UNIFIED FACILITIES GUIDE SPECIFICATIONS

References are in agreement with UMRL dated July 2023
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SECTION 33 51 43

INSTRUMENTATION AND PERFORMANCE MONITORING OF STRUCTURES

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SECTION 33 51 43

INSTRUMENTATION AND PERFORMANCE MONITORING OF STRUCTURES
05/22

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NOTE: This guide specification covers the requirements for instrumentation and monitoring for geotechnical and hydraulic structures.

Adhere to UFC 1-300-02 Unified Facilities Guide Specifications (UFGS) Format Standard when editing this guide specification or preparing new project specification sections. Edit this guide specification for project specific requirements by adding, deleting, or revising text. For bracketed items, choose applicable item(s) or insert appropriate information.

Remove information and requirements not required in respective project, whether or not brackets are present.

Comments, suggestions and recommended changes for this guide specification are welcome and should be submitted as a Criteria Change Request (CCR).

This guide specification is intended for use with construction contracts in which installation of instruments for monitoring performance of geotechnical and hydraulic structures (dams, levees, foundations, retaining structures, etc.) is required either during and/or following their construction or modification. It also includes data collection, management, and interpretation requirements. Typical items to monitor include, but are not limited to, water level, pore pressure, earth pressure, deformation, and load and strain in structural members. This section was originally developed for USACE Civil Works Projects.

Although not all instruments for monitoring geotechnical and hydraulic structures are included in this guide specification, and the state of practice continues to develop with new technologies,

more common instruments have been included.
****

PART 1 GENERAL

1.1 DESCRIPTION

Provide all plant, labor, equipment, and materials for the installation and maintenance of performance monitoring instrumentation for the duration of the contract. Provide all labor, equipment, and materials for data collection, data management, interpretation, and reporting unless otherwise specified.

1.1.1 Instrumentation and Monitoring Plan

Develop an Instrumentation and Monitoring Plan that outlines the project performance monitoring requirements, recommended thresholds values and response actions, as well as roles and responsibilities based on the requirements of this scope.

1.1.2 Supervision and Quality Control

Provide supervision and quality control to assure the accuracy, quality, timeliness, and completeness of the work. Provide all related and miscellaneous components and appurtenances to make the specified systems complete and functional. Perform all work in strict accordance with this section of the specifications and the applicable contract drawings.

1.1.3 Scope of Work

****
NOTE: The following tables have been included to summarize the scope of work. Edit these tables, and remove information and requirements not required in respective project, whether or not brackets are present.
****

The following tables summarize the instrumentation that is currently installed within the project area (Existing Instruments), instrumentation to be installed as part of the contract work (New Instruments), and instrumentation that is currently installed within the project area that is to be modified (Existing Instruments to be Modified).

Existing Instruments					
Instrument	Type	Model No.	Data Collection Method	Data Collection Frequency	Existing Quantity
[Piezometer]	[Vibrating Wire Piezometer]	[_____]	[Automated]	[Hourly]	[12]
[Piezometer]	[Standpipe]	[N/A]	[Manual]	[Monthly]	[5]
[Inclinometer]	[Traversing]	[_____]	[Manual]	[Quarterly]	[3]

Existing Instruments					
[Rain Gauge]	[Tipping Bucket]	[_____]	[Automated]	[Daily]	[1]

New Instruments to be Installed				
Instrument	Type	Data Collection Method	Data Collection Frequency	Existing Quantity
[Piezometer]	[Vibrating Wire Piezometer]	[Automated]	[Hourly]	[20]
[Piezometer]	[Standpipe]	[Manual]	[Monthly]	[5]
[Inclinometer]	[Traversing]	[Manual]	[Quarterly]	[2]
[Tilt Meter]	[Biaxial MEMS]	[Automated]	[Daily]	[1]

Existing Instruments to be Modified		
General Description	Data Collection Method	Quantity
[Retrofit existing standpipe piezometer with vibrating wire transducer]	[Automated]	[3]
[Change riser elevation of standpipe piezometer]	[Manual]	[2]
[Change riser elevation of manual inclinometer]	[Manual]	[2]
[Decommission inclinometer]	[Manual]	[1]

1.2 REFERENCES

****

NOTE: This paragraph is used to list the publications cited in the text of the guide specification. The publications are referred to in the text by basic designation only and listed in this paragraph by organization, designation, date, and title.

Use the Reference Wizard's Check Reference feature when you add a RID outside of the Section's Reference Article to automatically place the reference in the Reference Article. Also use the Reference Wizard's Check Reference feature to update the issue dates.

References not used in the text will automatically be deleted from this section of the project specification when you choose to reconcile references in the publish print process.

****

The publications listed below form a part of this specification to the

extent referenced. The publications are referred to within the text by the basic designation only.

AMERICAN SOCIETY OF MECHANICAL ENGINEERS (ASME)

ASME B40.100	(2022) Pressure Gauges and Gauge Attachments

ASTM INTERNATIONAL (ASTM)

ASTM D1785	(2015; E 2018) Standard Specification for Poly(Vinyl Chloride) (PVC), Plastic Pipe, Schedules 40, 80, and 120
ASTM D5640	(1995; R 2008) Standard Guide for Selection of Weirs and Flumes for Open-Channel Flow Measurement of Water
ASTM F480	(2014; R 2022) Standard Specification for Thermoplastic Well Casing Pipe and Couplings Made in Standard Dimension Ratios (SDR), SCH 40 and SCH 80

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

NFPA 70	(2023) National Electrical Code

U.S. ARMY CORPS OF ENGINEERS (USACE)

EM 1110-1-1002	(2012) Survey Markers and Monumentations
EM 1110-2-1908	(2020) Instrumentation of Embankment Dams and Levees
ER 1110-1-1807	(2014) Drilling in Earth Embankment Dams and Levees

1.3 DEFINITIONS

****

NOTE: Only use this paragraph to define terms used in this specification section that are not defined by a commercial or Government standard and to provide a common interpretation of a term for Contractual purposes. Remove any terms listed that are not used within this section and add terms as needed.

****

1.3.1 Automated Data Acquisition System (ADAS)

An Automated Data Acquisition System (ADAS) is a system of electronic devices that automatically collect, process, store, and transmit measurements from instrument sensors. An ADAS may include, but is not limited to the following components: dataloggers, vibrating wire analyzer, LMU/RMU, RIO, multiplexer, power, and communication hardware and service. The system also includes enclosures and mounts, software, and transient voltage surge suppressors.

1.3.2 Readout Unit

A readout unit is a device used to display measurements from an instrument. Some readout units also have data collection capability. The readout unit may be portable and connected to instrument terminals when monitoring is required (e.g. notebook computer, datalogger, or a proprietary system), or may be an on-line connection (fixed line or wireless) to a remote monitoring system.

1.3.3 Data Collector

A data collector is a device used to collect, store, and transfer recorded data from an instrument. A data collector may be a portable device or be located in-place at the instrument location. Data collectors may be equipped with remote data access.

1.3.4 Data Logger

A data logger is a device that can perform measurements at a prescribed interval, process the data from raw values to engineering units, store time-stamped data, and communicate with other devices.

1.3.5 LMU/RMU

Local monitoring unit (LMU) and remote monitoring unit (RMU) are electronic units comprised of a datalogger along with, but not limited to, associated power, communication equipment, and enclosure. They have both inputs to read sensors and outputs to control other devices. LMU/RMU can perform calculations, run programs that have been uploaded to it, and can interface with other LMUs and RMUs and a central control unit via some means of communications. It can hold and store data and then transmit it upon individual data calls or can be retrieved by a remote server via FTP on an as needed basis. LMU and RMU differ only in communication method. RMUs communicate via radio or some other method that designates them as remote from the central control unit.

1.3.6 RIO

A remote input output (RIO) unit is an automated measurement device without onboard data storage. It is comprised of a power supply, communication equipment (for transferring data to LMU/RMU), and enclosure. RIOs report instrumentation readings upon request from a LMU/RMU. A RIO unit may have a multiplexer attached to it.

1.3.7 Multiplexer

A multiplexer is a device used to allow several sensors to share one input channel of the LMU/RMU. This allows many more sensors to be read by one LMU/RMU. A multiplexer is used in conjunction with LMU/RMU software that controls which input channel is being read so that each sensor value is stored in the correct memory location.

1.3.8 Communications

Communications is a method used to allow two devices to "talk" to or exchange information with one another. This can be by wire, fiber optic cable, satellite, radio or other means. In every case there is a preferred "language" for sending the data. This is often referred to as

the "protocol". The protocol may be different for each sending method.

1.4 QUALITY ASSURANCE

In addition to using the current state of practice in the field of geotechnical and structural instrumentation and all manufacturer's recommendations for installation and operation; the following Codes, standards, regulations, and references apply for all features of the instrumentation system with the most stringent being applicable: NFPA 70 [, EM 1110-2-1908][_____].

1.5 MEASUREMENT AND PAYMENT

****

NOTE: When lump sum payment for work under this section is desired, revise these paragraphs accordingly. Delete these paragraphs when the work covered by this section is included in one lump sum contract price for the entire work covered by the Invitation for Bids.

If Section 01 20 00 PRICE AND PAYMENT PROCEDURES is included in the project specifications, appropriately edit this subpart, and move into Section 01 20 00. For bracketed items, choose applicable item(s) or insert appropriate information.

****

1.5.1 Method of Measurement

1.5.1.1 Readout Units

Readout unit quantities will be measured by each complete readout unit provided and any peripheral equipment or materials needed for them to perform their data collection function, such as batteries and terminal clips.

1.5.1.2 Data Collector

Data collector quantities will be measured by each complete data collector provided and any peripheral equipment or materials needed for them to perform their data collection function, such as batteries and terminal clips.

1.5.1.3 Instruments

Instrument quantities will be measured as follows:

a. [Open Tube Piezometer][Observation/Monitoring well]: by the linear foot from the instrument tip to the riser top. Any required length over a foot will be counted to the next foot for measurement. All materials for the installation, to include at a minimum, cap, screen, connectors, [PVC][steel] pipe, [vibrating wire instrument and wiring][_____], sand pack, bentonite for zone sealing, grout fill in rock; and granular fill in soil must be included in the payment per linear foot. Drilling of borehole is a separate pay item. Linear Foot (LF) per borehole location.

b. [Fully Grouted Piezometer][Closed Tube Piezometer] [one] [two]: per

borehole, by the linear foot from the bottom of the piezometer to the ground surface. Any required length over a foot will be counted to the next foot for measurement. All materials for the installation, to include at a minimum, the cap, screen, connectors, PVC pipe, vibrating wire instruments and wiring, and grout must be included in the payment per linear foot. Drilling of borehole is a separate pay item. Linear Foot (LF) per borehole location.

For the following instruments a complete installation means: All materials necessary to provide a fully functioning unit to include, but not be limited to, connection to surfaces, wiring and or wireless communication equipment, enclosures, batteries, as required to fully function with the specified readout and/or data collector device.

c. Vibrating wire instrument: by each complete installation. Each (EA)

d. Water level sensor: by each complete installation. Each (EA)

e. Staff gauge: by each complete installation. Each (EA)

f. Pipe Flow Meter: by each complete installation. Each (EA)

g. Weir: by each complete installation. Each (EA)

h. Flume: by each complete installation. Each (EA)

i. Weather station: by each complete installation. Each (EA)

j. Barometer: by each complete installation. Each (EA)

k. Automated Multiparameter Sonde: by each complete installation. Each (EA)

l. pH sensor: by each complete installation. Each (EA)

m. Turbidity meter: by each complete installation. Each (EA)

n. Temperature sensor: by each complete installation. Each (EA)

o. Conductivity meter: by each complete installation. Each (EA)

p. [Probe][Fixed Borehole]Extensometer: by the linear foot from the bottom of the borehole anchor to the top of the extensometer. Any required length over a foot will be counted to the next foot for measurement. Include all installation materials in the payment per linear foot. Drilling of borehole is a separate pay item Linear Foot (LF)

q. Settlement [Surface Points][Plates]: by each complete installation. Each (EA)

r. Borros Type Anchor: by the linear foot from the bottom of the point to the ground surface. Linear Foot (LF)

s. [Portable (Traversing)][Automated In-Place] Inclinometer Casing: by the linear foot from the bottom cap to the ground surface. Any required length over a foot will be counted to the next foot for measurement. All materials for the installation to include casing, cap, grout, inclinometer, and cable, and covers. Drilling of borehole

is a separate pay item. Linear Foot (LF) per borehole location.

t. [Portable (Traversing) Probe][Automated In-Place Sensors]: Each (EA)

u. Crackmeter/Jointmeter: by each complete installation. Each (EA)

v. Tiltmeter: by each complete installation. Each (EA)

w. Terrestrial Positioning System: by each complete installation. Each (EA)

x. Surface Monument: by each complete installation. Each (EA)

y. Survey Prism: by each complete installation. Each (EA)

z. Earth pressure cell: by each complete installation. Each (EA)

aa. Load cell: by each complete installation. Each (EA)

bb. Strain Gauge: by each complete installation. Each (EA)

cc. Signal Cable, Linear Foot (LF)

dd. Outdoor camera: by each complete installation. Each (EA)

ee. Seismograph: by each complete installation. Each (EA)

ff. Time Domain Reflectometer, Linear Foot (LF)

gg. Pendulum, Each (EA)

1.5.1.4 ADAS

The Automated Data Acquisition System (ADAS) will be measured on a lump sum basis. This does not include the individual instruments listed in the prior paragraph. This item includes all equipment, supplies, materials, and programming/configuration necessary for a fully functional ADAS which polls and communicates successfully with those data collection devices identified separately above. This item includes, but is not limited to, the following components:

a. Enclosures and mounts.

b. Data loggers.

c. LMU/RMU.

d. RIO.

e. Multiplexer.

f. Power.

g. Software.

h. Transient voltage surge suppressors.

i. Communication hardware and services.

1.5.1.5 General Instrumentation Requirements

General instrumentation requirements will be measured on a [lump sum][per month] basis.

1.5.1.6 Vibration Monitoring

Vibration monitoring will be measured on a [lump sum][per month] basis.

1.5.2 Basis of Payment

1.5.2.1 Readout Units

Payment will be made at the Base Bid contract line item price for each readout unit listed below, which price will constitute full compensation for providing the readout unit including factory calibrations, pre installation acceptance testing, any peripheral equipment or materials needed for them to perform their data collection function, instruction manuals, and delivery to the Government as specified:

****
NOTE: Revise the following list to only include readout units specified for your project.
****

a. [Open tube piezometer][Observation well]: water level indicator.

b. [Fully grouted piezometer][Closed tube Piezometer]: readout unit.

c. Water level sensor: readout unit.

d. pH sensor: readout unit.

e. Turbidity meter: readout unit.

f. Temperature sensor: readout unit.

g. Conductivity meter: readout unit.

h. [Probe][Fixed Borehole] Extensometer: reed switch probe, tape, and reel.

i. [Portable (Traversing)][Automated In-Place] Inclinometer: probe, carrying case, cable, readout unit, and software.

j. Crackmeter/Jointmeter: readout unit.

k. Tiltmeter: readout unit.

l. Earth pressure cells: readout unit.

m. Load cells: readout unit.

n. Strain Gauge: portable readout unit.

o. Signal Cable: readout unit.

p. Seismograph.

1.5.2.2 Data Collector

Payment will be made at the Base Bid contract line item price for each data collector listed below, which price will constitute full compensation for providing the data collector including factory calibrations, any peripheral equipment or materials needed for them to perform their data collection function, instruction manuals, and delivery to the Government as specified:

****

NOTE: Include a list of data collectors specified for your project. See prior paragraph for example format.

****

[_____]

1.5.2.3 Instruments

Payment will be made at the Base Bid contract line item price for each instrument listed below, which price will constitute full compensation for all materials left in place, all cable, labor, tools and equipment, instruction manuals, [drilling,][sampling,]pre installation acceptance testing, installation, post installation acceptance testing, installation of surface and other protection, determination of as-built location, and all incidentals necessary to complete the work in accordance with the plans and in every respect to the satisfaction of the Government:

a. [Open tube piezometer][Observation well]

b. [Fully grouted piezometer][Closed tube Piezometer]

c. Water level sensor

d. Staff gauge

e. Pipe Flow Meter

f. Weir

g. Flume

h. Weather station

i. Barometer

j. pH sensor

k. Turbidity meter

l. Temperature sensor

m. Conductivity meter

n. [Probe][Fixed Borehole] Extensometer

o. Settlement [Surface Points][Plates]

p. Borros Type Anchor

q. [Portable (Traversing)][Automated In-Place] Inclinometer

r. Crackmeter/Jointmeter

s. Tiltmeter

t. High Precision GPS Unit

u. Terrestrial Positioning System

v. Surface Monument

w. Survey Prism

x. Earth pressure cell

y. Load cell

z. Strain Gauge

aa. Signal Cable

bb. Outdoor camera

cc. Seismograph

1.5.2.4 ADAS

The Automated Data Acquisition System (ADAS) will be paid for at the base bid contract lump sum price. This item includes all equipment, supplies, materials, programming/configuration, and labor to have a fully functional ADAS. This system must poll and communicate successfully with those data collection devices identified separately above such as fully grouted piezometers, weather stations, etc. This item includes, but is not limited to, the following components:

a. Enclosures and mounts

b. Data loggers

c. LMU/RMU

d. RIO

e. Multiplexer

f. Power

g. Software

h. Architecture

i. Transient voltage surge suppressors

j. Communication hardware and services

1.5.2.5 General Instrumentation Requirements

General instrumentation requirements provided will be paid for at the base bid contract [lump sum price][line item price per month]. This item includes the following:

a. Protecting and maintaining all instruments.

b. Repairing or replacing damaged instruments.

c. Storing and disposing of instruments.

d. Providing safe access to instruments for data collection by the Government.

e. Monitoring and data collection.

f. Interpreting data.

g. Presenting data.

h. All other items of work specified in this Section for which no separate bid item is provided.

1.5.2.6 Vibration Monitoring

Vibration monitoring will be paid for at the base bid contract [lump sum price][line item price per month] and includes provision of all material, labor, and equipment necessary to meet the requirements in this section, including, but not limited to the following:

a. Vibration Test Program and Report

b. Public meeting

c. Preconstruction and Postconstruction Condition surveys

d. Vibration monitoring and reports

e. Monitoring instruments for structural movement or settlement, vibration, and noise reduction mitigation measures

1.6 SUBMITTALS

****

NOTE: Review submittal description (SD) definitions in Section 01 33 00 SUBMITTAL PROCEDURES and edit the following list, and corresponding submittal items in the text, to reflect only the submittals required for the project. The Guide Specification technical editors have classified those items that require Government approval, due to their complexity or criticality, with a "G." Generally, other submittal items can be reviewed by the Contractor's Quality Control System. Only add a “G” to an item, if the submittal is sufficiently important or complex in context of the project.

For Army projects, fill in the empty brackets

following the "G" classification, with a code of up to three characters to indicate the approving authority. Codes for Army projects using the Resident Management System (RMS) are: "AE" for Architect-Engineer; "DO" for District Office (Engineering Division or other organization in the District Office); "AO" for Area Office; "RO" for Resident Office; and "PO" for Project Office. Codes following the "G" typically are not used for Navy, Air Force, and NASA projects.

The "S" classification indicates submittals required as proof of compliance for sustainability Guiding Principles Validation or Third Party Certification and as described in Section 01 33 00 SUBMITTAL PROCEDURES.

Choose the first bracketed item for Navy, Air Force and NASA projects, or choose the second bracketed item for Army projects.

****

Government approval is required for submittals with a "G" or "S" classification. Submittals not having a "G" or "S" classification are [for Contractor Quality Control approval.][for information only. When used, a code following the "G" classification identifies the office that will review the submittal for the Government.] Submit the following in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

SD-01 Preconstruction Submittals

Instrumentation Specialist; G[, [_____]], RO

Instrumentation and Monitoring Plan; G[, [_____]], RO

Permit Documentation; G[, [_____]], RO

Backups, Archiving, And Disaster Recovery Plan; G[, [_____]], RO

Seismologist/Vibration Consultant; G[, [_____]], RO

Vibration Monitoring Plan; G[, [_____]], RO

Preconstruction Condition Survey; G[, [_____]], RO

Drilling Program Plan; G[, [_____]], RO

Grounding And Lightning Protection Plan; G[, [_____]], RO

Quick Reference Guide; G[, [_____]], RO

Web Interface; G[, [_____]], RO

SD-02 Shop Drawings

Instrument Modification Report; G[, [_____]], RO

SD-03 Product Data

Factory Test Reports; G[, [_____]], RO

Riser Pipe; G[, [_____]], RO

Filter Pack Material; G[, [_____]], RO

Proprietary Data Determination Request; G[, [_____]], RO

Raw Data; G[, [_____]], RO

SD-05 Design Data

Method Statements; G[, [_____]], RO

Grout Mix Design; G[, [_____]], RO

SD-06 Test Reports

Pre-Installation Acceptance Tests; G[, [_____]], RO

Vibration Test Program And Report; G[, [_____]], RO

Vibration Complaint Report; G[, [_____]], RO

Monitoring Data Reports; G[, [_____]], RO

Deficiency Correction Report; G[, [_____]], RO

Instrument Alert Assessment; G[, [_____]], RO

Action Threshold Exceedance Report; G[, [_____]], RO

Daily Vibration Monitoring Reports; G[, [_____]], RO

Postconstruction Condition Survey; G[, [_____]], RO

Installation Record; G[, [_____]], RO

SD-07 Certificates

Seismologist/Vibration Consultant Qualifications; G[, [_____]], RO

Instrumentation Specialist Qualifications; G[, [_____]], RO

SD-08 Manufacturer's Instructions

Factory Test Reports; G[, [_____]], RO

SD-10 Operation and Maintenance Data

Installation; G[, [_____]], RO

Instrument Modification Report; G[, [_____]], RO

Operations Manual; G[, [_____]], RO

SD-11 Closeout Submittals

Instrument Removal List; G[, [_____]], RO

As-Built Drawings; G[, [_____]], RO

ADAS Final Report; G[, [_____]], RO

1.7 INSTRUMENTATION SPECIALIST

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NOTE: This position is essential for the successful completion of an instrumentation monitoring program. Geotechnical instrumentation is a specialized field and as such, a specialist is highly recommended for involvement in all aspects of the instrumentation program from selecting and purchasing instruments, installing them, collecting data, and analyzing that data. Typically, general construction contractors do not possess the in-house instrumentation expertise, and consequently often provide insufficient attention and resources to an instrumentation and monitoring program required during construction. Inclusion of an experienced instrumentation specialist often results in cost savings for both the contractor and the owner. The contract requirement for an experienced instrumentation specialist signals the importance of this work to the owner, and helps ensure all potential bidders include sufficient cost in their bids for this work. Further, the bid schedule could be configured to include estimated equipment costs and specialist labor hours instead of "1 Job" listing, or a lump sum cost developed by the owner could be included in the bid schedule to ensure adequate funding is allocated to this work after contract award. More preferably, this specialist would instead be acquired under separate contract by the owner and the general construction contractor required to coordinate work activities with this individual. In this case, the owner would pay the specialist for instrument selection and purchase, installation, and collection of data. The analysis of the data would then be the responsibility of the construction contractor, with review of their interpretation and recommendation being conducted by the instrumentation specialist on behalf of the owner. An instrumentation specialist may not be justified or required for smaller contracts.

For larger projects, consider also utilizing a Data Manager or Instrumentation Data Manager position. Requirements for these positions are described in Section 01 31 20 PROJECT TECHNICAL DATA MANAGEMENT AND VISUALIZATION.

For bracketed items, choose applicable item(s) or insert appropriate information.

****

1.7.1 General

Acquisition of reliable and high-quality data is the primary objective of the instrumentation specialist. This individual must be retained by the contractor for the duration of the work. Approval of an equivalent backup is required prior to the start of the work. Duties of the instrumentation specialist include selection of the instruments to be purchased by the Contractor; installation, calibration, and maintenance of that specialized equipment in the field; and acquisition and reporting of readings. Supporting work, which does not require specialized skills, may be performed by the construction contractor. See Section [01 31 20 PROJECT TECHNICAL DATA MANAGEMENT AND VISUALIZAION][_____] for requirements of the [Data Manager][Instrumentation Data Manager][_____] position.

1.7.2 Qualifications

The individual assigned as lead instrumentation specialist must be a registered Professional Engineer (PE) and recognized professional in the field of instrumentation and monitoring of geotechnical and hydraulic structures with over [5][10] years of work experience relevant to the scope and magnitude of work specified in this contract. An experienced alternate individual, not meeting the PE license requirement, may work under the direction and supervision of the PE to carry out all tasks of the instrumentation specialist, with exception of the selection of alert values, analysis of reported instrument readings, and directed response actions. A detailed, concise narrative describing the instrumentation specialist qualifications and relevant work completed by those experienced alternate individuals on a minimum of [3][_____] projects, within the last [7][_____] years, is required for Government review and approval. Likewise, equivalent backups meeting the aforementioned qualifications must be identified and included with the required submittal of the instrumentation specialist(s).

The responsibilities of the instrumentation specialist are selection of the instruments required for purchase for the work; installation, calibration, and performing necessary maintenance of that specialized equipment in the field; and compiling readings and reporting them. Supporting work, which does not require specialized skills, may be performed by the construction contractor, with prior approval of the Government.

1.7.3 Instrumentation and Monitoring Plan

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NOTE: EM 1110-2-1908 currently does not address concrete structures but is being updated to include.

****

An Instrumentation and Monitoring Plan must be prepared by the Instrumentation Specialist and submitted for Government approval a minimum of 30 days prior to any work being completed at the site. No physical work is to start at the site until this plan is approved by the Government. At a minimum, the Instrumentation and Monitoring Plan must address the following: responsibilities and authority for all phase of the monitoring program; types (including detailed manufacturer data), purpose, and location of each instrument; installation procedures (detailed below) and documentation; instrument reliability and limitations; calibration and maintenance, in accordance with manufacturer's requirements and EM 1110-2-1908; redundancy; backup

instruments/parts; baseline data; procedures for ensuring data validity; data collection frequency; visual observation; data processing and reporting including example tables and plots; and threshold values and response actions.

Include detailed method statements for installation of each type of instrument. Method statements must list the sequence of carrying out the work and include such dimensioned sketches, completed using computer-aided design and drafting (CADD) software, as may be required to illustrate the spatial or temporal relationship of the various components of the work. The method statements must include:

a. Method of pre-installation acceptance tests.

b. Description of quality control procedures.

c. Full details of both type and quantity of any equipment to be used.

d. Drillhole diameter, drill casing size, the method and sequence of withdrawing drilling casing.

e. Method of cleaning the inside of casing, where applicable.

f. Specifications for proposed grout mixes, including commercial names, proportions of admixtures and water, mixing sequence, mixing methods and duration, pumping methods and tremie pipe type, size and quantity and means of grout quality control.

g. Depth increments for backfilling drillholes with sand and/ or granular bentonite.

h. Method of overcoming buoyancy of instrumentation components during grouting.

i. Method of sealing joints in pipes, tubes, and inclinometer casing to prevent ingress of grout.

j. Method of conducting post-installation acceptance tests.

k. Method of protecting instruments from damage.

l. Method of determining as-built locations.

m. Method of field calibration and maintenance of each type of instrument.

n. Calibration and maintenance schedule for each type of instrument.

o. Method of supplying power, when applicable.

p. Method of monitoring each type of instrument, including method of identifying and eliminating any reading errors.

q. Method of carrying out temperature corrections and/or barometric pressure corrections, when applicable.

qr Method of data reporting for each type of instrument, including method of transmitting and storing data.

s. Drillhole record forms.

1.8 SEISMOLOGIST/VIBRATION CONSULTANT

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NOTE: Remove this individual and related paragraphs from this section if vibration monitoring is not included in the scope of your project.

****

1.8.1 General

An independent Seismologist/Vibration Consultant is required to monitor, record, analyze, and report the ground and noise vibrations being generated by construction activities. Such construction activities include, but are not limited to, [hauling,][excavation,][trenching,][blasting,][drilling,][fill and backfill placement,][compaction,][pile driving,]and other activities which may generate ground vibrations and noise. Within [60 calendar][_____] days of the Notice to Proceed, the Contractor must submit the Seismologist/Vibration Consultant along with names and resume of qualifications of the personnel dedicated to this project.

1.8.2 Qualifications

The Seismologist/Vibration Consultant must be a registered Professional Engineer with a minimum of [5][_____] years of experience, including a minimum of four projects of similar magnitude and subsurface conditions. This individual must have experience with assessing vibration monitoring and recording operations, interpreting ground vibration and sound data, determining parameter values for vibration attenuation through soil, analyzing ground motion spectra, and assessing the structural responses to vibrations. The Seismologist/Vibration Consultant qualifications also include experience with pre- and post-construction condition surveys of structures, familiarity with construction methods and materials, and knowledge of structural response to ground vibrations generated by construction activities. The Professional Engineer must sign and seal all reports, results, interpretations, and assessments obtained from vibration monitoring and structural condition surveys. The Professional Engineer must be on site and supervise the initial installation of each vibration monitoring instrument, [the Vibration Test Program][_____], [Public Meeting][_____], and [Preconstruction and Postconstruction Condition Surveys][_____].

A minimum of one on-site technician, working under direct supervision of the Seismologist/Vibration Consultant, must be on site full-time during the construction. The on-site technician must have a minimum of five years of experience in controlling and monitoring vibrations originating from construction activities and be experienced and trained to install and use vibration monitoring instrumentation and interpret the instrumentation data. Their experience and training must also include analyzing ground and sound vibration parameters, implementing proper monitoring and recording methods, knowledge of proper vibration control methods, capability to install and read supplemental instrumentation to monitor movement and settlement of structures.

1.8.3 Vibration Monitoring Plan

A Vibration Monitoring plan must be prepared by the Seismologist/Vibration Consultant and submitted by the Contractor [60 calendar][_____] days prior

to any on-site work.

The Vibration Monitoring Plan must include, but is not limited to, the following:

a. A description of the organizations and individuals that will be involved in the vibration monitoring activities, including planned duties, responsibilities and authorities of the organizations and individuals, and contact information for organizations and key individuals.

b. A description of the monitoring equipment in accordance with Paragraph VIBRATION MONITORING INSTRUMENTATION with example data output.

c. List established or estimated vibration limits (peak particle velocity at [25-foot][_____] distance) for the particular construction equipment and methods proposed. Provide evidence or justification that the proposed construction equipment and methods meets the specified vibration limits, in accordance with paragraph CONSTRUCTION VIBRATION CONTROL AND MONITORING.

d. A description of the location, methods, equipment, and procedures that will be used to perform Vibration Test Program on various construction equipment in accordance with paragraph VIBRATION TEST PROGRAM AND REPORT.

e. Provide an initial plan for typical setup and location of vibration monitoring equipment during various construction activities.

f. Provide description of any separate measures or methods required to reduce vibrations.

g. Provide procedure for addressing public complaints pertaining to construction vibrations, noise levels and potential damages. Include an example of a Vibration Complaint Report. Include a vibration screening procedure that includes both defining the problem and actions required to be taken.

1.9 SEQUENCING AND SCHEDULING

1.9.1 Scheduling Work

Install instruments and receive Government concurrence on formal initial readings prior to the start of related construction activities as detailed in paragraph BASELINE READINGS.

1.9.2 Vibration Monitoring Schedule

The frequency and duration of vibration monitoring for any construction activity must be performed in accordance with the approved Vibration Monitoring Plan. The Contractor must make all necessary arrangements for scheduling the Seismologist/Vibration Consultant. Construction activities requiring monitoring must not begin until the approved Seismologist/Vibration Consultant's on-site technician is onsite.

1.10 DATA REQUIREMENTS

1.10.1 Data Ownership

All data generated on site by instrumentation, monitoring, construction equipment, sampling, testing, and other data associated with the construction of the project is the property of the Government. For any data the Contractor wishes to exclude from the system, submit a Proprietary Data Determination Request including detailed justification to the Government for determination of whether data can be classified as proprietary. No data source is exempt from these data requirements unless a specific exemption is requested of and granted by the Government. Do not allow "proprietary data" to impede the Government's ability to monitor construction, perform analyses, or evaluate the effectiveness of construction.

1.10.2 Data Integrity

Maintain the integrity of data such that records are accurate and internally consistent. Ensure that all data and records reflect the quality of the data gathered on the site and that all data is preserved and archived for future use.

1.10.3 Backups, Archiving, and Disaster Recovery

Minimize data loss by backup and archival of all digital and paper data records from the time of data generation until final data turnover. This includes having specific policies, workflows, and infrastructure in place to archive and have redundant backups on servers in either the cloud or multiple locations according to industry standard practice. Detail this information in a Backups, Archiving, and Disaster Recovery Plan submittal for Government review and approval prior to the start of work.

If a data loss occurs, the Contractor is responsible for regeneration of the data. Any data which is re-generated from a non-primary source must be clearly noted in the record shown in the [EDB][_____]. Backup data within [24 hours][_____] of generation. Should a data loss occur, even if it is within this [24-hour][_____] window, the Contractor is responsible for all steps necessary to recover from this data loss and will receive no additional payment for these data recovery efforts.

1.10.4 Disclosure of Data or Advertisement of Project

Do not disclose any project data to third parties, and do not publish any data without prior written approval of the Government. This includes, but is not limited to, published papers or presentations to any third parties not associated with this contract.

1.11 DELIVERY, STORAGE, AND HANDLING

Deliver all instrumentation materials to the site in undamaged condition and store in an indoor, clean, dry, and secure storage space, that is approved by the Government, after receipt at the site and prior to installation. Instrument components must not be exposed to temperatures outside the manufacturer's stated working temperature range. The materials, instruments, and hardware must be stored, handled, and installed in such a manner as to preclude damage. The Contractor must restore or replace, at no cost to the Government, any items damaged or lost during storage, handling, or installation.

PART 2 PRODUCTS

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NOTE: The Buy American Act (BAA), which will be included in the non-technical portion of the contract, will preclude the use of nondomestic products, with the exception of those produced in Canada and 46 other countries covered by the revised World Trade Organization Agreement on Government Procurement (WTO GPA). The Buy American Act applies to all U.S. federal government agency purchases of goods valued over the U.S. micro-purchase threshold (currently set at US $10,000). Ensure that all products listed below meet the requirements of the BAA.

For bracketed items, choose applicable item(s) or insert appropriate information.

****

2.1 GENERAL

All products in this section must conform to the requirements indicated on the Drawings, or specified herein, to adequately monitor the condition and record data to ensure performance parameters are met. A summary of existing instruments at [_____], including those to be modified, as well as new instruments to be installed as part of this contract are included in tabular format in paragraph DESCRIPTION above.

All products must be the standard products of a manufacturer regularly engaged in the manufacture of such.

All components provided for connection with an existing automated data acquisition system (ADAS) must function properly with that system, if it's specified to remain in operation, or with a new system, if one is specified for installation.

2.2 MATERIALS

2.2.1 General

All materials must conform to the Buy American Act. They must be new and meeting the requirements indicated on the drawings or referred to herein, and, when not covered thereby, materials and equipment of commercial grade quality suited to the intended use and as approved by the Government must be furnished. All materials must be compatible and match the existing equipment at the project location, if applicable. If multiples of the same instrument are required, use the same manufacturer for each.

2.2.2 Instrument Factory Calibration

A factory calibration must be conducted on all instruments at the place of manufacture prior to shipment. For each factory calibration include a calibration curve with data points clearly marked and a tabulation of the data and required formulae for data reduction. Ensure each instrument is marked with a unique identification number or serial number. Provide the manufacturer's [warranty][extended warranty] for each instrument and readout unit. Submit required factory test reports to the Government for

approval.

2.3 PORE-PRESSURE AND GROUNDWATER MONITORING

2.3.1 [Open-Tube Piezometer][Observation/Monitoring Well]

****

NOTE: Open-tube piezometer construction is similar to observation/monitoring well construction and are included together herein. Piezometers represent a point water pressure measurement while observation/monitoring wells represent an integrated water pressure measurement over the screened interval. Piezometers can have an open bottom or short screen interval (porous tube). A Vibrating Wire or Pressure Transducer can be installed within the open-tube to allow remote reading.

****

[2.3.1.1 Porous Tip/Casagrande Filter

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NOTE: A porous tip is commonly used for open-tube piezometer sensing (water intake) zone but can also be slotted or perforated screens as included below in brackets. Slotted screens are more commonly used for observation/monitoring wells.

****

For porous tip or Casagrande filter, provide high-density polyethylene plastic with 60 micron pores meeting the requirements shown on the drawings. Each porous tube must be free from contamination by dirt, mud, oil, or any other substance which in the Government's opinion may contribute to the reduced performance of the instrument. Porous tips with any oil or mud smears will be considered unsatisfactory for installation and must be replaced at the Contractor's expense. Instruments, which have been contaminated, must be properly abandoned and replaced at the Contractor's expense. Immerse each tip in water for not less than 24 hours before installation. No glues or primers are permitted on the porous portion of the tips.

[2.3.1.1.1 Stainless Steel Screen

Provide [continuous wire-wound non-clogging stainless steel screen][drive-in stainless steel filter] with threaded couplings of the specified screen length, [slot width][opening size] and screen diameter as shown on the drawings. For PVC wire wrapped screen, it must be continuous, wire-wound PVC, non-solvent welded with threaded couplings which must mate with the PVC casing.

][2.3.1.1.2 Slotted Screen

Construct slotted screens of flush-joint Schedule [40][80] PVC conforming to the requirements of ASTM D1785 and ASTM F480. Determine slot diameter, spacing, and screen length based on hydrologic conditions, analysis of formation materials, or interpretation of geotechnical logs, if no specific requirements are included on the drawings.

][2.3.1.1.3 Perforated Screen

Provide perforated screens consisting of Schedule [40][80] high-density polyethylene plastic conforming to the requirements of ASTM D1785 and ASTM F480 and as detailed on the drawings. Each screen must be free from contamination of dirt, mud, oil, or any other substance which in the Government's opinion may contribute to the reduced performance of the instrument. Any screen material with mud smears will be considered unsatisfactory for installation and must be replaced at the Contractor's expense. Instruments, which have been contaminated, must be properly abandoned and replaced at the Contractor's expense.

]]2.3.1.2 Riser Pipe

Provide riser pipe consisting of PVC or stainless-steel well casing. PVC pipe must be watertight, flush-joint schedule [40][80] conforming to the requirements of ASTM D1785 and ASTM F480 and as detailed on the drawings. Provide glue and primer for assembly of the piezometer tip and pipe as recommended by the manufacturer.. Steel well casing must be threaded and coupled black carbon steel pipe with no mill coating and a minimum wall thickness of 6 mm 0.237 inches.

2.3.1.3 Sump or Cap/Bottom Plug

For bottom plug, provide Schedule [40][80] PVC with a flush-joint coupling, or approved equivalent. For a steel bottom plug, provide a threaded and coupled black carbon steel Schedule 40 with no mill coating. An end cap may also be attached directly to the bottom of the screen or sump.

2.3.1.4 Centralizers

Attach centralizers, constructed of PVC or stainless steel, to the riser pipe with clamps. Centralizer ribs must have sufficient strength to adequately center the riser pipe in the drill hole. Centralizers for steel surface casing may be carbon steel and welded to the casing.

2.3.1.5 Filter Pack Material

****

NOTE: Provide the required gradation of filter pack material based on the screen size of the instrument being installed. Typically, an allowable range is given for each sieve size listed for a particular gradation. Common gradations for silica sand from manufacturers are 6-9, 8-12, 8-16F, 10-20, 16-30, 20-40; modify these tables as needed.

****

Provide filter pack material of uniformly graded silica sand of grade [_____] provided below and dimensioned as shown on the drawings. Filter material must consist of washed, clean, uniform, tough, and durable particles free from any coating. The filter material must not contain any detrimental impurities or soft, friable, thin, or elongated particles. Submit filter pack material source, gradation, and quality test result information to the Government for review and approval prior to installation.

GRADE 6/9 TYPICAL SIEVE ANALYSIS			GRADE 8/12 TYPICAL SIEVE ANALYSIS		
SIEVE	PERCENT RETAINED	PERCENT PASSING	SIEVE	PERCENT RETAINED	PERCENT PASSING
No. 4	0.1	99.9	No. 4	0.49	99.5
No. 6	1.4	98.5	No. 6	23.85	75.7
No. 7	19.2	79.3	No. 7	38.39	37.3
No. 8	64.1	15.2	No. 8	29.94	7.3
No. 10	14.1	1.1	No. 10	6.73	0.6
No. 12	0.9	0.2	No. 12	0.52	0.1
PAN	0.2	0.0	PAN	0.058	0.0

GRADE 8/16F TYPICAL SIEVE ANALYSIS			GRADE 10/20 TYPICAL SIEVE ANALYSIS		
SIEVE	PERCENT RETAINED	PERCENT PASSING	SIEVE	PERCENT RETAINED	PERCENT PASSING
No. 6	0.0	100.0	No. 8	0.0	100.0
No. 8	2.6	97.4	No. 12	0.1	99.9
No. 10	23.5	73.9	No. 14	12.1	87.8
No. 12	29.4	44.5	No. 16	31.4	56.4
No. 14	30.3	14.2	No. 18	32.8	23.6
No. 16	12.5	1.7	No. 20	17.3	6.3
No. 18	1.5	0.2	No. 30	5.9	0.4
PAN	0.2	0.0	PAN	0.4	0.0

GRADE 16/30 TYPICAL SIEVE ANALYSIS			GRADE 20/40 TYPICAL SIEVE ANALYSIS		
SIEVE	PERCENT RETAINED	PERCENT PASSING	SIEVE	PERCENT RETAINED	PERCENT PASSING
No. 12	0.0	100.0	No. 16	0.0	100.0
No. 16	0.4	99.6	No. 20	0.6	99.4
No. 18	4.3	95.2	No. 25	8.1	91.4
No. 20	50.8	44.4	No. 30	40.8	50.6

GRADE 16/30 TYPICAL SIEVE ANALYSIS			GRADE 20/40 TYPICAL SIEVE ANALYSIS		
No. 25	39.3	5.1	No. 35	39.8	10.8
No. 30	4.8	0.4	No. 40	9.3	1.6
No. 40	0.4	0.0	No. 50	1.5	0.1
PAN	0.0	0.0	PAN	0.0	0.0

2.3.1.6 Seal Material

Seal material must be coated bentonite pellets, from naturally occurring sodium bentonite, sized 3/8 to 1/2-inch in diameter. Angular chips, uncoated pellets, or other bentonite products may be used with prior approval from the Government.

2.3.1.7 Backfill Material

Backfill material may be impervious clay, bentonite, or a nonshrinking, low permeability grout, placed by tremie method. Place backfill material to the depth and thickness identified in the drawings. Grout must have a mix specific gravity, prior to placement in the borehole, of between [1.03 and 1.10][_____]. If used, bentonite must be hydrated in accordance with the manufacturer's recommendation.

2.3.1.8 Protective Casing

Provide protective casing of either [eight][twelve]-inch diameter or square steel pipe with a minimum 0.250-inch wall thickness, with threaded and coupled ends with no mill coating and a locking flip cap of either steel or aluminum [square]. Steel protective casing must be painted [_____]. Casings must be cleaned by power tool or wire brush prior to painting. The first coat must be brush or spray applied in the shop or field, as indicated, with a Steel Structures Painting Council Paint 25 (Zinc Oxide, Alkyd, Linseed Oil Primer) and touched up in the field as necessary during installation. Apply second and third coats in the field using P-38 (aluminum, ready mixed) type paint.

2.3.1.9 Protective Bollards

Dome capped protective bollards must be [76 mm][152 mm] [3-inch][6-inch] diameter [steel] [galvanized] pipe with a minimum 6 mm 0.250-inch wall thickness. Embed bollards a minimum depth of 76 cm 30 inches below the final grade. Paint steel bollards [_____].

2.3.2 Fully Grouted Vibrating Wire Piezometer

****

NOTE: There are several methods of installing vibrating wire piezometers, A: in a sand filter with a bentonite seal above, then grouted to fill the hole, B: in a sand filter with grout to the top of the hole, C: fully grouted with a cement bentonite grout, D: lowered into a conventional porous tip or slotted screen and associated standpipe. Method D is useful for retrofitting existing instruments or for long term monitoring. It also allows for

calibration or replacement of the vibrating wire sensor as needed. Method C is the most responsive and is good for shorter term monitoring and has the benefit of not being able to have the filter sand or tip contaminated with grout. Methods A, B and C, cannot be re-calibrated or verified and are a total loss if damaged.

****

2.3.2.1 Vibrating Wire Piezometer

Provide quality pore pressure monitoring devices (vibrating wire pore pressure piezometer) including all cables, wiring connections, splice kits, desiccant chambers (if vented sensors are used), vibrating wire transducer, readout unit, and [data logger][data collector] from a reputable manufacturer that has been in the business for [5][_____] years or more. Each vibrating wire transducer must be pressure sized to the expected load range and dimensioned to the specified location. Transducer resolution and accuracy requirements are 0.025 percent (minimum) and plus or minus 0.1 percent, respectively, of full scale range.

2.3.2.2 Grout Mixture

Provide a cement-bentonite grout designed to match the properties of the surrounding in-situ materials, with respect to strength and deformation characteristics, and as recommended by the manufacturer of the vibrating wire transducer. Use Type I or II Portland cement. Marsh Funnel viscosity of the grout prior to placement must be between [50 and 60][_____] seconds. Submit the proposed grout mix design to the Government for review and approval prior to start of the work.

2.3.2.3 Grout/Carrier Pipe (PVC)

Provide sacrificial grout/carrier pipe consisting of PVC conforming to the requirements of ASTM D1785 and as detailed on the drawings. Use PVC 32-mm 1-1/4 inch Schedule 80 threaded pipe for all grout pipe and connections. Utilize manufacturer recommended materials for securing the vibrating wire transducer and cable to the pipe.

2.3.3 [Uplift Cells][Closed Tube Piezometer]

2.3.3.1 Tubing and Fittings for Tubing

Tubing utilized in the construction of uplift cells must conform to the requirements for [PVC or]Crosslinked Polyethylene (PEX) Tubing. Fittings to be used with PEX tubing must be of the Cold Expansion type for use with PEX Reinforcing Rings. Tubing must be compatible with fittings.

2.3.3.2 Fittings

Fittings must be brass or bronze, and compatible with PEX tubing, as recommended by the manufacturer.

2.3.3.3 Conduit

Conduit for uplift cell tubing must be of a size large enough such that the uplift cell tubing can be pulled through the entire length of conduit without damage to the tubing.

2.3.3.4 Gauges

Gauges for uplift cells must be dual scale, ASME B40.100 Grade 2A, brass process connection, bronze tube, solid case, dry. Mark scales in pounds per square inch (PSI) with a range of [_____] meters [_____] feet of water (FT H_2O). Face diameter must be 114 mm 4-1/2 inches.

2.3.3.5 Mounting Hardware and Brackets

Hardware and other components necessary to fix uplift cell tubing, gauges, valves, and ancillary fitting securely to the wall must be 300 series stainless steel or approved equal. The clamps must hold the tubing and/or pipes firmly in place without deformation of the tubing or pipe.

2.3.3.6 Valves

Valves for uplift cells must be full port ball valves of either stainless steel or brass.

2.3.3.7 Cable Gland Seals

Cable glands must meet requirements for cable diameter, pressure rating, and mounting hole diameter. Cable gland mounting may include adhesive or compound, flanged or bolted, threaded or nut mount. The Cable gland material must be compatible with cable material to prevent corrosion, excessive wear, or damage and must be liquid tight.

2.4 SURFACE WATER LEVEL

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NOTE: Common instruments for measuring surface water levels consist of manually read and automated gages. Manually read gages are numerous and include, but are not limited to, staff, weight, and float Automated gages include weir monitors and laser or non-contact radar level sensors.

For bracketed items, choose applicable item(s) or insert appropriate information.

****

2.4.1 Water Level Sensor

2.4.1.1 Laser Water Level Sensor

Provide water level sensors as indicated in the contract plans. Install all water level sensors in accordance with the manufacturer's recommendations. Perform operation and field calibration checks of all instruments. Factory-calibration curves are required for each laser water level sensor, including individual gage factor and temperature correction factor. Protect each instrument against short-duration, high voltage surges with an external surge protection board, which uses tripolar plasma surge arrestors, transient suppression diodes, and inductors.

2.4.2 Staff Gauges

Provide [porcelain enameled steel][fiberglass] staff gauges graduated to centimeters, marked every 10 centimeters and meter hundredths and marked at every foot and every tenth.

2.5 FLOW MEASUREMENT

2.5.1 Flow Meters

2.5.1.1 Pipe Flow Meter

Provide in line [magnetic flowmeters] [ultrasonic (doppler)] [mechanical-impeller or nutating disk] in accordance with the plans. Accuracy must be [_____] percent. Care must be taken to ensure the pipe is full and flow is not turbulent per manufactures directions. Provide electronic gauges showing flow rate and accumulated flow and with communications to a datalogger. Mechanical meters must show total flow.

2.5.1.2 Open Channel Flow Meter

Open channel flow meter must be [ultrasonic][_____] and use the depth of water along with the flow rate to calculate total flow. The open channel flow meter must communicate with an approved datalogger and include a gauge that shows the flow rate and accumulated flow.

2.5.2 Weirs

Provide a [v-notch][trapezoidal][rectangular] weir plate made of 304 stainless steel meeting the dimension requirements [as specified on the drawings][_____]. Include proper mounting hardware as provided by the manufacturer and meeting requirements of ASTM D5640.

2.5.3 Flumes

Provide a [Parshall][trapezoidal][cutthroat][H] flume made of [fiberglass reinforced plastic][304 stainless steel] for measurement of flow range from [_____] to [_____] meeting the dimension requirements [as specified on the drawings][_____]. The inside of the flume must be smooth and free of any irregularities. Provide all anchorage hardware in accordance with the manufacturer's recommendations and submit documentation showing the proposed flume meets all specified requirements.

2.6 ENVIRONMENTAL MONITORING

****

NOTE: Environmental factors such as rainfall, can affect lake and river elevations, increase flow in monitored streams, and infiltrate into piezometers and cracks. Rainfall may be correlated to changes in these parameters and that is why it is important to monitor. Temperature may affect expansion and contraction of materials leading to changes in crack displacements.

If you are in an extremely cold climate, consider a heated rain gauge and/or a snowfall sonic distance sensor if these parameters are import to your project.

You may want to monitor other environmental parameters that affect your project, such as air temperature, barometric pressure, humidity, wind speed/direction, evaporation, solar radiation.

****

2.6.1 Precipitation

Monitor precipitation with a tipping bucket rain gauge with an accuracy of 1 percent up to 2 inches per hour. Rainfall per tip of the bucket is to be 0.01 inch.

2.6.2 Barometer

Provide a barometer with accuracy to 0.6 Hpa or better for correction of sealed vibrating wire pressure transducers. The barometer must be read by the automated data acquisition system.

2.6.3 Water Quality

Monitor water quality parameters such as temperature, pH, turbidity, and conductivity. The readings must be taken by [grab samples] [automated multiparameter sonde] at the specified locations, depths, and frequency.

2.6.3.1 pH

Provide a pH sensor with an accuracy of plus or minus 0.1 units. Calibrate instruments per manufactures directions for the expected range.

****

NOTE: Common pH calibration solutions are 4, 7, and 10, but if monitoring for grout (Portland cement) pH will likely be higher, so calibration at 12.45 is also required.

****

2.6.3.2 Turbidity

Provide a turbidity meter that reports in NTUs with an accuracy of plus or minus 2 percent and plus or minus 2 units. Calibrate instruments per manufactures directions for the expected range.

2.6.3.3 Temperature

Provide a temperature sensor that reports in degrees C F with an accuracy plus or minus 0.5 degrees.

2.6.3.4 Conductivity

Provide a conductivity meter that reports in µS/cm with an accuracy of plus or minus one percent. Calibrate instruments per manufactures directions for the expected range.

2.7 DEFORMATION/DISPLACEMENT

Monitor for deformation or displacement using the instruments described below:

2.7.1 Extensometer

****

NOTE: Provide extensometers based on the application and need of the project. Select

extensometer type based on soil type, reading type, reading frequency, data transmission, open/sealed hole, etc.
****

2.7.1.1 Probe Extensometer

Provide probe extensometers consisting of induction coils or magnet/reed switch transducers. Provide a telescoping access pipe when the predicted vertical strain is greater than about 1 percent

****
NOTE: The diameter of the access pipe is typically 33 mm 1.3 inches, and the borehole diameter typically 76-230 mm 3.0-9.0 inches.
****

2.7.1.2 Fixed Borehole Extensometer

Select fixed borehole extensometers based on anchor type, transducer type and extensometer head. Provide either a single-point borehole extensometer (SPBX) or multipoint borehole extensometer (MPBX). For MPBX, provide a maximum of six anchors and rods in a 150 mm 6-inch diameter borehole.

Provide [stainless steel][fiberglass][carbon composite] rods. Provide vibrating wire transducer capable of measuring over a range between 0 - 100 mm to 0 - 300 mm and frequency range between 1200 - 2800 Hz and operable at temperatures ranging from minus 20 to plus 80 degrees Celsius.

2.7.2 Settlement [Surface Points][Survey Monuments][Plates]

2.7.2.1 Surface Points

Provide surface points consisting of [25 mm] [1 inch] long survey nails designed for installation in [concrete][asphalt]. Include a suitable metal washer or plastic disc hub for high visible marking of each surface point.

2.7.2.2 Survey Monuments

Provide survey monument consisting of [90 mm] [3-1/2 inch] diameter domed bronze marker designed for installation in [concrete], unless otherwise provided by the Government.

2.7.2.3 Settlement Plates

Provide 610-mm 24-inch square settlement plates consisting of a [steel][wood][concrete] base. Provide connectable riser pipes consisting of [galvanized][stainless] steel. Clearly mark and protect the riser pipes from impact during fill operations and other construction activities.

2.7.3 Settlement/Heave Points

2.7.3.1 Borros Type Anchor

Provide [settlement][heave] measurement points consisting of a three-pronged Borros type anchor, 6 mm 0.25 inch steel inner pipes with couplers, and 25 mm 1 inch steel outer pipe with couplers. Connect inner

and outer pipes using standard couplers as recommended by the manufacturer. Anchors prongs may be manual or hydraulically actuated.

2.7.4 Inclinometers

2.7.4.1 Portable (Traversing) Inclinometer

Provide ABS plastic inclinometer casing in [3-meter][1.5-meter] [10-foot][5-foot] long sections with a minimum outside diameter of [48 millimeters][70 millimeters][85 millimeters] [1.9 inches][2.75 inches][3.3 inches]. Provide casing section connections in accordance with the inclinometer manufacturer's recommendation. Ensure the casing has high quality flat surface grooves to permit free passage of the probe through curves in the casing without the wheel of the probe coming out of the groove. Casing anchors and grout valves are to be used if required. Grout the casing in place with grout that approximates the subsurface formation strength in accordance with ER 1110-1-1807. At a minimum, equipment and supplies for monitoring and processing inclinometer data must include a probe at wheelbase of 500 mm 24 inches. The cable must be a [30][60][90]-meter [100][200][300]-foot cable graduated into 500 mm two foot intervals. Other equipment required includes a cable gate system for accurate positioning of the probe, a digital readout device, and graphing software. Calibrate the sensor for plus or minus 30 degree range with a resolution of 0.005 mm 0.0002 inch. Submit the selected inclinometer sensor type, including manufacturer and methods for data retrieval, for Government approval a minimum of 30 days prior to inclinometer casing installation. All inclinometer devices and accessories must be on the job site prior to installation of the first inclinometer. Monitoring equipment must be new and maintained in complete, fully functional operating conditions throughout the duration of the contract; this equipment becomes the property of the Government at the conclusion of the contract.

Applicable instruction manuals published by the inclinometer manufacturer are considered part of these specifications. Use these instructions for detailed installation procedures, calibration, and monitoring.

2.7.4.2 Automated In-Place Inclinometer (IPI)

Provide [ABS plastic] inclinometer casing in [3-meter][1.5-meter] [10-foot][5-foot] long sections with a minimum outside diameter of [48][70][85] millimeters [1.9][2.75][3.3] inches. Provide casing section connections in accordance with the inclinometer manufacturer's recommendation. Ensure the casing has high quality flat surface grooves to permit free passage of the probe through curves in the casing without the wheel of the senor coming out of the groove. Casing anchors and grout valves are to be used if required. Grout the casing in place with grout that approximates the formation strength in accordance with ER 1110-1-1807.

Document casing installation with traversing inclinometer and document two baseline readings prior to installation of IPIs. Baseline readings must be performed at least [seven][28] days after grouting the casing. Provide [biaxial MEMS][Triaxial MEMS Shape Accelerometer Array (SAA)][uniaxial VW] IPI sensors with an accuracy of plus or minus one percent of full scale. Replace casing that exceeds the accuracy of [_____] or spiral limitations of [_____] at the contractor's expense.

2.7.4.3 Shape Accelerometer Array

Provide [250][500]-mm [10][20]-inch segmented shape array sensors of the length(s) shown in the plans. The device must have MEMS sensors and be accurate to approximately plus or minus 1/16th of an inch in 100 feet. They must connect to existing ADAS systems. Casing must be [27][47][100]-mm [1][2][4]-inch inside diameter. In accordance with ER 1110-1-1807, select grout strength for backfill which approximates the formation strength.

2.7.5 Crackmeter/Jointmeter

Provide crackmeters consisting of a vibrating wire or potentiometer displacement transducer within a stainless steel telescopic body with two anchoring points. Vibrating wire crackmeters must measure over a range of [0-12.5 mm], [0-25 mm], [0-50 mm], [0-100 mm], [0-150 mm], with a total accuracy ranging from plus or minus 0.50 percent to 0.30 percent full scale depending on range capability of the instrument. The vibrating wire crackmeter's frequency range must be between 2250 - 3000 Hz and operable at temperatures ranging from minus 20 to plus 80 degrees Celsius. Electrical crackmeters must measure over a range of [0-100 mm][0-200 mm], with a total accuracy ranging from plus or minus 0.30 percent to 0.15 percent full scale depending on range capability of the crackmeter.

Manual crackmeters must be clear polymer with [+-20mm][+-25mm][-55+105mm] range on the x axis and high contrast grid. They must have a unique serial number for tracking and be attached to the surface with epoxy and screws.

2.7.6 Tiltmeter

****

NOTE: Select tiltmeters based on the application and need of the project. Consider the need for uniaxial or biaxial monitoring, temperature correction, measuring range, sensor type and waterproofness. Ensure tiltmeters are compatible with IPI if applicable.

****

Provide a [vibrating wire][MEMS] waterproof [uniaxial][biaxial] tiltmeter. Standard operating range must be [plus or minus 10][plus or minus 20] degrees. Resolution must be [08][_____] arc seconds. Operating temperature must range from minus [20][_____] to plus [80][_____] degrees Celsius.

2.7.7 High Precision GPS Unit

Provide high precision GPS unit, with wireless communication capability, that provides three-dimensional displacement and tilt measurements for deformation monitoring. Units must provide plus or minus [1][2] centimeter positioning accuracy.

2.7.8 Survey

Complete surveys to provide accurate positioning of instrumentation. Use horizontal and vertical datums specific to the project in which instrumentation is being installed. Critical points for surveys at a minimum must include horizontal and vertical data collection at the top of

protective casings, interior pipes, and a ground shot near the base of the instrument using equipment that can report collect to within at least plus or minus .03 cm .01 feet accuracy.

2.7.8.1 Terrestrial Positioning System (TPS)

Provide an automated robotic total station with an aiming range of 1 m to 1000m, distance accuracy of 1mm + 2 ppm, angular accuracy of 1 arcsec (0.3 mgon), and programmable to collect and transmit survey data at [hourly][daily][15 minute][_____] intervals. The TPS must also include any environmental protection and communications necessary.

2.7.8.2 Surface Monuments

Select surface monuments based on the application and need of each project. Select horizontal and vertical control monuments in accordance with EM 1110-1-1002.

Each monument must have a [brass][bronze][aluminum] disk that [will][will not] be provided by the Government. Each monument must be stamped by the Contractor with all corresponding monument details such as project name, monument ID, and elevation. Stamp the majority of information on the cap prior to installation.

2.7.8.3 Survey Prisms

Select surveying prisms, also known as retro-reflectors, based on size, range, holder accuracy and offset. Beam deviation must be less than [5][_____] seconds. Holder accuracy must be [1][_____] mm or less. Prism offset must be [0][minus 17.5][minus 30][minus 34][minus 40] mm.

2.8 LOAD/STRESS

****

NOTE: The more common instruments for load and stress measuring have been included below and consist of pressure cells, load cells, and strain gauges.

Pressure Cells are used to monitor total pressure in earth fill dams and embankments, rock stress changes, dynamic pressures, etc. They can be vibrating wire pressure transducers, semiconductor type transducers, or use a stainless steel pressure gauge.

Load Cells are used to monitor load and strain by measuring structural extension and compression that pass through the load cell.

Strain Gauges are also used to measure load and strain in a structure by attachment directly to the structure surface or embedment within the structure itself, or in situations where a load cell cannot be utilized.

For bracketed items, choose applicable item(s) or insert appropriate information.

****

2.8.1 Earth Pressure Cells

Provide [standard][contact][jackout][push-in][pile tip] type pressure cells with a rated load of [_____] [kPa][MPa].

2.8.2 Load Cells

****
NOTE: The throat diameter and load range will be determined by the designer, the Contractor, or the Government depending on the specific project and application. Vibrating wire cells are used in most applications. Electrical resistance cells are primarily used in tiebacks and rock bolts.
****

Provide [solid][center hole][vibrating wire][electrical resistance] type load cells with an inside or throat diameter of [_____] inches and a rated load of [_____] to [_____] metric tons [_____] to [_____] kips. Alternatively, based on the actual diameter of the object material being monitored, and on the manufacturer recommendations, the throat diameter may be as indicated by the [Contractor][Government]. Provide centralizer bushings to center the load cell, if necessary. The load cell must be specially hardened to withstand embedment in concrete for long-term monitoring requirements.

2.8.2.1 Load Bearing Plates

Provide load cell bearing plates consisting of [_____] mm [_____] inch thick plated ground steel based on the [_____] metric ton [_____] kip load and the [_____] center hole.

2.8.2.2 Calibration

Calibrate load cells under the following two conditions: 1) normal factory calibration of the load cell itself and 2) group or set calibration of the load cell with the bearing plates and lock-off assembly assigned to that load cell. Switching or transfer of bearing plates/lock-off assemblies is not allowed in the field without factory calibration.

2.8.3 Strain Gauge

Provide [electrical] [vibrating wire] [fiber] strain gauges with a rated load of [_____] to [_____] μ.

2.8.4 Signal Cable

Provide signal cables, as recommended by manufacturer, which are factory-connected to the measuring device in one continuous length. Mark and properly identify all signal cable at the device and at the cable termination as delivered. Each cable connection to the device must be independent of the other. Splicing of cables that are embedded in concrete or otherwise not accessible must have prior approval of the Government. For splices not in a climate-controlled enclosure, use a [stainless steel][plastic] sleeve with [compression fittings][soldered and heat shrink splices] for securing each cable section and use factory supplied epoxy filling materials.

2.8.5 Instrument Readout

Provide required readout device(s) and obtain initial, calibration, and subsequent manual readings of the sensor output. The readout device(s) must be compatible with the instrument and signal cables, and existing sensors and data logging equipment on site. Data formats must be [.csv][.dat] [.json] and compatible with [_____] software.

2.9 VISUAL OBSERVATION

2.9.1 Outdoor Cameras

Provide [HD] [daytime] [nighttime] camera(s) accessible by an Internet-based software and a secure connection. Cameras must provide [color] [color and black and white] images. Cameras must meet or exceed the following:

a. Image Size: [_____] Megapixels [_____] x [_____]

b. Lens: [_____] mm in., [_____] x optical zoom, F-Stop [_____]

c. Pan/Tilt: Pan Range [_____] degrees Continuous Pan, Tilt: [_____] degrees to [_____] degrees

d. [4K][_____] broadcast quality video

e. [4G][_____] cellular modem

f. [On-Board Data Backup][4 GB (microSD)]

g. Ambient Temperature Range: [_____] degrees C F

The Internet based online interface must include the following features:

a. Display project name

b. Real-time live video viewing

c. Daily auto-generated 360 degrees panoramas up to [_____] megapixels

d. Digital pan, tilt and zoom capability within a high definition image

The service must be available for the duration of the contract and allow the viewing of live video and high-definition digital still images captured of the project and stored on both mobile and desktop platforms. Capture and upload images every [30][_____] minutes, 24 hours per day. Provide all service and maintenance, including cleaning of the camera system throughout the life of the project including making appropriate arrangements for camera to remain in operation up to and through project completion.

2.10 VIBRATION MONITORING INSTRUMENTATION

Provide a minimum of [_____] vibration monitoring instruments at the location shown on the drawings or as directed by the authorized representative of the Government. Operate these instruments during construction activities that are within [_____] meters feet of the construction, or in the opinion of the Government would be a source of

ground vibration.

The location of the instrument(s) may vary daily, based on the location of construction activities, condition of structures in the vicinity of construction activities, and response to public and government interest.

2.10.1 Seismograph/Seismometer

Provide [_____] vibration monitoring instruments and in accordance with the following:

a. Capability to measure, display, and provide a digital graph of particle velocity and frequency components.

b. Capability to measure the 3 mutually perpendicular components of particle velocity in directions vertical, radial, and perpendicular to the vibration source.

c. Possess a seismic range of 0.01 in/sec to 4 in/sec with an accuracy of 5 percent of the measured peak particle velocity or better at frequencies between 10 Hz and 100 Hz, and with a resolution of 0.01 in/sec or less.

d. Possess a frequency response range of 2 Hz to 150 Hz.

e. Display the date of the most recent calibration. Calibration must have been performed within the last 12 months to a standard traceable to the National Institute of Standards and Technology.

f. Possess a reliable power source or battery for required duration of recordings, equipment suitable for site and weather conditions, and suitable length of geophone and microphone cables.

g. Continuous monitoring mode must be capable of recording single-component peak particle velocities and frequency of peaks with an interval of 1 minute or less.

h. Capability of measuring continuous sound levels ranging from 30 dBA to 140 dBA with 0.05 dB resolution.

i. Produce plots showing particle velocity and frequency relative to current OSM and USBM standards.

2.11 SURFACE PROTECTION

****

NOTE: Surface protection considerations are bollards, locking well caps, flush mount vs raised, vandalism, freeze thaw, construction access.

****

Provide temporary or permanent surface protection in accordance with the plans. Use caution and provide all means necessary to protect the instrumentation from construction activity performed on the construction site. This includes monitoring settlement of fill material in and around the buried conduits, concrete protective blocks at the instrument heads, concrete pads, and related items. Immediately replace any instrumentation equipment that is damaged by construction activities including damage caused by settlement of fill material due to improper placement or

compaction. Access must be maintained to permit periodic measurements and observation by the Government.

2.12 INSTRUMENTATION ENTERPRISE DATABASE (EDB)

****

NOTE: This paragraph may only apply to large geotechnical projects. Until/unless the Government is capable of ingesting and hosting its own instrumentation data real time during construction, regardless of if other data viewers are built and maintained internally, the contractor will host an enterprise SQL instrumentation database for large geotechnical projects. Because of the need for real-time reporting of data, which cannot be accomplished across the firewall, the Contractor may also need to provide an instrumentation web interface capable of plotting, and visualizing the instruments and data. In order for the government to provide this on an internally built web interface, the Contractor would need to utilize Microsoft Azure, and/or host the data to a restful service or API for Government ingestion.

****

Set-up, maintain and update a documented SQL enterprise database (EDB) for the duration of the contract in which to store all automated and manual instrumentation data. This can be the same database as the project database if one is utilized.

Store the EDB on the Contractor's servers or the Contractor's cloud storage account for the duration of the contract.[Update .csv files of the most current version of the database tables to the SFTP site by [midnight daily]. Update the most current version of these .csv files to the SFTP site at any time requested by the COR.]

[Make data available in HTTP (API) or sFTP for automated inclusion in external databases.

][Import relevant hydrologic data using publicly available datasets such as USACE CWMS RADAR or Access2Water APIs.

] Import all data for existing, active instrumentation in place prior to the contract into the EDB. The Government will provide the data for this purpose. Replace all historical survey coordinates and station offsets in the EDB for any instrument locations surveyed as a part of this Contract. Ensure all coordinates in the EDB are in the project coordinate system utilizing the correct datums.

Upon completion of the contract and before final demobilization, submit to the Government the final EDB .csv files and EDB documentation prior to final payment.

2.13 AUTOMATED DATA ACQUISITION SYSTEM (ADAS)

****

NOTE: Ensure contract plans include a minimum required elevation for above-ground ADAS boxes/equipment locations to prevent potential

inundation by high water events.
****

Provide an Automated Data Acquisition System (ADAS) to collect, process, store and communicate data with other systems. This system is generally to be comprised of sensors/transducers, dataloggers, communications devices, and associated accessories - see contract drawings. Automatically read and store instrumentation data at preset time intervals and reading frequencies. Provide the capability to modify reading frequency and provide ability to increase reading frequency during a [storm event]. Automatically scan all instruments for threshold exceedance. Have the ability to trigger alarms based on any of the following types of conditions: static level exceedance, rate of change, moving window rate of change, and time delay with multiple values verification.

Furnish all components and complete installation of all system components, cable, conduit, instruments, transducers, sensors, enclosures, power connections, grounding, and miscellaneous items to make the ADAS completely operational. Submit system design and components for Government approval.

2.13.1 Data Loggers

Provide data loggers that are capable of reading [vibrating wire][MEMs][_____] sensors, store data internally for [10][100][1000][10,000] readings, and communicate with [_____] protocols. Data loggers must be compatible with data collection devices and other data loggers on site and be capable of storing at least [3 months][1 year] data in local memory.

Program the data loggers to read the sensors. Annotate the programs with comments pertaining to its function. Data logger communications may be encrypted for security, but the program must be accessible by the Government on systems that will be owned or operated by the Government. Store programs on the data logger in non-volatile memory.

2.13.2 Enclosures

****
NOTE: Material type depends on application lifespan and vandalism potential.
****

Provide enclosures to protect ADAS components from the environment. Properly size enclosures so components can be neat and organized. (Check NEC requirement for capacity). Construct enclosures of [fiberglass reinforced polyester][stainless steel] and use water resistant gaskets at all entry points to sealed enclosures. For enclosures housing electronics, maintain a low humidity level within by using desiccants or heaters.

2.13.3 Conduit

Provide [PVC][rigid][EMT] conduit. Surface conduit must be resistant to UV and rugged to minimize or eliminate damage.

2.13.3.1 Underground Conduit

Bury underground conduit [46 cm18 inches below the surface][61 cm24 inches below the surface][below the frost line]. Install in accordance with NEC regulations.

2.13.4 Locations

****
NOTE: Specify locations of instrumentation and readout boxes. Consider: inundation, line of sight communications, weather freeze/thaw, accessibility, power(solar), vandalism, artesian conditions and access.
****

[_____]

2.13.5 LMU/RMU

Provide Local Monitoring Unit(s) (LMU)/Remote Monitoring Unit(s) (RMU) as shown in the contract plans. The LMU/RMU must poll sensors at a specified interval, record raw values, be capable of reducing raw values to engineering units, and communicate data to other systems.

2.13.6 RIO

Provide Remote Input Output (RIO) device(s) as shown in the contract plans. The RIO must poll sensors, as requested by a LMU/RMU, and communicate raw values back to the LMU/RMU.

2.13.7 Vibrating Wire Analyzer

Provide vibrating wire analyzers that poll vibrating wire transducers and measure the resulting frequency and associated data. The analyzer may be a stand-alone unit or integrated into a datalogger but must have a communications method for transferring data to other devices. The vibrating wire analyzer must use a [swept frequency method][Fourier transform and spectral analysis method] to determine the frequency of the vibrating wire with an accuracy of plus or minus 0.05 percent or better and read the thermistor of equipped sensors.

2.13.8 Multiplexer

****
NOTE: Multiplexers increase the number of sensors measurement devices can read.
****

Provide multiplexers that are compatible with the [existing][new] sensors/transducers and measurement devices on site.

2.13.9 Power

****
NOTE: Some installations may be powered by a non-rechargeable battery that lasts for x day, also consider snow covering solar panels and shorter recharge periods in northern latitudes.

****

Size power supply batteries appropriately to power the equipment for [3 days][10 days][6 months][12 months] without recharge. Power supply batteries are to be comprised of a rechargeable battery or batteries, charge controller, and power source. Power sources can be solar panels, wind turbines, 110 volt wall outlets, or combinations of these sources. Batteries must be of [sealed lead acid][lithium iron phosphate] chemistry.

2.13.10 Grounding

Grounding and lightning protection must be designed by an electrical engineer with experience in lightning protection. Include this design, with Professional Engineer's signature and stamp, in a Grounding and Lightning Protection Plan submitted for Government approved. Ground all enclosures and equipment that have grounding terminals. Install ground rods in accordance with the electrical engineer's recommendations regarding construction, size, spacing and allowable resistance . Install and maintain the transient voltage surge suppressor in accordance with the Electrical Engineer's grounding and lightning protection plan. Special care should be taken to protect sensors that are grouted in a borehole, or other inaccessible sensors.

2.13.11 Communications

Provide [wired][wireless radio][wireless cell modem][fiber optics] [satellite] communications between data logging devices and for transferring data files to local and remote Government offices.

2.13.12 Software

[Provide instrumentation software that communicates with the automated data acquisition system [and a windows-based PC][_____]. The software must allow remote retrieval of data, updating of programs and configuration, and viewing of data from the automated systems.

][Provide inclinometer software that communicates with the manual traversing data collection device. The software must plot greater than three cumulative displacement plots referenced back to a baseline survey and allow for corrections of the data for spiral and bias.

]2.13.13 Architecture

****

NOTE: Specify datalogger locations or allow the contractor to propose.

****

The Automated Data Acquisition System Architecture must be [centralized] [distributed] at the site.

2.13.14 Wiring Diagram

Submit full color wiring diagrams of the ADAS enclosures in the ADAS Final Report. Conduit, trenching, and cabling locations must be surveyed during installation and survey used in preparation of the required as-built drawings submittal.

2.13.15 Instrumentation Schedule

****

NOTE: Insert a chart here with desired data such as instrument type, location, depth, cable length, or reference contract drawings.

****

[_____]

2.13.16 System Maintenance and Spare Parts

Provide all hardware and/or other necessary item(s) required to ensure the entire instrumentation and data acquisition/reporting system is functioning according to manufacturer's specifications, and for maintaining the system in satisfactory working order for the length of the contract. This includes appropriate spares for repairing or replacing inoperable or unreliable components according to the expected replacement rate in the list below, or as otherwise as directed by the contract. All system maintenance must be performed in accordance with the manufacturer's requirements and EM 1110-2-1908.

Before work begins, prepare a list of all extra components required for continuous operation of the system and quantities to be stockpiled on-site according to the estimated replacement rate per the manufacturer. Submit this list to the Government for approval. The items on the approved list must be made available at the site during the entire period of the delivery order. If a stockpiled item is used, it must be replaced immediately. In the event of a malfunction or breakdown beyond the frequency below or beyond the control of the Contractor, notify the Government of the nature of the malfunction or breakdown within [12 hours][_____], and provide an estimate of when that part of the system will be back in service if the Government approves a replacement. Depending upon the status of the construction at that time, the Government will decide whether or not a manual backup system must be implemented by the Contractor.

****

NOTE: Tailor the text for the monitoring purposes of the instruments. If the system is for monitoring for life safety during construction, then the Contractor must have the system fully operational within 12 hours and have sufficient backups on site to meet this requirement.

****

Sensor or board replacements must be of the same model (manufacturer) and type as installed in the field at award of this contract unless a newer technology can be provided that meets the same or better requirements and performance. All deviations require approval of the Government prior to replacement. Replaced instrumentation components must be programmed and shown to functionally work with the system prior to Government acceptance.

PART 3 EXECUTION

3.1 PRE-INSTALLATION ACCEPTANCE TESTING

Perform pre-installation acceptance tests to ensure sensors and readout units are functioning correctly prior to installation. Blank

pre-installation acceptance test record forms for each instrument type must be provided by the Instrumentation Specialist. For pre-installation acceptance tests, include relevant items from the following list:

a. Examine factory calibration curve and tabulated data to verify completeness.

b. Examine manufacturer's final quality assurance inspection checklist to verify completeness.

c. Check cable length.

d. Check serial numbers on instrument and cable.

e. Check, by comparing with procurement document, that model, dimensions, and materials are correct.

f. Perform resistance and insulation testing, according to criteria provided by the instrument manufacturer, using a gage insulation or circuit tester that applies two volts or less for resistance testing and 15 volts or less for insulation testing.

g. Verify that all components fit together in the correct configuration.

h. Check all components for signs of damage in transit.

i. Check that quantities received correspond to quantities ordered.

Repair or replace any instrument that fails the specified pre-installation acceptance test.

3.2 PRODUCT HANDLING

3.2.1 Transportation and Handling

Pack, transport, and handle all monitoring equipment in accordance with the manufacturer's instructions. Arrange deliveries of monitoring equipment with proper sequencing and scheduling in accordance with the approved Project Schedule. Coordinate deliveries to avoid conflict with work, conditions at the site, and availability of personnel and handling equipment.

3.2.2 Storage and Protection

Use all means necessary to protect monitoring equipment before, during, and after installation and to protect installed work and materials including existing instrumentation installed by others. Store all monitoring equipment in strict accordance with the manufacturer's recommendation with all labels and seals intact and legible. Arrange storage of monitoring equipment to permit access for inspection. Periodically inspect to assure monitoring equipment is undamaged and is properly maintained. Replace in kind any equipment lost, damaged or stolen due to negligence on the part of the Contractor at no additional cost to the Government.

3.3 INSTALLATION

****

NOTE: Installation specifications have not been

provided for all the instruments included in Part 2 - Products. Only a few of the most common instruments are detailed below, for example only, due to variable project/site conditions and product specific requirements. As noted in paragraph INSTALLATION PLANS below, detailed method statements for installation of each type of instrument are required for Government review and approval as part of the INSTRUMENTATION AND MONITORING PLAN submittal. If chosen by the spec. writer, this approach enables the Instrumentation Specialist, who is selecting the specific instruments for purchase, to provide a comprehensive installation plan consistent with the contract specifications, site specific conditions/constraints, and instrument manufacturer's recommendations and requirements. The designer should include project specific installation requirements for each instrument they include in Part 2 - Products.
****

3.3.1 General

Provide all labor, equipment, materials, and incidentals required to install and read the instruments as shown on the Contract Drawings. Install instruments in accordance with approved method statements and the manufacturer's recommendations. Upon completion of the installation, test each instrument in accordance with the recommendations of the manufacturer. The Contractor is solely responsible for installation and the performance of the instrumentation after installation. After installation replace any inoperative or poorly performing (not within an acceptable range/calibrations) instrumentation at no additional cost to the Government. Obtain all necessary permits and pay associated fees required to construct the project. Implement the terms and requirements of the permits. Submit Permit Documentation to the Government for record.

3.3.2 Installation Plans

As outlined in paragraph INSTRUMENTATION AND MONITORING PLAN, detailed method statements for installation of each type of instrument must be submitted for Government review and approval prior to commencing installation.

3.3.3 Notification and Documentation

All installations may be monitored by the Government's Representative. Notify the Government Point of Contact at least [24][_____] hours prior to the installation of each instrument. For each instrument installed, prepare, and submit an Installation Record in PDF format, including but not limited to items listed below. Enter all as-built metadata for each instrument into the enterprise database for the project detailed in paragraph AVAILABILITY OF MONITORING DATA.

3.3.4 Instrument Coordinates

Survey final location of all installed instruments utilizing the survey control precision and accuracy requirements required by this Contract. Provide [easting and northing][_____] survey coordinates in accordance with the system and datums for the project. Provide all relevant

elevations for installed components and sensing regions, and hole inclination and azimuth as directed by the Government. Ensure all station and offset measurements for new instruments utilize the established station line of the project.

3.3.5 Borehole Installations

Perform borehole drilling in accordance with the [Section 02 32 13 SUBSURFACE DRILLING AND SAMPLING][the Government standard drilling specification provided].[Adhere to ER 1110-1-1807 for any borehole drilling in earthen embankment dams or levees or those with soil foundations. No drilling or excavation can occur on a constructed embankment dam or levee until a Drilling Program Plan has been approved by the Government. Appendix B of ER 1110-1-1807 defines the format of the Drilling Program Plan.]

****

NOTE: ER 1110-1-1807 applies to in-house and contracted drilling efforts for earth embankments or foundations associated with all dams and levees that have a federal interest. Drilling into, in close proximity to, or through embankment dams and levees and their foundations may pose significant risk to the structures. Water, compressed air, and various drilling fluids have been used as circulating media while drilling through earth embankments and their foundations. Although these methods have been successful in accomplishing the intended purposes, there have been incidents of damage to embankments and foundations. Ideally, it is best if the Government completes the Drilling Program Plan (DPP), with input from the Contractor on proposed items such as drill method, driller experience However, if the Contractor is to prepare the DPP it is recommended that the Government indicate they will furnish certain deliverables for use in development of the plan - items such as justification of need for drilling/instrumentation, PFM's, existing drawings/foundation information.

****

Installation procedures for instruments in boreholes must be performed in such a manner that all steps in the procedure can be quality assured. For each hole, maintain a detailed log, recording soil/rock and groundwater conditions encountered. Prior to installing any instrument through drill casing or augers, thoroughly remove all cutting and material adhering to the inside of the casing or augers. Instrument installation in a borehole must be completed in a continuous operation. Partially completed instrument installations must not be left in unsupported boreholes overnight. For boreholes in which piezometers are to be installed, bentonitic drilling muds must not be used. For holes where instrument casing is installed, verify that the drilled hole within two degrees of vertical (plumb) throughout its length and is at the correct depth.[When drilling below the water table or when the drill hole must not remain open, advance the drill hole using a steel outer casing and approved drilling fluid. Withdraw outer casing after instrument casing is installed and as the hole is being backfilled. Do not rotate the casing during removal. Steel outer casings remain the property of the Contractor. Fill annular void between drill hole and instrument casing as

indicated. Backfill each instrument specifically as indicated in its installation specification below or as indicate on the drawings. Backfill must be brought up in an equal fashion surrounding the instrument and/or casing. Measure the depth to fill surface as the work progresses (at top of each material increment) and confirm the depth reasonably matches the expected depth based on the volume of material placed.] Record the backfill quantities on the installation record.

****

NOTE: Instrumentation installation details presented below are to be project specific and should be developed further by the design engineers. Drilling, grouting or well installation may be described in further detail in a separate specification such as Section 02 32 13 SUBSURFACE DRILLING AND SAMPLING or Section 33 51 39 MONITORING WELLS. Also see above NOTE under paragraph INSTALLATION.

****

3.3.6 Pore-Pressure and Groundwater Monitoring

3.3.6.1 [Open Tube Piezometer][Observation/Monitoring Well]

Install the [open tube piezometer][observation well][monitoring well] immediately after each boring is complete to the design depth specified and as close to vertical as possible. Secure the screen to the riser casing by flush-jointed threads and place using centralizers. Before the screen and casing are placed on the bottom of the borehole, place at least 15 cm 6 inches of filter material at the bottom of the borehole. Place filter material around the screen to at least 61 cm 2 feet above the top of the screen unless otherwise specified. If hollow stem augers are used, place the filter material in 15 to 30 cm 6 to 12 inch lifts. If the borehole is open, place filter material by tremie methods, using water to wash the sand through the pipe. After the filter material has been installed, place a minimum 1-meter 3-foot thick bentonite seal above the filter pack. Granular bentonite must be placed in depth increments not exceeding 30 cm 1 foot. Check the depth to the top of each increment of sand or granular bentonite after placement. The bentonite seal must be allowed to hydrate a minimum of eight hours or the manufacturer's recommended hydration time, whichever is longer. After the seal has hydrated, pump well-mixed grout by tremie method into the annular space around the casing. Record the volume of grout used and compare to expected to evaluate excessive grout loss. Grout must set for a minimum of 24 hours before surface pad and protective casings are installed. Construct concrete pad or surface completion as shown on drawings. For above ground completions, install a painted lockable protective casing extending a minimum of two feet above the ground surface. For flush mount completions, install a waterproof and watertight protective casing even with the ground surface. All watertight protective hand holes or above ground casing must be the same and use the same locking or unlocking mechanism which must be provided to the Government at the end of construction.

After completion of installation, record an initial reading of the open standpipe piezometer. An initial reading consists of the average of three readings taken with a water level indicator where the indicator is removed from the riser pipe between each reading. Then, conduct a post-installation acceptance test by performing a falling head or rising

head permeability test. Conduct the test in accordance with procedures outlined in Appendix C of EM 1110-2-1908, including report of data and results.

3.3.6.2 Fully Grouted Vibrating Wire Piezometer

Install the vibrating wire (VW) transducer immediately after each boring is complete to the depth specified or shown on the drawings. Maintain the VW transducer in a bucket of water to keep the filter saturated for a minimum of 30 minutes until it must be removed to attach to the grout pipe. Immediately prior to attaching the transducer to the PVC grout pipe, remove the transducer porous tip and fill with clean water. After replacing the porous tip, use electrical tape to attach the transducer to the grout pipe upside down with the porous tip facing up. The porous tip must not be covered with electrical tape. Secure the transducer cable to the casing just below the transducer. Loop the cable to run up the casing past the VW transducer and eventually to the surface. The cable must be rotated around the casing to minimize bridging of grout. Avoid sharp bends in the cable. Lower the grout pipe with attached VB transducer and cable into the hole to the required depth. Read the piezometer to ensure it agrees (within plus or minus 10 mm 0.4 inch) with the water head as determined by a water level indicator, and record the elevation of the diaphragm. Use a drill rig pump or similar to first thoroughly mix the cement into the water for the cement-bentonite grout, and then carefully add the bentonite to ensure that clumps do not form and the required viscosity is attained. Perform a Marsh Funnel viscosity test to verify the target viscosity of [50 to 60][_____] seconds is obtained prior to grout placement. Do not pump grout into the borehole, but place grout using a tremie pipe with side discharge ports that remain submerged in the grout during the entire grouting process. Inject grout to within 30 cm 1 foot of the ground surface and allow to settle. After settlement has occurred, top off the grout to 30 cm 1 foot below top of ground surface. Mound natural soil at the ground surface to promote water drainage away from the piezometer.

After completion of installation, take a baseline reading. A baseline reading will consist of the average of a minimum of three stable readings. Construct surface components and piezometer cable routing and burial as specified and/or shown on the drawings. Protect instrument cables from mechanical or weather related damage. Free ends of cables must be protected at all times. Accurately record and clearly mark the position of all buried cables. Include any issues or changes that occurred during the construction in the Installation Record submittal, along with all required installation documentation detailed in paragraph NOTIFICATION AND DOCUMENTATION.

3.3.7 Deformation/Displacement

3.3.7.1 Inclinometer Casing

Install inclinometer casing immediately after each boring is complete to the design depth specified and as close to vertical as possible. Anchor casing prior to grouting to prevent excess deformation. Orient inclinometer casings such that one axis of the internal grooves are perpendicular to the expected direction of movement. Maintain groove orientation throughout installation. During and after installation, casing groove spiral must not exceed one degree per3 meters 10 feet of length.

After completion of installation, complete a post-installation acceptance test to verify that there is no grout in the inclinometer casing, that groove orientation, spiral limitations, and verticality satisfy the specifications, and that the inclinometer probe tracks correctly in all four orientations. Perform a vertical survey of the installed inclinometer casing at 60-cm 2-foot depth intervals using the standard probe, to determine the vertical profile of the casing, and develop an initial data set. Include any issues or changes that occurred during the construction in the Installation Record submittal, along with all required installation documentation detailed in paragraph NOTIFICATION AND DOCUMENTATION.

3.3.8 Load/Stress

3.3.8.1 Load Cells

Conduct a minimum of three sequential lift-off tests to determine the correlation between the actual hydraulic jack load and the measured load in the load cell following lock-off. Following lock-off and lift-off testing, read the load cell twice daily for a period of at least one week to document drift or changes in the load cell readings. If readings do not stabilize within approximately 1 percent of the lock-off load, provide an assessment in writing for approval of the possible reasons for the drift and the results submitted. Contractor must not backfill around the load cells until drift characteristics have been documented, submitted in writing, and approved by the Government.

3.4 DATA COLLECTION

At a minimum, collect the following data as applicable to each type of instrument installed:

a. Instrument ID Name

b. Instrument Type

c. Date and Time

d. Reservoir Pool Elevation

e. Tailwater Elevation

f. Observer

g. Readout unit number and last calibration date if appropriate.

h. Readings

i. Visual Observations (e.g. loose mounting materials, rusting, battery leakage, UV damage to instrument, wire or casing)

j. Other pertinent data, including weather, temperature, construction activities, and any events that could influence change in the data.

3.4.1 Baseline Readings

****

NOTE: It is recommended that baseline readings be recorded for at least 6 months prior to the

construction starting for projects involving life safety. This longer duration of baseline readings helps identify diurnal and seasonal effects, which can improve interpretation of "unusual" readings. However, this is not always allowable and shorter time frames are often considered.

****

Obtain initial readings from all instruments immediately after their installation and enough times (see reading frequencies in table of paragraph Frequency of Monitoring) before construction begins in order to verify that the instrument readings have stabilized, and initial (ambient) conditions are established. Collect initial or baseline readings for a minimum of [6 months][1 month][2 weeks]. Evaluate baseline readings and determine the cause of any data anomalies recorded. Those instruments that are to be installed with the purpose of monitoring the effect of the construction works on surrounding structures/ buildings/ utilities or terrain must be installed, tested for acceptance and fully operational at least [10 days][_____] prior to the commencement of the construction works whose effects are to be monitored, with the additional requirements as listed.

3.4.2 Frequency of Monitoring

****

NOTE: The table below includes general minimum recommended monitoring frequencies adapted from Table 8.1 of EM 1110-2-1908 for the enhanced or during construction monitoring condition. When defining the reading frequency of an instrument, also consider the frequency used in the data evaluation calculations, particularly for a rate of change evaluation method. For example, if a rate of change evaluation method is used, the difference between consecutive 15 minute readings may not raise a flag, but a rate of change calculated over a 1 hour period might.

****

The minimum frequency of monitoring presented herein (see table below) may be subject to adjustment in accordance with field behavior, or as requested by the Government. The frequency and extent of monitoring are subject to change in accordance with the threshold and limiting levels described herein or as established in the approved Instrumentation and Monitoring Plan.

Instrument Type	Data Collection Method	Reading Frequency (Minimum)
Crack Pins	Manual Automated	Weekly Weekly/Daily
Extensometers	Manual Automated	Weekly Weekly/Daily
Inclinometers	Manual Automated	Weekly Weekly/Daily
Piezometers or Observation Wells	Manual Automated	Daily Every 15 minutes
Pressure Relief Wells or Well Points	Manual Automated	Weekly/Daily Daily

Seepage Measurement Devices	Manual Automated	Weekly Daily
Settlement Gauges	Manual Automated	Monthly N/A
Surface Monuments and Survey Points	Manual Automated	Monthly Daily
Tiltmeters	Manual Automated	Weekly Daily/Hourly

3.4.3 Manual Readings

Collect and reconcile manual instrumentation data to the [instrumentation EDB][_____] within [4][_____] hours of data collection. Digital data collection devices may be used to facilitate rapid input of data without redundant manual data entry.

3.4.4 Instrumentation Metadata

At a minimum, collect the following data for each instrument installed and add to the appropriate table of the instrumentation EDB:

a. Instrument ID

b. Instrument type

c. Instrument manufacturer

d. Date of installation

e. Automation status

f. Instrument easting and northing coordinates in the same coordinate system and datums as existing instrumentation.

g. Instrumentation surface elevation

h. Instrument bottom of installation elevation

i. Top and bottom elevations of all instrument sensing zones (as applicable)

j. Top and bottom elevations of all relevant installed features (i.e. concrete, filter, sensors, standpipe)

3.4.5 Automated Data Acquisition System (ADAS)

3.4.5.1 Cyber Security Compliance (ECB 2018-11)

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NOTE: There is a cyber security UFGS that may be referenced if used - it's Section 25 05 11 CYBERSECURITY FOR FACILITY-RELATED CONTROL SYSTEMS.
****

Automated data acquisition systems collect, process, store and transmit data. They are not SCADA systems and thus they will not control any critical infrastructure including but not limited to gates, valves, utilities, traffic control, security, fire, or life safety systems.

3.4.5.2 Programming

Programming of dataloggers must be performed in a logical, well-annotated way. Data logger communications may be encrypted for security, but the program must be accessible by the Government on systems that will be owned or operated by the Government. Provide a copy of the program with the code annotated. The annotations must be descriptive and explain the different sections and clearly define constants.

3.4.5.3 Testing

Install and test the automation system in the presence of the Government's designated representative.

3.4.5.4 Project Specific Operations Manual

Submit an operations manual including wiring diagrams, photos of the inside of each Data Logger, RIO, LMU, RMU, or other boxed transmission device as well as each instrument location with clear views of the instrument showing wiring and location of all components, cut sheets, calibration sheets, datalogger programs, component configuration settings, troubleshooting, as-built drawings, and maintenance requirements.

3.4.5.5 As-Builts

Provide as-built drawings including installation/construction diagrams as well as instrument locations, datalogger or other readout devices, conduit, trenching and cabling. In addition to full scale drawing as-builts required as part of the construction contract, include 28 by 43-cm 11 x 17-inch size as-builts as an appendix in the Project Specific Operations Manual.

3.5 ANALYSIS, REPORTING, AND PRESENTATION OF MONITORING DATA

If not explicitly stated herein, analysis, reporting, and presentation of monitoring data must be consistent with the guidance provided in EM 1110-2-1908.

3.5.1 Analysis of Monitoring Data

Compare each acquired instrument reading with the previous readings of that instrument and the expected reading based on site conditions and in reference to baseline readings. Interpretation of data also includes making correlations between instrumentation data and specific construction activities. Determine whether the instrumentation response to construction activities is reasonable. Data interpretation and analysis should consider instrument precision levels and errors, data capturing errors and necessary corrections in accordance with the manufacturer's instructions. In addition, data analysis should consider connections to records of construction and weather-related activities at the site. Perform analyses in a timely manner to capture indications of distress development, the possible need for instrument maintenance, and to check for proper functioning. Determine if a threshold value has been exceeded, and if so, proceed in accordance with paragraph RESPONSE ACTIONS. If the comparison indicates that changes are not typical of previous changes, determine whether the reading is erroneous or legitimate. Erroneous readings include readings outside the accuracies, repeatability, standard deviations, and tolerances specified herein or as indicated by the

manufacturer. Ensure, and document, proper quality control is being conducted on the analyses and results.

3.5.2 Monitoring Data Reports

Submit monitoring data reports, consisting of all processed instrumentation data converted to standard English units of measure, to the Government's Representative at defined intervals throughout the construction period. Include readings for all instruments. Readings are to be cumulative for the reporting period. NO DAILY AVERAGING OF AUTOMATED DATA WILL BE ALLOWED.

a. For the duration of the contract, submit [monthly][weekly] Monitoring Data Reports within [24 hours][_____] from the last day covered in the report. Each report must include analysis of that [month's][week's] data collection and findings in relationship to work performed on-site which may impact readings. Provide cumulative plots of data for the reporting period. Plotted values must be discrete - no daily averaging between successive data points. Reports may be requested at a higher frequency by the Government for special instrumentation evaluation purposes. Provide such reports following the same format as [monthy][weekly] reports or as directed by the Government's authorized representative.

b. Ensure all erroneous data is masked from plots, but it must remain in the raw data file and be flagged as erroneous data in the database within a specifically designated field.

c. Reduce all automated sensor readings in accordance with the manufacturer's recommendations and equations.

3.5.3 Presentation of Monitoring Data

****

NOTE: It is recommended that Section 01 31 20 PROJECT TECHNICAL DATA MANAGEMENT AND VISUALIZATION be included in the contract specifications package for the project and referenced herein. If included, review the following paragraphs and remove redundant information that is included in Section 01 31 20.

If the web interface needs to have a geospatial component, that language must be added - this language will only get a graphical display output of the instrumentation readings according to the requirements specified in "Graphics".

Ensure that the format can be readily uploaded into the system you are using as your final storage location. The best way to accomplish this would be to provide the data dictionary of the final database schema to the Contractor and require they use the same tables, fields, field types and relationships.

Once projects are fully integrated to MIDAS, the web interface may become obsolete because MIDAS will offer most plotting functionality needed. If the Government will retrieve and host its own data through MIDAS or another web-based dashboard

platform, remove this requirement.
****

3.5.3.1 Web Interface of Interactive and Static Reports of Data

Through the use of a secure web interface, establish interactive and static reports generated from the instrumentation data gathered at the site. Establish the web interface within 30 days following Notice to Proceed. Provide backups for the website in accordance with the requirements stated in paragraph DATA REQUIREMENTS. The interface must be intuitive, easy to navigate, and include all graphical plots and displays as detailed in this section. Within [60][_____] days of the notice to proceed, provide a presentation (for training purposes) of all components of the web interface for submittal approval by the Government.

3.5.3.2 Quick Reference Guide

Within [60][_____] days of the Notice to Proceed, produce and submit a digital and paper Quick Reference Guide for use of the website that meets the following minimum criteria:

a. Describes in detail the website structure and contents.

b. Describes in detail the location and steps to use the features and functionality.

c. Describes in detail how to download plots and other graphical displays.

d. Is designed in a simplified, indexed, and well-organized manner.

e. Includes web addresses of web-hosted sites in use, and POC information for administrators who can provide user-access to the Government.

3.5.3.3 Training

Within [60][_____] days of the Notice to Proceed, provide training sessions, on site or at the Government office - as coordinated with the Government, to familiarize and train Government users on the web interface. Provide [2] sessions, [2 hours] in length each.

3.5.3.4 Graphics

a. Reduce piezometric data to elevation in meters feet and plot it, along with headwater and tailwater elevations, versus time.. The Y axis showing elevation must not be a dynamic axis. Plot values together on one scale range of the X axis.

b. Reduce alignment pin readings to total horizontal and vertical movement (in cm inches) from the initial positions and plot versus time.

c. Reduce and plot inclinometer data vs depth.

d. Reduce weir data and plot as a time series.

e. For weekly reports, the data plotted versus time must be shown in plots spanning the one-month report period, one year period, and lifetime period. Indicate on the plots maximum and minimum instrument readings spanning the life of the instrument. Include the following

information for the reading data:

(1) instrument location number,
(2) date of reading,
(3) reduced readings,
(4) all remarks from any field observations,
(5) water elevation,
(6) other work completed within the vicinity plotted on the date in which it took place,
(7) excavation elevation near that instrument, and
(8) ambient temperature.

f. Plot Automated Robotic Total Station Monitoring system data as x, y, z and resultant displacement versus time, and provide in tabular format.

3.5.3.5 Discussion

All automated data must include corrections for temperature and/or barometric pressures changes, as recommended by the manufacturer (and necessary for calculations). In all reports generated, include a written description of how the data was reduced, including any equations utilized.

3.6 AVAILABILITY OF MONITORING DATA

****
NOTE: It is recommended that Section 01 31 20 PROJECT TECHNICAL DATA MANAGEMENT AND VISUALIZATION be included in the contract specifications package for the project and referenced herein. If included, review the following paragraphs and remove redundant information that is included in Section 01 31 20.
****

3.6.1 Website Access

3.6.1.1 Security Credentials

Provide 24/7 read access to the data to the Government, the Contractor, and any related subcontractors for the duration of this contract. Within 30 days of Notice to Proceed, provide the COR any necessary username and password or other security credential for access. For new personnel requested by the Government throughout the contract, grant access and provide security credentials within 48 hours of the request.

3.6.1.2 Data Update and Display

The website must update all automated data within [10 minutes][_____] of data collection at a specific instrument. Post all manually read instruments and surveyed instrument data to the website within [4 hours][_____] of data collection on that specific instrument. Plot scales, offset, and layouts must be editable by users, with the new selected defaults saved for each user.

Displays must include automatically updated plots from all instrumentation as outlined in ANALYSIS, REPORTING AND PRESENTATION OF DATA.

3.6.1.3 Site Operability and Useability

The website must be fully functional, current, easy to navigate,

accessible through Government VPN, and complete with all instrumentation data available for retrieval by both automated and manual methods. Demonstrate the system to the Government prior to System/Website Training. If the website is not functional, with data available and easy to read, pertinent payments will be withheld until the issue is resolved and acceptable to the Government.

3.6.2 Raw Data

Furnish all collected data in a native CSV or TOA5 Data Format. Data must have, at a minimum, Instrument Id, timestamp, and value. Submit raw data files via the [project SFTP][_____] within [24 hours][_____] of generation.

3.7 THRESHOLDS AND RESPONSE ACTIONS

3.7.1 Threshold Values

****

NOTE: See Table 8.2 of USACE EM 1110-2-1908 (30 Nov. 2020) for example thresholds to trigger response evaluation for various geotechnical instruments.

****

Monitor instrument readings against the Alert and Action Threshold Values as defined individually for instruments [in the table below] [as outlined in the Instrumentation and Monitoring Plan prepared by the Instrumentation Specialist and approved by the Government]. The actions to be implemented when these Threshold Values are reached are referred to as Response Actions and are explained in paragraph RESPONSE ACTIONS. Threshold values must be identified on respective plots.

THRESHOLD VALUES				
Instrument Type	Instrument IDs	Unit of Measure	Alert Threshold Value	Action Threshold Value
Piezometer	[_____]	m ft	[_____] m ft, or rate of change	

3.7.2 Response Actions

If an Alert Threshold Value is reached, the Contractor's Instrumentation Specialist must immediately evaluate the instrument response by collecting a manual reading if possible, and also in relation to weather and physical conditions at the location of the instrument and provide an update to the Contractor and Government.

Within [24 hours][_____], analyze the instrument response and submit an Instrument Alert Assessment providing an assessment of the cause of the alert and predict further responses and their effect based on the trend to

date. Include recommendation for any corrective action, if needed.

If an Action Threshold Value is reached, the Contractor must immediately stop work, remove personnel from the affected work area, and implement the emergency response actions included in the Instrumentation and Monitoring Plan previously approved by the Government. The Instrumentation Specialist must immediately evaluate the instrument response with respect to physical conditions at the location of the instrument.

****
NOTE: Consider adding a note to the Plans to bring this to the construction contractor's attention and/or include in Section 01 14 00 WORK RESTRICTIONS.
****

Submit a detailed Action Threshold Exceedance Report documenting the site conditions, such as weather, and construction activities when the action threshold value was reached, analysis of the cause(s) for exceedance, and recommendations for any corrective actions needed. Resume suspended activities only after receiving written instruction from the Government.

3.8 VISUAL INSPECTION

Conduct routine visual observations of the site and instruments by selected individuals and at intervals defined in the approved Instrumentation and Monitoring Plan. Submit written and site photo documentation of these routine visual observations to the Government within [48 hours][_____] of completion. Areas that have been identified as potentially concerning should be noted and monitored at prescribed visual observation frequencies. While monitoring instruments, examine installed instrumentation for evidence of damage, malfunction and possible future damage caused by construction activities, and report any such issues, along with photos, to the Government. Submit this information, along with any site photos, to the Government. Also record nearby construction activities, such as pile driving, stockpiling, excavation or water control and environmental conditions, such as the weather or presence of floodwater and all other events that may influence instrumentation data.

Perform visual inspection at the location of any instrument that is producing unexpected or unusual readings. Immediately perform inspection of an instrument that has exceeded an Alert Threshold as further detailed in paragraph THRESHOLD VALUES.

3.9 SYSTEM RELIABILITY

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NOTE: The content of this paragraph applies to instruments installed for the purpose of monitoring active construction.
****

The entire instrumentation system including datalogging equipment, servers, sensors, wiring, etc. must be maintained at all times. If in the Government's opinion the instrumentation system is not functioning properly, as demonstrated by unreliable and/or questionable readings, all construction work must cease immediately and not resume until the system is performing as specified. No additional compensation will be made by the Government for any cessation of work. The Government will determine

whether the performance of the instrumentation system is satisfactory to resume work.

3.10 MAINTENANCE AND REPLACEMENT

Before work begins on a delivery order, prepare a list of all extra components that are required for continuous operation of the system and quantities to be stockpiled on-site according to the estimated replacement rate per the manufacturer recommendation. Submit this list to the Government for approval. The items on the approved list must then be available at the site during the entire period of the delivery order. If a stockpiled item is used, immediately replace it with the same item that was used.

If an instrument is repaired, replaced, or moved subsequent to installation, record new: instrumentation type, as-built location, and calibration sheets. Submit an Instrument Modification Report to the Government detailing the reason the original instrument was altered and the date the new instrument was operational.

For the duration of the contract period, maintain all instrumentation installations in progress and all completed instrumentation installations. In the event of a malfunction or breakdown, notify the Government of the nature of the malfunction or breakdown within 12 hours of initial observation of its occurrence, and provide an estimate of when that part of the system will be back in service if the Government approves a replacement. Depending upon the status of the construction at that time, the Government will determine whether a manual backup system must be implemented by the Contractor. If an instrument does not function properly for a cumulative total of [10][_____] calendar days or more within any 30 consecutive calendar day period, the Contractor will not be provided the [monthly][_____] payment for item General Instrumentation Requirements until repairs have been made and approved by the Government.

3.11 PROJECT CLOSEOUT AND RESTORATION

Upon completion of construction, as determined by the Contracting Officer, the Contractor must remove and properly dispose of all instruments and devices from the site, except for those instruments identified for long term monitoring [as detailed on the contract drawings][_____]. Confirm these instruments with the Government prior to initiation of removal activities by submitting an Instrument Removal List for Government review and approval a minimum of [30 days][_____] prior to the removal of any instruments. Retrieve all removable equipment and backfill holes with an approved grout mix. Any protruding parts, which cannot be removed completely without damage to the structure must be cut off flush with the surface. Remove all sharp edges. Repair any damage to existing structures from removal of instrumentation devices to the satisfaction of the Government and at no additional cost to the Government.

3.12 VIBRATION MONITORING

3.12.1 Preconstruction Condition Survey

The Seismologist/Vibration Consultant must conduct a Preconstruction Condition Survey of all existing structures and utilities within the area designated in the plans. The Contractor must have both letter and personal contact with residents, owners and operators of the structures

and must notify them a minimum of two weeks prior to performing the survey.

Obtain Right-Of-Entry or permissions for all properties entered as part of this survey. Any owners refusing the Preconstruction Condition Survey must be given the opportunity to sign a statement, produced and provided by the Contractor, stating any reasons for non-participation.

a. The Preconstruction Condition Survey must be performed by an experienced Professional Engineer familiar with construction methods and materials, and structural response to ground vibrations generated by construction activities.

b. The Preconstruction Condition Survey must consist of a description of the interior and exterior condition of each of the structures examined, including: above ground structures, foundations, basements, driveways, walkways, electrical, plumbing, utilities (overhead and buried), transmission lines, drains, wells and water systems. Describe any signs of existing distress, cracks, damage, spalling, settlement, leakage, or other defects. The survey must include such information to make it possible to determine the effect, if any, of the construction operations on the existing defect. Where significant cracks or damage exist, or for defects too complicated to document in words and sketches only, photographs must be taken or a good quality video survey with appropriate audio description of locations, conditions, and defects must be performed to supplement the written description. Survey must include a list of vibration sensitive equipment or furnishings, and potential falling debris hazards.

c. Install crack displacement monitoring gages as appropriate across any significant existing cracks and read [periodically][after the conclusion of blasting][after each blast][_____] to verify if any additional distress should develop. Include the crack gauge readings, recommendations for additional instrumentation types or survey monuments, if needed, in the report. Identify structures or elements that are potentially susceptible to damage and recommend, if warranted, potential: support, repair, vibration mitigation measures, or reduced ground vibration limits.

d. The Seismologist/Vibration Consultant must give written notice to the owner of any inspected structure, tenants, and any representative of local authorities required to be present at the Preconstruction Condition Survey. The notice must state the coordinated dates and time on which surveys are to be made.

e. Owners of the structures must be given a copy of the survey of their particular structure and be given the opportunity to comment on its accuracy. Submit the Preconstruction Condition Survey to the Government 30 days prior to construction activities that, in the opinion of the Government, would be a source of ground vibrations.

3.12.2 Postconstruction Condition Survey

Conduct a Postconstruction Condition Survey within 30 calendar days upon the completion of all construction work that, in the opinion of the Government, generate ground vibration. Postconstruction Condition Surveys must be conducted on all structures and utilities that previously had a Preconstruction Condition Survey, and on any additional properties, structures, and conditions for which complaints of damage have been received or damage claims have been filed. Give notice to all parties, as

identified in paragraph PRECONSTRUCTION CONDITION SURVEY, subparagraph d., so that they may be present during the final examination. Distribute records of the final examination in the same manner as the original Preconstruction Condition Survey. The Postconstruction Condition Survey must have the same requirements as the Preconstruction Condition Survey and must consist of a description with any measurements, surveys, photographs, and other information needed to document the postconstruction condition of surveyed structures. Preconstruction and postconstruction comparisons must be made of surveyed areas, including photographs and other measurements. The Seismologist/Vibration Consultant must include an evaluation of whether any noted differences between the Preconstruction and Postconstruction Condition Surveys are the result of construction vibrations or due to other causes.

3.12.3 Vibration Test Program and Report

Upon completion of the Preconstruction Condition Survey, a Vibration Test Program and Report must be directed and completed by the Seismologist/Vibration Consultant. The completed Vibration Test Program and Report must be submitted and approved prior to full production phase of any proposed construction activity that, in the opinion of the Government, could be a source of ground vibration. These construction activities include, but are not limited to: trenching, hauling, backfilling, compacting, and pile driving. The vibration test program must be conducted, in part, to verify vibration levels for proposed construction equipment listed in the Vibration Monitoring Plan.

Obtain ambient or baseline ground vibration values prior to vibration testing of construction equipment. Vibration monitoring must be performed for 12 daylight hours to obtain the ambient or baseline ground vibration values at [_____].

Perform the Vibration Test Program(s) in a remote area of the project, at a distance of at least [30 meters] [100 feet] [_____] from the nearest structure. Components of the Vibration Test Program must be established and directed by the Seismologist/Vibration Consultant. The vibration tests must include, but are not limited to: vibration monitoring at various distances from the vibration source, determination of the ground vibration source level for the construction equipment and methods (minimum requirement includes peak particle velocity and frequency values at various distances from the source), and establishing the attenuation rate through the project soil.

The Vibration Test Programs and Report must state the suitability of the proposed construction equipment and methods to perform within the specified vibration criteria. If it is determined, by the Vibration Consultant or Government, that the proposed construction equipment and methods cannot satisfy the specified vibration criteria, then alternative or supplemental equipment/methods, or vibration mitigation measures must be tested and report resubmitted for approval, at no additional cost to the Government.

The report must also include any recommendations to reduce construction impacts from ground vibrations or noise. Base recommendations on an analysis from the results of the Vibration Test Program, Preconstruction Condition Surveys, and site specific conditions. Recommendations could include, but are not limited to, the following: requirement for additional instrumentation to document potential settlement or displacement; requirement for more restrictive vibration criteria; ground

vibration or noise reduction measures.

3.12.4 Seismologist/Vibration Consultant Duties

The Seismologist/Vibration Consultant duties are as follows: direct and instruct the Contractor in operations to control vibrations within specified levels; participate in a public meeting; facilitate and complete the preconstruction and postconstruction surveys; perform Vibration Test Program(s) and complete report; provide, install, and use all necessary equipment to observe and record vibrations to ascertain that acceptable levels of vibrations are not exceeded; and monitor benchmarks, deflections, cracks, and other critical conditions on the existing structures. Obtain Rights-of-entry and permissions from landowners for access to perform vibration monitoring. Monitor vibrations, report findings, and furnish recommendations on a daily basis to the Contractor and Government, determine the level of observed vibrations attributed to the project's construction activities, and determine their subsequent effect on surrounding structures.

If the monitoring equipment can be operated automatically and monitored remotely, the Seismologist/Vibration Consultant must be present at the site for the start of new construction activities that require vibration monitoring, movement and setup of vibration monitoring instruments, monitoring devices for structural movement and settlement, and at other key times in the project as approved in the Vibration Monitoring Plan. Otherwise, the Seismologist/Vibration Consultant must be onsite during all applicable construction activities. The Seismologist/Vibration Consultant must be readily available if issues requiring attention arise during construction. When monitoring is occurring, the Seismologist/Vibration Consultant must check all equipment at the start of each work day to confirm that it is working properly.

3.12.5 Daily Vibration Monitoring Reports

At the end of each day of monitoring, the Seismologist/Vibration Consultant must record the following information on a form developed by the Seismologist/Vibration Consultant, and submit final signed reports electronically to the Government within 24 hours:

a. The name of the Contractor and/or Subcontractors responsible for the primary construction activities generating vibrations.

b. The name of the Seismologist/Vibration Consultant.

c. The name of the operator of the vibration monitoring equipment.

d. A sketch indicating the location of the vibration monitors and the construction activities generating vibrations.

e. Complete details of the particular construction activities which are being monitored, including all related equipment, operating frequencies, piling or excavation depths, distance from the construction activities to the monitoring equipment, and all other related information as requested by the Government.

f. Results of monitored vibrations and noise levels for the particular construction activity, including the frequencies of the measured peak particle velocities.

g. Identification of any activity resulting in the ground vibration or noise limits being exceeded and the time of day that the limits were exceeded. List time of day that the Contractor and Government were notified. List time of day that the construction activity was halted. Include corrective actions taken to reduce ground vibration and noise levels.

h. A summary of any vibration related complaints received during the day.

i. Reports must be reviewed and signed by the Seismologist/Vibration Consultant's experienced Registered Professional Engineer.

3.12.6 Web Interface of Interactive and Static Reports of Data

Through the use of a secure web interface, establish interactive and static reports generated from the vibration monitoring data gathered at the site. Establish the web interface within 30 days following Notice to Proceed. Provide backups for the website in accordance with the requirements stated in paragraph DATA REQUIREMENTS. The interface must be intuitive, easy to navigate, and include real-time monitoring data. Within 60 days of the notice to proceed, provide a presentation of all components of the web interface for submittal approval by the Government.

3.12.7 Adjustments in Construction Procedures

If the Contractor receives complaints by the public during construction, or during the Preconstruction and Postconstruction Condition Survey process, the Contractor must follow a Vibration Screening Procedure and fill out a Vibration Complaint Report, in accordance with the approved Vibration Monitoring Plan. The Contractor must notify the Government of any complaint within 24 hours and must submit a copy of the completed Vibration Complaint Report within one week of the complaint.

If the monitoring data indicates that the ground vibration limits for any of the three mutually perpendicular components, or noise limit, have been exceeded, the construction activity generating those vibrations must be halted immediately. A deficiency correction report, giving corrective actions or mitigation measures to reduce ground vibrations or noise levels, must be submitted by the Contractor. Construction activity may not resume until the report has been approved by the Government and corrective actions or mitigation measures are completed by the Contractor. Vibration or noise mitigation or reduction measures must be constructed or implemented at no additional cost to the Government.

3.12.8 Government Quality Assurance

The Government may check the vibration monitoring operations at any time and may perform independent vibration monitoring.

3.12.9 Ownership

At the end of this contract, on a date specified by the Government's Representative, all instrumentation components become the property of the Government. All data collection and recording devices must be calibrated and certified by the manufacturer or a certified laboratory prior to being delivered to the Government's Representative. The Contractor is responsible for all costs for the recalibration, shipping, and verification of these data recorders.

-- End of Section --