ALASKA
Department of Transportation and Public Facilities

Air Convection Embankment (ACE)
Experimental Feature in Highway Construction Final Report

Construction of Road Embankments with Reduced Air Convection Embankment (ACE) Shoulder Top-Widths
Dalton Highway MP 209-222 Reconstruction Project
Project No. 0655015/NFHWY00144
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The purpose of this experimental feature was to test the effectiveness of an insulated conventional embankment with reduced Air Convection Embankment (ACE) shoulder top-widths with varying top widths over a section of the Dalton Highway being realigned at MP 219 over thaw-unstable ice-rich permafrost in the foundation soils. This experimental feature consists of twelve test sections with varying shoulder widths, heights, and ACE classes. Amongst these test sections, shoulder widths range between 3 feet and 8.5 feet, shoulder heights range between 5.5 feet and 27.5 feet, and ACE class sizes consist of 3 inch to 5 inch (Class I) and 5 inch to 8 inch (Class II) installed in 2017 and 2018. The locations were monitored for 3 years and data probes collected were analyzed. The results of this study suggest thermal performance of an ACE shoulder embankment is largely a function of embankment height, followed by, in order of decreasing influence, ACE class size and shoulder width.

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METRIC (SI*) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4		mm
ft	feet	0.3048		m
yd	yards	0.914		m
mi	Miles (statute)	1.61		km
		AREA		
in^2	square inches	645.2	millimeters squared	cm^2
ft^2	square feet	0.0929	meters squared	m^2
yd^2	square yards	0.836	meters squared	m^2
mi^2	square miles	2.59	kilometers squared	km^2
ac	acres	0.4046	hectares	ha
		MASS (weight)		
oz	Ounces (avdp)	28.35	grams	g
lb	Pounds (avdp)	0.454	kilograms	kg
T	Short tons (2000 lb)	0.907	megagrams	mg
		VOLUME		
fl oz	fluid ounces (US)	29.57	milliliters	mL
gal	Gallons (liq)	3.785	liters	liters
ft^3	cubic feet	0.0283	meters cubed	m^3
yd^3	cubic yards	0.765	meters cubed	m^3

Note: Volumes greater than 1000 L shall be shown in m^3

Symbol	When You Know	Multiply By	To Find	Symbol
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (°F-32)	Celsius temperature	°C
		ILLUMINATION		
fc	Foot-candles	10.76	lux	lx
fl	foot-lamberts	3.426	candela/m^2	cd/cm^2
		FORCE and PRESSURE or STRESS		
lbf	pound-force	4.45	newtons	N
psi	pound-force per square inch	6.89	kilopascals	kPa

These factors conform to the requirement of FHWA Order 5190.1A *SI is the symbol for the International System of Measurements

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	Miles (statute)	mi
		AREA		
mm^2	millimeters squared	0.0016	square inches	in^2
m^2	meters squared	10.764	square feet	ft^2
km^2	kilometers squared	0.39	square miles	mi^2
ha	hectares (10,000 m^2)	2.471	acres	ac
		MASS (weight)		
g	grams	0.0353	Ounces (avdp)	oz
kg	kilograms	2.205	Pounds (avdp)	lb
mg	megagrams (1000 kg)	1.103	short tons	T
		VOLUME		
mL	milliliters	0.034	fluid ounces (US)	fl oz
liters	liters	0.264	Gallons (liq)	gal
m^3	meters cubed	35.315	cubic feet	ft^3
m^3	meters cubed	1.308	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 °C+32	Fahrenheit temperature	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/cm^2	candela/m^2	0.2919	foot-lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	pound-force	lbf
kPa	kilopascals	0.145	pound-force per square inch	psi

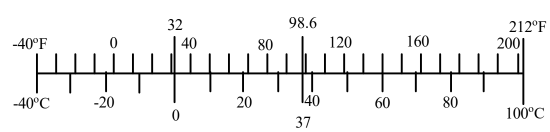


Table of Contents

List of Figures

Introduction:

Many of Alaska's roads are constructed on thaw-unstable permafrost. ACE Embankments have been demonstrated to maintain permafrost conditions in foundation soils. There are two general types of ACE embankments, full ACE embankments that are entirely comprised of ACE aggregate and conventional-aggregate core embankments that have ACE rock placed on the foreslope; the later of these may also incorporate rigid-foam insulation in the embankment core. The test sections of this experimental feature are comprised of insulated, conventional aggregate core embankments with ACE rock shoulders. For sake of discussion, these embankments are referred to as "ACE shoulder embankments".

In general, ACE shoulder embankments work via cold, dense air entering the lower portions of the shoulder in the winter, stripping heat from the soils between the ACE aggregate and conventional aggregate foreslope, warming and becoming less dense, and rising and escaping through upper portions of the ACE shoulder. This process can only occur when ambient air temperatures are sufficiently colder than the soils beneath the ACE aggregate

The test sections within this experimental feature are constructed within a realigned portion of the Dalton Highway near milepost (MP) 219 (see Figure 1). The purpose of this experimental feature is to test the effectiveness of ACE shoulders with varying top-widths.

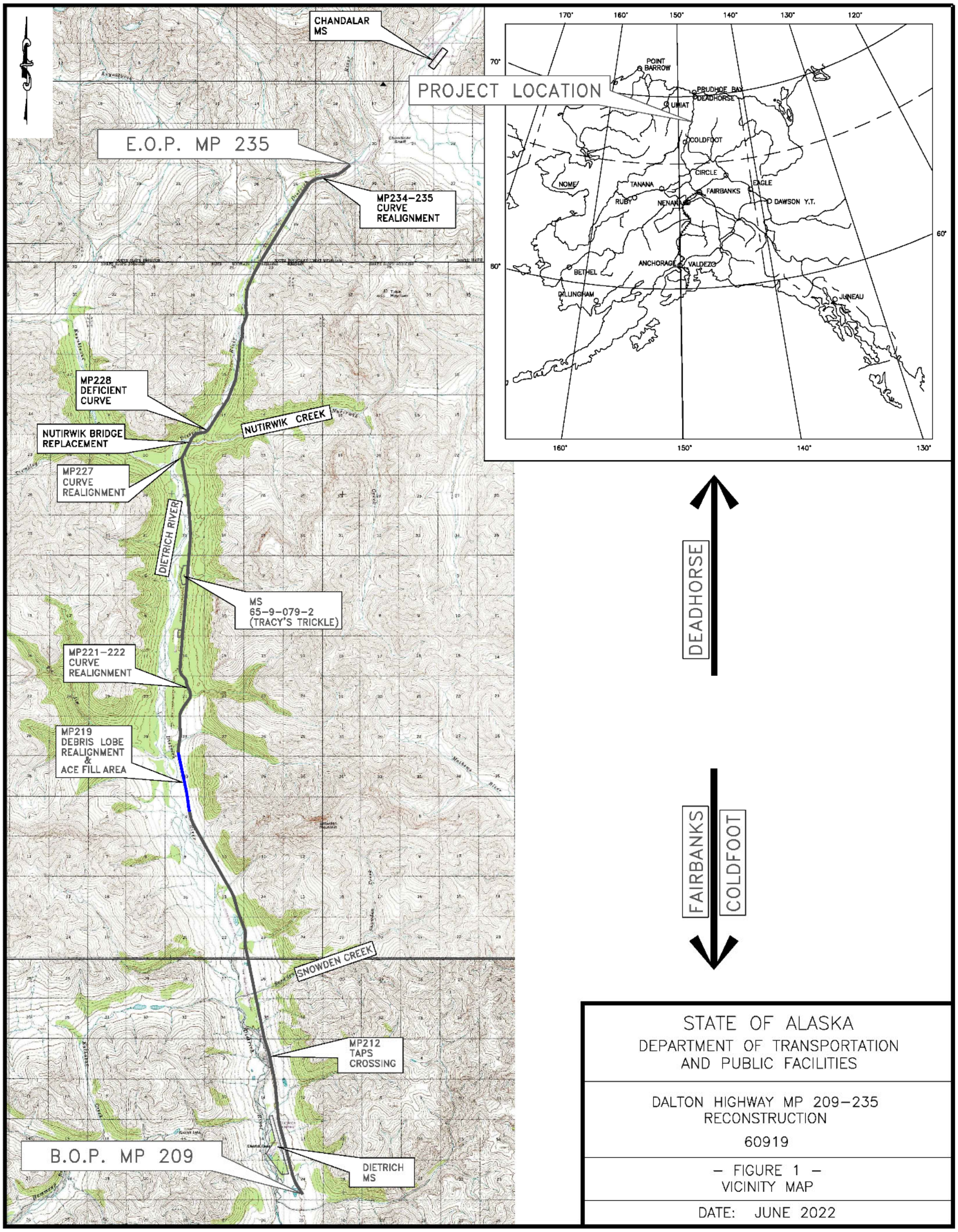


Figure 1: Project Location and Vicinity Map.

Problem Statement and Background:

The purpose of this experimental feature was to test the effectiveness of an insulated conventional embankment with reduced ACE Shoulder top-widths over a section of the Dalton Highway being realigned at MP 219 over thaw-unstable ice-rich permafrost in the foundation soils.

This Experimental Feature is complimentary to and builds upon the "Construction of an Air Convection Embankment (ACE) With non-Angular ACE Fill" Experimental Feature constructed as part of the Alaska Highway MP 1354-1364 Rehabilitation Project and the "Construction of an Air Convection Embankment (ACE) and ACE Shoulders with 1"-2" Rounded ACE Fill" Experimental Feature constructed with the Elliot Highway MP 0-12 Rehabilitation Project.

Many of Alaska's roads are constructed on thaw-unstable permafrost. Construction of standard highway embankments results in changing the thermal regime in the ice-rich foundation soils below the embankment, often resulting in thaw-related settlement and pavement distress. It has been observed that embankments made using coarse, poorly graded (highly permeable) rock promote significant winter-time cooling of underlying foundation soils. In general, natural convective heat transfer within a highly permeable rock embankment can be used to cool the foundations beneath the embankment. In permafrost areas, such cooling can be used to counteract the warming influence that results from construction of roads, runways, or other embankments. Northern Region DOT&PF spends millions of dollars annually in roadway maintenance, much of which is attributed to degrading permafrost. ACE Embankments and ACE Shoulders have been demonstrated to maintain permafrost conditions in foundation soils. If ACE Shoulders can be constructed with reduced top-widths, ACE shoulders will become more cost effective and may be incorporated into more highway reconstruction projects, reducing future maintenance costs.

This experimental feature consists of twelve test sections with varying shoulder widths, heights, and ACE classes. Amongst these test sections, shoulder widths range between 3 feet and 8.5 feet, shoulder heights range between 5.5 feet and 27.5 feet, and ACE class sizes consist of 3 inch to 5 inch (Class I) and 5 inch to 8 inch (Class II).

The main objective of this experimental feature is to examine the relationship between the thermal performance of ACE Shoulders and their top widths. Ancillary objectives of this experimental feature is to examine the relationship between thermal performance of the ACE shoulders and their heights as well as their ACE class size. Table 1 Summarizes the shoulder geometry and ACE class for each of the twelve test sections.

Table 1: Test Section Summary

Test Section #	ACE Class	ACE Shoulder Top-Width (Feet)	Station	Representative Station Interval	Project Left / Right	Approx. Shoulder Height (feet)
1	Class II	3	3234+00	3233+50 to 3234+50	Left	19.5
2	Class II	3	3234+00	3233+50 to 3234+50	Right	8
3	Class I	3	3235+00	3234+50 to 3235+50	Left	22
4	Class I	3	3235+00	3234+50 to 3235+50	Right	9.5
5	Class II	5	3240+00	3239+50 to 3240+50	Left	23
6	Class II	5	3240+00	3239+50 to 3240+50	Right	6
7	Class I	5	3241+00	3240+50 to 3241+50	Left	27.5
8	Class I	5	3241+00	3240+50 to 3241+50	Right	9.5
9	Class I	8.5	3245+00	3244+50 to 3245+50	Left	21
10	Class I	8.5	3245+00	3244+50 to 3245+50	Right	10
11	Class II	8.5	3246+00	3245+50 to 3246+50	Left	15
12	Class II	8.5	3246+00	3245+50 to 3246+50	Right	5.5

Scope and Objectives of Study:

Many locations along Alaska highways are known to have differential settlement due to thawing of ice-rich permafrost in the foundation soils. This is also true for many rural airport runways in Alaska. The purpose of this experimental features is to examine the following:

- The relationship between ACE shoulder thermal performance and the shoulder's top width. Historically ACE shoulders are constructed to be roughly 10 feet wide.
- The relationship between ACE shoulder thermal performance and different size ACE classifications.
- The relationship between ACE shoulder thermal performance and the shoulder height.

ACE Shoulder Embankment Construction

Construction of the conventional aggregate insulated embankment core took place during the 2017 to 2018 winter. Construction of the ACE shoulder treatment took place between April and July 2018. Table 2 summarizes some of the highlighted ACE shoulder treatment construction dates:

Table 2: Summary of ACE shoulder Construction

Date	Activities
4/9/2018	Contractor started producing ACE aggregate at Dietrich Quarry
4/17/2018	Contractor started to prepare foreslopes of embankment core for ACE placement.
4/27/2018 thru 7/13/2018	Contractor placed and shaped ACE aggregate on shoulder foreslopes.
7/15/2018	Final ACE aggregate quantities agreed upon for payment.

The ACE aggregate was end-dumped in roughly evenly-placed piles via dump truck. The ACE aggregate was then shaped with a Hitachi, 870, track-mounted excavator. Figures 2 and 3 illustrate the placement and shaping of the ACE aggregate on the conventional aggregate foreslopes.

Figure 2: ACE Placement

Figure 3: ACE Shaping

The initial design was to surface the embankment with asphalt. Due to movement observed during construction, however, it was decided to surface the embankment with a gravel surface course. As such, geotextile was placed on top of the shoulder to address concern that normal maintenance operations such as grading, plowing and winter-time sanding would not result in contamination of the upper portions of the ACE shoulders. We were concerned that such contamination would work its way down into the shoulder, cutoff air flow and reduce the shoulder's winter-time performance. We recognized the geotextile may limit the airflow through the top of the shoulder but felt that this adverse effect would be less than that of fines infiltrating deeper into the shoulder. Figure 4 illustrates the geotextile placed on top of the ACE shoulder.

Figure 4: Geotextile Placed on top of ACE Shoulder.

In addition to what would be necessary to construct the embankment, the contractor as well as Alaska Department of Transportation and Public Facilities (ADOT&PF) Northern Region Construction staff were responsible for performing tasks that would assist us with this experimental feature. In addition, personnel from ADOT&PF Northern Region Materials Section (NRMS) finalized the installation of data loggers and DTCs. These activities are summarized below:

Contractor:

- Porosity testing of both size classes of Angular ACE Fill was not conducted to the due to concerns that asbestos was encountered in the Dietrich rock quarry during rock production. This, however, is normally accomplished by measuring the volume, empty-vehicle weight, full-vehicle weight, and the specific gravity of the different sizes of ACE Fill.
- Contractor worked with the Project Engineer to place horizontal HDPE Tubing in ACE Fill test sections for future installation of Digital Temperature Cables (DTCs) by the Northern Regions Materials Staff (NRMS).
- Installed a 3-inch Galvanized Steel Pipe at Stations 3234+50, 3240+50, 3245+50 for future data logger installation by NRMS.

ADOT&PF Construction Staff:

- Monitored ACE Shoulder construction and documented any difficulties with the installation of ACE Fill.
- Provided photo documentation of ACE shoulder construction.
- Provided NRMS staff with gradation test results for all classes of ACE Fill to ensure it met specifications.
- Installed horizontal sections of HDPE Tubing during ACE Fill placement on shoulders in test sections.
- Surveyed in final cross-sections at conduit locations and provide As-Built cross-sections to NRMS in AutoCAD showing endpoints of horizontal conduits. (See Appendix A)

ADOT&PF NRMS:

- Installed Digital Temperature Cables, Air Temperature Sensor and data-loggers.
- Monitored the performance of the highway embankment for the test segments over a three-year period.
- Conducted site visits to download data, repair datalogger issues and assess embankment performance.

Design Details and Instrumentation of Experimental Feature

This ACE experimental feature has twelve test sections, each with ACE shoulders of varying geometry, and ACE Class. We instrumented each test section at a single station in an effort to create a cross-section that represents an approximate 100-foot-long portion of embankment. (See Table 1). Each instrumented station has two test sections that are located on the project left and right shoulders respectively.

The instrumentation for these test sections includes single-point Digital Temperature Cables (DTCs) for measuring ambient air temperature and DTCs with multiple temperature sensors for measuring temperatures at select locations within the embankment. The DTCs within the conventional aggregate portions of the embankment are loaded within 1-inch-diameter, HDPE conduit. In an effort to subject temperature sensors to temperature fluxes due to air flow, the DTCs within the ACE aggregate shoulders are loaded within 3-inch-diameter, perforated ABS pipe.

The DTCs for all twelve test sections are attached to three data loggers. These data loggers are attached to 3-inch-diameter, steel posts embedded in the ground near the toe of the embankment. Test Sections 1 through 4 are attached to a datalogger located near station 3234+50. Test Sections 5 through 8 are attached to a datalogger located near station 3240+50. Finally, test sections 9 through 12 are attached to a datalogger located near station 3245+50. Table 3 summarizes the test sections assigned to each datalogger as well as the number of sensors within them. Figure 5 below illustrates the basic Typical Section and DTC string locations for our twelve ACE test sections. More detailed sensor locations are shown in Appendix A.

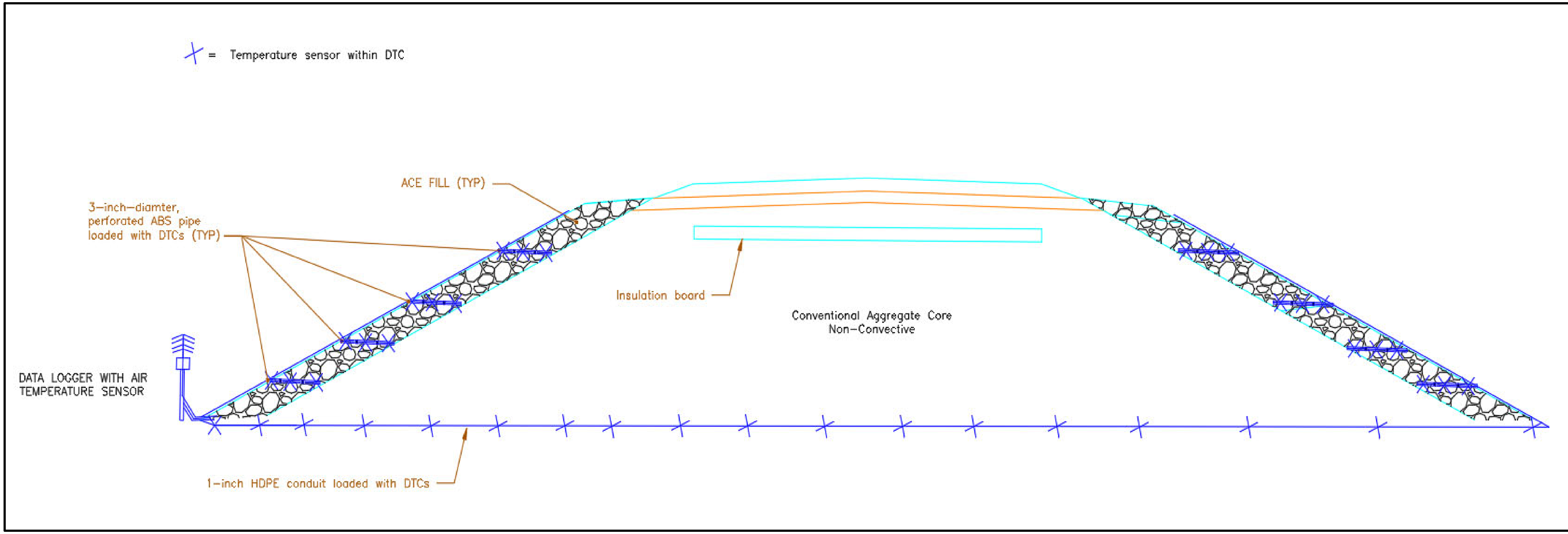


Figure 5: Experimental Feature Typical Section

Table 3: Summary of Data logger and Test Section Assignments

Data Logger	Station	Test Section	Sensor Count
D5050057	3234+50	AIR	1
		1	15
		2	30
		3	15
		4	30
D5050061	3240+50	5	15
		6	30
		7	15
		8	31
D5050062	3245+50	AIR	1
		9	15
		10	31
		11	15
		12	26

The purpose of the DTCs located in the ACE shoulders was to characterize the winter-time airflow pattern within the ACE shoulders. The purpose of the DTCs located at the bottom of the embankment was to determine annual average and seasonal temperatures between the embankment and foundations soils and characterize the effect that ACE shoulder cooling has on the temperature of the lower and center portions of the embankment.

Two ACE classes, designated as Class I and Class II, were used within this experimental feature. The ACE class used in each test section is summarized in Table 1. Table 4 summarizes this project's specifications for both Class I and Class II ACE aggregate. Actual gradations, however, varied slightly from those specified. These variations are also illustrated in Table 4. Figures 6 and 7 are photographs of the ACE aggregate taken during construction.

Table 4: Gradation Specifications for Class I and Class II ACE Aggregate

Class I			Class II		
Particle Size (inches)	Percent Passing		Particle Size (inches)	Percent Passing	
	Specified	Actual		Specified	Actual
6	100	100	9	100	100
5	95 - 100	100	8	95 - 100	100
3	0 - 5	6	5	0 - 5	22
1	0 - 3	0	1	0 - 3	0

Figure 6: Stockpile of Class I ACE with a 12-inch-Diameter, 3-inch Sieve for Scale.

Figure 7: Stockpile of Class II ACE with a 12-inch-Diameter, 3-inch Sieve for Scale.

Reporting and Monitoring

Northern Region Construction and Materials Section Staff monitored ACE Shoulder construction and documented conditions of installation and any difficulties with ACE Fill placement. NRMS staff submitted a work plan report to AKDOT&PF Research & T2 on 3/23/2018.

NRMS staff also visually monitored and compared the performance of the highway embankment and pavement for the test sections over a three-year period. Monitoring included observations of settlement and pavement distress.

Air and ground temperatures were monitored for three full-years post construction. Average annual ground temperatures are to be determined at the base, top and slope surface of Shoulder Treatment test segments to compare the performance of the different ACE Fill Materials and shoulder configurations.

Data Analysis

Our data loggers have been recording data since December 13, 2018. Our datasets, however, are not continuous due to technical issues including faulty cable connections and wye cable malfunction. In addition, data from test sections nine through twelve was effectively "scrambled" in the data logger. As such, data from these test sections was not used in our analyses.

In an effort to build continuous, annual-cycle datasets that we could analyze, we "stitched" the discontinuous data together. This process involved identifying dates with missing data, averaging the temperature values from other years on that date, and applying that average value to that missing data slot. In order to not build annual cycles that simply repeat average data values, for each test section, we limited the number of annual cycles in accordance to the number of "filled" data slots for a given day of the year. As an example, for each day of the year, we reviewed the number of populated data slots for every sensor in the test section. We then assigned the number of annual-cycles for our "stitched data" that would result in a minimum number of "artificial" data points assigned to empty data slots. We recognize this process is not perfect, introduces error, and makes it difficult to directly compare annual performance trends between test sections. However, we believe this process allows us to analyze the data in a way that simulates the general thermal performance trends of our test sections. Table 5 summarizes the number of annual cycles and the simulated date ranges for each test section's dataset.

Table 5: Summary of the Test Sections Simulated Data Ranges.

Test Section	"Stitched" Date Range*		
	# Annual Cycles	Start Date	End Date
1	3	12/13/2018	12/12/2021
2			
3			
4			
5	2	12/13/2018	12/12/2020
6			
7			
8			
9	N/A		
10			
11			
12			
Notes: * Start and end dates are simulated according to the number of annual cycles. N/A: Meaningful data not available for analysis.			

Climate Data:

Originally we had two air temperature sensors, one attached to the data logger for Test Sections 1 through 4, and the other attached to the data logger for Test Sections 9 through 12. However, because there are issues with the data for test Sections 9 through 12, our sole temperature record is from the single-point DTC associated with Test Sections 1 through 4.

Air temperature was recorded every 2 hours between 12/13/2018 and 01/08/2019, every 4 hours between 01/09/2019 and 05/11/2020, and every 6 hours between 05/12/2020 and 12/12/2022. We decided that average daily temperatures from each of these three record frequencies are likely similarly accurate. As such, we developed an average daily temperature record by calculating average temperature for each day within this record interval. The average daily temperature interval was then "stitched" together in the manner previously detailed and summarized in Table 5. Figure 6 illustrates the average daily temperature record used in our analyses.

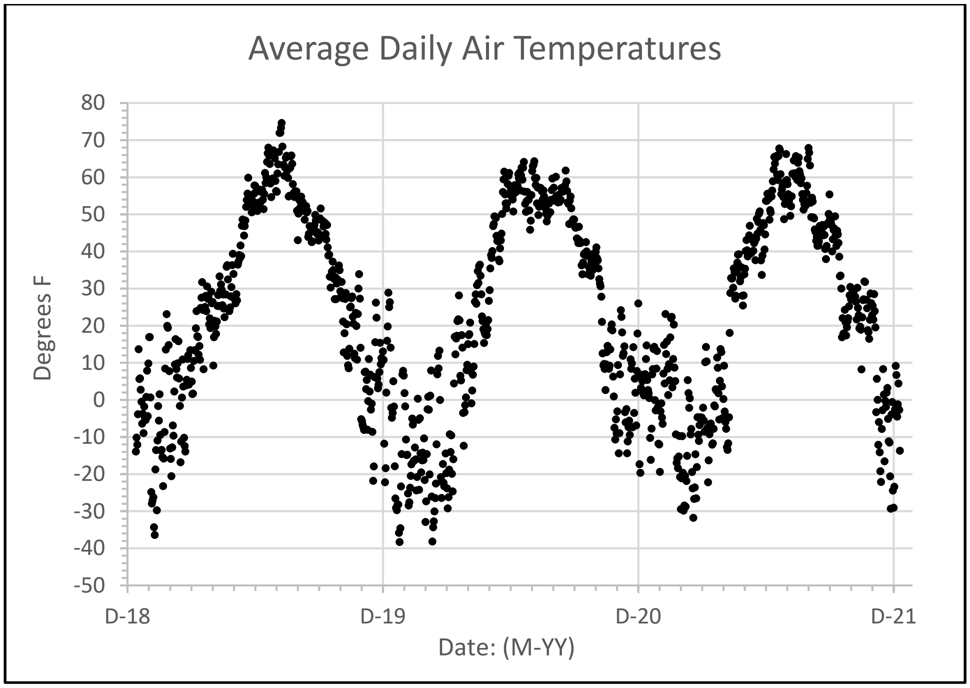


Figure 6: Average Daily Air Temperature Record.

Based upon this temperature record, we calculated both the air thawing and freezing indices (ATI and AFI) using Equations 1 through 4. As a check, we compared these climate parameters to those estimated from temperature data for Wiseman (which is roughly 33 miles south of the site) made available through the Alaska Climate Research Center (https://akclimate.org /data/data-portal/). This data suggests that Wiseman is slightly cooler than the area surrounding our experimental feature. However, the climate data of the two locations is similar enough to make us confident in our data. Table 6 summarizes and compares the climate data between our experimental feature and Wiseman.

$$Equation\ 1.: AFI = Air\ Freezing\ Index = \sum FDD_A;\ for\ each\ day\ in\ a\ given\ Record\ Period$$

$$Equation\ 2.: ATI = Air\ Thawing\ Index = \sum TDD_A;\ for\ each\ day\ in\ a\ given\ Record\ Period$$

$$Equation\ 3.: FDD = Freezing\ Degree\ Day = (32 - T_{AVE}); for\ a\ given\ day$$
$$Where\ T_{AVE} = average\ daily\ temperature\ AND\ T_{AVE} \leq 32$$

$$Equation\ 4.: TDD = Thawing\ Degree\ Day = \ (T_{AVE} - 32); for\ a\ given\ day$$
$$Where\ T_{AVE} = average\ daily\ temperature\ AND\ T_{AVE} > 32$$

Table 6: Climate Summary for our Experimental Feature and Wiseman.

Annual Cycle	Dataset*	Average Annual Air Temperature (ºF)	Air Freezing Index (AFI)	Air Thawing Index (ATI)
1	Experimental Feature	26.6	4,877	2,908
	Wiseman	25.2	5,205	2,768
2	Experimental Feature	21.4	6,773	2,890
	Wiseman	20.3	7,009	2,791
3	Experimental Feature	22.5	6,114	2,643
	Wiseman	20.8	6,704	2,587
* Wiseman Data: https://akclimate.org/data/data-portal/				

Embankment Temperature Data.

Figures 7 through 10 illustrate both the average annual temperature and thawing indices for each temperature sensor within Test Sections 1 through 8. From left to right, this data is illustrated for each available annual cycle.

The average annual temperature data is illustrated by color with below-freezing temperatures within the blue color spectrum and the above-freezing temperatures in the yellow to red color spectrum. The thawing indices are also illustrated by color with positive values in the yellow to red spectrum and zero illustrated in blue. The thawing index (TI) is the total thawing-degree-days in an annual cycle and is calculated as shown in Equation 6. Sensors that have a TI of zero have been at or below freezing for the entire annual cycle.

$$Equation\ 6.: TI = Thawing\ Index = \sum TDD;\ for\ a\ given\ Annual\ Cycle$$

We averaged the temperature sensor data along the interface between ACE aggregate and non-convective soils in order to simplify the analysis and provide values that may be used to assess relationship between thermal performance, shoulder width, ACE aggregate size and shoulder height. Table 7 Summarizes the Geometry, ACE class and average annual temperatures for each Test Section.

Table 7: Summary of Test Section Geometry, ACE Class, and Average Annual Temperature along the Interfaces.

Test Section	Interface	ACE Class	Shoulder Width (ft.)	Shoulder Height (ft.)	Average temperature (F)		
					AC* 1	AC* 2	AC* 3
1	Left	Class II	3	21	28.8	25.0	26.1
2	Right	Class II	3	7	31.9	29.4	27.7
3	Left	Class I	3	22	30.4	27.0	27.3
4	Right	Class I	3	9	31.5	28.9	27.8
5	Left	Class II	5	23	27.2	23.6	---
6	Right	Class II	5	6	31.1	28.2	---
7	Left	Class I	5	27	27.5	24.4	---
8	Right	Class I	5	9	32.6	29.9	---
Notes: * AC = Annual Cycle							

In an effort to quantify how much of the ambient air's cooling the ACE shoulder is utilizing at the ACE/non-convective material interface, we developed what we are calling the freeze-factor (FF). The FF is calculated by Equation 7 and is the ratio of the degrees below freezing at the interface and the degrees below freezing of the ambient air. Figure 11 illustrates the relationship between FF, the embankment geometry and ACE class. Note the value next to each data point in Figure 11 is the top width of that particular shoulder.

$$Equation\ 7.: FF = \frac{32 - Temperature\ at\ Interface}{32 - Ambient\ Air\ Temperature};\ \ for\ a\ given\ Annual\ Cycle.$$

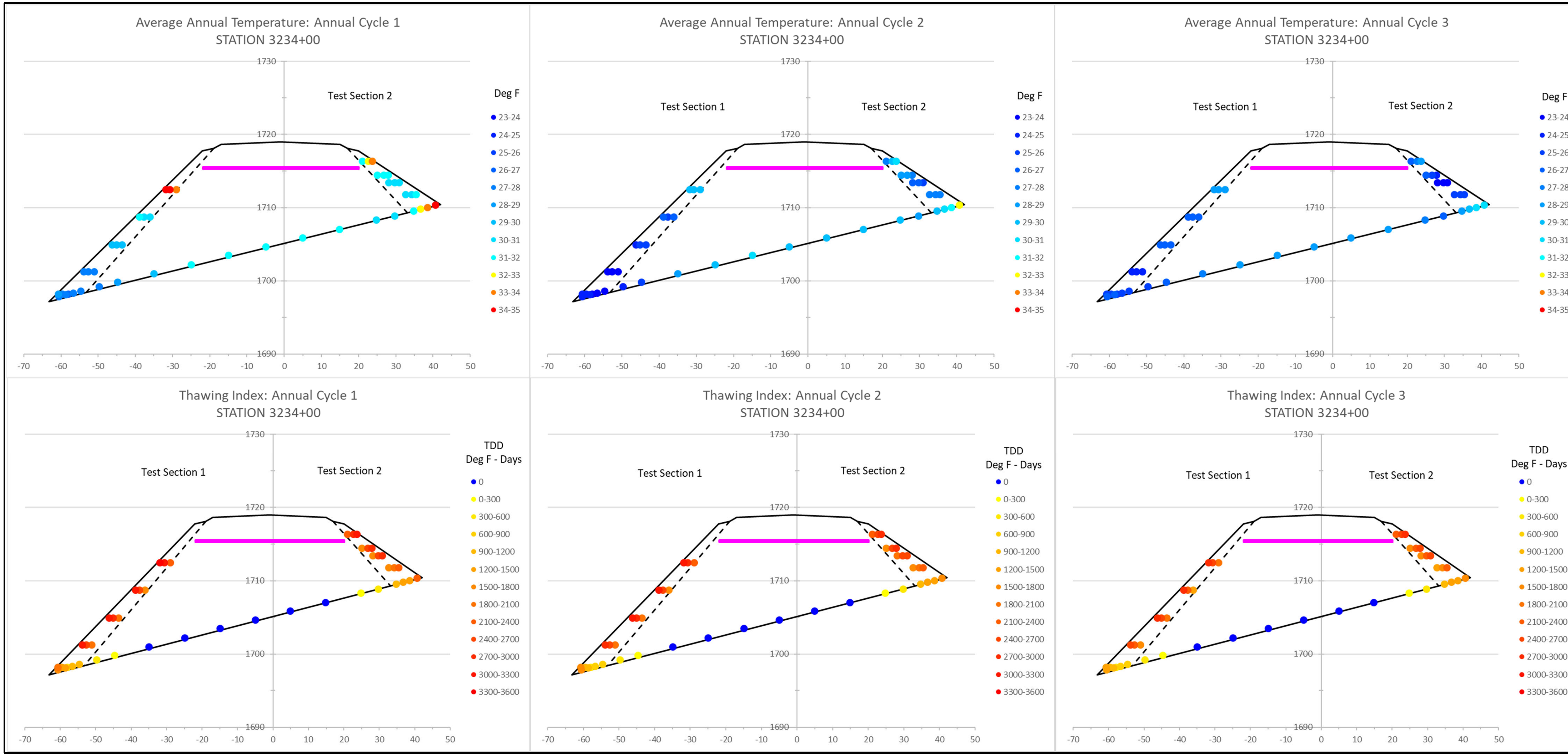


Figure 7: Average Annual Temperature and Thawing Index for Sensors Located in Test Sections 1 and 2.

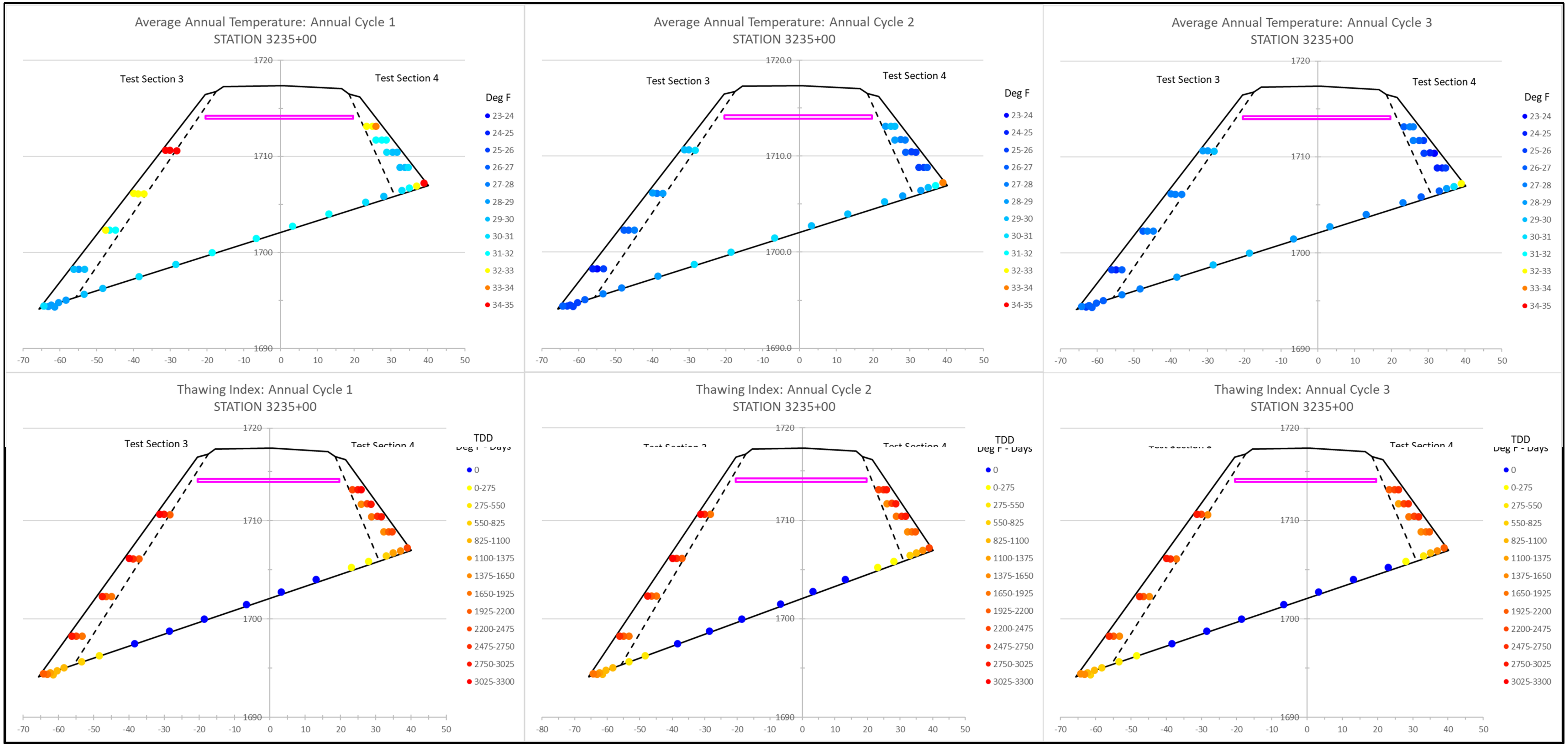


Figure 8: Average Annual Temperature and Thawing Index for Sensors Located in Test Sections 3 and 4.

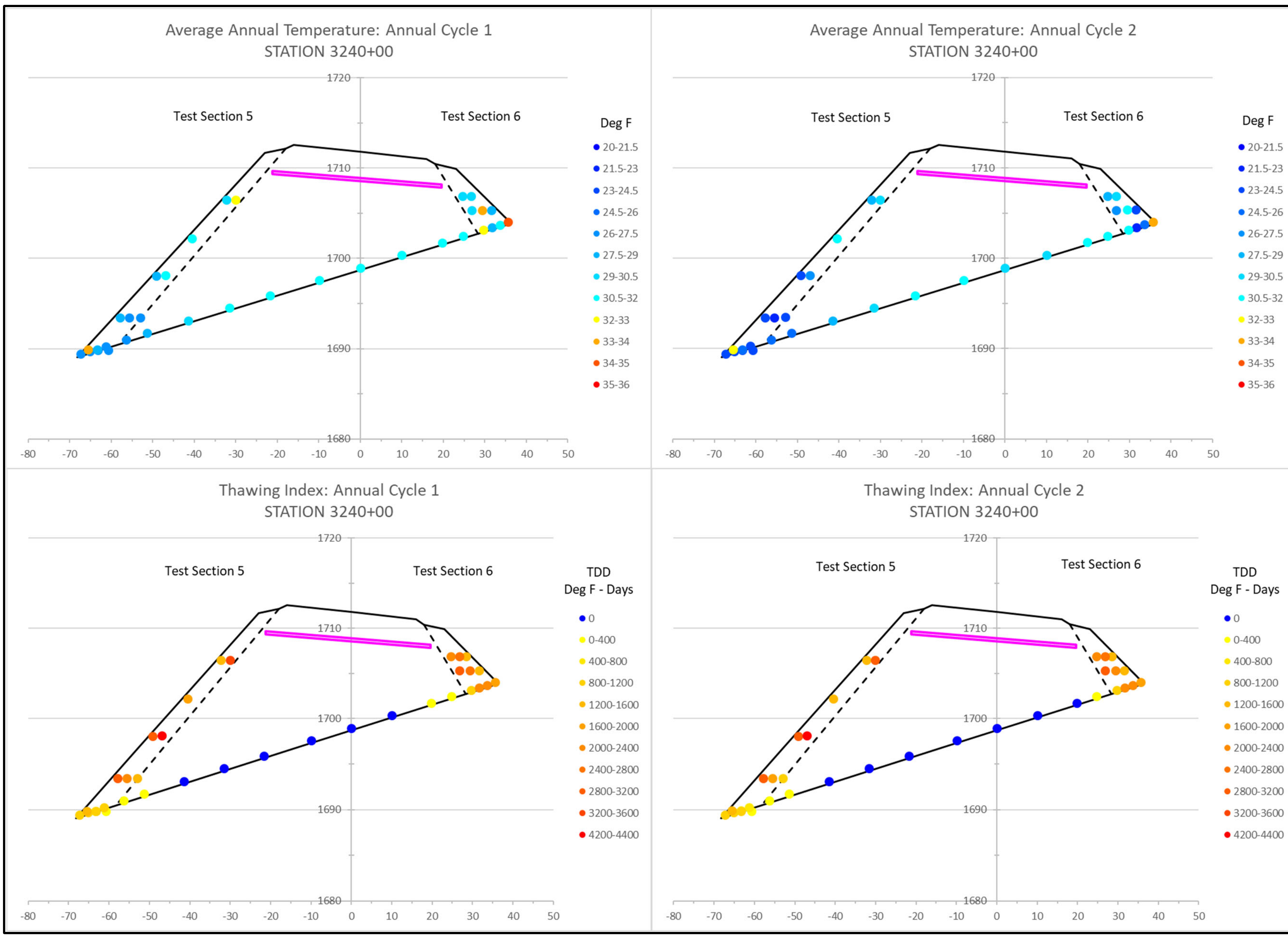


Figure 9: Average Annual Temperature and Thawing Index for Sensors Located in Test Sections 5 and 6.

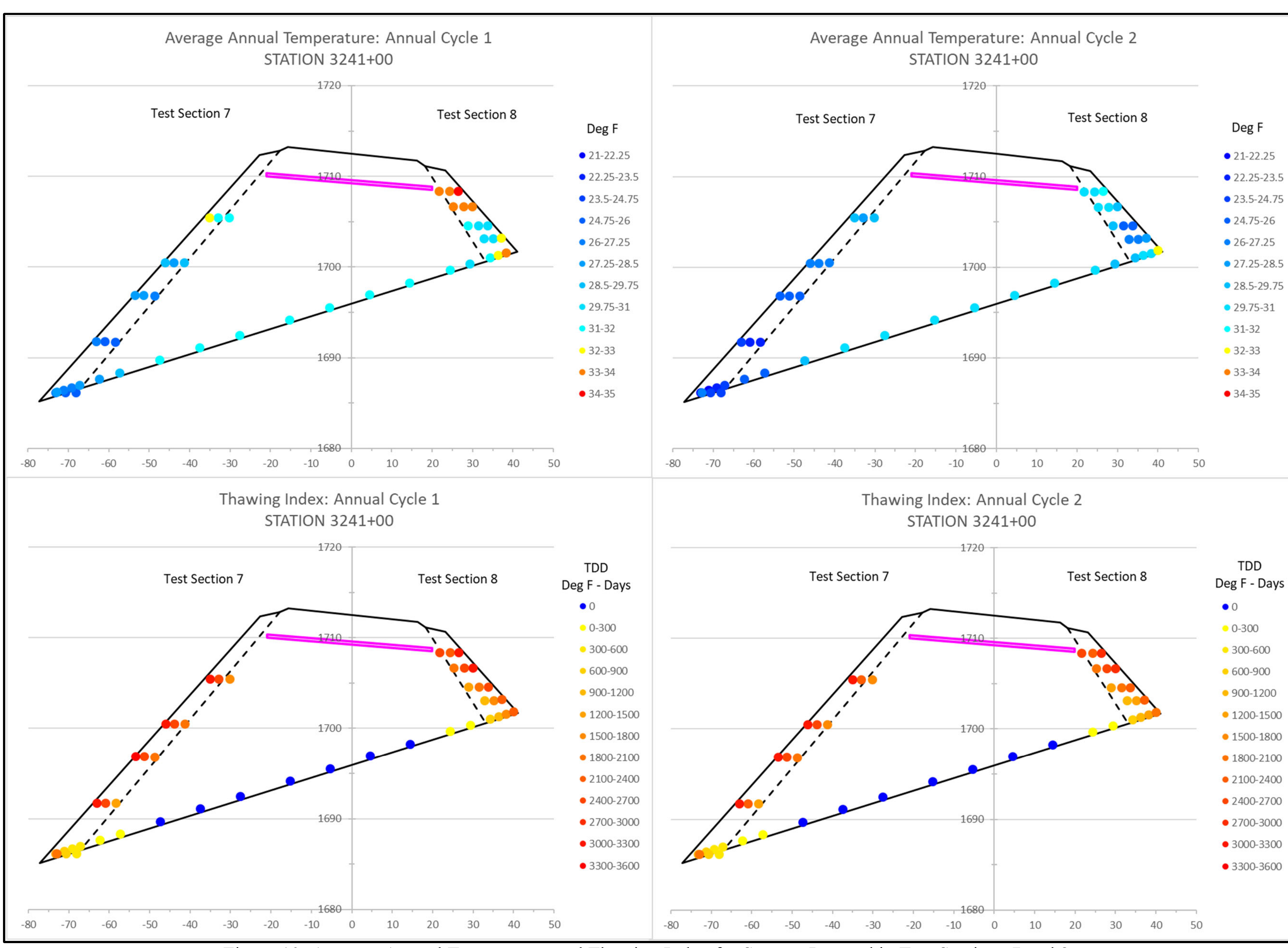


Figure 10: Average Annual Temperature and Thawing Index for Sensors Located in Test Sections 7 and 8.

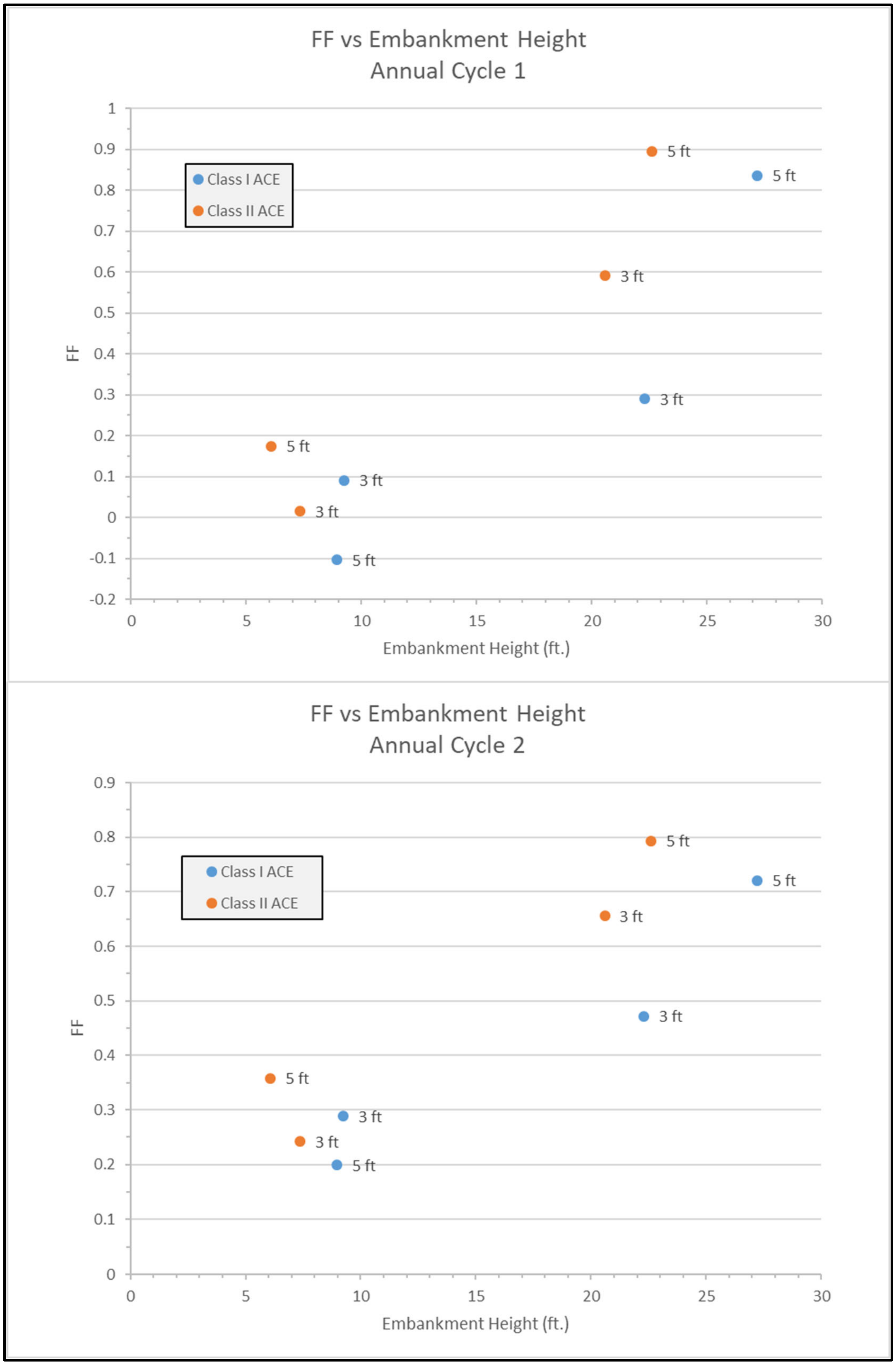


Figure 11: Freeze-Factor vs. Embankment Height and Width, and ACE Class.

Conclusions

As discussed in the introductory paragraphs of this report, this study intended to address several aspects of ACE shoulder embankment construction. Addressing these aspects has broadened our understanding of ACE shoulder embankments, as well as what embankment geometries and aggregates can be used successfully in their design. This information may make ACE embankments more viable and affordable in the future. The aspects of ACE embankments that were addressed with this study include:

- The relationship between ACE shoulder thermal performance and the shoulder's top width. Historically ACE shoulders have been constructed to be roughly 10 feet wide.
- The relationship between ACE shoulder thermal performance and different size ACE classifications.
- The relationship between ACE shoulder thermal performance and the shoulder height.

Regardless of geometry and ACE Class, construction of the embankment and ACE shoulders appeared to work well. No problems with placement and spreading of ACE aggregate were reported. However, construction activities were temporary halted due to concerns that asbestos was encountered in the Dietrich rock quarry. Laboratory results, however, suggest sample mineralogy best matched with the non-asbestos mineral, magnesiocarpholite. In spite of this, it was advised that the material within the pit be treated as if it contained asbestos. As such, rock mining practices within the pit were adjusted accordingly.

The results of this study suggest thermal performance of an ACE shoulder embankment is largely a function of embankment height, followed by, in order of decreasing influence, ACE class size and shoulder width. It is unfortunate that we were not able to use data from Test Sections 9 through 12 to analyze the performance of ACE Shoulder embankments constructed of 8.5-foot-wide shoulders. However, it does appear that embankment height has the largest influence on an ACE shoulder's thermal performance.

As discussed previously, it was decided to cover the ACE shoulder tops with geotextile in an effort to prevent contamination from surface aggregate due to routine maintenance. We do not know to what degree this geotextile is adversely effecting the thermal performance of the ACE shoulders. However, we speculate the adverse effect is likely minimal, particularly with the taller shoulders. This is supported by the relatively good performance we have observed in these shoulders thus far.

Increased thermal performance may be achieved with tall and wide ACE shoulders constructed of larger- diameter ACE classes. However, this study indicates that sufficient performance can be achieved with narrower-than-normal ACE shoulder widths and smaller-diameter aggregates. Note the level of performance at this site is driven by the ambient air temperature, which is relatively cold. Although we have had success with both ACE shoulder and Full ACE embankments in warmer regions of the state, we believe that ACE embankments will likely perform better in cooler regions.

It was originally intended to finish the embankment with an asphalt surface. Instability of the embankment observed during construction, however, prompted the decision to finish the embankment with a gravel-surface. We believe the majority of this instability was due to internal consolidation of the embankment core rather than settlement of the foundation soil. This belief is supported by the below-freezing average annual temperatures at the base of the shoulders and the perennially frozen ground near the bottom of the embankment centers.

Our observations during site visits suggest the embankment has stabilized since construction. This was recently confirmed via telephone conversation with Maintenance and Operations (M&O) personnel. According to M&O reports, excluding culvert crossings the embankment is performing well and is stable. This suggests the ACE shoulders are successfully cooling and stabilizing the foundation soils.

Recommendations

We believe the results of this study as well as our other ACE experimental features show that shoulder geometry, and ACE classes can be adjusted in an effort to reduce project costs without suffering large performance compromises. However, this experimental feature is located in a relatively cold region. As such, we recommend considering the local thermal regime when attempting to optimize the ACE design with geometry and ACE class.

As previously discussed, ACE shoulder performance is a function of the local climate, shoulder height, ACE class size and shoulder width. Other variables such as aspect to the sun, snow accumulation and methods of removal, and local wind patterns likely affect the shoulder performance as well. As such, we have not developed hard numbers with respect to optimal shoulder height and width, and ACE class. The optimal value for a given variable depends on the other variables that affect the performance of an ACE shoulder. We believe, however, design aspects of ACE shoulders such as shoulder geometry and ACE class can be adjusted to reduce project costs while considering the other variables that will affect their performance. In general, we recommend the following when designing an ACE shoulder embankment:

- Consider reducing shoulder-top-widths; particularly when embankment heights are relatively large.
- Consider not extending ACE shoulder treatment to top of the embankment when embankment heights are relatively large.
- Maximize height of ACE shoulder on relatively thin embankments by bringing ACE to the top of the embankment.
- Use larger ACE classes where possible, particularly when ACE shoulders are relatively short.
- Consider the effects of possible post-construction contamination of ACE shoulders, particularly where gravel-surfaced embankments are employed.

In order for an ACE aggregate to perform, it must facilitate air flow. As such, the aggregate needs to remain porous in order to provide a path for the air. This porosity is achieved through the specified gradation. Contamination from fines and aggregate breakdown can alter the aggregate's gradation and reduce its porosity. We recommend future projects constructing either ACE shoulder or full ACE embankments develop measures through placement and hauling plans, quality control, and quality assurance to prevent both contamination and aggregate breakdown.

The Department's understanding of ACE shoulder performance has increased and is continuously evolving. Consult with Northern Region Geotechnical Staff during the design process for project-specific recommendations and specifications.

It is unfortunate that we were not able to utilize the data for the 8.5-foot-wide shoulders in Test Sections 9 through 12. This data would have refined our analysis and conclusions. For future projects utilizing ACE shoulders, we recommend constructing three test sections of similar shoulder height and 5-foot, 8-foot, and 10-foot shoulders. Our recent experience leads us to believe that future test sections can be instrumented more simply than our past ones – using less cables and sensors, and targeting the more critical locations such as the interface between ACE and non-convective soils. We believe data from such test sections will supplement this study and fill the data gap between 5-foot-wide and 10-foot-wide shoulders.

References:

Alaska Climate Research Center (https://akclimate.org/)

Berggren, M. and Billings, M. *Post-Construction Report: Construction of Road Embankments with Reduced Air Convection Embankment (ACE) Shoulder Top-Widths.* Alaska Department of Transportation and Public Facilities Northern Region Materials Section. June, 2022.

Billings, M. *Final Report: Construction of an Air Convection Embankment (ACE) and ACE Shoulders with 1-inch to 2-inch and 3-inch to 5-inch ACE Fill.* Alaska Department of Transportation and Public Facilities Northern Region Materials Section. April, 2022.

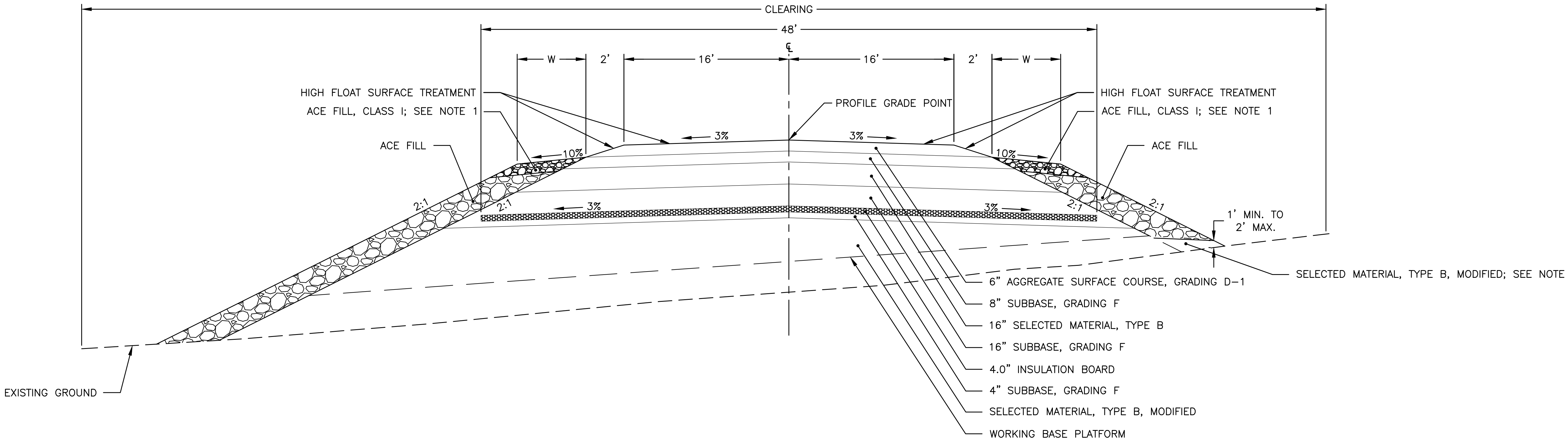
Billings, M. and Berggren, M. *Final Report: Construction of an Air Convection Embankment (ACE) with Non-Angular ACE Aggregate.* Alaska Department of Transportation and Public Facilities Northern Region Materials Section. November, 2021.

McHattie, R and Goering, D. *Air Convecting Embankment (ACE) Design Guide*. Alaska Department of Transportation Statewide Research Office, February 2009.

Appendix A: ACE Shoulder Typicals and Sensor Locations

NO.	DATE	REVISION
⚠	12/28/17	CHANGE ORDER #14

STATE	PROJECT DESIGNATION	YEAR	SHEET NO.	TOTAL SHEETS
ALASKA	HFHWY00127	2020	1	7



⚠ TYPICAL SECTION

FDL REALIGNMENT
STA 3225+00 TO STA 3270+50

⚠ NOTES:

1. THE UPPER 1-FOOT OF ACE SHOULDERS SHALL BE CLASS I ACE FILL.
2. BEGIN AND END STATIONS FOR ACE SHOULDERS MAY BE ADJUSTED IN THE FIELD BY THE ENGINEER.
3. ACE FILL BELOW THE UPPER 1-FOOT MAY BE CLASS I OR CLASS II AS PER TABLE 1 AND THE HAULING AND PLACEMENT PLAN APPROVED BY THE ENGINEER.
4. TIE ACE FILL SHOULDERS INTO RIPRAP ON EMBANKMENT FACE ON BOTH SIDES OF 10-FOOT SPP AT DEBRIS LOBE CREEK.
5. W=8.5-FEET EXCEPT FOR TEST SECTIONS WHERE IT WILL BE EITHER 3.0-FEET, 5.0-FEET, OR 8.5-FEET. SEE ACE SHOULDER WIDTH AND ACE FILL CLASS TABLE.
6. PLACE AND COMPACT SELECTED MATERIAL, TYPE B, MODIFIED TO DRAIN AT 5% TO 10%. TO PREVENT SURFACE RUNOFF ON ORIGINAL GROUND FROM ENTERING THE ACE SHOULDER, MAINTAIN A 1' TO 2' LIFT-HEIGHT ON THE RIGHT.

⚠ TABLE 1 - ACE SHOULDER WIDTH AND ACE FILL CLASS

BEGIN STATION	END STATION	PROJECT LEFT		PROJECT RIGHT	
		SHOULDER WIDTH (FT)	ACE FILL CLASS	SHOULDER WIDTH (FT)	ACE FILL CLASS
3225+00	3229+50	8.5	I OR II	0.0	N/A
3229+50	3233+50	8.5	I OR II	8.5	I OR II
3233+50	3234+50	3.0	II	3.0	II
3234+50	3235+50	3.0	I	3.0	I
3235+50	3239+50	8.5	I OR II	8.5	I OR II
3239+50	3240+50	5.0	II	5.0	II
3240+50	3241+50	5.0	I	5.0	I
3241+50	3244+50	8.5	I OR II	8.5	I OR II
3244+50	3245+50	8.5	I	8.5	I
3245+50	3246+50	8.5	II	8.5	II
3246+50	3249+00	8.5	I OR II	8.5	I OR II
3249+30	3266+50	8.5	I OR II	8.5	I OR II
3266+50	3270+50	8.5	I OR II	0.0	N/A

STATE OF ALASKA 49TH Stephen J. McGroarty AEL-9491 REGISTERED PROFESSIONAL ENGINEER

60761_P&P - TYPICAL

NO.	DATE	REVISION

STATE	PROJECT DESIGNATION	YEAR	SHEET NO.	TOTAL SHEETS
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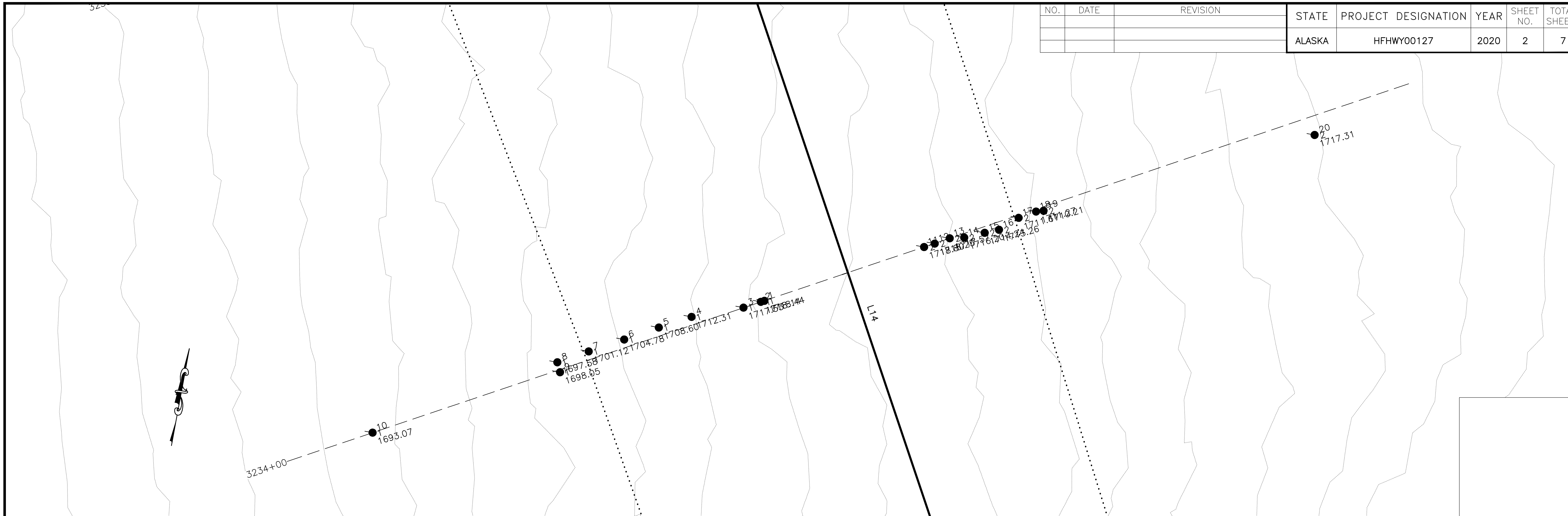

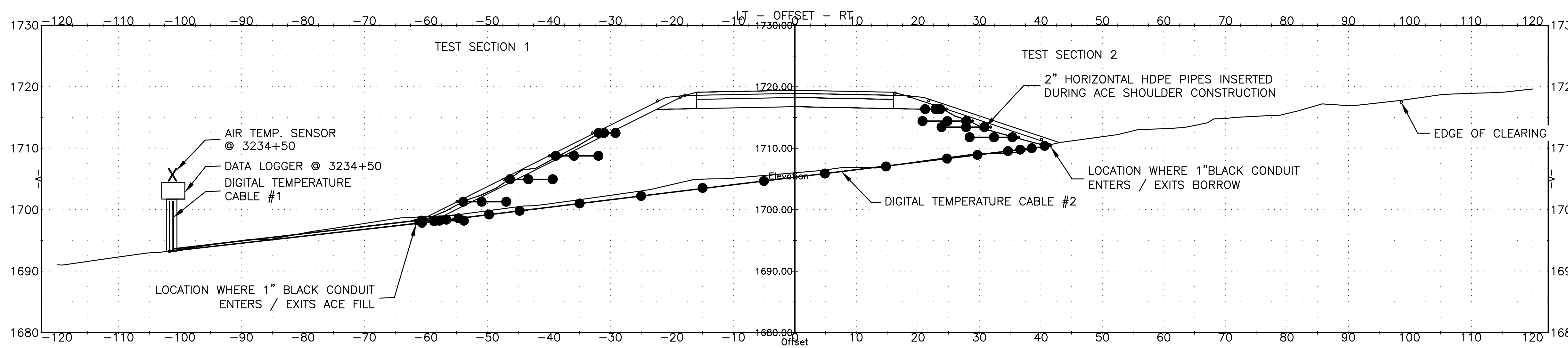

3234+00

PROFILE GRADE EL = 1695.35
EXISTING GROUND EL = 1695.3

PLANS DEVELOPED BY: STATE OF ALASKA DEPARTMENT OF TRANSPORTATION & PUBLIC FACILITIES, NORTHERN REGION, 2301 PEGER ROAD, FAIRBANKS, AK 99709 (907)451-2200
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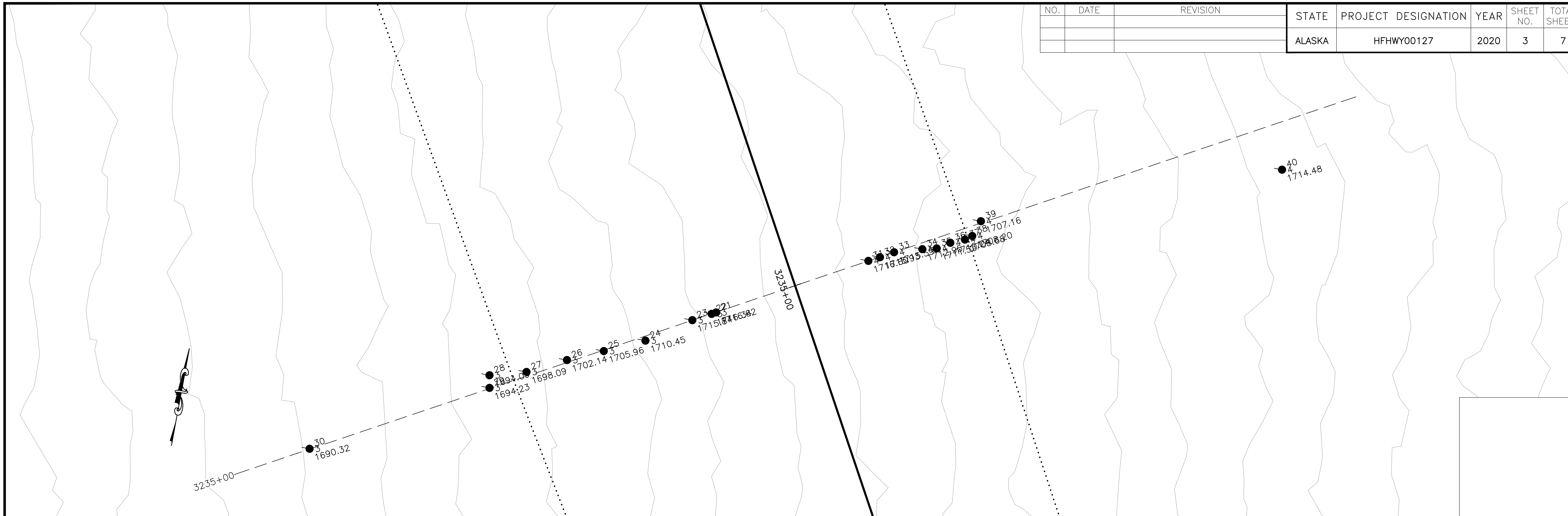

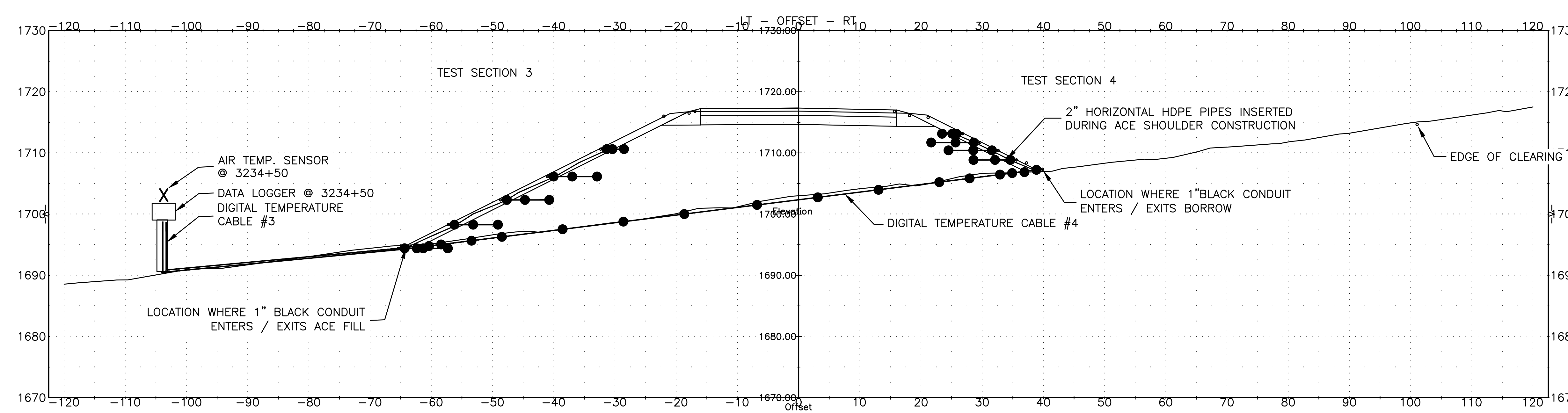

3235+00

PROFILE GRADE EL = 1693.81
EXISTING GROUND EL = 1693.8

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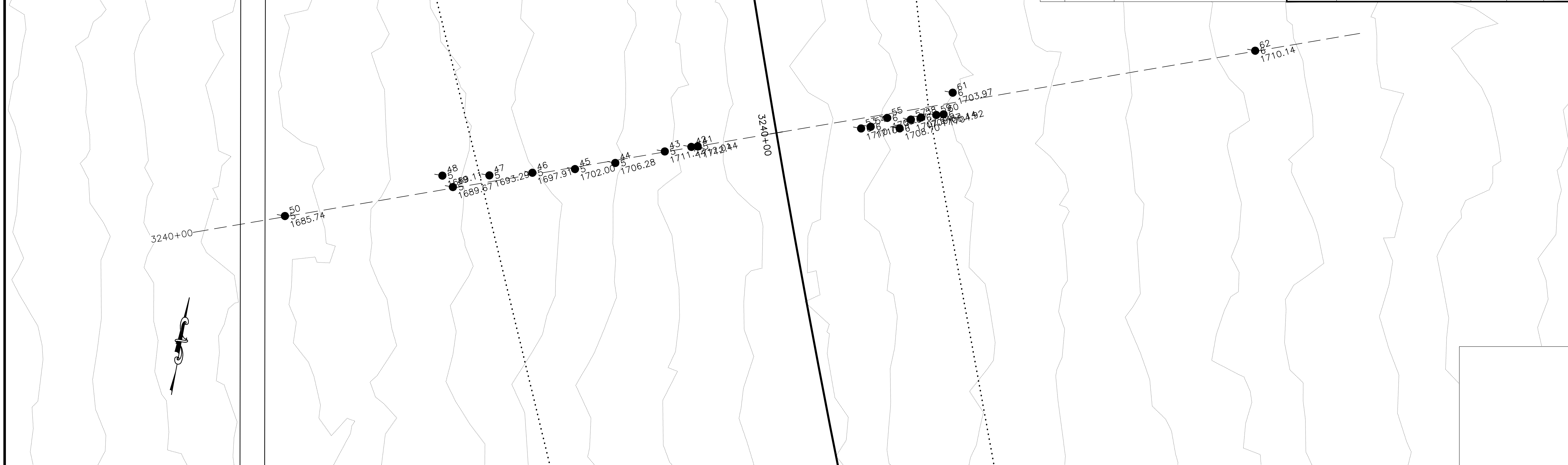

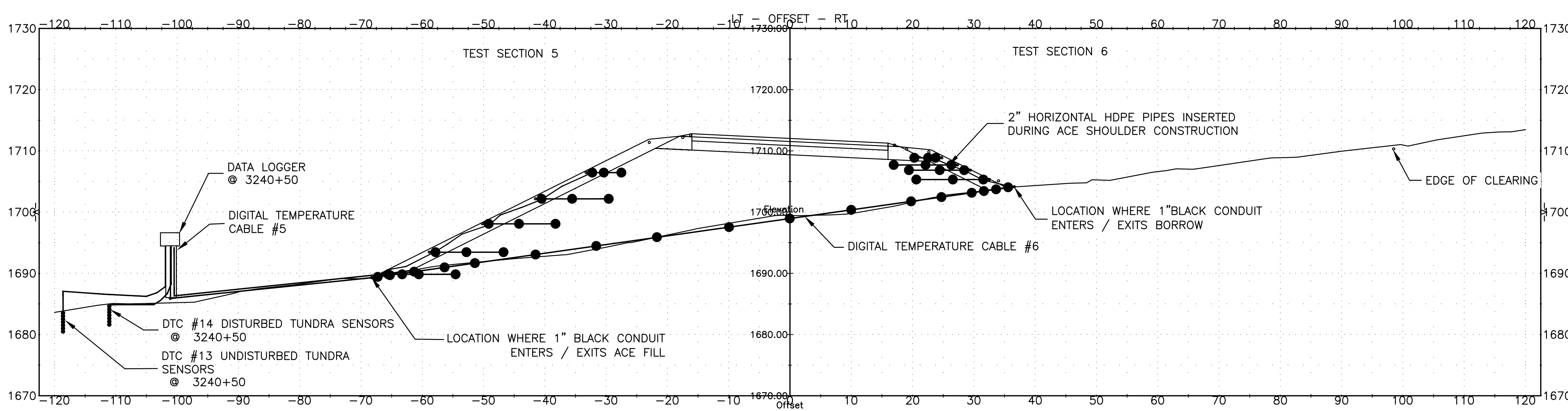

3240+00

PROFILE GRADE EL = 1686.09
EXISTING GROUND EL = 1686.1

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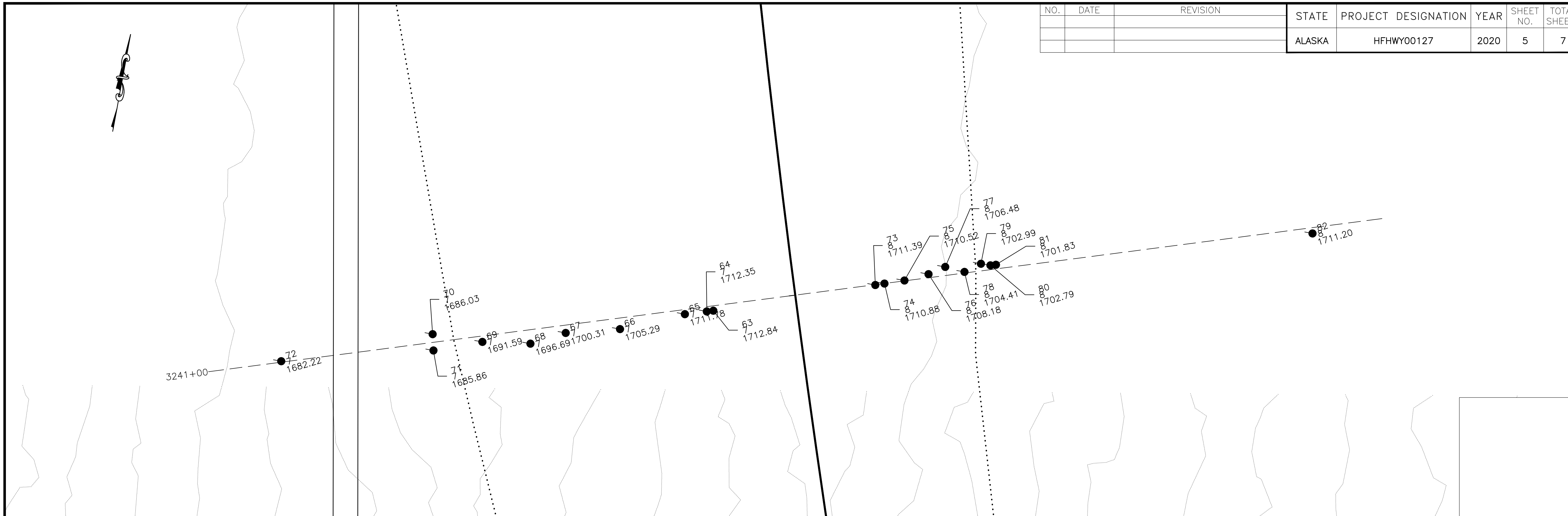

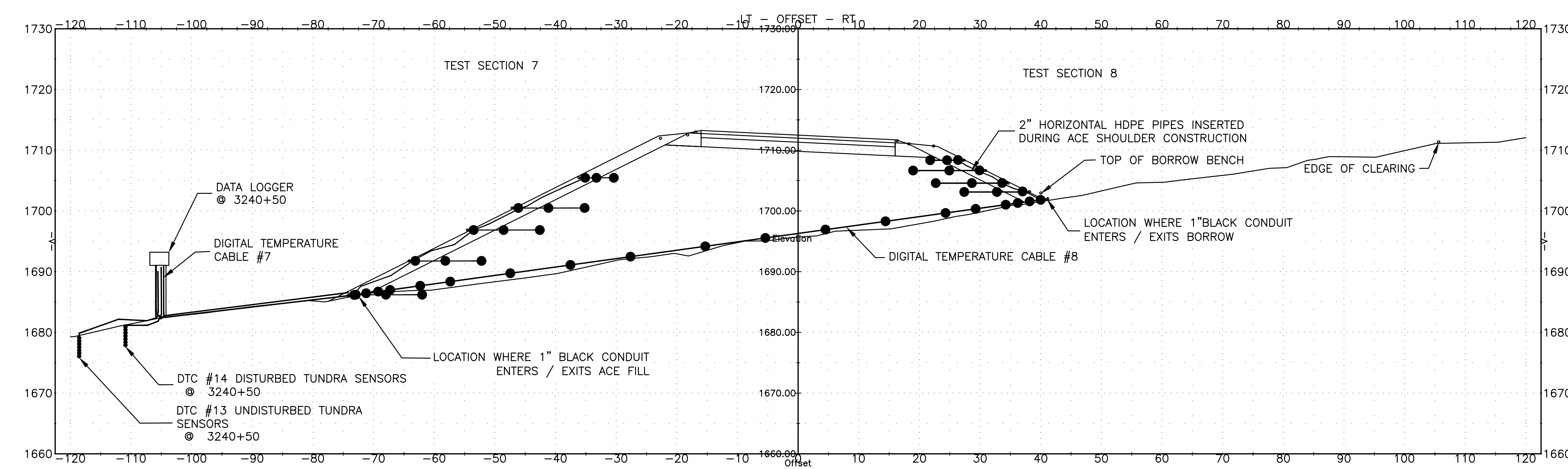

3241+00

PROFILE GRADE EL = 1684.54
EXISTING GROUND EL = 1684.5

NO.	DATE	REVISION

STATE	PROJECT DESIGNATION	YEAR	SHEET NO.	TOTAL SHEETS
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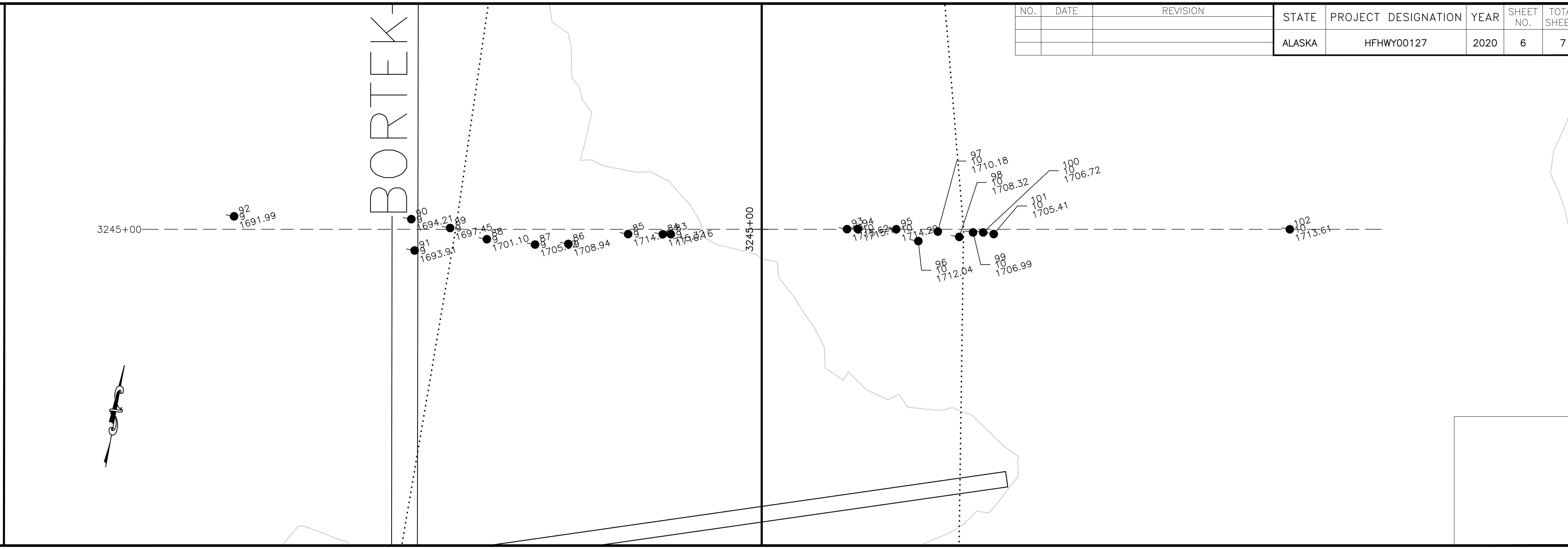

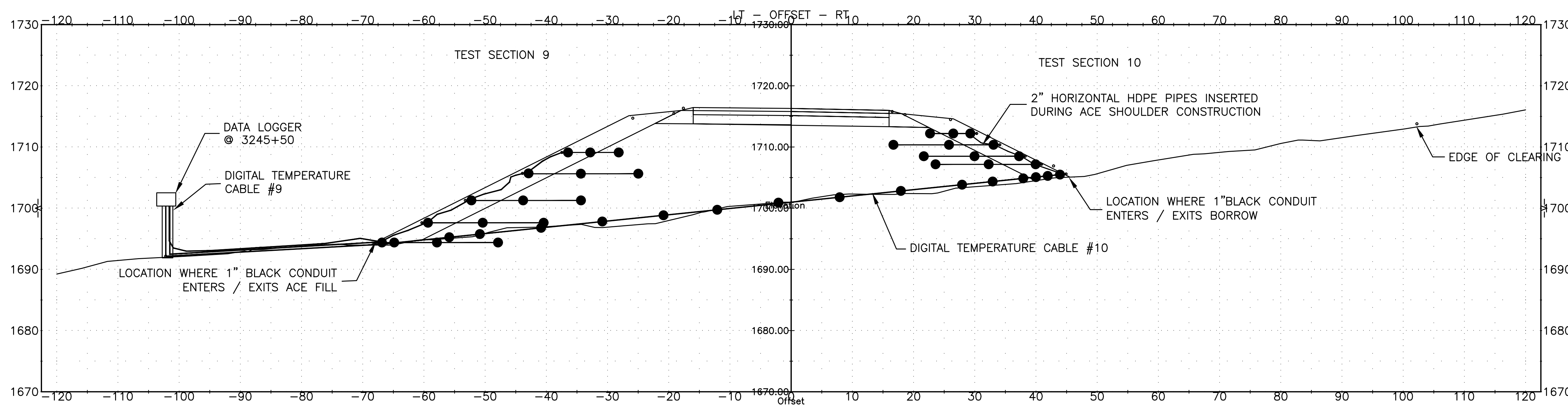

3245+00

PROFILE GRADE EL = 1700.99
EXISTING GROUND EL = 1701.0

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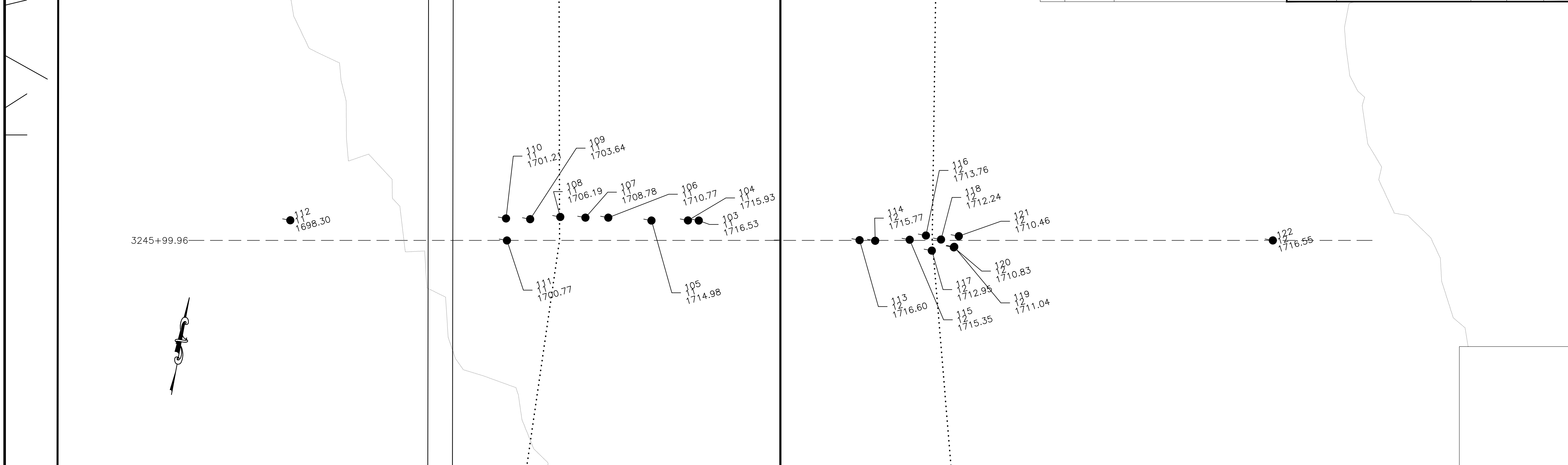
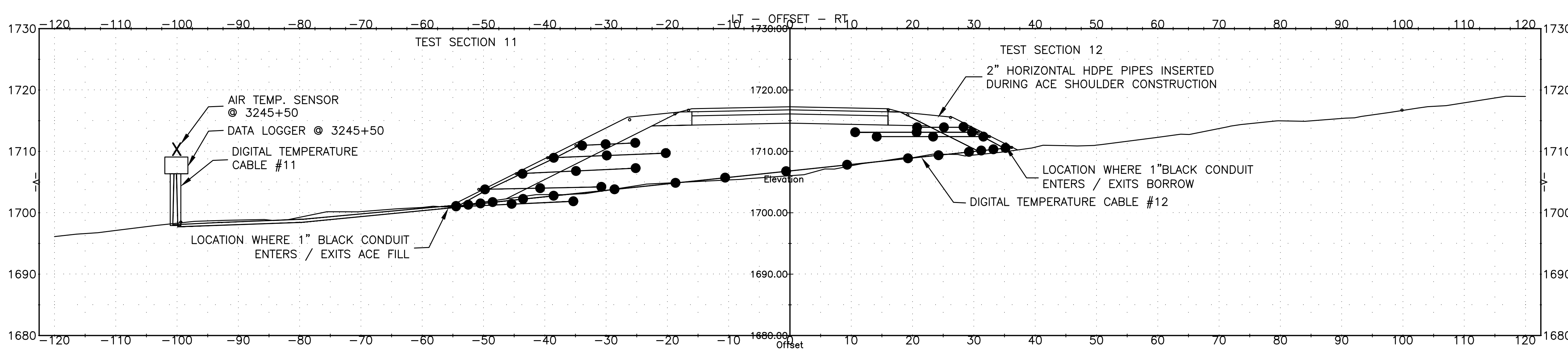
NO.	DATE	REVISION

STATE	PROJECT DESIGNATION	YEAR	SHEET NO.	TOTAL SHEETS
ALASKA	HFHWY00127	2020	7	7





3245+99.96

PROFILE GRADE EL = 1695.25
EXISTING GROUND EL = 1695.3

PLANS DEVELOPED BY: STATE OF ALASKA DEPARTMENT OF TRANSPORTATION & PUBLIC FACILITIES, NORTHERN REGION, 2301 PEGER ROAD, FAIRBANKS, AK 99709 (907)451-2200

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Appendix B: Experimental Feature Work Plan

Experimental Feature in Highway Construction Work-Plan

Construction of Road Embankments with Reduced Air Convection Embankment (ACE) Shoulder Top-Widths

For Inclusion in the

Dalton Highway MP 209 – 222 Reconstruction Project

0655015/NFHWY00144

Alaska Department of Transportation & Public Facilities
Northern Region Materials Section

Steve McGroarty, P.E.
Northern Region Geotechnical Engineer
And
Matt Billings, P.E.
Northern Region Assistant Geotechnical Engineer

March 23, 2018

Table of Contents

Appendices

Description of Experimental Feature

This experimental feature will test the effectiveness of an insulated conventional embankment with reduced ACE Shoulder top-widths over a section of the Dalton Highway being realigned at MP 219 over thaw-unstable ice-rich permafrost in the foundation soils.

This Experimental Feature is the third effort by the Northern Region to instrument an insulated conventional embankment with ACE Shoulder and will examine the question of "What is the minimum effective top-width of an ACE Shoulder?" Existing ACE Shoulders in Alaska have been constructed with 10 to 15-foot wide shoulders. If this can be reduced to 5-feet, this would represent a 50% to 67% reduction in ACE Fill Requirements with corresponding cost savings.

The cost of ACE Fill has ranged from $18/CY for the lowest bidder on the Alaska Highway MP 1354-1364 Rehabilitation Project to $71/CY for the change order incorporating ACE Fill into the Dalton Highway MP 209-222 Reconstruction Project. Bid-prices of the ACE Fill on the Thompson Drive Project at UAF were $26/CY. The current Dalton Highway Project incorporates an average ACE shoulder top-width of 5-feet for 4,550 feet of realignment for a total ACE Fill quantity of 31,500 CY. If this was been constructed using the standard 10-foot top-width, this would represent a cost increase of approximately $2.2-million. Using "bid prices" assumed to be $26/CY, being able to reduce ACE Shoulder top-widths from 10-feet to 5-feet would save approximately $950,000 per mile of highway constructed with ACE Shoulders.

This Experimental Feature is complimentary to, and builds upon, the on-going "Construction of an Air Convection Embankment (ACE) With non-Angular ACE Fill" Experimental Feature constructed as part of the Alaska Highway MP 1354-1364 Rehabilitation Project and the proposed "Construction of an Air Convection Embankment (ACE) and ACE Shoulders with 1"-2" Rounded ACE Fill" Experimental Feature associated with the Elliot Highway MP 0-12 Rehabilitation Project.

Problem Statement & Background:

Many of Alaska's roads are constructed on thaw-unstable permafrost. Construction of standard highway embankments results in changing the thermal regime in the ice-rich foundation soils below the embankment, often resulting in thaw-related settlement and pavement distress. It has been observed that embankments made using coarse, poorly graded (highly permeable) rock promote significant cooling of underlying foundation soils. In general, natural convective heat transfer within a highly-permeable rock embankment can be used to cool the foundation beneath the embankment. In permafrost areas, such cooling can be used to counteract the warming influence that results from construction of roads, runways or other embankments. Recent estimates indicate that the Northern Region of DOT&PF spends approximately $10+ million annually due to degrading permafrost. ACE Embankments and ACE Shoulders have been demonstrated to maintain permafrost conditions in foundation soils. If it can be demonstrated that ACE Shoulders can be constructed with reduced top-widths, ACE shoulders will become more cost effective and may be incorporated into more highway reconstruction projects thus reducing future maintenance costs.

Additional instrumented ACE Fill test sections are needed to allow refinement of design methods for ACE Technology; specifically, this work is intended to attempt to determine the minimum effective ACE Shoulder Treatment thickness. Test Sections will be constructed with two sizes of ACE Fill, three ACE Shoulder top-widths, and different heights.

Scope and Objectives of Study

This experimental feature proposes to examine the following:

- Performance of ACE Shoulders with reduced top-widths.
- Performance of ACE Shoulders on road embankments with different heights above the surrounding original ground surface.
- Performance of 3”-5” angular vs. 5”-8” angular ACE Shoulders of equal top-widths.
- Minimum thickness of ACE Shoulders for 3”-5” and 5”-8” angular ACE Fill.

Please see Table 1 for a comparison of the ACE test segment parameters.

Work Plan Summary

The Dalton Highway MP 209-222 Reconstruction Project required modification to incorporate ACE Shoulders. The project provides the opportunity to develop twelve different ACE Test Sections. These consist of twelve ACE Shoulder Tests as summarized in Table 1.

Table 1 – Test Section Summary

Test Section Number	Embankment Type	Size of ACE Fill	ACE Shoulder Top-Width	Begin Station	End Station	Project Left / Right	Approx. Height above Original Ground
1	Insulated with ACE Shoulder	5”-8”	3’	3233+50	3234+50	Left	19.5’
2	Insulated with ACE Shoulder	5”-8”	3’	3233+50	3234+50	Right	8’
3	Insulated with ACE Shoulder	3”-5”	3’	3234+50	3235+50	Left	22’
4	Insulated with ACE Shoulder	3”-5”	3’	3234+50	3235+50	Right	9.5’
5	Insulated with ACE Shoulder	5”-8”	5’	3239+50	3240+50	Left	23’
6	Insulated with ACE Shoulder	5”-8”	5’	3239+50	3240+50	Right	6’
7	Insulated with ACE Shoulder	3”-5”	5’	3240+50	3241+50	Left	27.5’
8	Insulated with ACE Shoulder	3”-5”	5’	3240+50	3241+50	Right	9.5
9	Insulated with ACE Shoulder	3”-5”	8.5’	3244+50	3245+50	Left	21’
10	Insulated with ACE Shoulder	3”-5”	8.5’	3244+50	3245+50	Right	10’
11	Insulated with ACE Shoulder	5”-8”	8.5’	3245+50	3246+50	Left	15’
12	Insulated with ACE Shoulder	5”-8”	8.5’	3245+50	3246+50	Right	5.5’

<u>Work Plan – Contractor Actions</u>

Contractor Actions have been coordinated with the Construction Project Engineer to minimize impacts to project schedule and cost, while maximizing data acquisition for refinement of ACE ACE Shoulder Treatment design methods.

General

- Contractor to coordinate with the Engineer to measure porosity of both size classes of Angular ACE Fill. This will be accomplished by measuring the volume, empty-vehicle weight, full-vehicle weight, and the specific gravity of the different sizes of ACE Fill.

- Contractor will allow Project Engineer to place horizontal HDPE Tubing during ACE Fill placement in the shoulder ACE Fill in the test sections for future installation of Digital Temperature Cables (DTCs) by the Northern Regions Materials Staff (NRMS).

- Contractor to install 3" Galvanized Steel Pipe on Project Left at Station 3234+50 for future data logger installation by NRMS.

- Contractor will install 3" Galvanized Steel Pipe on Project Left at Station 3240+50 for future data logger installation by NRMS.

- Contractor will install 3" Galvanized Steel Pipe on Project Left at Station 3245+50 for future data logger installation by NRMS.

Typical Section FDL Realignment

- ACE TEST SECTION # 1:
    - Contractor to construct a 100-foot ACE Shoulder test-segment (3-feet top-width) on Project Left between Station 3233+50 and 3234+50 using 5"-8" Angular ACE Fill Material.
    - Contractor to install 1-inch 200 psi SIDR 9 HDPE Conduit (Nominal I.D. 1.0-inch) DTCs on original ground at Station 3234+00. See Appendix A for instrumentation plans.

- ACE TEST SECTION # 2:
    - Contractor to construct a 100-foot ACE Shoulder test-segment (3-feet top-width) on Project Right between Station 3233+50 and 3234+50 using 5"-8" Angular ACE Fill Material.

- ACE TEST SECTION # 3:
    - Contractor to construct a 100-foot ACE Shoulder test-segment (3-feet top-width) on Project Left between Station 3234+50 and 3235+50 using 3"-5" Angular ACE Fill Material.

- Contractor to install 1-inch 200 psi SIDR 9 HDPE Conduit (Nominal I.D. 1.0-inch) for Digital Temperature Cables (DTCs) on original ground at Station 3235+00.

- ACE TEST SECTION # 4:
  - Contractor to construct a 100-foot ACE Shoulder test-segment (3-feet top-width) on Project Right between Station 3234+50 and 3235+50 using 3”-5” Angular ACE Fill Material.

- ACE TEST SECTION # 5:
  - Contractor to construct a 100-foot ACE Shoulder test-segment (5-feet top-width) on Project Left between Station 3239+50 and 3240+50 using 5”-8” Angular ACE Fill Material.
  - Contractor to install 1-inch 200 psi SIDR 9 HDPE Conduit (Nominal I.D. 1.0-inch) for Digital Temperature Cables (DTCs) on original ground at Station 3240+00.

- ACE TEST SECTION # 6:
  - Contractor to construct a 100-foot ACE Shoulder test-segment (5-feet top-width) on Project Right between Station 3239+50 and 3240+50 using 5”-8” Angular ACE Fill Material.

- ACE TEST SECTION # 7:
  - Contractor to construct a 100-foot ACE Shoulder test-segment (5-feet top-width) on Project Left between Station 3240+50 and 3241+50 using 3”-5” Angular ACE Fill Material.
  - Contractor to install 1-inch 200 psi SIDR 9 HDPE Conduit (Nominal I.D. 1.0-inch) for Digital Temperature Cables (DTCs) on original ground at Station 3241+00.

- ACE TEST SECTION # 8:
  - Contractor to construct a 100-foot ACE Shoulder test-segment (5-feet top-width) on Project Right between Station 3240+50 and 3241+50 using 3”-5” Angular ACE Fill Material.

- ACE TEST SECTION # 9:
  - Contractor to construct a 100-foot ACE Shoulder test-segment (8.5-feet top-width) on Project Left between Station 3244+50 and 3245+50 using 3”-5” Angular ACE Fill Material.

  - Contractor to install 1-inch 200 psi SIDR 9 HDPE Conduit (Nominal I.D. 1.0-inch) for Digital Temperature Cables (DTCs) on original ground at Station 3245+00.

- ACE TEST SECTION # 10:
  - Contractor to construct a 100-foot ACE Shoulder test-segment (8.5-feet top-width) on Project Right between Station 3244+50 and 3245+50 using 3”-5” Angular ACE Fill Material.

- ACE TEST SECTION # 11:
  - Contractor to construct a 100-foot ACE Shoulder test-segment (8.5-feet top-width) on Project Left between Station 3245+50 and 3246+50 using 5”-8” Angular ACE Fill Material.
  - Contractor to install 1-inch 200 psi SIDR 9 HDPE Conduit (Nominal I.D. 1.0-inch) for Digital Temperature Cables (DTCs) on original ground at Station 3246+00.

- ACE TEST SECTION # 12:
  - Contractor to construct a 100-foot ACE Shoulder test-segment (8.5-feet top-width) on Project Right between Station 3245+50 and 3246+50 using 5”-8” Angular ACE Fill Material.

Work Plan – Northern Region AKDOT&PF Construction Staff Actions

- Northern Region Construction Staff will monitor ACE Shoulder construction and document any difficulties with installation of ACE Fill.

- Northern Region Construction Staff to take photos documenting ACE shoulder construction.

- Northern Region Construction Staff to coordinate with Contractor to perform ACE Fill porosity tests and provide data to NRMS staff.

- Northern Region Construction Staff to provide NRMS staff with gradation test results for all classes of ACE Fill to ensure it meets specifications.

- Northern Region Construction Staff to install horizontal sections of HDPE Tubing during ACE Fill placement on shoulders in test sections.

- Northern Region Construction Staff to survey final cross-sections at conduit locations and provide As-Built cross-sections to NRMS in AutoCAD showing end-points of horizontal conduits.

Work Plan – Northern Region AKDOT&PF Materials Section Staff Actions

- NRMS Staff to install Digital Temperature Cables, Air Temperature Sensor and data-loggers.

- NRMS to conduct visual monitoring and compare the performance of the highway embankment and pavement for the test segments over a three-year period.

- NRMS to monitor ground temperatures for three-year period to evaluate effectiveness of ACE Shoulders.

- NRMS to collect ACE Fill samples for determination of particle shape and specific gravity.

Method of Evaluation

Construction: Northern Region Construction and Materials Section Staff will monitor ACE Shoulder construction and document conditions of installation and any difficulties with ACE Fill placement. NRMS staff will submit a construction report to AKDOT&PF Research & T2 by June 30, 2019.

Post-Construction Pavement-Condition Monitoring: NRMS staff will visually monitor and compare the performance of the highway embankment and pavement for the test sections over a three-year period. Monitoring will include observation and documentation of settlement and pavement distress.

Post-Construction Foundation Soil and Embankment Temperature Monitoring: Air and ground temperatures will be monitored for three full-years post construction. Average annual ground temperatures will be determined at the base, top and slope surface of Shoulder Treatment test segments to compare the performance of the different ACE Fill Materials and shoulder configurations.

Reporting

Project Status Updates: Brief project status reports will be provided to AKDOT&PF Research & T2 on a quarterly basis.

Construction Report: A construction report describing the construction of the insulated conventional embankment with ACE Shoulder Treatment and instrumentation of the test segments will be provided to AKDOT&PF Research & T2 by June 30, 2019.

Interim Data Reports: Interim reports describing Post-Construction Pavement-Condition Monitoring and Post-Construction Foundation Soil and Embankment Temperature Monitoring will be provided to AKDOT&PF Research & T2 by December 31, 2019, December 31, 2020, and December 31, 2021.

Experimental Feature Final Report: A final report will be submitted following the post-construction monitoring program. The primary author will be Steve McGroarty, Northern Region Geotechnical Engineer or Matt Billings, Northern Region Assistant Geotechnical Engineer, with contributions from Northern Region DOT&PF Maintenance and Construction personnel. The final report will include a complete record of air and ground temperature records, visual observations of embankment settlement and pavement performance, and a synopsis of the experimental feature including recommendations for the future use of ACE Fill. The final report will also contain a discussion of the use of ACE Shoulders for the stabilization of highway embankments over ice-rich permafrost foundation soils. The final report will address constructability issues, suggested improvements, project specifications, and field installation recommendations. The final report will be submitted to AKDOT&PF Research & T2 by June 30, 2022.

Schedule

Work Task	Completion Date
NRMS Staff to provide brief project status reports to AKDOT&PF Research & T2	Quarterly
Contractor to construct ACE Shoulder Test Sections	Summer 2018
Northern Region Construction Staff to document constructability of ACE Shoulders	Summer 2018
NRMS Staff to install DTCs and data-loggers	Summer 2018
Department and Contractor to measure porosity of Angular ACE Fill Material	Summer 2018
NRMS Staff to conduct visual monitoring of ACE Shoulder Test Sections to document embankment settlement and pavement condition	Fall 2018 (initial conditions) Summer 2019 Summer 2020 Summer 2021
NRMS Staff to conduct air and ground temperature monitoring	Fall 2018 – Fall 2021
NRMS Staff to submit Interim Reports	December 31, 2019, December 31, 2020 and December 31, 2021
NRMS Staff to submit Construction Report	June 30, 2019
NRMS Staff to submit Experimental Feature Final Report	June 30, 2022

Budget: Dalton Highway MP 209-222 Rehabilitation Project – Construction

Description	**Quantity**	**Cost / Unit**	**Total**
Digital Temperature Cables (DTC)	13	all	$57,438
D405 Satellite Data Loggers with Telemetry (40 months)	3	$8,000	$24,000
Stainless steel single point TAC with radiation shield for	1	$550	$550
Data Logger Wyes	2	$175	$350
Shipping	1	$500	$500
Miscellaneous Supplies	1	$5,000	$5,000
Personnel Services for DTC and data-logger installation	1	all	$18,500
		Sub-Total	$106,338
Contingency (5%)	1	5%	$5,317
		Sub-Total	$111,655
ICAP (4.65%)		4.65%	$5,192
		Total (rounded to nearest hundred)	**$116,800**

Budget: Research & T2

Description	Quantity	Cost / Unit	Total
Personnel Services for post-construction inspections	1	all	$13,000
Personnel Services for NRMS staff for ground temperature monitoring and analysis, and report compilation	1	all	$50,000
Personnel Services for AKDOT&PF Research & T2 staff	1	all	$5,000
		Sub-Total	$68,200
Contingency (5%)	1	5%	$3,410
		Sub-Total	$71,610
ICAP (4.65%)		4.65%	$3,330
		Total (rounded to nearest hundred)	**$74,900**

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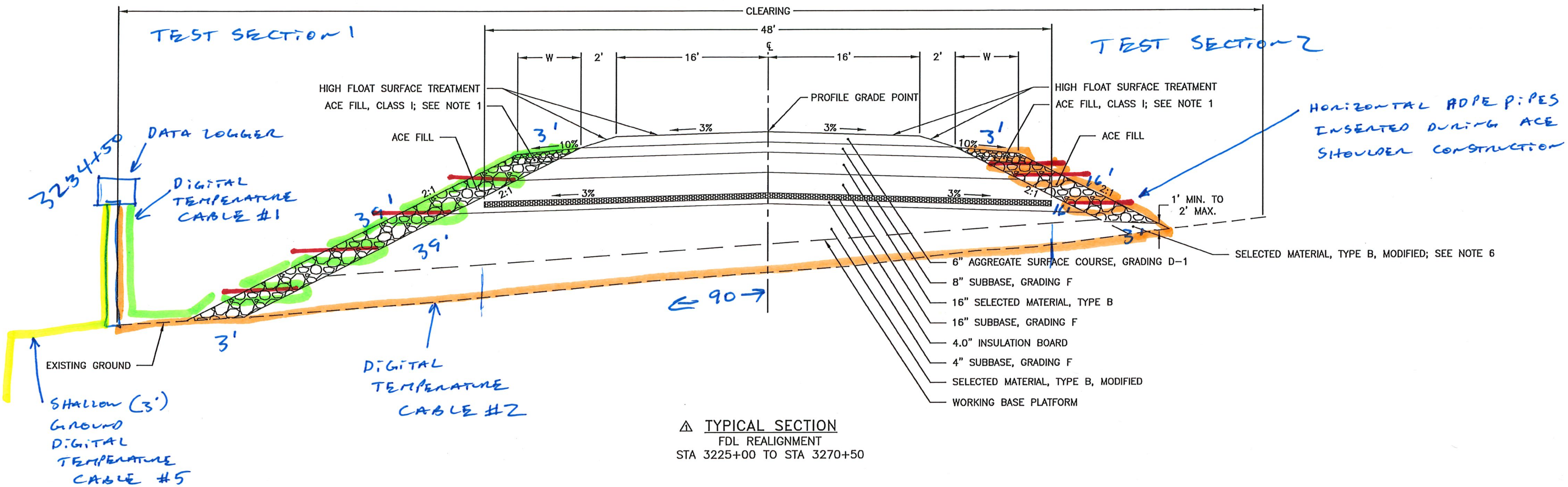
Appendix A

Experimental Feature Instrumentation Plans

NO.	DATE	REVISION
△	12/28/17	CHANGE ORDER #14

STATE	PROJECT DESIGNATION	YEAR	SHEET NO.	TOTAL SHEETS
ALASKA	0655015/NFHWY00144	2016	B2A	74

STA 3234+00



△ TYPICAL SECTION
FDL REALIGNMENT
STA 3225+00 TO STA 3270+50

△ NOTES:

1. THE UPPER 1-FOOT OF ACE SHOULDERS SHALL BE CLASS I ACE FILL.
2. BEGIN AND END STATIONS FOR ACE SHOULDERS MAY BE ADJUSTED IN THE FIELD BY THE ENGINEER.
3. ACE FILL BELOW THE UPPER 1-FOOT MAY BE CLASS I OR CLASS II AS PER TABLE 1 AND THE HAULING AND PLACEMENT PLAN APPROVED BY THE ENGINEER.
4. TIE ACE FILL SHOULDERS INTO RIPRAP ON EMBANKMENT FACE ON BOTH SIDES OF 10-FOOT SPP AT DEBRIS LOBE CREEK.
5. W=8.5-FEET EXCEPT FOR TEST SECTIONS WHERE IT WILL BE EITHER 3.0-FEET, 5.0-FEET, OR 8.5-FEET. SEE ACE SHOULDER WIDTH AND ACE FILL CLASS TABLE.
6. PLACE AND COMPACT SELECTED MATERIAL, TYPE B, MODIFIED TO DRAIN AT 5% TO 10%. TO PREVENT SURFACE RUNOFF ON ORIGINAL GROUND FROM ENTERING THE ACE SHOULDER, MAINTAIN A 1' TO 2' LIFT-HEIGHT ON THE RIGHT.

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3229+50	3233+50	8.5	I OR II	8.5	I OR II
3233+50	3234+50	3.0	II	3.0	II
3234+50	3235+50	3.0	I	3.0	I
3235+50	3239+50	8.5	I OR II	8.5	I OR II
3239+50	3240+50	5.0	II	5.0	II
3240+50	3241+50	5.0	I	5.0	I
3241+50	3244+50	8.5	I OR II	8.5	I OR II
3244+50	3245+50	8.5	I	8.5	I
3245+50	3246+50	8.5	II	8.5	II
3246+50	3249+00	8.5	I OR II	8.5	I OR II
3249+30	3266+50	8.5	I OR II	8.5	I OR II
3266+50	3270+50	8.5	I OR II	0.0	N/A

TEST SECTION 1

TEST SECTION 2

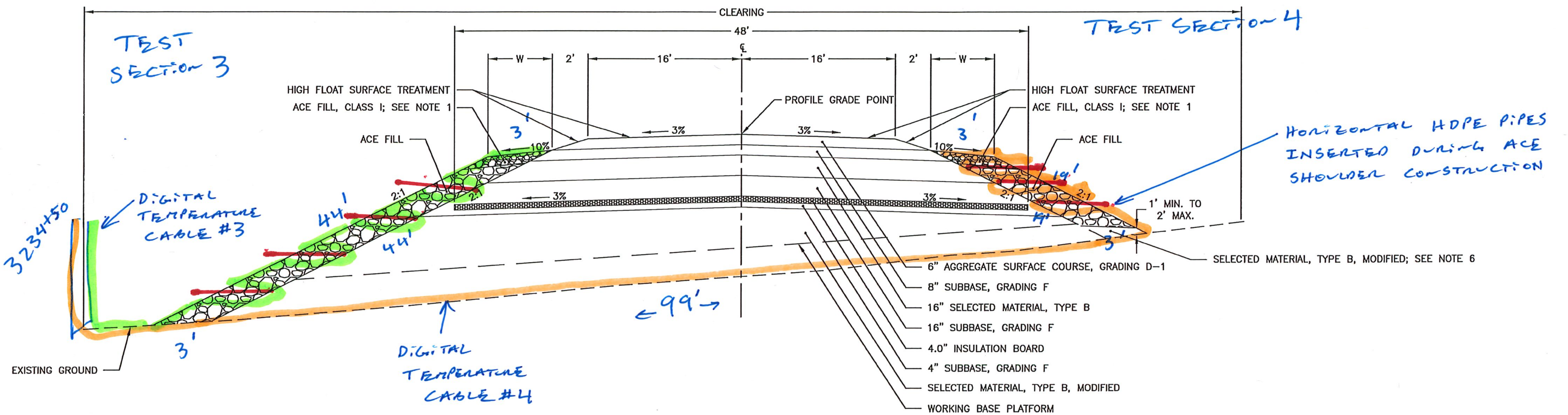
STATE OF ALASKA 49TH Stephen J. McGroarty AEL-9491 REGISTERED PROFESSIONAL ENGINEER

TYPICAL SECTION FDL

STA 3235+00

NO.	DATE	REVISION
⚠	12/28/17	CHANGE ORDER #14

STATE	PROJECT DESIGNATION	YEAR	SHEET NO.	TOTAL SHEETS
ALASKA	0655015/NFHWY00144	2016	B2A	74



⚠ TYPICAL SECTION
FDL REALIGNMENT
STA 3225+00 TO STA 3270+50

⚠ NOTES:

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4. TIE ACE FILL SHOULDERS INTO RIPRAP ON EMBANKMENT FACE ON BOTH SIDES OF 10-FOOT SPP AT DEBRIS LOBE CREEK.
5. W=8.5-FEET EXCEPT FOR TEST SECTIONS WHERE IT WILL BE EITHER 3.0-FEET, 5.0-FEET, OR 8.5-FEET. SEE ACE SHOULDER WIDTH AND ACE FILL CLASS TABLE.
6. PLACE AND COMPACT SELECTED MATERIAL, TYPE B, MODIFIED TO DRAIN AT 5% TO 10%. TO PREVENT SURFACE RUNOFF ON ORIGINAL GROUND FROM ENTERING THE ACE SHOULDER, MAINTAIN A 1' TO 2' LIFT-HEIGHT ON THE RIGHT.

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3229+50	3233+50	8.5	I OR II	8.5	I OR II
3233+50	3234+50	3.0	II	3.0	II
3234+50	3235+50	3.0	I	3.0	I
3235+50	3239+50	8.5	I OR II	8.5	I OR II
3239+50	3240+50	5.0	II	5.0	II
3240+50	3241+50	5.0	I	5.0	I
3241+50	3244+50	8.5	I OR II	8.5	I OR II
3244+50	3245+50	8.5	I	8.5	I
3245+50	3246+50	8.5	II	8.5	II
3246+50	3249+00	8.5	I OR II	8.5	I OR II
3249+30	3266+50	8.5	I OR II	8.5	I OR II
3266+50	3270+50	8.5	I OR II	0.0	N/A

TEST SECTION 3

TEST SECTION 4

TYPICAL SECTION FDL

STATE OF ALASKA 49TH Stephen J. McGroarty AEL-9491 REGISTERED PROFESSIONAL ENGINEER

PLANS DEVELOPED BY: STATE OF ALASKA DEPARTMENT OF TRANSPORTATION & PUBLIC FACILITIES, NORTHERN REGION, 2301 PEGER ROAD, FAIRBANKS, AK 99709 (907)451-2200
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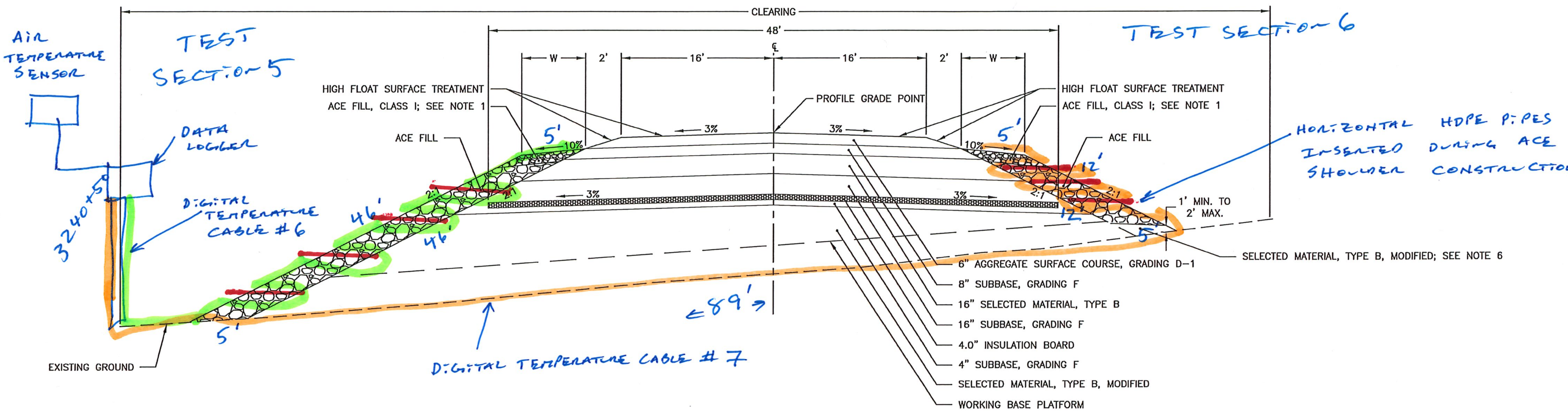
STA 3240+00

NO.	DATE	REVISION
⚠	12/28/17	CHANGE ORDER #14

STATE	PROJECT DESIGNATION	YEAR	SHEET NO.	TOTAL SHEETS
ALASKA	0655015/NFHWY00144	2016	B2A	74



⚠ TYPICAL SECTION

FDL REALIGNMENT

STA 3225+00 TO STA 3270+50

⚠ NOTES:

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3229+50	3233+50	8.5	I OR II	8.5	I OR II	
3233+50	3234+50	3.0	II	3.0	II	
3234+50	3235+50	3.0	I	3.0	I	
3235+50	3239+50	8.5	I OR II	8.5	I OR II	
3239+50	3240+50	5.0	II	5.0	II	TEST SECTION 6
3240+50	3241+50	5.0	I	5.0	I	TEST SECTION 5
3241+50	3244+50	8.5	I OR II	8.5	I OR II	
3244+50	3245+50	8.5	I	8.5	I	
3245+50	3246+50	8.5	II	8.5	II	
3246+50	3249+00	8.5	I OR II	8.5	I OR II	
3249+30	3266+50	8.5	I OR II	8.5	I OR II	
3266+50	3270+50	8.5	I OR II	0.0	N/A	

TYPICAL SECTION FDL

STATE OF ALASKA 49TH Stephen J. McGroarty AEL-9491 REGISTERED PROFESSIONAL ENGINEER

PLANS DEVELOPED BY: STATE OF ALASKA DEPARTMENT OF TRANSPORTATION & PUBLIC FACILITIES, NORTHERN REGION, 2301 PEGER ROAD, FAIRBANKS, AK 99709 (907)451-2200

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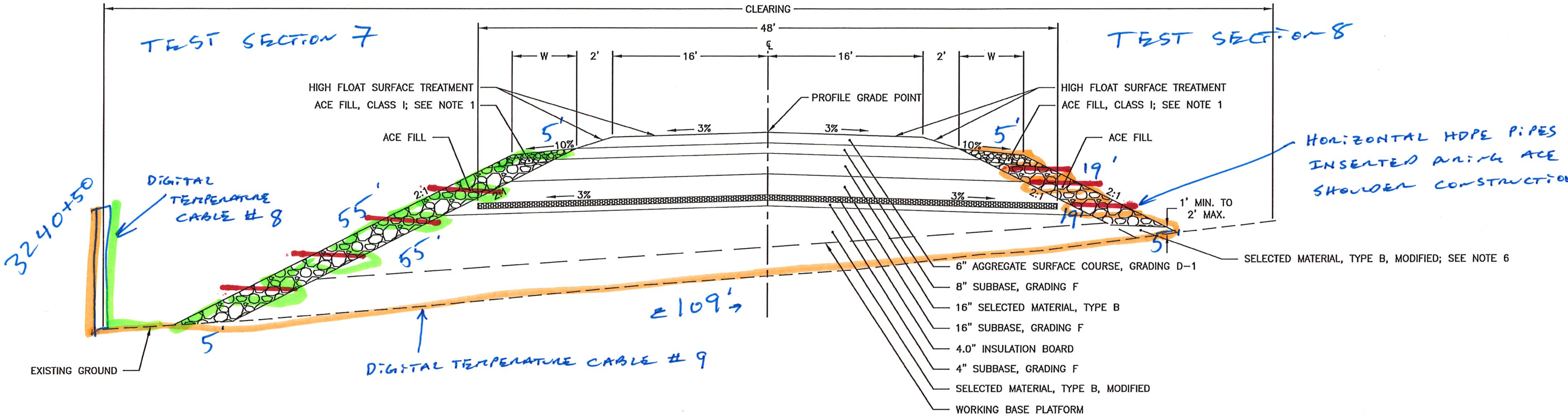
△	12/28/17	CHANGE ORDER #14

STATE	PROJECT DESIGNATION	YEAR	SHEET NO.	TOTAL SHEETS
ALASKA	0655015/NFHWY00144	2016	B2A	74

STA 3241+00



△ TYPICAL SECTION
FDL REALIGNMENT
STA 3225+00 TO STA 3270+50

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3241+50	3244+50	8.5	I OR II	8.5	I OR II
3244+50	3245+50	8.5	I	8.5	I
3245+50	3246+50	8.5	II	8.5	II
3246+50	3249+00	8.5	I OR II	8.5	I OR II
3249+30	3266+50	8.5	I OR II	8.5	I OR II
3266+50	3270+50	8.5	I OR II	0.0	N/A

TEST SECTION 7

TEST SECTION 8

TYPICAL SECTION FDL

STATE OF ALASKA 49TH Stephen J. McGroarty AEL-9491 REGISTERED PROFESSIONAL ENGINEER

PLANS DEVELOPED BY: STATE OF ALASKA DEPARTMENT OF TRANSPORTATION & PUBLIC FACILITIES, NORTHERN REGION, 2301 PEGER ROAD, FAIRBANKS, AK 99709 (907)451-2200
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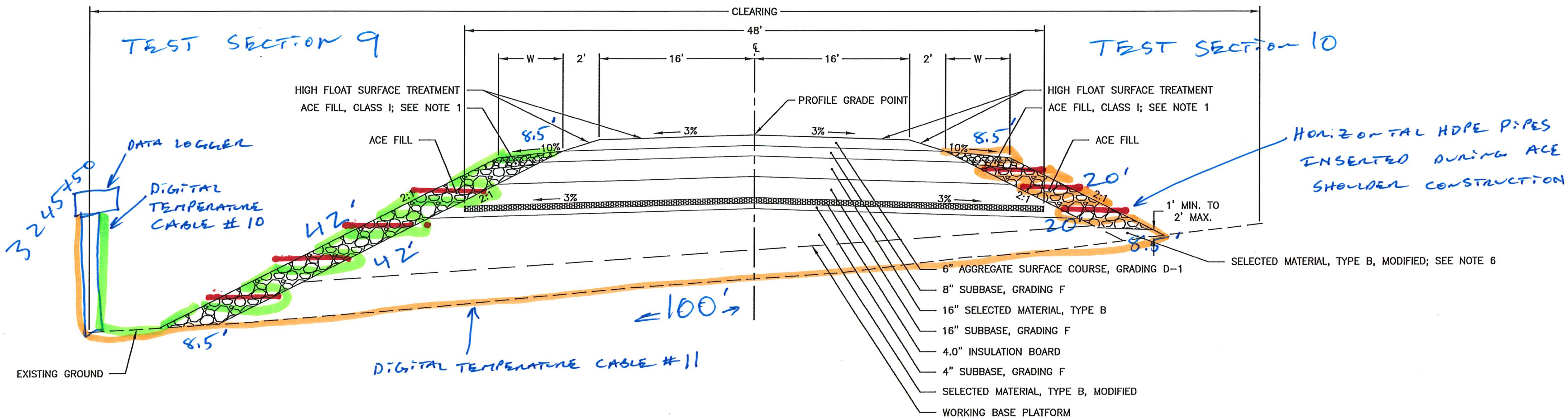
NO.	DATE	REVISION
△	12/28/17	CHANGE ORDER #14

STATE	PROJECT DESIGNATION	YEAR	SHEET NO.	TOTAL SHEETS
ALASKA	0655015/NFHWY00144	2016	B2A	74

STA 3245+00



△ TYPICAL SECTION
FDL REALIGNMENT
STA 3225+00 TO STA 3270+50

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3244+50	3245+50	8.5	I	8.5	I
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3246+50	3249+00	8.5	I OR II	8.5	I OR II
3249+30	3266+50	8.5	I OR II	8.5	I OR II
3266+50	3270+50	8.5	I OR II	0.0	N/A

TEST SECTION 9 (project left, 3244+50 to 3245+50)

TEST SECTION 10 (project right, 3244+50 to 3245+50)

STATE OF ALASKA 49TH Stephen J. McGroarty AEL-9491 REGISTERED PROFESSIONAL ENGINEER

TYPICAL SECTION FDL

PLANS DEVELOPED BY: STATE OF ALASKA DEPARTMENT OF TRANSPORTATION & PUBLIC FACILITIES, NORTHERN REGION, 2301 PEGER ROAD, FAIRBANKS, AK 99709 (907)451-2200
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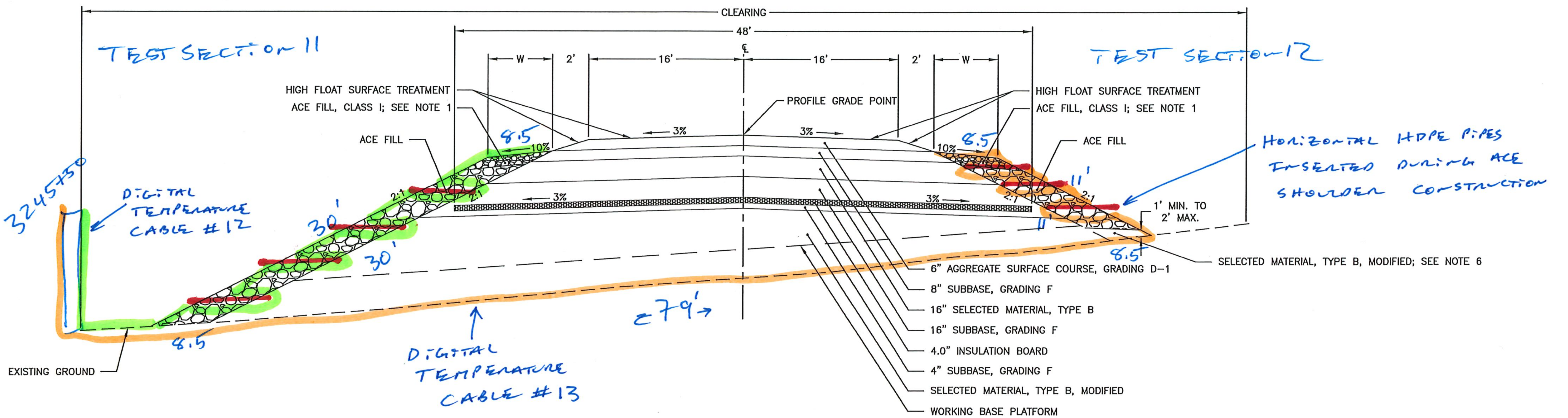
NO.	DATE	REVISION
△	12/28/17	CHANGE ORDER #14

STATE	PROJECT DESIGNATION	YEAR	SHEET NO.	TOTAL SHEETS
ALASKA	0655015/NFHWY00144	2016	B2A	74

STA 3246+00



△ TYPICAL SECTION
FDL REALIGNMENT
STA 3225+00 TO STA 3270+50

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3240+50	3241+50	5.0	I	5.0	I
3241+50	3244+50	8.5	I OR II	8.5	I OR II
3244+50	3245+50	8.5	I	8.5	I
3245+50	3246+50	8.5	II	8.5	II
3246+50	3249+00	8.5	I OR II	8.5	I OR II
3249+30	3266+50	8.5	I OR II	8.5	I OR II
3266+50	3270+50	8.5	I OR II	0.0	N/A

TEST SECTION 11

TEST SECTION 12

TYPICAL SECTION FDL

STATE OF ALASKA 49TH Stephen J. McGroarty AEL-9491 REGISTERED PROFESSIONAL ENGINEER

PLANS DEVELOPED BY: STATE OF ALASKA DEPARTMENT OF TRANSPORTATION & PUBLIC FACILITIES, NORTHERN REGION, 2301 PEGER ROAD, FAIRBANKS, AK 99709 (907)451-2200
H:\Projects\Dalton_Hwy\60919_Dalton_209_235\9 Drafting\60761,60761_B_Typ-B2a TYPICAL SECTION FDL Thu, Feb/15/18 12:14pm