TO: Don Connors, P.E.
Vice President
Wood, PLC
600 17th Street, Ste 500 – South Tower
Denver, CO 80202

FROM: Tom Allen, P.E.
Senior Project Manager

DATE: June 28, 2018

SUBJECT: CDOT Project Code 22420 – US 550 S Connection to US 160 D-B
Wildlife and Livestock Crossings, Preliminary Foundation Recommendations

This memo presents a summary of subsurface conditions, geotechnical considerations and preliminary foundation design recommendations for proposed Wildlife/Livestock Crossing Structure P-05-BB, Wildlife Crossing WX and Wildlife Crossing WX2 as shown on preliminary plans provided by CDOT for Project 19378 (Post-FIR dated 12-05-16) and recent revisions provided by Mueller Engineering. The recommendations are intended for use to develop Reference Design Plans for the Design-Build project.

Structure P-05-BB (Wildlife / Livestock Crossing)

The proposed Wildlife/Livestock Crossing is a bridge that spans the planned realignment of US 550 at approximate Station 1000+00 with a total length of approximately 207 feet. Post-FIR plans (dated 12-05-2016) indicate the bridge will consist of two spans with abutments at each end and a center pier. The cross-section plans show that US 550 at this location will be in a cut of approximately 30 feet in depth. The top of the bridge deck at the abutments will be at or near the existing ground surface.

Three (3) borings were drilled to investigate subsurface conditions at the Wildlife / Livestock Crossing using ODEX and Air Rotary methods. The boring locations and logs are shown on the attached Engineering Geology plan sheet. One exploratory hole was placed at each abutment and one at the pier location. The borings encountered 32 to 37 feet of surficial soil: very stiff to hard clay, with sand; and medium dense silty sand. These soils overlaid very dense terrace alluvium composed of cobbles (3-12 inch diameter) in a sand and gravel matrix, with boulders (>12 inch diameter). Boring A-01 encountered moderately weathered claystone bedrock (Animas Formation) from a depth of 67 feet to the bottom of the boring at 70 feet. Boring A-02 encountered claystone bedrock in the bottom few inches drilled. Bedrock was not encountered for the full depth of exploration in Boring A-03. A summary of the conditions encountered in each boring at the Wildlife/Livestock Crossing is provided in Table 1. Groundwater was not encountered in the borings at the time of drilling.

Table 1. Summary of Wildlife / Livestock Crossing Borings

Boring	Station	Offset	Total Depth (ft)	Depth to Alluvium (ft)	Depth to Bedrock (ft)
A-01	999+53	81' LT	70.0	32.5	67.0
A-02	999+74	11' RT	70.5	32.0	70.3
A-03	1000+59	88' RT	69.5	37.0	n/a

Laboratory test results show samples of the clayey soils have American Association of State Highway and Transportation Officials (AASHTO) classifications of A-6 and A-7-6. The silty sand soil encountered in Boring A-03 has an AASHTO classification of A-4. Test results for unconfined compressive strengths of the clay soils ranged from 7,063 psf to 8,357 psf. A swell/consolidation test performed on a sample of the hard clay soil showed settlement of 3.4 percent when wetted under light loading conditions. The clay soils have low to medium plasticity.

AASHTO classifications based on laboratory tests performed on the Terrace Alluvium may not be representative of the in-place deposit. The tested samples were recovered from drill cuttings and consist of fragments of the gravel, cobbles and boulders.

Foundations

The clay soils have relatively low density and potential for settlement when wetted (collapse). These soils are unsuitable for support of foundations with the relatively high bearing loads typically imposed by bridges. Pile foundations driven through the clay soils to penetrate the alluvium are recommended for support of the abutments at the Wildlife/Livestock Crossing. The pier is located in the proposed cut, where alluvium is a few feet below the planned profile grade. A spread footing foundation bearing on the alluvium is recommended for support of the pier.

Driven Piles: Based on the conditions encountered at Abutments 1 and 3 (Borings A-01 and A-03, respectively), it is assumed that driven pile foundations will be designed for these locations. Driven piles penetrating a distance of 5 feet into the terrace alluvium can be designed for a nominal tip resistance of 152 ksf for an assumed effective pile diameter of 12 inches. Piles should be designed as end bearing only. Side friction resistance in the clay soils should be neglected. The contribution to pile axial capacity of side friction resistance in the alluvium is small because of the shallow depth of penetration and should be ignored. The minimum spacing requirements between driven piles should be three diameters from center to center. Assuming a pile driving analyzer (PDA) is used to monitor pile driving, as required by Section 502 of the CDOT (2017), a resistance factor of 0.65 may be used per AASHTO (2017) Table 10.5.5.2.3-1. Section 502.05 of the CDOT (2017) stipulates that a minimum of two PDAs be performed per structure to determine the condition of the pile, efficiency of the hammer, static bearing resistance of the pile, and to establish pile driving criteria. Per AASHTO (2017) recommendations, a resistance factor of 0.5 can be used for wave equation analysis only without pile dynamic measurements such as PDA monitoring.

Spread Footings: Based on the conditions encountered at Pier 2 (Boring A-02), it is assumed that a spread footing foundation bearing on the alluvial terrace deposit will be designed for this location. Spread footings bearing on the terrace alluvium or Structure Backfill (Class 1) can be designed for a nominal bearing resistance of 35 ksf for an assumed footing width of 6 feet. A bearing resistance factor of 0.45 should be used in the design. Sub-excavation below the design profile grade will be required to expose the recommended bearing layer. The excavation can be brought back to the desired elevation using Structure Backfill (Class 1). Nominal sliding resistance should be calculated using Equation 10.6.3.4-2 in AASHTO (2017) for an internal friction angle of drained soil of 34 degrees. A sliding resistance factor of 0.80 should be used for cast-in-place concrete.

The parameters in Table 2 may be used for driven pile foundation lateral loading analysis using LPILE.

Table 2. LPILE Parameters for Driven Piles

Soil Type	LPILE Soil Criteria	Effective Unit Weight (pcf)	Friction Angle, ϕ (degrees)	Undrained Cohesion (psf)	Strain Factor, $\varepsilon 50$	p-y Modulus, k (pci)
Sandy Clay	Stiff Clay (Reese & Welch)	100	28	1000	0.007	500
Alluvial Gravel	Sand (Reese)	135	38	----	----	100

The minimum spacing requirements between driven piles should be three diameters from center to center. Recommended P multipliers to account for reduction in lateral resistance due to group effect are provided in AASHTO Section 10.7.3.12. Lateral earth pressures on abutment walls and wingwalls can be calculated in accordance with Article 3.11.5.1 of the AASHTO LRFD Specifications. A soil unit weight of 135 pcf and an angle of internal friction of 34 degrees should be used for backfill consisting of CDOT Structure Backfill (Class 1). Abutment wall backfill should conform to CDOT Standard Plan M-206.

Wildlife Crossing WX at Station 958+00

The Wildlife Crossing that Yeh has designated as WX is located in the vicinity of US 550 Station 958+00. We understand the proposed structure, may be a concrete box culvert or precast concrete arch. The Post-FIR plans dated 12-05-2016 show the structure to be a concrete box culvert (CBC) 23 feet wide, 14 feet high, and 241 feet in length. The CBC crosses beneath the northbound lanes, southbound lanes, and the proposed frontage road, and will be founded 13 to 16 feet below the existing ground surface.

Four (4) borings were advanced with a CME 750X All Terrain drill rig at the approximate location of the proposed wildlife crossing. The attached engineering geology plan sheet shows the boring location and the logs. The borings are designated as WX-01 through WX-04 and range in depth from 31.8 to 45.5 feet. Subsurface soil and gravel was visually described and classified in the field; samples were obtained from auger cuttings and with Split-Spoon and Modified California sample barrels. A summary of the conditions encountered in each boring at Wildlife Crossing WX is provided in Table 3.

Table 3. Summary of Wildlife Crossing WX Borings

Boring	Station	Offset	Total Depth (ft)	Depth to Alluvium (ft)	Depth to Bedrock (ft)
WX-01	957+95	71’ RT	31.8	30	n/a
WX-02	958+30	4’ RT	45.5	28	n/a
WX-03	958+37	69’ LT	35.0	28	n/a
WX-04	958+65	153’ LT	34.3	22	n/a

Borings WX-01 and WX-02 were drilled in agricultural land east of the existing US 550. Boring WX-01 was advanced using continuous flight hollow-stem auger (HSA). Stiff to very stiff clay was encountered to a depth of 29 feet. A layer of silt with some sand was encountered at 29 feet, transitioning into very dense gravel with sand and cobbles at 30 feet. Auger refusal was encountered at 31.8 feet in very dense gravel and cobble. Boring WX-02 was advanced using a combination of HSA and Down-Hole Hammer Drilling (ODEX). The upper 28 feet of the boring encountered stiff to very stiff clay with some sand. Drill methods were switched from HSA to ODEX at a depth of 24 feet. Dense to very dense gravel and cobble with some silt and sand was encountered from 28 feet to the bottom of the boring at 45.5 feet below ground surface.

Boring WX-03 was drilled on the shoulder of the northbound lane of existing US 550 using a combination of HSA and ODEX drilling. The upper 3.5 feet of materials encountered consisted of embankment fill comprised of gravel with some sand and clay. Native clay soil was encountered below the fill, noted as a stiff to very stiff clay with a trace of sand. Dense to very dense Gravel was encountered from 28 feet to the bottom of the boring at a depth of 35 feet.

Boring WX-4 was drilled on the west side of existing US 550 in agricultural land using a combination of HSA and ODEX drilling methods. Very stiff to hard clay was encountered from the ground surface to a depth of 22 feet. Dense to very dense gravel with some sand was encountered from 22 feet to the bottom of the boring at a depth of 34.3 feet. Groundwater was not encountered in the borings at the time of drilling.

Laboratory test results show relatively high moisture contents in samples of clay soils from Borings WX-02 and WX-03. High moisture content may be due to seasonal fluctuations in groundwater levels or the result of irrigation. Lab tests performed on the clay soils show AASHTO classifications of A-6 (11) and A-6 (16). Swell / consolidation tests performed on select samples showed -low potential for consolidation or swell when the samples were wetted under an applied load of 1 ksf.

Foundations

Driven piles that penetrate the underlying alluvial terrace gravel or spread footing foundations that bear on the undisturbed stiff clay can be used for support of the Wildlife Crossing WX structure. Pile foundations may be more appropriate for a pre-cast concrete arch where foundations loads may be relatively high and differential settlement can result in structural distress. A CBC will generally have lighter foundation loads that can be supported on spread footings and minor differential settlements are less of a concern with this type of structure.

Driven Piles: Based on the conditions encountered in Borings WX-01 through WX-04, driven pile foundations can be used for wildlife crossing WX. Driven piles penetrating a minimum of 5 feet into the terrace alluvium can be designed for a nominal tip resistance of 100 ksf for an assumed effective pile diameter of 12 inches. Piles should be designed as end bearing only. Side friction resistance in the clay soils should be neglected. The contribution to pile axial capacity of side friction resistance in the alluvium is small because of the shallow depth of penetration and should be ignored. For lateral loading analysis using LPILE, the parameters in Table 2 may be used.

The minimum spacing requirements between driven piles should be three diameters from center to center. Assuming a pile driving analyzer (PDA) is used to monitor pile driving, as required by Section 502 of the CDOT (2017), a resistance factor of 0.65 may be used per AASHTO (2017) Table 10.5.5.2.3-1. Section 502.05 of the CDOT (2017) stipulates that a minimum of two PDAs be performed per structure to determine the condition of the pile, efficiency of the hammer, static bearing resistance of the pile, and to establish pile driving criteria. Per AASHTO (2017) recommendations, a resistance factor of 0.5 can be used for wave equation analysis only without pile dynamic measurements such as PDA monitoring.

Spread Footings: Based on the conditions encountered in Borings WX-01 through WX-04, lightly loaded spread footing foundations bearing on the surficial soil (stiff clay) may be used for wildlife crossing WX. Assuming seasonal high groundwater levels at the top of the footings, spread footings bearing on the stiff clay can be designed for a nominal bearing resistance of 2.5 ksf for an assumed footing width of 6 feet. A bearing resistance factor of 0.45 should be used in the design. Long term consolidation under a load of 2.5 ksf is expected to be less than one inch. A structure with a wide foundation, such as a CBC where the foundation width is equal to that span will experience less settlement. Nominal sliding resistance should be calculated using Equation 10.6.3.4-2 in AASHTO (2017) for an internal friction angle of drained soil of 28 degrees. A sliding resistance factor of 0.80 should be used for cast-in-place concrete.

The nominal bearing resistance in this analysis was limited by punching shear for 6 foot wide footings. Subexcavation of the clay soils and replacement with a thickness of Structure Backfill (Class 1) equal one-half the footing width, and extending one-half the footing width to either side, will increase the nominal bearing resistance to 4.0 ksf and mitigate the potential for punching shear and long term settlement.

Lateral earth pressures on abutment walls and wingwalls can be calculated in accordance with Article 3.11.5.1 of the AASHTO LRFD Specifications. A soil unit weight of 135 pcf and an angle of internal friction of 34 degrees should be used for backfill consisting of CDOT Structure Backfill (Class 1). Wall backfill should conform to CDOT Standard Plan M-206.

Wildlife Crossing WX2 at Station 902+50

The Wildlife Crossing designated as WX2 is located at the south end of the project on US 550 near Station 902+50. We assume the structure will be a CBC or Pre-Cast Arch with a span of about 23 feet, similar to Wildlife Crossing WX. The layout plan for WX2 was not available at the time this memo was prepared.

Four (4) borings were advanced with a track-mounted CME 55 drill rig at the approximate location of the proposed wildlife crossing. The borings were located on the west side of the structure; the east side is irrigated farm land and was inaccessible at the time of our field work. The borings are designated as WX2-01 through WX2-04 and range in depth from 29.5 to 38.8 feet. Subsurface soil and gravel was visually described and classified in the field and samples were obtained from auger cuttings and with Split-Spoon and Modified California samplers. A summary of the conditions encountered in each boring at Wildlife Crossing WX2 is provided in Table 4.

Table 4. Summary of Wildlife Crossing WX2 Borings

Boring	Station	Offset	Total Depth (ft)	Depth to Alluvium (ft)	Depth to Bedrock (ft)
WX2-01	902+22	60’ LT	34.5	23	n/a
WX2-02	902+78	61’ LT	38.8	23.5	35
WX2-03	902+27	14’ LT	29.5	19	n/a
WX2-04	902+75	14’ LT	29.5	18	27

Borings WX2-01 and WX2-02 were drilled in the shoulder of the north bound lane of US 550. WX2-01 was advanced to a depth of 34.5 feet below the ground surface. Materials encountered in the upper 5 feet of the boring consisted of embankment fill comprised of gravel with some sand and clay. Native soils were logged at 5 feet, and consisted of stiff to very stiff clay with some sand to a depth of approximately 23 feet. Dense to very dense gravel with some sand and cobble was logged from 23 feet to the final depth of the boring at 34.5 feet. Boring WX2-02 encountered approximately 5 feet of embankment fill. Native stiff to very stiff clay was logged from 5 feet to 23.5 feet. Dense to very dense gravel with some sand and cobble was logged from 23.5 feet to 35 feet. Bedrock, consisting of moderately weathered to medium hard claystone, was logged at 35 feet to the maximum depth of the boring at 38.8 feet.

Borings WX2-03 and WX2-04 were drilled in agricultural land east of the existing roadway, each to a depth of approximately 29.5 feet. Boring WX2-03 encountered stiff to very stiff clay with some sand from the ground surface to a depth of 19 feet. Dense to very dense gravel with some sand layers was encountered below 19 feet to the maximum depth drilled of 29.5 feet. WX2-04 encountered approximately 18 feet of very stiff clay below the ground surface. Dense to very dense gravel with some sand, cobble and boulders was encountered from 18 to 27 feet.

Bedrock, consisting of moderately weathered to medium hard claystone, was encountered from 27 feet to the final depth of the boring at 29.5 feet.

Groundwater was no encountered in the borings at the time of exploration, but moisture contents in samples of the clay appear to be at or near saturation. Results of laboratory tests performed on the clay soils show an AASHTO classifications of A-6 and A-7-6. Swell / Consolidation tests performed on select samples showed -0.1 to -0.3% consolidation when wetted under an applied load of 1 ksf.

Foundations

Driven pile or spread footing foundations may be appropriate for support of the Wildlife Crossing WX2 structure. Piles should penetrate the dense gravel deposit. Spread footings can be placed on the stiff clay soils.

Driven Piles: Based on the conditions encountered in Borings WX2-01 through WX2-04, driven pile foundations can be used for wildlife crossing WX2. Driven piles penetrating a distance of 5 feet into the terrace alluvium can be designed for a nominal tip resistance of 100 ksf for an assumed effective pile diameter of 12 inches. Piles should be designed as end bearing only. Side friction resistance in the clay soils should be neglected. The contribution to pile axial capacity of side friction resistance in the alluvium is small because of the shallow depth of penetration and should be ignored. The parameters in Table 2 may be used for lateral loading analysis using LPILE.

The minimum spacing requirements between driven piles should be three diameters from center to center. Assuming a pile driving analyzer (PDA) is used to monitor pile driving, as required by Section 502 of the CDOT (2017), a resistance factor of 0.65 may be used per AASHTO (2017) Table 10.5.5.2.3-1. Section 502.05 of the CDOT (2017) stipulates that a minimum of two PDAs be performed per structure to determine the condition of the pile, efficiency of the hammer, static bearing resistance of the pile, and to establish pile driving criteria. Per AASHTO (2017) recommendations, a resistance factor of 0.5 can be used for wave equation analysis only without pile dynamic measurements such as PDA monitoring.

Spread Footings: Based on the conditions encountered in Borings WX2-01 through WX2-04, spread footing foundations bearing on the surficial soil (stiff clay) can be designed for wildlife crossing WX2. Assuming that groundwater is present at the top of the footing, spread footings bearing on the stiff clay can be designed for a nominal bearing resistance of 2.5 ksf for an assumed footing width of 6 feet. A bearing resistance factor of 0.45 should be used in the design. Settlement over time under a load of 2.5 ksf is expected to be less than one inch. Nominal sliding resistance should be calculated using Equation 10.6.3.4-2 in AASHTO (2017) for an internal friction angle of drained soil of 28 degrees. A sliding resistance factor of 0.80 should be used for cast-in-place concrete.

The nominal bearing resistance in this analysis was limited by punching shear. Subexcavation of the clay soils and replacement with a thickness of Structure Backfill (Class 1) equal one-half the footing width, and extending one-half the footing width to either side, will increase the nominal bearing resistance to 4.0 ksf and mitigate the potential for punching shear and settlement.

Lateral earth pressures on abutment walls and wingwalls can be calculated in accordance with Article 3.11.5.1 of the AASHTO LRFD Specifications. A soil unit weight of 135 pcf and an angle of internal friction of 34 degrees should be used for backfill consisting of CDOT Structure Backfill (Class 1). Wall backfill should conform to CDOT Standard Plan M-206.

Seismicity

The sites of the Mammal Crossings are classified as Site Class C, Soft Rock in accordance with Table 3.10.3.1-1 of the 2017 AASHTO Guide Specifications for LRFD Bridge Design. The Peak Ground Acceleration (PGA), and the short- and long-period response spectral acceleration coefficients (SS and S1 respectively) for the reference site (Table 4) were obtained using the USGS Design Maps tool for an event with a 7% Probability of Exceedance (PE) in 75 years and a Site Class B (reference site). An event with the above probability of exceedance has a return period of about 1,000 years. Because the bridge sites classification (Class C) is different from the reference site (Class B), site specific value adjustments are necessary. The seismic design parameters for the site are shown on Tables 4 and 5. These values may be used to construct the Design Response Spectrum for use in the seismic design of bridge structures.

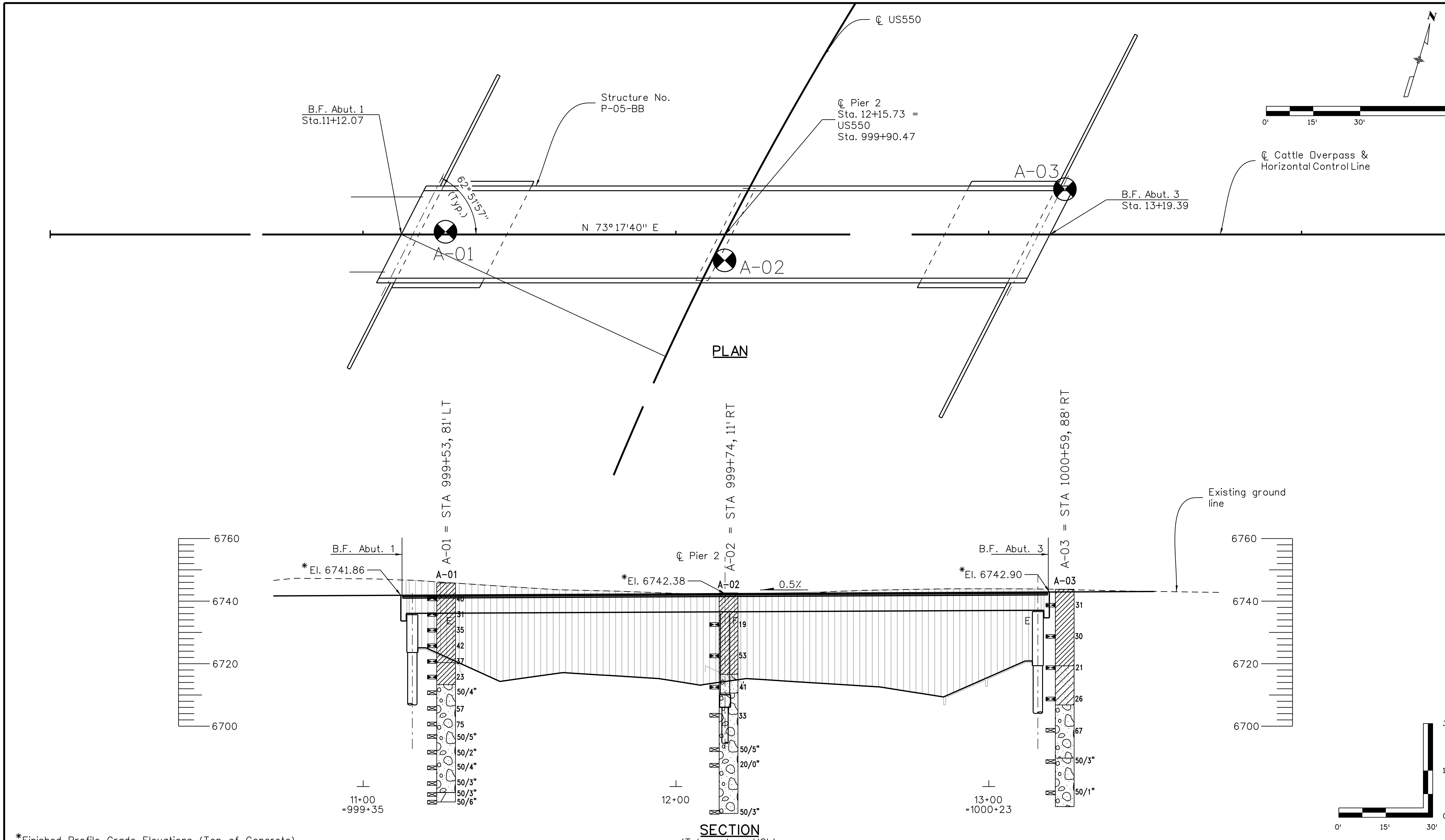
Table 4. Seismic Parameters for Reference Site Class B

Site Class	PGA (0.0 sec)	S_S (0.2 sec)	S_1 (1.0 sec)
B	0.061 g	0.134g	0.041 g

Table 5. Seismic Design Parameters for Bridges 1 and 2

Site Class	A_S (0.0 sec)	S_{DS} (0.2 sec)	S_{D1} (1.0 sec)	Seismic zone
C	0.073 g	0.161 g	0.069 g	1

Attachment: Engineering Geology Plans Sheets (Mammal Crossing Structure P-05-BB, Mammal Crossing WX, Mammal Crossing WX2)



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Unit Information	Unit Leader Initials

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Sheet Revisions

Date:	Comments	Init.

Colorado Department of Transportation
CDOT
3803 North Main Avenue
Suite 200
Durango, CO 81301
Phone: 970-385-1440 FAX: 970-385-8365
Region 5 DRV

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No Revisions:
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MAMMAL CROSSING
ENGINEERING GEOLOGY

Designer: ta	Structure Numbers	P-05-BB	
Detailer: lr			
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Project No./Code
NHPP 5501-029
22420
Sheet Number

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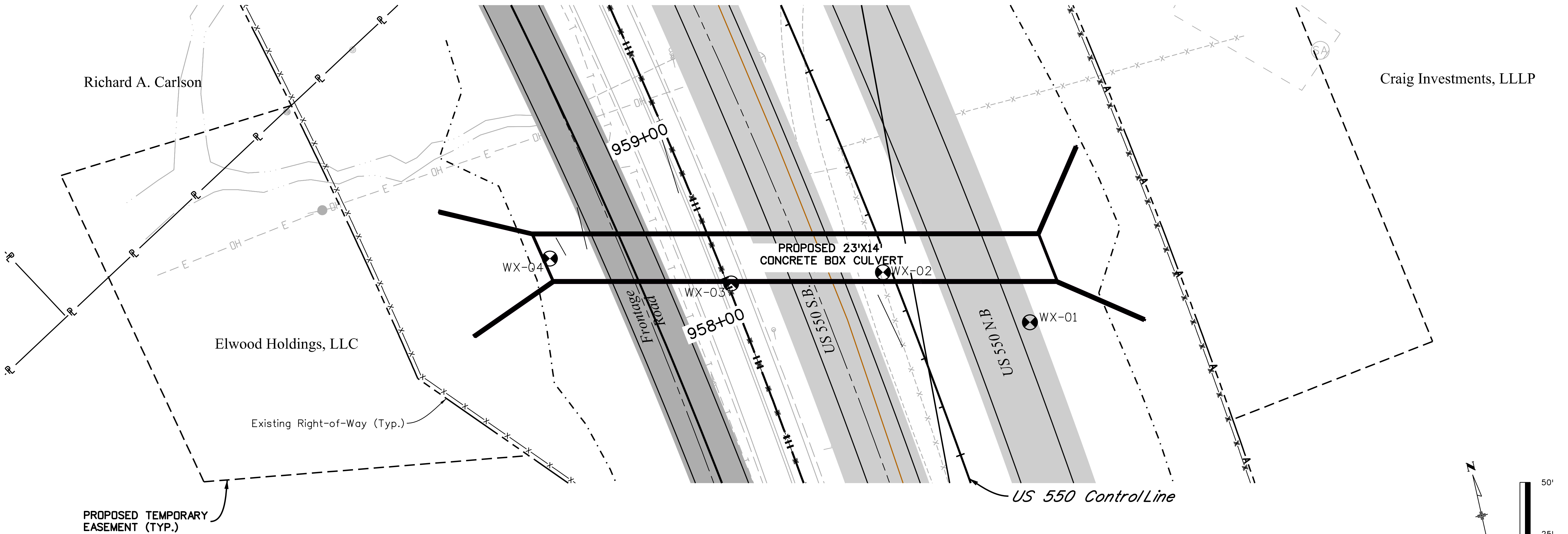

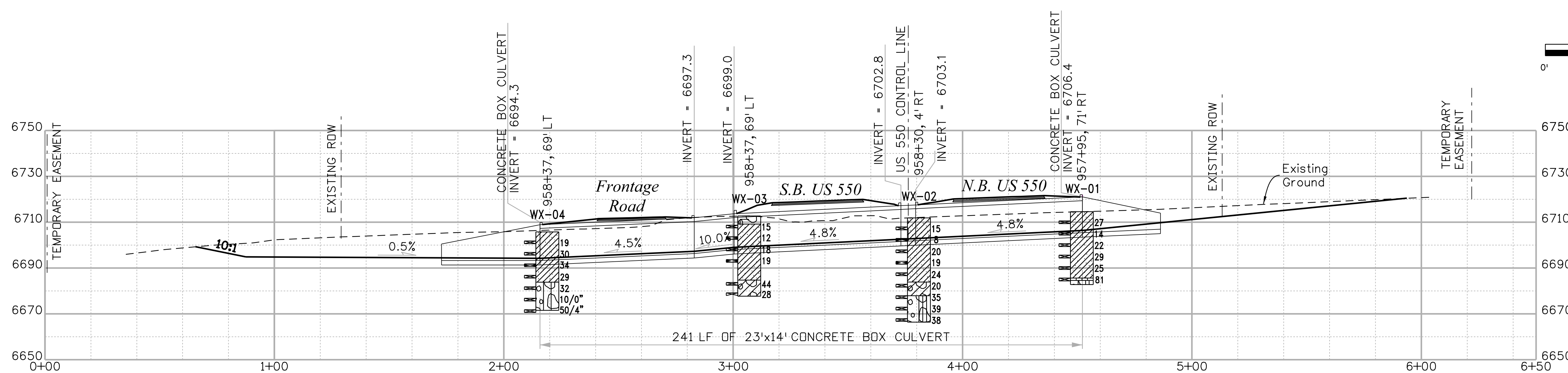

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3803 North Main Avenue
Suite 200
Durango, CO 81301
Phone: 970-385-1440 FAX: 970-385-8365
Region 5 DRV

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MAMMMAL CROSSING ENGINEEROMG GEOLOGY

Designer: TA	Structure Numbers		
Detailer: LR			
Sheet Subset: XG-XING	Subset Sheets: 2 OF 3		

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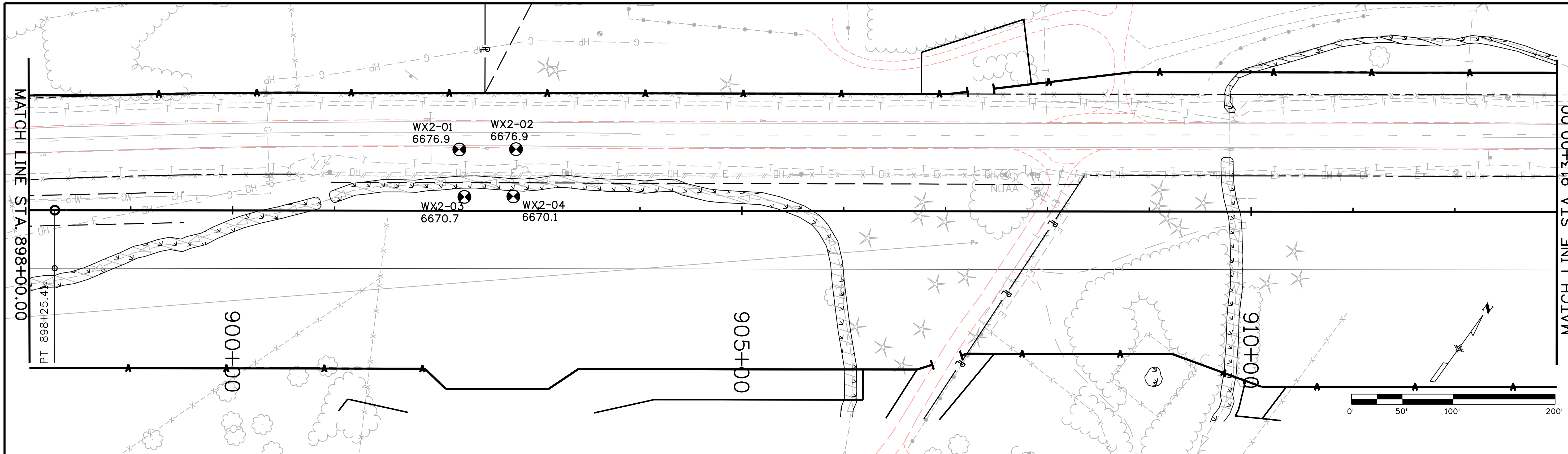

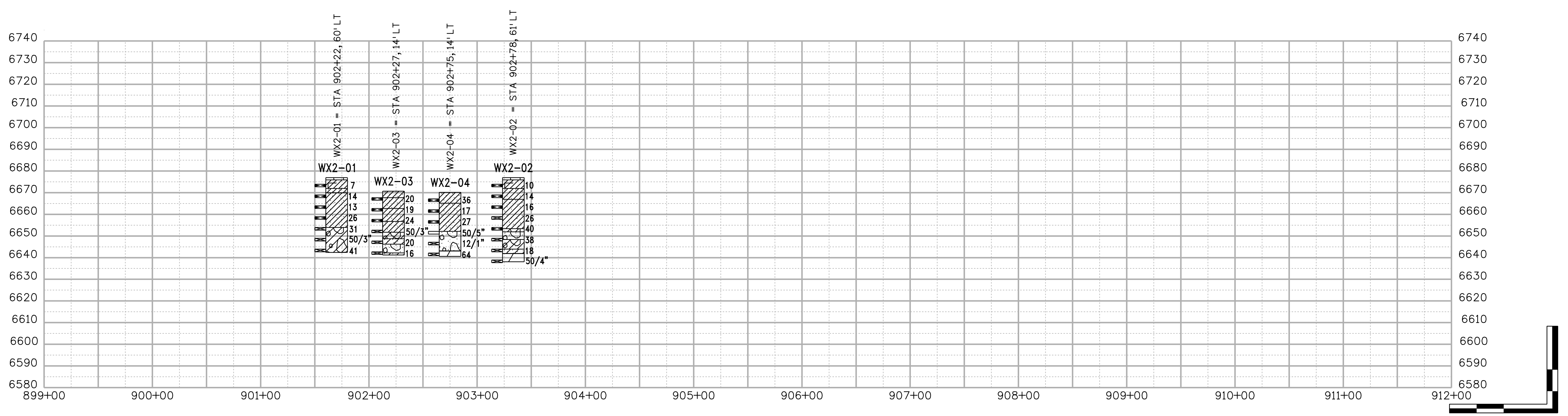

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Consulting Engineers & Scientists

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Colorado Department of Transportation
3803 North Main Avenue
Suite 200
Durango, CO 81301
Phone: 970-385-1440 FAX: 970-385-8365
Region 5
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Designer: TA
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Sheet Subset: EG-XING
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Subset Sheets: 3 OF 3

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