Valley City Landslide
Interstate 94

Colter Schwagler, Tyler Peterson, Greg Fischer

2020 Virtual OPD/Construction Conference

Bismarck, ND

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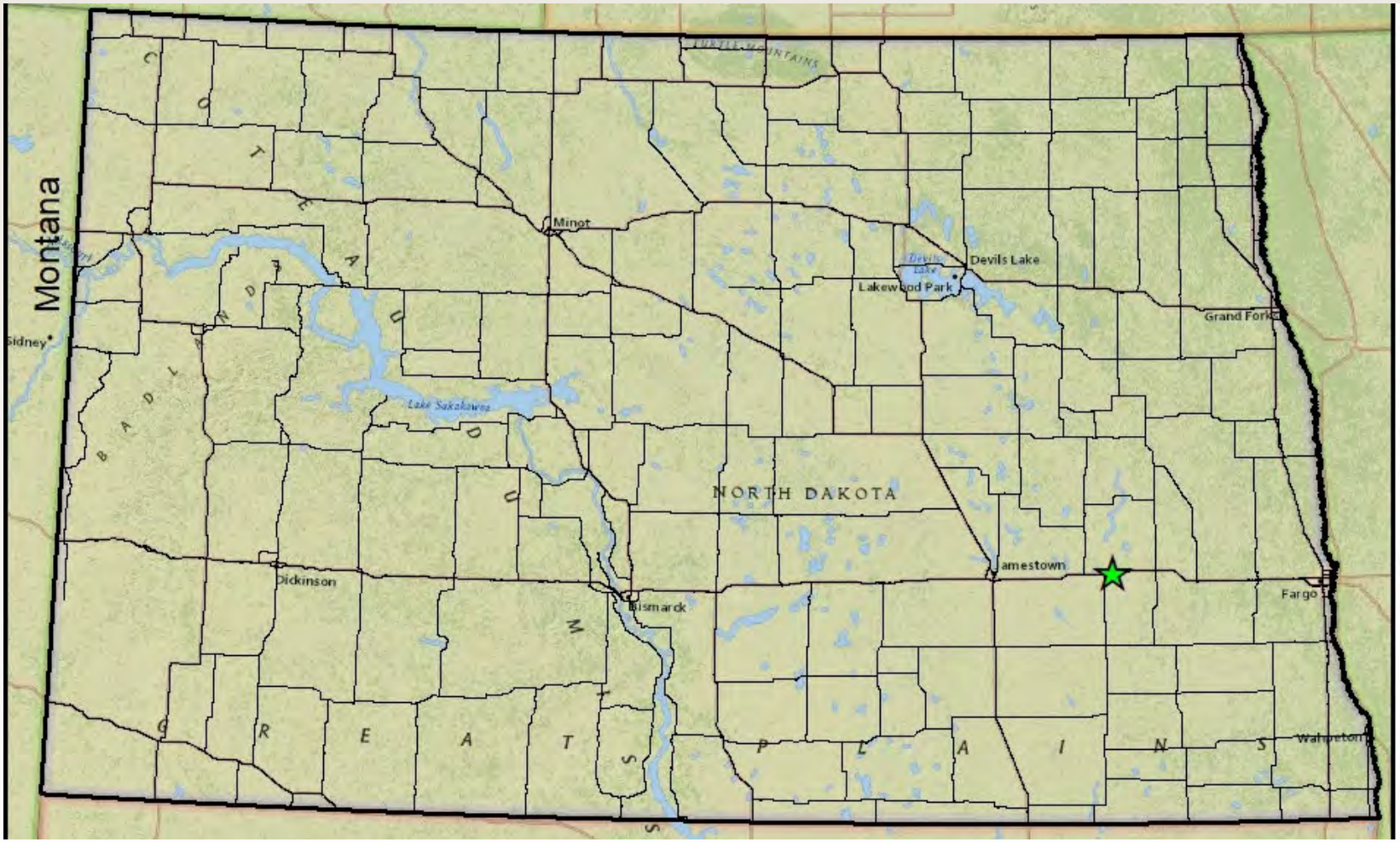
Slide Location



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Timeline

- Grade Raise and Realignment completed in 2000
- 2001 North Inslope begins to show distress

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Timeline

- Grade Raise and Realignment completed in 2000
- 2001 North Inslope begins to show distress

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Timeline

- Grade Raise and Realignment completed in 2000
- 2001 North Inslope begins to fail
- 2001 400 feet of sheet piling and longitudinal drain installed

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Timeline

- 2007 Road Shoulder has dropped noticeably, and sheet piling is deflecting

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Timeline

- 2014 Shoulder has continued to drop and pull away from driving lane. New shoulder area further west has noticeably dropped and pulled away.

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Timeline

- 2014 Shoulder has continued to drop and pull away from driving lane. New shoulder area further west has noticeably dropped and pulled away.
- Become concerned about larger failure

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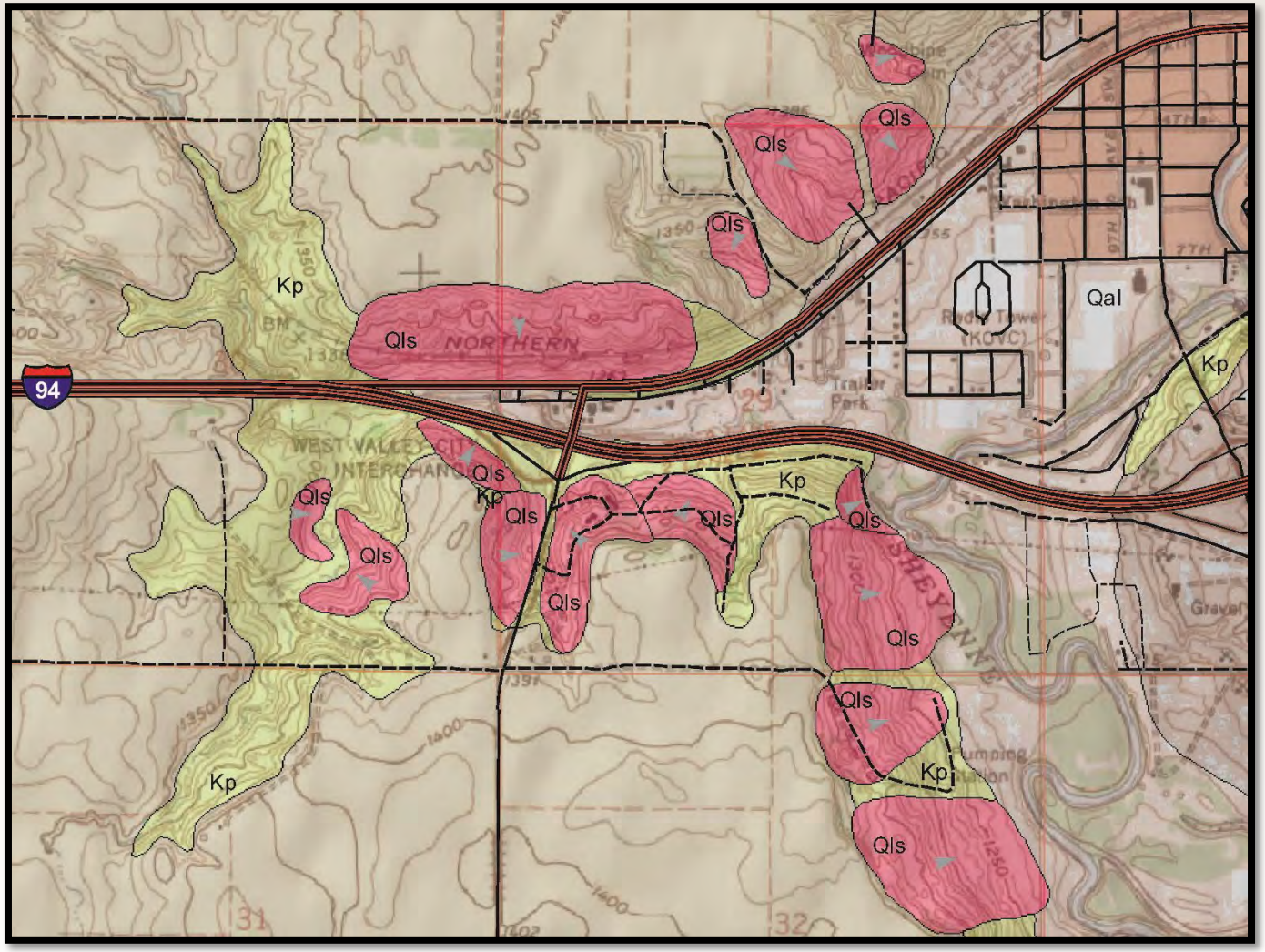
Geologic Map



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1959 Aerial

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Timeline

- 2016 Inclinometers installed through the area of distress North, South and in the Median of the Interstate

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Inclinometers

- Inclinometers are plastic tubes with internal grooves that guide a probe along the length of the tube.
- The inclinometers are placed in a borehole and grouted in place
- The inclinometers move with the surrounding soil and can be read using a portable probe
- Inclinometers can show depth, direction, and rate of movement over time.

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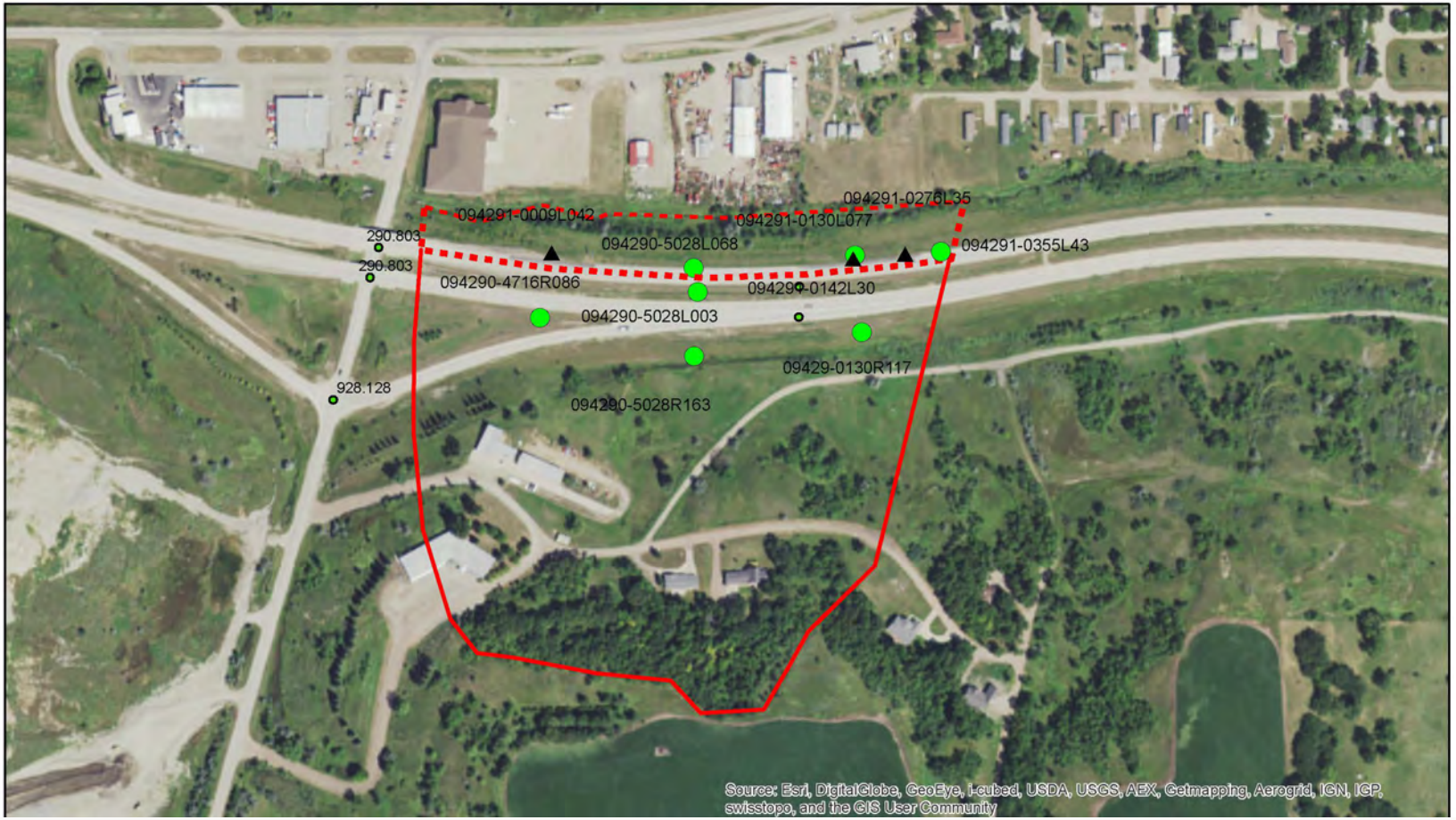
Inclinometer Locations



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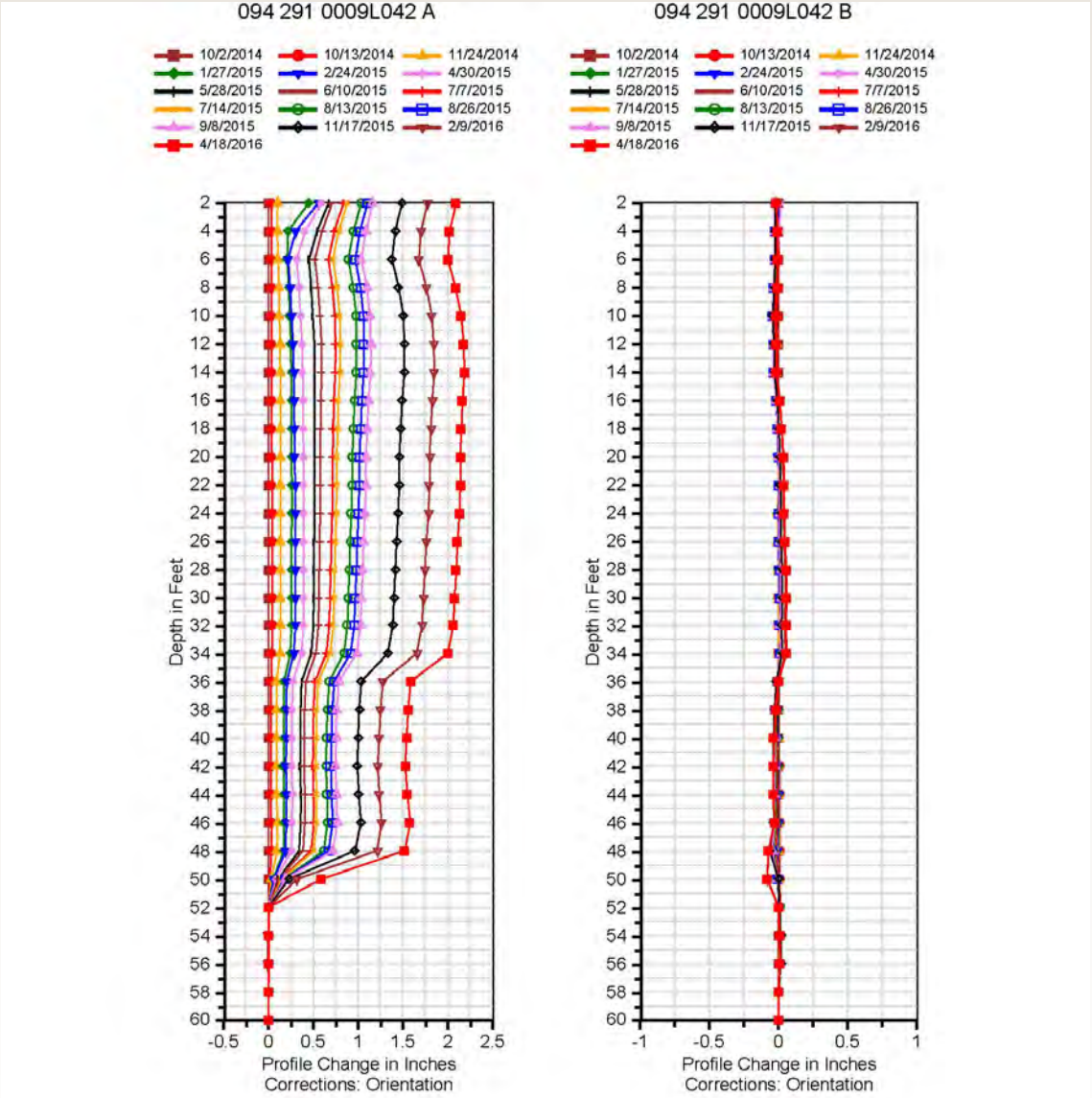

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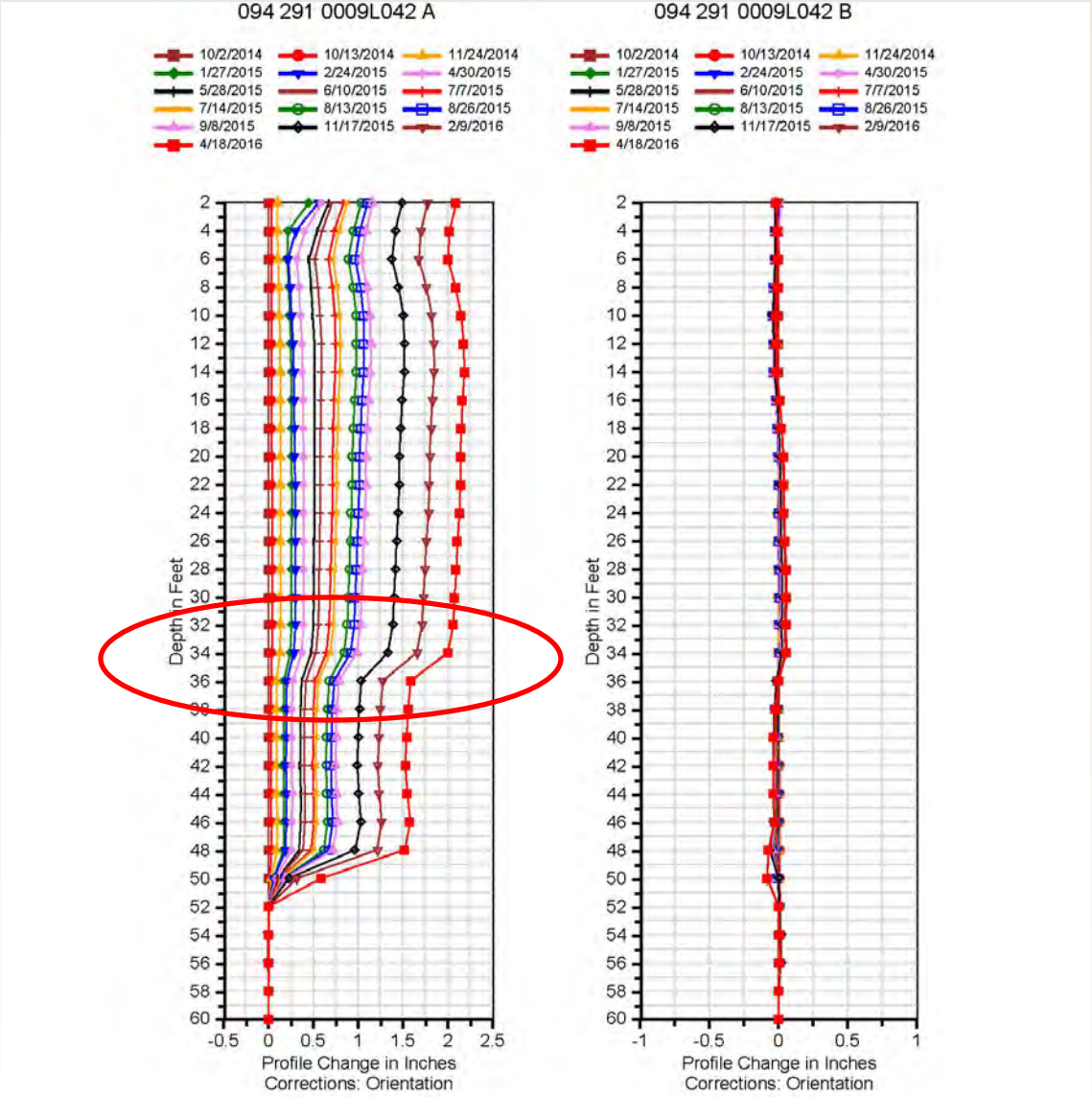

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300 AIRPORT ROAD
BISMARCK, ND 58504

LOG OF BORING SB - 5

PAGE 1 OF 1

PROJECT NUMBER NH-2-094(151)290 **DATE STARTED** 10/31/16 **COMPLETED** 11/1/16
PCN 21765 **ELEVATION** 1274 ft
LOCATION Barnes County **RP+FEET** 290+5028 **OFFSET** 68 **DIR** L
DRILLED BY Dallan **LOGGED BY** Jamie **DRILLING METHOD** Hollow Stem Auger
ENGINEER
NOTES Middle North Inslope

ELEVATION (ft)	DEPTH (ft)	MATERIAL DESCRIPTION	GRAPHIC LOG	AASHTO	USCS	SAMPLE TYPE & NUMBER	RECOVERY (%)	SPT N VALUE	MC / PL / LL / CLAY FRACTION (%)	TESTS & REMARKS
1274	0	Topsoil 1273.7 ft 0.3 ft		A-6	SC	SS 1490	40	7	22 57 1835	
		Loose Moist Clayey Sand Fill circa 2000 1270.0 ft 4.0 ft		A-7-6	CH	SS 1491	40		22 50	
1270		Medium Stiff to Stiff Moist Brown/Black/Grey Fat Clay and Elastic Silt with Gravel fill circa 2000 1263.0 ft 11.0 ft		A-7-6	SC	3TW 1492	50	4	25 60	γ_d = 101.4 pcf γ = 131.5 pcf UU=1953 psf
				A-7-6	CH	SS 1493	40		27 60	
	10			A-7-6	GC	3TW 1494	35		21 52	
				A-7-6	CH	SS 1495	65	8	1833	
1260		Medium Stiff to Stiff Moist Brown/Black/Grey Fat Clay and Elastic Silt with Gravel fill circa 1958		A-6	SC	3TW 1496	75		31 78	
				A-7-6	CH	SS 1497	25	11	37 81	
				A-7-6	MH	3TW 1498	75			
						SS 1499	10	10	43 86	
	20			A-7-6	MH	3TW 1500	65		36 78	
				A-7-6	MH	SS 1501	25	10	35 73	
1250		1249.0 ft 25.0 ft		A-7-6	MH	3TW 1502	65		26 68	γ_d = 83.5 pcf γ = 114.9 pcf UU=2739 psf
		Medium Stiff to Stiff Moist Brown/Black/Grey Fat Clay and Elastic Silt with Gravel		A-7-6	CH	SS 1503	50	14	24 60	
		1244.0 ft 30.0 ft		A-7-6	CH	3TW 1504	50		21 48	γ_d = 89.3 pcf γ = 125.7 pcf UU=2791 psf
	30	Coarse Sand 1243.4 ft 30.6 ft		A-7-6	CL	SS 1505	90	17		
		Stiff Moist Black/Grey Fat Clay Failure Plane at 61'				3TW 1506	75		23 55	
1240				A-7-6	CH	SS 1507	75	11	21 53	
				A-7-6	CH	3TW 1508			IL	
				A-7-6	SC	SS 1508	85	22	22 54	
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				A-7-6	CH	3TW 1514	75		32 97	γ_d = 79.2 pcf γ = 113.0 pcf
	50			A-7-6	CH	SS 1515	85	11	36 108	
				A-7-6	CH	3TW 1516	75		28 113	γ_d = 78.4 pcf γ = 114.4 pcf
1220				A-7-6	CH	SS 1517	75	12	31 118	
				A-7-6	CH	3TW 1518	85		30 141	γ_d = 86.3 pcf γ = 117.5 pcf UU=3172 psf
						SS 1519	85	11		
	60	1212.0 ft 62.0 ft		A-7-6	CH	3TW 1520	85		24 76	γ_d = 81.7 pcf γ = 121.3 pcf
		Very Stiff to Hard Moist Brown Grey/Grey/Black Grey Fat Clay		A-7-6	CH	SS 1521	85	21	24 77	c = 1272.9 psf ϕ = 18.0°
1210				A-7-6	CH	3TW 1522	85	35	24 76	γ_d = 82.0 pcf γ = 121.3 pcf
				A-7-6	CH	SS 1523	85	35	22 84	γ_d = 100.5 pcf γ = 138.7 pcf UU=4324 psf
	70			A-7-6	CH	3TW 1524	85		25 84	
				A-7-6	CH	SS 1525	85	40	26 105	
				A-7-6	CH	3TW 1526	100		26 88	
1200				A-7-6	CH	SS 1527	100	52	27 105	
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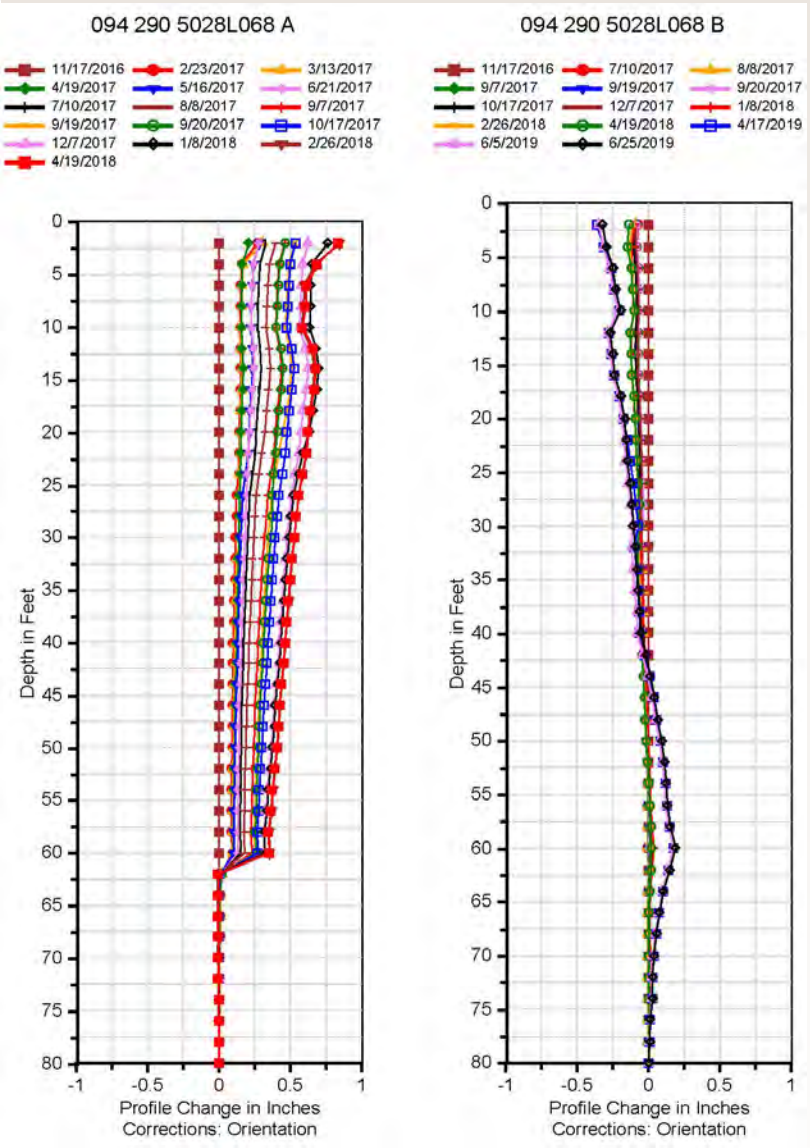
Bottom of borehole at 80.5 ft



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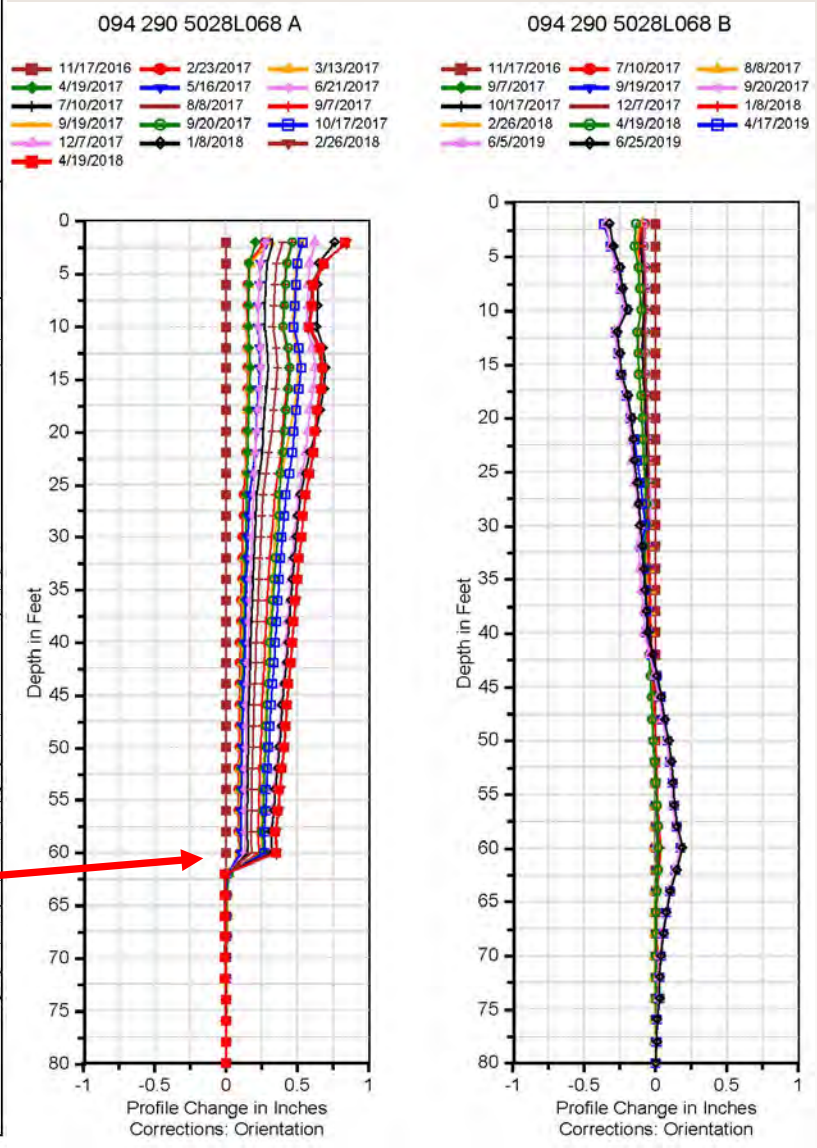

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Timeline

- 2017 Shannon and Wilson Hired to Peer Review Design Process
- 2017 Distress moves into the driving lane pavement and a project is triggered and design begins

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Peer Review Process

- NDDOT has no experience with structural landslide mitigation alternatives
- NDDOT has had consultants provide structural landslide mitigation alternatives in the past couple years
- Due to project constraints it was likely that this project would require a structural alternative
- RFP process was relatively quick and painless
- Consultant was chosen based on phone interviews and short presentation
- Allowed the NDDOT to rely on Shannon and Wilson's experience designing and constructing structural solutions during the design process

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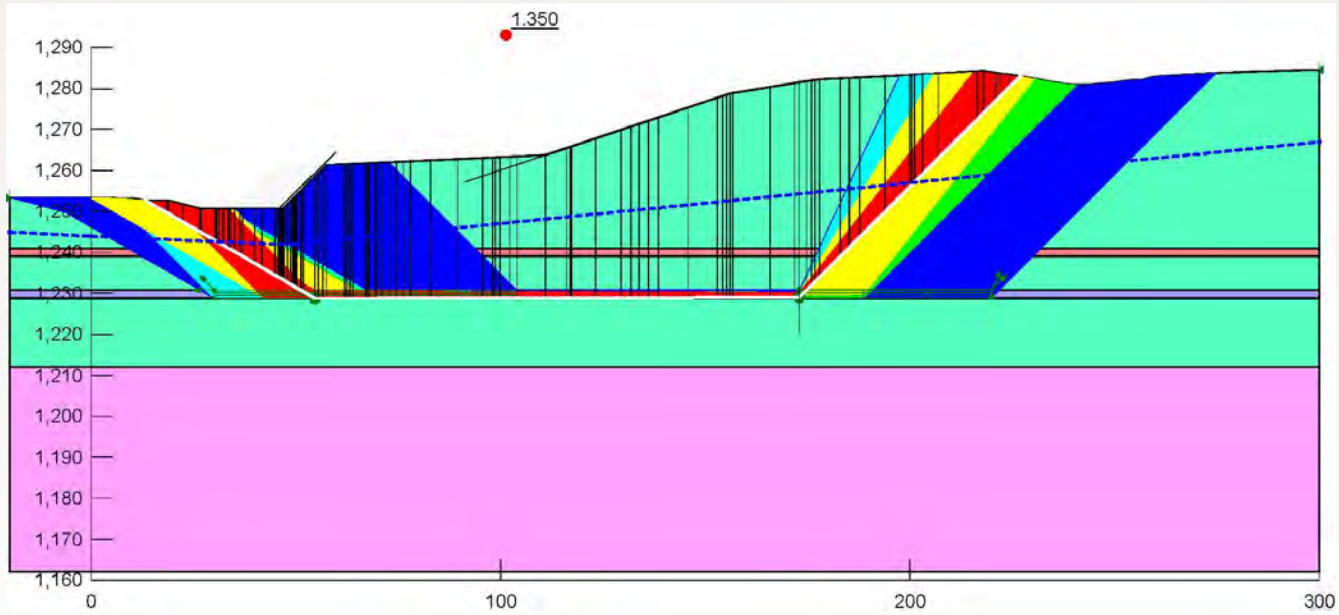
Options and Design Issues

- 1st choice mitigation alternative was a buttress
- Drainage at toe of slope must be accounted for both during construction and permanently
- Buttress option would require an 11’ x 9’ approximately 1000’ long box culvert



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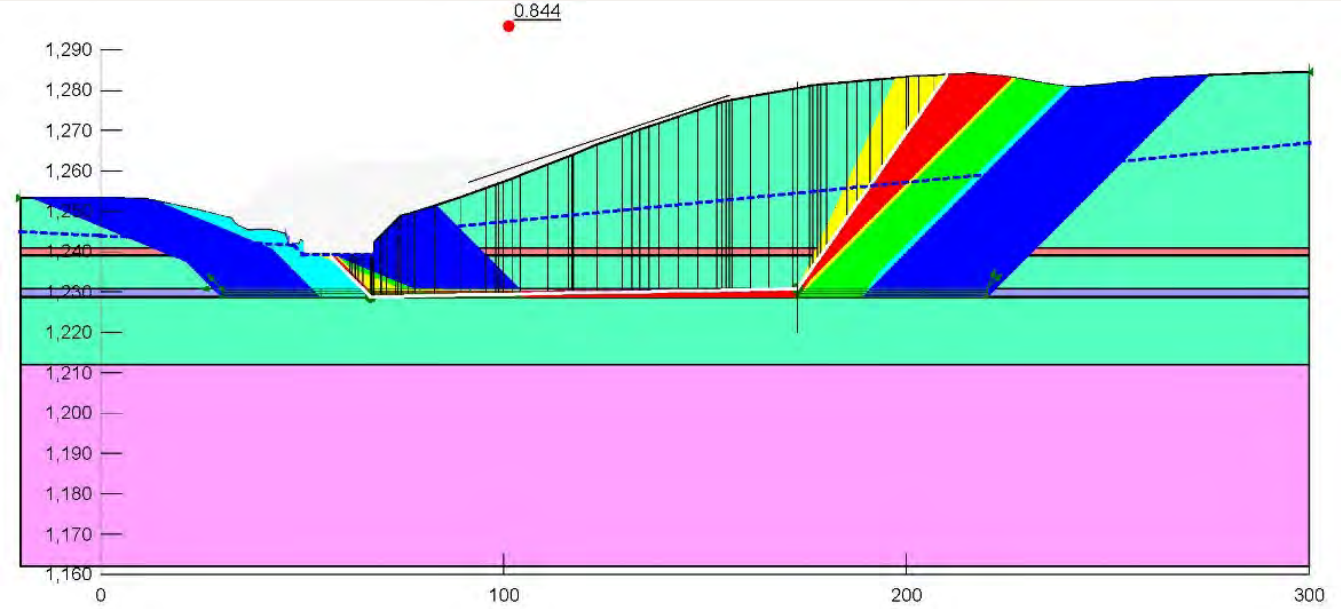
Options and Design Issues

- Excavation required for box culvert option results in very questionable temporary stability
- Buttress option is abandoned, and Ground Anchor Option is pursued



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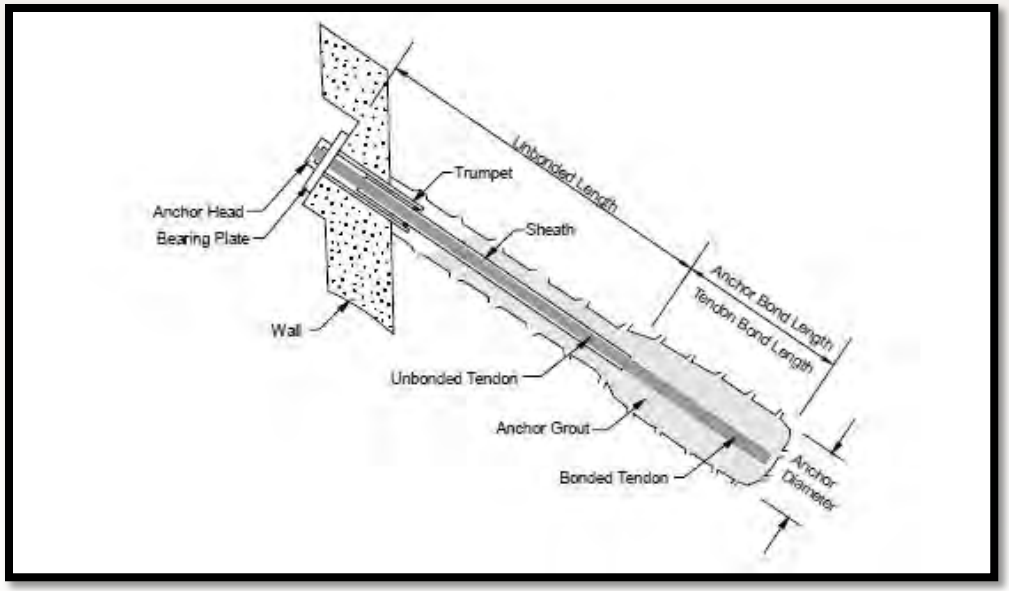
Ground Anchors

- Ground Anchors are grouted, prestressed structural elements installed in soil or rock that are used to transmit a tensile load into the ground
- Ground Anchors consist of a bond zone, anchorage, and unbonded zone.



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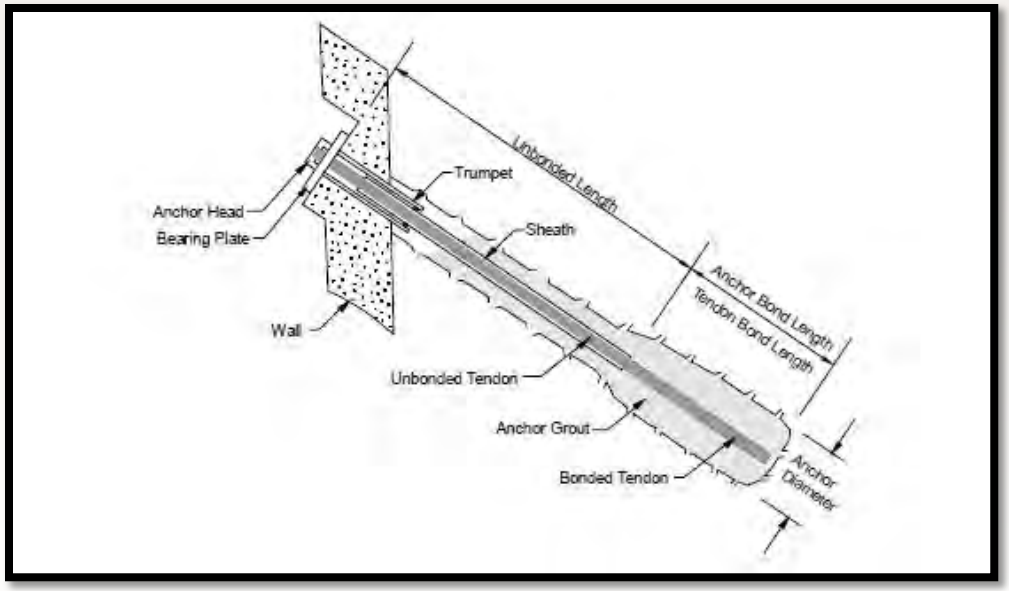
Ground Anchors

- The bond zone is a length of prestressed steel that is bonded to the grout and the soil
- The anchorage transmits the force from the prestressing steel to the ground
- The unbonded zone is a portion of the prestressed steel that is not directly exposed to grout allowing it to elongate elastically and transfer the force from the bond length to the anchorage.



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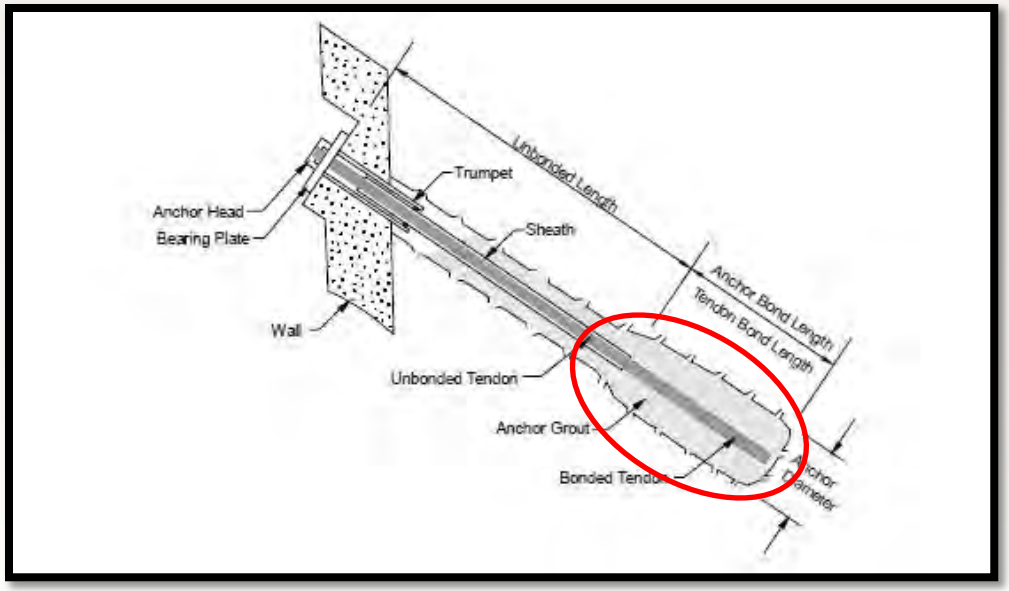

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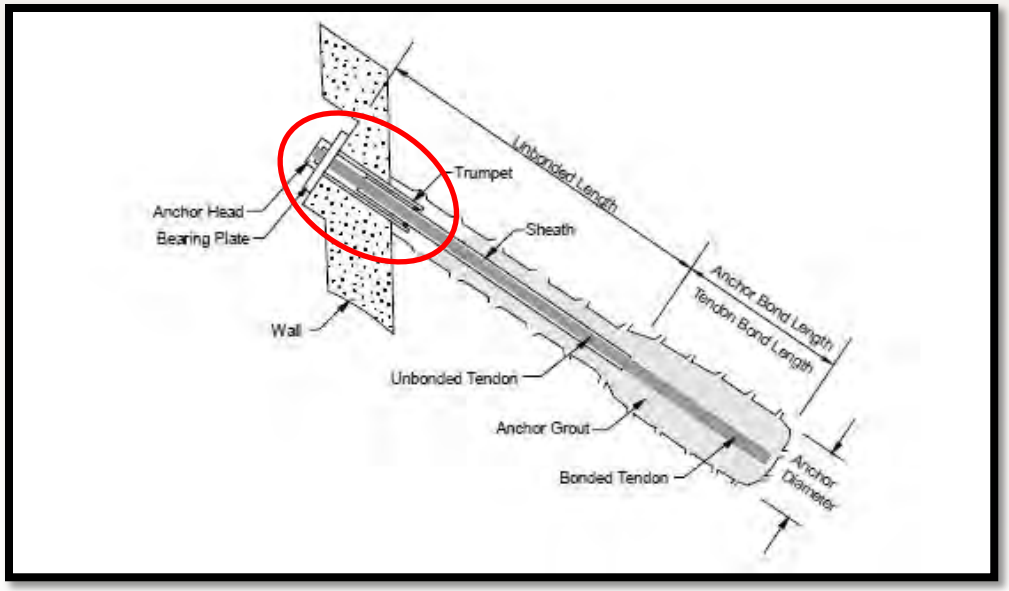

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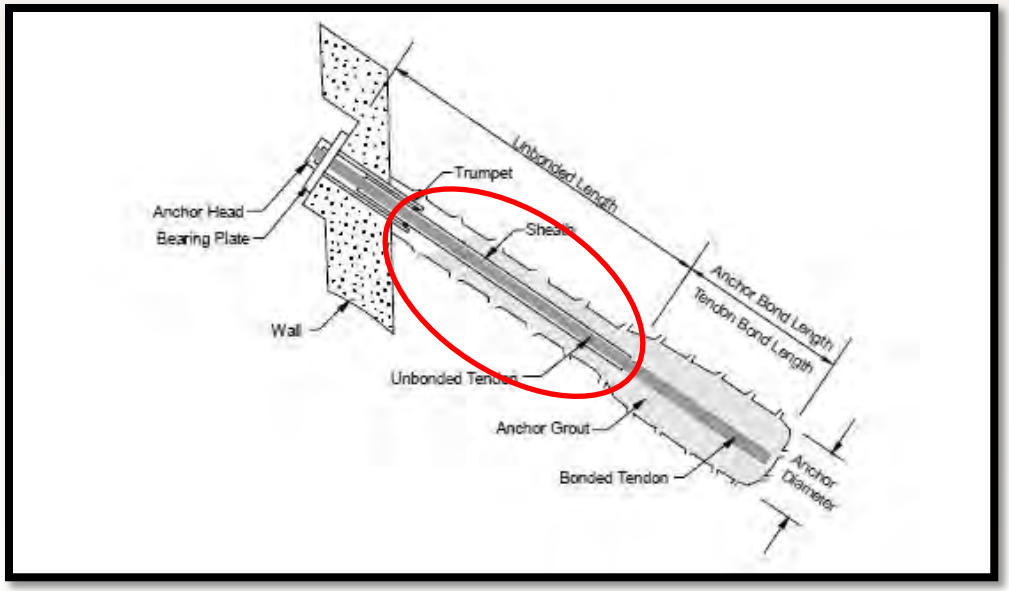

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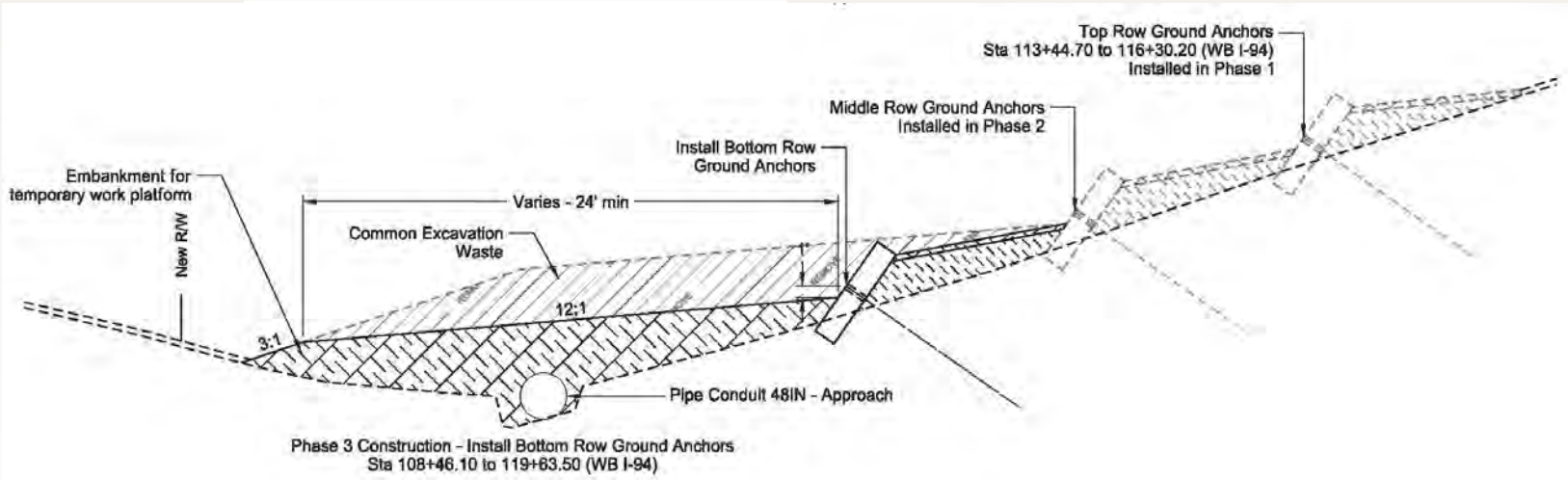
Options and Design Issues

- Access to Drill Ground Anchors is evaluated
- Cannot avoid impacting the drainage at the toe of the slope
- Requires a 48” diameter Temporary pipe to maintain drainage and temporary grading to provide a construction platform



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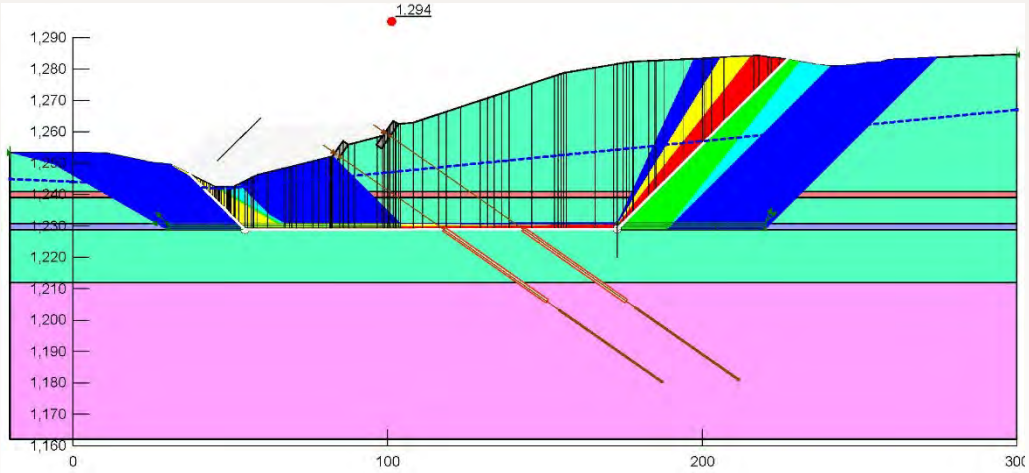
Final Design

- Satisfactory Ground Anchor Option is achieved
- 1-3 rows
- 5 strand 193.1 kip Design Load
- 125-140’ Long



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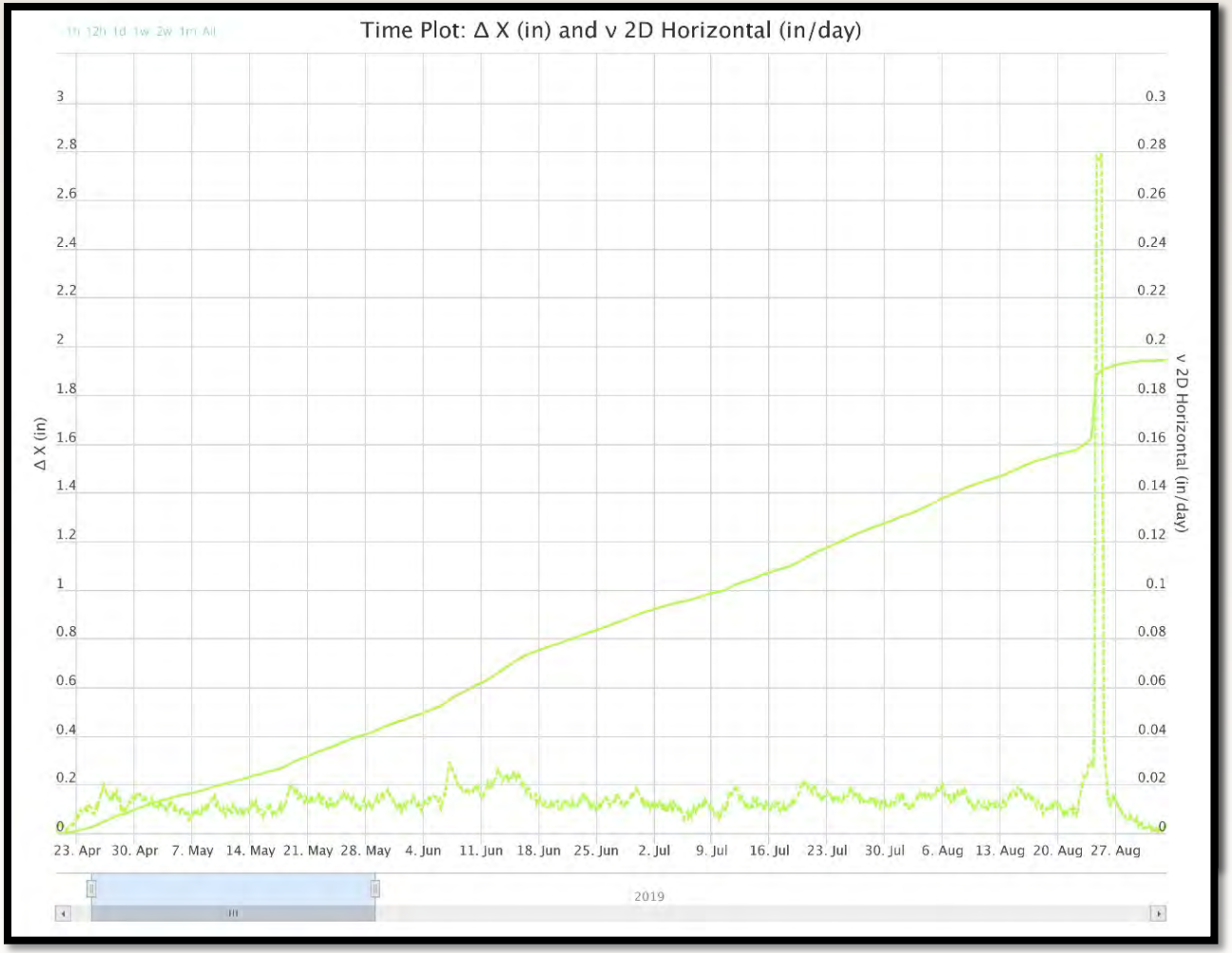
Timeline

- 2018 SAA installed
- 2018 Construction Begins



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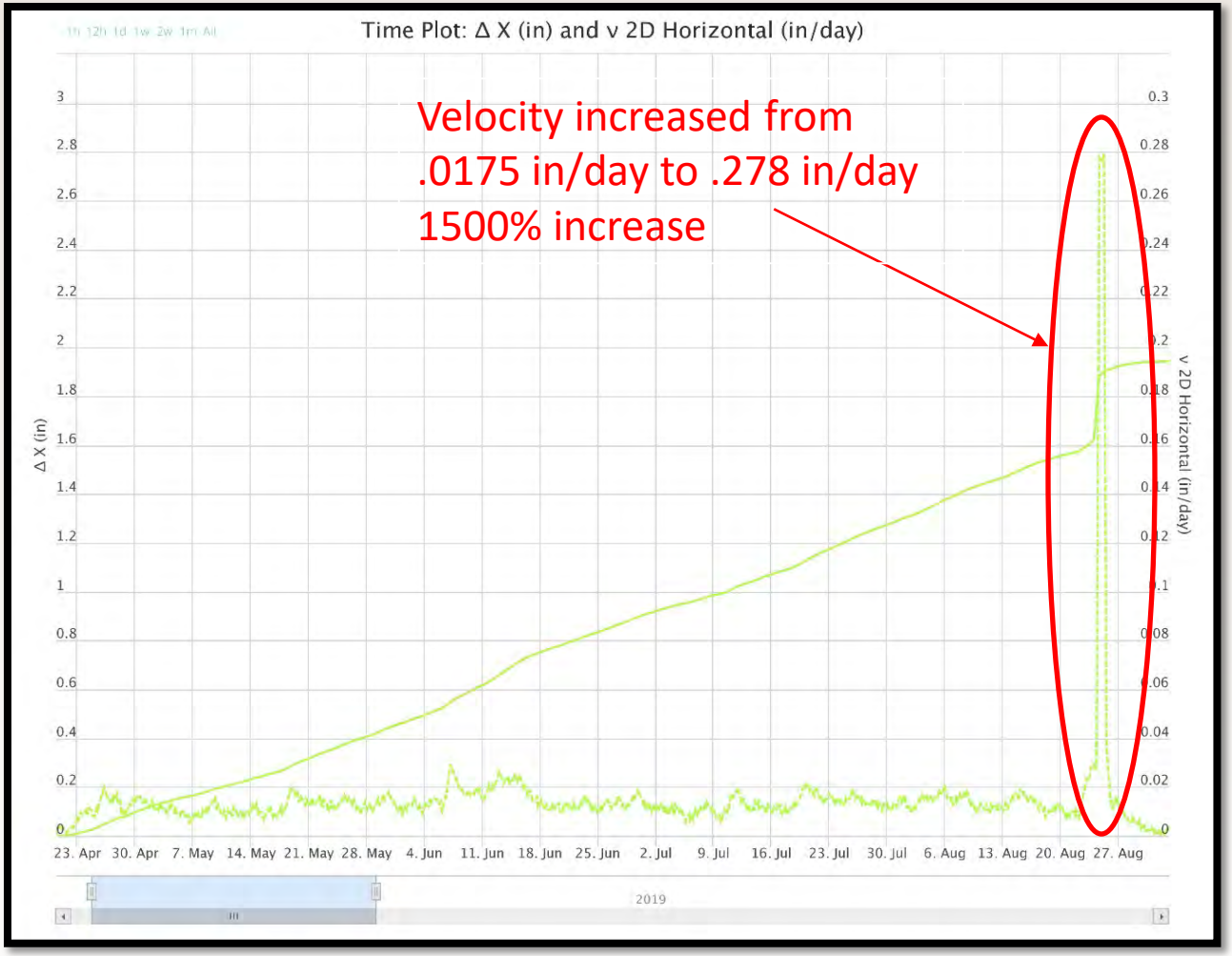

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Construction

- Project Engineering Staff
- Construction Phasing
- Major Project Issues

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Project Engineering Staff

- NDDOT
  - Project Engineer
  - Geotechnical Engineers (M & R)
- KLJ
  - Project Inspectors
  - Materials Tester
  - Surveyor
- Shannon and Wilson
  - Geotechnical Inspector
  - Geotechnical Engineer

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Construction Phasing

- Two Year Project
  - Year 1 – 2018
  - Year 2 - 2019

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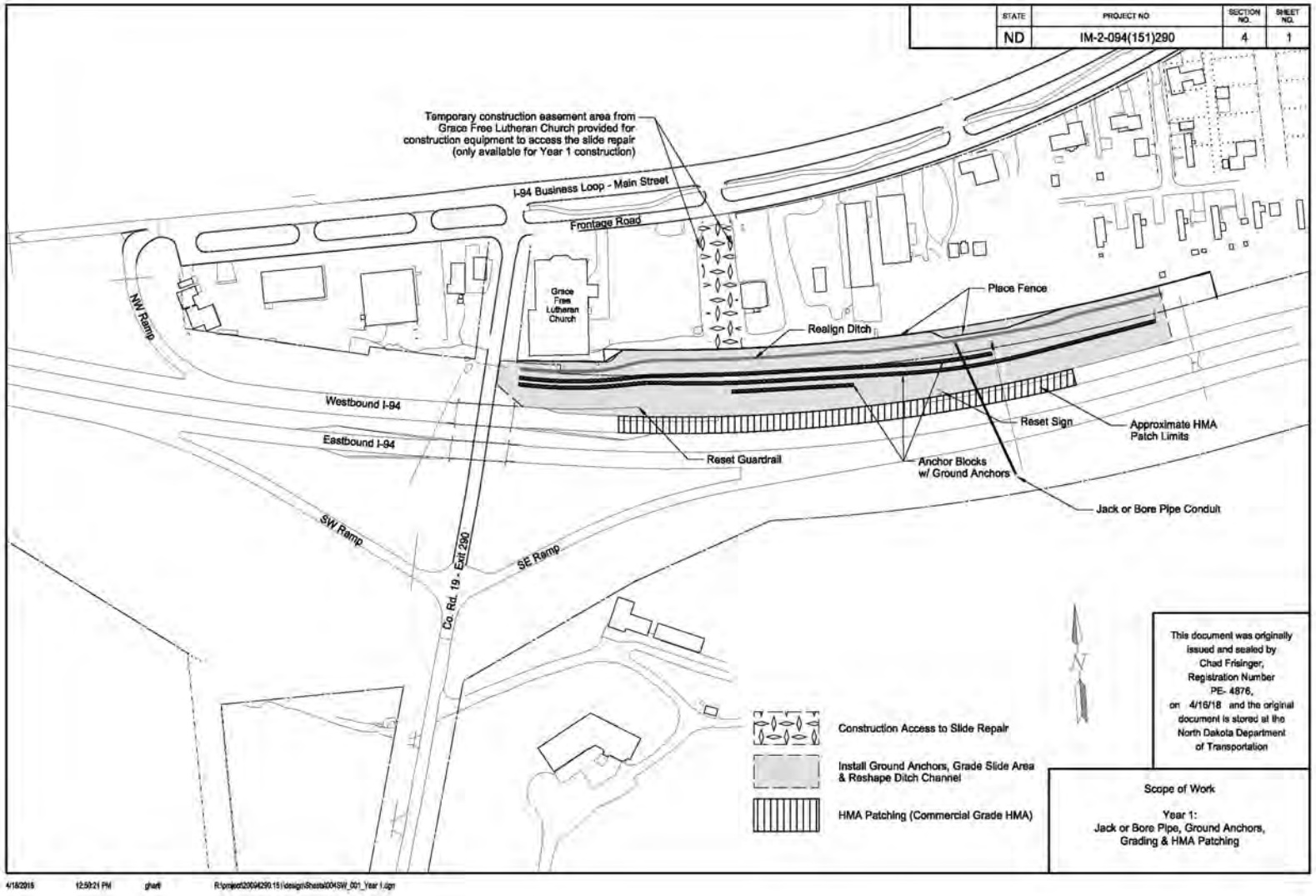

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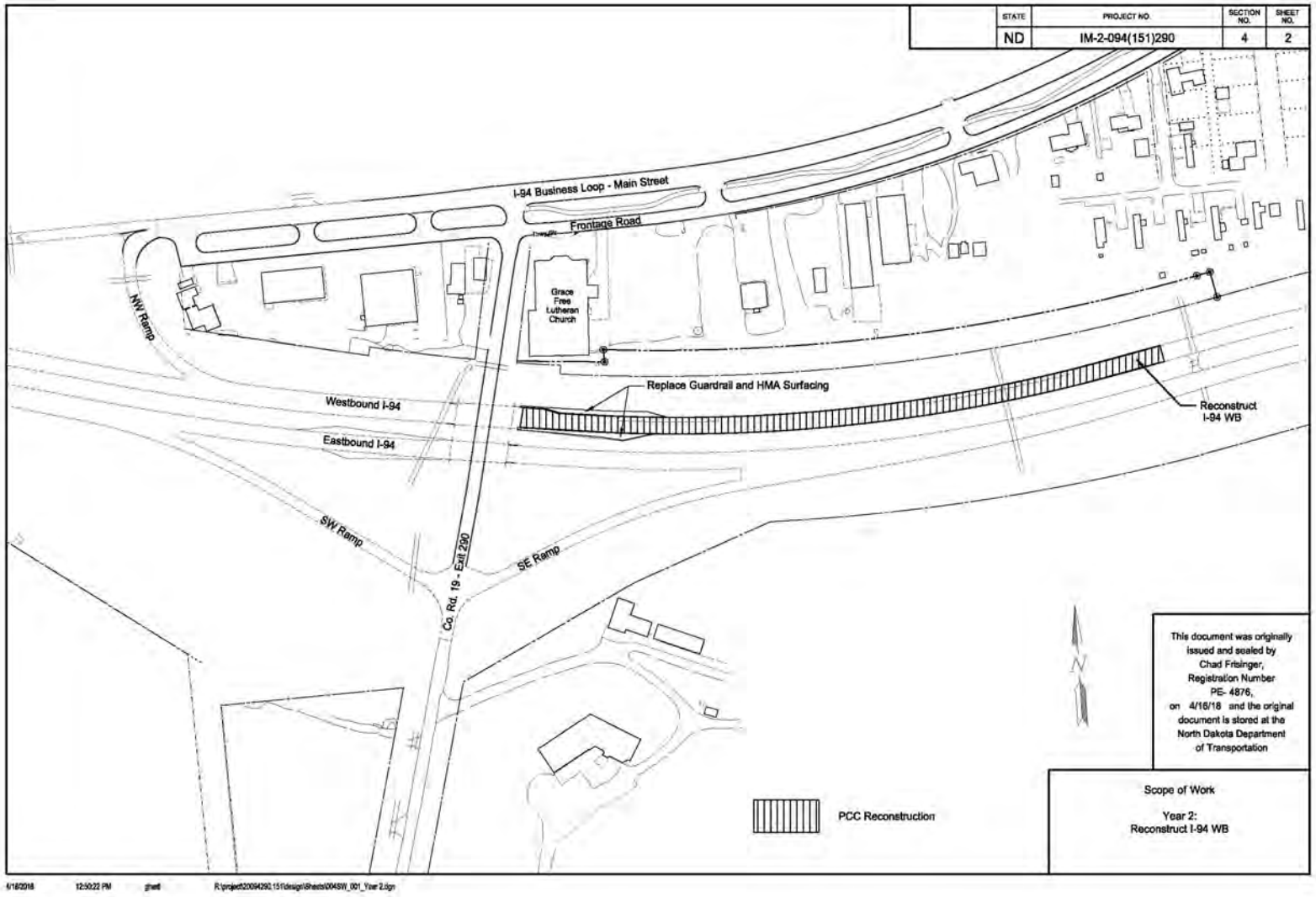

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Year 1 - 2018

- Place and Remove Temporary Drainage Pipe

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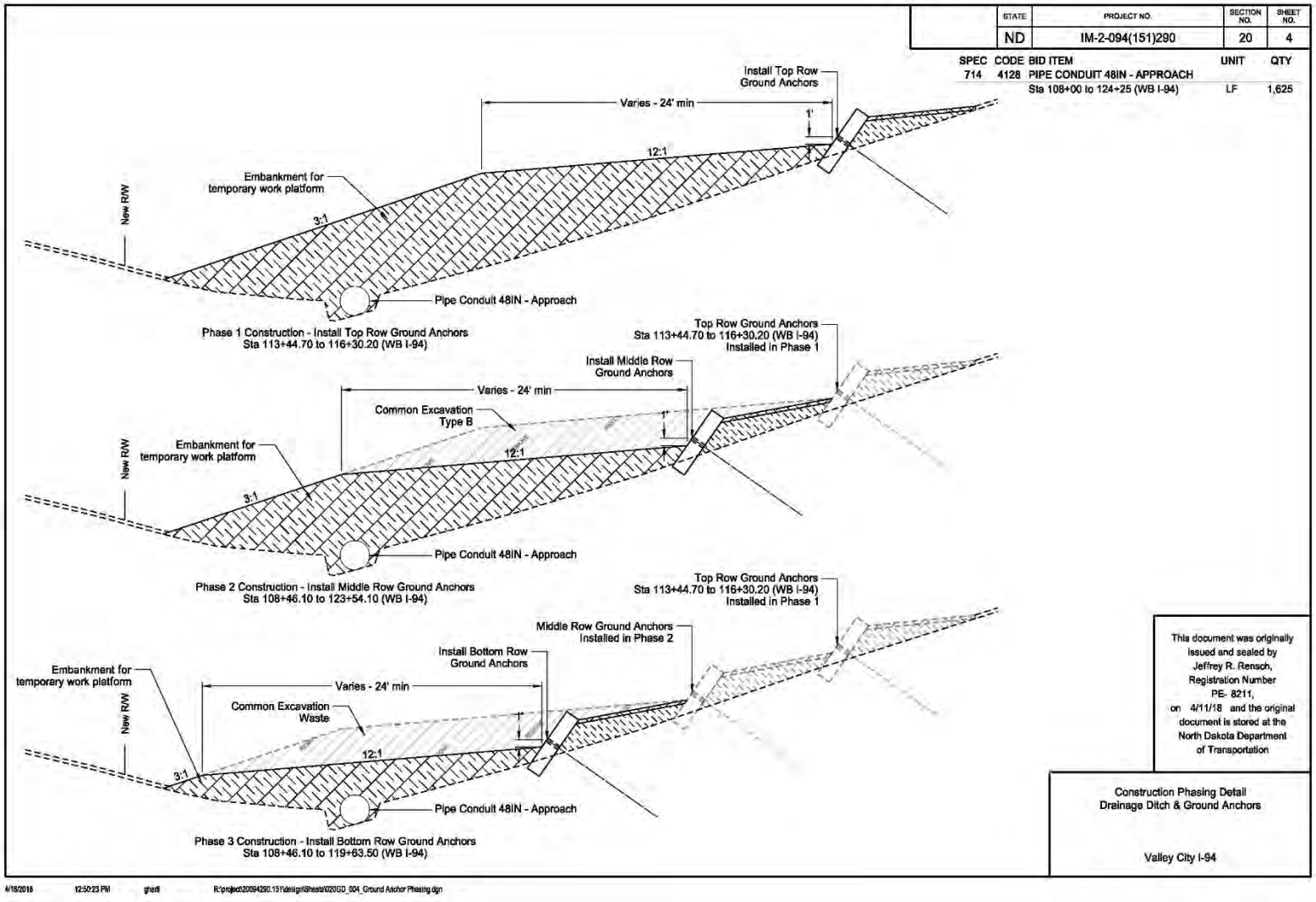

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Year 1 - 2018

- Place and Remove Temporary Drainage Pipe
- Grading
- Precast and Install Concrete Anchor Blocks
- Drill and Install Ground Anchors

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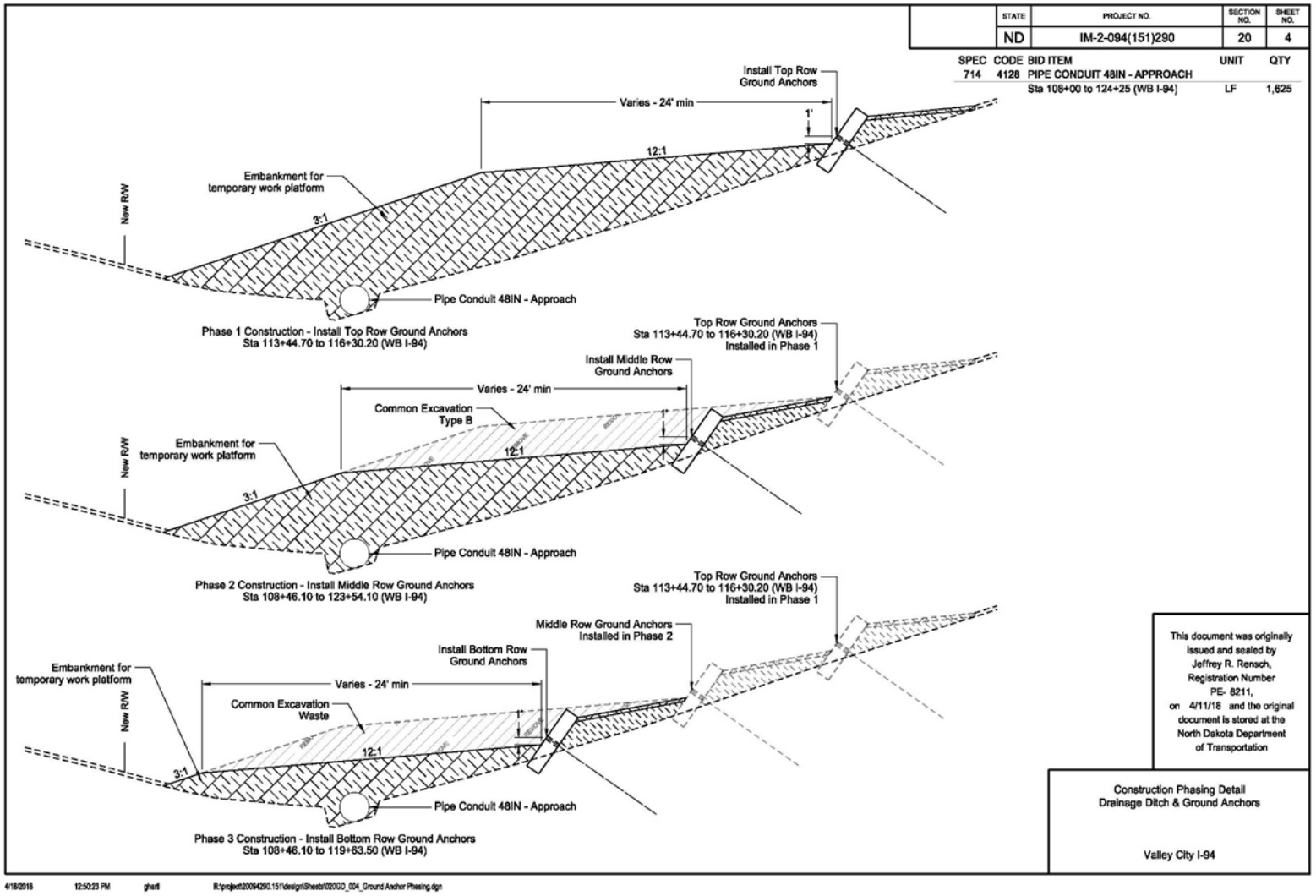

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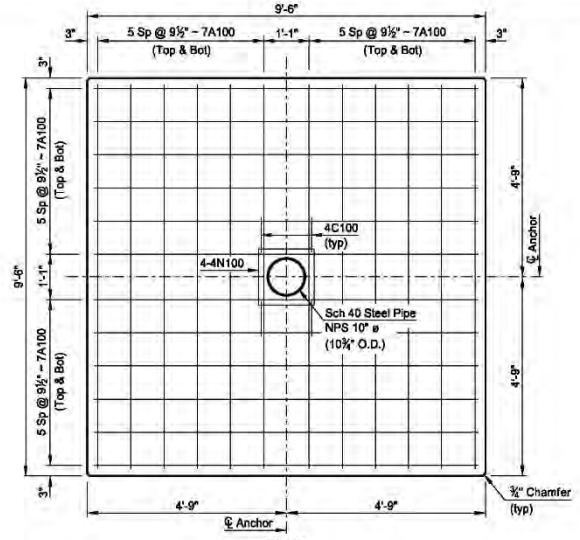
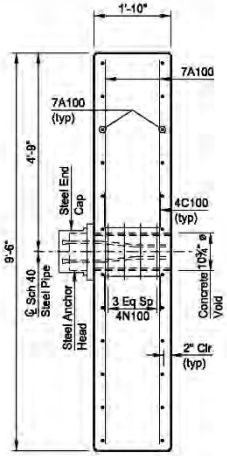
STATE	PROJECT NUMBER	SECTION NO.	SHEET NO.
ND	IM-2-094(151)290	20	1



PLAN



SIDE VIEW

DESIGN STRENGTHS:

f'c = 4,000 psi ~ Class AAE-3 Concrete
fy = 60,000 psi ~ Reinforcing Steel

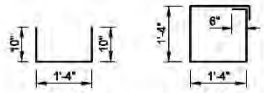
Load & Resistance Factor Design

BAR LIST - ONE ANCHOR BLOCK

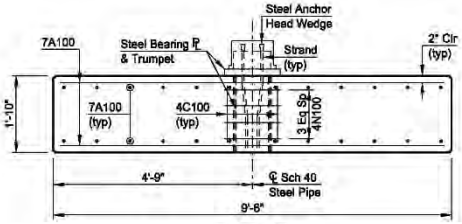
SIZE	MARK	NO.	LENGTH
7	A100	48	9'-2"
4	C100	4	3'-0"
4	N100	4	6'-4"

MATERIAL QUANTITIES (ONE ANCHOR BLOCK)

REINFORCING STEEL (LBS)	CONCRETE (CY)
924	6.1
TOTAL ANCHOR BLOCKS	285



(DIMENSIONS SHOWN ARE OUT TO OUT)
BENT BAR DETAILS



ELEVATION

SPEC	CODE	ITEM DESCRIPTION	UNIT	QUANTITY
602	0130	CLASS AAE-3 CONCRETE	CY	1,738.5
612	0115	REINFORCING STEEL-GRADE 60	LBS	263,340

NOTES:

1. The Contractor is to determine the size and thickness of the bearing plate, trumpet, anchor head and end cap. Provide a steel bearing plate and trumpet with a minimum yield strength of 50 ksi. Provide a bearing plate with minimum plan dimensions of 16" x 16".
2. Provide a Sch 40 steel pipe meeting ASTM A53 with a minimum yield strength of 30 ksi. Extend the pipe for the full depth of the concrete anchor block. Include the cost of furnishing and placing the steel pipe in the price bid for Class AAE-3 concrete.
3. Achieve a minimum 28-day concrete compressive strength of 4,000 psi in the anchor block before the ground anchor is stressed.
4. Install the anchor block so that it is in full contact with the soil prior to the application of tendon jacking loads. No voids between the anchor block and soil are permitted.

This document was originally issued and sealed by Brian W. Raschke, Registration Number PE 4361, on 04/09/18 and the original document is stored at the North Dakota Department of Transportation

NORTH DAKOTA DEPARTMENT OF TRANSPORTATION

I-94 VALLEY CITY SLIDE REPAIR

CONCRETE ANCHOR BLOCK DETAILS

PROJECT: IM-2-094(151)290

BARNES COUNTY

04/09/18 — Jon Ketterling
DATE — BRIDGE ENGINEER

4/9/2018 8:39:33 AM braschke R:\project\20094290.151\bridge\Section 20\02030D_001_CONC_ANCHORS.dgn 18ATC034 BWR

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Year 1 - 2018

- Place and Remove Temporary Drainage Pipe
- Grading
- Precast and Install Concrete Anchor Blocks
- Drill and Install Ground Anchors
- Jack and Bore Pipe Conduit
- Pipe Extensions

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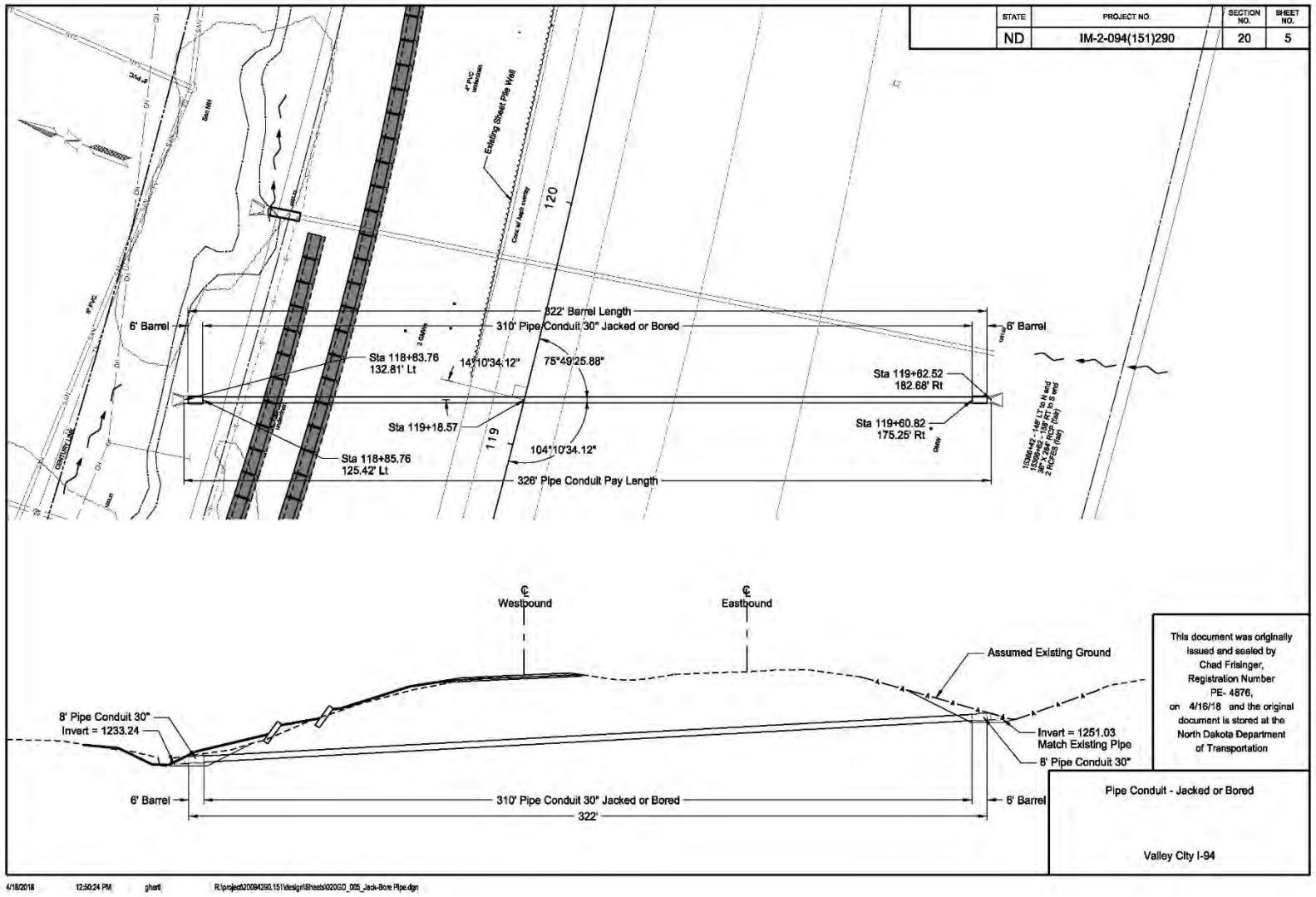

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Year 1 - 2018

- Place and Remove Temporary Drainage Pipe
- Grading
- Precast and Install Concrete Anchor Blocks
- Drill and Install Ground Anchors
- Jack and Bore Pipe Conduit
- Pipe Extensions
- Drill and Install Inclinometers

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Year 1 - 2018

- Place and Remove Temporary Drainage Pipe
- Grading
- Precast and Install Concrete Anchor Blocks
- Drill and Install Ground Anchors
- Jack and Bore Pipe Conduit
- Pipe Extensions
- Drill and Install Inclinometers
- Topsoil, Seeding, & Permanent Erosion Control

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Year 2 - 2018

- Removal of Pavement
- Grading
- PCC Pavement
- Permanent Erosion Control

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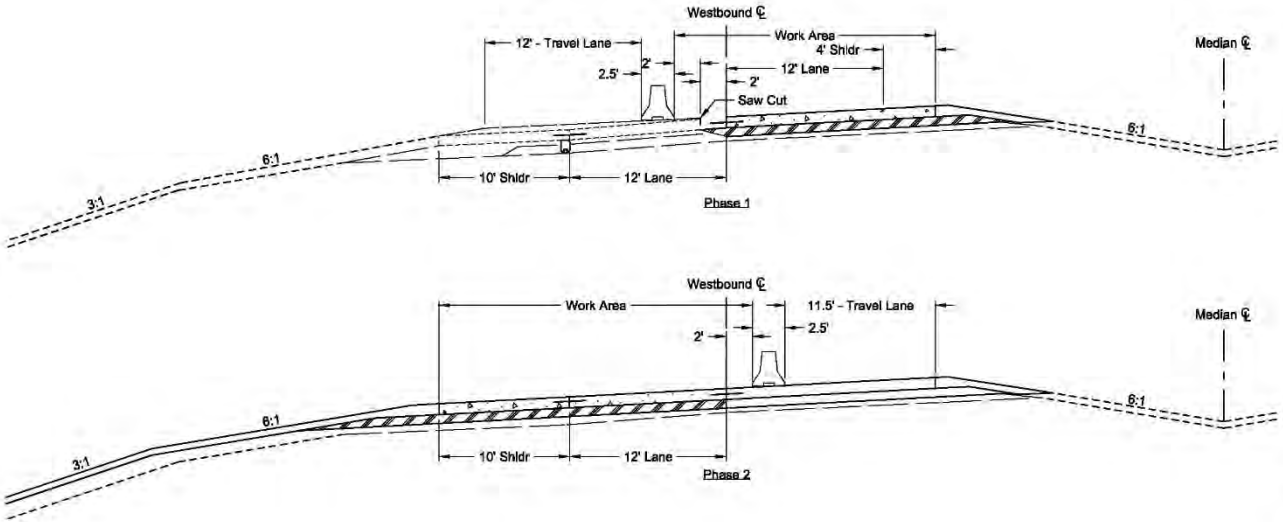
STATE	PROJECT NO.	SECTION NO.	SHEET NO.
ND	IM-2-094(151)290	100	4



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Reconstuction Work Zone
Traffic Contol Phasing

Year 2

Valley City I-94

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Major Project Issues

- Jack and Bore Pipe Conduit
- Erosion Control

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Jack and Bored Pipe

- Reconstruction of the pavement section triggered a hydraulic study
- Hydraulic study called for an additional 30” diameter pipe to be jack and bored through the slide area
- Original schedule called for this to take 21 days
- Work began on October 28th, 2018
- October 30th pipe contractor encountered boulders (approx. 140’ in)
- No boulders were encountered during geotechnical investigation
- Boulders required microblasting and manual removal for the rest of the 170’ of pipe
- 36 ground anchors could not be installed in 2018 due to the bore pit
- Construction completed on May 22nd , 161 total days to complete this work
- Contract revision due to differing site conditions

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Jack and Bored Pipe

- All labor, equipment, & material was tracked and accounted for
- Re-Mobilization to finish the ground anchor work

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Erosion Control

- The Original Design was to install seeding class II or Wetland Seed with Turf Reinforcement Mats
- In the Spring of 2019, the ditch experienced high turbulent flows
- The NDDOT and the Contractor evaluated the ditch and noticed excessive amounts of erosion

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Erosion Control

- The Original Design was to install seeding class II or Wetland Seed with Turf Reinforcement Mats
- In the Spring of 2019, the ditch experienced high turbulent flows
- The NDDOT and the Contractor evaluated the ditch and noticed excessive amounts of erosion
- A contract revision was made to line the ditch with Grade II RIP RAP to prevent future erosion from occurring.

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Consultant Role - Review

- Subsurface Information
  - Exploration and instrumentation by NDDOT
  - Review NDDOT landslide characterization
- Proposed Alternatives
  - Preliminary analyses
  - Comparison and selection of stabilization approach
- Design of Selected Alternative
  - Review of NDDOT analyses and Independent analyses
- Plans and Specifications
  - Review and support

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Consultant Role - ~~Review~~

- Independent Analyses
  - Limit Equilibrium
    - Preliminary evaluation of various alternatives
    - Check of NDDOT final design and evaluation of several construction cases (e.g. installation of access benches, culvert)
  - Stress Distribution
- Specialized Analyses
  - FLAC to evaluate A-Frame micropile structure

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Review Schedule

- 2 Weeks of Receiving Deliverable
- Concept – Engagement throughout Design Process to Expedite Review Process
- Coordinated effort to find and evaluate potential fatal flaws
  - Construction access and stability of slide
  - Anchor bond strength

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Add-Ons

- Ground Anchor Specifications
- Instrumentation for stability monitoring
  - Shape Accel Array
  - Real-time remote monitoring with alerts
  - Setting monitoring thresholds and dealing with triggers

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Construction

- Full-time representative during anchor installation
- Review of verification and proof test results
- Stability monitoring and review of SAA data
- Problems during construction?

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Submittal Review

- Anchor Contractor
- Anchor Working Drawing
- Instrumentation Plan
- Sacrificial Tests
- Work Plan to Remove Obstruction

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Inspector

- Interpret and verify the Contractors compliance
- Perform visual field verification of excavated soil/rock material for comparison to the projects boring logs
- Perform required reporting
- Perform inspection of instrumentation installation for compliance to plans and manufacturer recommendations

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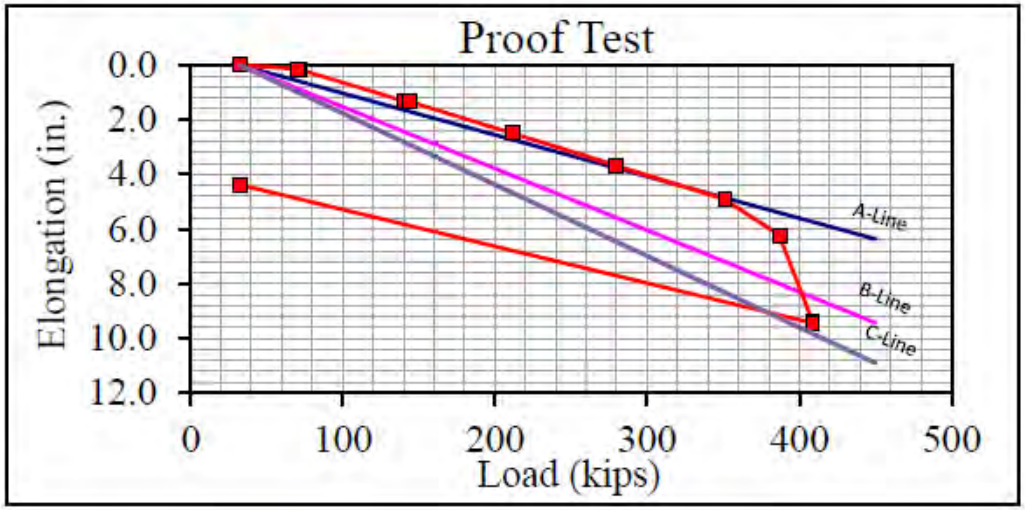
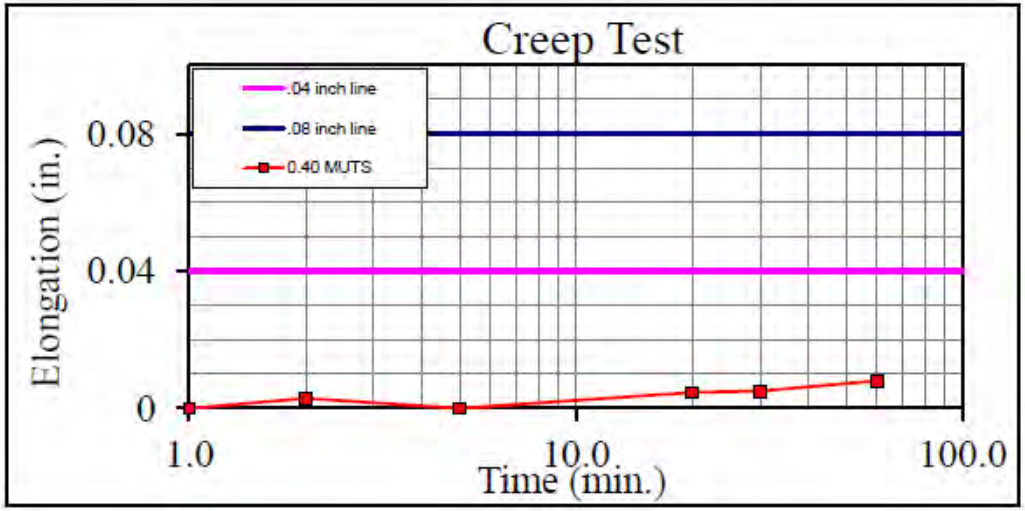
SHANNON & WILSON, INC.
GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

ANCHOR RE-TEST RESULTS





Apparent Free Length		
Min. Allowable (ft)	L_{app} (ft)	Max. Allowable (ft)
86.4	99.8	128.0

Elongation at 0.60 MUTS	
Elastic, δ_e (in.)	Residual, δ_r (in.)
6.245	4.375

Creep at 0.40 MUTS	
1 to 10 min (in.)	6 to 60 min (in.)
0.000	0.008

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Instrumented Anchors

Anchor A-19			
Strain Gauge	Test Load at 193 kips	18 Days after Lock-off	Readings taken 7/3/19
S1 (10' in bond zone)	Not Functioning	67.8 kips	72.7 kips
S2 (25' in bond zone)	31.2 kips	23.4 kips	27.6 kips
S3 (40' in free length)	151.8 kips	109.8 kips	91.8 kips

Anchor C-37				
Strain Gauge	Lock-off at 193 kips	2 Days after Lock-off	7 Days after Lock-off	Readings taken 7/3/19
S7 (10' in bond zone)	88.8 kips	90.6 kips	93.0 kips	97.8 kips
S8 (25' in bond zone)	28.2 kips	31.2 kips	31.2 kips	30 kips
S9 (40' in free length)	139.2 kips	132 kips	126 kips	140.4 kips

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Summary

- Consultant Review Role Successful
- Useful when Considering New Technology or New Design Approaches without In-House Experience
- Previous Working Relationship Helpful
- Ground Anchor Stabilization Successful
- Don’t Forget about the Other Features of a Project

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Questions

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