.41 Total Length (m)</b></td> </tr> <tr> <td>3.000</td> <td>Limestone</td> <td></td> <td></td> <td><b>-0- Top of Casing (m)</b></td> </tr> <tr> <td>4.000</td> <td>Limestone</td> <td></td> <td></td> <td><b>3.20 Bottom Casing (m)</b></td> </tr> <tr> <td>5.000</td> <td>Limestone/grout</td> <td></td> <td></td> <td><b>-0- Top Re-Steel (m)</b></td> </tr> <tr> <td>6.000</td> <td>Limestone</td> <td></td> <td></td> <td><b>9.41 Bottom Re-Steel (m)</b></td> </tr> <tr> <td>7.000</td> <td></td> <td></td> <td></td> <td><b>Depth of Re-Steel (m) (Approx.)</b></td> </tr> <tr> <td>8.000</td> <td></td> <td></td> <td></td> <td><b>Approx. Location of Centralizers:</b></td> </tr> <tr> <td>9.000</td> <td></td> <td></td> <td></td> <td><b>245/160 Hole Diameter (mm)</b></td> </tr> <tr> <td>10.000</td> <td></td> <td></td> <td></td> <td><b>72.9 Hole Inclination, Deg (averd by Angle Tool)</b></td> </tr> <tr> <td>11.000</td> <td></td> <td></td> <td></td> <td><b>30/100 Rebar</b></td> </tr> <tr> <td>12.000</td> <td></td> <td></td> <td></td> <td><b>Comments/Remarks:</b></td> </tr> <tr> <td>13.000</td> <td></td> <td></td> <td></td> <td><b>QA/QC Testing:</b></td> </tr> <tr> <td>14.000</td> <td></td> <td></td> <td></td> <td><b>Depth of Scale</b></td> </tr> <tr> <td>15.000</td> <td></td> <td></td> <td></td> <td><b>Top of Rock</b></td> </tr> <tr> <td>16.000</td> <td></td> <td></td> <td></td> <td><b>Bottom of Hole</b></td> </tr> <tr> <td>17.000</td> <td></td> <td></td> <td></td> <td><b>Bottom of Casing</b></td> </tr> <tr> <td>18.000</td> <td></td> <td></td> <td></td> <td><b>Location of Casing Joints</b></td> </tr> <tr> <td>19.000</td> <td></td> <td></td> <td></td> <td><b>Locations of Centralizers</b></td> </tr> <tr> <td>20.000</td> <td></td> <td></td> <td></td> <td><b>Location of ReGrout Tubes</b></td> </tr> <tr> <td></td> <td></td> <td></td> <td></td> <td><b>Extent of Bond Zone</b></td> </tr> </table>	Depth (m)	Casing Log Time	Casing Profile	Pile Installation	Connection Description:	0.00				<b>THREADED COUPLER</b>	1.000	Overburden			<b>337mm x 114mm OD</b>	2.000	Limestone			<b>9.41 Total Length (m)</b>	3.000	Limestone			<b>-0- Top of Casing (m)</b>	4.000	Limestone			<b>3.20 Bottom Casing (m)</b>	5.000	Limestone/grout			<b>-0- Top Re-Steel (m)</b>	6.000	Limestone			<b>9.41 Bottom Re-Steel (m)</b>	7.000				<b>Depth of Re-Steel (m) (Approx.)</b>	8.000				<b>Approx. Location of Centralizers:</b>	9.000				<b>245/160 Hole Diameter (mm)</b>	10.000				<b>72.9 Hole Inclination, Deg (averd by Angle Tool)</b>	11.000				<b>30/100 Rebar</b>	12.000				<b>Comments/Remarks:</b>	13.000				<b>QA/QC Testing:</b>	14.000				<b>Depth of Scale</b>	15.000				<b>Top of Rock</b>	16.000				<b>Bottom of Hole</b>	17.000				<b>Bottom of Casing</b>	18.000				<b>Location of Casing Joints</b>	19.000				<b>Locations of Centralizers</b>	20.000				<b>Location of ReGrout Tubes</b>					<b>Extent of Bond Zone</b>	<b>(D) Bond Zone Grouting</b>	
	Depth (m)	Casing Log Time	Casing Profile	Pile Installation	Connection Description:																																																																																																																
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Date of Bond Grouting: <u>11-19-06</u>		Cement Type: <u>I-II</u> Supplier: <u>Ashgrove (Bulk)</u>																																																																																																																			
W/C Ratio: <u>0.45</u> Spec. Gravity: <u>1.95</u>		Admixtures/Dosage: _____																																																																																																																			
Pressure: _____ Volume: <u>0.16 m<sup>3</sup></u>		GMAQC (i.e. cubes, beam balance, marsh cone, ASTM #1, etc.)																																																																																																																			
Date of Bond Grouting: <u>11-19-06</u>		Cement Type: <u>I-II</u> Supplier: <u>Ashgrove (Bulk)</u>																																																																																																																			
W/C Ratio: <u>0.45</u> Spec. Gravity: <u>1.94</u>		Admixtures/Dosage: _____																																																																																																																			
Pressure: _____ Volume: <u>0.21 m<sup>3</sup></u>		GMAQC (i.e. cubes, beam balance, marsh cone, ASTM #1, etc.)																																																																																																																			
Additional Remarks/notes: Cased Length: <u>3.20 m</u> Bonded Length: <u>6.50 m</u> Total Length: <u>9.70 m</u>																																																																																																																					
S. Overholts HNTB Representative		11-20-06 Date																																																																																																																			
		Layne's Representative																																																																																																																			

# Four Phases of Route 249 Construction

- **Mine Shaft Closure**
  - Explore at suspected shaft locations
  - Close known shaft locations and those found during exploration
    - Type 1 Closure – Fill with LMG
    - Type 2 Closure – Cap with Structural Concrete
- **Ground Treatment**
  - Explore and Fill Mine Voids at Bridge Approach Embankments and at known mined areas near bridge foundations
  - Involved Systematic drilling and treating with LMG on a grid pattern to a predetermined depth
- **Foundation Treatment**
  - Excavate Foundation Locations and Examine for Mining Activity
  - Treat with Combination of LMG and HMG to Improve Ground and Limit Micropile Grout Take
- **Micropiles**
  - Install and Test Design Verification Piles
  - Install Production Micropiles
  - Perform Proof Tests



# Mine Shaft Closure – Type 1

## “Critical Shaft”

- Definition:

“Mine shafts/open features located within 15-meters of a major structural element or within 5-meters of the footprint of an embankment or cut.”

- Construction Procedure

- Exploratory Mine Feature Inspection Excavation – Dig with Backhoe

If Mine Feature Exists:

- Excavate to top of rock
- Drill and grout from base of shaft to top of rock
- Verify closure with two secondary holes, grout as necessary

Abandoned Mine Shaft - 1.5 x 1.5 meters  
45 meters deep



# Grouting Mine Shaft with Low Mobility Grout



# Injection of Low Mobility Grout into Mine Shaft Previously Capped by MDNR



# Placement of Low Mobility Grout with Concrete Pump



## Mine Shaft Closure – Type 2 “Non-Critical Shaft”

- Definition:
    - “Mine shafts/open features located **beyond** 15-meters of a major structural element or **beyond** 5-meters of the footprint of an embankment or cut.”
  - Construction Procedure
    - Exploratory Mine Feature Inspection Excavation Dig with Backhoe
- If Mine Feature Exists:**
- Excavate to top of rock
  - Plug throat with polyurethane foam and cap with concrete

# Expose Mine Shaft Opening



# Type 2 Mine Shaft Closure – Structural Concrete Cap

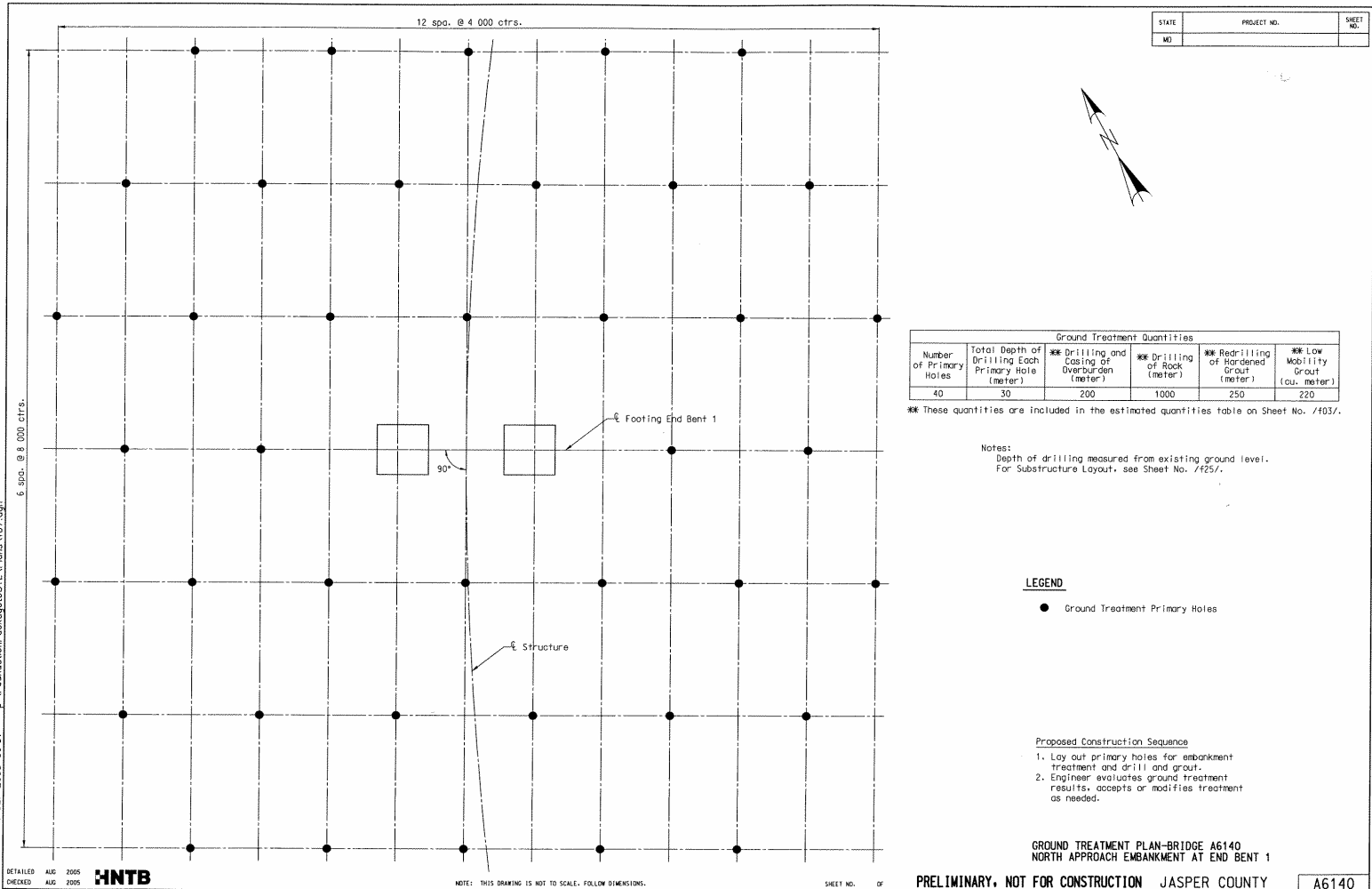




# Ground Treatment – Bridges – Walls - Culverts

- Philosophy:
  - Locate and treat unforeseen mine features and/or voids
- Construction Procedure
  - Drill primary holes (30-meters deep) in predetermined pattern shown on drawings
  - Grout primary holes utilizing Low Mobility Grout (LMG)
    - Small fissure grouting is not necessary

# Typical Layout - Ground Treatment – 4 Meter Grid



USER: cpeters  
PLOT/ICD: 15-SEP-2005 06:01 p:\FoundationPackets\STL\Plans\107.dgn

DETAILED AUG 2005  
CHECKED AUG 2005

**HNTB**

NOTE: THIS DRAWING IS NOT TO SCALE. FOLLOW DIMENSIONS.

SHEET NO. OF

PRELIMINARY, NOT FOR CONSTRUCTION JASPER COUNTY

A6140

# Typical Hole Layout for Ground Treatment



# Ground Treatment at Retaining Wall



# Ground Treatment at Box Culverts



# “Making Water” Adjacent Drill Hole Foundation Treatment



## “Losing Water” Adjacent Drill Hole



# Controlling Artesian Groundwater with High Mobility Grout





# Spread Footings Bearing on Rock



# Micropiles - Installing Permanent Casing



# Drilling Battered Micropile Bond Length



## Attaching Tremie Tube and Centralizers



# Micropile Reinforcing – 2 ¼” Thread bars



# Installing Reinforcing Bars



# Mixing Micropile Grout



# Freshly Grouted Micropile





# Micropile with Nut and Shear Plate



## Six Piles for Typical Footing



## Construction Costs “K” Job

Planned Cost = \$5,396,238

Actual Cost = \$5,565,100

3 Percent over run of plan cost

### Fun Facts

•17,895 Meters of Drilling = 58,710 Feet = 11 Miles

•6964 Cubic Meters of Grout = 9108 Cubic Yards = 2 Miles of Two Lane Roadway

•3,270 Meters Micropiles = 10,728 Feet = 2 Miles

A topographic map of a mountainous region, likely the Andes, showing contour lines, a river, and a road. The map is oriented with the mountain range running diagonally from the top-left to the bottom-right.

# Foundation Package Design Team

Geotechnical, Structural Engineering and Construction  
Engineering and Inspection

HNTB

Micropiles and Grouting

Geosystems Inc – Donald Bruce

Isherwood and Associates – Marcelo Chuaqui

Rock Mechanics

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