

SECTION 02495**GEOTECHNICAL INSTRUMENTATION****PART 1 GENERAL****1.01 SUMMARY**

- A. This Section includes:
 - 1. Furnishing, installing, protecting, maintaining, replacing, monitoring, reducing, plotting, interpreting, and reporting data from geotechnical instrumentation.
 - 2. Removal or abandonment of the geotechnical instrumentation.
- B. The purpose of the Geotechnical Instrumentation Program includes, but is not limited to, performing and providing the following:
 - 1. Pre-construction baseline data for comparison throughout construction and with post-construction data.
 - 2. Monitoring of soil, groundwater, support of excavation, structures, and facilities prior to, during, and after construction, to determine whether they have been adversely affected by construction activities.
 - 3. Implementing construction procedures to control vibration as well as movements of soil, structures, and facilities. Geotechnical instrumentation shall be installed as necessary to monitor ground conditions and ground response, to verify the effectiveness of these procedures, and provide an early warning system to allow for construction adjustments and prevention of movement, deflection, and vibration exceeding the Response Values as set forth herein.
 - 4. Implementing remedial measures based on the instrumentation data.
- C. Provide all labor, materials, equipment, tools, and services for all Works specified in this Section.
- D. Monitor all existing and newly constructed facilities, including, but not limited to, buildings, structures, utilities, highway ramps, sidewalks, pavements, and other facilities. This includes facilities that are constructed prior to or during the project duration.
- E. The requirements contained herein are minimum requirements and the Contractor is responsible to determine any additional or more stringent requirements including instrument quantities, frequency of monitoring, and instruments response levels based on results of pre-construction condition survey, Contractor's means and methods, and

existing site and subsurface conditions. Additional instrumentation and monitoring shall be provided where the Contractor deems it necessary to ensure the safety of personnel and the Work. The final Instrumentation and Monitoring Plan is subject to the approval of the Authority.

- F. Provide, install, and perform readings for at least: sixty (60) Surface Monitoring points (SMPs), five (5) Ground Monitoring Points (GMPs), thirty (30) Deformation Monitoring Points (DMPs), two (2) Utility Monitoring Points (UMPs), and five (5) crack gauges. The number of Excavation Support Monitoring Points (ESMPs) and groundwater Monitoring Wells (MWs) shall be determined based on the excavation support and dewatering systems utilized and shall comply with the requirements specified herein.
- G. Provide at least two (2) seismographs for vibration monitoring throughout the duration of vibration generating activities as specified herein.

1.02 RELATED SECTIONS

- A. Section 01050 – Field Engineering
- B. Section 01060 – Permits and Regulatory Requirements
- C. Section 01300 – Submittals
- D. Section 01390 – Condition Surveys
- E. Section 01400 – Quality Control Testing
- F. Section 02240 – Construction Dewatering and Groundwater Control
- G. Section 02311 – Support of Excavation

1.03 CODES AND STANDARDS

- A. ASTM International (ASTM):
 - 1. ASTM A53 – Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless.
 - 2. ASTM C33 – Standard Specification for Concrete Aggregate.
 - 3. ASTM C150 – Standard Specification for Portland Cement.
 - 4. ASTM C778 – Standard Specification for Standard Sand.
- B. American Petroleum Institute (API):
 - 1. API 13A – Specification for Drilling Fluids Materials.

1.04 SUBMITTALS

- A. Submit the following in accordance with Specification Section 01300 – Submittals.
- B. At least 45 days prior to commencing any construction activities which may produce vibrations, disturb subsurface conditions, or modify groundwater conditions submit for approval:
 - 1. Resumes and qualifications of the Geotechnical Instrumentation Engineer (GIE) and Professional Land Surveyor including relevant experience as specified herein.
 - 2. Resumes and qualifications and their respective roles and responsibility for the project of all other geotechnical instrumentation personnel and associated subcontractor(s) with their respective roles and responsibilities, to be assigned to the project.
 - 3. Instrumentation and Monitoring Plan prepared by the GIE. The Instrumentation and Monitoring Plan shall include, at a minimum, the following:
 - a. Layout plans and elevations of the proposed locations of each instrument.
 - b. Instrument type, details, product data from the manufacturer, including details of principal features, method of installation, mode of operation, measuring range, and degree of accuracy of instrumentation equipment.
 - c. Schedule for installation, monitoring, and data reporting.
 - d. Detailed descriptions of the methods for installing and protecting all instrumentation.
 - e. Details of the installation method for benchmarks.
 - i. Detailed step-by-step procedures for installation and monitoring of all instruments.
 - f. For all instrumentation installed in boreholes, provide a detailed procedure for installation, including pre- and post-installation acceptance tests and sample installation record sheets for each type of instrument. The installation procedures shall include drill casing or auger type and size; method for cleaning casing or auger; specifications for proposed grout mixes, proportions of admixtures and water, mixing sequence, pumping methods and tremie pipe type, size and quantity; depth increments for backfilling boreholes with sand and bentonite; method for overcoming buoyancy of instrumentation components during grouting; and method of sealing joints in pipe casing to prevent ingress of grout.

- g. Detailed step-by-step procedures for conducting all optical survey measurements to the specified accuracies, including types of instruments and data reduction procedures. The manufacturer's stated accuracy and the field procedures shall be such that the resulting accuracies meet the requirement specified in Section 01050 – Field Engineering.
 - h. A bar chart indicating the proposed schedule of instrument procurement, installation and testing.
 - i. Additional instruments required for safety or personnel shall be submitted for information.
- C. At least two (2) weeks prior to installation, submit records of all calibration certificates and tests of equipment to be used for installation.
- D. At least three (3) weeks prior to commencing any dewatering or construction activities, submit the Response Action Plan for approval.
 - 1. The Response Action Plan shall identify the specific anticipated actions or example actions to be implemented at each response action level for each element of the Work which may cause vibration, movement, or groundwater drawdown to reach the response action levels and shall include as a minimum the measures described above under Response Action Levels, all other potential response measures envisioned by Contractor, plus the names of the responsible person of Contractor's team for each element of the Work. The Response Action Plan, at a minimum, shall also identify all key structures and utilities throughout the Site and their owners and responsible contact persons, as well as define Contractor team person responsible for each structure. The Response Action Plan shall also identify the resources required for each Alert response and Stop Work response, including the notification required if action is taken at each level.
 - 2. The Response Action Plan shall be updated and submitted by Contractor from time to time as required by the Authority based upon performance in field and changes in responsible persons as the project proceeds.
 - 3. At a minimum, one copy of the Response Action Plan shall be maintained at Contractor's field office.
- E. Within five (5) working days of performing a field calibration, submit results of the calibration.
- F. Within fourteen (14) working days of installing each instrument, submit the as-built instrument location plan and instrument pre- and post-installation acceptance test, and installation record sheets, including:

1. Installation details showing all dimensions and materials used, including model and serial number of equipment and sensors installed.
2. As-built location of all instrumentation with unique instrument identification number, initial coordinates, initial elevation, as-built orientation, and routing of cabling. Include photo documentation with a location plan for each crack gauge.
3. Description of installation procedures, dates(s) of installation, subsurface data encountered during installation, drilling logs, inclinometer installation reports and completion diagrams, weather conditions during installation, and problems encountered.
4. Baseline readings of the installed instruments.

G. Progress Submittals:

1. Submit the latest survey elevations at each monitoring point along with all previous survey elevations, with plots against threshold values within 24 hours of each survey.
2. On a weekly basis submit interpretative reports including monitoring data for all instruments for a minimum of four (4) weeks prior to the current reporting period, baseline readings, and location plan for all instrumentation with the exception of vibration monitors. The report shall include daily weather records and a detailed summary of all construction performed during the reporting period as well as a summary of actions taken related to any Response Values exceedances.
3. The morning following each working day when vibration generating work occurs (e.g. pile driving, sheet pile installation, socketing into rock, etc.), submit a Vibration Monitoring Report on the form contained in Attachment 02495-A, including a plot of the peak particle velocity versus the frequency of vibration, and a copy of strip chart (or other permanent record of velocity/time waveform) with calibration and monitoring record marked with the date, time and location of the work, as well as the measured distance of the monitoring location relative to the work performed.
4. Submit complaint reports immediately after receipt of complaint. Complaint reports shall include the name and address of the party that made the complaint, time received, date and time of event that resulted in the complaint, description of the circumstances which led to the complaint, and any and all follow-up actions.
5. Submit a detailed updated Response Action Plan for actions to be taken if the Response Values are reached.

H. Final Monitoring Report:

1. Upon taking final readings for a given stage of the Work, provide a final monitoring report with a complete set of readings along with drawings that show how each instrument was removed/abandoned and surfaces reinstated, if applicable.
- I. Whenever a monitoring well is abandoned or removed, submit well abandonment report in accordance with applicable local, state, and federal requirements.

1.05 QUALITY ASSURANCE

- A. All Work shall be in accordance with Specification Section 01400 – Quality Control Testing.
- B. All Work shall be conducted in accordance with all applicable codes, standards, and permits, including local soil boring permits. The entity responsible for installation of subsurface geotechnical instrumentation shall be a licensed driller and shall have a valid and current Massachusetts Business License.
- C. Geotechnical instrumentation shall satisfy additional requirements specified in Specification Section 01050 – Field Engineering and Specification Section 01060 – Permits and Regulatory Requirements.
- D. Each instrument or component of instrument specified herein shall be the product of a reputable manufacturer currently engaged in manufacturing geotechnical instrumentation hardware of the specified types.
- E. Factory Calibration: as part of manufacturing quality control, factory calibration shall be conducted on all geotechnical instrumentation prior to shipment. Certification shall be provided to indicate that the test equipment used for this purpose is calibrated and maintained in accordance with the test equipment manufacturer's calibration requirements and that, where applicable, calibrations are traceable to the U.S. National Institute of Standards and Technology.
- F. A final quality assurance inspection shall be made prior to shipment. During the inspection, a checklist shall be completed to indicate each inspection and test detail. A completed copy of the checklist shall be supplied with each instrument.
- G. Field Tests
 1. If an automated geotechnical instrumentation monitoring system is used, for each instrument measured by a data logger, compare data captured manually at the data logger against the data reported to the Geotechnical Instrumentation Monitoring System over the same time period once per quarter.
 2. Document the results of these tests and submit information to the Authority.

3. Correct any deficiencies in the measurement instrument within 24 hours.
- H. All instrumentation installations shall be performed in the presence of the Authority including borehole drilling. Installations performed in the absence of the Authority shall not be accepted.

1.06 QUALIFICATIONS

- A. Personnel responsible for furnishing and installation, testing, calibration, reading, monitoring, and maintenance of the instruments, for analyzing, interpreting, and reporting instrument data, and for surveying the instruments shall have the qualifications specified herein.
- B. The instrumentation personnel shall include a GIE who is a Registered Professional Engineer licensed in the Commonwealth of Massachusetts and has demonstrated previous successful experience on a minimum of at least three (3) projects of similar size and complexity to the Work of this contract within the past five (5) years in similar subsurface conditions.
- C. Borehole drilling for installation of geotechnical instrumentation shall be monitored and logged by a geotechnical engineer, geologist, or geological engineer with a minimum of two (2) years of demonstrated experience in field boring inspection registered and licensed in the Commonwealth of Massachusetts.
- D. The Professional Land Surveyor (PLS) shall be registered in the Commonwealth of Massachusetts and have at least three (3) years of experience in surveying similar projects and complexity to the Work of this Contract within the last three (3) years. The field survey team chief shall also have experience in survey measurements of the types and accuracies specified herein.
- E. Field personnel responsible for monitoring manually collected instrumentation shall hold an engineering degree and have at least three (3) years of experience on projects of similar complexity to the Work of this Contract within the last three (3) years.

1.07 DELIVERY, STORAGE, AND HANDLING (NOT USED)

1.08 PROJECT/SITE CONDITIONS (NOT USED)

1.09 DEFINITIONS (NOT USED)

1.10 TOLERANCES

- A. Survey measurements for initial location of each of the instrumentation elements shall consist of determining the elevation and horizontal position with respect to benchmark(s).

B. Monitoring Points

1. Elevations of all instrumentation shall be determined to an accuracy of plus/minus 0.01 foot.
2. The horizontal position of surface monitoring points (SMPs), ground monitoring points (GMPs), and utility monitoring points (UMPs) shall be determined to an accuracy of plus/minus 0.05 foot.
3. The horizontal and vertical position of deformation monitoring points (DMPs) and excavation support monitoring points (ESMPs) shall be measured to a precision of plus/minus 0.01 foot.

1.11 PERFORMANCE REQUIREMENTS

- A. Repair or replace all damaged instruments within 24 hours. Report all damaged or non-functional instrumentation to the Authority within 24 hours. Upon repair or replacement, the monitoring data shall account for movement recorded by predecessor instruments in the readings.
- B. The Contractor shall be responsible for the adequacy of the Instrumentation and monitoring program to ensure safety and protection of the adjacent properties, which shall include, but is not limited to, buildings, structures, utilities, highway ramps, sidewalks, pavements, and other facilities. This includes facilities that are constructed prior to or during the project duration. Any damage due to the Contractor's work or inadequacy of instrumentation and monitoring program, and any corrective action or repairs needed to restore any damaged structure or facility to its condition that existed before the start of Work, shall be the responsibility of the Contractor.
- C. To the extent possible, protect and maintain the existing groundwater monitoring wells as shown on the Contract Drawings and perform groundwater readings. In addition to replacing Monitoring Well SB-FD-543-A (MW), replace, prior to the start of excavation activities, any other monitoring wells damaged or destroyed as a result of construction activities. All the remaining and new groundwater monitoring wells shall be monitored and reported for the duration of the project in accordance with the requirements specified herein and the approved dewatering and groundwater control plan per Specification Section 02240 – Construction Dewatering and Groundwater Control.
- D. Availability of Data
 1. Instrumentation and monitoring data shall be available at any time in a format that is easy to review visually and acceptable to the Authority.
 2. Monitoring data shall be the property of the Authority and shall not be disclosed to third parties or published without permission of the Authority.

E. The GIE Responsibilities

1. Prepare, sign and seal all submittals related to geotechnical instrumentation and monitoring specified herein.
2. Continuously screen data to ensure validity and oversee the configuration and ongoing operation of the Geotechnical Instrumentation Monitoring System.
3. Prepare detailed step-by-step procedures and data flow charts for all instruments and Geotechnical Instrumentation Monitoring Systems, as specified herein.
4. Be on site to supervise, at a minimum, the first five (5) installations of each instrument type.
5. Perform pre-installation and post-installation acceptance tests for all instruments, data logging, and reporting systems.
6. Manage the repair and replacement of damaged or inoperable instruments and monitoring system components.
7. Supervise data collection, reduction, plotting, interpretation, and reporting, except for manually collected survey data.
8. Participate in discussions with the Authority regarding instrumentation, monitoring systems, and data.
9. Coordinate instrumentation planning, measurement, interpretation, and reporting with the Contractor's Design Engineer responsible for the support of excavation designs.

PART 2 PRODUCTS**2.01 GENERAL**

- A. Provide all instrumentation hardware, protective covers, read-out equipment, and equipment and materials necessary to conduct the monitoring program. Prior to installation, all materials and equipment shall be available for inspection by the Authority. Furnish all installation tools, materials, and instrumentation components.
- B. Surface protection shall be provided for all instruments and shall be flush with the ground surface unless otherwise approved by the Authority.
- C. Grout:
 1. Cement: Portland, Type I or II, ASTM C150.

2. Bentonite: Satisfying API Specification 13A.
3. Sand Backfill: ASTM C33.
4. Drilling fluid shall be in accordance with API 13A.

2.02 DEFORMATION MONITORING POINTS

- A. Deformation Monitoring Points (DMPs) shall be used to monitor vertical and horizontal movement of adjacent above-ground utilities and structures. Installation of DMPs shall be reviewed and coordinated with the Authority, and the owners and operators of utilities, structures and facilities.
- B. DMPs shall consist of nails, screws, reinforcing bars, or bolts with well-defined measurement points, or optical survey targets (OSTs).
- C. DMPs shall be firmly attached and shall be protected from damage and vandalism.
- D. Remove or cover with a protective box or cap all elements of DMPs protruding more than 0.25-inches.
- E. Clearly identify all DMPs with permanent, legible letters and numbers.
- F. In the case where DMPs are not permissible to be affixed to property not owned or controlled by the Project, reflectorless survey measurements shall be performed at repeatable locations identified on such structures or facilities.

2.03 EXCAVATION SUPPORT MONITORING POINTS

- A. Excavation Support Monitoring Points (ESMPs) shall be fixed markers or OSTs on the elements of the excavation support system and shall be used to monitor horizontal deformation of the excavation support system designed by the Contractor. Clearly identify all points with permanent and easily readable letters and numbers as approved by the GIE. The area surrounding each point shall be clearly identified using fluorescent spray paint such that if the point becomes disturbed, the area absent of paint will provide a visual indicator of disturbance.

2.04 SURFACE MONITORING POINTS

- A. Surface monitoring points (SMPs) shall be used to monitor vertical deformation of the ground at or near the ground surface. Clearly identify all points with permanent, legible letters and numbers.
 1. SMP in paved areas shall be installed into asphalt or concrete covered surface and shall consist of either:

- a. A sleeved anchor with set bolt set.
 - b. A 2-inch-long hardened steel PK nail.
2. SMP in non-paved areas shall:
 - a. Consists of a three (3) foot long, three-fourths (3/4) inch diameter steel rod driven into the ground or set in concrete in the ground such that no more than three (3) inches of the rod is exposed above the ground surface.
 - b. The top of the rod shall be rounded and punch marked at its center.
 - c. Each rod shall be individually identified by a surface marking.
3. SMP on utility manholes shall:
 - a. Consist of an observable cross mark or welded bead on the top horizontal surface of utility manhole rims.
 - b. The surface, within three (3) inches of the point, shall be cleaned to permit easy identification of the exact monitoring point.
 - c. The point shall be clearly identified using fluorescent spray paint adjacent to the point.
4. Each SMP shall be individually identified by an identification tag or surface marking.

2.05 Ground Monitoring Points

- A. Ground Monitoring Point (GMPs) shall be used to monitor vertical displacement of the ground and shall consist of a one (1) inch-diameter Schedule 80 steel pipe that extends at least two (2) feet below bottom of pavement or three (3) feet below the ground surface. Split the bottom one (1) foot of pipe and spread end slightly. Install an end cap on the top of steel pipe inside a road box casing to protect the GMP from the traffic. Install the protective road box casing flush with ground surface.

2.06 UTILITY MONITORING POINTS

- A. Utility Monitoring Points (UMPs) shall be used to monitor vertical movement of selected utilities and underground structures as specified herein.
 1. UMP shall include, at a minimum, the following:
 - a. 3-1/2 inch extra strong steel pipe sleeve and 1-inch extra strong steel riser pipe, threaded and coupled, ASTM A53 Grade B.

- b. PVC centralizers consist of a schedule 40 PVC pipe conforming to ASTM D1785, sized to provide a tight fit on the riser pipe, and spring-formed to a larger diameter to provide a loose fit in the sleeve pipe.
2. UMPs shall be installed at the top of the utility or underground structure by vacuum excavation method. The monitoring rod with centralizers shall be set on top of the utility or underground structure and extend to within one (1) foot of the ground surface. The UMP shall be installed with a flush mount road box casing at grade and shall be clearly identified by surface marking.

2.07 OPTICAL SURVEY TARGETS (OST)

- A. OST shall be surveyor's high precision optical prisms or reflectors compatible with the survey equipment used and capable of providing measurements within the specified tolerances.

2.08 ACCESS COVER

- A. Furnish and install guard casing with access cover to protect installed monitoring points. Use steel of sufficient strength to withstand AASHTO HS-20 truck loadings where traffic rated covers are required. Access cover shall be watertight.

2.09 GROUNDWATER MONITORING DEVICES

A. General

1. Vibrating Wire Piezometers may be used in place of monitoring wells as approved by the Authority. Manufacturer's requirements, installation details, and equipment product sheets shall be submitted for approval. Monitoring requirements shall follow the monitoring well.

B. Monitoring Wells:

1. Materials that are used in the construction of a monitoring well shall be clean.
2. Filter material shall be provided around well screen to prevent loss of fines or clogging. Filter material shall be designed for compatibility with the surrounding materials. Sand material shall conform to ASTM C778 for 20-40 sand.
3. Provide granular bentonite by Enviroplug Medium, as manufactured by Wyo-Gen, Inc., or Holeplug, as manufactured by Baroid Division, Petroleum Services, Inc., PUREGOLD Medium Chips, as manufactured by CETCO (Minerals Technologies Inc.), or approved equal.
4. Well screen and riser pipes shall be composed of Schedule 40 PVC with minimum nominal internal diameter of two (2) inches.

5. Well screen shall be new, machine-slotted or continuous wrapped wire-wound. Slot size of the well screen shall be 0.010 inches Slot No. 10, unless otherwise approved by the Authority.
6. Provide end plug of the same material as the well screen with the capability to withstand installation and development stresses without becoming dislodged or damaged.
7. Protective casings shall have a lid capable of being locked shut by a locking device.
8. Cement shall be one (1) of the five (5) Portland cement types that are specified in ASTM C150.
9. Provide electrical water level indicator with a 50-foot-long graduated cable with graduations at 0.02-foot or smaller intervals.

2.10 VIBRATION MONITORS

- A. Vibration Monitors shall include at least two (2) seismographs and monitoring shall be performed full time during vibration generating construction activities. Vibration Monitors shall consist of geophones to directly measure velocities of ground vibrations resulting from construction activities as specified herein. Seismographs shall have been calibrated within the previous six (6) months in accordance with the requirements of the National Bureau of Standards. Seismographs shall have the following capabilities:
 1. Measure the three (3) mutually perpendicular components of particle velocity in directions vertical, radial, and perpendicular to the vibration source.
 2. Measure and display the maximum peak particle velocity component and frequency. These readings must be displayed and legible in the field and be plotted as part of the Report of Vibration Monitoring (Attachment 02495-A).
 3. Seismic range: 0.01 to 4 inches per second with an accuracy of plus or minus five percent (5%) of the measured peak particle velocity or better at frequencies between 4 Hertz and 125 Hertz, and with a resolution of 0.01 inches per second or less.
 4. Have a flat velocity frequency response with a minimum broad band of 6 Hertz to 150 Hertz with a tolerance equal to or better than plus or minus ten percent (10%).
 5. Have a low frequency omnidirectional transducer for measuring air blast overpressure with a flat frequency response within the limits of 2 Hertz to 250 Hertz with a tolerance equal to or better than plus or minus ten percent (10%).
 6. Acoustic range: 110 to 140 decibels (referenced to 20 micro-Pascals) with an accuracy and resolution of plus or minus 1 decibel.

7. Self-triggering wave form capture mode that provides the following information: plot of wave forms, peak particle velocities, peak overpressure, and frequencies of peaks.
8. Continuous monitoring mode must be capable of recording single-component peak particle velocities, and frequency of peaks with an interval of one (1) minute or less.

2.11 CRACK MONITORS

- A. Grid Crack Gauges shall include anchors, bolts, screws, and quick setting epoxy for monitoring the width of existing cracks and joints. The gauge shall be capable of operating in temperatures ranging from minus 25 degrees to 120 degrees Fahrenheit.
- B. Electronic crack gauges shall have threaded anchors with ball joints, which can be grouted to each side of the crack in any orientation and a transducer with a range of at least 1 inch, an accuracy of less than 0.1 percent, and a nonlinearity of no more than 0.5 percent.
- C. Non-electronic mechanical crack gauges shall be capable of measuring crack width changes to an accuracy of ± 0.005 inch. Crack gauges shall be constructed of durable, weather-resistant materials suitable for long-term outdoor exposure and shall include a fixed reference plate and a graduated transparent slide to allow direct visual readings.
- D. Provide a solid cover over each gauge which does not touch or otherwise interfere with the operation of the gauge.

PART 3 EXECUTION

3.01 GENERAL

- A. Install instruments as required herein and as necessary to monitor ground conditions, ground response, and facilities to achieve specified project requirements, and prevent damage to potentially affected facilities.
- B. Where boreholes and/or rock cores are required for instrument installation, create borehole and rock core logs in a format consistent and in accordance with industry practice. Borehole logs shall be signed by a geotechnical engineer, geologist, or geological engineer Licensed and Registered in the Commonwealth of Massachusetts.
- C. Prior to commencing any installation of excavation support, soil and rock excavation, pile installation and dewatering work, furnish components of instrumentation that are to be installed during construction and conduct pre-construction surveys in accordance with Specification Section 01390 – Condition Survey.
- D. Coordinate with the Authority and utility and structure owners and tenants for installation of instrumentation based on the findings of the pre-construction surveys.

The means and methods for installation and monitoring of instrumentation shall be coordinated such that the use and operation of the associated properties are not impacted.

- E. Provide and facilitate safe access to the Authority to the work area at all times for the purpose of observing core borings, instrumentation installation, and taking additional readings. No claim for lost production time due to this activity shall be permitted.
- F. Verify the reliability of all installed instruments a minimum of two (2) weeks prior to construction and maintain accurate monitoring data for the duration of the Work.
- G. Take every practical measure to prevent damage to the instruments and ancillary equipment during handling, installation, and subsequent operation. Maintain all the instruments required for long-term monitoring in working order. Protect instruments from being obstructed or otherwise damaged by construction operations or general public. Provide adequate access for maintenance and reading of the instrumentation.
- H. Install additional instrumentation in the event of an unforeseen condition being encountered for which more extensive monitoring is necessary for safety and performance of the Work.
- I. Install all instruments in accordance with the manufacturers' stated instructions.
- J. Locate conduits, underground and above-ground utilities in all areas where instruments are to be installed. Conduct utility clearance, inform Dig Safe (811 or 1-888-344-7233) and contact utility owners prior to any instrument installations. Instrument locations shall be modified, as approved by the Authority, to avoid interference with the existing conduits and utilities. Repair damage to existing utilities resulting from instrument installations at no additional cost to the Authority.
- K. Take every practical measure to prevent boreholes from collapsing during instrumentation installation.
- L. Notify the Authority at least 72 hours prior to installing each instrument.
- M. Secure all permits in accordance with Specification Section 01060 – Permits and Regulatory Requirements and confirm conformance to permit requirements prior to installation and removal of geotechnical instruments. All wetland permits or notification letters to the applicable Commissions shall be completed where applicable prior to construction and available for reference at the respective construction site.
- N. Immediately following installation, survey the location of all instruments to provide horizontal and vertical coordinates. Take a minimum of three (3) sets of initial readings to provide baseline readings and to demonstrate the adequacy of the completed installation. These measurements shall be made at least 24 hours apart. Instruments

with initial surveyed elevations or coordinates differing by more than 0.01 feet from any previous surveys shall be checked for secure installation and resurveyed. Resurvey if there is uncertainty regarding the instrumentation location or if directed by the Authority.

- O. Collect, reduce, process, plot, interpret, and report monitoring data obtained by survey, seismograph data, and groundwater levels, and submit to the Authority.
- P. Coordinate with the Authority to verify the validity and accuracy of collected data.
- Q. Implement remedial and precautionary measures based on the instrumentation data results.
- R. Rock core drilling shall be in accordance with ASTM D2113.
- S. Perform LiDAR at least in the pre- and post-condition surveys and reflectorless survey during excavation and dewatering activities. The survey shall be conducted from the public right-of-way, at each visible corner, at a minimum, of each existing structure. These points shall be photographically documented and produce repeatable measurements to a precision of plus or minus 0.01-foot in the horizontal plane. Repeat the reflectorless surveys once per quarter when excavation or dewatering is in operation within 100 feet or in the event a movement exceedance is recorded at a ground or surface monitoring point located within 50 feet of an existing structure.

3.02 PROVISIONS FOR MEASURING DEVICES

- A. All instrumentation and components shall be corrosion and vibration resistant. Instruments embedded in concrete shall be capable of withstanding vibrations from construction equipment. The accuracy and dependability of the equipment shall not be adversely affected by changes in temperature, humidity, stray currents or other conditions that may be encountered.
- B. Where appropriate, obtain calibration certificates from independent accredited testing laboratories.

3.03 INSTALLATION

- A. The locations and types of instruments shall be as specified herein or otherwise submitted and approved by the Authority.
- B. Install the equipment according to the manufacturers' recommendations. Testing shall be undertaken as necessary to ensure satisfactory functioning of the equipment at each stage of the installation. Instruments found to be malfunctioning at any time shall be replaced within 48 hours at no additional cost to the Authority.
- C. SMP, GMP, DMP, UMP and ESMP Locations:

1. SMPs shall be installed in the pavement along the open cut excavation that is over 10 feet deep and on ground surface overlying utilities located within a horizontal distance of twice the maximum depth of excavation, at no more than 50-foot spacing.
2. SMPs shall be installed in the pavement along the trenchless crossing and around the launching and receiving pits, at spacing no more than 25 feet. In addition to installation of SMPs along the centerline of the trenchless crossing, SMPs shall also be installed along two (2) parallel lines, each offset 10 feet from the centerline of the trenchless crossing. Along each of the three lines, SMPs shall be installed at a spacing of no more than 25 feet.
3. SMPs shall be installed on the rim of existing manhole covers of utilities located within a horizontal distance of twice the maximum depth of excavation.
4. GMPs shall be installed in the pavement along the open cut excavation that is over 10 feet deep, at no more than 200-foot spacing on alternating sides of the excavation.
5. DMPs shall be installed on the exterior walls of buildings or structures located within a horizontal distance of twice the maximum depth of excavation. As much as practical, DMPs shall be installed on supporting walls or columns. Installation on masonry structures shall be performed in solid mortar or grout joints.
6. At least two (2) DMPs shall be installed on the exterior wall corners of buildings, structures or boundary walls located within a horizontal distance of twice the maximum depth of excavation and at not more than 50-foot spacing. Where DMPs are unable to be installed, equivalent measurements shall be conducted by reflectorless methods or as otherwise approved by the Authority.
7. Install DMPs in cooperation with property owners so that installations are inconspicuous and acceptable to the property owners. Existing features of building foundations that are accessible and can be repeatedly surveyed may be substituted for DMPs.
8. Newly installed fixed survey points or existing fixed features may be used as reference points in lieu of, or in combination with DMPs.
9. For utility poles that are at least 10 feet high above ground level and located within 30 feet of the excavation, install deformation monitoring points (DMPs) at six (6) feet above grade.
10. UMPs shall be installed on existing utilities over 36 inches in diameter and located within a horizontal distance of less than the maximum depth of excavation. UMPs shall be located at a spacing of not more than 50 feet. Install UMPs on the telecom

duct bank located approximately at Station 1+60.

11. ESMPs shall be installed on excavation support systems other than moving trench shield along support walls at spacing not more than 25 feet.
- D. Install and obtain SMP, GMP, UMP, and DMP monitoring point readings prior to installing excavation support, beginning open cut and trenchless excavations, or operation of groundwater control system at the site. Install ESMPs prior to excavation within the excavation support system. Take Baseline Readings for all instruments.
- E. Monitoring Wells
1. Locations of new monitoring wells should be based on approved dewatering plan submittal and the Instrumentation and Monitoring Plan.
 2. To the extent feasible, protect and maintain existing groundwater monitoring wells and perform monitoring readings. Replace the monitoring wells damaged or destroyed as a result of construction activities. The elevation of the bottom of new groundwater monitoring wells shall be no higher than 90 ft BCB or approved otherwise.
 3. Monitoring wells shall be located, installed, and decommissioned in accordance with ASTM D5092, WSC-310-91, and requirements herein.
 4. Set screened interval of each well to monitor groundwater levels, unless otherwise approved.
 5. Monitoring wells shall be installed from the ground surface and initial surveys completed a minimum of two (2) weeks prior to removal of any earth excavation within the or near surface structure earth support system.
 6. A stable borehole must be constructed prior to attempting to install the monitoring well screen and riser. Provide temporary casing as needed. Boreholes that are not straight or are partially obstructed shall be corrected prior to attempting installation. Flush all cased holes with clean water through an approved bit. Flush until the discharge water is free of soil particles.
 7. Use approved drilling methods and install monitoring wells in accordance with the approved submittal. Bentonite drilling mud shall not be used in drilling holes for the monitoring wells.
 8. When the well screen and riser assembly is lowered to the predetermined level and held into position, ballast the assembly as needed to counteract the tendency to float in the borehole. Care shall be taken to minimize lifting the pipe with the withdrawal of the temporary casing/augers.

9. Construct monitoring well with at least 10 feet of slotted PVC well screen, filter sand, bentonite seal, couplings, a pipe cap, and a locking cover.
 - a. Install filter pack from bottom of drilled hole to above the screen for a distance of about 20 percent of the length of the well screen but no less than two (2) feet.
 - b. Install a bentonite pellet or a slurry seal in the annulus between the borehole and the riser pipe on top of the filter pack.
 - c. Backfill the remaining annulus with grout or approved materials.
10. Protect the monitoring wells at ground surface by providing a roadway box or outer protective casing with lockable top and padlock. Design the surface protection to prevent damage by vandalism or construction operations and to prevent surface water from infiltrating. The protective casing shall be sealed and immobilized in concrete placed around the outside of the protective casing. For above grade protective casing, a 1/4-inch diameter weep hole shall be drilled in the casing six (6) inches above the ground surface to permit water to drain out of the annular space. Coarse sand or filter gravel shall be placed in the annular space to above the weep hole to prevent entry of insects. In areas where there is a high probability of damaging the well (high traffic, heavy equipment, poor visibility), enhance the normal protection of monitoring well through the use of posts, markers, signs, etc. The level of protection shall meet the damage threat posed by the well location.
11. Monitoring wells shall be developed so as to provide a reliable indication of groundwater levels. Wells shall be re-developed if clogging is observed, in the event of apparent erroneous readings, or as directed by the Authority. Allowable methods of development include mechanical surging and bailing or pumping, over-pumping, air-lift pumping, and jetting. Development shall be continued until water is visually clear of suspended solids, free of the drilling fluids, cuttings, or other materials introduced during well construction.
12. All materials used, installed depths, dimensions, and well development method and results shall be documented on the well completion diagram. The monitoring well identification number shall be clearly visible on the inside and outside of the lid of the protective casing.
13. The vertical and horizontal position of each monitoring well in the monitoring system shall be surveyed and subsequently located by a licensed surveyor. The well location map shall include the location of all monitoring wells in the system and their respective identification numbers, elevations of the top of the riser position to be used as the reference point for water level measurements, and the elevations of the ground surface at the protective installations. The water level measurement reference point shall be permanently marked, for instance, by cutting a V-notch into

the top edge of the riser pipe.

F. Vibration Monitoring

1. Monitor peak particle velocities at structures or facilities within 50 feet of the limit of excavation or vibration-inducing activities using seismographs, operated by personnel meeting the requirements of herein.
 2. At least one sandbag weighing not less than 30 pounds, shall be placed over the geophone. Methods of securing the geophone shall be submitted for approval.
- G. Securely fix all instruments such that they are capable of resisting movement and pressure changes underground, vandalism, and adverse climatic conditions.
- H. Install crack gauges across existing cracks on structures identified during pre-construction survey in locations identified in the approved submittal. Contractor shall coordinate with the Authority to obtain site access prior to performing any work.
- I. Should actual field conditions prohibit installation at the location and elevations specified in this section, provide alternate instrument location and elevation for review and approval by the Authority at no additional cost to the Authority.

3.04 MAINTENANCE OF INSTRUMENTATION

- A. Protect and prevent damage to instruments, appurtenant fixtures, leads, connections, ancillary equipment, and other components of instrumentation systems during handling, installation, and subsequent operation. Maintain all the instruments required for long term monitoring in a satisfactory working order for the duration of the monitoring program.
- B. Repair or replace damaged or non-functional instrument within 48 hours at no additional cost to the Authority.
- C. Ensure instrumentation and read-out equipment in use have been correctly calibrated. Carry out periodic checks to confirm the validity of calibration of equipment in accordance with the manufacturer's instructions and carry out adjustments that are found necessary. Repeat readings that are suspicious.
- D. Maintain records of all calibration certificates and, when necessary, send equipment off site for re-calibration by an independent accredited testing laboratory.
- E. Maintain records on the as-installed locations of all instrumentation, including routing of all cabling and reference coding. Hidden electrical instrumentation shall be identifiable by color codes and/or tagged cables.
- F. Ensure electrical instrumentation is not adversely affected by other temporary or

permanent electrical services.

3.05 INSTRUMENTATION MONITORING AND REPORTING

- A. Conduct monitoring and obtain readings in accordance with approved submittals and methods as specified by the manufacturer.
- B. Field data records shall include contract number, contract name, date and time, weather and temperature, instrument type, observer, readout unit number, instrument number, readings, construction activities within 100 feet of the instrument, visual observations, and remarks.
- C. From two (2) weeks before beginning of dewatering and construction activities to one (1) month after readings stabilize after completing all construction activities, record readings from instruments specified herein. Stable measurements are defined as data that falls within one standard deviation of the precision of the instrument measurements performed after completion of construction that may potentially impact the performance of the instrument.
- D. Groundwater readings shall be to the nearest one-tenth of an inch. The frequency of readings shall be in accordance with approved submittal. Readings shall be taken once each working day until the rate of change in the readings falls off sufficiently to allow a lower frequency to be adopted with confidence that the safety of the work is not in doubt and such that the amount of data retrieved will allow trends with time to be clearly identified and evaluated. The frequency of readings shall not be less than that listed below, unless otherwise approved, and shall be increased when the need arises.
 - 1. For all groundwater measuring devices, daily monitoring shall begin prior to initial operation of drainage and dewatering system installation, through the time where groundwater control is in operation, and continue until adjacent structures and utilities are completed, excavation is backfilled, and groundwater control systems are turned off.
- E. Readings for DMPs, UMPs, GMPs and SMPs:
 - 1. Obtain a minimum of three (3) initial readings over a period of at least one (1) week prior to dewatering and trenchless and open cut excavation activities.
 - 2. Obtain daily readings when dewatering, open cut excavation or backfilling activities are within 100 feet of the monitoring point.
 - 3. Obtain two (2) daily readings at the start and end of each shift when trenchless excavation activities are within 100 feet of the monitoring point.
 - 4. Obtain readings twice per week, until dewatering, trenchless and open cut

excavations, and backfill activities are completed. The monitoring shall continue until a minimum of one (1) month after readings stabilize after completion of all construction activities. Readings shall be considered stabilized when three consecutive readings during this period indicate no consistent progressive movement, as approved by the Authority.

5. When taking readings for DMPs installed on utility poles, consider environmental factors (wind, ice, etc) which may affect the readings. If necessary, obtain multiple readings to help reduce potential impact from the environmental factors..
- F. ESMPs measurements shall be conducted, at a minimum, once per shift during associated excavation and construction activities until backfilling is completed. Take readings during dewatering, excavation, and SOE installation until the excavation is backfilled and SOE is removed or cut and left in place.
- G. Vibration Monitoring:
 1. Collect seismograph data, for at least two locations, for a continuous, 72-hour period, including one (1) weekend-day, prior to any vibration-producing construction activities to document background vibrations.
 2. Conduct continuous vibration monitoring during any vibration-producing construction activities, rock excavation, rock drilling, sheet pile installation or removal, pavement breaking, and demolition.
 3. Document all events that are responsible for the measured vibration levels and submit documentation to the Authority with the Report of Vibration Monitoring (Attachment 02495-A).
- H. Crack gauges shall be read at least twice per week when construction activities are conducted within 100 feet and once per month until end of instrumentation and monitoring program.
- I. In the event of any major change in circumstances, for example the influence of the construction of other structures nearby, or water level fluctuation during construction, the program of reading shall recommence.
- J. The same recording devices shall be used through the monitoring program. If for any reason this becomes impracticable, new datum readings shall be taken immediately with the replacement instrument and be used for all future readings. Similarly, if a monitoring location becomes unavailable, the instrument previously read from this point shall, within 48 hours, be read from an alternative point, the latter then being used for subsequent readings.
- K. Readings shall, wherever possible, be taken by the same personnel. Should the

personnel be replaced for any reason, a series of duplicate readings shall be carried out by the out-going person and the replacement.

3.06 INTERPRETATION OF READINGS

- A. Procedures shall be prepared for the regular interpretation and review of the readings.
- B. Perform visual inspection of ground surface and adjacent buildings in the vicinity of the site. Immediately notify the Authority of any observed settlement, heave, cracking, tilting, or other evidence of ground movement or structural damage.
- C. If readings exceed the threshold limits, the occurrence shall immediately be communicated to the Authority. Inform the Authority of proposed remedial action.
- D. Data or interpretations shall not be published or disclosed to other parties without advance written permission of the Authority.

3.07 DATA REPORTING

- A. Instrumentation data shall be submitted to the Authority within 24 hours after readings are taken.
- B. The instrumentation data shall be presented in tabular form showing all previous readings for the instrument. In addition, the data shall be plotted as follows:
 - 1. Monitoring wells and Vibrating Wire Piezometers – Plot groundwater elevation versus time.
 - 2. Monitoring Points (SMPs, GMPs, DMPs, UMPs, and ESMPs) – Plot deformation (vertical and horizontal separately) versus time. Readings shall be accurate to 0.01-feet.
 - 3. Seismographs – Plots of data shall be: plots, strip charts and full waveform plots.
 - 4. For seismograph data collected in continuous monitoring (strip chart) mode, provide a permanent record of all components of particle velocity. The strip chart shall identify the time and magnitude of maximum single-component peak particle velocity measured during each one-minute interval of the monitoring period. A summary of vibration producing activities for that week shall be listed along with any specific events which caused anomalous readings.
 - 5. For seismograph full waveform data, provide plots consisting of a graphical display of the three (3) component particle velocities and overpressure levels during the entire course of the vibration-producing construction activity. In addition, provide a plot of peak particle velocities, in inches per second, versus the frequency of the vibration, in hertz.

- C. Data from a replacement instrument shall include relative data from previous instrument so that data are plotted continuously, without an offset at the time of damage. The time of damage and replacement shall be noted on the plot.

3.08 RESPONSE VALUES

- A. If the Threshold and Limiting Values as shown in Table 1 are reached, Response Actions shall be required. The Threshold and Limiting Values are subject to adjustments by the Authority as indicated by the prevailing condition and/or circumstances.

Table 1 Response Values for Different Structures

Structure/Facility	Type of Measurement	Threshold Value	Limiting Value
Building/Walls	Vertical Movement	0.25 inch	0.50 inch
	Horizontal Movement	0.25 inch	0.50 inch
	Change in Width of Crack	0.01 inch	0.02 inch
Support of Excavation Wall	Horizontal Movement	1.0 inch	2.0 inch
Ground Surface and Hardscapes (Sidewalks / Pavements) (Sta 0+00 to 1+38)	Vertical Movement	0.25 inch	0.5 inch
Ground Surface and Hardscapes (Sidewalks / Pavements) (Sta 1+38 to 12+43)	Vertical Movement	0.5 inch	1.0 inch
Monitoring Wells	Drawdown ¹	±2 feet of anticipated drawdown	±4 feet of anticipated drawdown
Utilities, Surface Over Utilities, Manholes and Utility Poles	Vertical Movement	0.25 inch	0.5 inch
	Horizontal Movement for Utility Poles	1.0 inch	2.0 inch
Where the Vibration Will be Monitored ²	Vibration Frequency > 40 hertz	1.0 inch per second	2.0 inch per second
	30 hertz < Frequency ≤ 40 hertz	0.75 inch per second	1.50 inch per second
	20 hertz < Frequency ≤ 30 hertz	0.50 inch per second	1.0 inch per second
	Frequency ≤ 20 hertz	0.25 inch per second	0.50 inch per second
Notes: 1- The tabulated drawdown response values are based on the assumption that the monitoring well is located 10 feet from the excavation. These values shall be adjusted to reflect the actual distance between each monitoring well and the trenchless or open cut excavations. Submit for approval the anticipated drawdown values based on the actual field conditions. 2- See Paragraph 3.03.F.1 of this Section for the locations of vibration monitoring.			

3.09 RESPONSE ACTIONS

- A. If a Threshold Value is reached:
 - 1. Contractor and the Authority shall meet to discuss remedial measures.
 - 2. The frequency of readings shall be increased as directed by and at no additional cost to the Authority.
 - 3. Install and monitor additional instruments as directed by the Authority, at no additional cost to the Authority.
 - 4. Implement remedial measures per the established action plan to prevent reaching the Limiting Values.
- B. If the Limiting Values are exceeded, suspend construction activities in the affected area, with the exception of those activities necessary to stabilize the condition and avoid further movement, and immediately notify the Authority.

3.10 REMOVAL OF INSTRUMENTS

- A. Protect and maintain all instrumentation until such time as written authorization for removal of instrumentation has been received from the Authority.
- B. Instrumentation shall not be removed or abandoned without prior authorization from the Authority.
- C. Prior to completion of the Contract, remove and abandon instrumentation installed in boreholes under this Contract to a minimum depth of 5 feet and in accordance with MassDEP regulations.
- D. Extract and remove all monitoring points and crack gauges during the cleanup and restoration work, unless otherwise directed by the Authority.
- E. Removal of instruments shall include removing and disposing of protective covers, recovery of salvageable portions of instrumentation and grouting of casings.
- F. For monitoring wells, utility monitoring points, and other instruments installed within cased boring:
 - 1. Abandon the instrument by removing all material within the original borehole.
 - 2. Leave in place any casings located within the zone below 1H:1V planes extending downward and out from the edges of foundation elements of structures or within footprint of pipes, or where removal would result in ground movements causing adverse settlement to adjacent ground surface, utilities, or existing structures.

3. Where casings are pulled, fill holes with sand. Where left in place, fill casings with non-shrink cement grout and cut off at least 5 feet below finished ground level or 1 foot below foundation level so as to not interfere with finished structure or pipeline.
4. Restore the ground surface to its original condition. Remove vaults and well caps to the pavement subgrade. Repair or patch pavement with the same surface type.
- G. Remove all instrumentations per requirements of the applicable regulatory agency. Backfill holes with grout mix approved by the applicable regulatory agency or the Authority. Compact backfill and properly restore surfaces to match existing conditions.
- H. Fill holes drilled in masonry or concrete surfaces with cement mortar to present an appearance matching the surrounding surface.
- I. All instruments or portions thereof removed shall become property of the Contractor.
- J. Instrumentation readout and calibration equipment purchased under this Contract shall become property of the Authority.

PART 4 Attachments

4.01 Attachment 02495-A – REPORT OF VIBRATION MONITORING

**** END OF SECTION ****

ATTACHMENT 02495-A - REPORT OF VIBRATION MONITORING

PROJECT _____ REPORT NO. _____

GENERAL CONTRACTOR _____ CONTRACT NO. _____

EXCAVATION SUBCONTRACTOR _____ DATE _____

OBSERVER _____ TIME _____ AM/PM

WORK DATA:

PROJECT AREA: _____

WORK LOCATION: (SHOWN ON LOCATION PLAN)

BOTTOM OF LIFT EL. _____

VIBRATION DATA _____

WEATHER CONDITIONS _____

WIND DIRECTION _____

SEISMOGRAPH LOCATION: (SHOWN ON LOCATION PLAN)

SEISMOGRAPH MAKE AND MODEL NO. _____

SERIAL NUMBER _____

AMPLIFIER GAIN _____ CHART FEED RATE _____

PARTICLE VELOCITY SENSOR LOCATION (SHOWN ON LOCATION PLAN)

DISTANCE OF SENSORS FROM WORK (FEET) _____

VIBRATION MONITORING RESULTS _____

PARTICLE VELOCITY COMPONENTS (INCHES/SECOND):

TRANSVERSE _____

VERTICAL _____

LONGITUDINAL _____

PEAK PARTICLE VELOCITY _____

REMARKS _____