# CITY OF LYNNWOOD

**SNOHOMISH COUNTY** **WASHINGTON**

# LIFT STATION NO. 10
# FLOOD PROTECTION ANALYSIS

**G&O #13535**
**JUNE 2014**

Gray & Osborne, Inc.
CONSULTING ENGINEERS

# CITY OF LYNNWOOD

**SNOHOMISH COUNTY** **WASHINGTON**

LYNNWOOD
WASHINGTON

# LIFT STATION NO. 10
# FLOOD PROTECTION ANALYSIS

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24 June 2014

**G&O #13535**
**JUNE 2014**

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CONSULTING ENGINEERS

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## SUMMARY

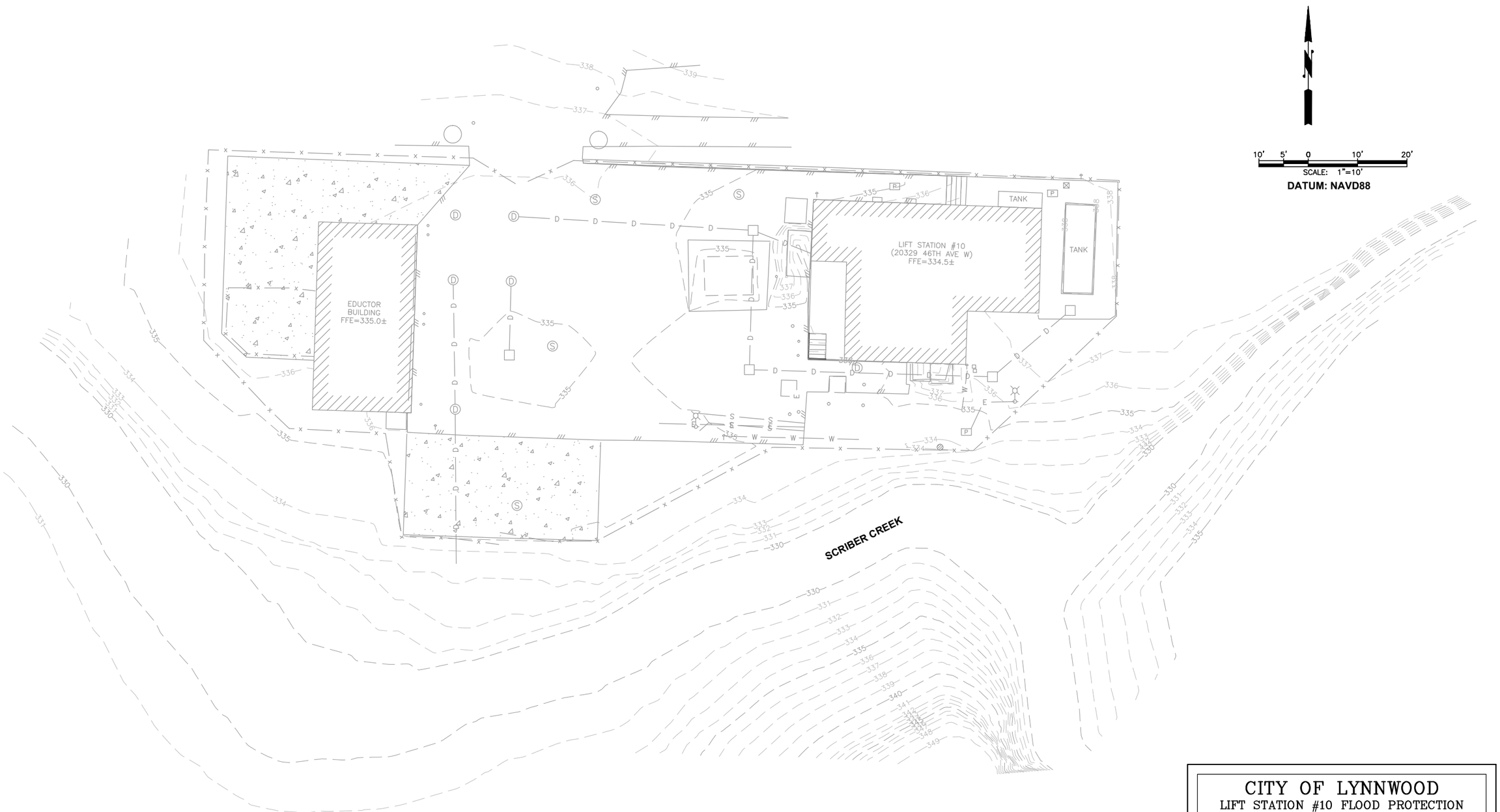
A number of alternatives were explored to address flooding issues at Pump Station No. 10 in the City of Lynnwood, which has experienced numerous floods since its construction in 1993. The pump station's low elevation and proximity to Scriber Creek make it susceptible to flooding which may compromise its operation. The historic high water mark is only 6 inches below the loading dock and finish floor elevation. Flooding in Scriber Creek near the pump station is due mainly to the very gradual slope of the creek, sediment accumulation, and beaver activity blocking flows. As these conditions are unlikely to change, the occasional flooding events will continue, making flood protection infrastructure at the pump station necessary.

Alternatives were explored that would allow for protection of the pump station's electrical panels, provide personnel access, or provide vehicle access during a flood event. These levels of flood protection could be provided by temporary, reusable, or permanent systems. Temporary systems considered for the site include sandbags, flood logs, panel replacement or relocation; systems considered to protect the integrity of the building and to allow access include sandbags and flood logs; reusable systems include inflatable dams and mechanically deployed sand walls; permanent systems include a wall, gates, or a footbridge. The permanent solutions are more expensive to implement than the temporary or reusable systems, but provide better protection and reliability with no prior warning necessary. The total cost of implementing a protection system will depend heavily on the level of protection deemed necessary and the permanence of the selected system. Since this lift station is a critical component of the sanitary sewer system, if funds are available, this report recommends construction of a permanent floodwall.

## BACKGROUND AND INTRODUCTION

In 1993, The City of Lynnwood constructed a new sewage pump station at the old location of Pump Station No. 10 near Scriber Creek. The pump station site has flooded numerous times since its construction. While the water has not entered the building, it has restricted vehicle and personnel access during times of high water. The implementation of flood protection improvements is necessary to ensure the continued operation of the pump station during flood events. A number of techniques were considered that could provide protection for the building's infrastructure or allow personnel or vehicle access during flood events. Both temporary and permanent techniques were considered. The highest recorded water mark is approximately elevation 337.7, based on reports from City staff describing the height of water in relation to the top of the lift station floor slab/loading dock. The building's loading dock and finish floor elevation is 338.2. Flood event duration that limits site access, has usually been relatively short, typically less than 24 hours. The site is shown in Figure 1.

The section of Scriber Creek in the vicinity of the pump station originates to the northwest at Scriber Lake. It flows past the pump station on the east side of the building




NOTE:
CONTOURS SHOWN BEYOND FENCE ARE ESTIMATED FROM 1990 AS-BUILT DRAWINGS.

# CITY OF LYNNWOOD

LIFT STATION #10 FLOOD PROTECTION

FIGURE 1

EXISTING SITE PLAN

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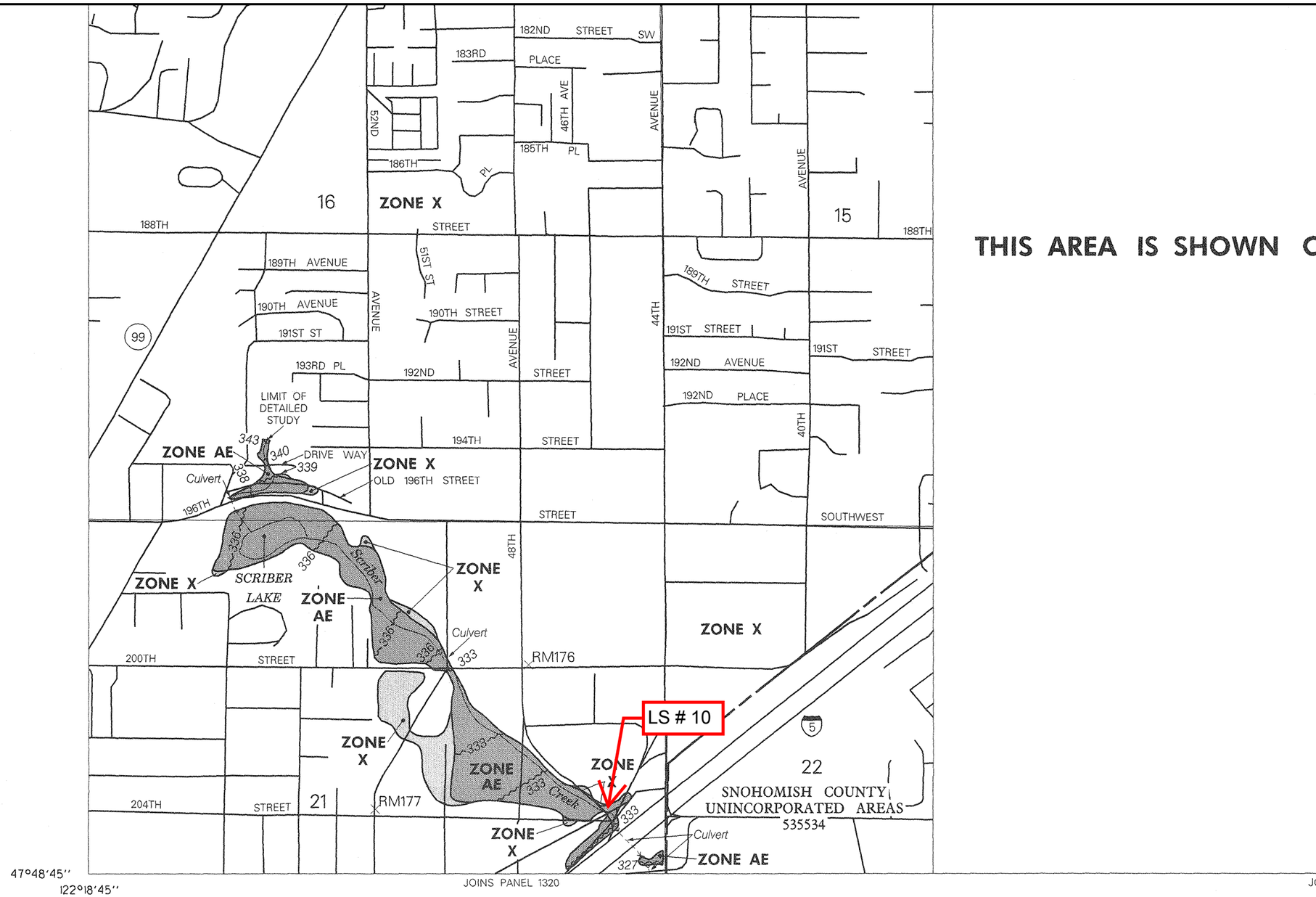



THIS AREA IS SHOWN O

APPROXIMATE SCALE IN FEET

1000 0 1000

NATIONAL FLOOD INSURANCE PROGRAM

# FIRM

## FLOOD INSURANCE RATE MAP

SNOHOMISH COUNTY, WASHINGTON AND INCORPORATED AREAS

**PANEL 1310 OF 1575**

(SEE MAP INDEX FOR PANELS NOT PRINTED)

CONTAINS:

| COMMUNITY | NUMBER | PANEL | SUFFIX |
|---|---|---|---|
| LYNNWOOD, CITY OF | 530167 | 1310 | E |
| MUKILTEO, CITY OF | 530235 | 1310 | E |
| SNOHOMISH COUNTY, UNINCORPORATED AREAS | 535534 | 1310 | E |

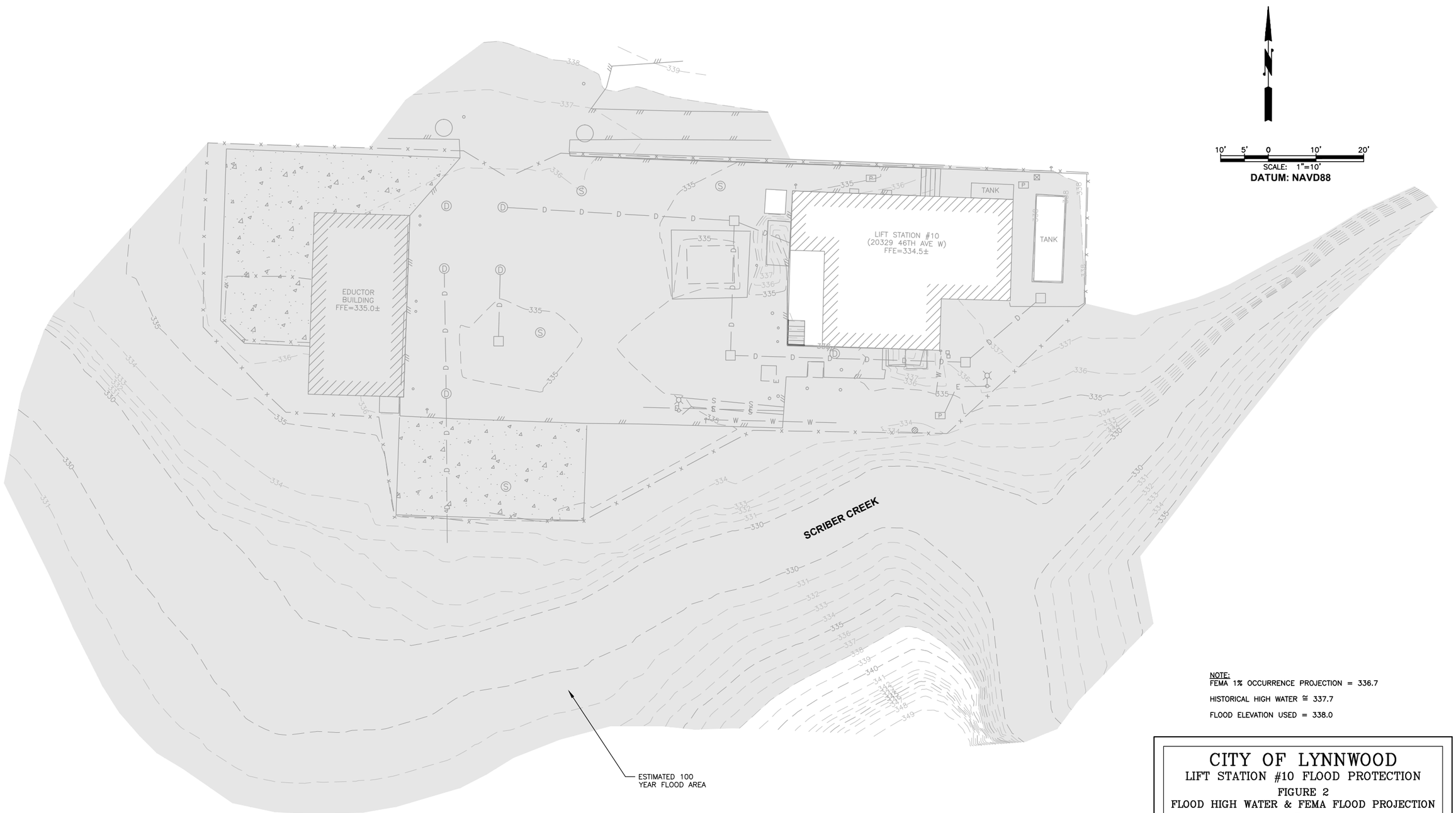
**MAP NUMBER 53061C1310 E**

**EFFECTIVE DATE: NOVEMBER 8, 1999**

Federal Emergency Management Agency

Figure A - FEMA Flood Plain Mapping at Lift Station No. 10

This is an official copy of a portion of the above referenced flood map. It was extracted using F-MIT On-Line. This map does not reflect changes or amendments which may have been made subsequent to the date on the title block. For the latest product information about National Flood Insurance Program flood maps check the FEMA Flood Map Store at www.msc.fema.gov




NOTE:
FEMA 1% OCCURRENCE PROJECTION = 336.7

HISTORICAL HIGH WATER ≅ 337.7

FLOOD ELEVATION USED = 338.0

NOTE:
CONTOURS SHOWN BEYOND FENCE ARE ESTIMATED FROM 1990 AS-BUILT DRAWINGS.

# CITY OF LYNNWOOD

## LIFT STATION #10 FLOOD PROTECTION

FIGURE 2

FLOOD HIGH WATER & FEMA FLOOD PROJECTION

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and passes through a culvert underneath I-5. According to the 2012 SAIC Draft Scriber Creek Design Memorandum, flooding in the creek is likely caused by a number of issues. The section of the creek between 200th Street SW and the I-5 culvert flows through a wide, flat wetland where flow velocities are low and sediments accumulate. W ater levels here rise during storms due to the sediment accumulation and beaver activity, which subsequently backs up the upstream section of the creek. The I-5 culvert is the limiting factor during flood events bigger than the 100-year event, as it fails to discharge fast enough and backs up flows upstream.

## FEMA FLOOD PLAIN ELEVATIONS

FEMA flood plain maps are available for the pump station location and are shown in Figure A. The map was prepared in November, 1999 using the NGVD29 datum. The present maps are prepared in the NAVD88 datum. The conversion from the NGVD29 datum to the NAVD88 datum is accomplished by adding 3.635 feet to the 29 datum. Therefore, the FEMA flood elevation of 333 is 336.63' in the NAVD88 datum. The historic high water mark of 337.7, as reported by operations staff and confirmed by PanGEO in the geotechnical report, corresponds within 1 foot of the FEMA prediction. FEMA defines this elevation as a 1 percent annual chance of flooding and a 26 percent chance of flooding over the life of a 30-year structure.

The 1990 northwest hydraulic consultants (NHC) Scriber Creek Flood Plain Mapping Study lists the 100-year recurrence elevation at 336.2 (converted to NAVD88). The 500-year recurrence event is not stated as an elevation but Figure 7A shows the levels flood profile to be approximately 338.

The 2012 SAIC Draft Scriber Creek Design Memorandum reports 336.2 as the “surveyed observed high water mark” from the 2007 flooding event. This report provided water surface elevations for various recurrence events as shown in the following table, with all elevations converted or reported on the NAVD88 datum.

| Recurrence Interval | FEMA | 1990 NHC WSE | 2012 SAIC WSE |
|---|---|---|---|
| 2 year | N/A | N/A | 330.78 |
| 10 year | N/A | 330.8 | 332.11 |
| 25 year | N/A | N/A | 332.85 |
| 50 year | N/A | 332.3 | N/A |
| 100 year | 336.63 | 336.2 | 335.21 |
| 500 year | N/A | 338 | 339.43 |

## FLOOD PROTECTION ELEVATION

The record flood elevation would arise from approximately the 100-year flood event. The City reports the historic elevation of 337.7, about 6 inches below the loading dock, is above the 100-year event projection. For planning purposes, the elevation of the loading dock will be called the 100-year flood elevation. It is common to provide 1-foot

freeboard to any flood elevation for a safety factor. Therefore, a flood protection elevation of 339.0 is recommended. Figure 2 shows the site with the FEMA flood elevation of 338.

## LEVEL OF SERVICE

During flood periods there may be varying level of service requirements for flood protection. They are defined as:

> **Structure and Equipment Protection –** This level of protection provides for structural integrity of the building and protection of the associated equipment necessary for the pump station to function and provide continuing service during the flood. This level of service does not necessarily include personnel or vehicle access to the building or equipment. The flood protection level allows the pump station to be an "island."
>
> **Personnel Access –** This level of protection provides for personnel pedestrian access to the pump station without crossing flood waters plus Protection A. Vehicle access is not provided without crossing 4-foot-deep water.
>
> **Vehicle Access –** This level of protection allows for protection of the structure and equipment, pedestrian access and vehicle access for equipment repair, installation and removal without crossing water.

Protection permanence is separated into three categories:

### TEMPORARY

Items and systems that are assembled on a one time basis and are discarded when the flood has passed. Items are typically sand bags, plywood and other flood blocking building materials.

### REUSABLE TEMPORARY

These items are reusable items of flood protection that require installation before the event reaches the pump station. Items can provide protection for Level A such as door dams, ventilation dams and PVC or hypalon dam tubes. After the flood waters retreat, the items can be removed and stored for future use.

### PERMANENT

Physical improvements that are constructed prior to flooding and remain in place permanently. Prevention features are operational 365 days per year without personnel assistance. Such items are flood walls, check valves, earth berms, waterproof gates and doors.

## ALTERNATIVE FLOOD PROTECTION IMPROVEMENTS

Table 1 presents a matrix of possible levels of flood protection and permanence for the pump station. The table is briefly discussed below.

**Protection Level A** will require flood proofing the entry doors, ventilation louvers and two exterior electrical panels located on the north building wall.

The exterior electrical panels are at approximately elev. 337. During the past flood events, they would be flooded unless protected. Protection can be provided by:

1. Temporary sand bags;
2. Flood Logs;
3. Flood Gate;
4. Panel replacement with waterproof panel boxes and conduit.

The exterior doors require flood proofing to an elevation of 339.0 to protect equipment and continue service.

1. Temporary sand bags;
2. Flood Logs;
3. Waterproof doors and ventilation grill for the Engine Generator set.

**Protection Level B** will require those elements from Protection Level A plus pedestrian access to the building. Without major restructuring of some exterior tanks, access to the station can be provided through the southeast rear door. The door is 36-inch wide with an existing metal grated platform. Access to the door will be from the pedestrian gate at the northeast corner of the site around the diesel tank circling to the east side of the platform. Possible improvements would be:

1. Sand bag wall from the diesel tank to the platform (40 lf) with a removable rail section on the east;
2. Inflatable berm from the diesel tank to the door platform;
3. A permanent elevation walkway or wall from the diesel tank to the entry platform with removal of the east railing.

**Protection Level C** will require select elements of A and B plus the addition of a berm or wall to connect the loading dock to the site entrance.

1. Sand bag wall from the loading dock through the entrance gate into the Park & Ride lot parking area (150 lf). Wall height would vary from one bag to 4-feet tall;

2. Inflatable berm from the loading dock through the entrance gate into the Park & Ride lot parking area (150 lf). The berm would vary from one tube to three tubes in order to obtain a 4-feet tall berm;

3. A permanent structural wall from the Park & Ride parking lot entrance around the educator building and oxygen storage tank then along the south fence line connecting to the pump station building. The wall would be up to 4-feet tall. The length would vary from 280 lf to 375 lf depending upon the terminus point.

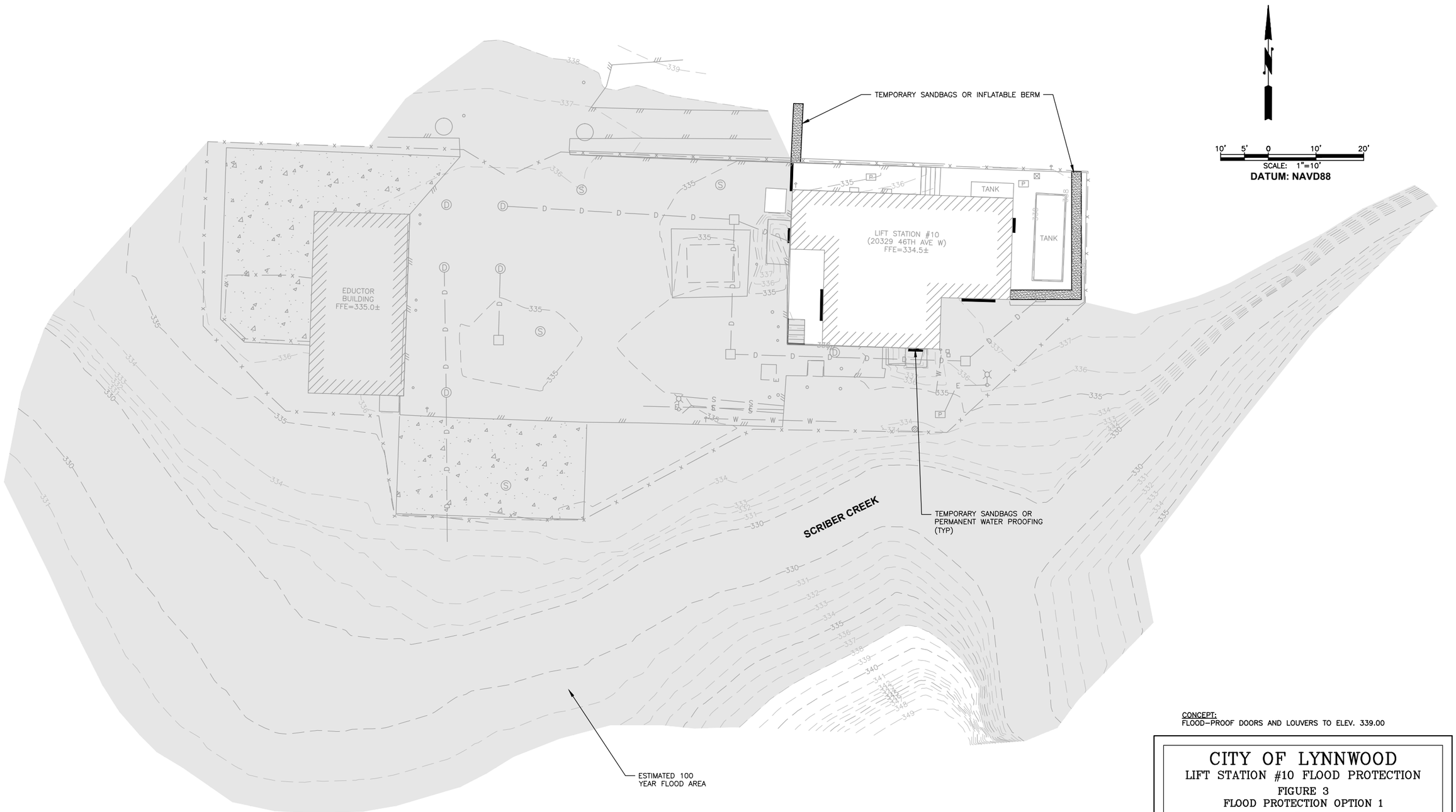
**Flood Protection Alternatives**

Various physical alternative improvements were analyzed to determine approximate requirements and cost. No physical alterations to the building or site were considered in order to reduce the number of possibilities to a manageable number and expense. While some variations and combination of improvements can be evaluated to fine tune the flood protection, this evaluation provides the approximate cost, intrinsic considerations and benefits.

One feature of the pump station requires immediate improvement. Two new electrical panels appear to have been installed on the exterior of the north wall. These panels are below the high water mark of the highest recorded flood. It appears the panels are not waterproof. It is recommended the panels be raised or made waterproof in order not to jeopardize their functionality during a flood. If feasible, raising the panels would be the least expensive solution. Waterproof panel boxes and conduits are estimated to cost more than $50,000. If neither of these alternatives is possible, either a permanent or temporary water stop, should be installed west of the panels in the paved walkway. Consideration should also be given to raising the retaining wall in that area to cut high water from the parking lot.

**Protection Level A** – Also called the island because while the building will be safe from flooding, entry to the building will require crossing water up to 4-feet deep. The systems are shown in Figure 3.

Temporary flood proofing will be the installation of sand bags in an attempt to seal the doors and low elevation of the engine generator (GE) louvers. While the cost is low, the high response time and prior planning necessary to stock pile materials is a major




NOTE:
CONTOURS SHOWN BEYOND FENCE ARE ESTIMATED FROM 1990 AS-BUILT DRAWINGS.

CONCEPT:
FLOOD-PROOF DOORS AND LOUVERS TO ELEV. 339.00

# CITY OF LYNNWOOD

## LIFT STATION #10 FLOOD PROTECTION

FIGURE 3
FLOOD PROTECTION OPTION 1

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consideration. Additionally, the flood protection level of 339 feet would be physically more difficult to assure than more permanent alternatives.

Reusable Temporary systems are not practical for this level of protection because of various physical restraints.

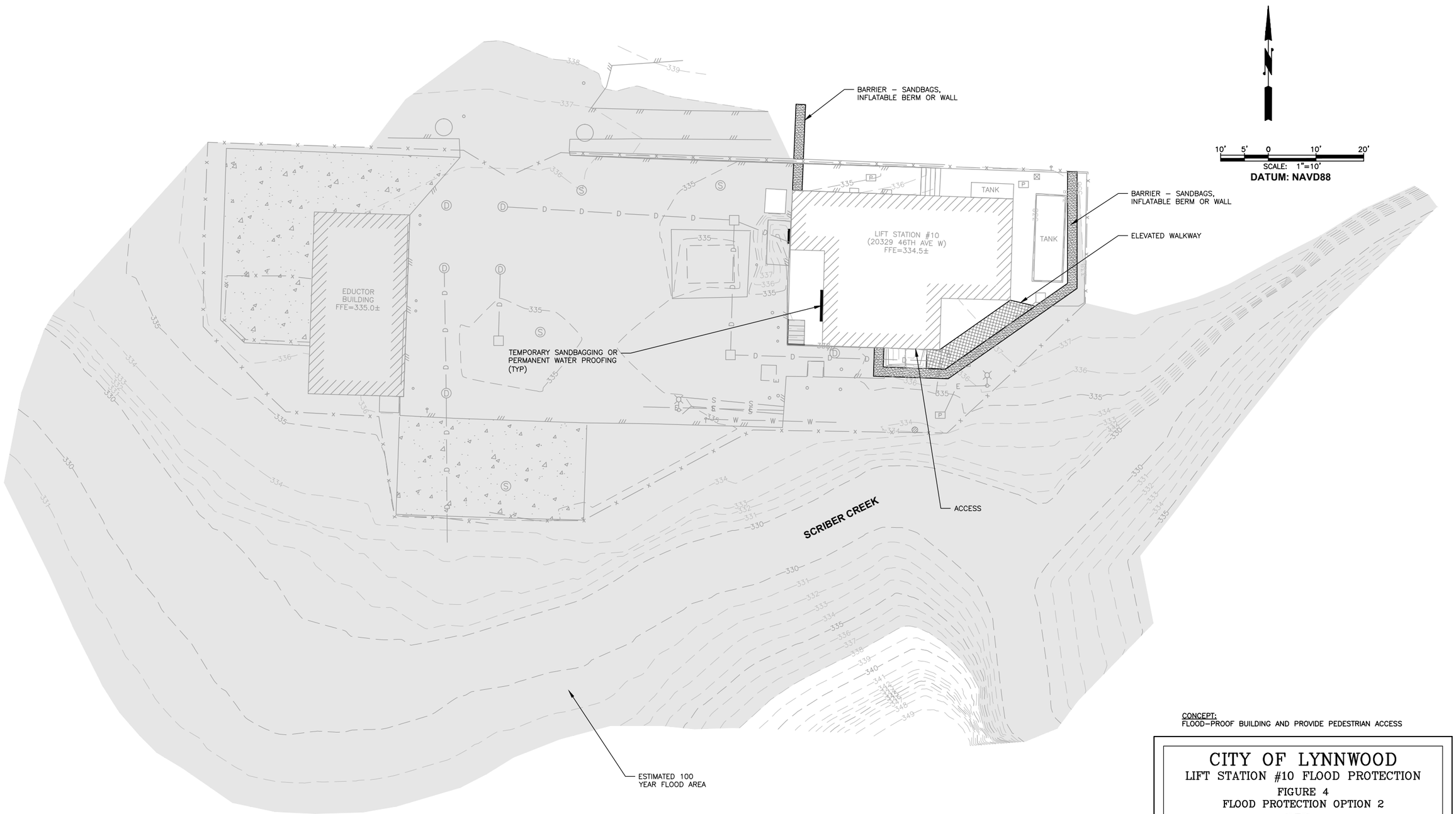
Permanent flood proofing can be obtained by installing water proof gates and barriers as manufactured by the Presray Corp. at the doors and louvers. These features can be permanently installed and quickly deployed while not affecting the day to day operation of the pump station.

**Protection Level B** – The pump station will have flood protection while allowing pedestrian access to the rear southeast door for personnel without having to cross standing water. These alternative configurations are shown in Figure 4.

Temporary flood protection would require a sand bag wall from the property's northeast corner around to the southeast door landing. The railing will require modification to its east guard rail in order to allow entrance. The sand bag wall will require a 5-foot top width to withstand 4 feet of water pressure. The wall footprint will be large and require a significant amount of time to install. Practically, filled sand bags will need to be stock piled and access to the site will be hindered by the pedestrian gate limiting the number of people used to build the wall. Equipment access would be limited to nonexistent. Construction time will be lengthy and dependent upon available personnel. The USCOE estimates it takes about 1.7 hours/sf to build a sand bag wall that will withstand 4 feet of water pressure. With a large crew, the effort would take well over 24 hours.

Reusable Temporary systems alternatives can be used for this level of protection. A sand wall structure can be built using the mechanical system rapid deployment flood wall (RDFW) manufactured by Geocells, Inc. It is a plastic containment system tested by the USCOE and FEMA. The wall will be identical to the sand bag alternative but the containment system is faster to install and is reusable. This alternative will require stockpiling material and rearrangement of the diesel fuel tank to allow access by a small skid loader. The second alternative is use of an inflatable berm as manufactured by US FLOOD CONTROL. Its trade name is Tiger Berm. The inflatable tubes will be aligned in a similar manner as the sand alternative and filled with water to inflate the tubes. The maximum practical diameter of the tubing is 3 feet; therefore, protection to the 339 elevation will require a pyramid shaped pile of 2-1 tubes to achieve that height. The tubes can be deployed then filled with water in about 2 to 3 hours using two 2-inch hoses from the local fire hydrant and three people. Flood protection of the doors on the loading dock area would still be required to protect the building while allowing pedestrian traffic.

Permanent flood proofing can be achieved by construction of a concrete wall on the southeastern side of the building to allow foot traffic. An elevated walkway could also provide the same level of access but would expose pedestrians to crossing over water




CONCEPT:
FLOOD–PROOF BUILDING AND PROVIDE PEDESTRIAN ACCESS

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## LIFT STATION #10 FLOOD PROTECTION
FIGURE 4
FLOOD PROTECTION OPTION 2

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NOTE:
CONTOURS SHOWN BEYOND FENCE ARE ESTIMATED FROM 1990 AS–BUILT DRAWINGS.

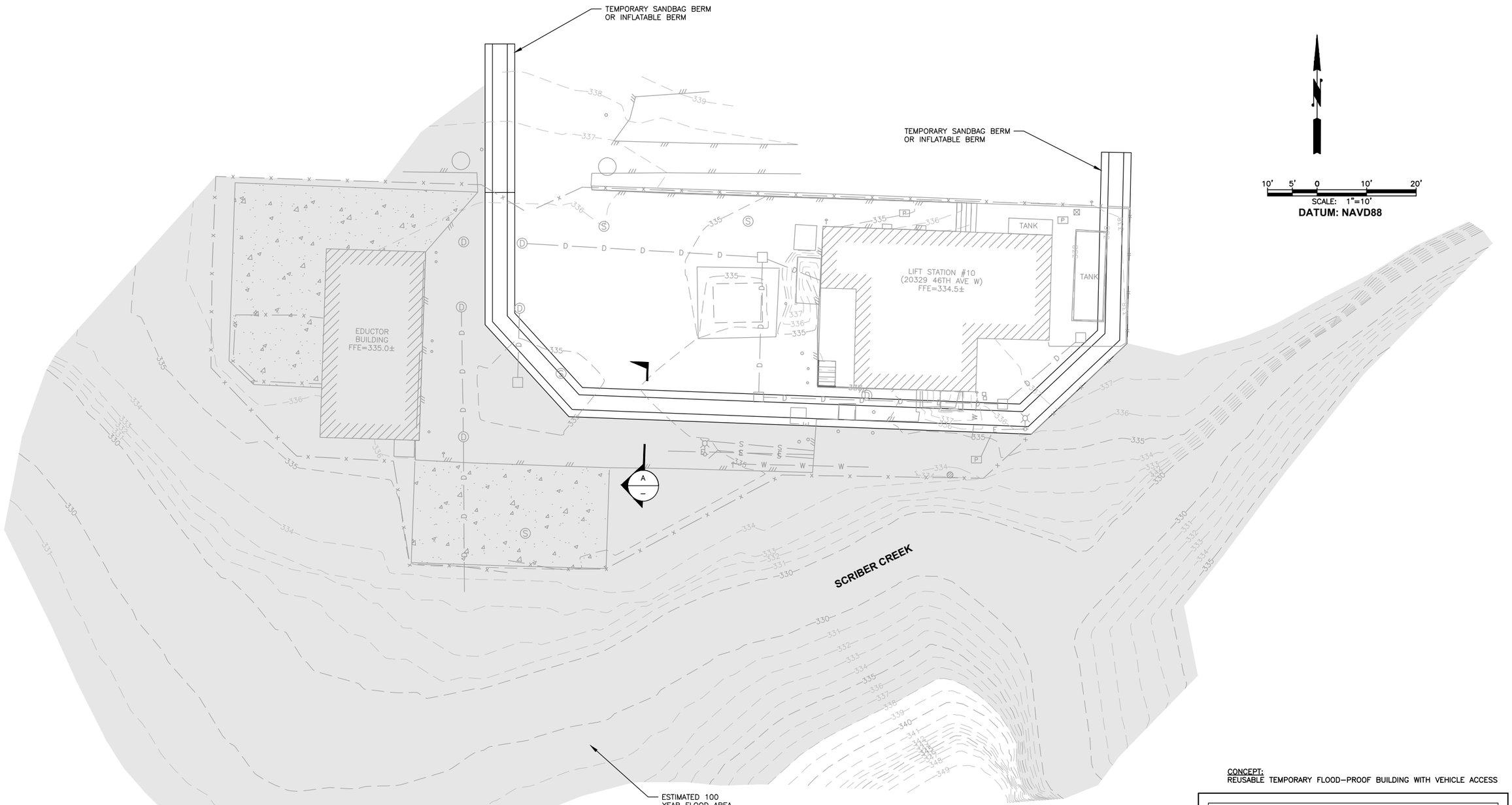
during the flood. These options would require a building permit. This alternative was not evaluated.

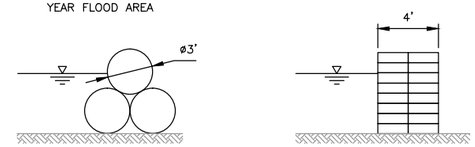
**Protection Level C** – Requires a flood wall from above the pump station entrance to the loading dock area for vehicles to access the building. These alternative configurations are shown in Figures 5 and 6.

Temporary flood protection would require a sand bag wall from above the entrance around to the southwest corner of the loading dock. This alternative is not considered for a number of reasons. First the wall being 4-feet tall would require a 5-foot top section with 1:1 side slopes in order to withstand the water pressure. Secondly the amount of leakage through the wall could be considerable and would require a pump to maintain a dry area. Lastly the time to fill and construct the wall would take a significant number of people and time. Perhaps more than 12 to 18 hours. Because of these considerations, a sand bag wall is not considered feasible.

Reusable Temporary system alternatives can be used for this level of protection similar to those described in Protection Level B, the pedestrian level of protection. The configuration of the walls would be similar to the temporary sand bag system discussed above. The issue of wall leakage would not be experienced with these alternative systems.

Permanent flood proofing can be achieved by construction of a concrete wall on the perimeter of the existing site with the additional requirement of a temporary berm in the Park & Ride lot to achieve an elevation of 339. The wall would be reinforced concrete with pile supports due to the soil conditions. A preliminary geotechnical exploration and report has been conducted and is included in Appendix A. While the most expensive of the protection options, it provides the most permanent long-term solution. Due to the pump station's proximity to the creek and the surrounding wetlands, a wetlands permit would likely be necessary in order to implement this protection system. The construction would also require a building permit.




INFLATABLE BERM

RDFW SAND BERM

A

**SECTION**

SCALE: NOT TO SCALE

NOTE:
CONTOURS SHOWN BEYOND FENCE ARE
ESTIMATED FROM 1990 AS-BUILT DRAWINGS.

CONCEPT:
REUSABLE TEMPORARY FLOOD-PROOF BUILDING WITH VEHICLE ACCESS

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## LIFT STATION #10 FLOOD PROTECTION

FIGURE 5

FLOOD PROTECTION OPTION 3

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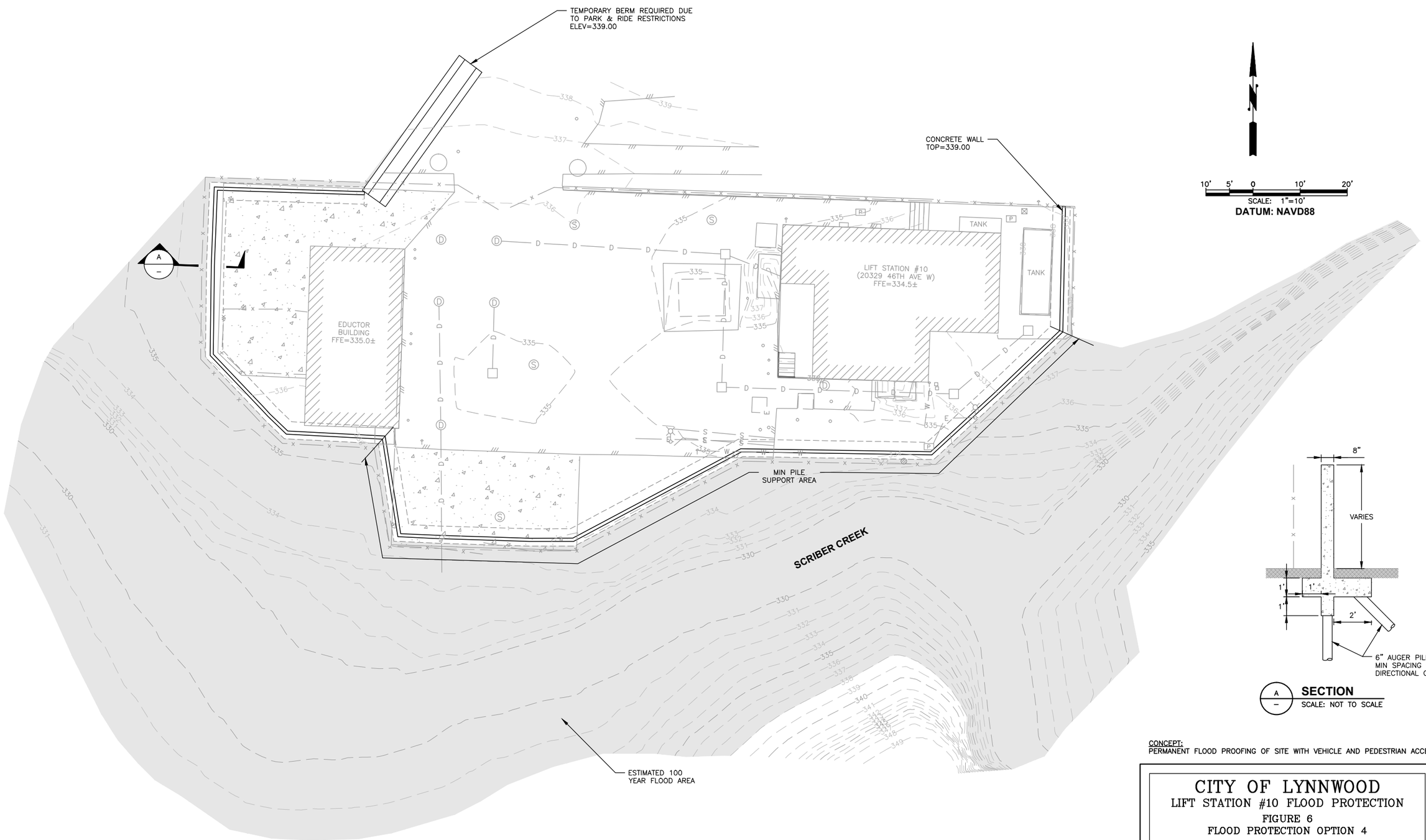


CONCEPT:
PERMANENT FLOOD PROOFING OF SITE WITH VEHICLE AND PEDESTRIAN ACCESS

# CITY OF LYNNWOOD

## LIFT STATION #10 FLOOD PROTECTION

FIGURE 6
FLOOD PROTECTION OPTION 4

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NOTE:
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## TABLE 1

## Alternative System Protection and Permanence

| Level of Protection/Alternative | Electrical Panels | Building |
|---|---|---|
| A – Structure Protection | | |
| 1 – Temporary | Sandbag | Sandbag |
| 2 – Reusable | Flood Log | Flood Log |
| 3 – Permanent | Flood Gate/Replace Panel | Watertight Doors |
| B – Pedestrian Access | | |
| 1 – Temporary | Sandbag | Sandbag |
| 2 – Reusable | Flood Log | Inflatable Dam |
| 3 – Permanent | Relocate | Footbridge or Wall |
| C – Building Access | | |
| 1 – Temporary | Sandbag | NF |
| 2 – Reusable | Flood Log | Inflatable Dam |
| 3 – Permanent | Relocate | Wall |
| | | |

NF- Not Feasible

## TABLE 2

## Cost Estimate

| Level of Protection | Sand Bang | Presray Corp. | Rapid Deployment Flood Wall | Inflatable Berm | Concrete Wall | Total |
|---|---|---|---|---|---|---|
| A | | | | | NR | |
| 1 | $9,000 | | | | NR | $9,000 |
| 2 | | NF | NR | NF | NR | |
| 3 | | $55,000(1) | | | NR | $55,000 |
| B | | | | | | |
| 1 | NF | | | | | |
| 2 | | $15,000(2) | $15,000(3) | $15,000(4) | | $30,000 |
| 3 | | $15,000(2) | | | $40,000 | $55,000 |
| C | | | | | | |
| 1 | NF | NR | | | | |
| 2 | | NR | $46,000(3) | $50,000(4) | | $50,000 |
| 3 | | NR | | | $200,000 | $200,000 |

(1) Four doors and E G louvers.
(2) Includes installation labor and refurbishment for second event.
(3) Materials only, installation and removal labor and water not included.
(4) Three doors only.
NR- Not Required
NF- Not Feasible

## TABLE 3

## Evaluation Considerations

| Level of Protection/ Alternative | Capital Cost | Storage Area | Flood Readiness | Equipment Requirements | Deployment Time | Service life | Reliability | Permit Requirements | Access Requirements |
|---|---|---|---|---|---|---|---|---|---|
| A – Structure Protection | | | | | | | | | |
| 1* | $9,000 | High | Low | Trucks & Loaders | 4 Hours | 1 Event | Low | None | None |
| 2 | NF | | | | | | | | |
| 3 | $55,000 | Small | High | None | 1 Hour | Permanent | Excellent | None | None |
| B – Pedestrian Access | | | | | | | | | |
| 1 | NF | | | | | | | | |
| 2 | $30,000 | Small | Moderate | Truck, skid Steer Loader/300’ – 2-inch Hose | Moderate | Multiple Events | Moderate | None | None |
| 3 | $55,000 | Small | High | None | Immediate | Permanent | Excellent | Building Permit | None |
| C – Building Access | | | | | | | | | |
| 1 | NF | | | | | | | | |
| 2 | $50,000 | Small | Moderate | Truck, skid Steer Loader/300' – 2-inch Hose | 5 to 6 Hours | Multiple Events | Moderate | None | Park & Ride Lot |
| 3 | $200,000 | None | High | None | Immediate | Permanent | Excellent | Building Permit/ Wetlands | Park & Ride Lot |

## CONCLUSION

Pump Station No. 10 is prone to flooding due to its low lying location and its proximity to Scriber Creek. Some form of flood protection should be implemented in order to ensure the continued operation of the pump station during flood events as the historic high water level recorded at the station is within 0.5 feet of the loading dock and floor elevation. A number of alternative protection techniques were evaluated for the pump station which would allow for either minimal (station infrastructure), moderate (personnel access), or maximum (vehicle access) protection. Techniques considered to protect the electric panels include sandbags, flood logs, panel replacement or relocation. Techniques considered to protect the integrity of the building and to allow access include sandbags, flood logs, inflatable dams, a wall, or a footbridge. The total cost of flood protection is highly dependent on the level of protection deemed necessary and the permanence of the selected protection technique.

The recommended course of action for the pump station is to provide the highest level of flood protection that can be met with available funds. Since this lift station is a critical component of the sanitary sewer system, if funds are available, we recommend construction of a permanent floodwall.

# APPENDIX A

# GEOTECHNICAL REPORT

PanGEO
INCORPORATED
*Geotechnical & Earthquake Engineering Consultants*

November 22, 2013
File No. 13-186

Mr. Barry Baker, P.E.
**Gray & Osborne, Inc.**
701 Dexter Avenue North, Suite 200
Seattle, Washington 98109

**Subject: Geotechnical Engineering Report - Draft**
**Lift Station No. 10 Flood Wall**
**Lynnwood, Washington**

Dear Mr. Baker,

Please find attached our draft geotechnical report to assist you and the project team with the design and construction of the proposed flood wall at the subject site. We will finalize the report once we receive review comments from the project team. We understand that the use of permanent cast-in-place concrete walls and temporary inflatable berms are being considered for flood protection at this site. From the geotechnical engineering perspective, both options are considered feasible. Because of the a portion of the flood protection walls will be located near the top of the nearby Scriber Creek bank, this portion of the concrete wall should be supported on a deep foundation system. Additional design recommendations are outlined in the attached report.

We appreciate the opportunity to work with you and your design team on this project. Please call if you have any questions.

Sincerely,

Siew L. Tan, P.E.
Principal Geotechnical Engineer

Encl.: Draft Geotechnical Report

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Seattle, WA 98102
Tel (206) 262-0370
Fax (206) 262-0374

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**GEOTECHNICAL REPORT - DRAFT**
**LIFT STATION NO. 10 FLOOD WALL**
**LYNNWOOD, WASHINGTON**

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## 1.0 INTRODUCTION

This report presents the results of our geotechnical engineering study that was undertaken to support the design and construction of a proposed flood wall to protect the Lift Station 10 facility. Our service scope included reviewing readily available geologic data in the vicinity of the project site, conducting a site reconnaissance, advancing two test borings along the proposed flood wall alignment, and developing the conclusions and recommendations presented in this draft report. We will finalize the report once we receive review comments from the project team.

## 2.0 SITE AND PROJECT DESCRIPTION

The subject property is located at 20329 46th Avenue West, in Lynnwood, Washington (see attached Figure 1, Vicinity Map). The project site is bounded by Lynnwood Transit Center parking lot to the north, by Scriber Creek bank to the south, and by undeveloped lands to the east and west (see aerial photo below).

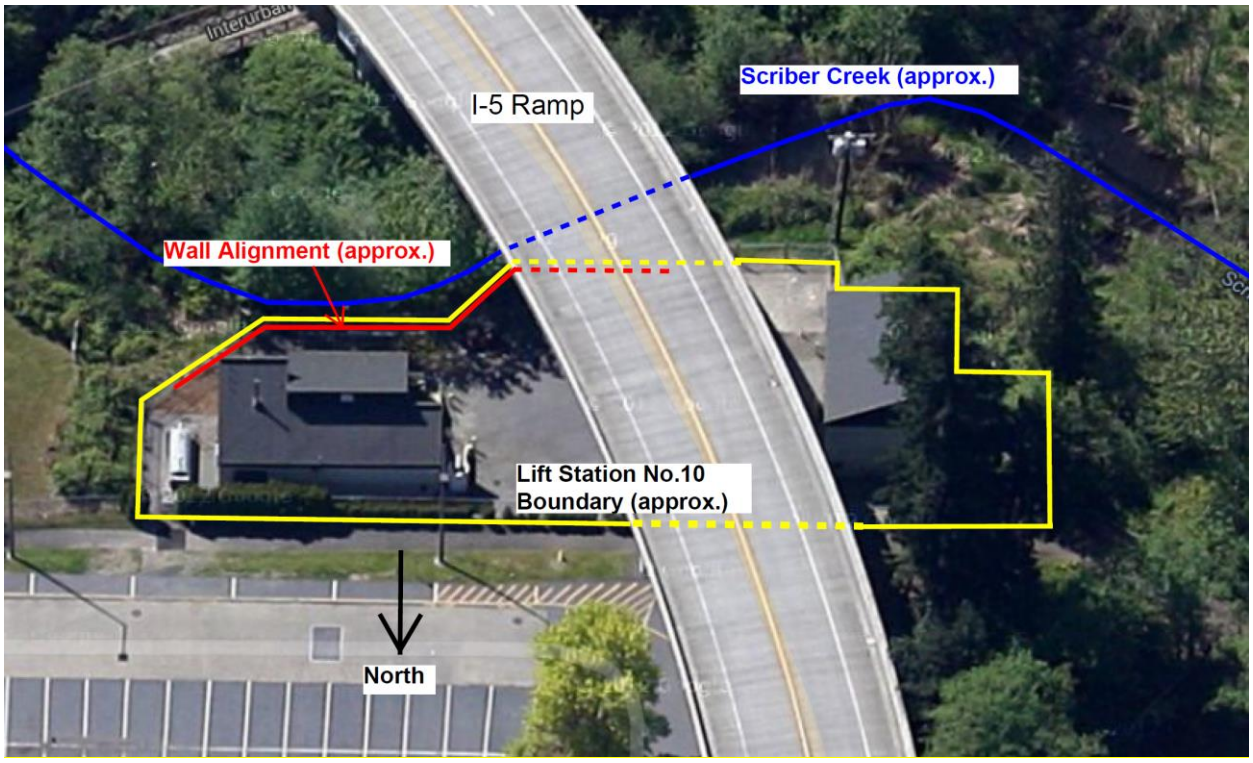



**Plate 1:** Existing Site Aerial Photo (Modified from Google Maps)

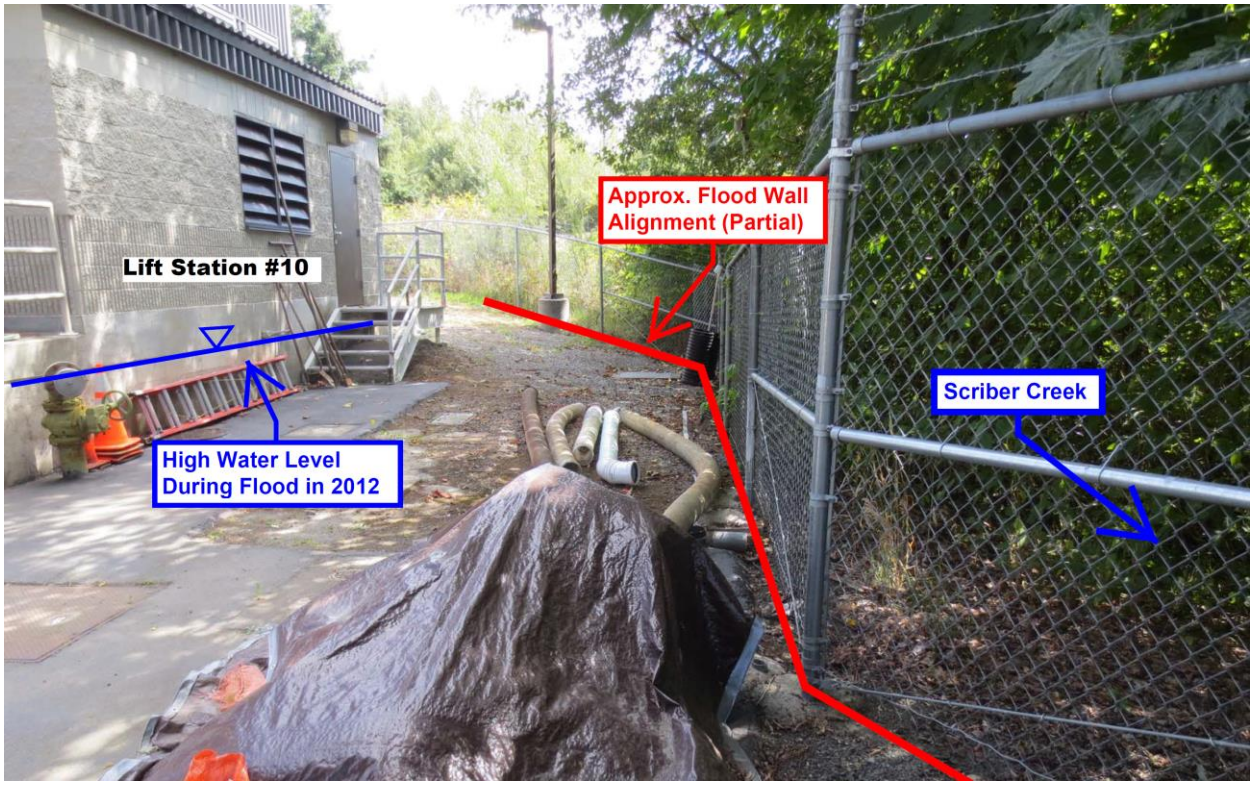



**Plate 2.** Looking east along the flood wall alignment (south of Lift Station building)

Currently, the site is occupied with Lift Station No. 10 facility, which consist of Lift Station No.10 building at the eastern portion of the site, an Educator Building to the west, and a series of tanks at various locations (see attached Figure 2). The areas immediately south and west of the Lift Station No.10 building is mostly covered with asphalt pavement, and based on the as-built site piping plan (dated October, 1990) provided by Gray & Osborne, underground utility (sewer and drain) lines and manholes structures are located below the pavement areas.

Site grades are very level, with the exception of the eastern half of the site where the ground surface slightly descends from northeast to southwest with a topographic relief of about 4 feet. The Scriber Creek is generally located south of the subject site, and portions of the developed area are located within 5 feet from the top of creek bank. The ground surface between the creek bank and the fence line is vegetated with bushes and mature trees. Based on the topographic contours indicated in Figure 2, the creek bank generally slopes downward from northwest to southeast at about 1Horizontal (H):1Vertical (V) to 2H: 1V.

A topographic survey of the existing site conditions is not available at this time, but the majority of the site grade is believed to be near elevation 335 feet. Based on the information provided by

the City of Lynnwood Public Works, the Scriber Creek water level rose to about elevation 337 feet in 2012 (see Plate 2 on previous page), approximately six inches below the floor of the lift station building. As such, the flood control measures are needed to mitigate the flood hazard at the site. We understand that the design flood level will be at Elevation 338 feet, and the top of the flood wall will be one foot higher than the design flood level at Elevation 339 feet. We understand that both permanent concrete walls and temporary inflatable berms are currently being considered.

## 3.0 SUBSURFACE EXPLORATIONS

Two test borings (PG-1 and PG-2) were drilled at the site on September 3, 2013, using a hand-operated portable drill rig owned and operated by CN Drilling of Seattle, Washington. The approximate boring locations are shown on the attached Figure 2. The borings were drilled to depths ranging from about $11^1/_2$ and $16^1/_2$ feet below the existing grades.

The drill rig was equipped with 4-inch outside diameter hollow stem augers. Soil samples were obtained from the borings at 2½- and 5-foot depth intervals in general accordance with Standard Penetration Test (SPT) sampling methods (ASTM test method D-1586) in which the samples are obtained using a 2-inch outside diameter split-spoon sampler. The sampler was driven into the soil a distance of 18 inches using a 140-pound weight freely falling a distance of 30 inches. The number of blows required for each 6-inch increment of sampler penetration was recorded. The number of blows required to achieve the last 12 inches of sample penetration is defined as the SPT N-value. The N-value provides an empirical measure of the relative density of cohesionless soil, or the relative consistency of fine-grained soils.

An engineer from PanGEO was present to observe the drilling, assist in sampling, and to describe and document the soil samples obtained from the borings. The soil samples were described using the system outlined on Figure A-1 in Appendix A, and the summary logs are included as Figures A-2 and A-3.

## 4.0 SUBSURFACE CONDITIONS

### 4.1 SOIL

According to the geologic map of the area complied by Booth and others (2004), the project site is underlain by Younger Alluvium, a heterogeneous mixture of silt, sand and gravel deposited by the nearby Scriber Creek. The results of our field explorations indicates that the site is underlain

by a surficial layer of fill underlain by the mapped Younger Alluvium, in turn underlain by a unit of medium dense to dense silty sand that we interpreted as Advance Outwash deposits. A summary of the soil units encountered are as follows. Please refer to the boring logs in Appendix A for additional details.

**Unit 1: Fill** – About $4^1/_2$ and 7 feet of undocumented fill soil was encountered PG-1 and PG-2, respectively. The fill soils generally consist of medium dense to dense, brown, gravelly, silty sand. It is likely that the fill was placed for the grading of the previous development, such as the existing facility. It also appears that, based on the SPT N-values recorded in the borings, the fill was densely compacted.

**Unit 2: Younger Alluvium -** Directly below the fill, a unit of loose to medium dense, brown to gray, well-graded sand was encountered in both test borings. This unit is about 2- to 3-foot thick. Because of Scriber Creek is adjacent to the site and the soil samples collected within this layer appeared to be loose/medium dense and well-graded, we interpret this unit as the mapped Younger Alluvium.

**Unit 3: Advance Outwash -** A layer of dense, slightly silty to silty, poorly-graded sand was encountered directly below the Younger Alluvial deposits, and extended to at least the bottom of the test borings. The top of this unit was about 7 and 9 feet below existing grades in PG-1 and PG-2, respectively. Note that about upper 4 feet of Advance Outwash found in PG-2 was disturbed and appeared to be medium dense.

### 4.2 GROUNDWATER

Groundwater was encountered at depths of about $4^1/_2$ and $6^1/_4$ feet below the existing grade in borings PG-1 and PG-2, respectively. The observed groundwater levels are generally consistent to the adjacent Scriber Creek water level at the time of drilling. It should be noted that groundwater elevations may vary depending on seasonal precipitations, local subsurface conditions, and other factors. Groundwater levels are normally highest during the winter and early spring. We anticipate that the groundwater levels to be greatly influenced by the fluctuation of water levels in the creek.

# 5.0 GEOTECHNICAL RECOMMENDATIONS

## 5.1 STABILITY OF EXISTING CREEK BANK

In general, the existing creek bank adjacent to the project site appears stable as we did not observe evidence of downslope movements. The vegetation on the surface of the bank generally does not show trends of leaning outward, suggesting lack of significant downslope movements. With proper design and construction, it is our opinion that the proposed flood control measures will not adversely affect the stability of the existing creek bank.

## 5.2 CONCRETE FLOOD WALL

We understand that a cast-in-place concrete flood wall is being considered at this time. In general, it is our opinion that the flood wall may be supported on conventional spread footings, except in the vicinity of our test borings where the proposed wall may be very close to the top of creek bank. We recommend that where the wall will be situated within 8 feet of the creek bank, the wall be supported on a deep foundation system. Given the site constraints in the area, the deep foundation will likely need to be constructed using small construction equipment. As a result, where a deep foundation system will be needed, it appears that small diameter (4- or 6-inch diameter) driven steel pipe piles (pin piles) are likely the most feasible option. Design parameters for conventional footings and pin piles are outlined in Section 5.2.1 and 5.2.2, respectively.

### *5.2.1 Conventional Footing*

***Allowable Bearing Pressure*** – We recommend that an allowable bearing pressure of 2,500 pounds per square foot (psf) be used to size the footing. We recommend at least one foot of over-excavation below the bottom of the footing, and backfilled with Crushed Surfacing Base Course. For allowable stress design, the recommended allowable bearing pressure may be increased by 1/3 for transient conditions. All footing excavations should be trimmed neat and footing subgrade should be carefully prepared. Any loose or softened soil should be removed from the footing excavation.

***Lateral Resistance*** – Lateral forces may be resisted by a combination of passive earth pressures acting against the embedded portions of the foundations and by friction acting on the base of the foundations. An allowable friction coefficient of 0.35 may be used. Passive resistance may be

determined using an equivalent fluid weight of 200 pounds per cubic foot (pcf), assuming saturated soils adjacent to the footings during flooding, and the structural fill adjacent to the sides of the footing will be adequately compacted. Both values include a factor of safety of 1.5.

***Footing Embedment and Key*** – The bottom of footings should be located at least 18 inches below the finished grade. In addition, we recommend that a concrete key be constructed below the footing to provide a barrier to prevent water from seeping into the site below the footings. The key should extend to the greater of (1) 2½ feet below the finished grade, or (2) 60% of retained water height.

### *5.2.2 Pin Pile*

***Pile Sizes –*** In our opinion 4- or 6-inch diameter piles represent an appropriate size pile to support the proposed concrete flood wall. Four- and 6-inch piles are typically installed using medium-sized hydraulic hammers (2,000 to 3,000 pound) mounted on an excavator.

***Axial Capacity -*** An allowable axial compression capacity of 20 and 30 kips may be used for 4- and 6-inch diameter piles, respectively, with an approximate factor of safety of 2. Penetration resistance required to achieve the capacities will be determined based on the hammer used to install the pile. Tensile capacity of pin piles should be ignored in design calculations. It is our experience that the driven pipe pile foundations should provide adequate support with total settlements on the order of ½-inch or less.

***Lateral Resistance*** – Lateral forces may be resisted by a combination of passive earth pressures acting against the embedded portions of the pile caps and batter piles. Batter piles may be inclined no flatter than 12V:3H. Passive resistance may be determined using an equivalent fluid weight of 200 pounds per cubic foot (pcf), assuming saturated soils adjacent to the footings during flooding, and the structural fill adjacent to the sides of the footing will be adequately compacted. The value includes a factor of safety of 1.5.

***Pile Specifications -*** We recommend that the following specifications be included on the foundation plan:

1. Four- or 6-inch diameter piles should consist of galvanized Schedule-40, ASTM A-53 Grade “A” pipe.

2. Piles shall be driven to refusal with a minimum 2,000-lb hydraulic hammer. The driving criteria will be determined based on the actual hammer size selected by the contractor, and a static load test program (see discussion in Item 4).

3. Piles shall be driven in nominal sections and connected with compression fitted sleeve couplers. We discourage welding of pipe joints, particularly when galvanized pipe is used, as we have frequently observed welds broken during driving.

4. The geotechnical engineer of record or his/her representative shall provide full time observation of pile installation.

The quality of a pin pile foundation is dependent, in part, on the experience and professionalism of the installation company. We recommend that a company with experienced personnel be selected to install the piles.

***Estimated Pile Length -*** The required pile length in order to develop the recommended pile capacity will depend on the actual driving conditions encountered, which are expected to vary across the site. For planning and cost estimating purposes, however, we estimate that the pile will need to be embedded in the underlying dense sand about 15 to 20 feet. Therefore, we estimate that an average pile length of about 25 to 30 feet will be needed below the existing ground surface. It should be noted that the pile capacity may not be achieved at the end of initial driving, and that the load test may need to occur after the pile set-up has occurred.

***Key*** – A concrete key should be constructed below the pile caps to provide a barrier to prevent water from seeping into the site below the footings. The key should extend to the greater of (1) 2½ feet below the finished grade, or (2) 60% of retained water height.

***Obstructions –*** Obstructions may be encountered within the fill soil at the site. Where possible, the obstructions should be removed to facilitate the pile driving. If obstructions cannot be removed, the structural engineer of record should be notified to revise the pile layout to accommodate moving the piles.

### 5.3 TEMPORARY INFLATABLE BERMS

We understand that a temporary water-filled berm may also be used. It is our opinion that the site soils are adequate for supporting the weight of the berm. For design purposes, for a

temporary structure, an allowable bearing pressure of 4,000 psf may be used for design calculations.

### 5.4 Seismic Site Class

A seismic site class D per the 2012 IBC is considered appropriate.

### 5.5 Temporary Cut and Dewatering

We anticipate the footing excavation will likely be less than 4 feet deep. Assuming the flood wall will be constructed during the drier summer months, we do not anticipate the excavation will encounter significant amount the groundwater.

Where space is allowed, an unsupported slope cut can be made within the open excavation. For planning purposes, we recommend that a temporary cut less than 4 feet of total depth may be sloped no steeper than ½H:1V (horizontal:vertical), and that a temporary excavation deeper than 4 feet be sloped at a maximum angle of 1H:1V.

### 5.6 Drainage Considerations

It should be noted that water could be trapped at the site by the flood wall. As such, it may be necessary to install pumps to remove the water from the site in the event that water accumulates at the site.

## 6.0 CONSTRUCTION CONSIDERATIONS

### 6.1 Structural Fill

We anticipate that structural fill will be needed to backfill the footings and pile caps. It is opinion that, if the construction is to occur during drier summer months, the excavated on-site soils may be used to backfill against the pile cap and footings. Imported structural fill, if needed, should consist of Gravel Borrow, as described in Section 9-03.14 (1) of the 2012 WSDOT Standard Specifications. However, any backfill below the footings should consist of imported Crushed Surfacing Base Course.

The structural fill should be moisture conditioned to within about 3 percent of optimum moisture content, placed in loose, horizontal lifts less than 8 inches in thickness, and systematically

compacted to a dense and relatively unyielding condition and to at least 95 percent of the maximum dry density, as determined using test method ASTM D 1557.

### 6.2 WET WEATHER EARTHWORK RECOMMENDATIONS

General recommendations relative to earthwork performed in wet weather or in wet conditions are presented below:

- Because site soils are moisture sensitive, all footing subgrades should be protected against inclement weather. One option is to place a 2- to 3-inch thick layer of clean crushed rock or lean mix concrete on the footing subgrade as soon as the subgrade is exposed.

- Earthwork should be performed in small areas to minimize subgrade exposure to wet weather. Excavation or the removal of unsuitable soil should be followed promptly by the placement and compaction of clean structural fill. The size and type of construction equipment used may have to be limited to prevent soil disturbance.

- During wet weather, the allowable fines content of the structural fill should be reduced to no more than 5 percent by weight based on the portion passing ¾-inch sieve. The fines should be non-plastic.

- The ground surface within the construction area should be graded to promote run-off of surface water and to prevent the ponding of water.

- Bales of straw and/or geotextile silt fences should be strategically located to control erosion and the movement of soil. Erosion control measures should be installed along all the property boundaries.

- Excavation slopes and soils stockpiled on site should also be covered with plastic sheets.

## 7.0 CLOSURE

We have prepared this report for Gray & Osborne and the project design team. Recommendations contained in this report are based on a site reconnaissance, a review of pertinent subsurface information, completion of a subsurface exploration program, and our

understanding of the project. The study was performed using a mutually agreed-upon scope of work.

Variations in soil conditions may exist between the locations of the explorations and the actual conditions underlying the site. The nature and extent of soil variations may not be evident until construction occurs. If any soil conditions are encountered at the site that are different from those described in this report, we should be notified immediately to review the applicability of our recommendations. Additionally, we should also be notified to review the applicability of our recommendations if there are any changes in the project scope.

The scope of our work does not include services related to construction safety precautions. Our recommendations are not intended to direct the contractors' methods, techniques, sequences or procedures, except as specifically described in our report for consideration in design. Additionally, the scope of our work specifically excludes the assessment of environmental characteristics, particularly those involving hazardous substances. We are not mold consultants nor are our recommendations to be interpreted as being preventative of mold development. A mold specialist should be consulted for all mold-related issues.

This report has been prepared for planning and design purposes for specific application to the proposed project in accordance with the generally accepted standards of local practice at the time this report was written. No warranty, express or implied, is made.

This report may be used only by the client and for the purposes stated, within a reasonable time from its issuance. Land use, site conditions (both off and on-site), or other factors including advances in our understanding of applied science, may change over time and could materially affect our findings. Therefore, this report should not be relied upon after 24 months from its issuance. PanGEO should be notified if the project is delayed by more than 24 months from the date of this report so that we may review the applicability of our conclusions considering the time lapse.

It is the client's responsibility to see that all parties to this project, including the designer, contractor, subcontractors, etc., are made aware of this report in its entirety. The use of information contained in this report for bidding purposes should be done at the contractor's option and risk. Any party other than the client who wishes to use this report shall notify PanGEO of such intended use and for permission to copy this report. Based on the intended use of the report, PanGEO may require that additional work be performed and that an updated report

be reissued. Noncompliance with any of these requirements will release PanGEO from any liability resulting from the use this report.

We appreciate the opportunity to be of service.

Sincerely,

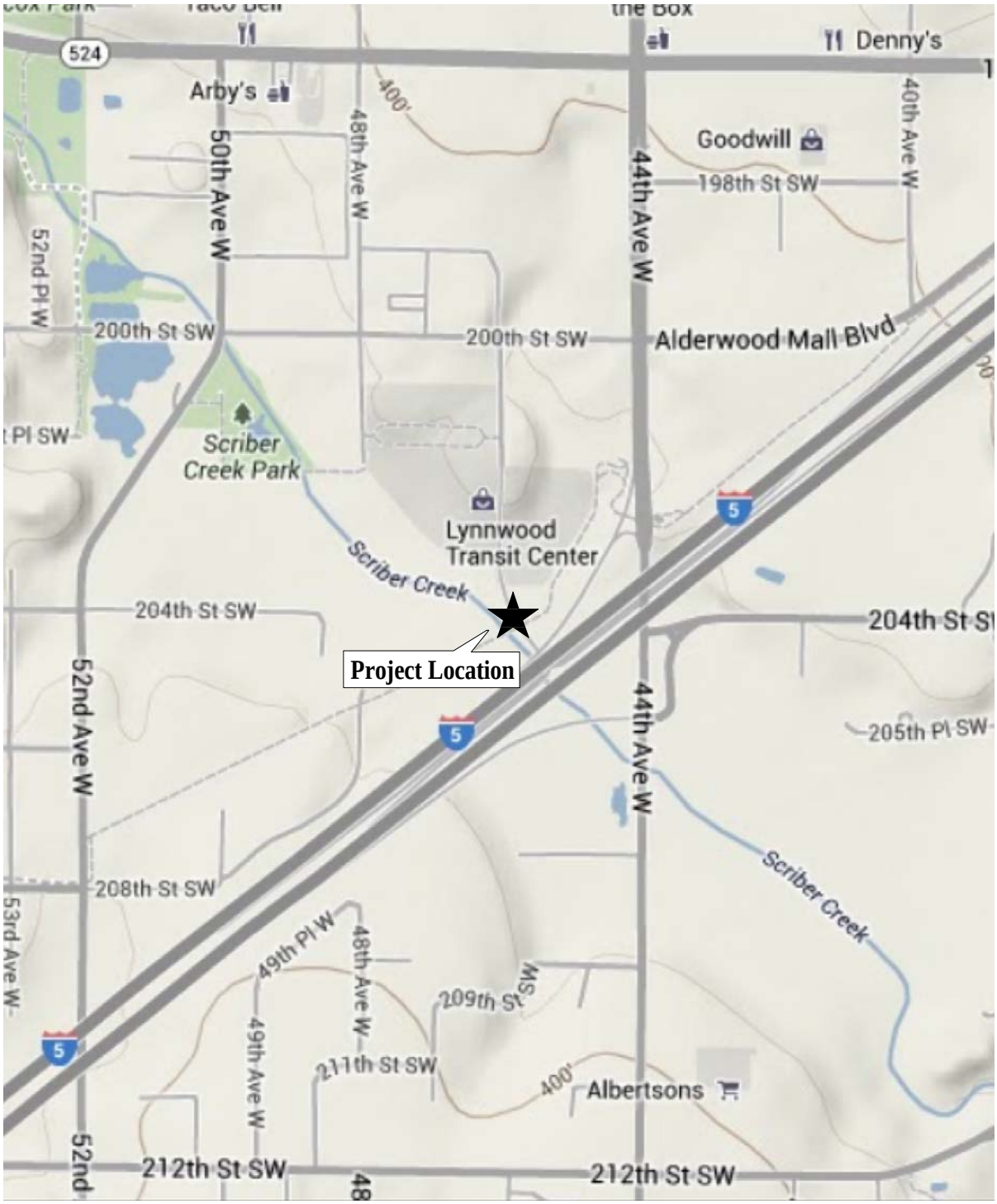
**PanGEO, Inc.**

(DRAFT)

Yi-Hsun (William) Chao, P.E.
Staff Geotechnical Engineer

(DRAFT)

Siew L. Tan, P.E.
Principal Geotechnical Engineer

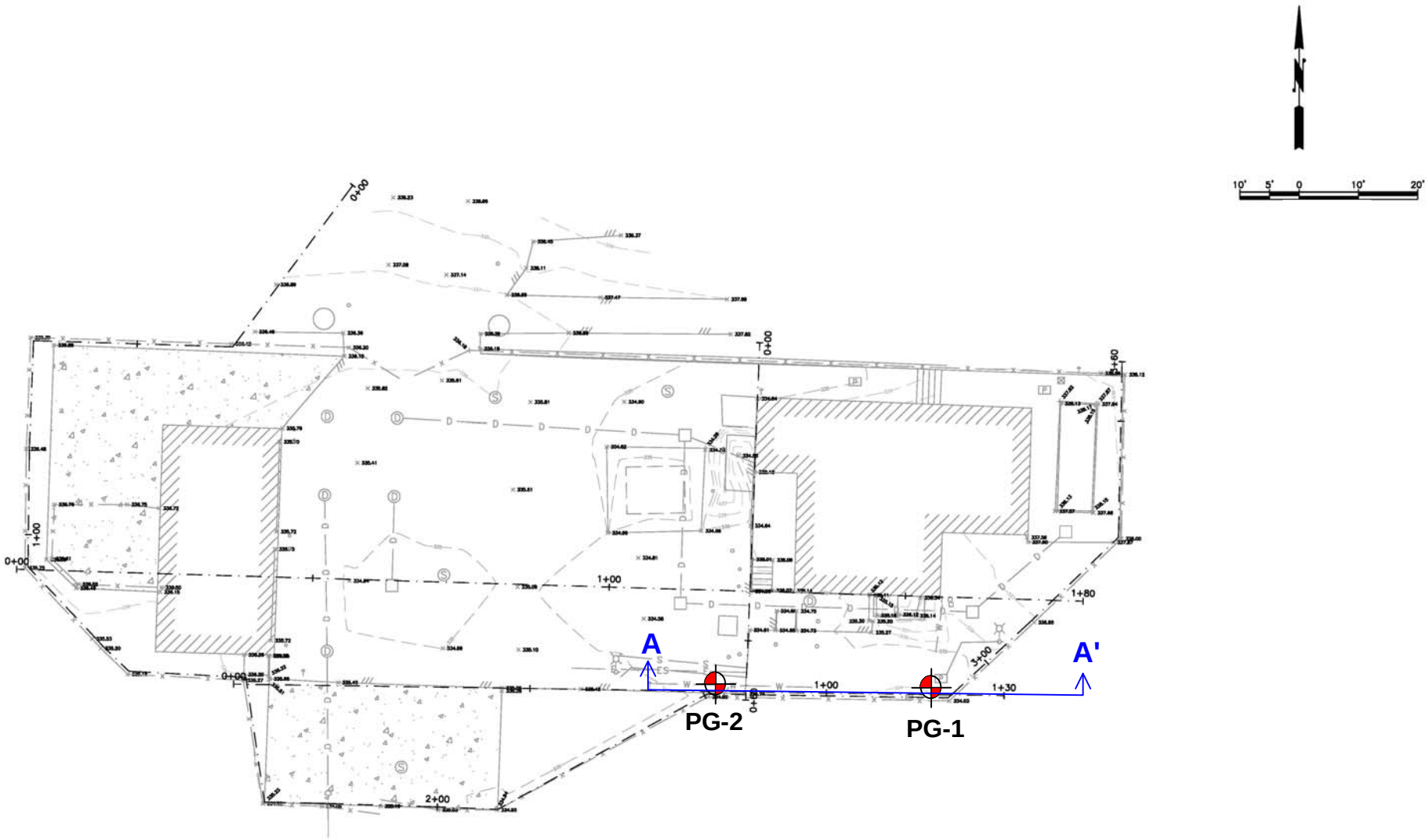



Scale
1 inch = 500 feet
(Approximate)

Note:
Base map obtained and modified from Google Maps (Google Inc.)

| | | | |
|---|---|---|---|
| PanGEO INCORPORATED | **Lift Station #10 Flood Wall**<br>**Lynnwood, Washington** | **VICINITY MAP** | |
| | | Project No.<br>**13-186** | Figure No.<br>**1** |

Site PlanP.grf w/ file.dat 9/19/13(16:46) TEA2




**Legend:**

Approx. Borehole Location

Approx. Location of Cross Section A-A'

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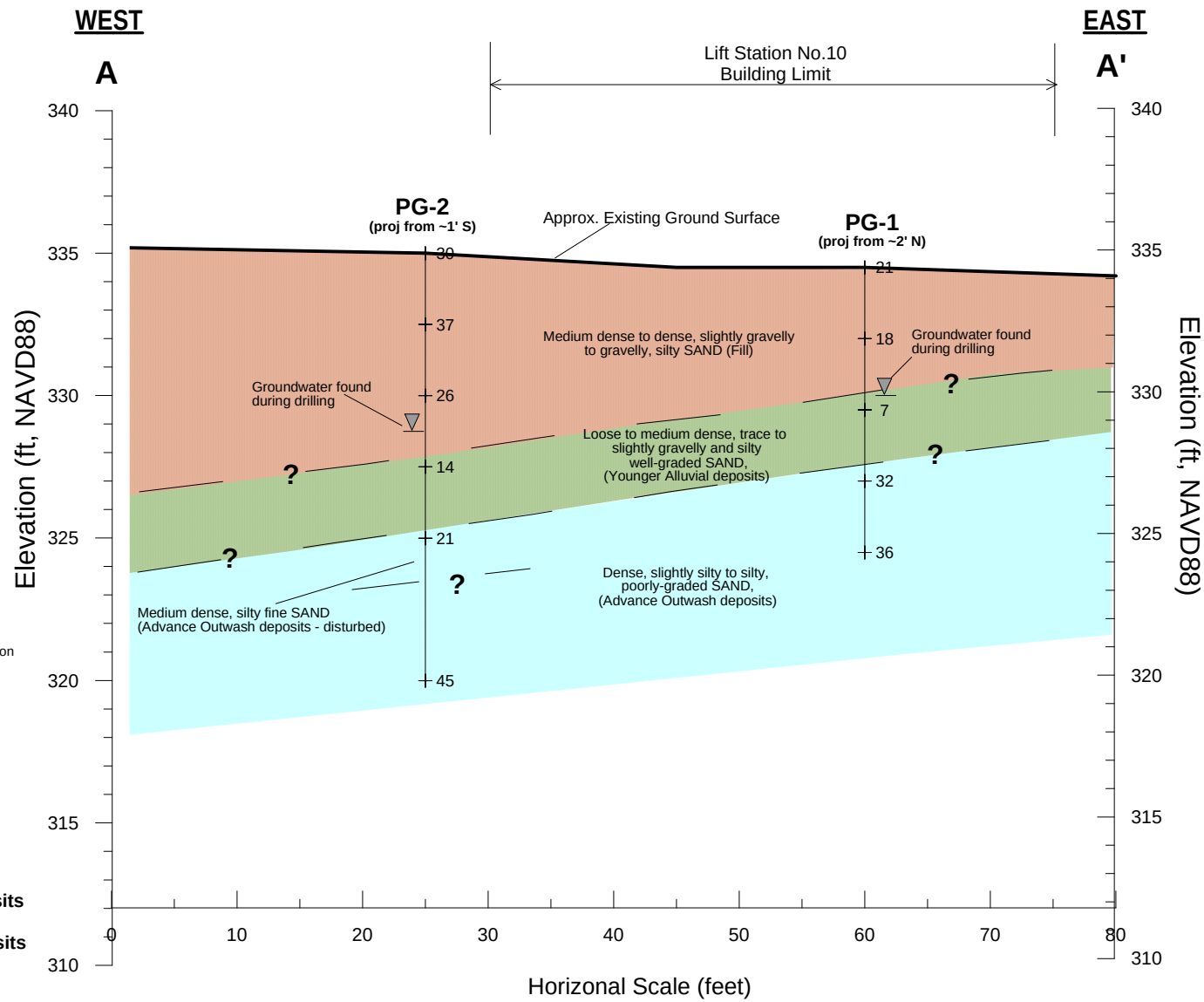
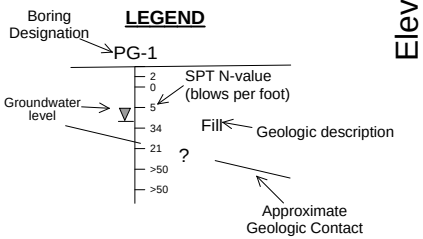
**Lift Station No.10 Flood Wall**
**Lynnwood, Washington**

**SITE AND EXPLORATION PLAN**

| Project No. | Figure No. |
|---|---|
| 13-186 | 2 |




**GEOLOGIC DESCRIPTION**

- **Fill**
- **Younger Alluvium deposits**
- **Advance Outwash deposits**

Note:
1. See Figure 2 for location of Cross Section A-A'

PanGEO INCORPORATED

**Lift Station No.10 Flood Wall**
**Lynnwood, Washington**

**GENERALIZED SUBSURFACE PROFILE A-A'**

| Project No. | Figure No. |
|---|---|
| 13-186 | 3 |

# APPENDIX A

# SUMMARY TEST BORING LOGS

## RELATIVE DENSITY / CONSISTENCY

| SAND / GRAVEL | | | SILT / CLAY | | |
|---|---|---|---|---|---|
| Density | SPT N-values | Approx. Relative Density (%) | Consistency | SPT N-values | Approx. Undrained Shear Strength (psf) |
| Very Loose | <4 | <15 | Very Soft | <2 | <250 |
| Loose | 4 to 10 | 15 - 35 | Soft | 2 to 4 | 250 - 500 |
| Med. Dense | 10 to 30 | 35 - 65 | Med. Stiff | 4 to 8 | 500 - 1000 |
| Dense | 30 to 50 | 65 - 85 | Stiff | 8 to 15 | 1000 - 2000 |
| Very Dense | >50 | 85 - 100 | Very Stiff | 15 to 30 | 2000 - 4000 |
| | | | Hard | >30 | >4000 |

## UNIFIED SOIL CLASSIFICATION SYSTEM

| MAJOR DIVISIONS | | GROUP DESCRIPTIONS | |
|---|---|---|---|
| Gravel<br>50% or more of the coarse fraction retained on the #4 sieve. Use dual symbols (eg. GP-GM) for 5% to 12% fines. | GRAVEL (<5% fines) | GW | Well-graded GRAVEL |
| | | GP | Poorly-graded GRAVEL |
| | GRAVEL (>12% fines) | GM | Silty GRAVEL |
| | | GC | Clayey GRAVEL |
| Sand<br>50% or more of the coarse fraction passing the #4 sieve. Use dual symbols (eg. SP-SM) for 5% to 12% fines. | SAND (<5% fines) | SW | Well-graded SAND |
| | | SP | Poorly-graded SAND |
| | SAND (>12% fines) | SM | Silty SAND |
| | | SC | Clayey SAND |
| Silt and Clay<br>50%or more passing #200 sieve | Liquid Limit < 50 | ML | SILT |
| | | CL | Lean CLAY |
| | | OL | Organic SILT or CLAY |
| | Liquid Limit > 50 | MH | Elastic SILT |
| | | CH | Fat CLAY |
| | | OH | Organic SILT or CLAY |
| Highly Organic Soils | | PT | PEAT |

**Notes:** 1. Soil exploration logs contain material descriptions based on visual observation and field tests using a system modified from the Uniform Soil Classification System (USCS). Where necessary laboratory tests have been conducted (as noted in the "Other Tests" column), unit descriptions may include a classification. Please refer to the discussions in the report text for a more complete description of the subsurface conditions.

2. The graphic symbols given above are not inclusive of all symbols that may appear on the borehole logs. Other symbols may be used where field observations indicated mixed soil constituents or dual constituent materials.

## DESCRIPTIONS OF SOIL STRUCTURES

| | | | |
|---|---|---|---|
| Layered: | Units of material distinguished by color and/or composition from material units above and below | Fissured: | Breaks along defined planes |
| Laminated: | Layers of soil typically 0.05 to 1mm thick, max. 1 cm | Slickensided: | Fracture planes that are polished or glossy |
| Lens: | Layer of soil that pinches out laterally | Blocky: | Angular soil lumps that resist breakdown |
| Interlayered: | Alternating layers of differing soil material | Disrupted: | Soil that is broken and mixed |
| Pocket: | Erratic, discontinuous deposit of limited extent | Scattered: | Less than one per foot |
| Homogeneous: | Soil with uniform color and composition throughout | Numerous: | More than one per foot |
| | | BCN: | Angle between bedding plane and a plane normal to core axis |

## COMPONENT DEFINITIONS

| COMPONENT | SIZE / SIEVE RANGE | COMPONENT | SIZE / SIEVE RANGE |
|---|---|---|---|
| Boulder: | > 12 inches | Sand | |
| Cobbles: | 3 to 12 inches | Coarse Sand: | #4 to #10 sieve (4.5 to 2.0 mm) |
| Gravel | | Medium Sand: | #10 to #40 sieve (2.0 to 0.42 mm) |
| Coarse Gravel: | 3 to 3/4 inches | Fine Sand: | #40 to #200 sieve (0.42 to 0.074 mm) |
| Fine Gravel: | 3/4 inches to #4 sieve | Silt | 0.074 to 0.002 mm |
| | | Clay | <0.002 mm |

## TEST SYMBOLS

for In Situ and Laboratory Tests listed in "Other Tests" column.

| | |
|---|---|
| CBR | California Bearing Ratio |
| Comp | Compaction Tests |
| Con | Consolidation |
| DD | Dry Density |
| DS | Direct Shear |
| %F | Fines Content |
| GS | Grain Size |
| Perm | Permeability |
| PP | Pocket Penetrometer |
| R | R-value |
| SG | Specific Gravity |
| TV | Torvane |
| TXC | Triaxial Compression |
| UCC | Unconfined Compression |

## SYMBOLS

Sample/In Situ test types and intervals

- 2-inch OD Split Spoon, SPT (140-lb. hammer, 30" drop)
- 3.25-inch OD Spilt Spoon (300-lb hammer, 30" drop)
- Non-standard penetration test (see boring log for details)
- Thin wall (Shelby) tube
- Grab
- Rock core
- Vane Shear

## MONITORING WELL

- Groundwater Level at time of drilling (ATD)
- Static Groundwater Level
- Cement / Concrete Seal
- Bentonite grout / seal
- Silica sand backfill
- Slotted tip
- Slough
- Bottom of Boring

## MOISTURE CONTENT

| | |
|---|---|
| Dry | Dusty, dry to the touch |
| Moist | Damp but no visible water |
| Wet | Visible free water |



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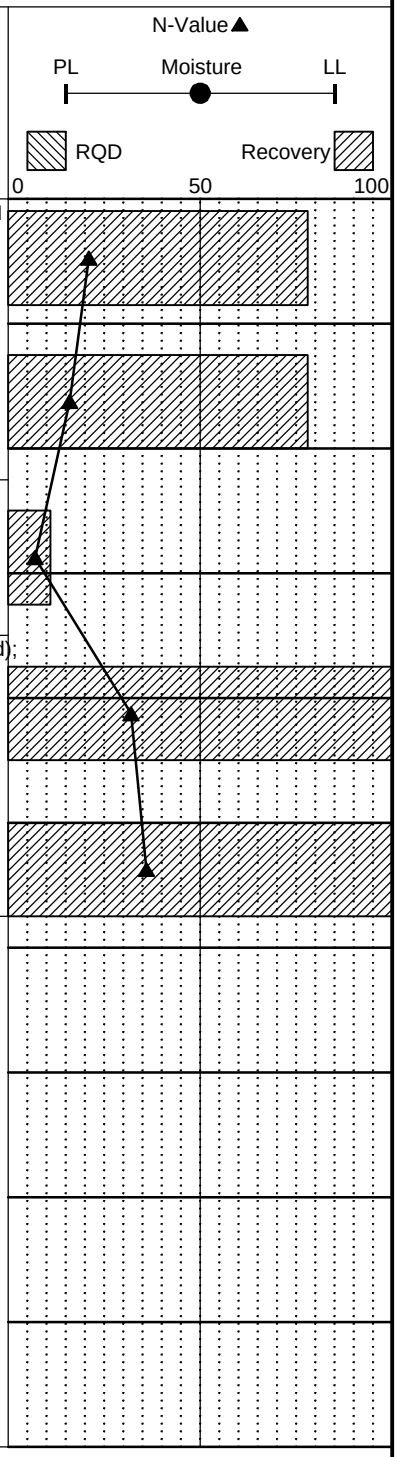
Phone: 206.262.0370

**Terms and Symbols for Boring and Test Pit Logs**

**Figure A-1**

| | | | |
|---|---|---|---|
| Project: | Lynnwood Lift Station 10 | Surface Elevation: | Approx. 334 feet NAVD |
| Job Number: | 13-186 | Top of Casing Elev.: | N/A |
| Location: | Lynnwood, Washington | Drilling Method: | Hollow Stem Auger |
| Coordinates: | Northing: , Easting: | Sampling Method: | SPT |

| Depth, (ft) | Sample No. | Sample Type | Blows / 6 in. | Other Tests | Symbol | MATERIAL DESCRIPTION |
|---|---|---|---|---|---|---|
| 0 | 1 | | 3, 7, 14 | | | Medium dense, brown, slightly gravelly to gravelly, silty SAND, moist; SM (Fill). |
| 2 | 2 | | 16, 10, 6 | | | Grades gravelly at about 3.5 feet. |
| 4 | | | | | | Groundwater at about 4.5 feet. |
| 6 | 3 | | 2, 3, 4 | | | Loose, brown to gray, slightly gravelly and silty, well-graded SAND, wet (saturated); SP-SM (Younger Alluvium). |
| 8 | 4 | | 14, 18, 14 | | | Dense, brown to gray, slightly silty to silty, gravelly, SAND, wet (saturated); SP-SM/SM (Advanced Outwash). |
| 10 | 5 | | 8, 13, 23 | | | |
| 12 | | | | | | Bottom of boring at 11.5 feet below ground surface. Groundwater encountered at a depth of about 4.5 feet below grade during drilling. |
| 14 | | | | | | |
| 16 | | | | | | |
| 18 | | | | | | |
| 20 | | | | | | |




| | |
|---|---|
| Completion Depth: | 11.5ft |
| Date Borehole Started: | 9/3/13 |
| Date Borehole Completed: | 9/3/13 |
| Logged By: | W. Chao |
| Drilling Company: | CN Drilling |

Remarks: Standard Penetration Test (SPT) sampler driven with a 140 lb. safety hammer. Hammer operated with a rope and cathead mechanism.

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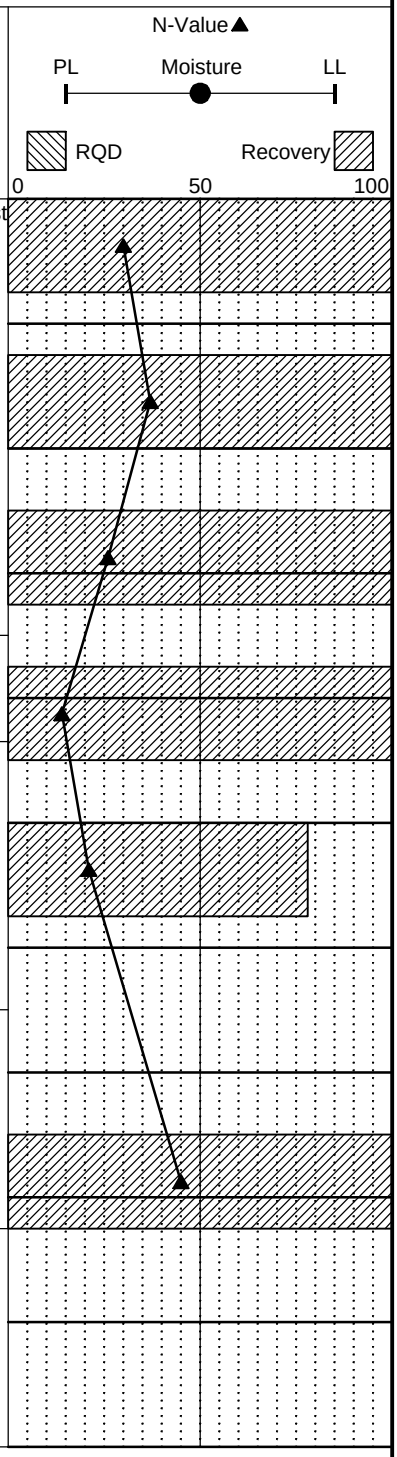
# LOG OF TEST BORING PG-1

**Figure A-2**

The stratification lines represent approximate boundaries. The transition may be gradual.

| | | | |
|---|---|---|---|
| Project: | Lynnwood Lift Station 10 | Surface Elevation: | Approx. 335 feet NAVD |
| Job Number: | 13-186 | Top of Casing Elev.: | N/A |
| Location: | Lynnwood, Washington | Drilling Method: | Hollow Stem Auger |
| Coordinates: | Northing: , Easting: | Sampling Method: | SPT |

| Depth, (ft) | Sample No. | Sample Type | Blows / 6 in. | Other Tests | Symbol | MATERIAL DESCRIPTION |
|---|---|---|---|---|---|---|
| 0 | 1 | X | 4<br>10<br>20 | | | Medium dense to dense, brown to dark brown, silty, gravelly SAND, moist (wet below about 6.3 feet); SM (Fill).<br>Scattered wood debris at about 12 inches. |
| 2 | 2 | X | 15<br>19<br>18 | | | |
| 4 | 3 | X | 9<br>13<br>13 | | | Fabric debris at about 5.5 feet.<br>Groundwater at about 6.3 feet. |
| 6 | 4 | X | 7<br>7<br>7 | | | Medium dense, brown to gray, well-graded SAND, wet; SP (Younger Alluvium). |
| 8 | 5 | X | 7<br>8<br>13 | | | Medium dense, brown to gray, silty fine SAND, poorly-graded, wet; SM (Advanced Outwash - Disturbed). |
| 10 | | | | | | |
| 12 | | | | | | Dense, brwon to gray, silty SAND, poorly-graded, wet; SM (Advanced Outwash). |
| 14 | 6 | X | 17<br>21<br>24 | | | About 6 inches of heave encountered at about 15 feet during SPT (blow count may be overstated). |
| 16 | | | | | | Bottom of boring at 16.5 feet below ground surface. Groundwater encountered at a depth of about 6.3 feet below grade during drilling. |
| 18 | | | | | | |
| 20 | | | | | | |




| | |
|---|---|
| Completion Depth: | 16.5ft |
| Date Borehole Started: | 9/3/13 |
| Date Borehole Completed: | 9/3/13 |
| Logged By: | W. Chao |
| Drilling Company: | CN Drilling |

Remarks: Standard Penetration Test (SPT) sampler driven with a 140 lb. safety hammer. Hammer operated with a rope and cathead mechanism.

PanGEO INCORPORATED

# LOG OF TEST BORING PG-2

**Figure A-3**

The stratification lines represent approximate boundaries. The transition may be gradual.

# APPENDIX B

# COST ESTIMATES

# PRESRAY CORP., WATER TIGHT DOORS

**PRESRAY**
Critical Containment Solutions

Presray Corporation
32 Nelson Hill Road
P.O. Box 200

Phone: (845) 373-9300
Fax: (845) 855-8034
Web: www.presray.com

*Engineered Watertight Doors, Barriers & Hatches*

**Attention:**
**Tom Kearns**

Gray & Osborne, Inc
Phone: (360)454-5490
Fax: (360)454-5491

**Address:**
3710 168th Street NE
Bldg B, Suite 210
Arlington, WA 98223
U.S.A.

**Proposal #:** AAAQ3934-R2
**Date:** Nov 21, 2013

**Job Name:** Lynnwood WA PS

| Lead Time | |
|---|---|
| **Drawing Submittal:** | 1-3 Weeks |
| **Product Shipment:** | 7-9 Weeks Upon Drawing Approval |

**Taxes:** 9.5%
**Terms:** 1/3 - Due on Order
**FOB:** Wassaic
**Carrier:** Motor Freight

| Item | Qty | Description | Unit Price | Ext. Price |
|---|---|---|---|---|
| 1 | 1 | Opening: 1<br>Presray Model FB33 Expandable Flood Barrier, designed to protect an opening approx 36" wide to a protection height of 24". Includes Z-brackets and mounting hardware for a face-mount seating load installation. Requires 2" sapacer to miss hinge and door hardware | $1,685.00 | $1,685.00 |
| 2 | 1 | Opening: 2<br>Presray Model FB33 Expandable Flood Barrier, designed to protect an opening approx 42" wide to a protection height of 24". Includes Z-brackets and mounting hardware for a face-mount seating load installation. Requires 2 inch spacers to misss hinges and door hardware. | $1,775.00 | $1,775.00 |
| 3 | 1 | Opening: 3<br>Presray FastLogs™ Flood Barrier, designed to protect an opening approx. 60" wide to a protection height of 24". Seating direction. Comprised of 6" stackable aluminum extrusions, face-mount frame and all mounting-hardware for a bolt-in-place installation. | $2,266.00 | $2,266.00 |
| 4 | 1 | Opening: 4<br>Presray Model FB33 Expandable Flood Barrier, designed to protect an opening approx 36" wide to a protection height of 24". Includes Z-brackets and mounting hardware for a face-mount seating load installation. Requires 2 inch spacers to miss hinges and door hardware. | $1,685.00 | $1,685.00 |
| 5 | 1 | Opening: 1 Engine Generator<br>Presray Model CG22 Bolt-In-Place removable aluminum flood panel with compression gasket for 3 sided protection. Louver width approximately 102" to a | $13,491.00 | $13,491.00 |

| Item | Qty | Description | Unit Price | Ext. Price |
|---|---|---|---|---|
| | | stillwater protection height of approximately 24" above bottom of louver. Includes sub frame and all hardware needed for a seating load installation. Requires 12 inch frame spacers. | | |
| 6 | 1 | Installation of Flood Barriers and frames at a Prevailing Wage. Any modifications to the openings including, but not limited to: moving of bollards, electric wiring, conduit, tile, switches, cutting of drywall/stucco/concrete walls or any obstructions is to be done by others. If at the time of installation any modifications need to be made to the opening, or moving of obstructions stops installation, additional time and materials may apply. Patching and painting chipped broken stucco, drywall, and other interior or exterior finishes and floors is to be done by others. All frames and sills will be surface mounted to existing wall/slab. | $16,360.00 | $16,360.00 |
| 7 | 1 | Shipping & Handling | $2,200.00 | $2,200.00 |
| 8 | 1 | Sales Tax at: 9.5% (Freight Included) | $2,194.69 | $2,194.69 |
| | | | Total: | $41,656.69 |

All of the openings are seating loads unless unseating is noted in the description.

Installation of barriers is an available option not included in this proposal.

This proposal does not include Bonding, Permits, Field Testing, Shop Testing, or PE/Calculations.

Presray Corporation has not received any specifications at the time of this proposal. If at any time a specification is made available, and differs from the materials or options quoted, additional cost may apply.

Warranty - Standard factory warranty of: 1 year on materials unless otherwise stated. Also, a 1 year warranty shall apply on labor and installation on labor and installation if Presray or a certified Presray install team completes the work. Any other installation done by another party is NOT covered under the 1 year warranty for: Labor and Installation. Extended Warranty is available.

THIS PROPOSAL IS VALID FOR 60 DAYS from the date listed on this proposal unless otherwise stated. Any decision to approve this proposal after the 60 day expiration will result in all product pricing on this proposal to be null and void. All products must be re-quoted subsequent to the 60 day threshold.

Kevin Harris
Phone: 845-373-6718
Fax: 845-895-8054
Email: kharris@presray.com

# GENERAL CONDITIONS OF PRESRAY OFFER

## AGREEMENT

This quotation, the purchaser's order and the acknowledgement by Presray of the order, shall constitute the entire agreement between Presray and the purchaser. Modifications, changes, cancellations or suspensions shall not be binding upon Presray unless approved by Presray upon terms, which will compensate and reimburse Presray for all loss. Printed or stamped provisions contained in purchaser's orders that are inconsistent with the written, printed or stamped provisions of this quotation shall not be binding on Presray. Quoted prices are exclusive of any city, county, state, provincial or federal taxes.

## DELIVERIES

Delivery schedules quoted are Presray's best estimate, based on conditions prevailing at the time of quotation. However, deliveries cannot be guaranteed, since conditions may change due to accidents, fires, floods, regulatory delays, delays of carriers, ability to obtain material and qualified labor, and other reasons beyond the reasonable control of Presray. All shipment shall be sent F.O.B. Wassaic.

## CREDIT

Presray's standard terms of payment for domestic orders from pre-approved accounts are 1/3 - Deposit, 1/3 - prior to Shipment, and 1/3 - Net 30 days from the date of the Shipment. For international accounts, 1/3 of total with receipt of order, 1/3 of total prior to shipment, and 1/3 of total net 30 days from the date of shipment. Other terms can be negotiated. Unless expressly indicated, there is no provision in the quoted price for the retention of any portion of payment beyond the thirty day limit. *Progress Payments based on Project Milestone and Credit Application.

## QUANTITIES/PRODUCT

The quoted prices are based on the quantities offered. Since engineering and setup are frequently a significant factor in price, should there be changes quantities or product, there will be an increase in price. All requested changes must be accompanied by a formal change order. All quoted prices include 1 submitted Engineered drawing and 1 revised and resubmitted Engineered drawing via electronically submitted. If paper drawings are required there will be a $25.00 charge for each print.

## CANCELLATION

In the event of a cancellation, the purchaser is obliged to reimburse Presray for lost profits as well as for expenses incurred up until the time of cancellation, including material, labor, overhead, selling, general and administrative expenses, based on standard Presray rates. Included in these expenses are all costs related to engineering/design/drafting effort whether or not any material has been supplied or is in process.

## DEFECTIVE MATERIAL

Presray agrees to replace or issue credit for, at it's option, all products which are defective because of material or workmanship, provided that the defect is not a result of the purchaser's design or specifications, and further provided that the claim therefore is made by the purchaser in writing within 60 days after receiving said product. Presray will not be held responsible, nor will any claim be allowed for consequential damages or for the cost of labor or charges of any kind incurred outside of the plant of Presray, this to include costs of transportation, removal, installation, or other losses resulting from such defect. No other warranty is expressed or implied.

## LIABILITY

a) In the event any of the products produced under the purchaser's order infringe or are claimed to infringe any patent, copyright of trademark, or
b) In the event the use of any such product by purchaser or any third party results in a claim against Presray for negligence, strict product liability, or breach of any warranty not expressed in writing herein, the purchaser hereby agrees to indemnify and save harmless Presray from any and all claims, suits, demands or judgments and any and all amounts incurred from settlements entered into with or without the purchaser's consent.

## DISCLAIMER

Presray products have a well-deserved reputation for giving long and dependable service, even under severe use. However, because Presray products are handled, installed, and used under varying conditions, and maintenance of such products is controlled exclusively by the user, Presray disclaims all responsibility for damage or injury resulting from use of these products, and the purchaser assumes all responsibility for, and agrees to indemnify Presray from, any and all claims arising directly from these products and/or their use.

# REINFORCED CONCRETE FLOOD WALL

City of Lynnwood
PS # 10 Flood protection
19-Nov-13
G & O 13535.0

Concrete Flood Wall
Planning Estimate

| | | CY | Cost | $750 | per CY |
|---|---|---|---|---|---|
| 1 | Footing | 61 | $45,833 | | |
| 2 | Wall | 40 | $30,000 | | |
| 3 | Footing Excavation, Site work | | $ 8,800 | | |
| 4 | Piles | | $33,250 | | |
| 5 | Fencing | | $ 15,000 | | |
| | | subtotal | $132,883 | | |
| | | contingency | $39,865 | | |
| | | sales tax, 8.9% | $15,375 | | |
| | | Total | $188,123 | | |
| | | Round to | $190,000 | | |

City of Lynnwood
PS # 10 Flood protection
19-Nov-13
G & O 13535.0

Concrete Flood Wall
Wall Footing

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1 | footing | depth, | width, ft | thickness, | length, ft | CY | |
| | | | 4 | 1 | 300 | 50 | |
| | cutoff wall | 1 | | 1 | | 11 | |
| | | | | | subtotal | 61 | CY |

City of Lynnwood
PS # 10 Flood protection
19-Nov-13
G & O 13535.0

Concrete Flood Wall
Wall Stem

| W, ft | L,ft | SF* | CY |
|---|---|---|---|
| 0.67 | 300 | 1250 | 40 |

* adds 0.5' of stem for underground additional depth.
estiamted using 1100sf of wall from a preliminary profile

City of Lynnwood
PS # 10 Flood protection
19-Nov-13
G & O 13535.0

Concrete Flood Wall
Foundation Excavation and Restoration

| | | length | depth | width | cy | unit cost | cost |
|---|---|---|---|---|---|---|---|
| 1 | excavation | 300 | 3 | 6 | 200 | $ 15 | $ 3,000 |
| 2 | backfill | 300 | 2 | 4 | 90 | $ 50 | $ 4,500 |
| 3 | Asphalt | 50 | 0.333 | 5 | 4 | $ 325 | $ 1,300 |
| 4 | | | | | | | |
| | | | | subtotal | | | $ 8,800 |

| | | | | | | |
|---|---|---|---|---|---|---|
| City of Lynnwood | | | | | | |
| PS # 10 Flood protection | | | | | | |
| 19-Nov-13 | | | | | | |
| G & O 13535.0 | | | | | | |
| | | | | | | |
| | | Concrete Flood Wall | | | | |
| | | Foundation Piles | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | Pile Requirement | | | 6 inch diameter auger pile | | |
| | | | | | | |
| | spacing | 10 | lf | L | Number | |
| | | | | 300 | 30 | |
| | direction change | | | | 8 | |
| | | | | total piles | 38 | |
| | | | | | | |
| | | | | | | |
| | depth, avei | 35 | | LF | 1330 | |
| | | | | | | |
| | | | unit cost | | | |
| | | | $25 | per LF | $33,250 | |

| | | | | | |
|---|---|---|---|---|---|
| City of Lynnwood | | | | | |
| PS # 10 Flood protection | | | | | |
| 19-Nov-13 | | | | | |
| G & O 13535.0 | | | | | |
| | | | | | |
| | | Concrete Flood Wall | | | |
| | | Fencing Replacement | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | Fencing | R& R | | | |
| | | 9 gage , schedule 40, 2" pipe, 8' tall | | | |
| | | | unit cost | L, ft | Cost |
| | | | | | |
| | | | $ 50 | 300 | $ 15,000 |

# GEOCELLS, INC. RDFW

City of Lynnwood
PS # 10 Flood protection
19-Nov-13
G & O 13535.0

RDFW Estimate

| | | | | | |
|---|---|---|---|---|---|
| | | L,ft | SF* | Unit Cost | Cost |
| 1 | RDFW | ~~300~~ 150 | 563 | $ 42 | $ 23,663 |
| | | L | H #1 | H#2 | SF |
| | straight wall | 75 | 5 | | 375 |
| | Sloped Wall | 75 | 5 | 0 | 188 |
| | | | | subtotal | 562.5 |
| | | CY/sf | | Unit Cost | Cost |
| 2 | Sand | 0.129 | | $25 | $1,814 |
| | | Install, SF/hr | Man Hours | Unit Cost | Cost |
| 3 | Labor | 50 | 11.25 | $ 55 | $619 |
| 4 | Equipment | Hrs | | Unit Cost | Cost |
| | | 4 | | $ 55 | $ 220 |
| 5 | Removal | SF/hr | Man Hours | Unit Cost | Cost |
| | | 250 | 2.25 | $ 55 | $ 124 |
| 6 | Cleaning | SF/hr | Man Hours | Unit Cost | Cost |
| | | 150 | 3.75 | $55 | $ 206 |
| 7 | Replacement | | Percent | 20% | $ 4,733 |
| | | | | Subtotal | $ 32,503 |
| | | | Contingency | 30% | $ 9,751 |
| | | | Sales Tax | 8.9% | $ 3,761 |
| | | | Total | | $ 46,015 |

Geocell Systems Inc.

Pier 54, Terry Francois Blvd.
San Francisco, CA 94107-1220
Phone: 415-541-5300
Fax: 415-541-5369
email: info@geocellsystems.com

# RDFW ESTIMATING SHEET

**RDFW MK4 ESTIMATING SHEET CALCULATES:**
RDFW UNITS REQUIRED
AMOUNT OF CONTAINERS NEEDED TO BE SHIPPED
SAND YARDAGE
ESTIMATED RDFW COST W/O DISCOUNTS

**PLEASE NOTE:**
THERE ARE 90 RDFW BASE UNITS PER RDFW CONTAINER
EACH CONTAINER MEASURES: 44" L X 60" W X 42" H
EACH FULL CONTAINER WEIGHS APPROX. 2,000 POUNDS
EACH CONTAINER PROVIDES A BARRIER 4 FEET HIGH X 50 Lineal Feet

| FIELD NOTES | Layers | Height | Units Required | RDFW Container | CU/YDS SAND | 150 | COST PER LF | COST FOR RDFW | per/sf | CY/sf |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | **8 Inches High** | 43 | 0.48 | 12.9 | 0.09 | $27.93 | $4,204.11 | | |
| FLOOD BARRIER WALLS 3.5 FT. WIDE | | | | | | | | | $ 41.83 | 0.128 |
| | 2 | **16 Inches High** | 86 | 0.96 | 25.8 | 0.17 | $55.87 | $8,408.22 | | |
| FLOOD BARRIER WALLS 3.5 FT. WIDE | | | | | | | | | $ 42.15 | 0.129 |
| | 3 | **24 Inches High** | 129 | 1.43 | 38.7 | 0.26 | $83.80 | $12,612.33 | | |
| FLOOD BARRIER WALLS 3.5 FT. WIDE | | | | | | | | | $ 42.04 | 0.129 |
| | 4 | **32 Inches High** | 172 | 1.91 | 51.6 | 0.34 | $111.74 | $16,816.44 | | |
| FLOOD BARRIER WALLS 3.5 FT. WIDE | | | | | | | | | $ 44.84 | 0.129 |
| | 5 | **40 Inches High** | 215 | 2.39 | 64.5 | 0.43 | $139.67 | $21,020.55 | | |
| FLOOD BARRIER WALLS 3.5 FT. WIDE | | | | | | | | | $ 42.08 | |
| | 6 | **48 Inches High** | 258 | 2.87 | 77.4 | 0.52 | $167.61 | $25,224.66 | | |
| FLOOD BARRIER WALLS 3.5 FT. WIDE | | | | | | | | | $ 42.04 | |
| | 7 | **56 inches High** | 301 | 3.34 | 90.3 | 0.60 | $195.54 | $29,428.77 | | |
| FLOOD BARRIER WALLS 3.5 FT. WIDE | | | | | | | | | $ 42.01 | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| City of Lynnwood | | | | | | | | |
| PS # 10 Flood protection | | | | | | | | |
| 19-Nov-13 | | | | | | | | |
| G & O 13535.0 | | | | | | | | |
| | sand bag doors | | | L | H | A | | |
| | | SE back door | | 3 | 2 | 6 | | |
| | | SW personnel | | 3 | 2 | 6 | | |
| | | SW equip | | 7 | 2 | 14 | | |
| | | EG louver | | 9 | 2 | 18 | | |
| | electrical boxes | | | | | | | |
| | | | | 6 | 5 | 30 | | |
| | | | | | toal area | 74 | | |
| | | | | | cost / sf | $ 122.62 | | |
| | | | | | cost | $ 9,074 | bags | 2000 |
| | Sand bag to SE entrance door | | | | | | | |
| | | | L | Sta 0 | Sta 36 | A | | |
| | | | 36 | 0 | 4 | 72 | | |
| | | | | | cost | $ 8,829 | | |
| | Sand bag for vehicle access | | | | | | | |
| | | | L | Sta 0 | Sta 60 | A, sf | | |
| | | | 95 | 4 | 0 | 380 | | |
| | | | | | cost | $ 46,597 | | |

City of Lynnwood
PS # 10 Flood protection
19-Nov-13
G & O 13535.0

Sandbag cost estimate

Source Geoscell Systems Inc. data

| | L | H | sf |
|---|---|---|---|
| wall size | 1000 | 4 | 4000 |

| | | | | |
|---|---|---|---|---|
| number of bags | | 103320 | | bags /sf |
| | bag/sf | 26 | | 25.83 |

time to place

| | | | |
|---|---|---|---|
| workers | 350 | men | |
| time | 19.5 | hrs | |
| | 6825 | man hours | |
| hrs per sf | 1.7 | | |

| | | | |
|---|---|---|---|
| sand bag doors | crew | 3 | |
| | sf | 74 | |
| | time | 42 | |
| assume install | | 50% | 21 hr |
| tear down | | 50% | |

conclusion
1. need to stockpile sand bags
2. sand bag wall will have to be several feet thick
3. Reaction time is too slow compared to storm surge

City of Lynnwood
PS # 10 Flood protection
19-Nov-13
G & O 13535.0

Sandbag cost estimate

Source Geoscell Systems Inc. data

| | L | H | sf |
|---|---|---|---|
| wall size | 1000 | 4 | 4000 |

Source Geoscell Systems Inc. da $ 490,498

$/sf $ 122.62

# US FLOOD CONTROL, INFLATABLE BERM

City of Lynnwood
PS # 10 Flood protection
19-Nov-13
G & O 13535.0

Tiger Berm System
Planning Estimate

| | | Quantity | Unit Cost | Cost |
|---|---|---|---|---|
| 1 | 19" Tubes | 1 | $1,250 | $1,250 |
| 2 | 30" Tubes | 10 | $2,850 | $28,500 |
| 3 | Stacking Straps | 9 | $ 25 | $225 |
| 4 | Fill adapters | 10 | $145 | $1,450 |
| 5 | | | | |
| | | | subtotal | $31,425 |
| | | | contingency, 30% | $9,428 |
| | | | sales tax, 8.9% | $3,636 |
| | | | Total | $44,488 |
| | | | Round to | $50,000 |

City of Lynnwood
PS # 10 Flood protection
19-Nov-13
G & O 13535.0

| | | | |
|---|---|---|---|
| | Tube Diameter, in. | 19 | |
| | Tube Length, ft | 50 | |
| 1 | Location | Length | tubes reqd |
| | East | 40 | 1 |

| | | | |
|---|---|---|---|
| City of Lynnwood | | | |
| PS # 10 Flood protection | | | |
| 19-Nov-13 | | | |
| G & O 13535.0 | | | |
| | | | |
| | | 30In. Tubing | |
| | | | |
| | | | |
| | Tube Diameter, in. | 36 | |
| | Tube Length, ft | 50 | |
| | | | |
| | | | |
| | Location | Length | tubes reqd |
| | | | |
| | west entrance | 50 | 1 |
| | | | |
| | West, South & South East | | |
| | | | |
| | 2-1 stacks required | 150 | 9 |
| | | | |
| | | subtotal | 10 |

| | | | |
|---|---|---|---|
| City of Lynnwood | | | |
| PS # 10 Flood protection | | | |
| 19-Nov-13 | | | |
| G & O 13535.0 | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| 1 | Straping | | Stacks |
| | | | 9 |

| | | | | |
|---|---|---|---|---|
| City of Lynnwood | | | | |
| PS # 10 Flood protection | | | | |
| 19-Nov-13 | | | | |
| G & O 13535.0 | | | | |
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| | | | | |
| | | | | |
| | | | | |
| 1 | Fill adapters | | 30" Tubes | |
| | | | 10 | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| City of Lynnwood | | | | | | | |
| PS # 10 Flood protection | | | | | | | |
| 19-Nov-13 | | | | | | | |
| G & O 13535.0 | | | | | | | |
| | | | Fill Time | | | | |
| | | | | | | | |
| | | Tube Size | Quantity | Tim, min. | hoses | Minutes | |
| | 1 | 19" | 1 | 6 | 1 | 6 | |
| | 2 | 30" | 10 | 30 | 2 | 150 | |
| | | | | | | | |
| | | | | | subtotal | 156 | min |
| | | | | | | 2.6 | hrs |
| | | | | | contingenc | 2.6 | |
| | | | | | | | |
| | | | | | total | 5 | hrs |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| City of Lynnwood | | | | | | | |
| PS # 10 Flood protection | | | | | | | |
| 19-Nov-13 | | | | | | | |
| G & O 13535.0 | | | | | | | |
| | | | Fill Time | | | | |
| | | | | | | | |
| | | Tube Size | Quantity | Tim, min. | hoses | Minutes | |
| | 1 | 19" | 1 | 6 | 1 | 6 | |
| | 2 | 30" | 3 | 30 | 2 | 45 | |
| | | | | | | | |
| | | | | | subtotal | 51 | min |
| | | | | | | 0.85 | hrs |
| | | | | | contingenc | 0.85 | |
| | | | | | | | |
| | | | | | total | 2 | hrs |

| | | | | |
|---|---|---|---|---|
| City of Lynnwood | | | | |
| PS # 10 Flood protection | | | | |
| 19-Nov-13 | | | | |
| G & O 13535.0 | | | | |
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| | | | | |
| | | | | |
| | | | | |
| | | | | |
| 1 | Fill adapters | | 30" Tubes | |
| | | | 3 | |

| | | | |
|---|---|---|---|
| City of Lynnwood | | | |
| PS # 10 Flood protection | | | |
| 19-Nov-13 | | | |
| G & O 13535.0 | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| 1 | Straping | | Stacks |
| | | | 3 |

| | | | |
|---|---|---|---|
| City of Lynnwood | | | |
| PS # 10 Flood protection | | | |
| 19-Nov-13 | | | |
| G & O 13535.0 | | | |
| | | | |
| | | 30In. Tubing | |
| | | | |
| | | | |
| | Tube Diameter, in. | 36 | |
| | Tube Length, ft | 50 | |
| | | | |
| | | | |
| | Location | Length | tubes reqd |
| | | | |
| | 2-1 stacks required | 50 | 3 |
| | South & East | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | subtotal | 3 |