Date: June 21, 2011

RE: City of Duluth Bid #11-4402
(VALE Program Bid Package)

Addendum No. 2

TO: Prospective Bidders

This Addendum forms a part of the Contract Documents and modifies the original Bidding Documents dated June 9, 2011. Acknowledge receipt of this Addendum in the space provided on the Bid Form. Failure to do so may subject the Bidder to disqualification.

Technical Specifications:

Volume No. 3 Specification: Modify Division 15 – Mechanical Section 15747 – GROUND HEAT EXCHANGER – Modify Sub-paragragh A.1 of Article 1.3 – SUBMITTAL to read:

1. Submittal shall utilize drilling logs and thermal conductivity test information provided from (2) on site test bores. Any other parameters that the contractor uses in determining the GHEX shall be noted.
   a. Refer to Appendix I – Boring Logs for Test VHE Installations 1 & 2.
   b. Refer to Appendix II – Formation Thermal Response Testing Results for Test VHE Installations 1 & 2.

Volume No. 3 Specification: Modify Division 15 – Mechanical Section 15747 – GROUND HEAT EXCHANGER – Add: Appendix II – Formation Thermal Response Testing Results for Test VHE Installations 1 & 2; attached to this addendum.

Drawings: *Replace drawings listed below with sheets included with this Addendum No. 1*

Sheet C003 – Construction Safety Phasing Plan: Revised Pipe Routing.
Sheet C211 – Fencing Layout Site Plan and Notes: Revised Fence Layout.
Sheet M-100 – Overall Geothermal Site Plan: Revised Geothermal Well Field Layout and GWS & GWR Pipe Routing.
Sheet M-101 – Geothermal Site Mechanical Partial Plan: Revised Geothermal Well Field Layout and GWS & GWR Pipe Routing.
Sheet M-102 – Geothermal Site Mechanical Partial Plan: Revised Geothermal Well Field Layout and GWS & GWR Piping Routing.
Sheet M-110 – Geothermal First Floor Mechanical Plan Part A: Revised GWS & GWR Pipe Routing.
Sheet M-114 – Geothermal Third Floor Mechanical Plan Part A: Revised GWS & GWR Pipe Routing.

Add new drawing listed below.

Sheet M-112 – Geothermal Second Floor Mechanical Plan Part A.

Other:

Log and location map for Geotechnical Boring No. 09-05 attached for reference.

END OF ADDENDUM NO. 2

APPENDIX II

Formation Thermal Response Testing Results

For

Test VHE Installations 1 & 2

Formation Thermal Response Testing Results

Duluth International Airport – New Terminal
Duluth, Minnesota

Prepared for

Kraus-Anderson Construction Company

Prepared by

Braun Intertec Geothermal, LLC

Professional Certification:
I hereby certify that this plan, specification or report was prepared by me or under my direct supervision and that I am a duly Licensed Professional Geologist under the laws of the State of Minnesota.

Gy S. Browne, PG

Gregory S. Browne, PG
Geological Services Manager
License Number: 30088

Print Name: Gregory S. Browne
Signature: [signature]
Date 6-20-11 License #30088

Project: GT-11-02378
June 20, 2011

Introduction

Ground coupled heat pump HVAC systems utilize the earth as a heat source and sink by combining geothermal heat pumps with a system of buried, fluid-filled, high density polyethylene pipes. This system of closed loops provides efficient transfer of heat between the geologic formations and the fluid flowing in the pipes.

For commercial and institutional applications, vertical bore is the ground heat exchanger configuration of choice. This is due to a combination of enhanced heat exchange efficiency in saturated formations at depths greater than 50 feet, and reduced site area required for installation.

The size and cost of a vertical bore ground heat exchanger (VHE) system is highly dependent on the formation thermal properties unique to each site. Accuracy in design requires certain site-specific parameters, most importantly formation thermal conductivity, borehole thermal resistance and undisturbed ground temperature measurements. Without the data gathered and calculations documented in this report, the VHE system is likely to be disproportioned, resulting either in unnecessary first costs if oversized, or in unreliable HVAC performance if undersized.

Braun Intertec Geothermal, LLC (Braun Intertec) Formation Thermal Response Testing provides a reliable method of determining ground thermal properties and borehole thermal resistance utilizing representative borehole heat exchangers installed at the site of the future VHE system. This report provides details of the drilling, installation, data gathering, and subsequent analysis of the formation thermal response testing.

Two (2) VHEs were installed during the period June 7 to June 10, 2011 by Sam's Well Drilling. A Braun Intertec technician performed thermal response testing for not less than 36 hours for the VHEs during the period June 13 to June 17, 2011. A map showing the site location and the location of the VHEs is attached as Figure 1. Boring logs showing the encountered geology and VHE schematics, and a copy of the Minnesota Department of Health (MDH) completion form is also attached. Grout samples were collected from each installation, Grout Sample #1 (Test VHE #2) and Grout Sample #2 (Test VHE #1). The results are reported later in this report and the laboratory reports are attached.

Drilling and installation of the VHEs was observed by a Minnesota Professional Geologist. Photographs showing the progress of the drilling and installation of the VHEs are attached.

Ground Temperature, Thermal Response Testing, and Data Collection Procedures

Based on research conducted by the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), the International Ground Source Heat Pump Association (IGSHPA) developed a standard for performing thermal conductivity tests for closed-loop geothermal ground heat exchangers.

Braun Intertec Thermal Response Testing procedures are based on the most stringent interpretation of the IGSHPA Closed-Loop/Geothermal Heat Pump Systems - Design and Installation Standards (2010). We further attempt to increase the practicality of the results by including a measurement of borehole thermal resistance as well as calculations for volumetric heat capacity. All of which improve design accuracy.

Thermal Response Testing is performed by injecting heat at a constant rate into a heat carrier fluid (water), circulating the fluid through the borehole heat exchanger, and measuring the rate of temperature change over the stated test duration. With our equipment, heating capacity and flow rate are adjustable to target a temperature development in the heat carrier fluid as similar as possible to that of the final heat pump system. Desired heating rate is 20 Watts per bore foot to target the median range of the IGSHPA Standard of 15 to 25 Watts. Desired flow rate is 3 GPM/12 Mbh to ensure turbulence and realistic fluid temperature differential. Fluid temperatures are measured and logged 60 times every hour, without significant interruption[1], to maximize data convergence and reliability. Collected data is then analyzed to determine thermal conductivity, thermal diffusivity, and borehole thermal resistance. Calculation procedures and results are documented later in this report.

Braun Intertec testing apparatus includes a hydronic heater, a data logger, electrical network with reliable generation, hydronic circuit, and measuring devices for the following six parameters:

- Voltage to heating elements (x2)
- Amperage to heating elements (x2)
- Incoming fluid temperature
- Outgoing fluid temperature
- Flow rate of heat conducting fluid
- Ambient air temperature within the apparatus cabinet

A total of 12.5 kW of onboard electrical generation capacity provides portable power for all equipment, enabling dependable operation at any location at system depths up to 500 feet. Braun Intertec developed and constructed this testing apparatus in 2007 to meet or exceed ASHRAE and IGSHPA standards in effect at that time.

[1] "Significant Interruption" is defined as any loss of data collection, flow, and/or heat input for any single duration of greater than 10 minutes.

For a complete list of pertinent standards, please refer to ASHRAE's 2007 HVAC Applications Handbook, page 32.12 and ASHRAE's Research Summary 1118-TRP "Methods for Determining Soil and Rock Formation Thermal Properties from Field Tests" as well as IGSHPA's 2010 Design and Installation Standards.

Undisturbed Ground Temperature Testing Procedure:

The IGSHPA Standard for undisturbed ground temperature measurement states that it can be obtained by either observing the temperature of the water as it returns from the U-bend to the test equipment at start up, or by direct measurement at various depths with a thermocouple probe.

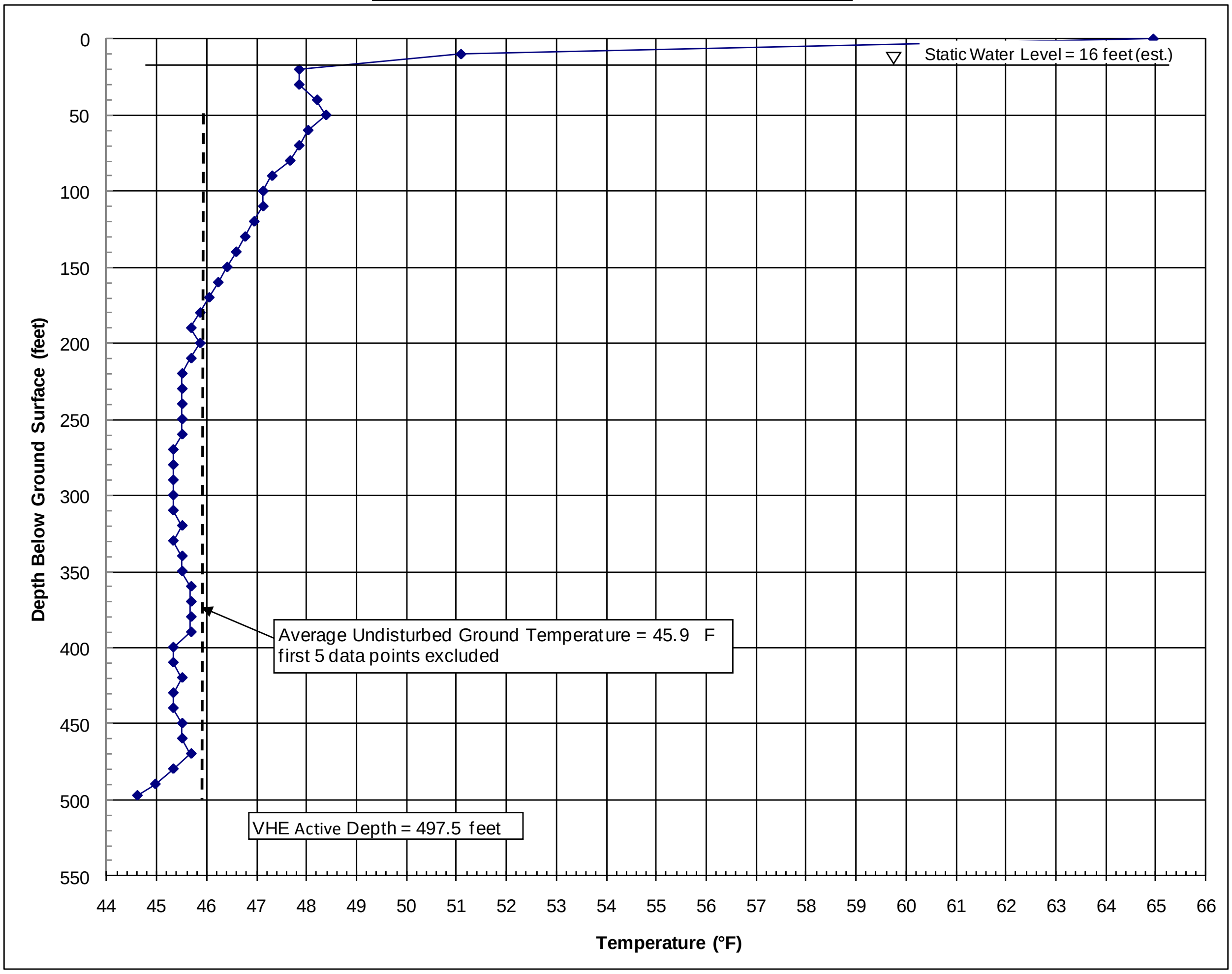
Braun Intertec chooses to measure by direct insertion of a thermocouple probe into the water filled U-bend. This measurement was performed at 10-foot intervals from ground surface to the bottom of the U-bend pipe, after allowing sufficient time (3 days minimum after installation) for the grout emplaced in the bore and the water temperature in the pipe to equalize with the surrounding formations, and before connection to the thermal response testing equipment. The temperature measurements were then averaged to obtain the undisturbed ground temperature of the VHEs.

Table 1 presents the undisturbed ground temperature measurements obtained for Test VHE #1, and shows which data were excluded for calculation of average undisturbed ground temperature. The first five temperature measurements were excluded from the calculation of average undisturbed ground temperature due to seasonal influence. Temperature sensor error prevented the collection of temperature measurements from Test VHE #2. Temperature variability in the gabbro bedrock should be minimal, so the undisturbed ground temperature measured in test VHE #1 was used also for calculations with regard to Test VHE #2. The temperature profile for Test VHE #1 is presented in Figure 2, and is also shown on the attached boring log.

Table 1: Undisturbed Ground Temperature Measurements – Test VHE #1

Depth Below Ground Surface (ft)	Temperature		Temperature
	°C	°F	°F
0	18.3	64.9	Excluded
10	10.6	51.1	Excluded
20	8.8	47.8	Excluded
30	8.8	47.8	Excluded
40	9.0	48.2	Excluded
50	9.1	48.4	48.4
60	8.9	48.0	48.0
70	8.8	47.8	47.8
80	8.7	47.7	47.7
90	8.5	47.3	47.3
100	8.4	47.1	47.1
110	8.4	47.1	47.1
120	8.3	46.9	46.9
130	8.2	46.8	46.8
140	8.1	46.6	46.6
150	8.0	46.4	46.4
160	7.9	46.2	46.2
170	7.8	46.0	46.0
180	7.7	45.9	45.9
190	7.6	45.7	45.7
200	7.7	45.9	45.9
210	7.6	45.7	45.7
220	7.5	45.5	45.5
230	7.5	45.5	45.5
240	7.5	45.5	45.5
250	7.5	45.5	45.5
260	7.5	45.5	45.5
270	7.4	45.3	45.3
280	7.4	45.3	45.3
290	7.4	45.3	45.3
300	7.4	45.3	45.3
310	7.4	45.3	45.3
320	7.5	45.5	45.5
330	7.4	45.3	45.3
340	7.5	45.5	45.5
350	7.5	45.5	45.5
360	7.6	45.7	45.7
370	7.6	45.7	45.7
380	7.6	45.7	45.7
390	7.6	45.7	45.7
400	7.4	45.3	45.3
410	7.4	45.3	45.3
420	7.5	45.5	45.5
430	7.4	45.3	45.3
440	7.4	45.3	45.3
450	7.5	45.5	45.5
460	7.5	45.5	45.5
470	7.6	45.7	45.7
480	7.4	45.3	45.3
490	7.2	45.0	45.0
497.5	7.0	44.6	44.6
Average	8.1	46.5	45.9

Figure 2: Temperature Profile – Test VHE #1



Control of Testing Conditions:

The importance of accurate Linear Slope calculation: Accurate measurement of temperature rate-of-change, or Linear Slope, is dependent on carefully controlled testing conditions. Flow rate, heat input, and ambient air temperature within the testing cabinet all must be maintained within close tolerances to obtain an accurate Slope for use in calculating a dependable thermal conductivity value. Braun Intertec measures its effectiveness of testing condition control by averaging the incoming and outgoing fluid temperatures $(T_{in} + T_{out})/2$, and plotting the results against a trend line of the full data set. The IGSHPA 2010 Standard states a maximum deviation of +/- 0.5 °F when comparing to the trend line of the full data set.

Method and data exclusion: Braun Intertec uses the Line Source method of data analysis (Gehlin, 1998; Mogensen, 1983; Witte, et al. 2002) as prescribed by the 2007 ASHRAE Applications Handbook. This method assumes an infinitely thin line source of heat in a continuous medium.

To allow the effect of the finite dimensions of the pipes and grouting material to become insignificant, a number of initial hours of data collected must be omitted from the thermal conductivity calculation. However, neither the IGSHPA Standard nor the ASHRAE research it is based upon, specify this value.

We utilize a calculation (see Equation 1 below) developed by Spitler, et al.[2], to establish the proper point at which the average of the incoming and outgoing fluid temperatures begin to fit the linear slope trend line for the remainder of the test. At this hour, it is assumed that the borehole heat exchanger becomes essentially saturated and the heat within the fluid begins to transfer to the formation in a constant manner. Test VHEs #1 and #2 both became saturated at 10 hours.

$$t \geq 5 r_b^2 / a_{ground} \qquad \text{Equation 1}$$

Where,

- t Time of borehole heat saturation *hr*
- r_b Nominal borehole radius *ft*
- a_{ground} Formation thermal diffusivity ft^2/hr

[2] For additional information on this procedure, please refer to *In Situ Measurement of Ground Thermal Conductivity: A Dutch Perspective*, ASHRAE Transactions 4521 (2002).

Thermal Response Testing Control Quality:

Figures 3 through 6 present the testing control effectiveness by presenting the average fluid temperature, trend line of the full data set, and the Control Parameters described above, and the resultant linear slope utilized in the calculation of formation thermal conductivity, thermal diffusivity and borehole thermal resistance, for the tests.

Formation Thermal Response:

To model actual operating system performance, and per ASHRAE recommendations, the fluid flow rate during testing should be sufficient to maintain a temperature differential of 6 to 12 °F, as this is the common operating range for heat pump systems. Figures 7 through 10 present the fluid temperature into and out of the ground heat exchangers and the resultant delta T for the tests.

Heat Rate and Power Consistency:

ASHRAE/IGSHPA recommend a heat development of 15 – 25 W (51 – 85 Btu/hr) per foot of borehole heat exchanger. Furthermore, ASHRAE/IGSHPA recommends a peak power deviation of ≤10%, and a standard deviation ≤1.5%. Braun Intertec experience has shown that power interruptions have a profound effect on the reliability of the test results and carefully control testing procedures to prevent this occurrence. Figures 11 through 14 present the heat rate and consistency of power applied for the tests.

Figure 3: Control Quality of Testing Conditions (0 to 36 hours) – Test VHE #1

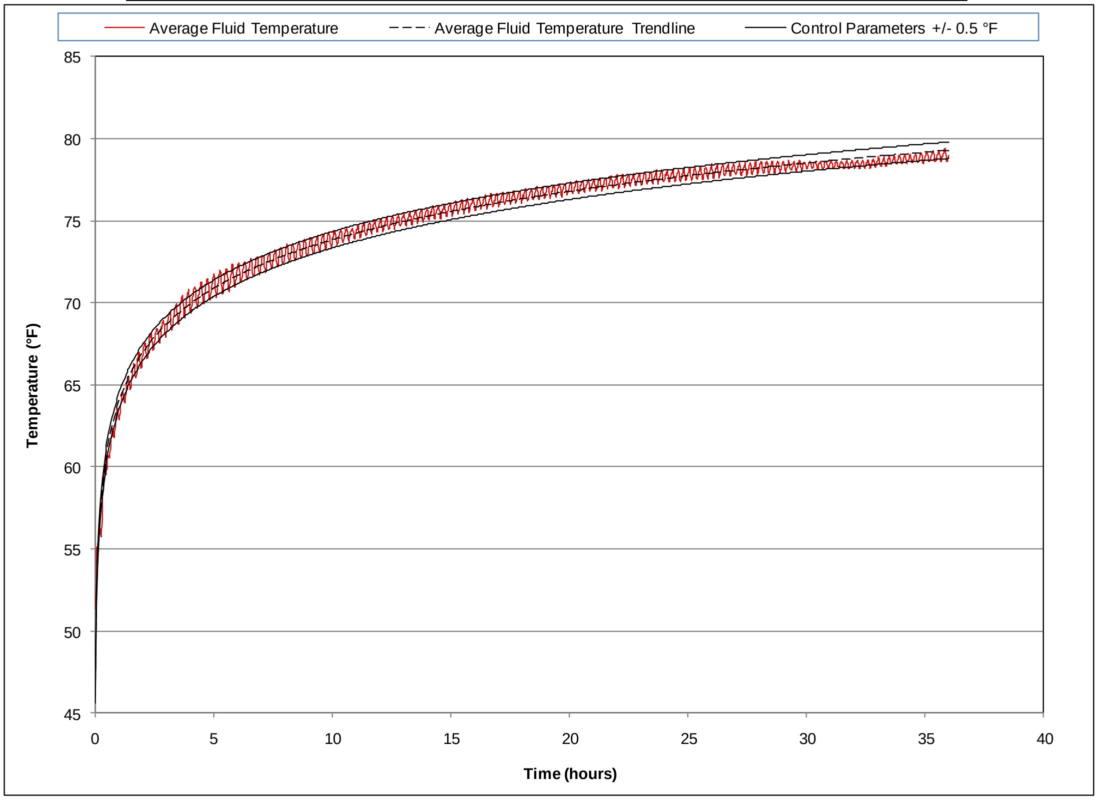


Figure 4: Temperature vs. Linear Time (10 to 36 hours) – Test VHE #1

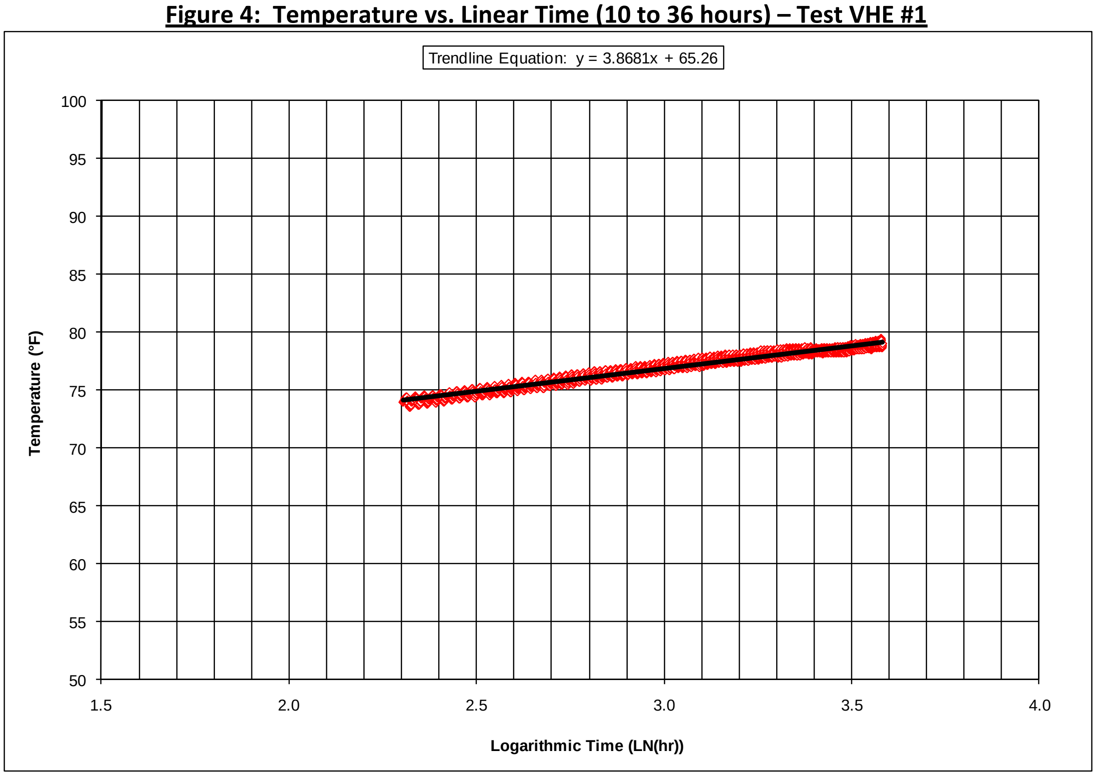


Figure 5: Control Quality of Testing Conditions (0 to 36 hours) – Test VHE #2

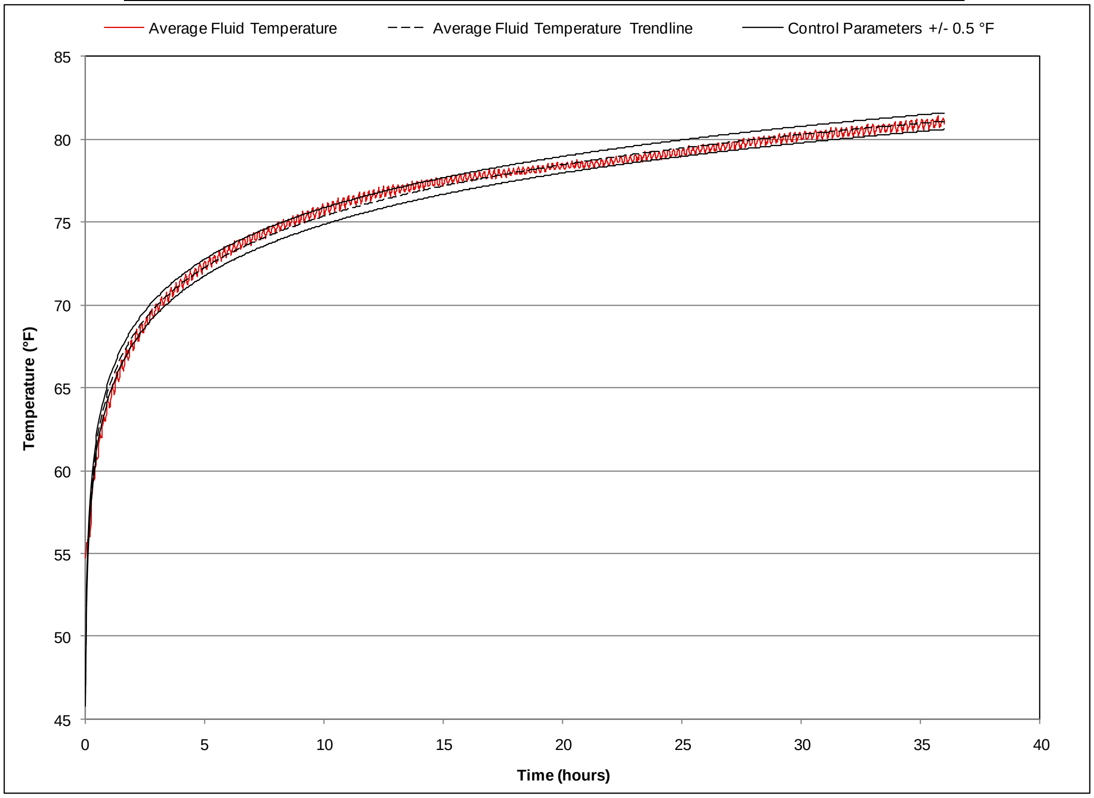


Figure 6: Temperature vs. Linear Time (10 to 36 hours) – Test VHE #2

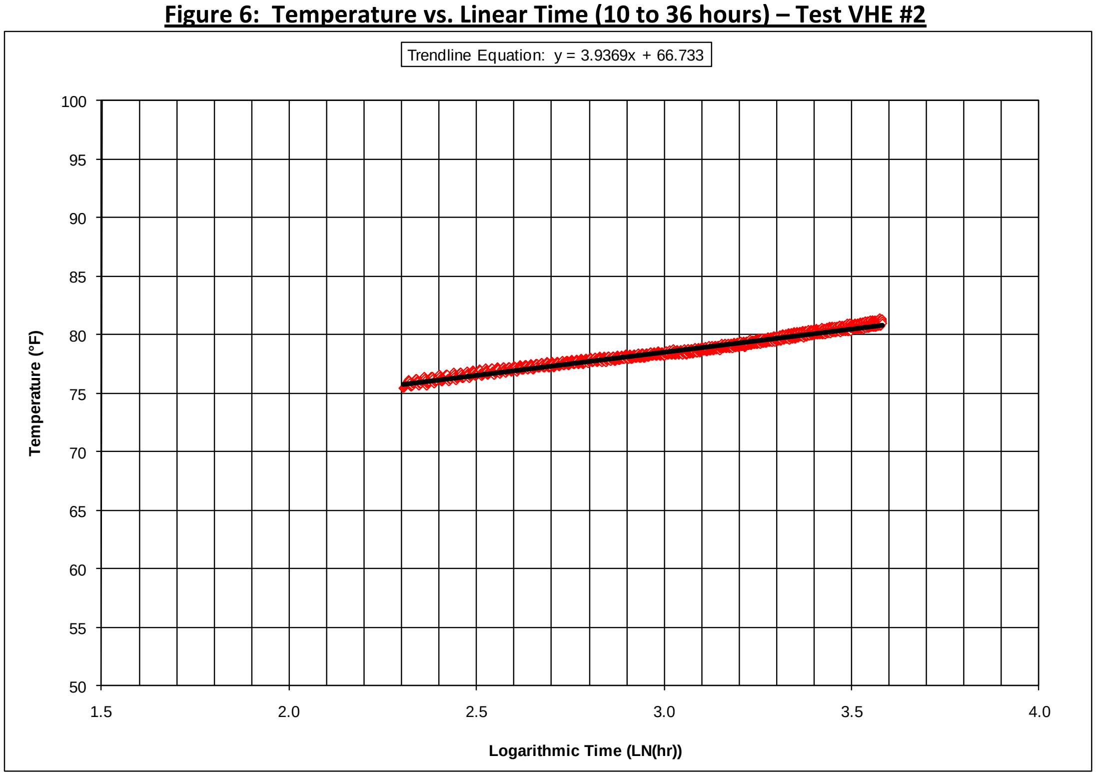


Figure 7: Temperature vs. Time (0 to 36 hours) – Test VHE #1

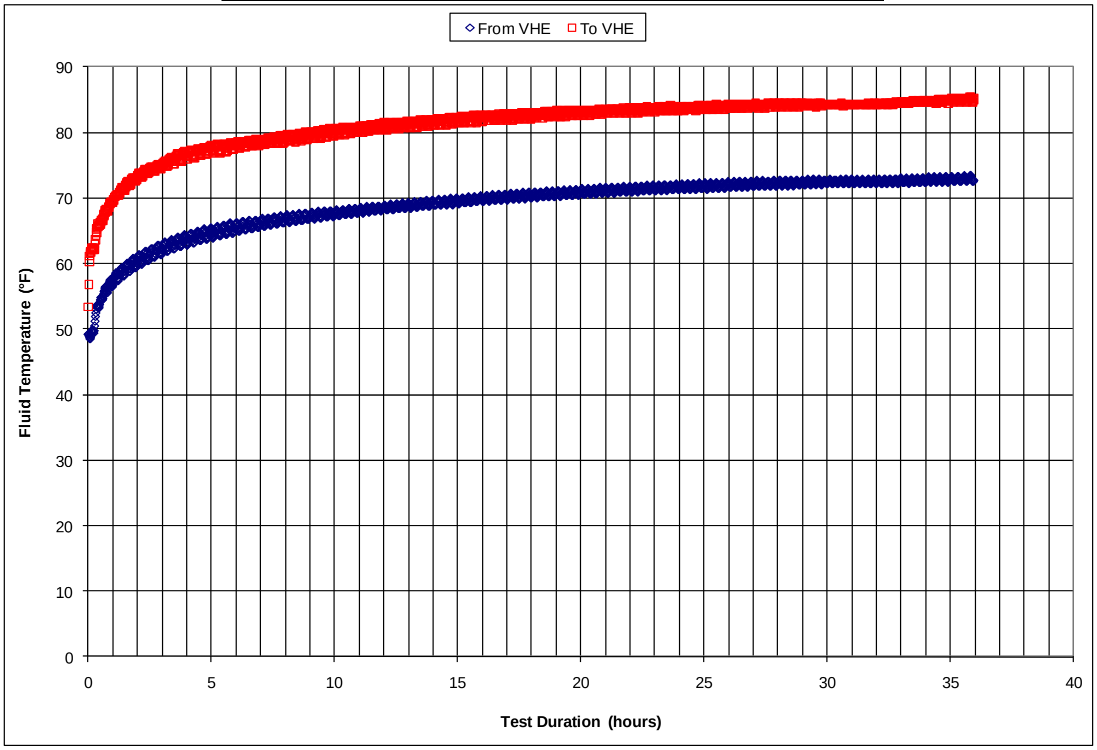


Figure 8: Fluid Delta T vs. Time (10 to 36 hours) – Test VHE #1

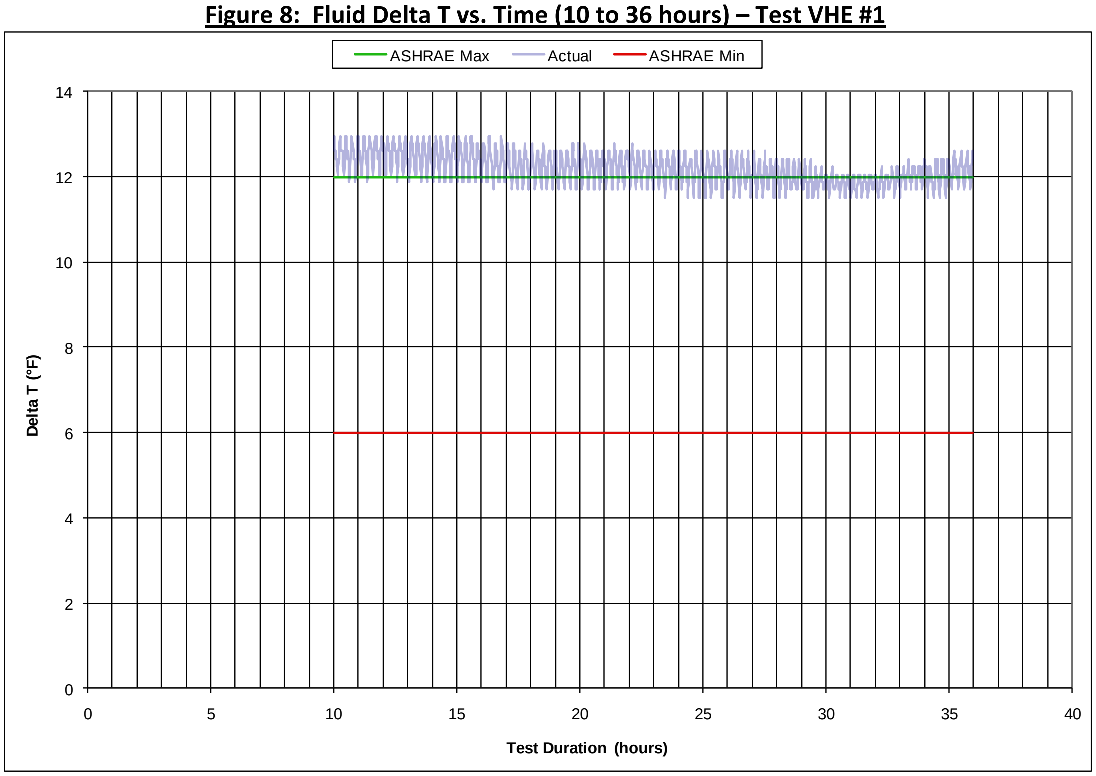


Figure 9: Temperature vs. Time (0 to 36 hours) – Test VHE #2

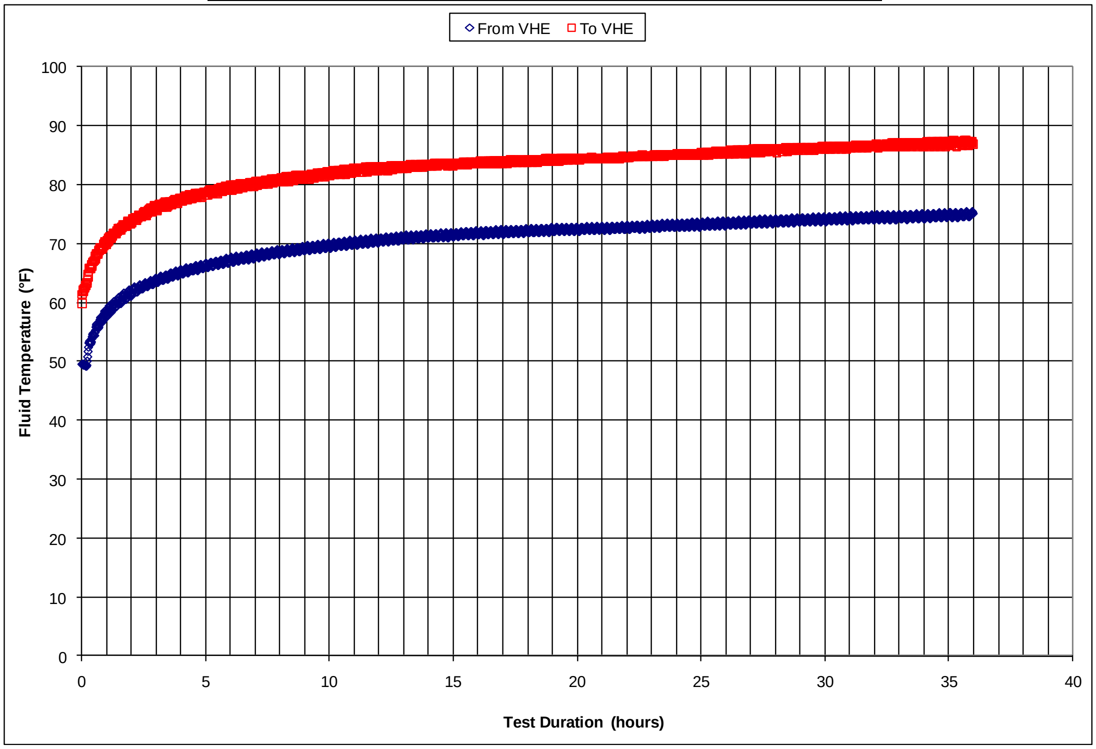


Figure 10: Fluid Delta T vs. Time (10 to 36 hours) – Test VHE #2

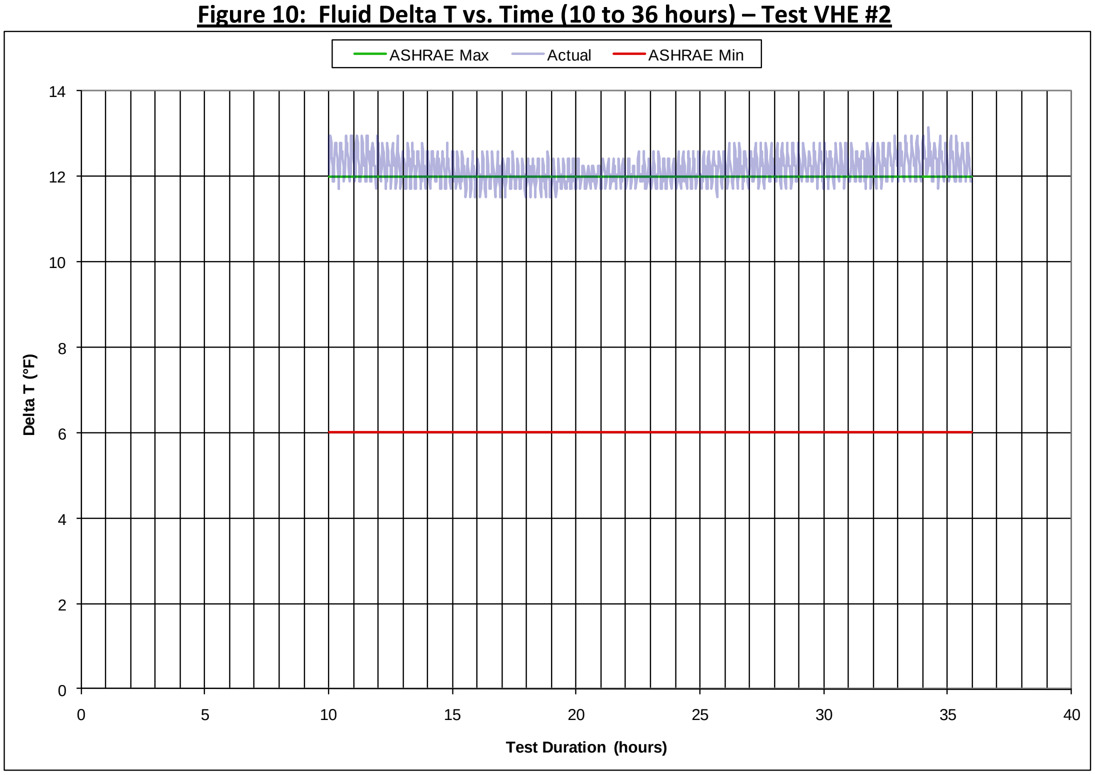


Figure 11: Heat Rate (10 to 36 hours) – Test VHE #1

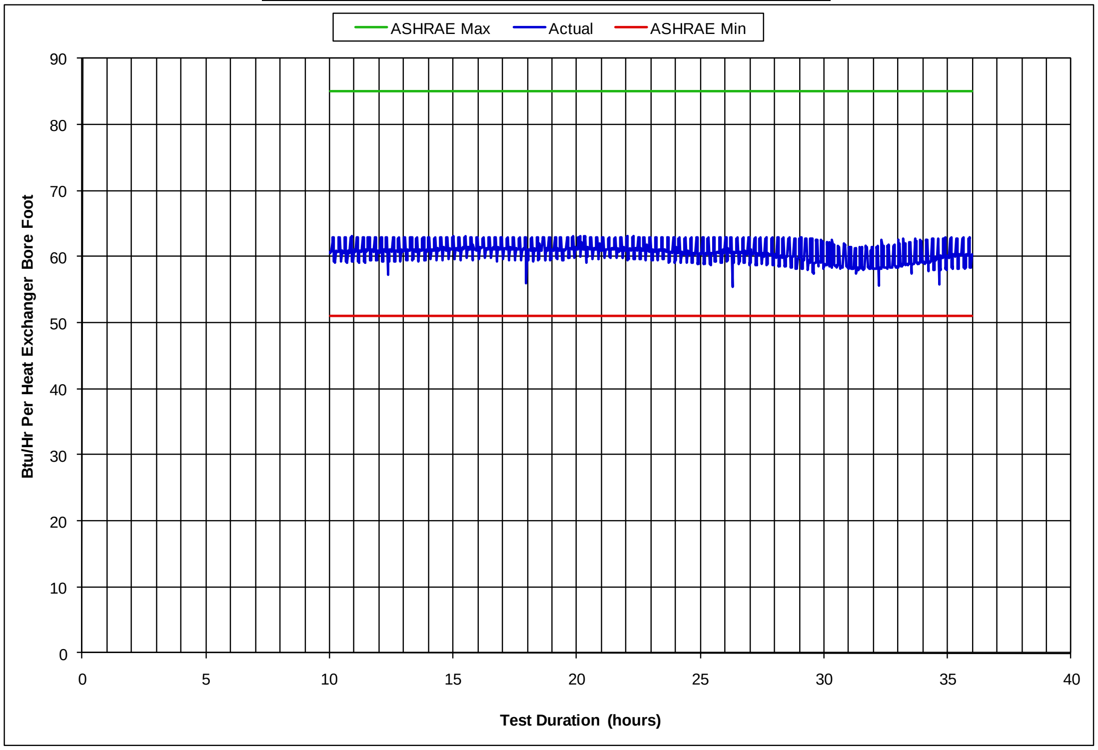


Figure 12: Power Consistency (10 to 36 hours) – Test VHE #1

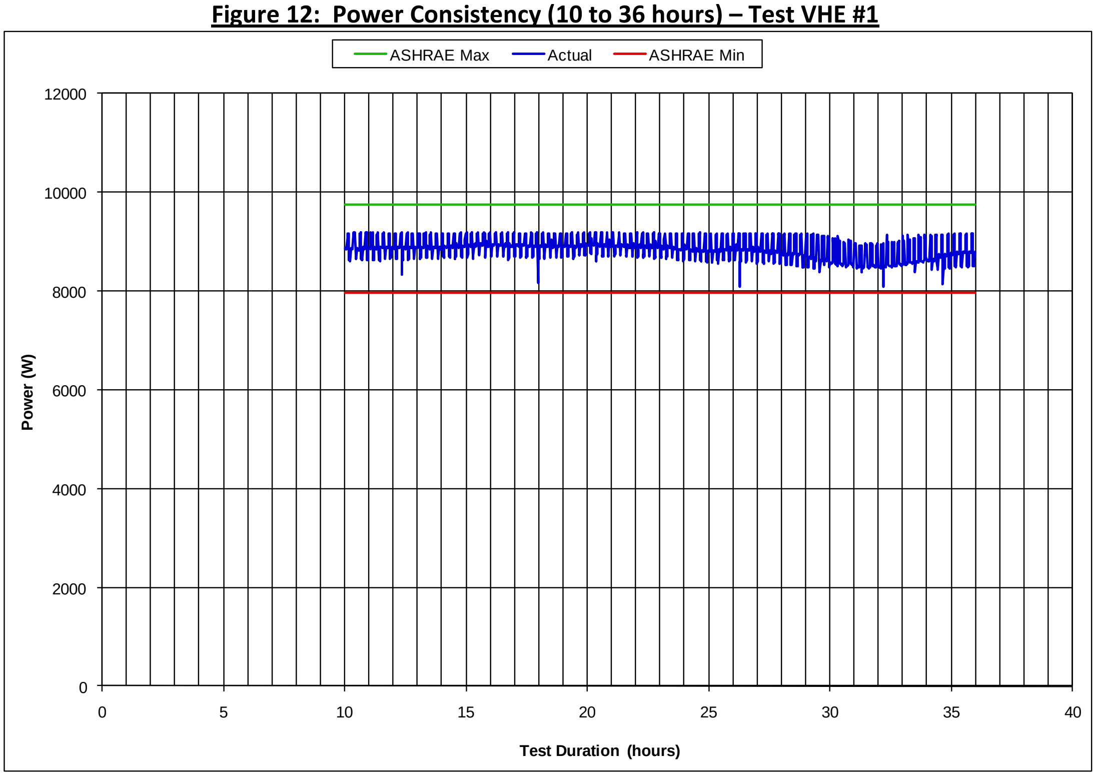


Figure 13: Heat Rate (10 to 36 hours) – Test VHE #2

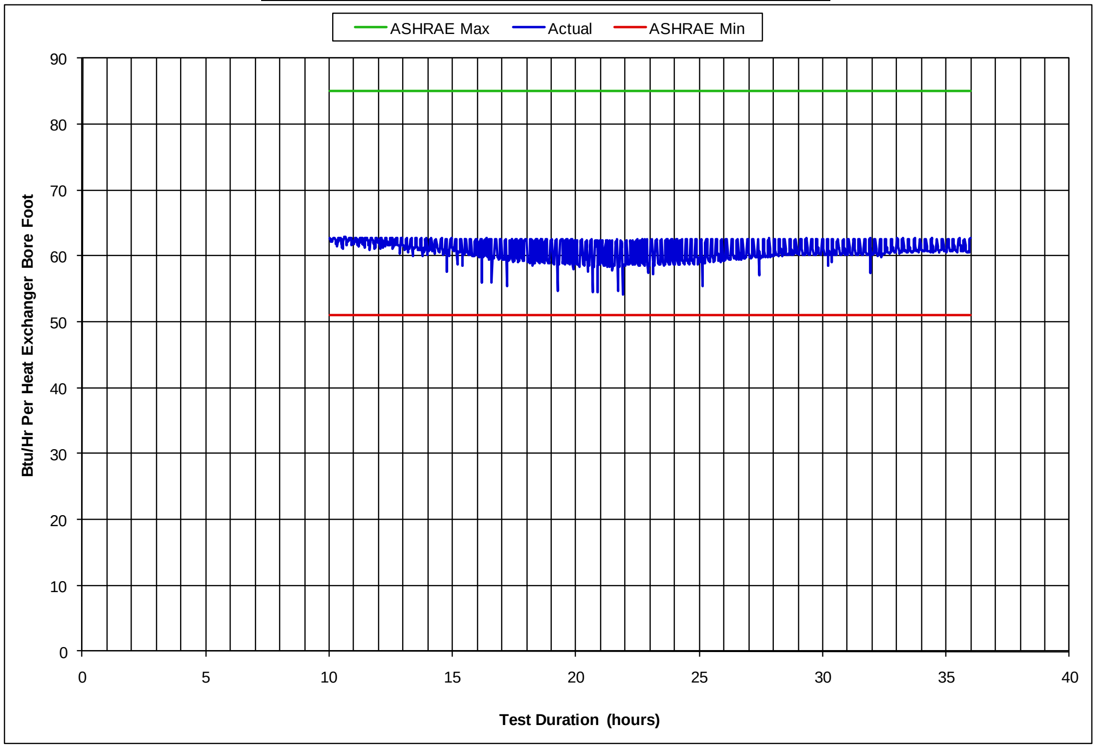
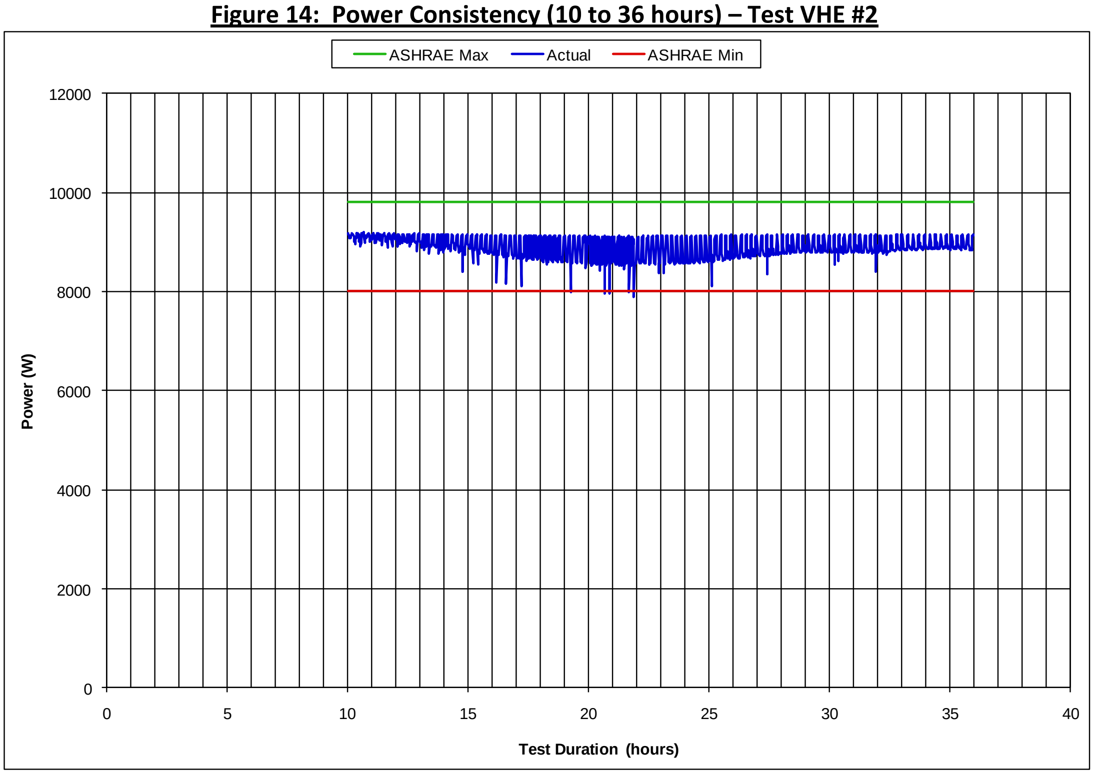


Figure 14: Power Consistency (10 to 36 hours) – Test VHE #2



Vertical Heat Exchanger Drilling, Installation and Testing Details

Test VHE #1:

Drilling results

- Drilling contractor: Sam's Well Drilling (under Enviro-Tec, Inc.)
- MN State License No.: 2130
- Drilling start date: June 9, 2011
- Drilling end date: June 10, 2011
- Depth drilled: 500 ft
- Productivity (time to drill to stated depth): 13 hrs
- Drilling technique utilized: mud rotary / air percussion hammer
- Temporary casing installation: 6 in., 0-40 ft (see comments)
- Bore diameter: 8 ¾ in. 0-40 ft; 6 in. 48-500 ft
- Bore diameter (weighted average): 6.2 in.
- Static water level: 16 ft Estimated
- Geology: See attached boring log

Vertical heat exchanger installation

- Installation date: June 10, 2011
- Active depth of installation: 497.5 ft
- Pipe type: HDPE
- Field pressure testing specification: Passed
- Pipe diameter / SDR: 1.25 in. / 9
- Grout thermal conductivity: 0.95 Btu/(hr-ft-°F), see attached lab report
- Portland cement amount used: 7,050 lbs
- Silica sand amount used: 7,050 lbs, Unimin 4030
- Installation record filed with: MDH
- Record identification number: VL-3086 (copy attached)

Testing results

- Testing dates: June 16 – June 17, 2011
- Test duration: 36 *hrs*
- Ground temperature equilibration period: 6 *days*
- Average undisturbed ground temperature: 49.5 *°F*
- Average delta T: 12.2 *°F*
- Average flow rate: 5.0 *gpm*
- Estimated volumetric heat capacity: 34.1 ft^3-*°F*
- Tested formation thermal conductivity: 1.25 *Btu/(hr-ft-°F)*
- Calculated formation thermal diffusivity: 0.88 ft^2*/day*
- Tested borehole thermal resistance: 0.304 *(hr-ft-°F)/Btu*

Drilling and VHE installation comments:
The U-bend loop began floating out of the borehole after installation and grouting on June 10, 2011. The temporary casing could not be removed since the U-bend loop would also have been lifted out of the borehole. Since the Portland-cement based grout was curing by the end of day, the temporary casing could not be removed so it was left in place.

Test VHE #2:

Drilling results

• Drilling contractor:	Sam's Well Drilling (under Enviro-Tec, Inc.)
• MN State License No.:	2130
• Drilling start date:	June 7, 2011
• Drilling end date:	June 8, 2011
• Depth drilled:	500 ft
• Productivity (time to drill to stated depth):	13 hrs
• Drilling technique utilized:	mud rotary / air percussion hammer
• Temporary casing installation:	6 in., 0-48 ft
• Bore diameter:	8 ¾ in. 0-48 ft; 6 in. 48-500 ft
• Bore diameter (weighted average):	6.3 in.
• Static water level:	16 ft Estimated
• Geology:	See attached boring log

Vertical heat exchanger installation

• Installation date:	June 9, 2011
• Active depth of installation:	498.5 ft
• Pipe type:	HDPE
• Field pressure testing specification:	Passed
• Pipe diameter / SDR:	1.25 in. / 9
• Grout thermal conductivity:	0.95 Btu/(hr-ft-°F), see attached lab report
• Portland cement amount used:	5,640 lbs
• Silica sand amount used:	5,640 lbs, Unimin 4030
• Installation record filed with:	MDH
• Record identification number:	VL-3086 (copy attached)

Testing results

• Testing dates:	June 13 – June 15, 2011	
• Test duration:	36	*hrs*
• Ground temperature equilibration period:	4	*days*
• Average undisturbed ground temperature:	45.9	*°F*
• Average delta T:	12.2	*°F*
• Average flow rate:	5.0	*gpm*
• Estimated volumetric heat capacity:	34.1	ft^3-°F
• Tested formation thermal conductivity:	1.23	*Btu/(hr-ft-°F)*
• Calculated formation thermal diffusivity:	0.87	ft^2/day
• Tested borehole thermal resistance:	0.330	*(hr-ft-°F)/Btu*

Formation Thermal Property Calculations

Formation Thermal Conductivity:

Formation thermal conductivity can not be measured directly but must be inferred from the measurements recorded during thermal response testing. In order to do so, and in accordance with ASHRAE/IGSHPA guidelines, a heat transfer model must be adopted, such as the line source method utilized in this analysis. This method is based on Fourier's Law of Heat Conduction. The basis of in situ thermal conductivity testing is to impose a pulse of known and fixed energy flux into the fluid contained in the VHE and to measure the resulting temperature response. The relationship between energy flux and temperature establishes the inferred thermal conductivity of a material (Spitler, et al., 2002).

In order to determine the effective thermal conductivity, the average of the incoming and outgoing fluid temperatures $(T_{in} + T_{out})/2$, was plotted against the logarithm of time after data omission (see Page 6 and Figures 4 and 6).

To solve for thermal conductivity, λ_{ground}, the value of the slope of the lines for each test were inserted, along with the average heat injected, P, and the active borehole length, H, into Equation 2:

$$\lambda_{ground} = \frac{3.413 * P}{4\pi H * Slope} \qquad \text{Equation 2}$$

Where,

- λ_{ground} Formation thermal conductivity *Btu/(hr-ft-°F)*
- P Average power injected *W*
- H Active depth of the borehole heat exchanger *ft*

Test VHE #1 – Thermal conductivity calculation

Where,

- P = 8865.0 *W*
- H = 497.5 *ft*
- $Slope$ = 3.868

$$\lambda_{ground} = \frac{3.413 * 8865.0}{4 * 3.1415 * 497.5 * 3.868} = \frac{30256.3}{24181.1} = 1.25 \text{ Btu/(hr - ft - °F)}$$

Average heat per ft of active bore: 17.8 W
Peak power deviation: 91.2% - 103.7%
Standard deviation: 2.5%

Test VHE #2 – Thermal conductivity calculation

Where,

- P = 8912.4 *W*
- H = 498.5 *ft*
- $Slope$ = 3.937

$$\lambda_{ground} = \frac{3.413 * 8912.4}{4 * 3.1415 * 498.5 * 3.937} = \frac{30418.0}{24662.0} = 1.23 \, \text{Btu/(hr - ft - °F)}$$

Average heat per ft of active bore: 17.9 W
Peak power deviation: 88.6% - 103.2%
Standard deviation: 2.4%

Formation Volumetric Heat Capacity and Thermal Diffusivity Estimation Procedure:

While neither ASHRAE nor IGSHPA specify the manner in which thermal diffusivity shall be calculated, simply dividing calculated formation thermal conductivity by the estimated volumetric heat capacity of the formation provides this value according to the following equation:

$$a_{ground} = \frac{\lambda_{ground}}{c_{ground}} x24 \qquad \text{Equation 3}$$

Where,

- a_{ground} = Thermal diffusivity *ft²/day*
- c_{ground} = Volumetric heat capacity *Btu/(ft³-°F)*

Volumetric heat capacity is difficult to measure directly, but can be effectively estimated by averaging the soil/rock fractions encountered, along with an estimation of the percentage of groundwater present within the formations. Using published soils data, specific heat and density values are assigned to the soil/rock fractions as follows.

Table 2: Estimated Physical Properties of Encountered Formations – Test VHE #1

Formation Log	Depth From (ft)	Depth To (ft)	Total Porosity (%)	Equivalent water (ft)	Specific Heat (Btu/lb-°F)	Density (lb/ft³)
Silty sand with gravel, dry	0	15	42	0.0	0.19	103
Gravel, saturated	15	40	33	8.3	0.19	126
Gabbro, moist	40	497.5	3	13.7	0.18	187

Dividing the estimated water content in the formations surrounding the borehole (22.0 feet) by the total depth yields a percentage of groundwater present within the formations of approximately 4%. Using the estimated water content and the specific heat and density values assigned to water and to the formations encountered results in a nominal volumetric heat capacity calculated to be 34.1 Btu/(ft^3-°F).

Thermal diffusivity for Test VHE #1 is then calculated as follows:

$$\frac{1.25}{34.1} x24 = 0.88 \text{ ft}^2/\text{day}$$

Table 3: Estimated Physical Properties of Encountered Formations – Test VHE #2

Formation Log	Depth From (ft)	Depth To (ft)	Total Porosity (%)	Equivalent water (ft)	Specific Heat (Btu/lb-°F)	Density (lb/ft^3)
Silty sand with gravel, dry	0	16	42	0.0	0.19	103
Silty sand with gravel, saturated	16	38	42	9.2	0.19	126
Gravel, saturated	38	48	33	3.3	0.19	126
Gabbro, moist	48	498.5	3	13.5	0.18	187

Dividing the estimated water content in the formations surrounding the borehole (26.0 feet) by the total depth yields a percentage of groundwater present within the formations of approximately 5%. Using the estimated water content and the specific heat and density values assigned to water and to the formations encountered results in a nominal volumetric heat capacity calculated to be 34.1 Btu/(ft^3-°F).

Thermal diffusivity for Test VHE #2 is then calculated as follows:

$$\frac{1.23}{34.1} x24 = 0.87 \text{ ft}^2/\text{day}$$

Borehole Thermal Resistance Calculation Procedure:

Borehole thermal resistance (R_b) is the total resistance to heat transfer between the fluid in the pipe and the formation surrounding the borehole heat exchanger. This takes into account pipe resistance, fluid convective resistance, grout resistance, and spacing of the pipe in relation to the bore wall. Due to the inconsistency in pipe spacing, borehole thermal resistance is difficult to calculate directly without test data. This measurement is very important as it has a proportional effect on the size of the ground heat exchanger system.

Braun Intertec addresses this problem by installing representative borehole heat exchangers and applying the temperature response data, bore depth, injected heat power rate, formation thermal conductivity, formation thermal diffusivity, radius of the borehole heat exchanger, and the undisturbed ground temperature to a formula established by Gehlin (2002, Page 137) to solve for borehole thermal resistance.

Based on the line-source approximation as used by Mogensen (1983), Eskilson (1987) and Hellstrom (1991), and further simplified by Gehlin (2002), the thermal resistance, R_b , between the fluid and the borehole wall can be reliably modeled using the following formula:

$$T(t) = T_{ug} + \frac{Q}{4\pi\lambda_{ground}H} * \left[E1\left(\frac{r_b^{\ 2}}{4a_{ground}t} \right) \right] + \frac{Q}{H} R_b \qquad \text{Equation 4}$$

Where,

- $T(t)$ Temperature dependent on time t — *°F*
- T_{ug} Undisturbed ground temperature — *°F*
- Q Average heat injected — *Btu/hr*
- λ_{ground} Formation thermal conductivity — *Btu/(hr-ft-°F)*
- H Active depth of the borehole heat exchanger — *ft*
- a_{ground} Formation thermal diffusivity — *ft²/hr*
- r_b Nominal borehole radius — *ft*
- R_b Borehole thermal resistance — (h*r-ft-°F)/Btu*
- $E1(x) = \int_x^{\infty} \frac{e^{-u}}{u} du$

A serial development may be used as an approximation of the exponential integral, $E1$, for small values of x, the normal case for thermal response tests on ground heat exchangers. The following approximation of the exponential integral is used (Gehlin, 2002 from Abramowitz and Stegun, 1964):

$E1 \approx -\gamma - \ln x + A * x - B * x^2 + D * x^3 - E * x^4 + F * x^5$

Where,

A = 0.99999193
B = 0.24991055
D = 0.05519968
E = 0.00976004
F = 0.00107857
γ = Euler's constant = 0.5772….

For a given time (t), a solution for borehole thermal resistance can be obtained by assuming it to be constant over time.

T (t) is established by determining the hour in which the average temperature begins to fit the linear slope line for the remainder of the test (see Page 6 for further information), with all data prior to that point omitted from the analysis. The calculations are then averaged for every (t) after data omission to obtain R_b.

For additional information on this procedure, please refer to Signhild Gehlin's Doctoral Thesis, Division of Water Resources Engineering, Department of Environmental Engineering, Lulea University of Technology (2002).

<u>Borehole thermal resistance calculations – Test VHE #1</u>

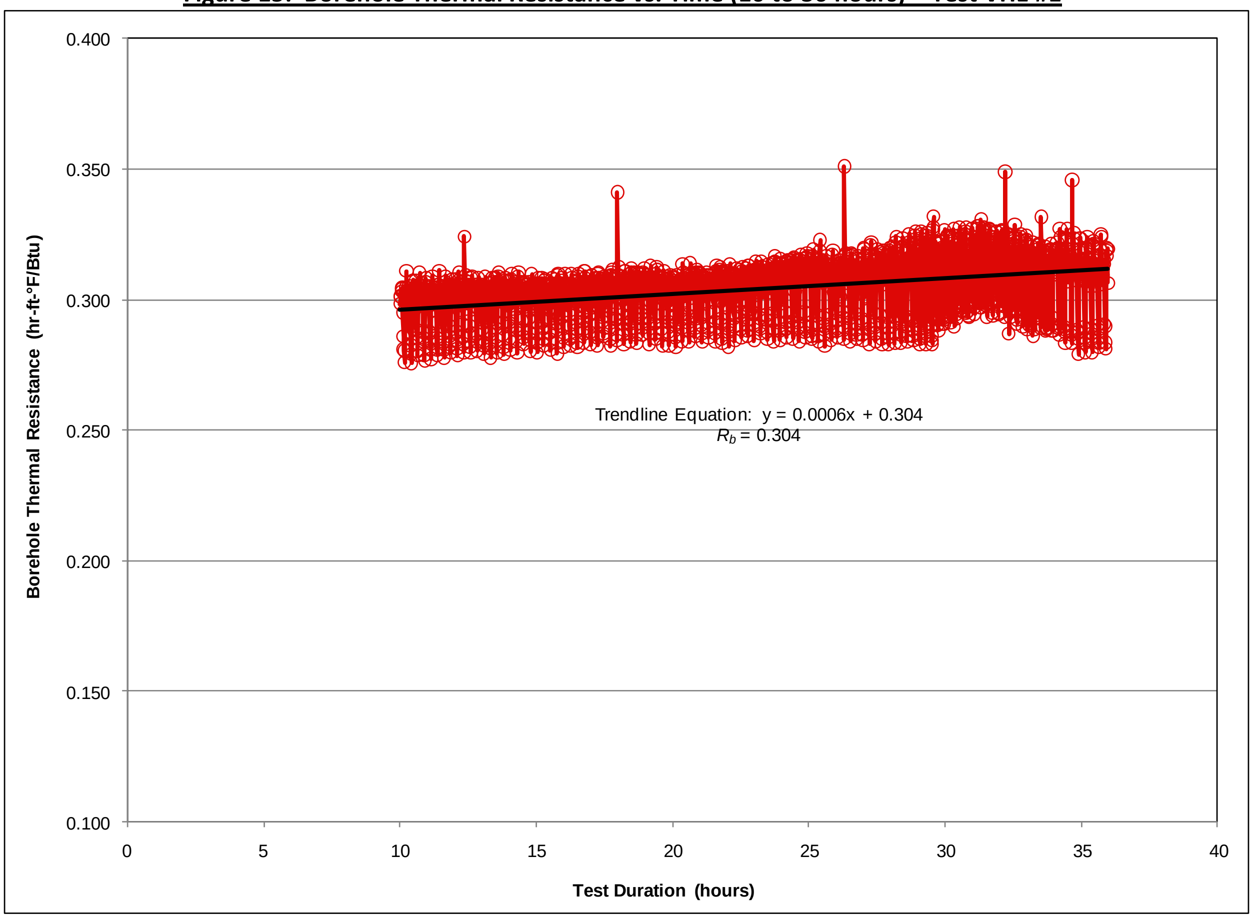
Where,

T_{ug} =	45.9	°F
Q =	30256	Btu/hr
λ_{ground} =	1.25	Btu/(hr-ft-°F)
H =	497.5	ft
a_{ground} =	0.037	ft^2/hr
r_b =	0.26	ft

$$T(t) = 45.9 + \frac{30256}{4\pi * 1.25 * 497.5} * \left[E1\left(\frac{0.26^2}{4 * 0.037 * t} \right) \right] + \frac{30256}{497.5} * R_b$$

The following figure presents the result of this calculation. Note: (t) was obtained every 60 seconds.

<u>Figure 15: Borehole Thermal Resistance vs. Time (10 to 36 hours) – Test VHE #1</u>



<u>Borehole thermal resistance calculations – Test VHE #2</u>

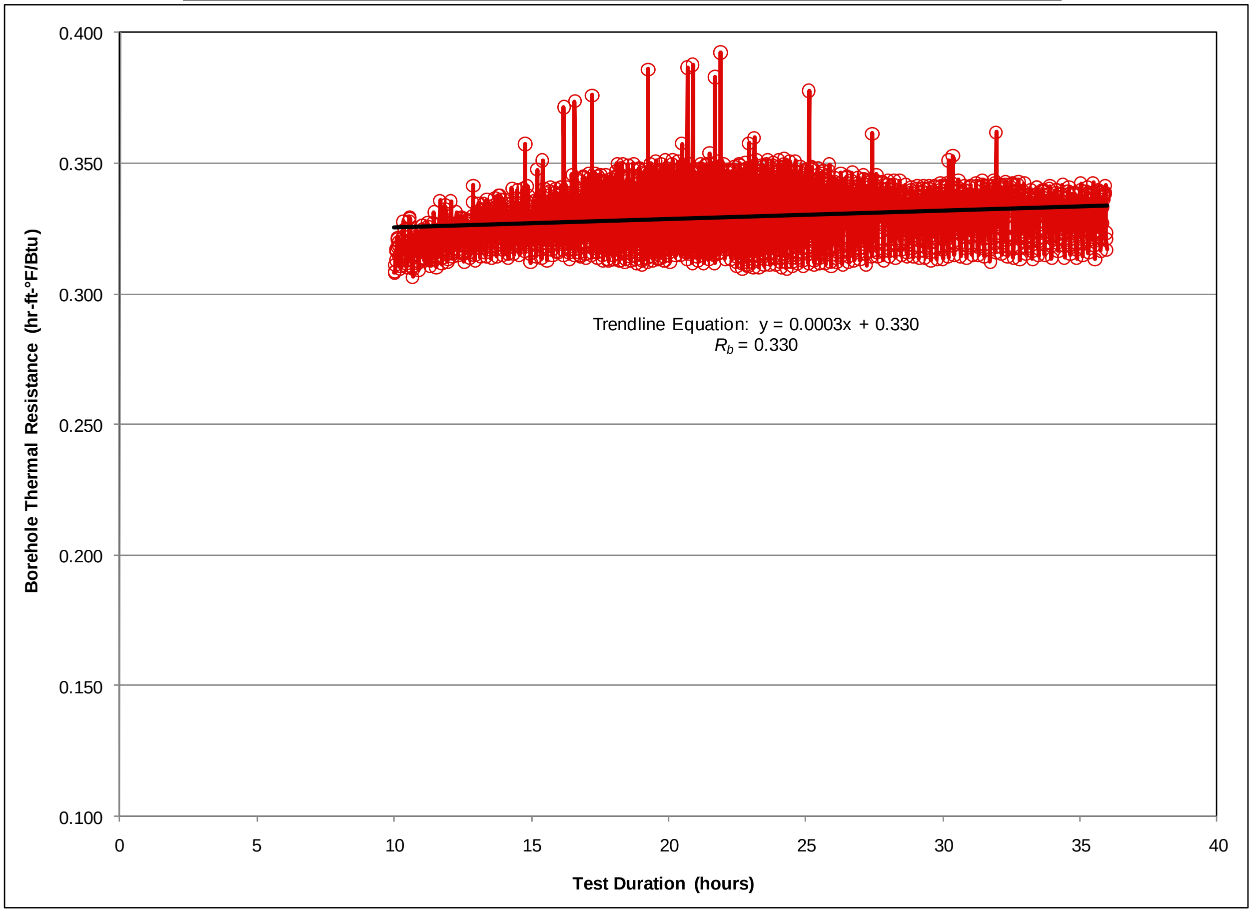
Where,

T_{ug} =	45.9	°F
Q =	30418	Btu/hr
λ_{ground} =	1.23	Btu/(hr-ft-°F)
H =	498.5	ft
a_{ground} =	0.036	ft^2/hr
r_b =	0.26	ft

$$T(t) = 45.9 + \frac{30418}{4\pi * 1.23 * 498.5} * \left[E1\left(\frac{0.26^2}{4 * 0.036 * t} \right) \right] + \frac{30418}{498.5} * R_b$$

The following figure presents the result of this calculation. Note: (t) was obtained every 60 seconds.

<u>Figure 16: Borehole Thermal Resistance vs. Time (10 to 36 hours) – Test VHE #2</u>



The following table presents a summary of the physical properties of the geologic formations and calculated results for the formation thermal property tests conducted at this site, as well as averages of the presented values.

Table 4: Summary of Physical Data and Formation Thermal Properties

Test VHE	Active Depth (ft)	Undisturbed Ground Temperature (°F)	Formation Thermal Conductivity (Btu/(hr-ft-°F))	Volumetric Heat Capacity (Btu/(ft^3-°F))	Formation Thermal Diffusivity (ft^2/day)	Borehole Thermal Resistance ((hr-ft-°F)/Btu)
1	497.5	45.9	1.25	34.1	0.88	0.304
2	498.5	45.9	1.23	34.1	0.87	0.330
Average	498.0	45.9	1.24	34.1	0.88	0.317

Conclusion

Additional ground heat exchanger development services offered by Braun Intertec include construction budgeting, design consulting, project management and construction testing/observation, and Hydrocommissioning™ of the constructed heat exchanger. Please contact us to learn more about how our specialized services help ensure cost effective project delivery and long term operational reliability.

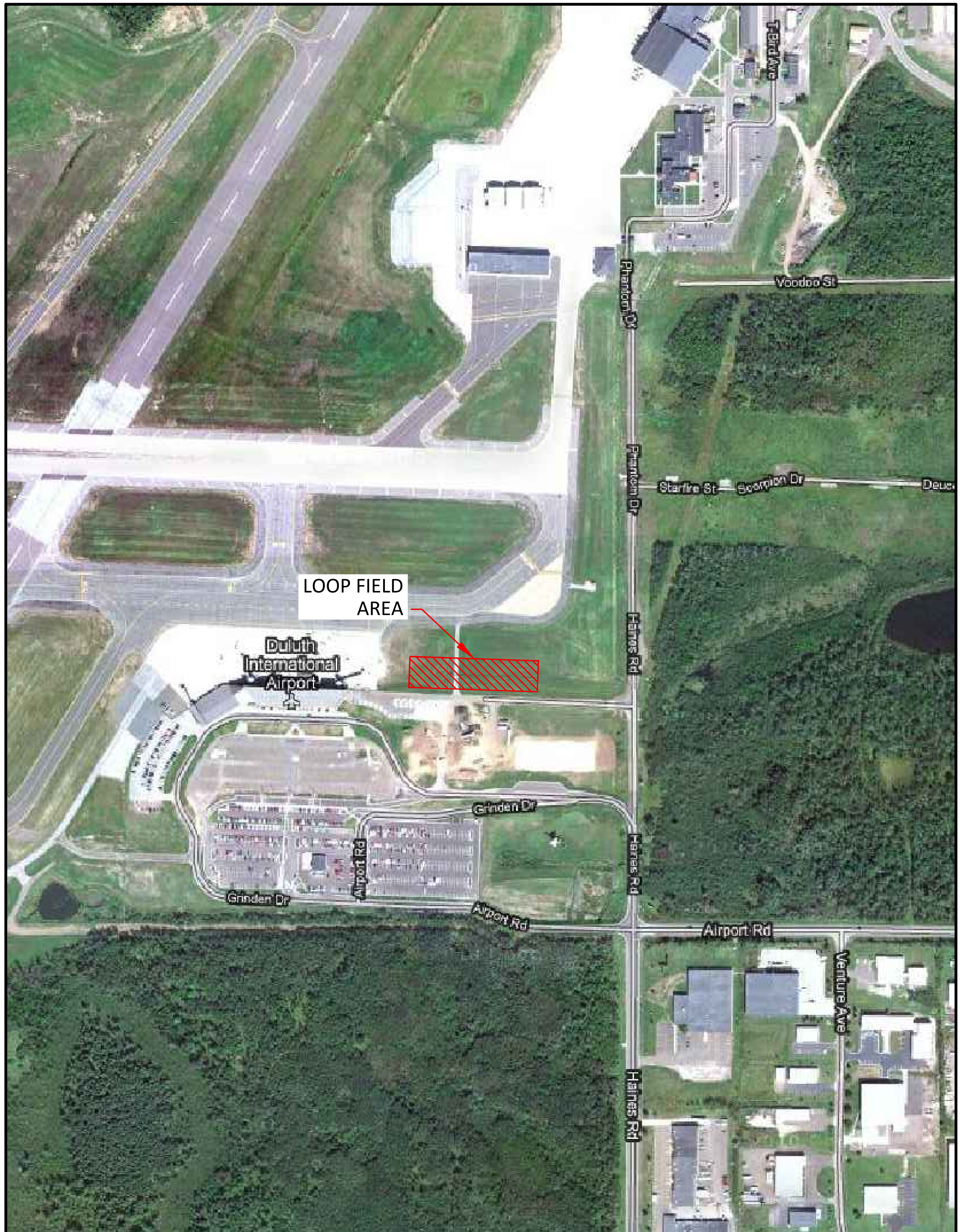
Sincerely,

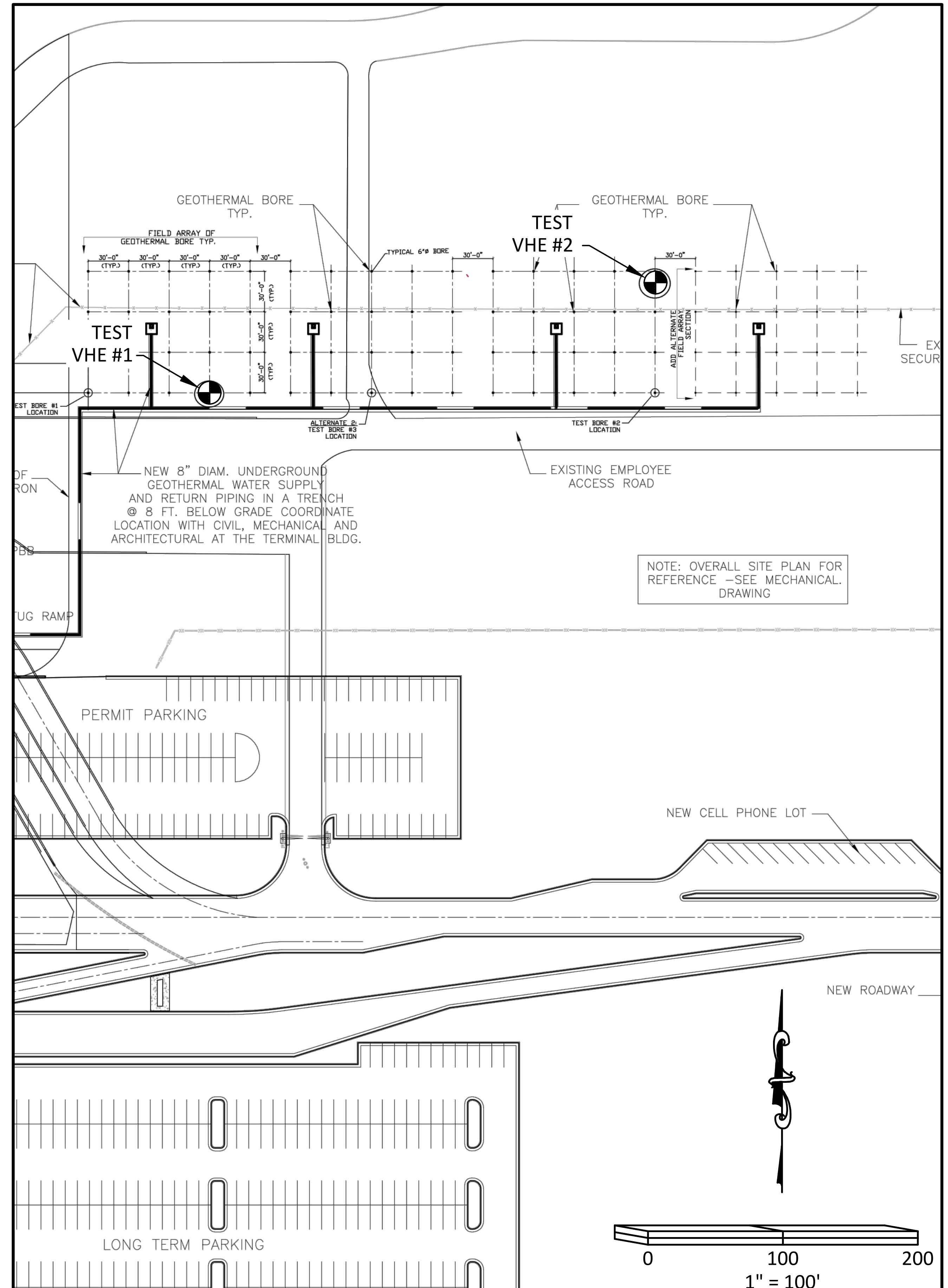
BRAUN INTERTEC GEOTHERMAL, LLC

Gregory S. Browne, PG
Geological Services Manager

Scott Freitag
Principal

Attachments:
- Figure 1
- Boring Logs
- MDH Vertical Heat Exchanger Record
- Grout Sample Laboratory Reports
- VHE Installation Observation Photographs





BRAUN INTERTEC GEOTHERMAL

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www.braunintertec.com

PROJECT DESCRIPTION

DULUTH INTERNATIONAL AIRPORT - NEW TERMINAL

FORMATION THERMAL RESPONSE TESTING

CITY DULUTH

STATE MINNESOTA

ISSUE DATES

MARK	DESCRIPTION	DATE

PROJECT NO: GT-11-02378

DRAWN BY: JBC

CHECKED BY: GSB

DRAWING TITLE

SITE LOCATION AND TEST VHE LOCATION MAP

FIG. 1

File Location: Q:\ACTIVE PROJECTS\Minnesota\Duluth\Duluth Airport TC\Drawings\DULUTH SITE MAP.dwg
Plot Date: 20-Jun-11

BRAUN INTERTEC GEOTHERMAL
16744 11th Street NE
Little Falls, MN 56345
Phone 320.632.1081
Fax 320.632.1673

PROJECT NAME:	DULUTH INTERNATIONAL AIRPORT - NEW PASSENGER TERMINAL
PROJECT ADDRESS:	4701 Airport Road Duluth, MN 55811
COUNTY:	ST. LOUIS
REPORT PREPARED BY:	GSB
PROJECT No:	GT-11-02378

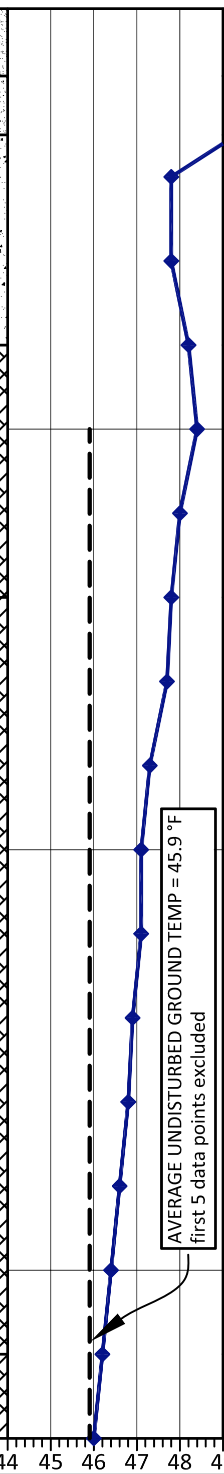
LOG OF BORING: TEST VHE 1

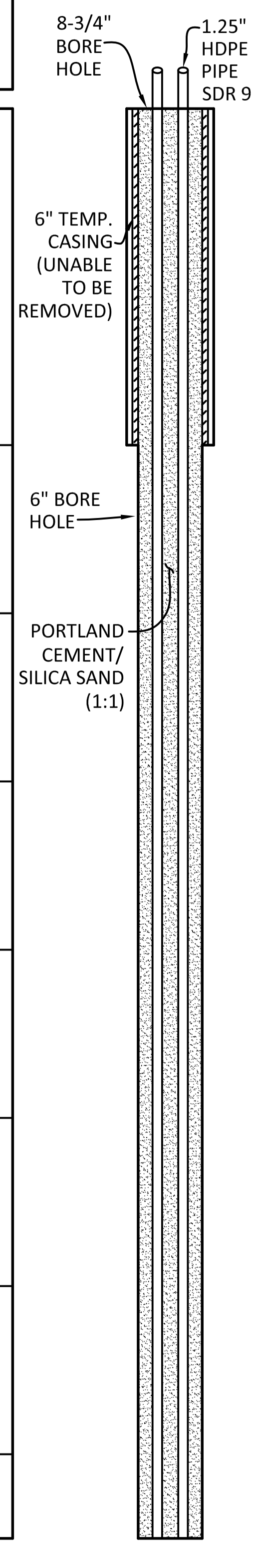
DATE: 6/9/11 - 6/10/11
COMPANY/METHOD:
SAM'S WELL DRILLING / MUD ROTARY 0 - 40 FT
HALCO AIR PERCUSSION HAMMER 40 - 500 FT

DEPTH IN FEET	SURF. ELEV. 1410	USCS	DESCRIPTION	WATER LEVELS	REMARKS
0	1410	TS-SM	SILTY SAND, very dark grayish brown 10YR 3/2, fine grained, moist		
		SM	SILTY SAND, strong brown 7.5YR 4/6, fine grained, with gravel	∇	SWL=16' (ESTIMATED)
20	1390	GP	GRAVEL, with silt, strong brown 7.5YR 4/6, fine grained - possible boulder at 18'		
40	1370	Mdl	GABBRO, grayish black N 2/0, hard		DULUTH COMPLEX (Mdl) DRILLING PRODUCTION RATE: 1.1 FT/MIN 40' - 80' NO WATER PRODUCTION
60	1350				DRILLING PRODUCTION RATE: 1.4 FT/MIN
		Mdl	GABBRO, medium dark gray N 4/0		
80	1330				DRILLING PRODUCTION RATE: 1.2 FT/MIN
100	1310				DRILLING PRODUCTION RATE: 1.25 FT/MIN
120	1290				DRILLING PRODUCTION RATE: 1.3 FT/MIN
140	1270				DRILLING PRODUCTION RATE: 1.1 FT/MIN
160	1250	Mdl	GABBRO, medium light gray N 6/0, to medium gray N 5/0		DRILLING PRODUCTION RATE: 1.1 FT/MIN

GRAPHIC

TEMPERATURE (°F)





COORDINATES: LATITUDE: 46° 50.341'N; LONGITUDE: 92° 10.674'W
COORDINATE SYSTEM: NONE - ESTIMATED FROM GOOGLE EARTH
SURFACE ELEVATION: 1410 (FT-AMSL)
BENCHMARK: NONE
TOTAL HOLE DEPTH: 500 FT
ACTIVE VHE DEPTH: 497.5 FT

BOREHOLE DIAMETER: 0' - 40': 8-3/4"
40' - 500': 6"

DRILLING TIME: 6/9 START 14:24 END 18:55 @ 200'
6/10 START 06:26 END 13:43 @ 500'

LOG DATE: 6/20/11

BRAUN INTERTEC GEOTHERMAL

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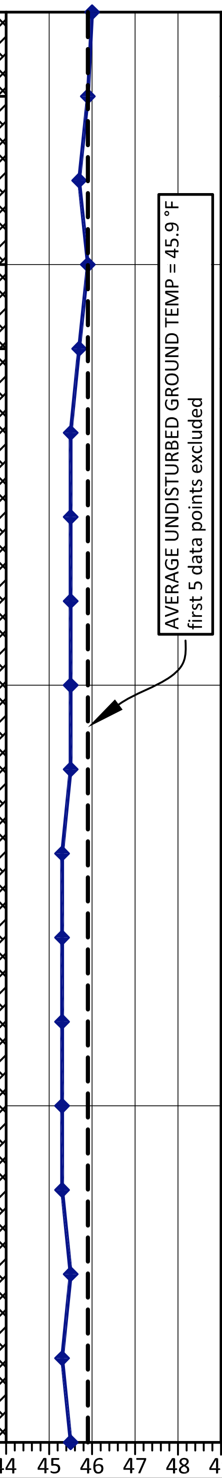
PROJECT NAME: DULUTH INTERNATIONAL AIRPORT - NEW PASSENGER TERMINAL
PROJECT ADDRESS: 4701 Airport Road, Duluth, MN 55811
COUNTY: ST. LOUIS
REPORT PREPARED BY: GSB
PROJECT No: GT-11-02378

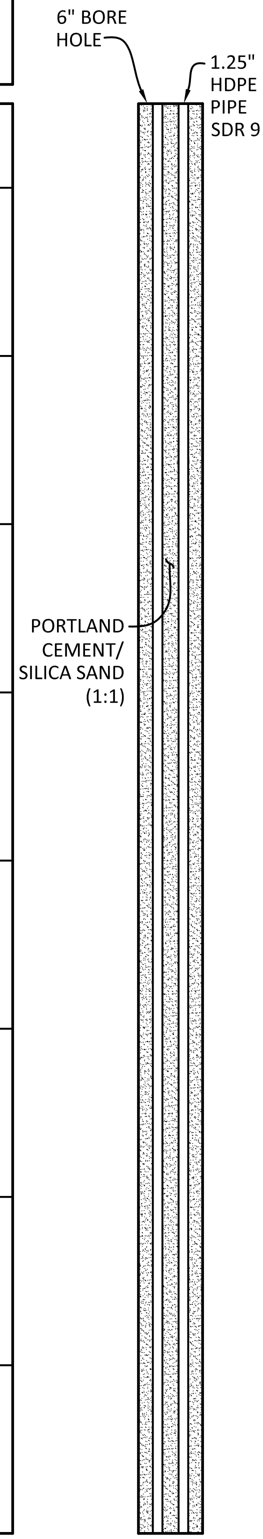
LOG OF BORING: TEST VHE 1

DATE: 6/9/11 - 6/10/11
COMPANY/METHOD:
SAM'S WELL DRILLING / MUD ROTARY 0 - 40 FT
HALCO AIR PERCUSSION HAMMER 40 - 500 FT

DEPTH IN FEET	SURF. ELEV. 1410	USCS	DESCRIPTION	REMARKS
170-180	1240-1230	Mdl	GABBRO, medium light gray N 6/0, to medium gray N 5/0	
180-200	1230-1210	Mdl	GABBRO, dark grey N 3/0, to grayish black N 2/0	DRILLING PRODUCTION RATE: 0.95 FT/MIN
200-210	1210-1200	Mdl	GABBRO, grayish black N 2/0, soft seam at 205 FT	DRILLING PRODUCTION RATE: 0.7 FT/MIN WATER: 1-2 GPM AT 205 FT
210-340	1200-1070	Mdl	GABBRO, grayish black N 2/0, hard	
220-240	1190-1170			DRILLING PRODUCTION RATE: 0.8 FT/MIN
240-260	1170-1150			DRILLING PRODUCTION RATE: 0.8 FT/MIN
260-280	1150-1130			DRILLING PRODUCTION RATE: 0.8 FT/MIN
280-300	1130-1110			DRILLING PRODUCTION RATE: 0.74 FT/MIN
300-320	1110-1090			DRILLING PRODUCTION RATE: 0.8 FT/MIN
320-340	1090-1070			DRILLING PRODUCTION RATE: 0.77 FT/MIN

TEMPERATURE (°F)





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SURFACE ELEVATION: 1410 (FT-AMSL)
BENCHMARK: NONE
TOTAL HOLE DEPTH: 500 FT
ACTIVE VHE DEPTH: 497.5 FT

BOREHOLE DIAMETER: 0' - 40': 8-3/4"
40' - 500': 6"

DRILLING TIME: 6/9 START 14:24 END 18:55 @ 200'
6/10 START 06:26 END 13:43 @ 500'

LOG DATE: 6/20/11

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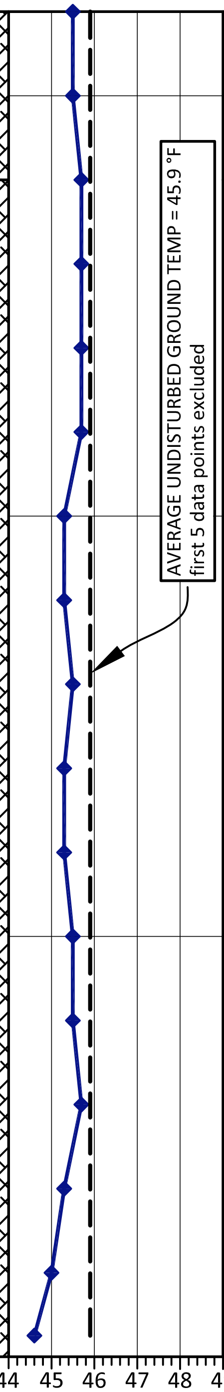
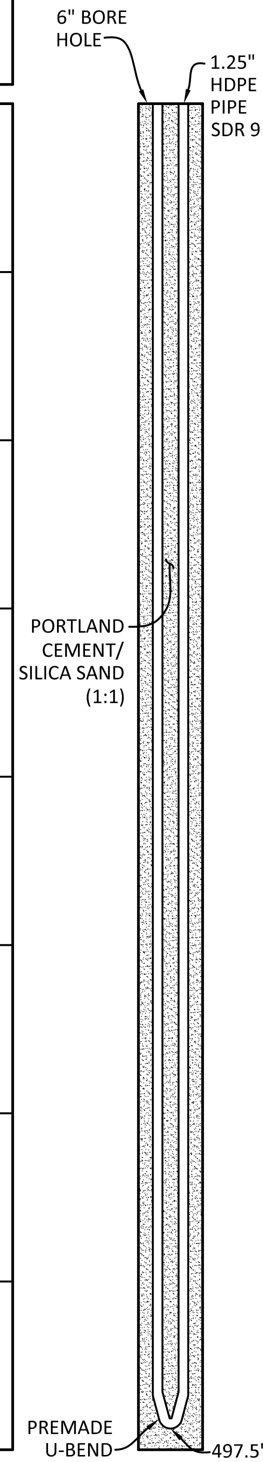
PROJECT ADDRESS:	4701 Airport Road Duluth, MN 55811
COUNTY:	ST. LOUIS
REPORT PREPARED BY:	GSB
PROJECT No:	GT-11-02378

LOG OF BORING: TEST VHE 1

DATE: 6/9/11 - 6/10/11
COMPANY/METHOD:
SAM'S WELL DRILLING / MUD ROTARY 0 - 40 FT
HALCO AIR PERCUSSION HAMMER 40 - 500 FT

DEPTH IN FEET	SURF. ELEV. 1410	USCS	GRAPHIC	TEMPERATURE (°F)	DESCRIPTION	WATER LEVELS	REMARKS
340	1070	Mdl			GABBRO, grayish black N 2/0, hard		DRILLING PRODUCTION RATE: 0.8 FT/MIN WATER: 4 GPM, ASSUMED PRIMARILY FROM UPPER LAYER
360	1050	Mdl			GABBRO, medium dark gray N 4/0, to dark gray N 3/0		DRILLING PRODUCTION RATE: 0.8 FT/MIN
380	1030						DRILLING PRODUCTION RATE: 0.8 FT/MIN
400	1010						DRILLING PRODUCTION RATE: 0.8 FT/MIN
420	990						DRILLING PRODUCTION RATE: 0.77 FT/MIN
440	970						DRILLING PRODUCTION RATE: 0.77 FT/MIN
460	950						DRILLING PRODUCTION RATE: 0.8 FT/MIN
480	930						DRILLING PRODUCTION RATE: 1.0 FT/MIN
500	910				END OF BORING AT 500 FEET BELOW GRADE		





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SURFACE ELEVATION: 1410 (FT-AMSL)
BENCHMARK: NONE
TOTAL HOLE DEPTH: 500 FT
ACTIVE VHE DEPTH: 497.5 FT

BOREHOLE DIAMETER: 0' - 40': 8-3/4"
40' - 500': 6"

DRILLING TIME: 6/9 START 14:24 END 18:55 @ 200'
6/10 START 06:26 END 13:43 @ 500'

BRAUN INTERTEC GEOTHERMAL
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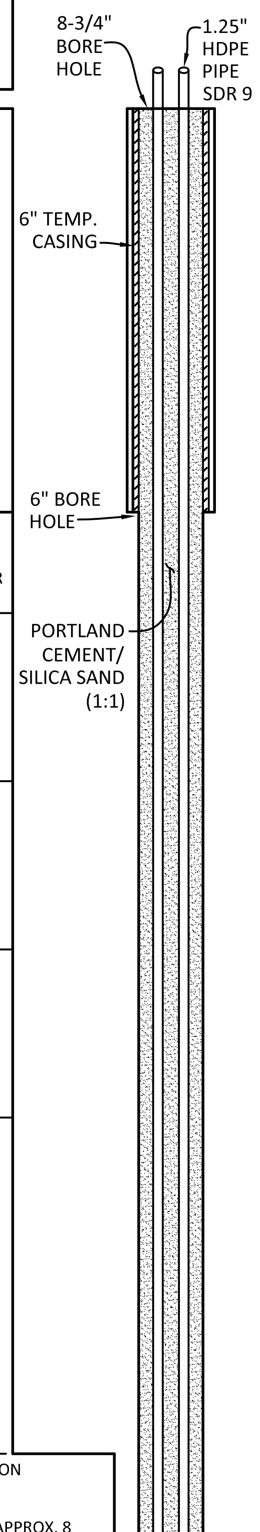
LOG OF BORING: TEST VHE 2

PROJECT NAME: DULUTH INTERNATIONAL AIRPORT - NEW PASSENGER TERMINAL
PROJECT ADDRESS: 4701 Airport Road, Duluth, MN 55811
COUNTY: ST. LOUIS
REPORT PREPARED BY: GSB
PROJECT No: GT-11-02378

DATE: DRILL 6/7/11 - 6/8/11, GROUT 6/9/11
COMPANY/METHOD: SAM'S WELL DRILLING / MUD ROTARY 0 - 48 FT, MINCON MC61 AIR PERCUSSION HAMMER 48 - 500 FT

DEPTH IN FEET	SURF. ELEV. 1392	USCS	TEMPERATURE (°F)	DESCRIPTION	WATER LEVELS	REMARKS
0	1392		GROUND TEMPERATURE NOT MEASURED DUE TO SENSOR ERROR			
		SM		SILTY SAND, dark brown 10YR 3/3, fine grained, with medium gravel, angular to subrounded, dry	∇	CAVE-IN AT 15' SWL=16' (ESTIMATED)
20	1372	SM		SILTY SAND, dark brown 10YR 3/3, very fine grained, with trace gravel, moist		
		SM		SILTY SAND, dark brown 10YR 3/4, very fine grained, with trace fine gravel, moist		
		GP		GRAVEL, red/gray, fine to medium grained, trace wood		
40	1352	GP		GRAVEL, gray, fine to medium grained, rocky		
		GP		GRAVEL, brown/gray 10YR 3/3, fine to medium grained, subrounded		
		Mdl		GABBRO, dark gray N 3/0, thin chips of granite, hard		DULUTH COMPLEX (Mdl) 48' - 100' NO WATER PRODUCTION
60	1332					DRILLING PRODUCTION RATE: 1.3 FT/MIN
80	1312					DRILLING PRODUCTION RATE: 1.25 FT/MIN
100	1292					DRILLING PRODUCTION RATE: 1.5 FT/MIN LITTLE WATER 100' - 120' = 1 GPM
120	1272					WATER: 1 GPM
140	1252					
160	1232					DRILLING PRODUCTION RATE: 2.0 FT/MIN WATER: 160' - 180' APPROX. 8 GPM, NO EVIDENCE OF FRACTURES



COORDINATES: LATITUDE: 46° 50.351'N; LONGITUDE: 92° 10.594'W
COORDINATE SYSTEM: NONE - ESTIMATED FROM GOOGLE EARTH
SURFACE ELEVATION: 1392 (FT-AMSL)
BENCHMARK: NONE
TOTAL HOLE DEPTH: 500 FT
ACTIVE VHE DEPTH: 498.5 FT

BOREHOLE DIAMETER: 0' - 48': 8-3/4"
48' - 500': 6"

DRILLING TIME: 6/7 START 09:52 END 18:17 @ 330'
6/8 START 07:57 END 11:38 @ 500'

LOG DATE: 6/20/11

BRAUN INTERTEC GEOTHERMAL
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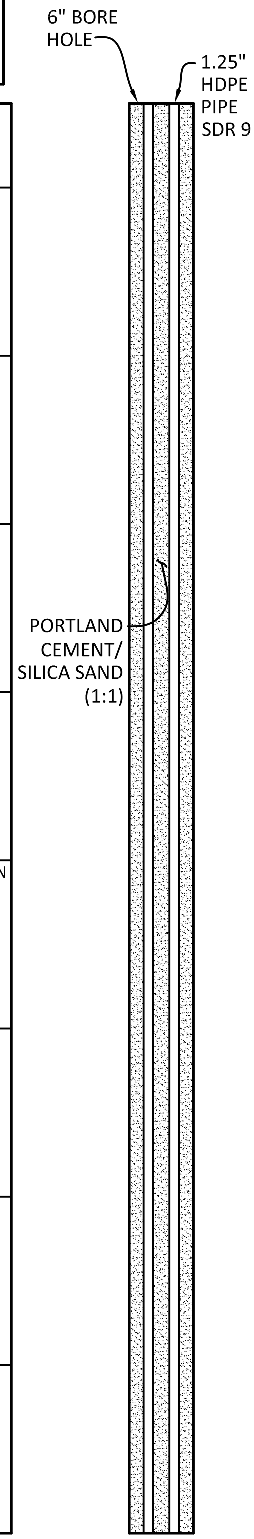
PROJECT ADDRESS:	4701 Airport Road Duluth, MN 55811
COUNTY:	ST. LOUIS
REPORT PREPARED BY:	GSB
PROJECT No:	GT-11-02378

LOG OF BORING: TEST VHE 2

DATE: DRILL 6/7/11 - 6/8/11, GROUT 6/9/11
COMPANY/METHOD:
SAM'S WELL DRILLING / MUD ROTARY 0 - 48 FT,
MINCON MC61 AIR PERCUSSION HAMMER 48 - 500 FT

DEPTH IN FEET	SURF. ELEV. 1392	USCS	GRAPHIC	TEMPERATURE (°F)	DESCRIPTION	WATER LEVELS	REMARKS
170		Mdl			GABBRO, dark gray N 3/0, thin chips of granite, hard		DRILLING PRODUCTION RATE: 2.0 FT/MIN
180	1212						DRILLING PRODUCTION RATE: 2.0 FT/MIN
200	1192	Mdl			GABBRO, dusky green 5G 3/2 pieces in primarily olive black 5Y 2/1 matrix, dusky green pieces 40%		DRILLING PRODUCTION RATE: 2.2 FT/MIN WATER: 10 GPM
220	1172	Mdl			GABBRO, light olive gray 5Y 6/1, moderate brown 5YR 4/4, medium dark gray N 4/0		DRILLING PRODUCTION RATE: 2.2 FT/MIN
240	1152	Mdl			GABBRO, medium dark gray N 4/0, hard		DRILLING PRODUCTION RATE: 1.3 FT/MIN
260	1132	Mdl			GABBRO, grayish black N 2/0, with minor inclusions of dark greenish gray, 5GY 4/1		DRILLING PRODUCTION RATE: 1.4 FT/MIN
280	1112	Mdl			GABBRO, medium light gray N 6/0		DRILLING PRODUCTION RATE: 1.8 FT/MIN
		Mdl			GABBRO, porphyritic (dark spots) with minor inclusions in light colored micaceous base, softer formation 295' - 300'		
300	1092	Mdl			GABBRO, grayish black N 2/0		DRILLING PRODUCTION RATE: 1.25 FT/MIN
320	1072				6/7 END OF DAY: WATER LEVEL MEASURED AT 261 FT BELOW GRADE WITH 330' OPEN HOLE 6/8 START OF DAY: WATER LEVEL MEASURED AT 16 FT BELOW GRADE W/ 330' OPEN HOLE		WATER: 8-10 GPM DRILLING PRODUCTION RATE: 1.0 FT/MIN
340	1052						



COORDINATES: LATITUDE: 46° 50.351'N; LONGITUDE: 92° 10.594'W
COORDINATE SYSTEM: NONE - ESTIMATED FROM GOOGLE EARTH
SURFACE ELEVATION: 1392 (FT-AMSL)
BENCHMARK: NONE
TOTAL HOLE DEPTH: 500 FT
ACTIVE VHE DEPTH: 498.5 FT

BOREHOLE DIAMETER: 0' - 48': 8-3/4"
48' - 500': 6"

DRILLING TIME: 6/7 START 09:52 END 18:17 @ 330'
6/8 START 07:57 END 11:38 @ 500'

LOG DATE: 6/20/11

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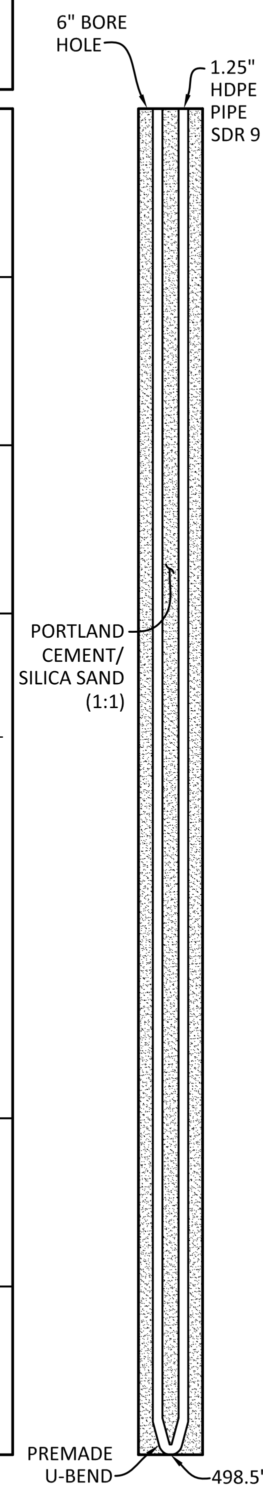
PROJECT NAME: DULUTH INTERNATIONAL AIRPORT - NEW PASSENGER TERMINAL
PROJECT ADDRESS: 4701 Airport Road, Duluth, MN 55811
COUNTY: ST. LOUIS
REPORT PREPARED BY: GSB
PROJECT No: GT-11-02378

LOG OF BORING: TEST VHE 2

DATE: DRILL 6/7/11 - 6/8/11, GROUT 6/9/11
COMPANY/METHOD:
SAM'S WELL DRILLING / MUD ROTARY 0 - 48 FT,
MINCON MC61 AIR PERCUSSION HAMMER 48 - 500 FT

DEPTH IN FEET	SURF. ELEV. 1392	USCS	GRAPHIC	TEMPERATURE (°F)	DESCRIPTION	WATER LEVELS	REMARKS
340	1052	Mdl			GABBRO, grayish black N 2/0		
360	1032						DRILLING PRODUCTION RATE: 1.3 FT/MIN WATER: 8-10 GPM, ASSUMED PRIMARILY FROM UPPER LAYER
380	1012						DRILLING PRODUCTION RATE: 1.3 FT/MIN
400	992						DRILLING PRODUCTION RATE: 1.2 FT/MIN WATER: 400' - 420' INCREASED BY 4 GPM, 12 GPM TOTAL FROM 200' - 420'
420	972	Mdl			GABBRO, medium dark gray N 4/0, to dark gray N 3/0		
440	952						
460	932						DRILLING PRODUCTION RATE: 1.0 FT/MIN
475		Mdl			GABBRO, medium dark gray N 4/0, to dark gray N 3/0, with pale reddish brown 10R 5/4 (40%)		
480	912						DRILLING PRODUCTION RATE: 1.3 FT/MIN
485		Mdl			GABBRO, grayish black N 2/0		
500	892				END OF BORING AT 500 FEET BELOW GRADE		



COORDINATES: LATITUDE: 46° 50.351'N; LONGITUDE: 92° 10.594'W
COORDINATE SYSTEM: NONE - ESTIMATED FROM GOOGLE EARTH
SURFACE ELEVATION: 1392 (FT-AMSL)
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TOTAL HOLE DEPTH: 500 FT
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6/8 START 07:57 END 11:38 @ 500'

LOG DATE: 6/20/11

MINNESOTA MDH DEPARTMENT OF HEALTH

Minnesota Department of Health
Well Management Section
625 North Robert Street, P.O. Box 64975
St. Paul, Minnesota 55164-0975
651/201-4600 or 800/383-9808
Deaf and hard-of-hearing: TTY 651/201-5797

VL- 3086

VERTICAL HEAT EXCHANGER RECORD

Vertical Heat Exchanger Location

County Name: St. Louis

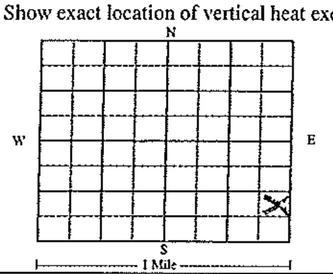
Township Name	Township No.	Range No.	Section No.	Fraction	Depth (completed)	Date Work Completed
Hermantown	50N	15	1	NE ¼ SE ¼ SE ¼	500 ft.	6-10-11

House Number, Street Name, City, and ZIP Code of Vertical Heat Exchanger Location: 4701 Grinden Drive, Duluth, MN 55811

Hole Diameter: 8.75 in. to 50 ft.; 6 in. to 500 ft.

Pipe Diameter: 6 inches

Show exact location of vertical heat exchanger in section grid with "X." Sketch map of installation. Show property lines, roads, and buildings.



See Attached

Number of Bore Holes: 2

Capacity (Tons): 6

Pipe Material
- [x] High Density Polyethylene
- [ ] Other ______

Type of Joint
- [ ] Butt Fusion ______
- [ ] Socket Fusion ______
- [ ] Other ______

PROPERTY OWNER'S NAME: Duluth Airport Authority

Property owner's mailing address if different than vertical heat exchanger location indicated above.

Type of Grout Used (Indicate Product Name)
- [ ] Cement Sand from 0 to 500' ft.
- [ ] Neat Cement from ______ to ______ ft.
- [ ] Bentonite from ______ to ______ ft.
- [ ] Thermally Enhanced Bentonite from ______ to ______ ft.
- [ ] Other ______ from ______ to ______ ft.

Geological Materials	Color	Hardness of Formation	From	To
Clay/Boulder	Red	Soft	0	48
Granite	Gray	Hard	48	500

Type of Coolant Used (Indicate Product Name)
- [x] Water
- [ ] Propylene Glycol ______
- [ ] Other ______

Pressure Test of Installed Piping
Test Pressure (lbs.) 100
Test Duration (minutes) 60

Remarks, Elevation, Source of Data, etc.
12,690 # cement / 12,690 # Sand for entire project
(+-) 16' to static water
Test Bores constructed for conductivity tests

Contractor's Certification

This vertical heat exchanger was constructed under my jurisdiction and this report is true to the best of my knowledge and belief.

Enviro-Tec Inc — 2130
↑ Contractor Business Name ↑ License No.

[signature] 1123
↑ Certified Representative Signature ↑ Certification No. ↑ Date

Jason Rickard 6-10-11
↑ Name of Driller ↑ Date

NA
↑ Name of Heat Pump Installer (HVAC Contractor), if different (Optional)

Minnesota Department of Health Copy

BRAUN
INTERTEC

Braun Intertec Corporation
11001 Hampshire Avenue S
Minneapolis, MN 55438

Phone: 952.995.2000
Fax: 952.995.2020
Web: braunintertec.com

Thermal Conductivity of Grouts Comprised of Portland Cement and Aggregate In Accordance with ASTM D 5334

Date: **16 June, 2011**

Project Number: **GT-11-02378**

Client:
Brett Cahoon
Kraus-Anderson Construction Company
3716 Oneota Street
Duluth, MN 55807-2827

Project Description:
Thermal Conductivity Testing
Duluth IAP
4701 Grinden Drive
Duluth, MN 55811

Batch Data:

Mix Description:	Portland/Silica Sand 1:1
Date/Time Sampled:	6/10/11 at 4:34 PM
Date/Time Received:	6/15/11 at 12:00 PM
Sample Location:	Set #2/Test Bore #1
Samples Cast By:	Braun Intertec / G. Browne
Type of Sample:	5"x5" Plastic Mold

Laboratory Data:

Batch ID:	**N/A**
Date Tested:	6/16/2011
Average Thermal Conductivity	**.95 Btu / hr-ft-°F (1.65 W / m-°C)**

Remarks: **Sample tested more than once to verify measurement.**
The sample exceeds the minimum specified thermal conductivity.

Reviewed By:
[signature]
Wayne Golembeck
Concrete Lab Supervisor

BRAUN
INTERTEC

Braun Intertec Corporation
11001 Hampshire Avenue S
Minneapolis, MN 55438

Phone: 952.995.2000
Fax: 952.995.2020
Web: braunintertec.com

Thermal Conductivity of Grouts Comprised of Portland Cement and Aggregate In Accordance with ASTM D 5334

Date: **16 June, 2011**

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Client:
Brett Cahoon
Kraus-Anderson Construction Company
3716 Oneota Street
Duluth, MN 55807-2827

Project Description:
Thermal Conductivity Testing
Duluth IAP
4701 Grinden Drive
Duluth, MN 55811

Batch Data:

Mix Description:	Portland/Silica Sand 1:1
Date/Time Sampled:	6/9/11 at 12:50 PM
Date/Time Received:	6/15/11 at 12:00 PM
Sample Location:	Set #1/Test Bore #2
Samples Cast By:	Braun Intertec / G. Browne
Type of Sample:	5"x5" Plastic Mold

Laboratory Data:

Batch ID:	**N/A**
Date Tested:	6/16/2011
Average Thermal Conductivity	**.95 Btu / hr-ft-°F (1.64 W / m-°C)**

Remarks: **Sample tested more than once to verify measurement. The sample exceeds the minimum specified thermal conductivity.**

Reviewed By:

Wayne Golembeck
Concrete Lab Supervisor

For Braun Intertec Use Only
Laboratory Work Order No.

BRAUN INTERTEC GEOTHERMAL

Braun Intertec Geothermal, LLC
16744 11th St. NE
Little Falls, MN 56345

Phone: 320.632.1081 Fax: 320.632.1673

REQUEST FOR GROUT TESTING SERVICES

IMPORTANT
Date Results Requested: 6-16-11
Time: 1200
Rush Charges Authorized? Yes (No)
Rush/Quote #:

REPORT RESULTS TO
Contact Name: Greg Browne
Project ID/Name: Duluth IAP
P.O. #/Project #: GT-11-02378
Company: Braun Intertec Geothermal
Mailing Address:
City, State, Zip:
Telephone #: Fax #:
E-mail: gbrowne@braunintertec.com

SEND INVOICE TO
Contact Name: Same
Company:
Address:
City, State, Zip:
Telephone #: Fax #:

Special Instructions and/or Specific Regulatory Requirements:
(method, limit of detection, reporting units)

Site Location (State)

Analysis Requested
(Enter an "X" in the boxes below to indicate request.)

Lab ID#	Client Sample Identification (IDs must be unique)	Date Sampled	Time Sampled	Batch Number	Type of Grout	Number of Containers	Thermal Conductivity	Permeability									FOR LAB USE ONLY
	Grout Sample #1	6-9-11	1250	—		1	X										
	Grout Sample #2	6-10-11	1634	—		1	X										

CHAIN OF CUSTODY
Collected by: (Print) Greg Browne
Relinquished by: [signature] Date/Time: 6-13-11/1330
Relinquished by: Date/Time:
Custody Seal Intact: ☐ Yes ☐ No ☐ N/A ☐ Hand Delivered by Client

Portland/Silica Sand 1:1

Collector's Signature: [signature]
Received by: Wayne Golembeski [signature] Date/Time: 6-15/12:00
Received Contents Not Verified: Date/Time:
Received Contents Verified: Date/Time:
Comments:

Photo 1 – Drilling setup, Test VHE #2 (east), 06/06/11, view S


Photo 2 – Preparing to drill Test VHE #2 (east), new terminal in background, 06/07/11, view W

Photo 3 – Drill rig setup on Test VHE #2 (east), 06/07/11, view WSW

Photo 4 – Drilling Test VHE #2, water containment silt fence foreground, 06/07/11, view WSW

Photo 5 – Air percussion hammer tooling

Photo 6 – Air percussion drill bit

Photo 7 – Minor drill mud emanating from test VHE #2 drill area, 06/07/11, view W


Photo 8 – Silt fencing containing majority of drill cuttings around Test VHE #2 drill area, 06/07/11, view S


Photo 9 – Drill cuttings from Test VHE #2, 260-foot depth on right, 280-foot depth on left, 06/07/11


Photo 10 – Preparing Day 2 drilling at Test VHE #2, 06/08/11, view N

Photo 11 –Attaching 5-foot long, 1-inch diameter rebar to bottom of loop prior to insertion into Test VHE #2 bore, 06/08/11, view SSE

Photo 12 – Loading U-bend loop into Test VHE #2, 06/08/11, view SSW


Photo 13 – Tremie pipe and loop loaded into Test VHE #2, 06/09/11


Photo 14 – Grouting completed at Test VHE #2, 06/09/11, view ESE


Photo 15 – Setting up at Test VHE #1 (west), 06/09/11, view SW


Photo 16 – Mud drilling top portion of Test VHE #1 (west), 06/09/11, view W

Photo 17 – Preparing to air percussion hammer (installing tooling) at Test VHE #1, 06/09/11, view W

Photo 18 – Silt fencing installed downgradient of Test VHE #1 drill area, 06/10/11, view WSW

Photo 19 – Flowing water through U-bend loop installed in Test VHE #1, prior to grouting, 06/10/11, view NW

Photo 20 – Tremie pipe installed in Test VHE #1 bore, 06/10/11, view NW

Photo 21 – Redi-mix truck at Test VHE #1, preparing to grout, 06/10/11, view E


Photo 22 – Setting up Redi-mix to deliver grout into grout tank for grouting Test VHE #1, 06/10/11, view NNE

Photo 23 – Test VHE #1 installed and grouted, note casing remained in bore, 06/10/11, view NW

AMERICAN ENGINEERING TESTING, INC.

SUBSURFACE TEST BORING LOG

AET JOB NO: **07-04216.2** LOG OF BORING NO. **09-05 (p. 1 of 1)**

PROJECT: **Duluth International Airport Terminal; Duluth, MN**

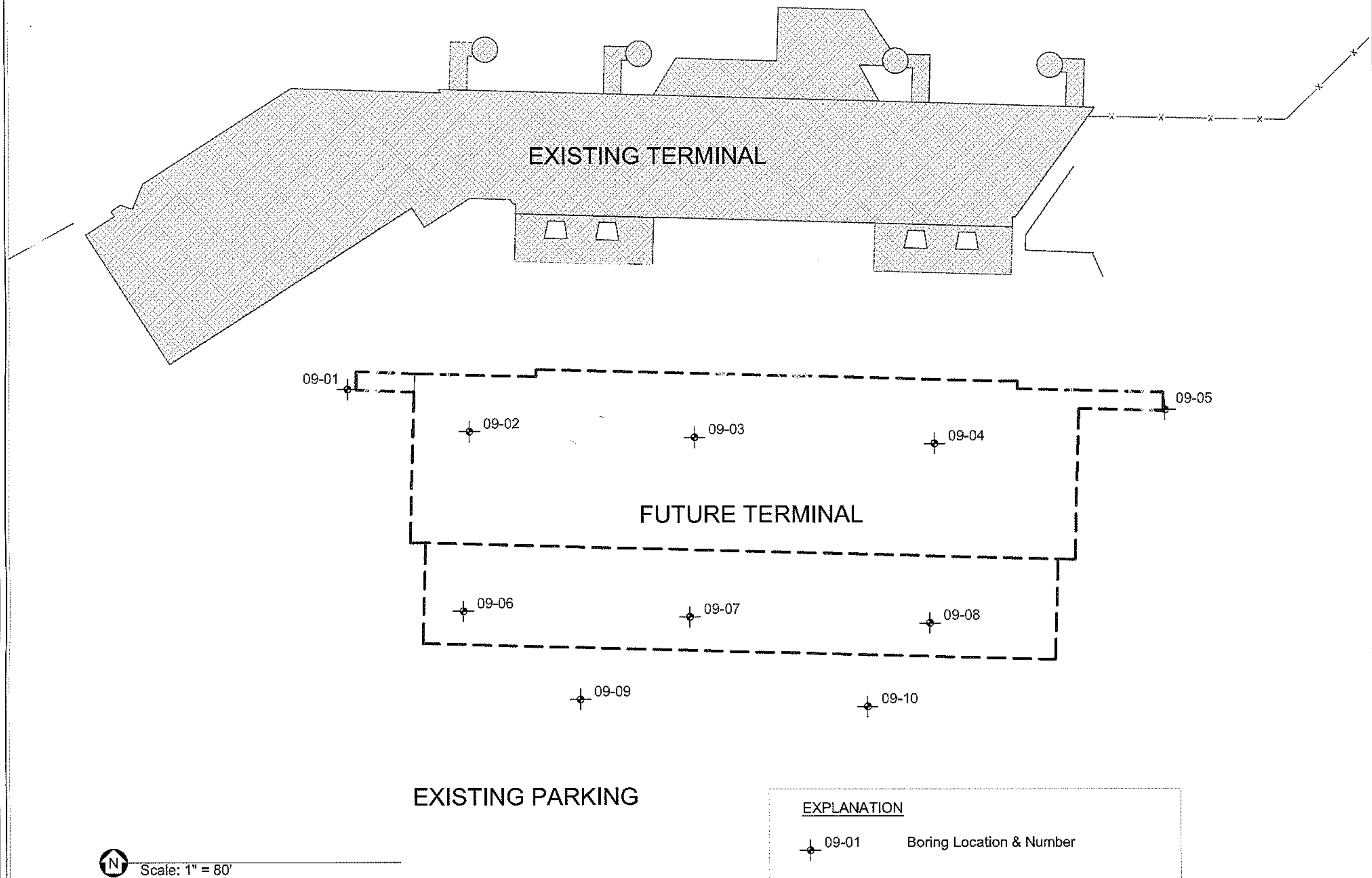
DEPTH IN FEET	SURFACE ELEVATION: MATERIAL DESCRIPTION	GEOLOGY	N	MC	SAMPLE TYPE	REC IN.	WC	DD	LL	PL	%-#200
1	FILL, slightly organic silty sand with roots, dark brown	FILL		M	SU						
2	FILL, medium to coarse sand with gravel, brown										
3	SILTY SAND WITH GRAVEL, dark brown, moist, medium dense, trace roots above about 2.5' (SM) (may be fill)	TILL OR FILL	15	M	SS	15					
4–5			14	M	SS	11					
6–11	SILTY SAND, a little gravel, dark brown, moist, medium dense (SM)	TILL	22	M	SS	11					
			30	M	SS	15					
12–13	SILTY SAND WITH GRAVEL, dark brown, moist, dense (SM)		37	M	SS	5					
14–15	SILTY SAND, a little gravel, dark brown, moist, medium dense (SM)		29	M	SS	17					
16	**END OF BORING AT 16.0 FEET** Borehole backfilled with auger cuttings										

DEPTH: DRILLING METHOD	DATE	TIME	SAMPLED DEPTH	CASING DEPTH	CAVE-IN DEPTH	DRILLING FLUID LEVEL	WATER LEVEL
0-14½' 3.25" HSA							
	9/15/09	**14:57**	**16.0**	**14.5**	**15.0**	---	**None**
	9/15/09	**15:03**	**16.0**	**None**	**12.7**	---	**None**
BORING COMPLETED: **9/15/09**							
DR: **LA** LG: **TDD** Rig: **51**							

NOTE: REFER TO THE ATTACHED SHEETS FOR AN EXPLANATION OF TERMINOLOGY ON THIS LOG

06/06

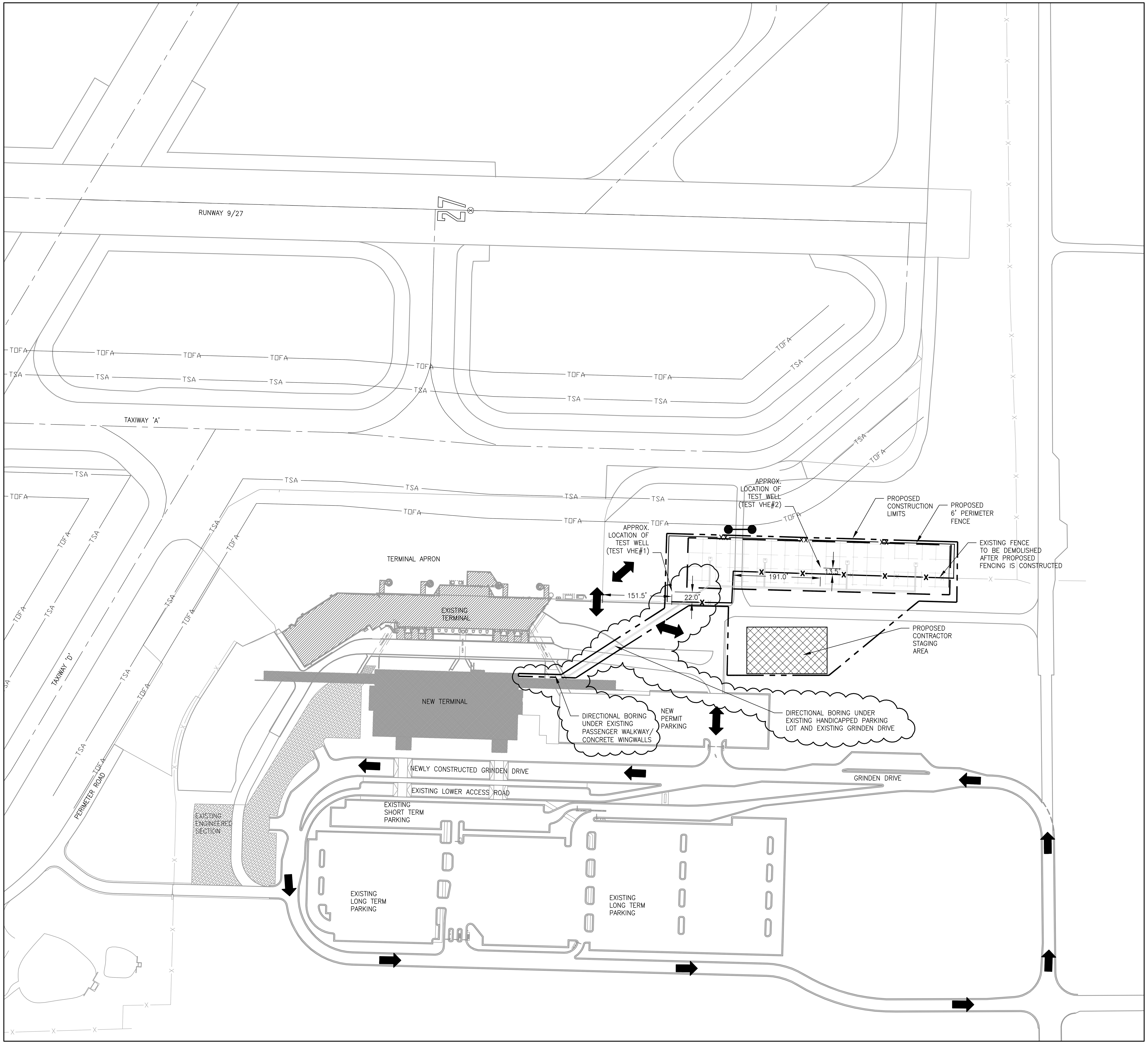
www.amengtest.com
AMERICAN ENGINEERING TESTING, INC.
P.O. BOX 16008; DULUTH, MINNESOTA 55816



Reference: Sketch provided by Reynolds, Smith, & Hills, Inc.

FIGURE NO.	PROJECT NO. 07-04216.02 ALTERED BY: DWA CHECKED BY: DATE: 10/06/09	APPROXIMATE BORING LOCATIONS	DULUTH INTERNATIONAL AIRPORT TERMINAL Duluth, Minnesota

AMERICAN ENGINEERING TESTING, INC.



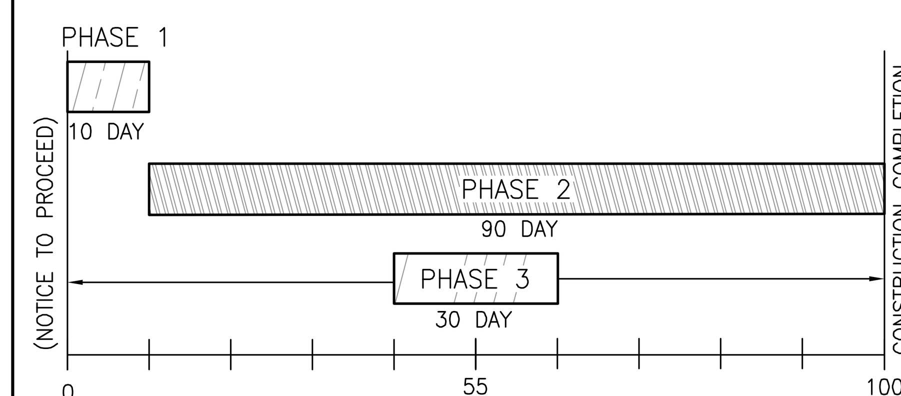
NORTH

0 100' 200'

LEGEND

- PROPOSED GRADING LIMITS
- PROPOSED CONTRACTOR STAGING AREA
- PROPOSED TERMINAL
- EXISTING TERMINAL & BUILDINGS
- PROPOSED LOW LEVEL BARRICADE
- PROPOSED PERIMETER FENCE
- EXISTING PERIMETER FENCE TO BE DEMOLISHED
- EXISTING PERIMETER FENCE TO REMAIN

SCHEMATIC CONSTRUCTION SEQUENCING



NOTE: ALL CONTRACT WORK SHOWN IS ANTICIPATED TO BE COMPLETED WITHIN THE 100 CALENDAR DAYS.

PHASING NOTES

PHASE 1 – FENCE RELOCATION

THE WORK PERFORMED IN THIS PHASE SHALL INCLUDE:

1. INSTALL NEW LINE AND CORNER POSTS
2. SALVAGE AND REINSTALL EXISTING CHAIN LINK FABRIC. INSTALL NEW FENCING FABRIC.
3. DEMOLISH EXISTING FENCE LINE POSTS, CORNER POSTS, AND GATE.

PHASE 2 SHALL NOT COMMENCE UNTIL THE FENCING IS RELOCATED.

PHASE 2 – WELL DRILLING

THE WORK PERFORMED IN THIS PHASE SHALL INCLUDE:

1. WELL DRILLING
2. INSTALLATION OF PIPING AND MANHOLES

PHASE 3 – BUILDING WORK

THE WORK PERFORMED IN THIS PHASE SHALL INCLUDE:

1. PIPING ADJACENT TO THE BUILDING
2. INSTALLATION OF PIPING AND SOLAR PANELS

NOTE:
ALL NORTHINGS, EASTINGS AND ELEVATIONS LABELED ON THESE PLANS ARE IN:
MINNESOTA STATE PLANE NORTH (1996)
VERTICAL DATUM IS NAVD 88
HORIZONTAL DATUM IS NAD83

NOTE:

1. CONTRACTOR IS RESPONSIBLE TO RETURN ALL DISTURBED AREAS TO ORIGINAL CONDITION. THIS INCLUDES TURF ESTABLISHMENT AS WELL AS PATCHING EXISTING BITUMINOUS.
2. THRUST BLOCKING SHALL BE INSTALLED PER THE CITY OF DULUTH STANDARD SPECIFICATIONS.

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Reynolds, Smith and Hills, Inc.
4525 Airport Approach Rd, Ste A
Duluth, Minnesota 55811
218-722-1227 Fax: 218-722-1052
www.rsandh.com

DULUTH AIRPORT AUTHORITY

DULUTH INTERNATIONAL AIRPORT DULUTH, MN

NEW PASSENGER TERMINAL VALE PROGRAM

CONSULTANTS

Structural Engineers:
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501 Lake Avenue South, Suite 300, Duluth MN 55802
TEL: (218) 722-1056 / FAX: (218) 722-9306

M/E/P/FP Engineers:
COSENTINI ASSOCIATES INC.
1 South Wacker Drive, 37th Floor, Chicago IL 60606
TEL: (312) 201-7408 / FAX: (312) 201-0031

REVISIONS

NO.	DESCRIPTION	DATE
ADD #2	ADDENDUM # 2 06/21/2011	

DATE ISSUED: 06-06-11
REVIEWED BY: JEH
DRAWN BY: RDRE
DESIGNED BY: JEH

AEP PROJECT NUMBER
213-1882-110

SHEET TITLE

CONSTRUCTION SAFETY PHASING PLAN

SHEET NUMBER

C003

VALE PROGRAM BID PACKAGE

FENCING NOTES

1. THE EXISTING CHAIN LINK FABRIC SHALL BE SALVAGED AND REUSED ON A SECTION OF PROPOSED FENCING. ALL OTHER MATERIALS SHALL BE SUPPLIED AND INSTALLED BY THE CONTRACTOR AS SPECIFIED.

2. THE DEMOLITION OF FENCE (FABRIC TO BE SALVAGED AND REUSED) SHALL INCLUDE THE COMPLETE REMOVAL AND DISPOSAL OF THEIR CONTENTS, FOUNDATIONS. ANY UNFILLED EXCAVATION OR OTHER HAZARD LEFT UNATTENDED DURING PERIODS OF INACTIVITY SHALL BE PROPERLY FENCED OR PROTECTED BY THE CONTRACTOR. THIS WORK SHALL BE CONSIDERED INCIDENTAL TO THE COST OF THE FENCE DEMOLITION.

3. THERE ARE EXISTING UNDERGROUND ELECTRICAL AND COMMUNICATIONS CABLES IN THE PROJECT WORK AREAS. THE ENGINEER HAS MADE EVERY EFFORT TO SHOW THEIR APPROXIMATE LOCATIONS. IT SHALL BE THE RESPONSIBILITY OF THE CONTRACTOR TO HAVE EVERY CABLE LOCATED, FLAGGED AND IDENTIFIED PRIOR TO CONSTRUCTION. ANY DAMAGE DONE TO FLAGGED OR OTHERWISE LOCATED CABLES SHALL BE REPLACED AT THE CONTRACTORS EXPENSE. LOCATION OF EXISTING UTILITIES MAY BE DONE BY CALLING GOPHER STATE ONE CALL 1-800-252-1166 TO NOTIFY LOCAL UTILITIES. THIS IS REQUIRED BY LAW.

4. ALL EXISTING AIRPORT SIGNAGE ON ANY FENCING DEMOLITION WILL BE REUSED, OR SALVAGED AND TURNED OVER TO THE OWNER.

5. A SECURE PERIMETER MUST BE MAINTAINED AT ALL TIMES. ALL EMPLOYEES, AGENTS, VENDORS, INVITEES, ETC. OF THE CONTRACTOR OR SUBCONTRACTORS WORKING IN THE AIRCRAFT OPERATIONS AREA (AOA) SHALL, IN ACCORDANCE WITH THE AIRPORT OPERATIONS SECURITY PROGRAM, BE REQUIRED TO DISPLAY AIRPORT ISSUED IDENTIFICATION OR BE UNDER ESCORT BY PROPERLY BADGED PERSONNEL. THESE BADGES WILL BE IDENTIFIED NUMERICALLY AND ISSUED TO INDIVIDUAL EMPLOYEES WITH A PERMANENT RECORD MAINTAINED ON EACH INDIVIDUAL TO WHOM A BADGE IS ISSUED. SEE SECURITY REQUIREMENTS, SHEET C002.

GENERAL NOTES

1. DIMENSIONS:
ALL DIMENSIONS, SIZES, GAUGES, WEIGHTS, OR THICKNESSES SHOWN ARE THE MINIMUM ACCEPTABLE, UNLESS OTHERWISE INDICATED

2. SPECIFICATIONS:
THE FEDERAL SPECIFICATIONS SHOWN SHALL BE INTERPRETED TO MEAN THE LATEST ISSUE OR AMENDMENT OF SUCH SPECIFICATION, IN EFFECT ON THE DATE OF PLAN APPROVAL FAA SPECIFICATIONS SHOWN ARE FROM THE FEDERAL AVIATION ADMINISTRATION "STANDARD SPECIFICATIONS FOR CONSTRUCTION OF AIRPORTS" MATERIALS AND CONSTRUCTION METHODS NOT DETAILED HEREON, SHALL BE IN ACCORDANCE WITH THE FAA SPECIFICATION LISTED FOR EACH CLASS OF FENCE, UNLESS OTHERWISE NOTED ON THE CONTRACT PLANS. GATES ARE MEASURED IN UNITS FOR EACH TYPE AND SIZE INSTALLED

3. FABRIC INSTALLATION:
WIRE OR FABRIC ON BOUNDARY AND SECURITY FENCES SHALL BE ON THE SIDE OF POSTS AWAY FROM AIRPORT OPERATIONS AREA AOA. FENCES BETWEEN TERMINAL BUILDINGS AND APRONS, OR ADJACENT TO SIDEWALKS, SHALL HAVE FABRIC ON THE BUILDING OR SIDEWALK SIDE OF POSTS. ALL OTHER BUILDING AREA FENCES SHALL HAVE FABRIC ON SIDE OF POSTS AWAY FROM BUILDINGS OR INSTALLATION BEING FENCED, UNLESS OTHERWISE NOTED.

4. CONCRETE:
CONCRETE SHALL HAVE A MINIMUM 28 DAY COMPRESSIVE STRENGTH OF 3000 PSI. FOOTING TOPS SHALL BE 1" MINIMUM ABOVE GROUND AT THE POST, AND TROWEL FINISHED TO SLOPE AWAY FROM POST.

5. OPENINGS UNDER FENCE:
ANY OPENING UNDER FENCES, WHEREIN THE BOTTOM FENCE WIRE IS MORE THAN 4" ABOVE GROUND AND THE TOTAL AREA OF OPENING IS 96 SQ. INCHES OR MORE, SHALL BE CLOSED.

OPENINGS LESS THAN 18" HIGH SHALL BE CLOSED BY INSTALLING ONE OR MORE ADDITIONAL LINE POSTS NEAR THE OPENING CENTER AND STRETCHING STRANDS OF BARBED WIRE BETWEEN THE EXTRA POSTS AND ADJACENT LINE POSTS AT 6" MAXIMUM VERTICAL SPACING, VERTICAL STRANDS OF BARBED WIRE SHALL BE INSTALLED AT 12" MAXIMUM HORIZONTAL SPACING AND TIED TO ALL HORIZONTAL STRANDS AND THE FABRIC BOTTOM WIRE. THIS WORK SHALL BE INCIDENTAL TO FENCE INSTALLATION COSTS.

OPENINGS 18" OR MORE IN HEIGHT, OPENINGS IN HIGH SECURITY RISK AND HAZARD AREAS, DITCHES, DRAINAGE COURSES, ETC., SHALL BE CLOSED BY METHODS APPROVED BY THE ENGINEER. PAYMENT FOR CLOSURES SHALL BE INCIDENTAL TO THE F-162 FENCING ITEM.

6. GROUND RODS:
GROUND RODS SHALL BE INSTALLED AT 400' MAXIMUM INTERVALS, INCIDENTAL TO FENCE COST. EACH SECTION OF FENCE SEPARATED BY NON-METALLIC CONNECTORS, BUILDINGS OR OTHER OPENINGS SHALL HAVE A MINIMUM OF ONE GROUND ROD. EACH GATE LEAF FRAME SHALL BE CONNECTED TO THE GATE POST BY A BRAIDED FLEXIBLE COPPER STRAP. EACH GATE POST SHALL BE GROUNDED AS DETAILED. GROUND RODS SHALL BE 5/8" x 8' MIN. SIZE, COPPER CLAD. ALL GROUND RODS TO BE TESTED WITH MAXIMUM RESISTANCE TO GROUND OF 10 OHMS. GROUND CABLE SHALL BE NO. 4 AWG. MIN., BARE STRANDED COPPER WIRE. FOR FENCES GROUNDING SHALL BE AS DETAILED. IF GROUNDING IS REQ'D THROUGH EXISTING RUNWAY/TAXIWAY/APRON PAVEMENT, CONTRACTOR SHALL CORE A 4-INCH HOLE THROUGH THE PAVEMENT AND PLACE REQUIRED GROUND ROD. CONNECTIONS TO FENCE AND RODS SHALL BE MADE WITH SUITABLE NON-CORROSIVE METAL CLAMPS, LUG OR CONNECTORS.

7. FENCE LINE AND ALIGNMENT:
FENCE LINES SHALL BE CLEARED OF ALL OBSTRUCTIONS AND SMOOTH GRADED TO THE GENERAL CONTOUR OF THE ADJACENT GROUND FOR A 10' MIN. WIDTH EACH SIDE OF LINE. STUMPS AND ROOTS NOT INTERFERING WITH FENCE CONSTRUCTION, MAY BE CHIPPED TO GROUND LEVEL

THE FENCE SHALL BE CONSTRUCTED VERTICAL, STRAIGHT AND TRUE TO LINE. THE LONGITUDINAL GRADIENT SHALL PARALLEL THE GENERAL SLOPE OF THE GROUND.

8. FENCE SIGNAGE:
ANY NEW SIGNS TO BE PLACED ON NEW OR EXISTING FENCING MATERIALS SHALL BE AS DETAILED ON THE PLANS. ALL FURNISHING AND INSTALLING OF SIGNAGE IS INCIDENTAL TO ITEM F-162.

NORTH

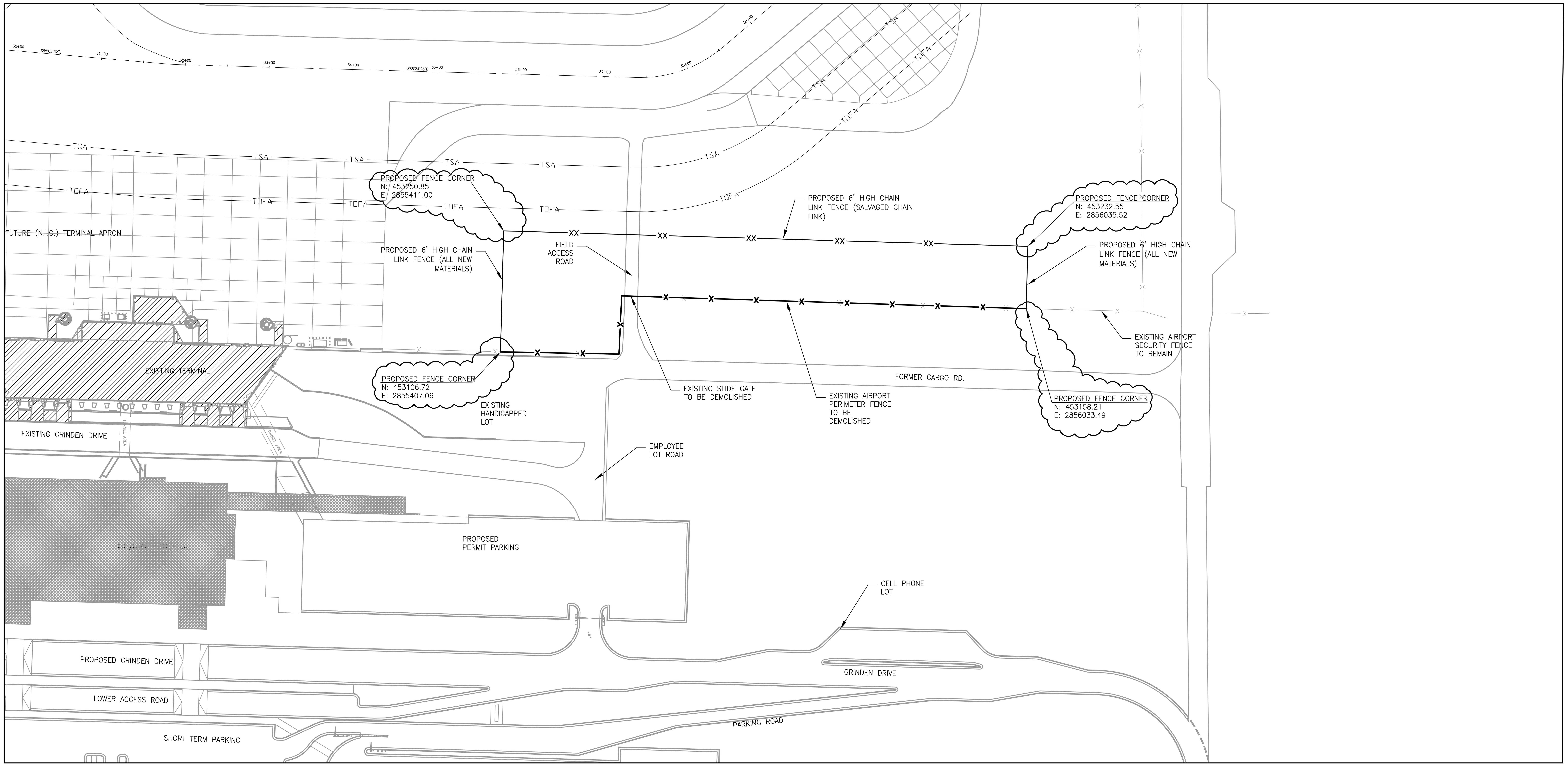
0 60' 120'

FENCING LEGEND

—XX— PROPOSED PERIMETER FENCE

—X—X— EXISTING PERIMETER FENCE TO BE DEMOLISHED

—X—X— EXISTING PERIMETER FENCE TO REMAIN



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DULUTH AIRPORT AUTHORITY

DULUTH INTERNATIONAL AIRPORT
DULUTH, MN

NEW PASSENGER TERMINAL VALE PROGRAM

CONSULTANTS

Structural Engineers:
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501 Lake Avenue South, Suite 300, Duluth MN 55802
TEL: (218) 722-1056 / FAX: (218) 722-9306

M/E/P/FP Engineers:
COSENTINI ASSOCIATES INC.
1 South Wacker Drive, 37th Floor, Chicago IL 60606
TEL: (312) 201-7408 / FAX: (312) 201-0031

REVISIONS

NO.	DESCRIPTION	DATE
ADD #2	ADDENDUM # 2 06/21/2011	

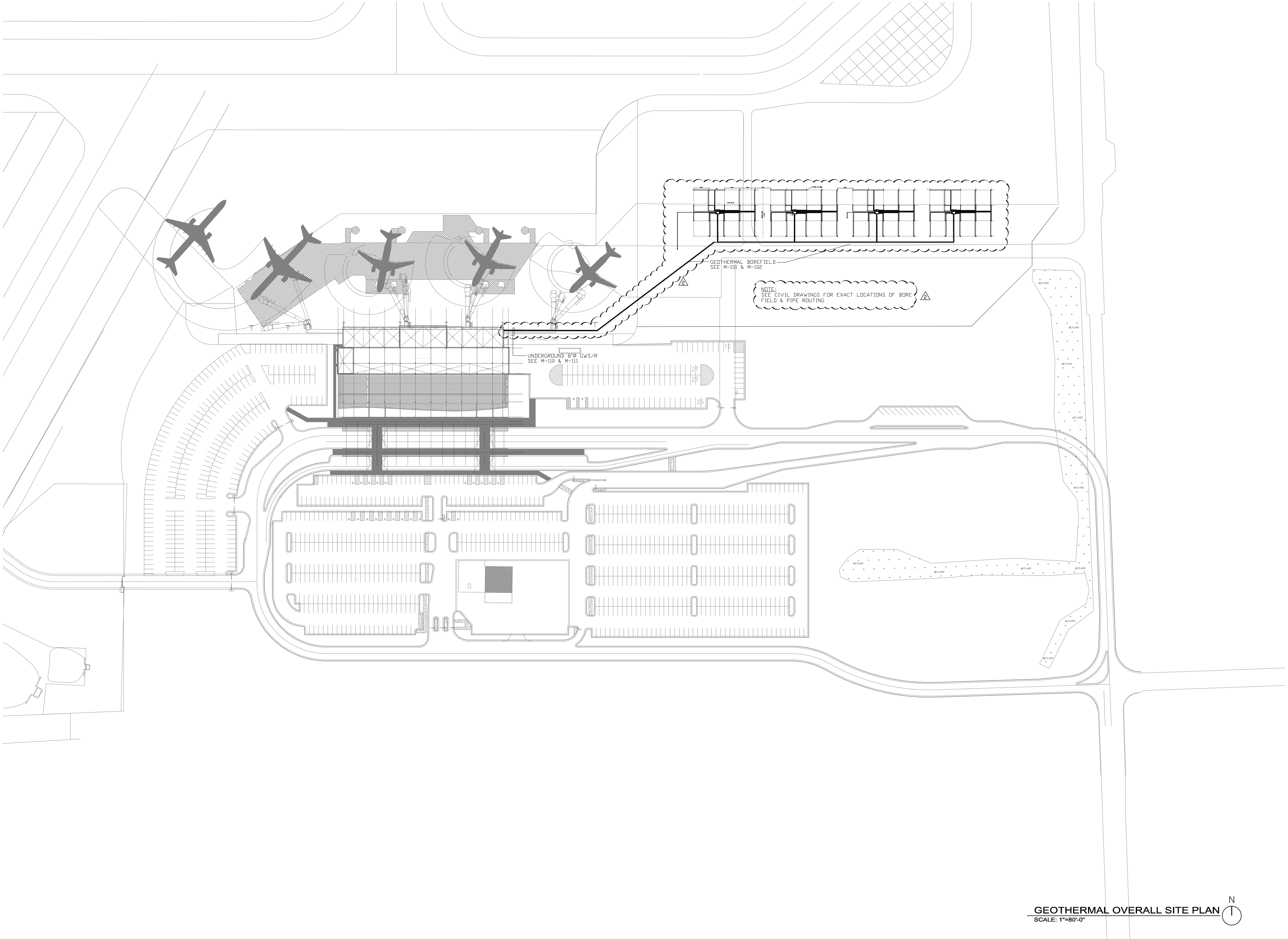
DATE ISSUED: 06-06-11
REVIEWED BY: JEH
DRAWN BY: RDRE
DESIGNED BY: JEH

AEP PROJECT NUMBER
213-1882-110

SHEET TITLE
FENCING LAYOUT SITE PLAN AND NOTES

SHEET NUMBER
C211

VALE PROGRAM BID PACKAGE



GEOTHERMAL OVERALL SITE PLAN

SCALE: 1"=80'-0"

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4525 Airport Approach Rd, Ste A
Duluth, Minnesota 55811
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DULUTH AIRPORT AUTHORITY

DULUTH INTERNATIONAL AIRPORT
DULUTH, MN

NEW PASSENGER TERMINAL
VALE PROGRAM

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1 South Wacker Drive, 37th Floor, Chicago IL 60606
TEL: (312) 201-7400 / FAX: (312) 201-0031

REVISIONS

NO.	DESCRIPTION	DATE
2	ADDENDUM #2	06.21.11

DATE ISSUED: 06-06-11
REVIEWED BY: BR
DRAWN BY: GB
DESIGNED BY: BR

AEP PROJECT NUMBER
213-1882-110

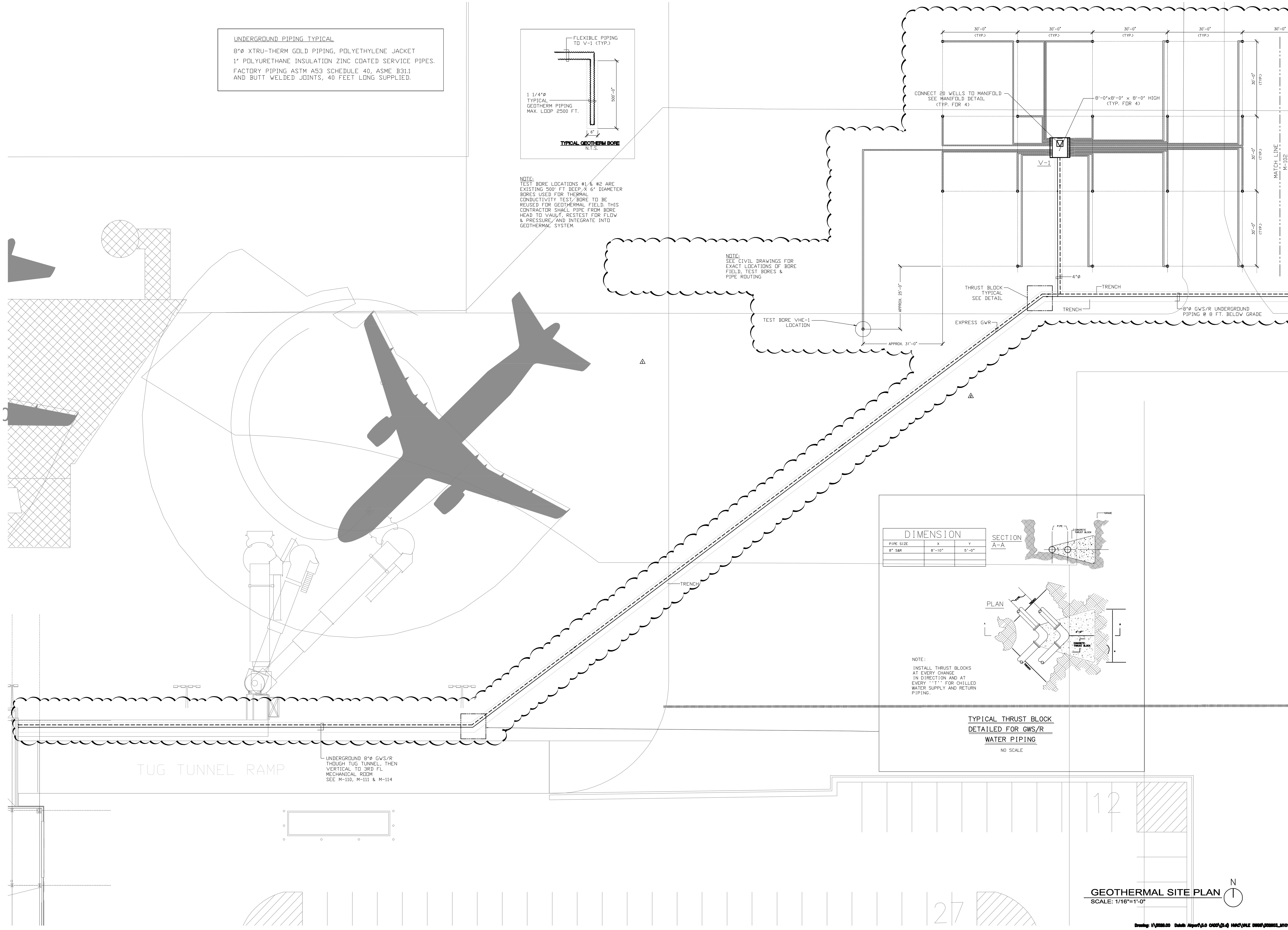
SHEET TITLE

OVERALL GEOTHERMAL SITE PLAN

SHEET NUMBER

M-100

VALE PROGRAM
BID PACKAGE



DIMENSION		
PIPE SIZE	X	Y
8" S&R	8'-10"	5'-0"

RS&H IMPROVING YOUR WORLD

Reynolds, Smith and Hills, Inc.
4525 Airport Approach Rd, Ste A
Duluth, Minnesota 55811
218-722-1227 Fax: 218-722-1052
www.rsandh.com

DULUTH AIRPORT AUTHORITY

DULUTH INTERNATIONAL AIRPORT
DULUTH, MN

NEW PASSENGER TERMINAL
VALE PROGRAM

CONSULTANTS

Structural Engineers:
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M/E/P/FP Engineers:
COSENTINI ASSOCIATES INC.
1 South Wacker Drive, 37th Floor, Chicago IL 60606
TEL: (312) 201-7400 / FAX: (312) 201-0031

REVISIONS

NO.	DESCRIPTION	DATE
1	ADDENDUM #1	06.16.11
2	ADDENDUM #2	06.21.11

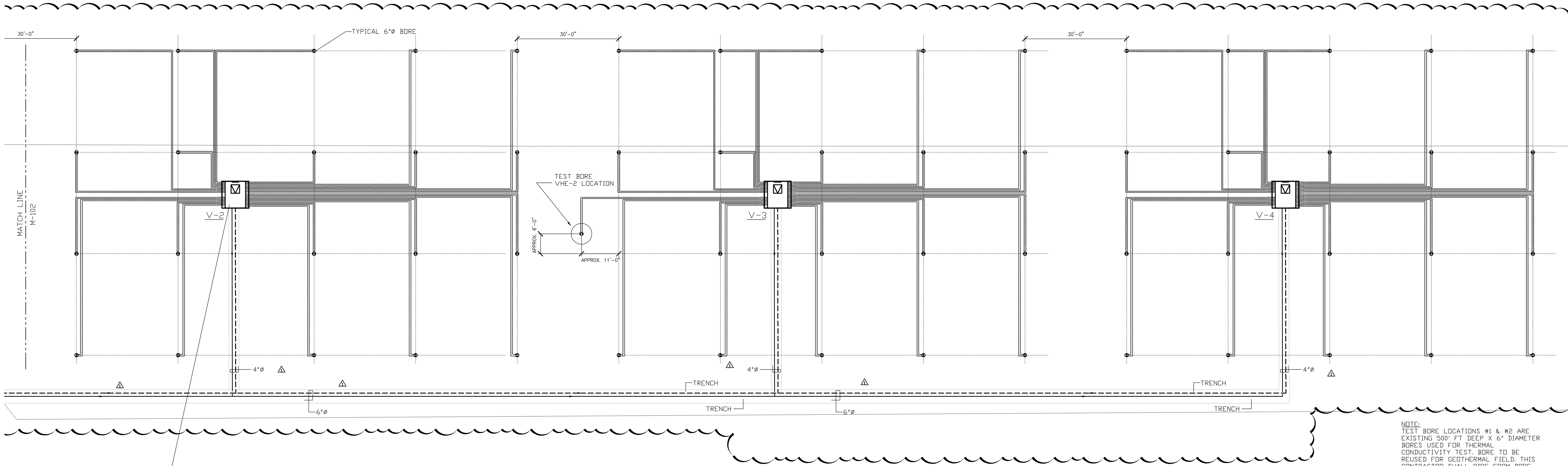
DATE ISSUED: 06-06-11
REVIEWED BY: BR
DRAWN BY: GB
DESIGNED BY: BR

AEP PROJECT NUMBER
213-1882-110

SHEET TITLE
GEOTHERMAL SITE MECHANICAL PARTIAL PLAN

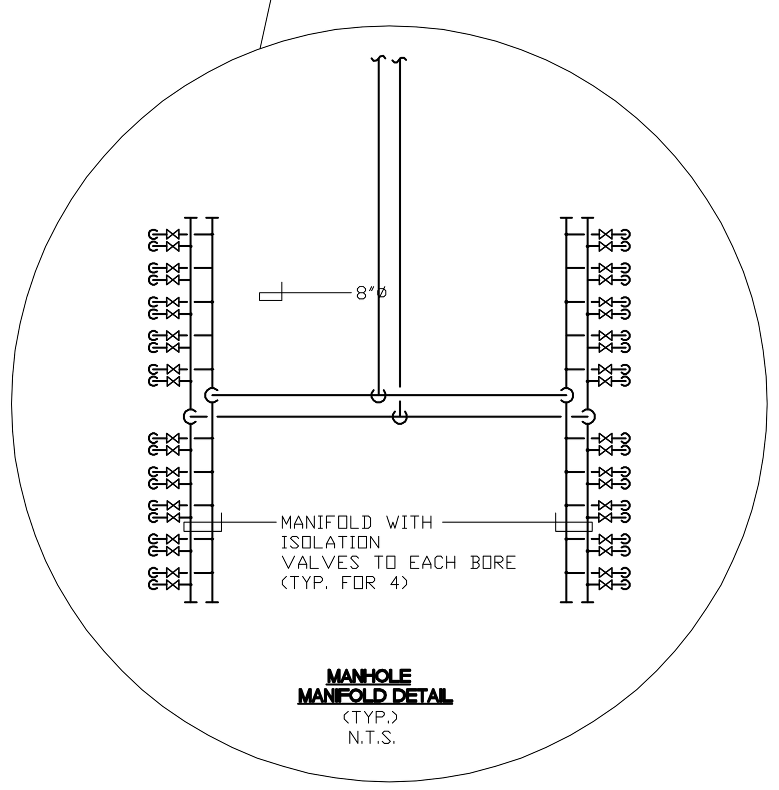
SHEET NUMBER
M-101

VALE PROGRAM
BID PACKAGE

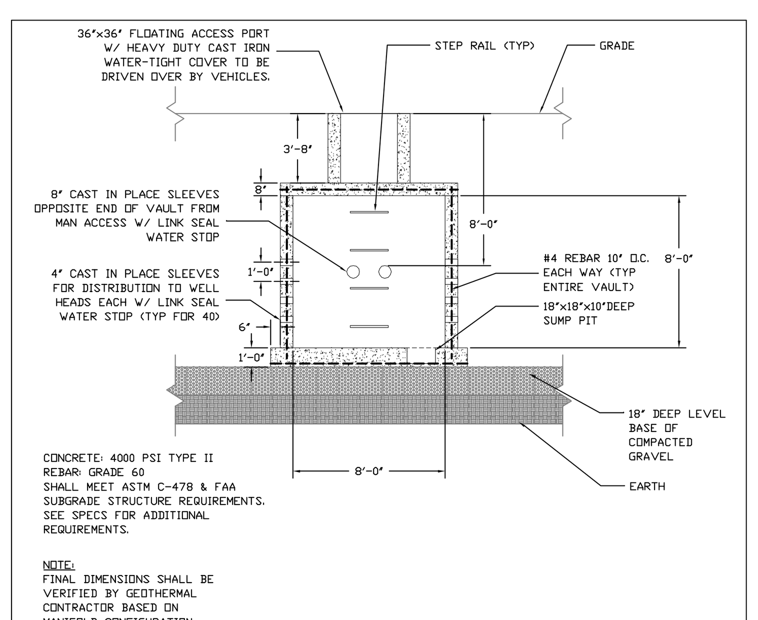


NOTE:
TEST BORE LOCATIONS #1 & #2 ARE EXISTING 500' FT DEEP X 6" DIAMETER BORES USED FOR THERMAL CONDUCTIVITY TEST. BORE TO BE REUSED FOR GEOTHERMAL FIELD. THIS CONTRACTOR SHALL PIPE FROM BORE HEAD TO VAULT, RESTEST FOR FLOW & PRESSURE, AND INTEGRATE INTO GEOTHERMAL SYSTEM.

GEOTHERMAL SITE PLAN
SCALE: 1/16"=1'-0"



MANHOLE MANIFOLD DETAIL
(TYP.)
N.T.S.



CONCRETE: 4000 PSI TYPE II
REBAR: GRADE 60
SHALL MEET ASTM C-478 & FAA SUBGRADE STRUCTURE REQUIREMENTS. SEE SPECS FOR ADDITIONAL REQUIREMENTS.

NOTE:
FINAL DIMENSIONS SHALL BE VERIFIED BY GEOTHERMAL CONTRACTOR BASED ON MANIFOLD CONFIGURATION.

TYPICAL GEOTHERMAL MANIFOLD VAULT DETAIL
NO SCALE

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DULUTH INTERNATIONAL AIRPORT
DULUTH, MN

NEW PASSENGER TERMINAL
VALE PROGRAM

CONSULTANTS

Structural Engineers:
MBJ CONSULTING ENG.
501 Lake Avenue South, Suite 300, Duluth MN 55802
TEL: (218) 722-1056 / FAX: (218) 722-9306

M/E/P/FP Engineers:
COSENTINI ASSOCIATES INC.
1 South Wacker Drive, 37th Floor, Chicago IL 60606
TEL: (312) 201-7400 / FAX: (312) 201-0031

REVISIONS

NO.	DESCRIPTION	DATE
1	ADDENDUM #1	06.16.11
2	ADDENDUM #2	06.21.11

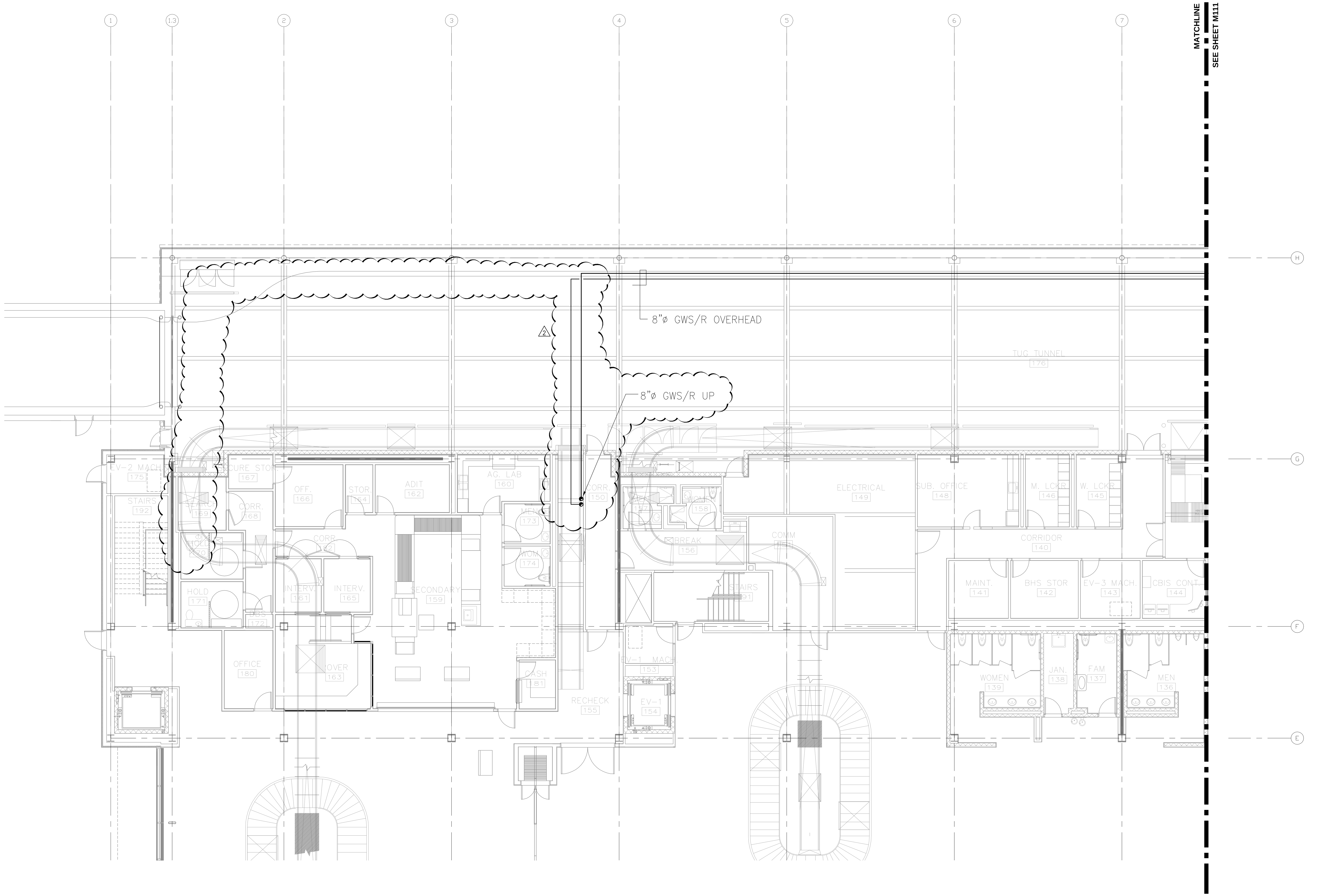
DATE ISSUED: 06-06-11
REVIEWED BY: BR
DRAWN BY: GB
DESIGNED BY: BR

AEP PROJECT NUMBER
213-1882-110

SHEET TITLE
GEOTHERMAL SITE MECHANICAL PARTIAL PLAN

SHEET NUMBER
M-102

VALE PROGRAM BID PACKAGE



GEOTHERMAL FIRST FLOOR MECH. PLAN
SCALE: 1/8"=1'-0"

N

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NO.	DESCRIPTION	DATE
2	ADDENDUM #2	06.21.11

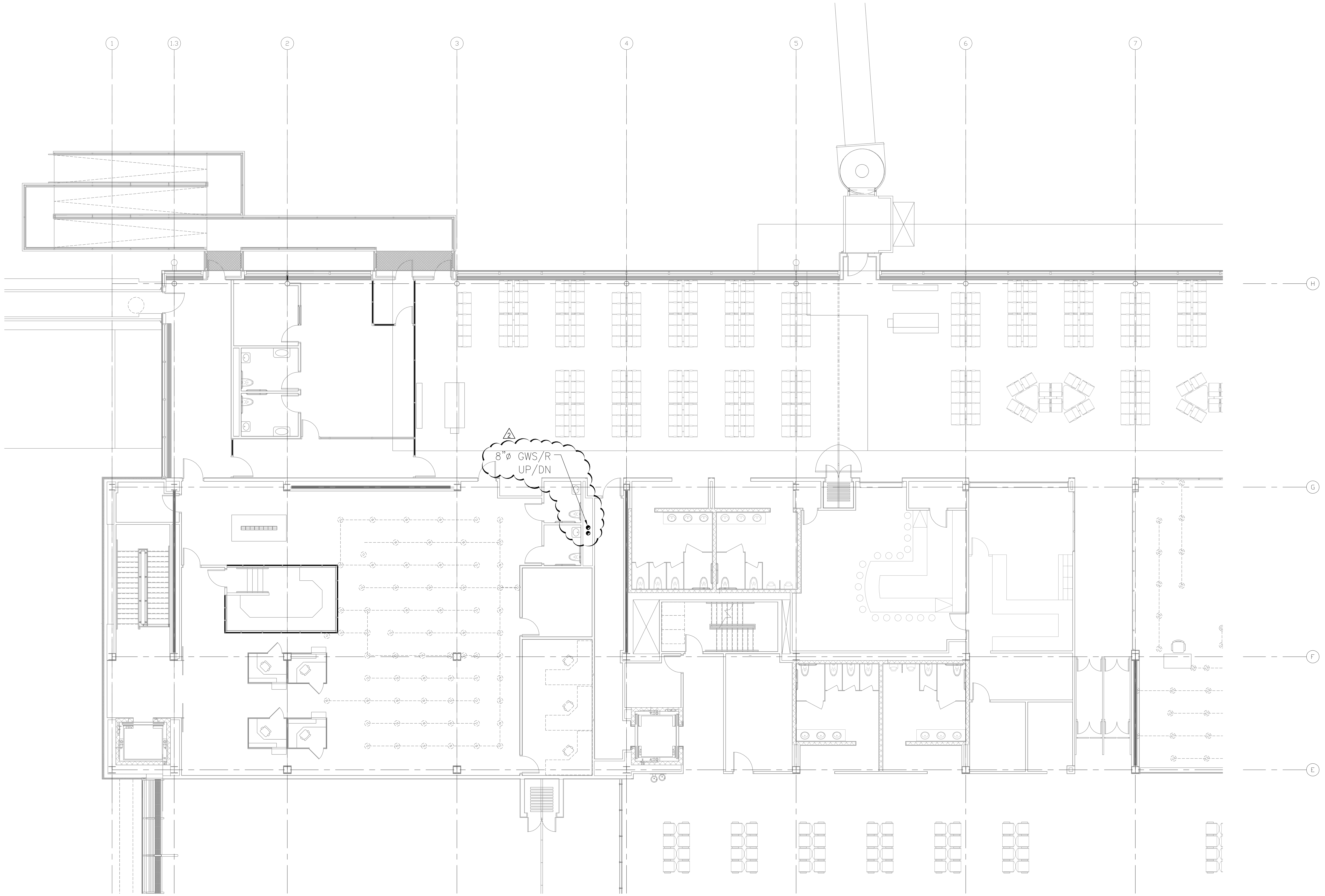
DATE ISSUED: 06-06-11
REVIEWED BY: BR
DRAWN BY: GB
DESIGNED BY: BR
AEP PROJECT NUMBER
213-1882-110

SHEET TITLE

GEOTHERMAL FIRST FLOOR MECHANICAL PLAN AREA A

SHEET NUMBER
M-110

VALE PROGRAM
BID PACKAGE



GEOTHERMAL SECOND FLOOR MECH. PLAN
SCALE: 1/8"=1'-0"

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2	ADDENDUM #2	06.21.11

DATE ISSUED: 06-06-11
REVIEWED BY: BR
DRAWN BY: GB
DESIGNED BY: BR

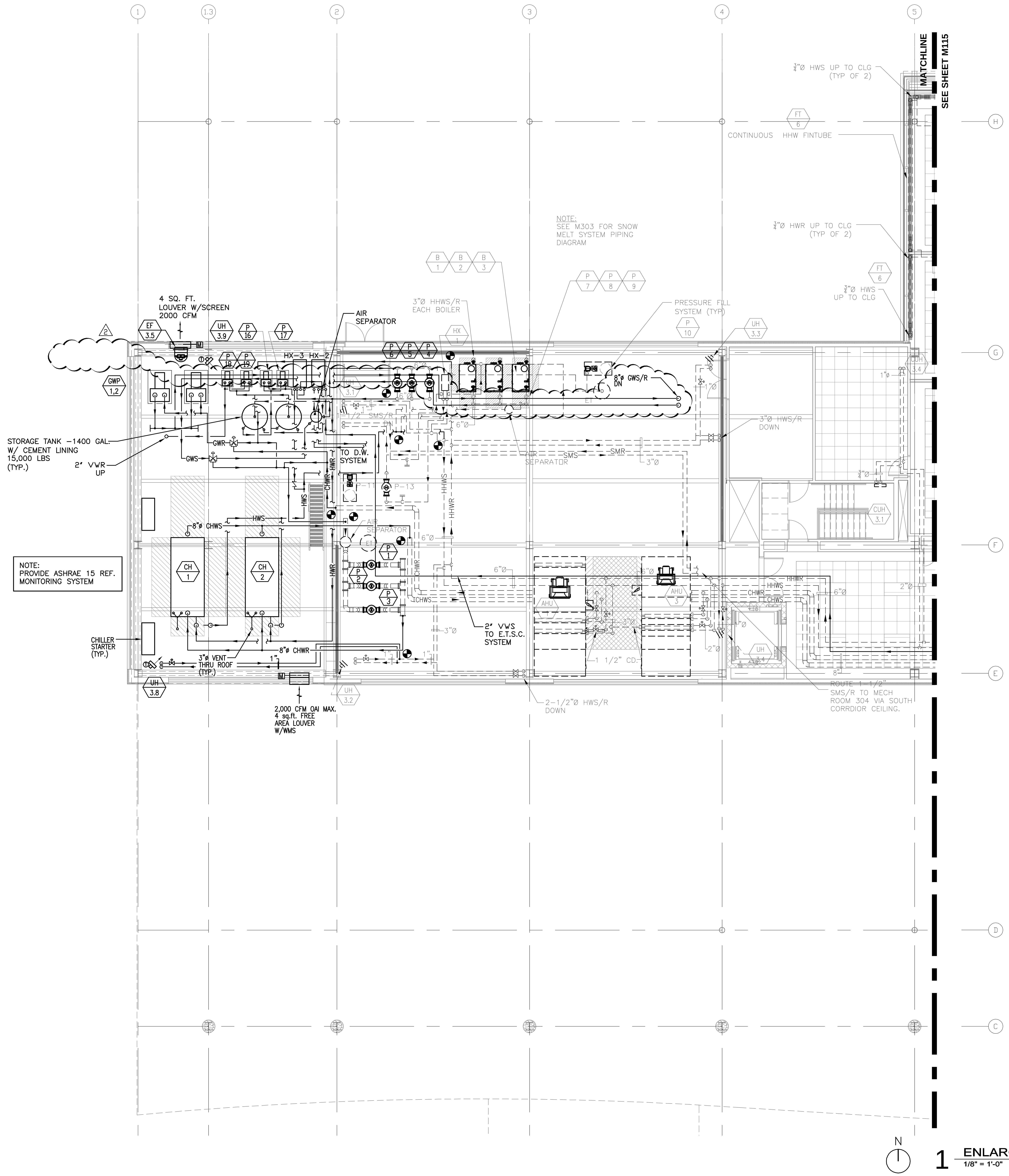
AEP PROJECT NUMBER
213-1882-110

SHEET TITLE
GEOTHERMAL SECOND FLOOR MECHANICAL PLAN AREA A

SHEET NUMBER
M-112

VALE PROGRAM
BID PACKAGE

Drawing: I:\5528.00 Duluth Airport\5.0 CADD\(5.d) HVAC\VALE DWGS\552803_M112.dwg Plotted on: 6/21/2011 11:23 AM Plotted by: Brandl, Mark



1 ENLARGED THIRD LEVEL PLAN - AREA A
1/8" = 1'-0"

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REVISIONS

NO.	DESCRIPTION	DATE
2	ADDENDUM #2	06.21.11

DATE ISSUED: 06-06-11
REVIEWED BY: MXB
DRAWN BY: MB/JH
DESIGNED BY: MXB

AEP PROJECT NUMBER
213-1882-110

SHEET TITLE
ENLARGED THIRD FLOOR MECHANICAL PIPING PLAN - AREA A

SHEET NUMBER
M114

VALE PROGRAM
BID PACKAGE