APPENDIX 5A

Settlement Monitoring Requirements for Cast Iron Water Mains

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1. INTRODUCTION

When any project in the City of Seattle water service area can cause potential ground movement, Seattle Public Utilities (SPU) requires that the City's water mains be monitored. These projects are generally those that involve large scale earth work, which can create ground settlement. This appendix presents Seattle Public Utilities (SPU) requirements for settlement monitoring of cast iron water mains. See DSG Chapter 5 **Appendix 5B** for settlement monitoring requirements for ductile iron water mains.

The audience for this document includes SPU design engineers, consultant engineers, or other agency engineers if necessary.

1.1 GENERAL REQUIRMENTS

Settlement monitoring is required to provide reliable information and documentation during construction to minimize potential ground movement impacts on cast iron water mains. The following are SPU general requirements for this monitoring:

1. Settlement monitoring work must include furnishing all equipment, material, and labor for installing, maintaining, monitoring, analyzing, reporting, and removing instrumentation for monitoring cast iron water main displacement.
2. The contractor must maintain and protect new and existing instrumentation at no additional cost to the City of Seattle. The contractor must replace damaged instruments at no additional expense to City of Seattle.

1.2 CONDITIONS THAT REQUIRE MONITORING

Settlement monitoring is likely to be required when trenching, tunneling, or excavating in the area of influence of a cast iron water main (Figure 5A-1). The following conditions require monitoring:

- When excavations, de-watering, tunneling and/or trenching enters the zone of influence of the water main. See Figure 5A-1 for the typical zone of influence.
- When any construction activity might cause horizontal displacements in addition to vertical displacements, horizontal displacement must be monitored as well, and the total displacement calculated.

The design engineer or SPU may require monitoring, for reasons other than those noted above. Such reasons might include:

- For construction activities in areas with poor soil conditions

- When the engineer or SPU believes the construction activity may cause severe vibrations in the soils within 10 feet horizontally of the water main.

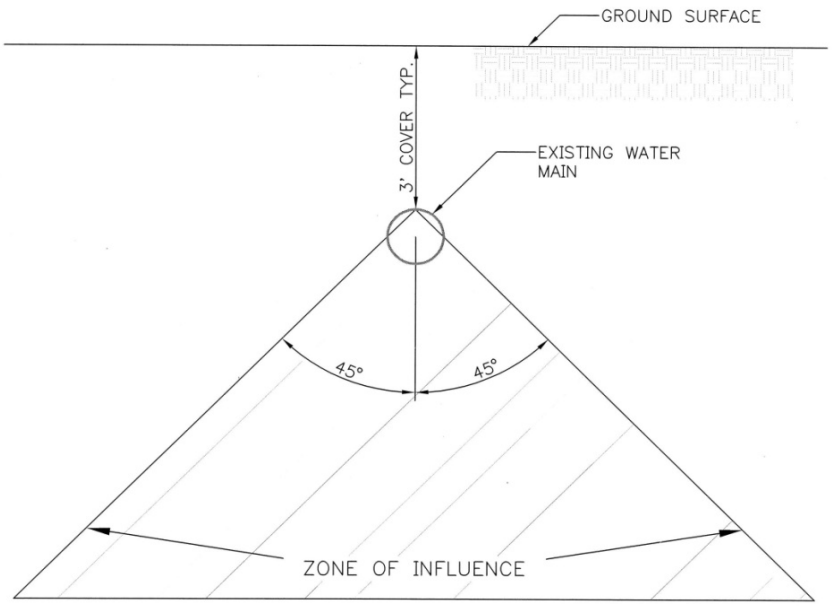
  Note: this distance is to the vibration, not the activity causing the vibration.

- Whenever vibration monitoring at the cast iron water main shows vibrations greater than or equal to 1.0 inches per second (IPS).
- When de-watering for a project is believed to be occurring in the soil within 25 feet of a cast iron water main.

  Note: for some deep excavations, this distance can be much larger.

- When any construction activity might cause horizontal displacements in addition to vertical displacements, horizontal movement should also be monitored and the total displacement calculated.

Figure 5A-1
Zone of Influence



The engineer or SPU engineering may require monitoring, for reasons other than those noted above. Such reasons might include:

1. For construction activities in areas with poor soil conditions
2. Where the cast iron water main is believed to be in poor condition
3. In environmentally critical areas.
4. Where the cast iron water main is believed to have been previously deflected

SPU may waive settlement monitoring requirements at a given site with concurrence from SPU Water Design and the SPU Materials Lab.

1.3 DEFLECTIONS TRIGGERING REPLACEMENT IN CAST IRON WITH LEAD JOINTS

The following are SPU requirements for projects that will trigger the need to replace water mains:

1. When an outside entity proposes a project that will likely cause settlement and or horizontal displacement, that entity must provide predicted ground movement data and settlement contours to SPU early in the design process. This information will be used to identify pipelines that are candidates for monitoring, pre-construction modification, or replacement.
2. Sufficient utility monitoring points must be installed on all pipes that are anticipated to be in the settlement trough to identify the shape of the actual settlement trough and the actual pipe deflections.
3. When any of the maximum pipe displacement criteria shown in pipe replacement tables (Table 5A-1 and Table 5A-2) have been exceeded, the affected water main must be replaced by the contractor back to the point of zero displacement along the water main. SPU will determine where the point of zero displacement occurred based on available settlement data.

Table 5A-1 and Table 5A-2 assume that the pipe was installed in a straight line with no planned joint deflections. If the record drawings (as-builts) show that the pipe was installed with joint deflections, the maximum allowable joint deflection of the installed pipe deflection plus settled deflection must not exceed the values shown in the pipe replacement tables.

If any of these criteria are exceeded, the pipe must be replaced back to the point of zero displacement as described above.

1.3.1 Maximum Displacement Criteria

Pipe movement that exceeds any of the values listed in Table 5A-1, triggers replacement. Movement may be in any direction: top, bottom, side, or in combination. The pipe must be replaced back to the location where SPU detects or interpolates zero displacement to have occurred. Maximum joint rotation is calculated from maximum joint pullout.

Note: *A staggered factor of safety is used to compute the values in Table 5A-1. The factor of safety is set at 1.5 for pipes 12-inches and smaller, rising to 1.6 for 16-inch pipe, 1.75 for 20-inch pipe, and 2.0 for pipes larger than 20-inches.*

1.3.2 Geographical Displacement Criteria

For Seattle areas that have poor soils (i.e. defined by geologic units Qw, Qp, Qb, Qbu, Qtf, Qal, Qyal, Ql, Qf, Qt, Qmw, or Qls) as shown on the Geology (in review) layer in SPU GIS, SPU has developed maximum deflection values (see Table 5A-2). These values are approximately half of those used for the rest of the city.

Note: *The name of the Geology GIS layer may change. The maximum values in these parts of the city are reduced to account for prior and future natural movements. Should the area in question border two different geologic units, check to* confirm the geologic unit of the project *(http://pubs.usgs.gov/of/2005/1252/).*

Table 5A-1
Cast Iron Pipe Deflection Replacement Triggers for Normal Soil Conditions

Pipe Size	6"	8"	12"	16"	20"	24"	30"
Maximum displacement per 12' pipe length any direction[2]	1.4"	1.1"	0.8"	0.6"	0.4"	0.3"	0.25"
Max total displacement at any one point[1]	2.8"	2.2"	1.6"	1.2"	0.9"	0.6"	0.50"

[1]All maximum movement numbers are calculated based on worst case scenario of the inflection point. These are the values to use in construction.

Table 5A-2
Cast iron Pipe Deflection Replacement Triggers in Poor Soils, Liquefaction Zones and Known Landslide areas defined by SPU GIS

Pipe Size	6"	8"	12"	16"	20"	24"	30"
Maximum displacement per 12 ft pipe length any direction[1]	0.7"	0.6"	0.4"	0.3"	0.2"	0.2"	0.2"
Max total displacement at any one point[1]	1.4"	1.2"	0.8"	0.6"	0.4"	0.4"	0.4"

[1]All maximum movement numbers are calculated based on worst case scenario of the inflection point. These are the values to use in construction.

1.4 EQUIPMENT REQUIREMENTS

The following are requirements for equipment setup, use, quality assurance, and data collection for cast iron water main settlement monitoring:

1. The owner must provide monitoring point locations, either on the contract drawings or as a separate drawing. This information will be provided with the contract documents.
2. The installation, calibration, data collection, and analysis of results from the instrumentation must be performed by qualified individuals with a minimum of 5 years of previous experience with the devices or systems specified here. The contractor must

provide an instrumentation specialist to be responsible for the oversight of all monitoring at the site.

3. An equipment monitoring plan is required. SPU engineering and/or the SPU Materials Lab must approve monitoring methods and equipment in writing before the plan can be approved. Any comments from SPU must be addressed and the engineer must approve the plan before construction may begin.
4. The contractor must provide instrumentation systems for this monitoring and at all times during the monitoring program must be able to show that the equipment's calibration meets the manufacturer's minimum calibration requirements. Equipment to be used along with copies of specification sheets for the monitoring equipment must be included in the settlement monitoring plan. In case of equipment failure, the contractor must replace failed instruments within 24 hours of detection.

1.5 SETTLEMENT MONITORING PLAN

A settlement-monitoring plan is required before work can begin. The plan must detail the equipment and methods to be used to monitor settlement at the site. The plan should include how, where, when and who will set up the equipment, calibrate, and use it during construction at the site. The settlement monitoring plan must also list the information that will be included in settlement monitoring report and give an example of the report format (see section 1.6, Data Summary Reports). The monitoring plan must describe how the following will be met:

1. Equipment**.** What equipment will be used at the monitoring point locations to check for settlement? An example of this is utility settlement markers using a 1-inch fiberglass bar attached to the utility and placed inside a 1.5-inch PVC pipe riser.
2. Equipment Protection. Details on how the monitoring point equipment will be protected from damage or vandalism (e.g. locking covers or fencing the area off).
3. Monitoring Point Installation. How will the settlement points be installed before beginning excavation, tunneling, or dewatering near the utility? For example, the utility settlement markers cited in item #1 above would be installed by:
    a. Excavating a small pit or hole above the pipe at each monitoring point
    b. Cleaning the exposed pipe of debris in the area where the marker is to be attached
    c. Affixing the fiberglass bar to the pipe
    d. Encasing the rod with the PVC pipe riser that is cut to form a tight fit at the pipe
    e. Back-filling the excavated area with the removed material or approved equal
    f. Install pavement patch to match existing pavement
4. Monitoring Frequency. The monitoring plan must describe how and when the contractor will establish a baseline reading for the utility. At a minimum, the reading should be performed when within 50 feet of any utility monitoring point locations. When construction activities are adjacent to the utility, monitoring must be implemented. Monitoring frequency should in general occur as noted in Table 5A-3 for a

typical project. Project specific Frequencies differing from those in Table 5A-3 may be allowed but must first be approved by the engineer.

Note: *Large and very deep excavations and tunnels generally have far-reaching long-duration settlement. They should have a settlement monitoring plan that modifies both duration and frequency to time frames that make sense for the project.*

Table 5A-3
Monitoring Frequency

When	Duration	Frequency
Baseline: Before coming w/in 50 ft of first utility monitoring point	Once	Once
During Construction	While within 50ft of utility monitoring point	Once a day
After Construction	2 Months*	Every month*

*Or until two consecutive readings show no movement of the utility

5. Fixed Points. Describe how all elevations will be referenced to fixed points, which must be a minimum of 200 feet away from all excavations to assure that the reference points remain accurate. These fixed points (control points) must be shown in the monitoring plan.
6. Minimum Tolerance. The settlement monitoring plan must describe how the following minimum tolerance requirements for monitoring will be met:
    a. Establish the initial elevations of monitoring points on all instrument elevation points to 0.01 foot.
    b. Record the subsequent elevations of monitoring points and all instrument elevation points to 0.01 foot.
    c. Establish the initial horizontal coordinates of deep cased bench marks, settlement points and all instruments to 0.01 foot.
    d. Install instrument casings within 2˚ of vertical for the entire length and to the specified depth.

1.6 DATA SUMMARY REPORTS

Contractors must perform instrumentation readings and data collection, analyses, record keeping, and prepare daily data reports. Reports and monitoring frequencies can be scalable to the project. Smaller projects will not require the same level of reporting as that of large-scale earthwork projects. SPU requires two types of data summary reports:

1. Daily Data Report. This is a summary of data collected each day.
2. Project Data Report. This summary report must include an analysis of all monitoring data collected. This report is to be submitted to the engineer and the SPU Materials Lab

at the end of the work. The overall analysis should include information from the daily reports (see below) and an overall evaluation of the data taken as a whole.

A daily summary of the data collected is required. This summary is due by the following morning, before construction resumes and shall include the items listed in the following section:

1.6.1 Daily Data Report

The report must include the following:

1. A short summary of the day's work that notes the work being performed, times that monitoring was conducted, and what work required the monitoring. The contractor should also include any observations that will help describe monitoring for the day.
2. A description of the work occurring when settlement monitoring indicates a vertical displacement of greater than half the maximum allowed displacement from Table 5A-1 or Table 5A-2 above based on pipe size and soil conditions.
3. A copy of the day's raw data (electronic and hard copy)
4. A chart detailing the monitoring data that includes:
    a. Time
    b. Mean Temperature
    c. Reference elevation (last recorded elevation prior to the start of any construction for the project.) of each Monitoring point
    d. Current elevation of each Monitoring point
    e. Change in elevation if any between the reference and current elevations of each Monitoring point
    f. Brief description of the work being done

1.6.2 Project Data Summary

This report will vary with project and is specified in the contract.

1.7 NOTIFICATION AND CORRECTION REQUIREMENTS FOR EXCEEDING

1.7.1 Action Triggers

Any cast iron water main settlement noted must be reported to the engineer for evaluation as soon as possible, settlement of 50% (½) the maximum displacement allowance from Table 5A-1 or Table 5A-2 above based on your pipe size and soil conditions or greater must be entered into the daily report as outlined above.

If 50% (½) of the maximum deflection is detected, at the discretion of SPU's Engineer, SPU will require leak tests and dig-ups of the pipe to determine conditions. Based on the conditions found by this testing and investigation, repairs will be made to the pipe at the expense of the contractor where the pipe has been determined to have been adversely impacted by SPU's Engineer. The contractor may opt to replace the impacted pipe rather than pay SPU to perform dig ups and leak test when less than maximum settlement has been detected.

If cast iron water main displacements in excess of 75% (¾) of the maximum settlement allowance are detected, the contractor is required to stop work and consult with SPU to determine how work can proceed and whether remedial action is required.

If cast iron water main displacements) in excess of the maximum settlement allowed per Table 5A-1 and Table 5A-2 are detected for the pipes size and soil conditions present, replacement of all affected pipe sections with ductile iron pipe will be required as directed by SPU. The cost for pipe replacement shall be at no additional cost to SPU.

1.7.2 Further Actions

If any abnormal movements, settlements in excess of allowable, or damage is noted, immediate steps must be taken to stop the causes of movements or settlements. The contractor must prepare and execute a corrective program within 24 hours of identification of the problem at no cost to the City of Seattle. This plan must be reviewed and stamped by a Registered Geotechnical Engineer familiar with the work. Remedial measures may require modifications of construction procedures, up to and including replacement of the effected section of cast iron water main with ductile iron pipe.