Revised Task Report 1 – Summary of Construction Plans

Project Title: Relative Operational Performance of Geosynthetics Used as Subgrade Stabilization

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Unit Conversions

Measurement	Metric	English
Length	1 cm	0.394 in
	1 m	3.281 ft
	1 km	0.621 mile
Area	1 cm^2	0.155 in^2
	1 m^2	1.196 yd^2
Volume	1 m^3	1.308 yd^3
	1 ml	0.034 oz
Force	1 N	0.225 lbf
	1 kN	0.225 kip
Stress	1 MPa	145 psi
	1 GPa	145 ksi
Unit Weight	1 kg/m^3	1.685 lbs/yd^3
Velocity	1 kph	0.621 mph

Introduction

Multiple test sections are to be constructed this summer to investigate the relative benefit to an unpaved road of various geosynthetics available on the market. An "artificial" subgrade will be constructed to provide uniform conditions for each test section to facilitate direct comparisons between geosynthetic products based primarily on rutting. Test sections will be constructed at the TRANSCEND test facility in Lewistown, Montana to provide researchers with a safe and controlled environment to conduct this experiment, while helping to ensure the quality and consistency of the entire construction effort. This document summarizes the work accomplished on the project to prepare for construction of the field experiment. These preparations generally include refining the testbed layout, reviewing the construction schedule, preparing construction specifications and bid documents, procuring material, and beginning work on the instrumentation and data acquisition systems.

Test Section Layout

The experiment consists of 17 test sections that are each 4.7 m wide and 15 m long (15 ft wide and 50 ft long) for a total length of about 255 meters (837 ft). Three control sections (i.e., no geosynthetic) will be constructed at the northern end of the testbed. Each of the three control test sections will have a different thickness of base aggregate. The nominal thickness of the base course aggregate layer has not yet been determined, but is preliminarily estimated to be about 35 cm (14 in) for planning purposes. Final depth of the base aggregate layer will be determined based on the results of the cyclic plate load "big box" test. One control test section will have the same thickness as the remaining test sections (i.e., ~35 cm or 14 in), one will be thicker (~45 cm or 18 in thick), and one thicker still (~55 cm or 22 in thick). At the southern end of the testbed, three Tensar BX (Type 2) test sections will be constructed with three different subgrade strengths that span the nominal strength of the reinforced test sections. One BX (Type 2) test section will have the same subgrade strength as the other reinforced test sections (i.e., CBR=1.7), one will have a lower strength (CBR=1.4), and one will have a higher strength (CBR=2.0). The test section layout in Figure 1 shows this arrangement. The specific geosynthetics to be used in the remaining test sections are listed below in the Construction Materials section of this task report. Their exact locations in the remaining sections of the testbed will be determined at the time of construction.

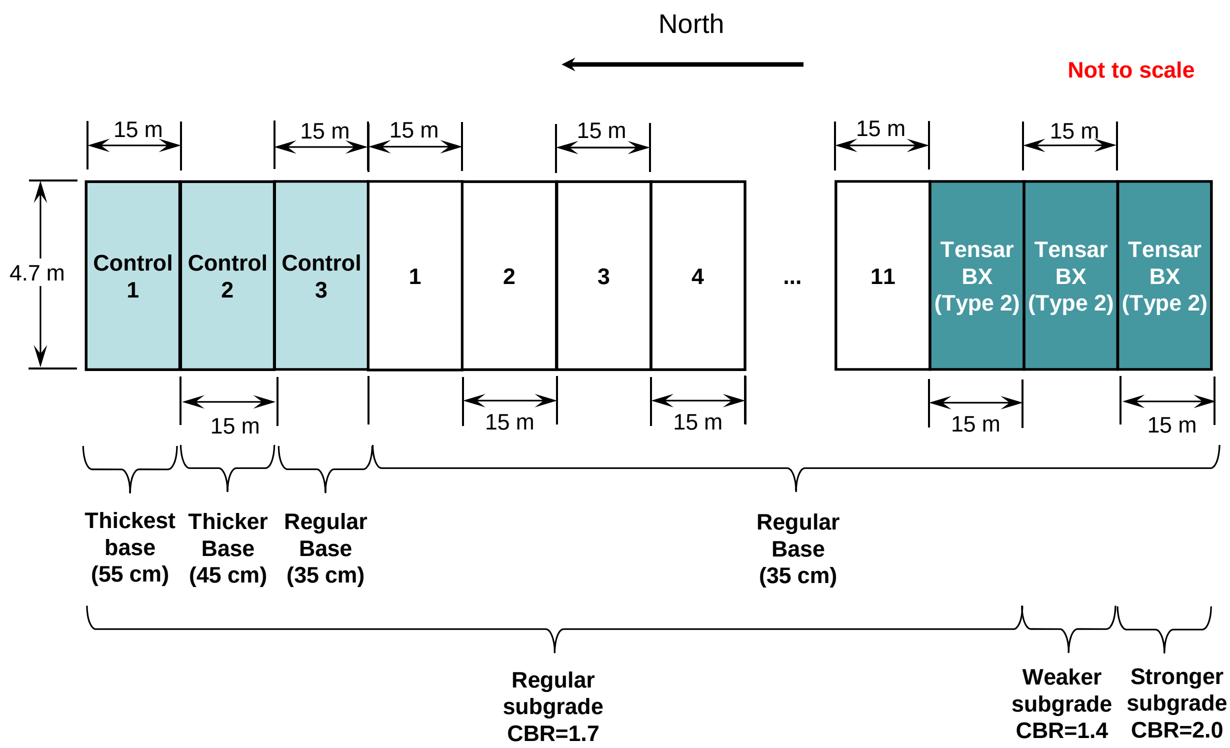


Figure 1: Basic layout of test sections.

Construction Details

Construction of the test sections will involve: 1) excavating and widening the existing trench (used earlier in the subgrade stabilization project), 2) lining the trench with plastic, 3) preparing and placing the artificial subgrade, 4) installing the sensors and geosynthetics, and 5) preparing and placing the base course aggregate. Construction is anticipated to begin with excavation during the week of July 2. Subgrade construction may take one to three weeks to complete and is currently scheduled to occur from July 9 to 26. The last week of construction will involve installation of the pore-water pressure sensors, lead wires and geosynthetics, which will occur simultaneously with placement of the base course aggregate. This step is anticipated to take about one week between July 24 and August 3, depending on completion of the subgrade. After placement and compaction of the base course aggregate, researchers at the Western Transportation Institute (WTI) will install and set up the instrumentation, data acquisition, and power systems, and prepare for trafficking. The Gantt chart in Figure 2 shows the anticipated construction schedule.

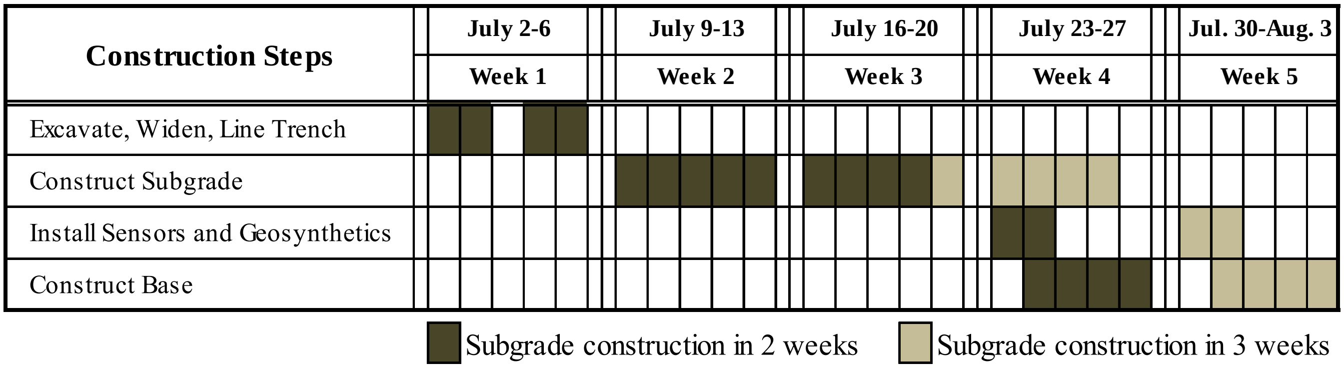


Figure 2: Anticipated construction schedule.

The office of Facilities, Planning, Design and Construction at Montana State University (MSU) administers all construction contracts for campus-related activities, including the contract to construct the test sections for this project. WTI met with Facilities Services to 1) discuss the purpose of the project, 2) review the technical specifications, 3) prepare the bid documents, and 4) establish a timeline for bidding and construction. The bid documents will contain standard information pertaining to payment, bonds, prevailing wages, insurance, etc., as well as the technical specifications written by WTI for constructing the experiment in Lewistown. The technical specifications, including construction drawings, are attached in Appendix A.

The bid documents will be advertised for three weeks beginning the week of April 8, with bid responses due by 2:00pm on Thursday, April 26. A mandatory pre-bid meeting will be held at TRANSCEND on Tuesday, April 17 for all interested contactors. At the pre-bid meeting, WTI will present the technical specifications and construction requirements. WTI will also demonstrate how the various quality control devices (vane shear, dynamic cone penetrometer and lightweight deflectometer) will be used to ensure accurate and consistent strength in the subgrade. A sample of the subgrade prepared at a CBR of 1.7 will be brought to the meeting to allow contractors to acquaint themselves with this material. The construction contract will be awarded to the bidder that has the lowest cost and meets all of the bid requirements.

Construction Materials

The three basic materials needed for construction of this experiment consist of the artificial subgrade, the base course aggregate and the geosynthetics. Characterization, selection and procurement efforts associated with these materials are currently underway, as summarized in the following subsections.

Artificial Subgrade

The same source of subgrade soil from the previous project (Cuelho and Perkins, 2009) will be used for this project. This material is a natural overburden material that classifies as an A-6 soil. Samples collected from the stockpile are being tested in the laboratory to verify and document its material properties. Atterberg limits have varied only slightly compared to the previous experiment (Cuelho and Perkins, 2009), with recent tests finding a liquid limit of 32 (previously 32), plastic limit of 19 (previously 17), and plasticity index of 13 (previously 15). To date, 35 CBR tests have been conducted on the subgrade, 21 of which had a CBR between 1.3 and 2.1. The preliminary correlation between vane shear and CBR is shown in Figure 3. Additional CBR tests are being conducted to further refine and substantiate this correlation. This correlation will be used in the field during construction to allow subgrade strength to be monitored with the vane shear device.

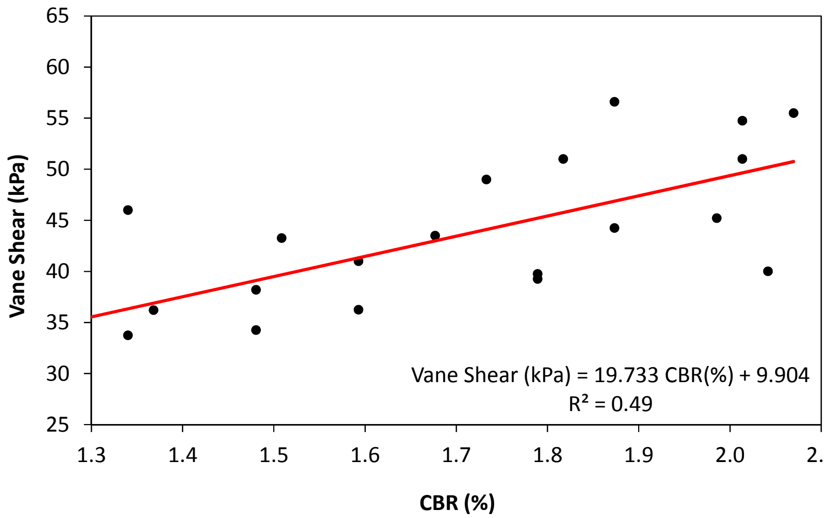


Figure 3: Preliminary correlation between vane shear and CBR on the subgrade.

Base Course Aggregate

A base course aggregate that meets the specified gradation and index properties listed in Table 1 is currently being sought from multiple sources, as detailed below.

Table 1: General Properties of the Base Course Aggregate

Sieve (US)	Sieve (mm)	Montana 5A (% pass.)
2-inch	**50.8**	100
1 1/2-inch	**38.1**	94-100
3/4-inch	**19**	70-88
3/8-inch	**9.5**	50-70
#4	**4.75**	34-58
#40	**0.425**	6-30
#200	**0.075**	0-8
Liquid limit		< 25
Plasticity index		< 6
Fractured faces (%)		≥ 50%
No. of fractured faces above #4 sieve		2+

- **<u>Source 1</u> (**Nelcon Inc., Windham pit)—This gravel pit is currently under contract to provide material to the Montana Department of Transportation (MDT) for a nearby project. The Windham pit is located less than 40 km (25 mi) from the experiment site and, based on a preliminary analysis, is likely able to provide material for the field test sections at a reasonable cost. WTI and MDT have conducted sieve analyses for several stockpiles at the pit. Using two separate stockpiles at the Windham pit, WTI has determined an appropriate blend that will generally meet requirements for gradation, Atterberg Limits, and fractured faces. Samples were recently shipped to an independent testing facility, GeoTesting Express (GTX), to test gradation, modified Proctor, and resilient modulus. If test results are satisfactory, this gravel will be used in the box test and the field test sections.
- **<u>Source 2</u>** (Knife River Corporation, Livingston pit)—This pit is located about 200 km (130 mi) from the test site. This source can also provide material that meets gradation and fractured face specifications for the field experiment; however, this base course aggregate is more expensive than the Windham aggregate due to transportation costs. Samples of this aggregate were also shipped to GTX to measure gradation, modified Proctor, and resilient modulus. If the results from the resilient modulus tests conducted on the Windham aggregate are unsatisfactory, this aggregate is a second candidate for the box test and the field test sections.
- **<u>Source 3</u>** (Knife River Corporation, Belgrade pit)—This pit is located about 275 km (170 mi) from Lewistown and can provide aggregate that meets specification, but at a considerably higher cost to the project. This source has been removed from consideration at this time.

<u>Geosynthetics</u>

Geosynthetic manufacturers and suppliers have been contacted and many have already shipped or agreed to provide geosynthetics for the project. A summary of the geosynthetic procurement is provided in Table 2.

Table 2: Status of Geosynthetics Procurement

Company	Product Name	Status
Colbond	Enkagrid Max30	Received
Huesker	Fornit 30	Received
NAUE	Secugrid 30-30	Received
Propex	Geotex801	Received
Syntec	Tenax MS 330	On order, expected soon
Synteen	SF-11	Received
Synteen	SF-12	Received
TenCate	Mirafi BXG-11	Received
TenCate	Mirafi RS580i	Received
Tensar	BX (Type 2)	On order, expected soon
Tensar	TX140	On order, expected soon
Tensar	TX160	On order, expected soon

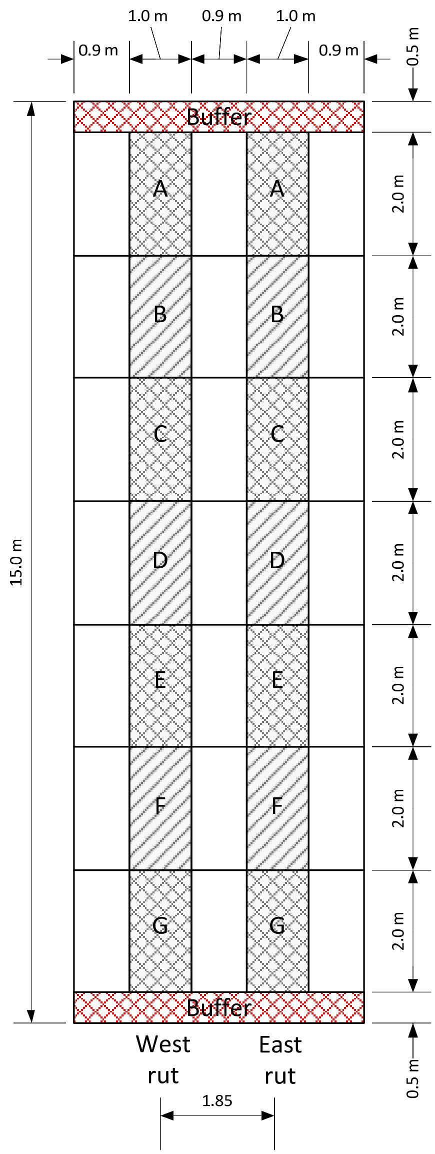
Cyclic Plate Load "Big Box" Test

Geotechnical testing laboratories were contacted to submit bids for the cyclic plate load "big box" test. The winning bidder was GTX in Alpharetta, GA. A contract between MSU and GTX has been executed for this test. Soils and geosynthetic will be shipped to GTX once a source for the base aggregate is determined and the BX (Type 2) geogrid is obtained. The box test is currently scheduled to occur during the week of April 30.

Soil Monitoring Plan during Construction

Extensive in-field soil testing is planned during construction of the subgrade and base course. A summary of the proposed tests and their locations within each test section is provided in Figure 4. On each lift of the subgrade, within each test section, 14 vane shear and 6 lightweight deflectometer (LWD) measurements will be taken. These vane shear tests are in addition to ones that will be conducted during construction for acceptance of the contractor's work. On the final lift of the subgrade, within each test section, 6 dynamic cone penetrometer (DCP) tests, 2 in-field CBR tests, and 2 nuclear densometer tests will also be conducted. During base course construction, 6 LWD measurements will be conducted after the first and final passes of the compactor on the first lift. After the last compactor pass of the final lift, an additional 6 LWD, 6 DCP, 2 in-field CBR, and 2 nuclear densometer tests will be conducted. The majority of the measurements will be taken in the wheel paths, illustrated as two 1-meter wide (3.3-ft wide) strips along the test section in Figure 4. The wheel paths will be further delineated into 2 m long (6.6 ft long) subsections (A through G) to account for multiple tests in various regions, which will allow future correlations of the material properties to be made during the analysis.

Subsection D will be measured using all devices. A 0.5 m long (1.6 ft long) buffer zone at each end of a test section will not be used in the analysis to avoid possible influences from the transition of the truck between adjacent test sections.



Subgrade			
Measurement Device	**Layers**	**Measurements per Layer**	**Location of Measurement**
Vane Shear	all	14	A,B,C,D,E,F,G
Light Weigt Deflectometer	all	6	B,D,F
Dynamic Cone Penetrometer	final	6	A,D,G
In-Field CBR	final	2	D
Nuclear Density Gage	final	2	D

Base Course Aggregate			
Measurement Device	**Layers**	**Measurements per Layer**	**Location of Measurement**
Light Weigt Deflectometer	first	12	B,D,F
Light Weigt Deflectometer	final	6	B,D,F
Dynamic Cone Penetrometer	final	6	A,D,G
In-Field CBR	final	2	D
Nuclear Density Gage	final	2	D

Figure 4: Measurement layout and plans for field soil tests within a single test section.

Monitoring Equipment

The planning, purchase and assembly of many of the components for the instrumentation and data acquisition systems is underway. Electronic instrumentation mainly consists of displacement sensors (LVDTs), resistance strain gages, and pore-water pressure gages. Data from the sensors will be collected and stored using two CR9000 data loggers from Campbell Scientific, Inc., which are expected to be delivered in early April. Other monitoring equipment includes the lightweight deflectometer, dynamic cone penetrometer, vane shear device and survey equipment, which have already been purchased.

A mobile laboratory will house the data logging equipment on site during testing. As proposed, pore-water pressure, displacement and strain will be measured in two locations within each test section. Instrumentation will be housed in two separate enclosures that will be mounted to the ground adjacent to each test section. This arrangement is illustrated in Figure 5. The two enclosures (boxes) will be about 5 m (15 ft) from one another and plumbed together to provide a conduit for wiring. One of the boxes will be designated as the master, which will be directly wired to the data acquisition computers that are housed in the mobile laboratory. The other enclosure (slave) will be wired through its corresponding master.

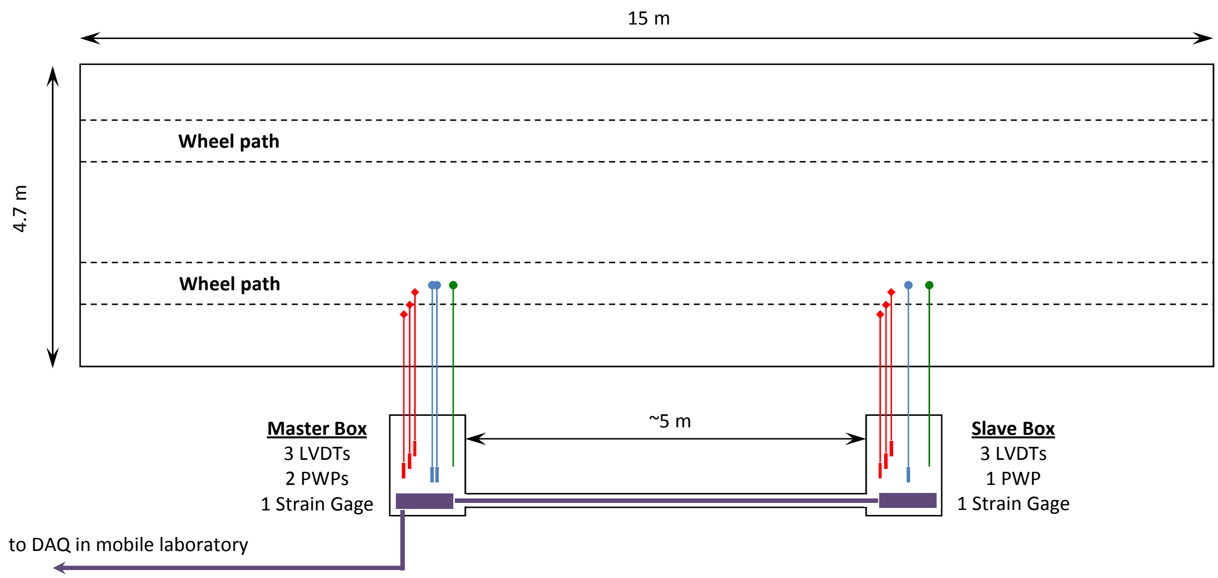


Figure 5: Illustration of instrumentation arrangement within a single test section.

Pore-water Pressure Gages

Pore-water pressure measurements will be made using a pressure transducer connected to a rigid plastic tube which is attached to a porous ceramic stone. The rigid tubing and porous stone will extend the point of measurement from the rut area to the pressure sensor which will be housed in the equipment enclosures adjacent to the test sections. These sensors have been purchased using specifications that were developed specifically based on the needs of this project.

A laboratory evaluation of this setup is currently underway to verify the expected response when the porous stones are embedded in subgrade that has been prepared at CBR = 1.7. These sensors will be tested under static and dynamic loads to evaluate their response to anticipated stresses generated during construction and trafficking. Information from this laboratory evaluation will be used to refine the way in which these measurement devices are set up and used in the field experiment to ensure accurate measurements of pore-water pressure development during this experiment.

<u>*Displacement Gages*</u>
Linearly varying differential transformers (LVDTs) with a range of 50 mm (2 in) will be used to make the displacement measurements on the geosynthetic (6 gages per test section). These sensors will be housed in the equipment enclosures mounted adjacent to the test sections, and lead wires attached to the geosynthetic will extend the point of measurement from the rut area to each sensor.

<u>*Resistance Strain Gages*</u>
Resistance strain gages will be used to measure the strain response on the transverse reinforcing members of the geosynthetic. Gage selection was done mainly based on their size in relation to the size of the elements they need to be mounted on. A summary of the pertinent properties of these gages is listed in Table 3 for each geosynthetic product. The EP series of gage was selected because it accommodates large strain measurements (± 20 percent in some cases).

The geosynthetics will be cut to length and the strain gages attached in a controlled laboratory environment prior to construction. Circuitry associated with the strain gages is currently being built, and mainly consists of an array of Wheatstone bridge circuits necessary for proper processing of the signals from the resistance strain gages. The efficacy of installation procedures and circuitry will be verified in the laboratory prior to field installation. Strain gages will be installed on the various materials and tested in the laboratory in a wide-width format to verify their behavior and calibrate their responses at levels of global strain anticipated in the field during trafficking.

Table 3: Summary of Resistance Strain Gages for Each Geosynthetic

Product Name	Strain Gage Type	Gage Size (width/length, mm)	Gage Resistance (ohms)
Enkagrid Max30	EP-08-500GC	1.52 / 12.70	350
Fornit 30	EP-08-230DS	0.56 / 5.84	120
Secugrid 30-30	EP-08-500GC	1.52 / 12.70	350
Geotex801	EP-08-20CBW	4.78 / 50.80	120
Tenax MS 330	EP-08-230DS	0.56 / 5.84	120
SF-11	EP-08-500GC	1.52 / 12.70	350
SF-12	EP-08-500GC	1.52 / 12.70	350
Mirafi BXG-11	EP-08-500GC	1.52 / 12.70	350
Mirafi RS580i	EP-08-20CBW	4.78 / 50.80	120
BX (Type 2)	EP-08-500GC	1.52 / 12.70	350
TX140	EP-08-230DS	0.56 / 5.84	120
TX160	EP-08-230DS	0.56 / 5.84	120

References

Cuelho, E.V. and Perkins, S.W. (2009). Field Investigation of Geosynthetics Used for Subgrade Stabilization, U.S. Department of Transportation, Federal Highway Administration, Washington, DC, Report No. FHWA/MT-09-003/8193, 140 p.

Appendix A: Construction Specifications

It is important that you carefully read this section so that you fully understand what the project entails.

1. Purpose

The purpose of this work is to construct an artificial road for research purposes made of a weak subgrade soil layer overlaid by several geosynthetics and a typical base course gravel layer.

2. Background

A research project is being conducted by Montana State University (MSU) Western Transportation Institute (WTI) for Montana Department of Transportation (MDT), in partnership with the state departments of transportation of Idaho, New York, Ohio, Oklahoma, Oregon, South Dakota, Texas, and Wyoming.

An artificial road with strict construction tolerances for thickness, moisture content, and strength is needed to compare the relative performance of several types of geosynthetic materials. The road will utilize a weak clayey–sandy subgrade constructed in a trench. Geosynthetics will be installed and a gravel-surfaced road will be constructed.

3. Location of Project

The project is located at the TRANSCEND research and testing facility south of the Lewistown airport in Lewistown, Montana as shown in the attached map and picture (Figure 1). The construction will occur on the western side of a decommissioned north-south taxiway.

4. Construction Details and Specifications

The following steps are involved in the construction of the artificial road:

1. excavation and expansion of existing trench,
2. installation of a plastic liner in the trench,
3. preparation and placement of the artificial subgrade soil,
4. installation of sensors and geosynthetics (done by WTI),
5. preparation and placement of the base course aggregate, and
6. post-test excavation in specific areas for forensic analyses.

Construction drawings shown in Exhibits A–D provide plan views and cross-sectional perspectives of the project.

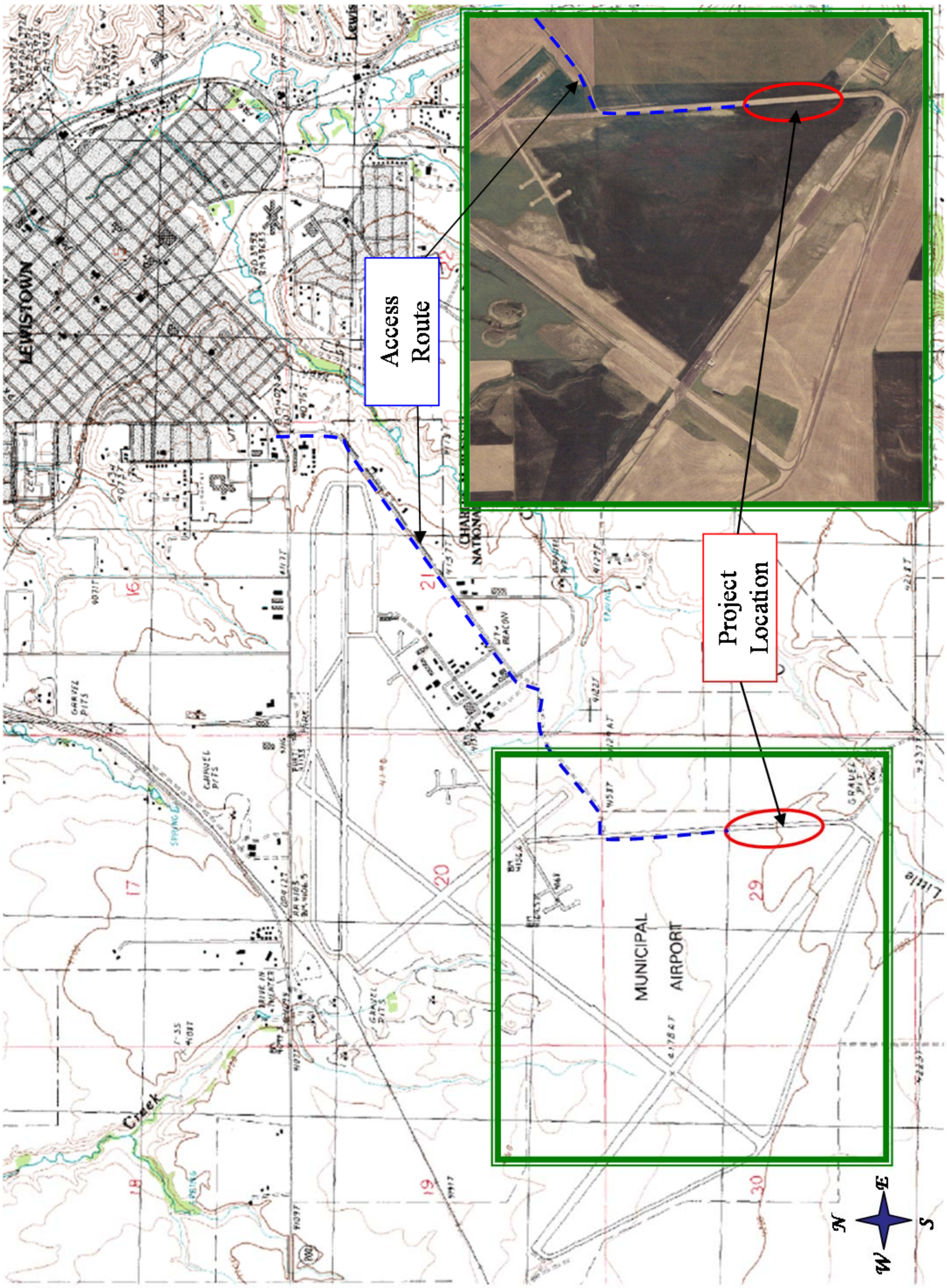


Figure 1: The location of the project is towards the southern portion of the decommissioned north–south taxiway at Lewistown Airport.

4.1. Excavation:

Existing Conditions: A similar research project was conducted in summer 2008 in which a trench was excavated and filled with a soft clayey–sandy subgrade. That trench was 13 feet wide (vertical sides), 690 feet long (tapered ends), and 3 feet deep. The subgrade was topped with geosynthetics and 8 inches of gravel. The surface is disturbed from subsequent excavations and too uneven and soft to drive across.

Figure 2: Existing conditions of construction site.

The gravel and subgrade soils need to be removed and deposited elsewhere on site. The geosynthetics must be discarded by the contractor. The plastic liner at the bottom of the existing trench should be removed and discarded. A reasonable effort should be made to remove as much plastic from the excavated material as possible. After such effort, any pieces larger than 1 square foot exposed on the surface of the stockpile created from this material should be removed or trimmed and discarded. The trench must be lengthened to 860 feet by extending the southern end and widened to 15 feet by extending the eastern side. The asphalt layer of the taxiway is approximately 8 inches thick and must be saw-cut prior to excavating material to create a clean edge along the length. The sides of the trench must be kept as vertical as possible without the use of shoring equipment. Therefore, care must be taken when excavating the trench so that the sidewalls are kept intact. Some sloughing of the sidewalls is expected but should be minimized. The ends of the trench should be tapered; a slope of 4H:1V is recommended. Refer to Exhibit A, B and C.

The elevation of the bottom of the trench must be grade controlled to be within 1 inch of the specified 3-ft depth based on a 6-ft by 25-ft grid. The bottom of the trench should be uniformly compacted. Grade must be maintained and measured by the contractor and will be inspected by WTI before moving ahead with the next step in construction.

4.2. Liner Installation:

A 6-mil plastic liner (e.g., clear low density polyethylene construction plastic, visqueen) must be installed along the bottom and sides of the excavated trench prior to placing the subgrade material. This liner will be used to minimize moisture loss in the subgrade soil during construction and future testing. The liner must extend past the sides of the trench at least 10 feet on each side and be sufficiently secured to keep from moving or blowing away as the trench is filled. Adjacent sections should overlap by at least 2 feet. Care must be taken to prevent significant damage to and movement of the liner as the first layer of subgrade is placed in the trench.

4.3. Preparation and Placement of Artificial Subgrade:

The clayey-sandy soil to be used as the artificial subgrade fill will be stored on the taxiway near the excavated trench (placement of subgrade soil can be modified at the contractor's request). In order for this project to be successful, the subgrade soil must be prepared and placed uniformly in the trench. The soil should be placed into the trench via construction equipment from the east side of the trench only. The only equipment that should be operated within the trench is the wetting, mixing and compacting equipment.

Equipment: Suggested equipment includes front-end loader, water truck, track-driven skid-steer tractor, tractor-mounted roto-tiller, single smooth-drum vibratory roller compactor, and motor grader. The artificial subgrade material shall be placed in consistent lifts of approximately 6 inches. The contractor shall provide tillage/mixing equipment which shall be able to thoroughly process the artificial subgrade material to a depth of lift thickness + 1 inch. Tillage/mixing equipment proposed by the contractor shall be capable of thoroughly mixing and processing each pass to a depth of lift thickness + 1 inch so that processed sections are sufficiently aerated to provide drying or wetting to reach specified water content and/or soil shear strength.

Strength: The artificial subgrade along the majority of the length of the test site must be prepared and compacted so that it has a California Bearing Ratio (CBR) strength of 1.7 ±0.1 (Exhibit C). As a point of reference, a soil with a CBR of 1.7 resembles soil that has an R-value of approximately 2.8 and a vane shear of approximately 44 kPa. Any area of the subgrade that does not meet these criteria will be repaired or replaced. During construction, WTI will make frequent measurements of the soil strength using a vane shear device. About four vane shear tests will be performed within every 10-foot length of the constructed subgrade. If the test results indicate that the specified CBR has not been met, additional measurements will be taken to determine the extent of the area that needs to be remedied. Areas larger than about 15 feet in length will be required to be reworked.

The subgrade at the southern end of the trench (an area approximately 100 feet long, Exhibit C) will be constructed to have subgrade strengths slightly lower and slightly higher than CBR = 1.7. One 50-foot section will be constructed to CBR = 1.4 ±0.1 (vane shear of 36 kPa) and the other

50-foot section will be constructed to a CBR = 2.0 ±0.1 (vane shear of 51 kPa). WTI may choose to physically separate these sections as they are constructed.

Water Content: The natural water content of the loosely piled subgrade soil is about 12 to 15% (by mass). To achieve the specified CBR of 1.7 ±0.1, the moisture content of the subgrade soil should be approximately 21% and be compacted to have uniform density. The strength of the subgrade is highly dependent on the water content of the soil. Preparation of the subgrade at the aforementioned moisture content will help achieve the design CBR; however, minor modifications to these parameters may be necessary to achieve the specified CBR strength in the field. The weaker subgrade section will require slightly wetter subgrade (and the stronger subgrade section will require a slightly drier subgrade) before compaction.

The subgrade must be covered with plastic by the contractor when it is not actively being constructed to minimize changes in moisture content. The work should not occur during rain events. If the strength of previously-constructed and approved sections is affected by rain or drying, the soil may need to be 1) tilled, 2) wetted or allowed to dry, and 3) re-compacted and tested by WTI for approval. Extra care must be taken to maintain the subgrade strength and moisture content once it is constructed.

Grade: The subgrade will be placed in lifts approximately 6 inches thick. The final grade of the subgrade should be crowned along the centerline and have about a 1% slope towards each edge. The edges of the subgrade should be 1 inch above the original taxiway surface and the centerline crown should be 2 inches above the grade of the taxiway (refer to Exhibit D). This grade should be controlled to be within 0.5 vertical inches based on a 6 foot by 25 foot grid. Grade must be maintained and measured by the contractor and will be inspected by WTI before moving ahead with the next step in construction.

WTI Soil Testing: The project consists of 17 individual test sections, each about 50-ft in length. Fifteen sections will have a CBR = 1.7, one with CBR = 1.4, and one with CBR = 2.1. In addition to the vane shear tests that will be conducted for QA/QC mentioned above (four per 10-ft length), WTI will need about 20 minutes per test section per lift to conduct additional vane shear and lightweight deflectometer soil tests. The contractor can work on other test sections as these measurements are being taken. As the final lift of subgrade is constructed and passes inspection, WTI will conduct additional soil tests on the subgrade, including: vane shear, field CBR, Dynamic Cone Penetration, stiffness, moisture content, and density. This may take a day to a day and a half before the base course aggregate can be placed (about 30 minutes per test section).

Schedule: WTI anticipates the subgrade construction will take about 9 days of work and should be completed in a period not to exceed 14 business days. Work should only occur on weekdays (Monday through Friday).

4.4. Sensors and Geosynthetic Installation (done by WTI)

After completion of the subgrade construction, WTI will install sensors in the subgrade and install the geosynthetics on the surface of the subgrade. Twelve different geosynthetic products will be installed on fourteen test sections, as illustrated in Figure 3. Geosynthetics will not be installed in three test sections known as the controls. Thus, there are 17 total sections (14 with geosynthetics, 3 without) along the length of the test area, each with a length of 50 feet. WTI will install sensors in the subgrade and attached to the geosynthetics. Wires associated with these sensors will be run through schedule 80 PVC protective conduit and will exit the construction area on the west side of the project. These wires will be routed into special boxes that will be bolted to the pavement by WTI. Care must be taken not to disturb the electrical conduit and the sensor boxes after they are installed by WTI.

This effort can be done in conjunction with placement of the base course, but WTI will need about a half day head start before the contractor can begin placement of the base course.

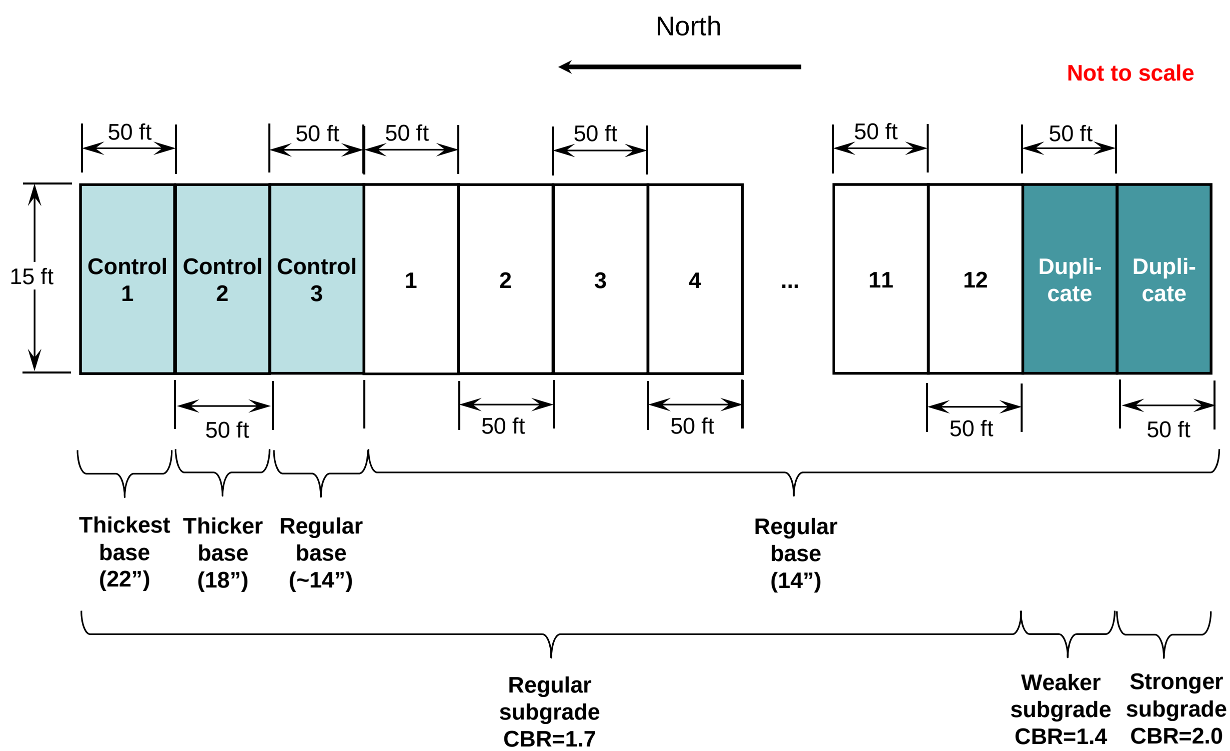


Figure 3: Layout of geosynthetics after subgrade construction (WTI will install the geosynthetics and sensors)

4.5. Base Course Construction:

WTI will coordinate purchase and delivery of the gravel so that it is placed adjacent to the test sections for easy preparation and placement. Grade stakes should be used to ensure correct depth of each gravel layer. After placement of the geosynthetics, the first lift of gravel surfacing aggregate should be carefully placed and leveled. The gravel must be compacted to 95 percent of maximum density based on a Modified Proctor using a single or double smooth-drum vibratory roller. This level of compaction will likely be accomplished by rolling each lift between 3 and 6 passes. Equipment that does not permanently rut the gravel surface during compaction must be used. Even if the base course has not reached 95% after 6 passes, additional passes will not be required.

Water Content: The base course material must be constructed at a specific water content. The target water content for the base has not been determined yet, but will be approximately 7%. To achieve uniform moisture throughout, the water must be mixed with the base course using tilling or discing equipment. The mixing operations must not be done directly on top of the subgrade and geosynthetics, but can be done on the east side of the construction area adjacent to the test plot.

Dimensions: The base course shall be constructed to be 15 feet wide and 910 feet long centered over top of the subgrade. The depth of the compacted base course will be 22 ± 0.25 inches along the northern 75 feet, taper to a depth of 18 ± 0.25 inches for another 50 feet, and taper again to a depth of 14 ± 0.25 inches for the remaining 775 feet. The 14-inch base will be constructed in two lifts. A third lift will be added to the northern end to achieve the 18- and 22-inch thicknesses. The north and south ends of the compacted gravel layer are tapered at an 8:1 slope (refer to Exhibit C). The edges along the east and west side of the compacted gravel layer are tapered at a 2:1 slope (refer to Exhibit D).

Placement: The gravel must be placed on the subgrade/geosynthetics from the east side using a track-driven skid-steer tractor or other approved lightweight equipment (Figure 4a). Grading must also be done with approved lightweight equipment or from the sides using a road grader with extended blade attachment (Figure 4b). Approval for such equipment must be sought from WTI prior to construction. It may be necessary to allow the grader to operate atop the gravel surface for final leveling of the gravel; however, this will be determined by WTI during that time. Extra care must be taken during construction not to disturb or damage the geosynthetic materials or sensors. If the geosynthetics are damaged during construction due to negligence (not normal construction activities), the contractor will be responsible for the delay and costs associated with replacing the damaged geosynthetics and reconstructing the affected area.

Figure 4: Placement (a) and grading (b) of base course aggregate.

Grade: The finished aggregate surface has a smoothness tolerance of 0.04 feet (0.48 inches) per 60 feet of distance, which is consistent with the standard MDT specification found in Section 301.03.5G. The final grade of the base should be crowned along the centerline and have about a

1% slope towards each edge (refer to Exhibit D). This grade should be controlled to be within 0.25 vertical inches based on a 6 foot by 25 foot grid.

<u>Soil Testing During Compaction</u>: WTI will perform lightweight deflectometer soil tests on the gravel surface between passes of the vibratory compactor. The contractor may not proceed with additional roller passes until WTI has collected the necessary data. Do not expect to be able to construct more than one lift of gravel per day.

4.6. Forensic Excavations (done by WTI with Contractor's Assistance)

Trafficking of the test sections will be performed by WTI staff using a loaded tandem-axle dump truck. This activity will occur for approximately 1.5 months after construction of the base course. After trafficking, various sections identified by WTI of the test plots will be removed. As illustrated in Figure 5, a full-depth segment of each test section will be excavated, with a length of 15 feet and width of 4.5 feet. The contractor is responsible for gently breaking up the base course. WTI will rent an industrial vacuum to facilitate careful removal of the base aggregates above the geosynthetic without causing damage to the geosynthetic. WTI will cut out the exposed portion of geosynthetic (if present) and conduct several soil tests on the exposed subgrade. The contractor will then carefully excavate the subgrade and WTI will take pictures and samples within each of the exposed areas. Afterward, these areas will be loosely filled in by the contractor using the subgrade and base excavation spoils. This effort is anticipated to take about 3 days to complete.

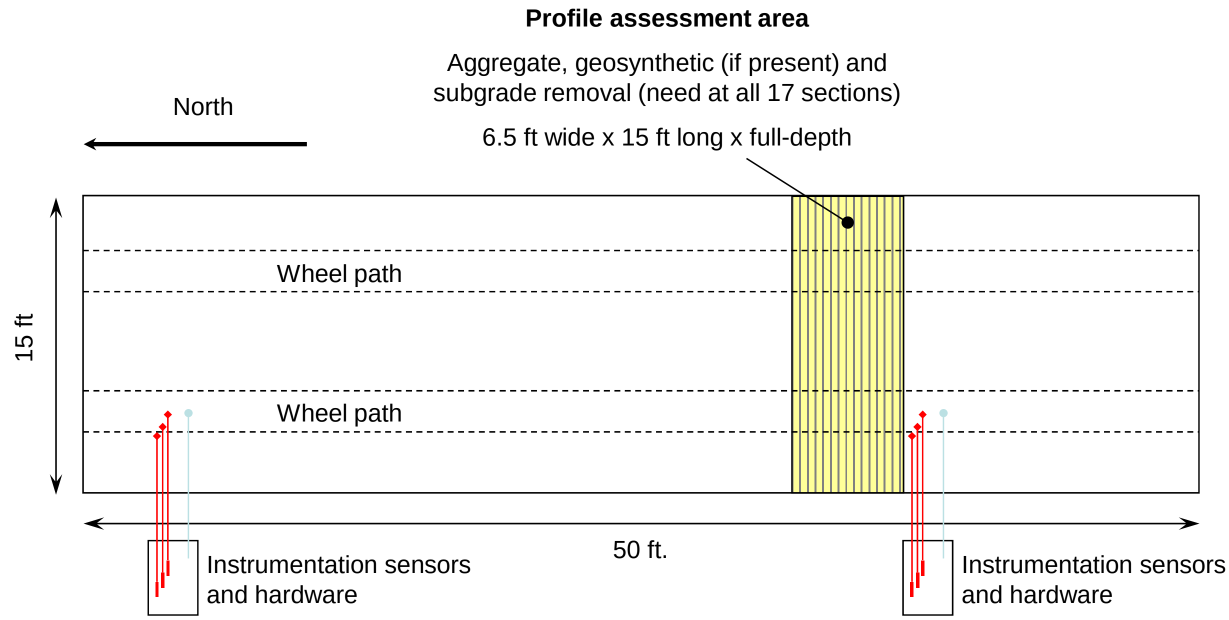


Figure 5: Forensic excavation layout.

4.7. Clean up

WTI will be responsible for removing any leftover subgrade soil in the storage berm. The contractor is responsible for sweeping the taxiway in the construction area to remove excess construction-related debris. The contractor is also responsible for removing any surplus gravel that was used to construct the base course driving surface and sweeping all affected surfaces without disturbing the constructed project test site.

5. MEETINGS AND SCHEDULES

A required Preconstruction Meeting between the winning bidder and WTI will be held in Lewistown 5 to 10 business days prior to construction of the test sections. WTI will arrange the meeting once the winning bidder is selected.

The estimated schedule for bidding and construction is listed below and shown in Figure 6.

- Week of June 18 or 25, 2012: Preconstruction meeting (one day within this time frame)
- Week 1: Excavation
- Weeks 2-4: Construct subgrade (this effort is anticipated to take about 2 to 3 weeks to complete)
- Week 4-5: Install sensors and geosynthetics (WTI), and construct base (Contractor)—this effort is anticipated to take about 1 week to complete
- August 10: Complete construction to avoid liquidated damages
- Week of September 17th or week of September 24th: Forensic excavations (this effort is anticipated to take about 3 days to complete)

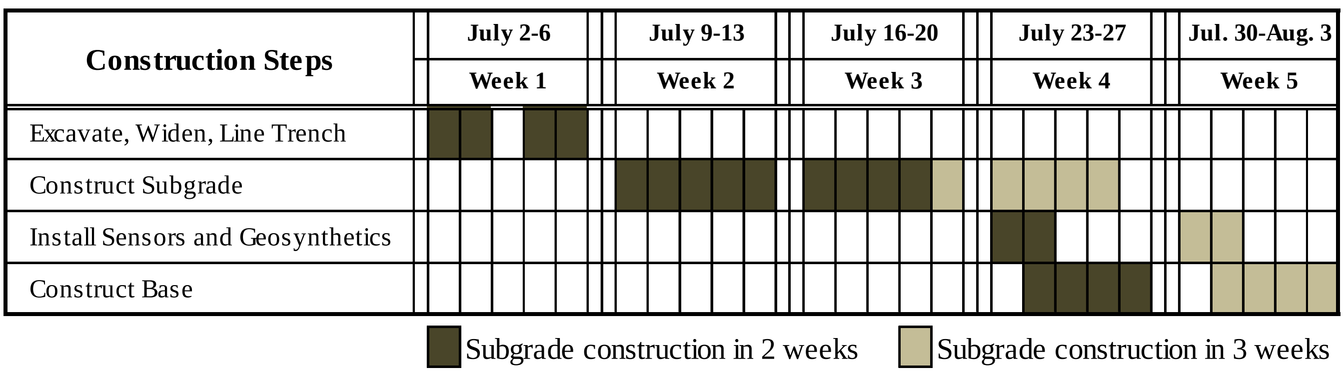
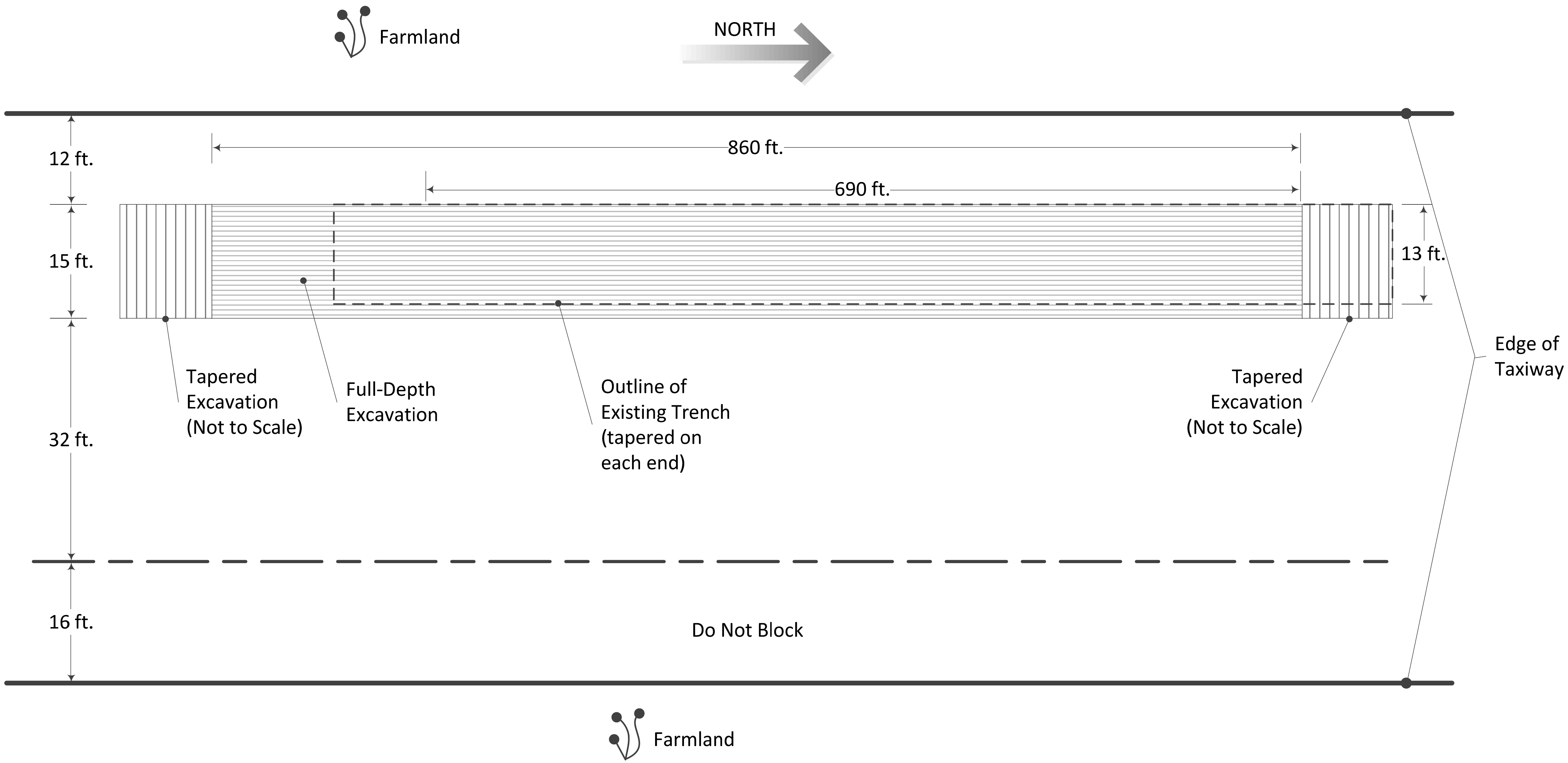


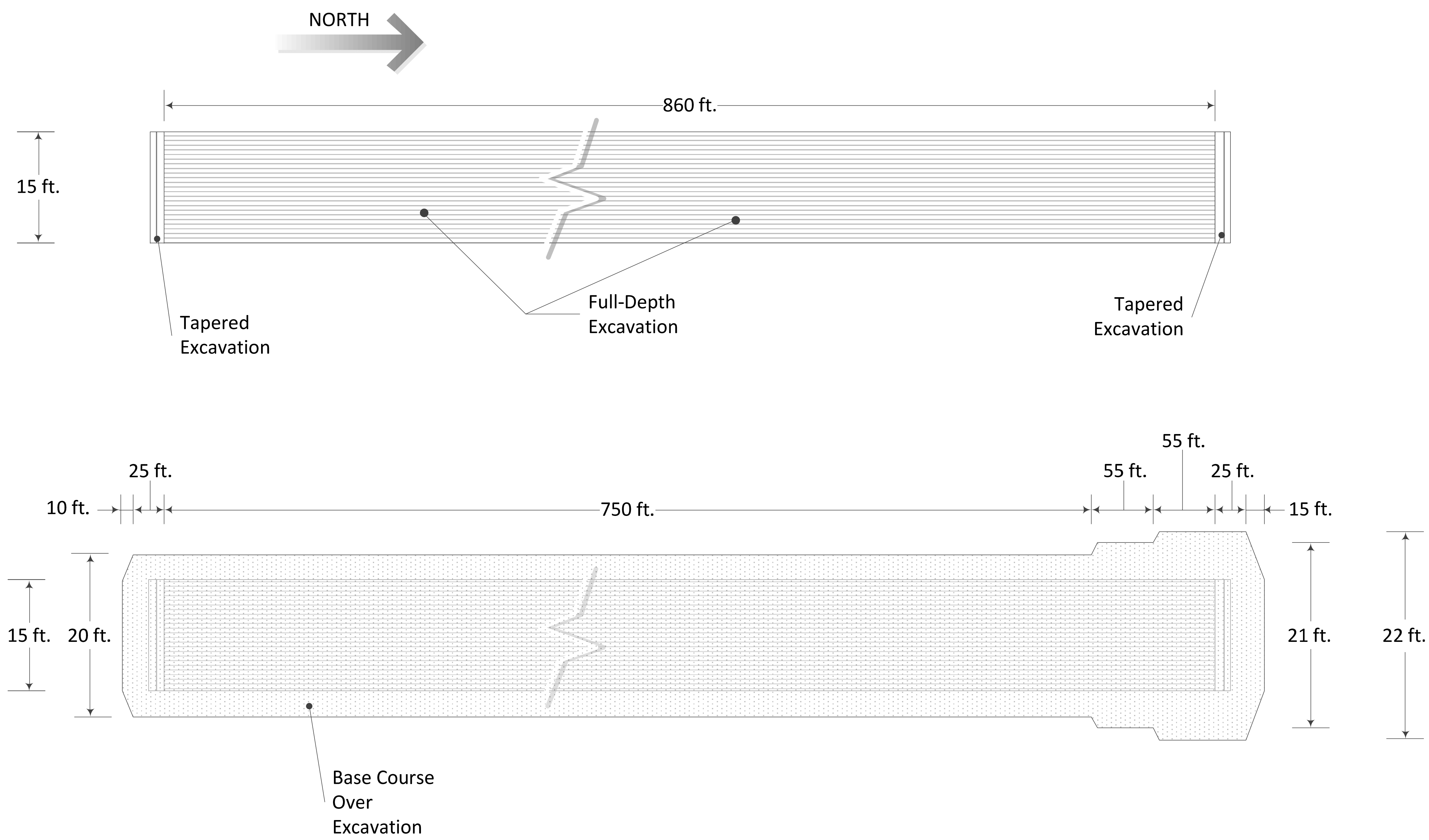
Figure 6: Estimated construction schedule.

EXHIBIT A: PLAN VIEW WITH LOCATION OF TRENCH



COMPANY	Montana State University — Western Transportation Institute
PROJECT	Geosynthetic Subgrade Stabilization
PROJECT NO.	4W3850
DESCRIPTION	Plan View with Location of Trench
DATE	3/19/2012
DRAWING NO.	1 of 4
AUTHOR	MRA

EXHIBIT B: PLAN VIEW OF PROJECT



COMPANY
Montana State University — Western Transportation Institute

PROJECT NO.
4W3850

DATE
3/19/2012

AUTHOR
MRA

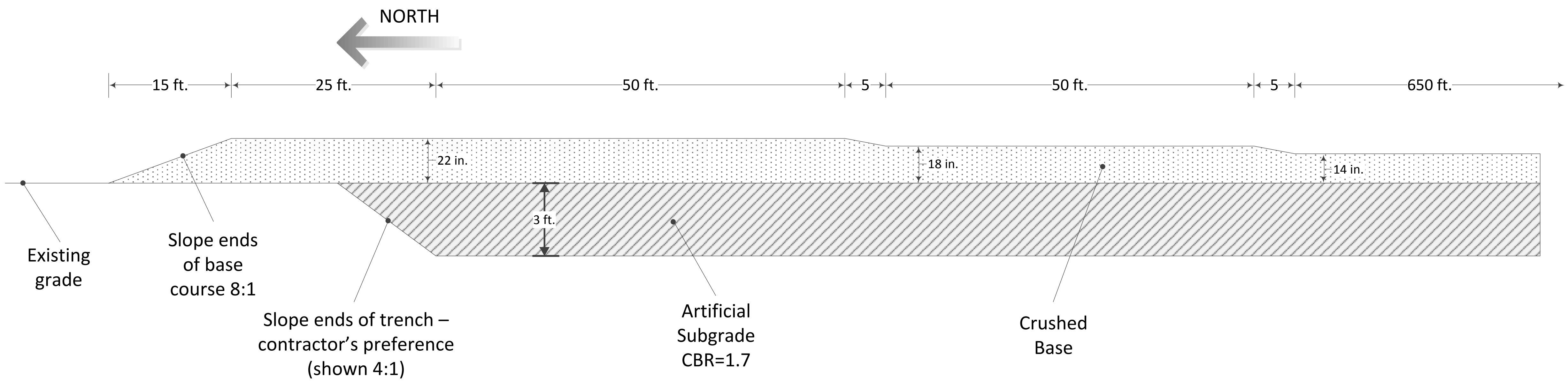
PROJECT
Geosynthetic Subgrade Stabilization

DESCRIPTION
Plan View of Project

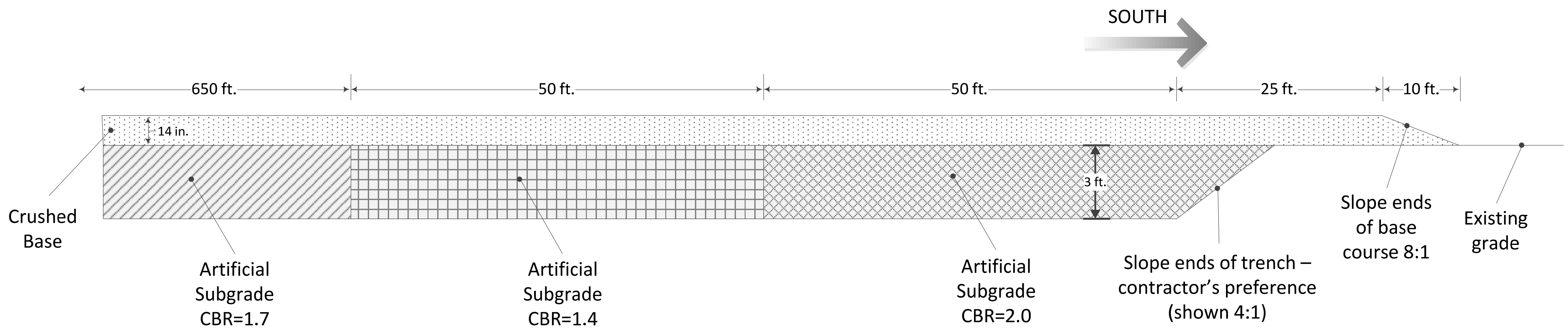
DRAWING NO.
2 of 4

EXHIBIT C: LONGITUDINAL CROSS SECTION

NORTH END



SOUTH END



COMPANY
Montana State University — Western Transportation Institute

PROJECT
Geosynthetic Subgrade Stabilization

PROJECT NO.
4W3850

DESCRIPTION
Longitudinal Cross Section

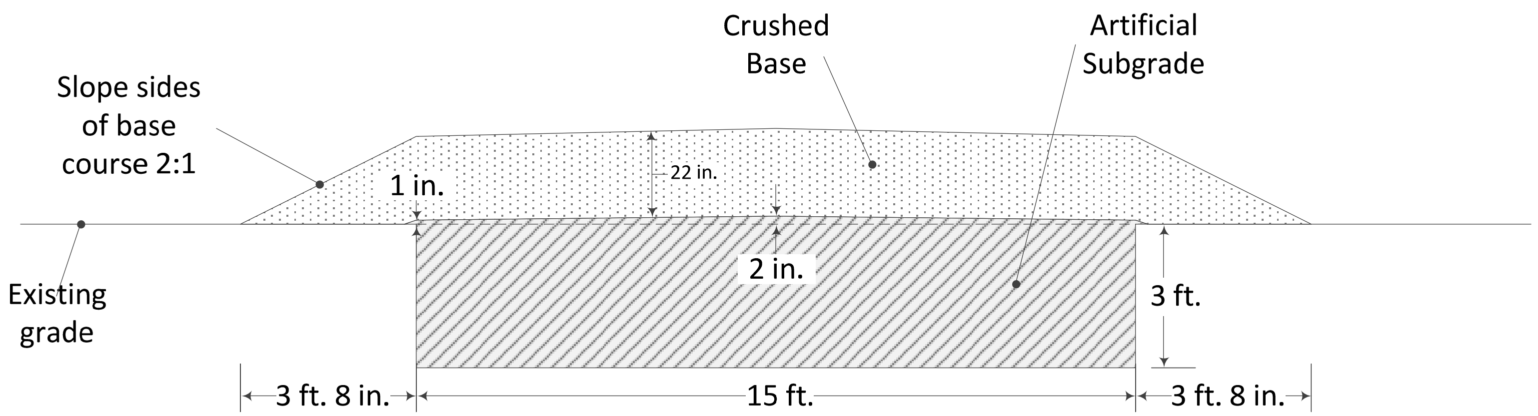
DATE
3/19/2012

DRAWING NO.
3 of 4

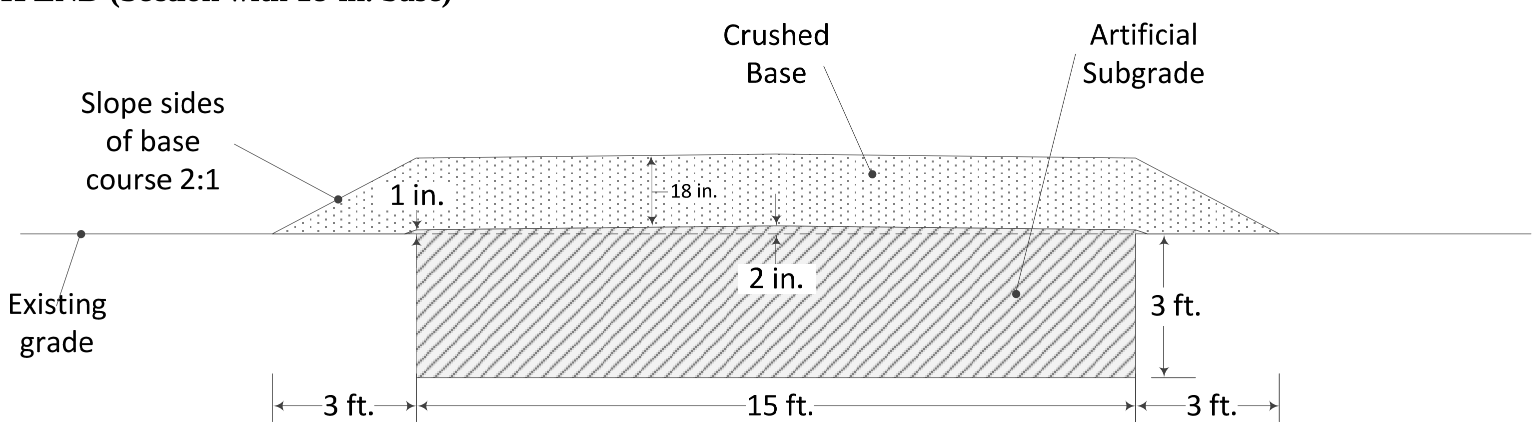
AUTHOR
MRA

EXHIBIT D: TRANSVERSE CROSS SECTION

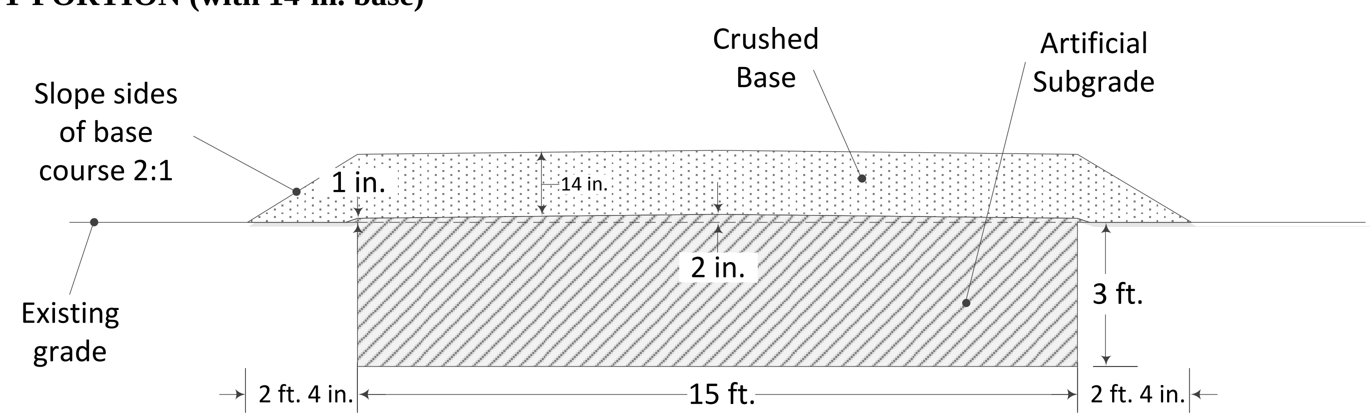
NORTH END (Section with 22-in. base)



NORTH END (Section with 18-in. base)



MAJORITY PORTION (with 14-in. base)



Notes:

- Crown of subgrade is 2 inches above existing grade.
- Edge of subgrade is 1 inch above existing grade.
- Crown of base course matches crown of subgrade. Thickness of base is uniform.

COMPANY	PROJECT NO.	DATE	AUTHOR
Montana State University — Western Transportation Institute	4W3850	3/19/2012	MRA

PROJECT	DESCRIPTION	DRAWING NO.
Geosynthetic Subgrade Stabilization	Longitudinal Cross Section	4 of 4