SPECIAL PROVISION
FOR
GEOTECHNICAL INSTRUMENTATION

Des Moines County
NHSX-061-2(66)--3H-29

Effective Date
September 19, 2023

THE STANDARD SPECIFICATIONS, SERIES 2015, ARE AMENDED BY THE FOLLOWING MODIFICATIONS AND ADDITIONS. THESE ARE SPECIAL PROVISIONS AND THEY SHALL PREVAIL OVER THOSE PUBLISHED IN THE STANDARD SPECIFICATIONS.

159020.01 DESCRIPTION

A. Scope of Work.
In accordance with contract documents, furnish all labor, materials and equipment required to furnish, install, protect, maintain and monitor instrumentation consisting of six vibrating wire piezometers, three vibrating wire data loggers and remote sensing, near real-time, automated data acquisition system, which includes three monitoring stations.

B. Definitions.
Instrumentation: various sensors, instruments, or systems used to measure piezometric trends (pore water pressure changes), and temperature.

Monitoring: the measurement of instrumentation, as well as the transmission, reduction, presentation, and evaluation of the instrumentation data.

Instrumentation Program: general specifications, details, and plans regarding instrumentation (and associated monitoring). Also, general reference to the full instrumentation and monitoring system.

Geotechnical Instrumentation Engineer: personnel (hired by the Contractor) responsible for proper installation and performance of both field components and the web-based data presentation and reporting system, as well as instrumentation deliverables and documents.

Vibrating Wire (VW): a type of instrumentation sensor technology, manufactured by GEOKON, Inc., RST, Inc., or approved other, known for its long-term performance and resilience.

VW Piezometer (PZ): a sensor customarily installed and sealed within a borehole; used to measure piezometric pressure (pore water pressure), which can be converted to the effective groundwater table elevation (piezometric head or hydraulic head).

Communication Cable: (also referred to as Data Cable) the data transmission wire pre-attached to an automated sensor by its manufacturer, with exposed leads or plugs that can be manually

measured or connected directly to a datalogger or cloud-connector (usually routed through conduit) for automated monitoring.

VW Datalogger: physical hardware, manufactured by GEOKON, Inc., or RST, Inc., that automatically measures the vibrating wire instrumentation sensors (vibrating wire communication cables are connected to this, and this connects to a THREAD)

THREAD: physical hardware, manufactured by Sensemetrics, Inc. (THREAD V3 or X-Series), or approved equivalent, that automatically and immediately transmits instrumentation data (from VW dataloggers) through a wireless mesh and/or cellular network to the cloud, whereby data is automatically and remotely reduced, presented, and accessible via a secure, web interface hosted by Sensemetrics, Inc., or approved other.

Monitoring Station (MS): a pole-mounted arrangement, assembled by the Geotechnical Instrumentation Engineer, located at each designated instrumentation cross-section, consisting of a solar panel, VW datalogger, THREAD, cable connections, and mounting hardware.

Automated Data Acquisition System (ADAS): all monitoring station components (solar panel, VW dataloggers, and THREADs) and the online Sensemetrics monitoring system, working together to provide automated instrumentation measurements, accessible via a near real-time, customized web interface.

Instrumentation Cross-Section: a specific area of the project where a series of instrumentation will be installed and monitored;

- US 61 Station 2004+00
- US 61 Station 2019+70
- US 61 Station 2035+50

C. Purpose.

Instrumentation is implemented to monitor performance of embankments and engineered subgrades, using automated pore water pressure (via VW Piezometers). The purpose of the VW piezometers is to monitor excess pore water pressures in the soil to confirm that primary consolidation is complete, the rate has stabilized, and that clay gained enough shear strength to allow staged construction. Automated instrumentation will remain in use after embankment construction and into the warranty period, to monitor long-term embankment performance.

D. Qualifications.

The Contractor shall hire a geotechnical engineering consultant (referred herein to as Geotechnical Instrumentation Engineer) to procure, test, program, coordinate, install and monitor all appropriate instrumentation, appurtenances and monitoring systems. The Geotechnical Instrumentation Engineer will meet the following requirements:

- Demonstrate experience with the specified instrumentation on two long term instrumentation and monitoring projects, utilizing required sensors and monitoring systems, in the past 5 years.
- Professional Engineer registered in the State of Iowa.

Provide such record of experience to the Engineer no later than 1 month prior to delivering instrumentation, appurtenances, and monitoring systems to the project site, and before proceeding with any work.

E. Construction Requirements.

1. Submittals.

a. Record of Experience: submit documentation detailing the record of experience of the Geotechnical Instrumentation Engineer. At a minimum, this document shall detail the experience with the required performance instrumentation as specified under

QUALIFICATIONS and resumes of personnel that will be responsible for implementing the instrumentation and monitoring systems.

b. Instrumentation Methods Statement: submit an instrumentation methods statement (IMS) to the Engineer for review and approval. The IMS shall be submitted 1 month prior to procuring and/or installing any instrumentation, appurtenances, and/or monitoring systems, or with sufficient time without impacting the construction schedule. The IMS shall include, but not limited to:
   1) Installation, maintenance and monitoring methods and procedures, including; final proposed location of all instrumentation and monitoring stations, sequence of instrumentation installation, specific methods for maintenance, protection, repair, and replacement of instrumentation (including anticipated timeline for such activities), detailed description of ADAS (including method for implementing and accessing the instrumentation monitoring website), detailed description of the hand-off of ADAS to Engineer and any proposed modifications to the proposed plans.
   2) Model numbers and catalog data sheets for all proposed instrumentation, including proposed cable lengths.
   3) Instrumentation plan (map) relative to the project containing sensor and monitoring station locations, including proposed modification to proposed plans.
   4) Example instrumentation installation records and wiring diagrams.

c. Installation Records: submit a completed installation record for each instrumentation sensor installation, within 1 week following its installation. Each installation record shall have a description of the location plan-view, a sketch or diagram of the sensor, the sensor ID number, the date it was installed, all relevant baseline information, the GPS coordinates, elevation and other important installation details. Complete a new installation data sheet for any repaired or replaced sensor.

d. Wiring Diagram: submit a completed wiring diagram for each monitoring station, within 2 weeks of the final connection. Each wiring diagram shall include a photograph and/or diagram of the ADAS components, with cables and wires labeled according to the unique instrumentation ID, and other important details. Including a physical copy of each diagram in the respective protective enclosure.

e. Data Monitoring: maintain ADAS such that Engineer can access data at anytime, to download and view eliminating the need for reporting. The Geotechnical Instrumentation Engineer shall coordinate a training meeting to facilitate online access. All monitoring data shall be available for archival viewing or download until 6 months after instrumentation has been removed from the project.

2. Vibrating Piezometer Installer Requirements.

The vibrating wire piezometer installer will meet the following requirements:

a. Minimum five vibrating wire piezometer installations using a fully-grouted installation technique within the previous 2 years.

b. Ability to successfully drill a soil boring within the formation to the depth and size required to complete the installations.

159020.02 MATERIALS.

1. Vibrating Wire Piezometers.

a. Vibrating Wire (VW) Piezometers (PZ): Vibrating wire piezometers shall be standard, groutable, unvented, with stainless steel filters, and shall be Model 4500S as manufactured by Geokon, Inc., Model VW2100 as manufactured by RST Instruments, Ltd., Part number 52611030 as manufactured by Durham Geo Enterprises, Inc., or approved equal. The vibrating wire piezometer manufacturer shall have ISO 9001:208 certification. The vibrating wire piezometers shall fulfill the following requirements:

TABLE 1: Vibrating Wire Piezometer Requirements

Technical Specifications:	***Minimum Requirements:***
Standard Range	350 Kpa (50 psi)
Over Range	2 x rated pressure
Resolution	0.025% F.S.
Accuracy	± 0.1% F.S.
Nonlinearity	< 0.5% F.S.
Temperature Range	-20°C to +80°C
Length x Diameter	133 x 19.1 mm (maximum size)

b. Vibrating Wire Piezometer Communication Cables: Vibrating wire piezometer communication cables shall consist shielded cable with four 22-gauge tinned-copper conductors within a polyurethane jacket, as recommended, supplied, and connected to the sensor by the vibrating wire tiltmeter manufacturer.

c. Tremie Pipe: Tremie pipe shall consist of PVC (1 inch minimum diameter) with factory threaded flush joints, and will be used to both grout the boreholes from the bottom up and set the VW piezometers tip-down (adhered to the outside of the tremie pipe) at their specified depths.

d. Cement-Bentonite Grout: In order to support the "fully grouted" method for vibrating wire piezometer installation, cement-bentonite grout shall be composed of a mixture of water, Portland cement, and bentonite. The grout mixture shall meet:

TABLE 2: Cement-Bentonite Grout Mix Requirements

	Grout for Soft Soils	
Materials	***Weight***	***Ratio by Weight***
Water	75 gallons	6.6
Portland Cement	94 lbs (1 sack)	1
Bentonite	39 lbs. (as required)	0.4
Notes	When placed, cement-bentonite grout shall be in colloidal form attained by high speed mechanical mixing. Borehole grouted from bottom, filled to top.	

2. Vibrating Wire Analyzer.

The portable vibrating wire analyzer, used for gathering baseline readings, shall be manufactured by Campbell Scientific, Geokon, or approved equivalent. The VWA shall be available on site throughout the monitoring period for manual confirmation, as directed by Engineer.

3. Monitoring Stations.

Each instrumentation cross-section shall include one monitoring station, consisting of a pole-mounted assembly of hardware for automated embankment monitoring. Each monitoring station shall consist of three major monitoring-related products (and related appurtenances): a solar panel, a VW datalogger, and a THREAD or mesh-network data collection device.

a. Solar Panel: The ready-to-mount solar panel, supplied by the THREAD manufacturer, shall utilize renewable energy to power the THREAD (which will in turn power the VW datalogger) at each monitoring station.

b. VW Datalogger: Manufactured and quality tested through ISO 9001:2015, the VW datalogger, shall comprise a self-contained, 4-channel logger, connecting to the vibrating wire instrumentation installed beneath the embankment via their communication cable leads routed to the monitoring station. The VW datalogger shall be manufacturer-modified to connect to, and immediately transmit vibrating wire measurements to, the THREAD. A VW Datalogger-to-THREAD cable is required for each Monitoring Station.

Table 3: VW Datalogger Requirements

Technical Specifications:	***Minimum Requirements:***
Measurement Accuracy	±0.05% F.S. (450-4000 Hz)
Measurement Resolution	1 part in 20,000
Program Memory	24K Flash
Data Memory	320K EEPROM
Temperature Range	−30°C to +50°C
L × W × H	260 × 160 × 91 mm
VW Channels	4
Power	Direct connection to THREAD
Notes:	Must be customized by the manufacturer to connect to THREAD

At instrumentation locations where there are two or fewer instruments connecting to a THREAD, Geokon Model 8960-01C Addressable Vibrating Wire Interfaces can be used to connect the instruments directly to the THREAD without the use of a multi-channel VW datalogger.

c. THREAD: The THREAD shall connect to the VW datalogger—and power the GEOKON datalogger—while also automatically collecting the vibrating wire measurements immediately. Next, the THREAD, through its wireless/cellular antennas, shall transmit instrumentation data through a wireless mesh and/or cellular network to the cloud, whereby data is automatically, immediately, and remotely reduced, presented, and accessible via a secure, web interface hosted by Sensemetrics and managed by the Geotechnical Instrumentation Engineer.

4. Automated Data Acquisition System.

a. Monitoring Station Components: The hardware required for the ADAS, including the solar panels, VW Dataloggers, and THREADs, is specified in the previous section.

b. Sensemetrics Platform: The Sensemetrics cloud-based platform shall automatically retrieve the measurements collected on site by the VW Datalogger and THREAD, and immediately populate the online interface with near-real time data. The browser-based software interface shall be configured to communicate with each THREAD and calibrated according to sensor calibration certificates, baseline readings, and measured sensor elevations, such that measurements will be automatically reduced and presented in graphical and tabular form.

The online platform shall be monitored throughout construction through project completion through the warranty period. The online platform shall be decommissioned and archived such that the State can access instrumentation data for up to 1 year later (or until successful online transfer of data to Department).

F. References.

The following publications (and denoted extents) form a part pf these Specifications, and are either referred to herein by basic designation or their information is generally inferred:

- Mikkelson and Green, “Piezometers in Fully Grouted Boreholes.” Proceeding of FMGM 2003, Field Measurement in Geomechanics, Oslo, Norway, September 2003.
- GEOKON, Inc., “Table 1 showing Cement/Bentonite/Water ratio for two grout mixes.” Installation C, Instruction Manual, Model 4500 series Vibrating Wire Piezometers.

159020.03 CONSTRUCTION.

A. Preparation.

1. Confirmation Testing.

Prior to arrival on site for installation, all received instrumentation, cables, and appurtenances shall be inspected and tested for proper operation in accordance with the procedures recommended by the respective manufacturers. Any improper sensor function, or lack of continuity in the communication cables, shall be immediately repaired (or replaced) in accordance with manufacturer recommendations, and as approved by the Engineer. Dataloggers, modems, readout devices, and appurtenances shall be similarly inspected and tested, and if required, shall be repaired (or replaced). No additional time will be granted for any delays due to replacing/repairing damaged instrumentation or related components. Please include confirmation testing results in each submitted Installation Record.

2. Location.

The prospective (and installed) location of all instrumentation shall be staked or marked (and measured), with GPS coordinates recorded to the nearest 0.1 foot, and elevation survey accuracy to the nearest 0.01 foot.

B. Installation.

1. General.

The Geotechnical Instrumentation Engineer shall oversee all installations of vibrating wire piezometers and Monitoring Stations. The Contractor shall coordinate instrumentation installation, protection, and maintenance activities with the remainder of the Work. Unless otherwise approved by the Engineer, the installation of instrumentation relative to the construction sequence shall satisfy the requirements for items detailed herein and on the Plans.

2. Sequence.

The Sequence is where instrumentation fits into the bigger picture of the project; a chronology of various construction activities surrounding the various instrumentation installations. The subsequent section, Procedure, will describe the specific sequence (procedure) of the various instrumentation installations themselves.

Instrumentation installation activities are required at two distinct junctures during embankment construction and will need to fit into the general construction sequence as detailed chronologically below, in order to provide the Contractor and the Engineer with meaningful instrumentation data. The Engineer has the right to refuse payment for any instrumentation not installed at the appropriate juncture. The same general sequence applies to each instrumentation cross-section.

a. Before the embankment is constructed
    1) Subgrade corrections (i.e. topsoil removal, pavement removal, subcuts, etc.).
    2) Automated instrumentation (VW piezometers) installation, including drilling, instrumenting boreholes, installing monitoring station, and trenching in conduit and cable runs.
    3) ADAS testing; fully functional via the Sensemetrics online platform. Trench backfilled. ADAS tested again.
    4) Hold period of at least 24 hours for fully grouted boreholes to set up; confirmed by piezometer measurement trends via online platform. Engineer will give go-ahead.
    5) Additional fill placement above the instrumentation. Construction traffic shall exercise caution within 2 vertical feet above instrumentation sensor locations and conduit. Advance fill placement is acceptable in areas 100 feet away from each GIMP cross-section. Protect monitoring station and immediate surroundings.
b. After the embankment is constructed
    1) Embankment construction continuing above automated embankment instrumentation, lift by lift.
    2) Waiting period commencement for embankment and/or preload monitoring, with ongoing surveying.

3. Procedure.

The installation procedures for all instrumentation and monitoring systems shall abide by the following, listed in order of precedence:

- Instructions and recommended best practices provided by the respective instrumentation and/or monitoring system manufacturer.
- The plans
- The Instrumentation Methods Statement (IMS)
- Project experience of the Geotechnical Instrumentation Engineer

The following discussion has been arranged per the Sequence section above (chronologically), highlighting the two distinct junctures and the three sets of instrumentation installations accordingly.

a. Borings
   1) Borings shall be drilled at the six piezometer locations within each instrumentation cross-section (beneath the left edge of embankment slope crest and right edge of embankment slope crest).
   2) Borings shall be drilled to the depth required to reach specified depth indicated in Instrumentation plan Q.34.
   3) Borings shall be logged, with boring logs submitted with their respective instrumentation installation record. Boring logs shall be logged per ASTM D2488 standard with sampling at 5 foot intervals.
   4) Each boring will contain one VW piezometer (six total)

b. VW Piezometers
   1) VW piezometers shall be installed at the depths shown on the instrumentation plans, according to the manufacturer's recommendations, and any modifications proposed (and accepted by the Engineer) in the IMS.
   2) VW piezometers shall be installed per the fully grouted method, per Article 159020.02, 1, d – Table 2.
   3) Baseline readings shall be recorded immediately prior to installation using the VW Analyzer.
   4) Piezometers shall be affixed to the tremie pipe at a location correlating to the specified depth, prior to grouting the borehole.
   5) Piezometer depths shall be recorded to the nearest 0.1 foot, including measurement from bottom of tremie pipe to affixed piezometer. Record tremie pipe quantity and lengths installed within borehole. Do not cut or modify any tremie pipes during/after installation.
   6) Borehole grouted from the bottom to top. Tremie pipe (with piezometer attached) abandoned in place. Borehole should be topped off with grout if subsidence occurs.
   7) Once borehole grout sets up, top of tremie pipe shall be surveyed for elevation to the nearest 0.1 foot, in order to back calculate installed piezometer elevation. All relevant measurements and baseline readings to be included on Installation Records. Top of tremie pipe section may be removed, or cut flush with grade, after surveyed elevation measurement.
   8) Communication cables from each piezometer shall run through separate protective schedule 40, 1 inch conduit to the monitoring station, and connect to the VW dataloggers.
   9) Protective conduit shall be embedded at least 2 feet below the finished ground surface, and feature strain-relief measures for both the cable and the conduit.

c. Monitoring Station and ADAS
   1) Monitoring stations shall be installed at the locations shown on the drawing according to the manufacturer's recommendations.
   2) Confirm field hardware connections to online platform configurations.

C. Monitoring and Maintenance.

1. General Maintenance.

The Contractor shall be responsible for all instrumentation maintenance, repairs, and replacements to ensure all instrumentation and monitoring systems are in proper working order and fully operational throughout the monitoring period, up until 1 year following substantial completion. The instruments and appurtenances shall be checked for proper operation in accordance with the procedures recommended by the respective manufacturers, or to the discretion of Engineer and/or State. Any instrumentation, ADAS components damaged by the Contractor, its Subcontractors, or others (i.e. from vandalism, weather, flooding, negligence, etc.), shall be immediately repaired or replaced at no cost to the Contracting Authority. The Engineer reserves the right to halt construction until non-working instrumentation and/or monitoring systems are repaired or replaced (Contractor is encouraged to keep extra sensors, spare components, and supplies on site). Instrumentation may only be decommissioned/transitioned as approved by the Engineer.

2. General Monitoring.

The Contractor and Geotechnical Instrumentation Engineer shall be responsible for monitoring all instrumentation at specified intervals, evaluating all instrumentation data, assisting decisions regarding instrumentation data, providing written recommendations, and immediately notifying the Engineer and State if there are data threshold exceedances, or if the ADAS has not been fully operational for a defined period of time. During construction, the Engineer will verify the construction instrumentation on an ongoing basis. Verification will include evaluation of the readings with respect to historical and/or anticipated readings, observe data trends, respond to the notification group concerning validity of automated alarms and/or instrumentation readings, and to immediately halt construction activities where necessary if a valid action level alarm has been exceeded (only permitting construction activities following Contractor corrective action acceptable to the Engineer or the Engineer accepts the risk of proceeding with given conditions).

3. Reading Frequencies.

In the absence of unusual events, the Contractor will be responsible for monitoring all instrumentation with 1 hour reading frequency. The Engineer reserves the right to increase or decrease reading frequencies at any time, requiring the Contractor to reprogram the dataloggers and online platform within 24 hours.

4. Notification Group

Designated Project personnel deemed the “Notification Group” will be identified upon commencement of the project, and are subject to receiving the automatic notifications and reporting. At a minimum, the Notification Group shall consist of two personnel each from the following parties: Contractor, Instrumentation Consultant, and Engineer.

5. Online Platform Configuration

The online interface, as accessed by Engineer, shall be customized, including:

- A map/plan, including project elements and sensor locations (that point to respective data graphs).
- VW Piezometer graphs, plotting piezometric head (elevation in feet) vs. time (with ability to toggle between normal time and logarithmic time).
- Monitoring Station diagnostic graphs, including voltage, temperature, barometric pressure vs. time.
- Automatic alerts consisting of automatic emails to the Notification Group, triggered by either data outages (any ongoing interruption longer than 12 hours for any sensor) and data thresholds.
- Notation on graphs of embankment construction filling and waiting periods, and other noteworthy items post-construction.
- Automatic weekly reports for the VW piezometers, including graphs (both normal and logarithmic time).

D. Decommissioning.
Maintain automated instrumentation and monitoring systems for 1 year following substantial completion of the embankment, or as directed by the Engineer. Written authorization from Engineer is required before any decommissioning may occur. Remove instrumentation according to manufacturer's recommendations, remove monitoring stations, solar panels, VW Dataloggers, THREADs and cables, and cut exposed metal mounting poles, conduits and VW poles, flush with the grade. deliver all equipment to the Department. All automated data shall be available for viewing or download until 6 months after the monitoring station decommissioning, or until virtual archival, or transfer to the Department.

159020.04 METHOD OF MEASUREMENT.
Measurement for Instrumentation and Monitoring will be lump sum.

159020.05 BASIS OF PAYMENT.
Payment for Instrumentation and Monitoring will be at the contract unit price per lump sum. Payment is full compensation for:

A. Authoring required submittals

B. Procuring all instrumentation, monitoring systems, and related appurtenances

C. Installing all instrumentation, monitoring systems, and related appurtenances, including but not limited to, vibrating wire piezometers, monitoring stations and a remote sensing, real-time, ADAS

D. Protecting, maintaining and monitoring all instrumentation, monitoring systems, and related appurtenances

E. Troubleshooting, repair and replacement of instrumentation, monitoring systems and related appurtenances

F. Initial set-up and ongoing service fee for online platform of ADAS

G. Configuration of online platform of ADAS

H. Data evaluation, analyses, reporting, communication recommendations and engineering time related to instrumentation data

I. Decommissioning all instrumentation, monitoring systems, and related appurtenances