# ANALYSIS OF ALTERNATIVES

Kersh-Wishkah Flood Levee Project

Grays Harbor County, Washington

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# EXECUTIVE SUMMARY

AMEC Environment & Infrastructure, Inc. (AMEC), developed and evaluated alternative solutions to reduce flooding of Wishkah Road, and homes west of it. During the course of the project, AMEC's design team determined that the site is underlain by soft and continuously settling soils. AMEC also worked with stakeholders to evaluate the extreme flood levels likely to be expected at the site. Stakeholders chose a target flood protection level of 16 feet relative to the North American Vertical Datum of 1988 (NAVD88). The combination of poor foundation soils and the level of flood protection desired by stakeholders make raising the road or creating a new flood levee infeasible options.

AMEC identified one viable option to provide the desired level of flood protection: a sheet pile wall installed along the east edge of Wishkah Road, with regulated tide gates to provide a drainage pathway through the sheet pile wall. The regulated tide gates would manage water flow to prevent water from flowing back through the drainageways during extreme flood events, but would allow free movement of water and aquatic life at all other times. The low points along Wishkah Road can be raised as an early action item prior to installing the sheet pile wall in order to reduce the frequency and duration of flooding on those low points along the road. Parcels located east of Wishkah Road in the project area would need to be purchased, because installation of sheet piling between the properties and the road would block access to them. Purchase of the properties would also allow the structures on these parcels to be removed for the safety of the residents, to reduce floodplain encroachment, and to provide habitat improvements to mitigate project impacts.

We recommend that the project move forward into the design, permitting, and property acquisition phases, subject to acquiring the funding necessary to complete the project.

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## 1.0 GOALS AND DESIGN CRITERIA

AMEC Environment & Infrastructure, Inc. (AMEC), prepared this report to summarize the analysis of alternative solutions considered to reduce flooding along Wishkah Road from milepost 2.2 to 2.7. The purpose of our analysis was to develop alternatives to reduce the flooding and recommend an alternative approach that best meets the project objectives.

During a project kickoff meeting on February 21, 2013, the project stakeholders met to review the basic parameters of this project, determine the project objectives, discuss the flooding concerns, discuss frequency of flooding, and decide on the appropriate range of flood protection levels to consider. A memorandum, dated March 5, 2013, documented the information discussed and the decisions made at the meeting; a copy of the memorandum is included as Appendix A.

### 1.1 Project Objectives

Currently, Wishkah Road is frequently flooded, at times preventing emergency responders from travelling north of Baretich Road. As flooding starts, the water level encroaches onto the northbound travel lane of Wishkah Road around the bend just south of the intersection with Baretich Road (Figure 1). As the water level increases, the water eventually covers both lanes of travel along limited portions of the road. Depending on the predicted height of flooding, Grays Harbor County will typically close the road by the time the water depth in the lowest portions of the road reaches about 1 foot. The primary project objective is to reduce flooding on Wishkah Road to facilitate emergency response to the homes in the project area and beyond. A secondary benefit of the project will likely be to reduce the frequency of flooding experienced in homes and properties located west of the roadway.

### 1.2 Project Limits

The project area for flood protection is limited to an approximately 2,700-foot-long segment of Wishkah Road approximately centered at the intersection with Frosty Road (Figure 1). Modeling and analysis by necessity were extended beyond the project area toward the river's mouth and upstream in order to develop and validate the hydraulic model, but detailed results were focused on the project area only.

## 1.3 Frequency and Ramifications of Flooding

Residents indicated that floods overtop Wishkah Road two to three times each year. During these flood events, water from the Wishkah River can overtop the roadway to a depth that makes it impassible and floods properties on the west side of the road. Shallow flooding that does not overtop the road is very frequent (approximately 20 times last year, according to Frank Kersh, a longtime resident) and appears to be caused primarily by high water levels at the river mouth, driven by tidal influences. There are about 10 homes that flood in the project area, but about 60 whose access is affected by flooding on this portion of the road.

According to residents, the worst flooding on the road has been observed in the last 5 years, with a maximum depth of about 2 to 3 feet on top of the road. Water depths are even greater in adjacent homes and yards, due to their lower elevations relative to the road, with water depths of up to 4 feet in some yards. The home that has historically been most severely impacted was in the process of being raised while this scope of work was being carried out.

Significant flood events were noted by residents on approximately the following dates:

- December 31, 2005
- December 5, 2007
- January 1, 2009 (Frank Kersh noted worst flooding in recent times)
- November 24, 2011

The dates listed above were written by hand on flood photos taken in and around the homes along the west side of Wishkah Road in the project area. Based on nearby tidal and river flood records, it is likely that the photos dated January 1, 2009, were actually taken on January 7, 2009. All of these floods inundated septic systems, garages, outbuildings, and crawl spaces. Photos of the 2009 flood taken by landowners show a variety of flooded buildings, including the inside of one home. See Appendix B for a subset of these photos.

Emergency vehicles can travel through shallow water depths, but emergency responders avoid using the road when the depth of water is more than about 1 foot, which is about the elevation at which Grays Harbor County closes the road. Grays Harbor County indicated that the flooding is deep enough to close the road once every year or two, though the road has not been closed for about the last year and a half. Depending on the predicted high-water elevation, the road may be closed at the project site before the water level reaches 1 foot deep, since locations farther north on Wishkah Road are more susceptible to flooding than the road in the project area.

An analysis of the frequency of flooding expected from tidal sources was performed as a result of questions raised at a Chehalis River Basin Flood Authority (Flood Authority) meeting, but those results were reported separately. The analysis estimates that just from tidal action alone, the road is likely to be overtopped every year or two to a depth of 1 foot or more. The influence of river flooding was not accounted for in that tidal analysis due to the lack of gage data on the Wishkah River. The focus of this project was to determine the level of water expected during more extreme events and to identify viable solutions to reduce the flooding, with a suitable level of protection.

## 2.0 SITE AND PROJECT DESCRIPTION

The project site is a segment of Wishkah Road along the west side of the Wishkah River north of Aberdeen, Washington, as shown on Figure 1. According to Russ Esses, County Engineer for Grays Harbor County, Wishkah Road is classified as a major collector route, and has average daily traffic estimated at 1,500 vehicles per day at the project site. The overall segment of Wishkah Road in the project area is about 0.5 mile long, extending from about 400 feet south of the Baretich Road intersection, to about 850 feet north of the Hoffman Road intersection, and lies between road stationing 40+00 to 66+00. Aerial photos from 1942 and 2011 are included as Figures 2 and 3, respectively. Berglund, Schmidt, & Associates completed a topographic survey of the road and nearby features through the project site under subcontract to AMEC. The results of the survey are included as Appendix C.

After working with project stakeholders to establish project goals and design criteria, data were gathered that allowed the design team to generally characterize subsurface conditions at the project site (see Appendix D). An existing two-dimensional (2-D) model of Grays Harbor was extended upstream to the project site in order to evaluate the likely extreme flood levels at the site (see Appendix E). Using this information, AMEC worked in coordination with Grays Harbor County to develop alternative approaches to provide the desired flood protection of Wishkah Road. Background information that was made available included records from the City of Aberdeen, studies from the Federal Emergency Management Agency (FEMA), records and photographs from Grays Harbor County, and photographs from various private landowners, as compiled by Frank Kersh. The photos provided by Frank Kersh included many photos taken during flooding events. The features that are visible in these photos were surveyed by Berglund, Schmidt, & Associates to determine the approximate flood water levels in the project area for specific flood events.

Six culverts currently drain water from the west side of Wishkah Road to the east side of Wishkah Road. All but one of these culverts have tide gates on the riverward side to prevent back-flow when the river level rises. The exception is the 36-inch-diameter pipe that crosses the intersection of Wishkah and Baretich Roads, which is not equipped with a tide gate. The Hydraulic Project Approval for replacement of that culvert was approved in 1986 and specified in part that the “culvert extensions shall not restrict the free movement of fish at any life stage." The 1986 HPA is included as Appendix F. Local residents indicated that stickleback had been reportedly found in the watercourse along Baretich Road prior to replacement of the culvert, and that potential presence of stickleback was the impetus for providing free fish passage.

There would be no viable way to provide flood protection to homes within the project area if regulatory agencies would not allow all backflow beneath Wishkah Road to be stopped during high-water events. During a meeting hosted by the Flood Authority on May 15, 2013, and attended by representatives from numerous regulatory agencies, the concern about the open culvert was discussed. The project team noted that several types of regulated tide gates exist that can remain open to allow unimpeded flows through the gate in either direction, closing only when the water level on the river side of the gate reaches a desired set point representing a critical point for flood protection. This potential solution was received favorably by the regulatory staff present; furthermore, the presence of stickleback alone, absent the presence of salmonids or other aquatic species of concern, is not likely to result in the denial of the addition of a tide gate, though some mitigation may be required.

## 3.0 DATA COLLECTION

Early on in the project, AMEC collected and reviewed available existing data. A technical memorandum dated April 10, 2013, summarized the available existing data and outlined efforts planned to collect additional data required to complete this evaluation. This memo is included as Appendix G. Table 1 includes the list of data previously collected, plus the additional information collected as part of this project.

## 4.0 GEOTECHNICAL INFORMATION

Grays Harbor County provided scanned copies of design drawings for two former road improvement projects from the 1980s for the segment of Wishkah Road in the project area. Together, these design drawings cover the entire segment of Wishkah Road in the project area. These designs do not appear to necessarily represent as-built conditions; however, as suggested by Russ Esses, Grays Harbor County Engineer, they are likely to very closely represent what was constructed. Generally, the road was raised by a few feet throughout the project reach, to an elevation of approximately 13.5 feet (North American Vertical Datum of 1988 [NAVD88]), and the curve in the northern portion of the project area was realigned to improve safety. Compared to the road elevations recorded during the recent survey, the road has settled between 1.0 and 2.5 feet since the improvement projects in the 1980s. Frank Kersh mentioned that this settlement would explain why flooding seems to be occurring more frequently.

A Geotechnical Memorandum completed by AMEC on April 25, 2013, identified several factors that could be contributing to the observed settlement (Appendix D). About 25 percent of the observed settlement was likely due to primary settlement, in other words, settlement due to the addition of fill. The remainder was likely due to consolidation of the over-saturated soils. The presence of over-saturated soils is expected to result in ongoing settlement of the road.

## 5.0 ELEVATION DATA

LiDAR-derived elevation data were acquired by FEMA and downloaded from the Puget Sound LiDAR Consortium website. These elevation data were supplemented by a topographic survey of the road corridor and features of interest through the project site and a bathymetric survey of the Wishkah River. Both surveys were completed during the course of this project. The bathymetric survey was performed by HydroGraphix and consisted of two longitudinal surveys and numerous cross-sections that together mapped the bed of the Wishkah River.

## 6.0 HYDRAULIC MODELING

Coast & Harbor Engineering (CHE) performed most of the hydraulic and hydrodynamic modeling for the project. The resulting hydraulic/hydrodynamic modeling report is included as Appendix E. The modeling domain was constructed using existing information available to CHE and data from a recent survey of the river channel bottom in order to tie in with the existing bathymetry beyond the mouth of the river.

The hydraulic modeling report summarizes the data used, the process to generate and validate the hydraulic model, and the results of the modeling. Early in the project, the design protection level was established in coordination with the County at 16 feet NAVD88, which would provide about 1 foot of freeboard above the height predicted for a 50-year discharge event, combined with a 10-year high tide. The freeboard is intended to provide an extra level of protection to the homes and road, as well as to generally account for soil subsidence and sea level rise. Once this desired level of protection was agreed, the remaining tasks focused on identifying and evaluating alternative approaches that could feasibly provide this level of protection.

## 7.0 PERMITS

During the data-gathering phase of the project, general information was collected from relevant regulatory agencies regarding the permits that could be applicable. This information is summarized in Table 2. In addition, on May 15, 2013, the Flood Authority hosted a meeting between sponsors of projects funded within Grays Harbor County and the cities within it, their consultants, and numerous regulatory agencies. The purpose of the meeting was to provide an early opportunity for the agency representatives to hear about the projects and provide input for the sponsors and consultants to consider to make the permit process go more smoothly in the future.

# 8.0 ALTERNATIVES

This section presents an analysis of three alternative options to provide flood protection along Wishkah Road plus the "Do Nothing" alternative as a baseline against which to evaluate the benefits and costs of the other three options.

## 8.1 Do Nothing

This option would involve leaving Wishkah Road and the existing drainage systems in place.

### *8.1.1 Description*

It has been determined that Wishkah Road has settled significantly since it was raised in the 1980s, and will likely continue to settle. The road currently floods multiple times per year, and the water depth over the road is significant enough to close the road about once every year or two. As sea levels rise and the road continues to settle, the road will flood and be closed more frequently. The flood-prone homes west of the road will continue to be damaged during floods, and emergency vehicle access will be restricted at times. The stakeholders for the project agreed that this is not a preferred option, but it is worth comparing how the other options compare with the option of doing nothing.

### *8.1.2 Level of Protection*

In the present condition, Wishkah Road floods regularly, with a depth of flooding sufficient to close the road occurring every year or two for about 1 to 5 hours. As sea levels rise and the soils continue to consolidate, the frequency and severity of flooding will continue to get worse. This option would provide no further protection.

### *8.1.3 Permit Considerations*

Since no action is proposed in this option, no permits would be required.

### *8.1.4 Feasibility*

Wishkah Road will continue to settle, and sea water levels are anticipated to keep rising relative to the land. Without making any changes, the flooding will likely worsen.

### *8.1.5 Cost Estimate*

While there is a cost to operate and maintain the road as it exists, those costs have not been estimated. The cost of the remaining options will not consider these ongoing costs, but only those costs that would change in the course of implementing one of the other options.

### 8.1.6 Risks

There is an ongoing risk to life and property when Wishkah Road floods. As noted above, we predict that those risks will increase over time.

## 8.2 Option 1: Raise Roadway Embankment

This option involves placement of fill to raise the surface of the road to the target height of 16 feet NAVD88, and thereby reduce the threat of the road being closed due to flooding. If tide gates were included on all of the road culvert outlets, this option would also protect the properties west of Wishkah Road from flooding.

### 8.2.1 Description

This option would involve bringing in fill to increase the height and width of the road prism throughout the project site, ideally to at least the target height of 16 feet NAVD88. A depiction of this option is shown as Figure 4. The driveways on the west side of the roadway would need to be re-graded to meet the raised road elevation. The existing culverts under the road would need to be replaced with longer pipes and fitted with tide gates on the outlet side of each, in order to prevent flood waters from back-flowing through the culverts and flooding the homes.

### 8.2.2 Level of Protection

Theoretically, the road could be raised to the target elevation of 16 feet NAVD88, which would involve placing over 5 feet of fill at the lowest portion of the road. Adjacent property and homes would be protected, but ongoing monitoring of the elevation of the road would be required, and maintenance would need to be performed in a timely manner in order to keep the level of protection as it was designed.

### 8.2.3 Permit Considerations

Any alternative that involves placing a significant amount of fill to elevate the roadway would result in significant impacts to wetlands, utilities, and potentially to the function of residential driveways. The footprint of the wetland impact would be narrow and parallel the road. It is anticipated that the project could successfully move forward to completion after considering the environmental impacts and providing suitable mitigation. In addition, some utilities may need to be relocated, and residential driveways would need to be modified to tie into the higher road elevation, while keeping the slope of the driving surface reasonable.

To avoid delays and added project cost, we recommend contacting the permitting agencies early in the design process and coordinate often as the project progresses. Grays Harbor County's CLEAR (Comprehensive Land-use and Environmental Application Review) process provides an established mechanism to provide an initial review of a project and identify project concerns, challenges, and permits that would be required. While the process to obtain a similar review from state and federal agencies is not as clearly defined, we recommend using the results of the CLEAR process as a starting point to see what additional concerns and permit processes would be required.

### 8.2.4 Feasibility

Based on the findings in the Geotechnical Memorandum, it would only be practical to raise the road a limited amount, especially in the low areas of the road where it has settled the most. The fill height should be limited to keep the road fill prism within the footprint of the existing right-of-way, which would likely be on the order of 1 foot to 2 feet. That level would reduce the frequency that the road was flooded and closed, but do nothing to protect adjacent property and homes. Additionally, construction would have to be phased over at least two construction seasons to avoid bearing capacity failure, and anticipated settlement would create unacceptable ongoing maintenance requirements.

Removal of some of the existing road fill and replacing it with light-weight materials to reduce the amount of settlement over time was considered, but this option would be very disruptive to the flow of traffic and the ability of residents to access their homes, since detours around the project area would be very lengthy. A minor amount of road fill may be feasible to raise the lowest portions of the road as one component of a more comprehensive approach. This minor road raising could be done during an early phase of the project as a road maintenance activity, which would require little to no permitting effort and could be done in advance of a more comprehensive solution to the flooding problem that would take more time to design and permit.

Significantly raising the road more than 1 foot to 2 feet would present a few significant challenges that make it infeasible. First, the road work would result in significant disruption to traffic, both to local residents and people traveling through the area, and likely extend over two construction seasons. Second, tide gates would need to be added to the outlets of all the culverts in order for homes to see a reduction in the frequency of flooding. Third, raising the road to an elevation of less than 16 feet NAVD88 and adding tide gates to the culverts would increase the risk of damage to the road, road shoulder, and private properties when the road does get overtopped during extreme flood events. Finally, if the water did start flowing over the roadway, residents would likely experience a more rapid rise in water levels than they are accustomed to, which could increase the risk that people would become trapped by flood waters.

### 8.2.5 Cost Estimate

Since significantly raising the road does not appear to be very feasible, no specific detailed cost estimates were prepared for Option 1 to significantly raise the road. However, the cost of raising the road a minor amount in limited areas as one part of a more comprehensive approach is included within the cost estimate for Option 3: Sheet Pile Flood Wall.

### *8.2.6 Risks*

Raising the road and using it as a means of flood protection for adjacent homes would present several significant safety risks:

- The road would likely continue to settle due to the presence of oversaturated soils.
- The road would settle at an accelerated rate once additional fill was added.
- It would be difficult and costly to maintain the road at the design elevation due to the above factors.

As the road settled, overflow from the river would tend to become concentrated in low spots, increasing the risk of damage to the road and to the privately owned property west of the road.

## 8.3 Option 2: New Levee

This option would involve creating a new levee parallel to the eastern side of Wishkah Road, in order to provide flood protection to the road and the homes west of the road.

### *8.3.1 Description*

A depiction of this option is shown as Figure 5. Nearly the entire footprint for this option would be within existing undisturbed areas and outside of the existing road right-of-way. Settlement issues associated with the new levee option would be even more severe than under the road fill alternative, and impacts to wetlands would be much more substantial.

### *8.3.2 Level of Protection*

A levee could be constructed that would provide a significant level of protection, but it would have many of the same challenges discussed in Section 8.2 for Option 1: Raise Roadway Embankment. Adjacent property and homes would be protected, but ongoing monitoring of the condition and elevation of the levee would be required, and maintenance would need to be performed in a timely manner in order to keep the level of protection as it was designed.

### *8.3.3 Permit Considerations*

Installing a new levee would create significant environmental concerns. These concerns would include potential impact to wetlands, placement of a significant amount of fill in the floodplain, reducing available habitat, restricting fish passage, and creating the potential for scour and erosion in the

Wishkah River. These issues would be very challenging to overcome, and would likely include a significant amount of mitigation, both on site and at other locations nearby.

To avoid delays and added project cost, we would recommend contacting the permitting agencies early in the design process and coordinating often as the project progresses. We would recommend using the CLEAR process described in Section 8.2.3 as a starting point to see what additional concerns and permit processes would be required.

### *8.3.4 Feasibility*

This option is challenging due to the expected significant settlement in the short term and over the long term, which would need to be addressed on an ongoing basis to continue to provide the level of protection desired. In addition, the permitting challenges would result in long delays and very costly mitigation measures to satisfy the potential environmental impacts. This option is not likely to be feasible for these reasons.

### *8.3.5 Cost Estimate*

Since creating a new levee does not appear to be very feasible, no specific cost estimates were prepared for this option.

### *8.3.6 Risks*

The levee option presents a high risk that the required permits could not be obtained while completing the project at a reasonable cost. The permit process would require an evaluation of alternatives, which would likely result in this option being rejected for the reasons described here. If it were permitted and constructed, ongoing settlement and subsidence of soils would result in the risk that the desired level of protection would be reduced over time without efforts to monitor the condition of the levee and promptly address deficiencies.

## 8.4 Option 3: Sheet Pile Flood Wall

This option would involve creating a sheet pile flood wall along the eastern side of Wishkah Road, which would provide flood protection to the road and the properties to the west of the road.

### *8.4.1 Description*

The Geotechnical Memorandum concluded that the only practicable way to provide flood protection above the chosen design water level was to install a sheet pile flood wall. This option is depicted on Figure 6. The Geotechnical Memorandum includes a preliminary design for a sheet pile wall to provide the design flood protection. Every foot of height of the sheet pile wall above the ground surface would require 2.0 – 2.5 feet of sheet pile below ground in order for the wall to remain stable during a flood. The preliminary design calls for a sheet pile wall with a top elevation of about 16 feet NAVD88. The wall would parallel the east side of Wishkah Road for a distance of approximately 2,700 feet, where the roadway is below that elevation.

This alternative should likely include raising the lowest portions of the road in the project area in order to reduce the risk that local flooding would flood the road. This portion of the work could be completed as an early action to provide an immediate reduction in road flooding while the remainder of this alternative is in design and permitting phases. Three dips on Wishkah Road within the project area and another dip at milepost 3.6 could be raised approximately 0.75 feet at an estimated cost of $500,000, according to Russ Esses, County Engineer for Grays Harbor County. This work is shovel ready and would reduce the frequency and duration of road closures that would isolate residents and limit access by emergency responders.

We recommend that the tide gates be removed from the existing culverts and that new regulated tide gates be installed in the sheet pile wall, where the open channels cross it. In this configuration, water would flow through the road culverts to the open channels on the east side of the road. The water would then flow through these channels to and through the regulated gates in the sheet pile wall. Since the tide gates would be placed in the sheet pile wall instead of at the end of each culvert, fewer would be required and problems associated with differential settlement would be avoided. Once the sheet pile wall and new tide gates were installed, the tide gates on the ends of the culverts could be removed. Removal of these tide gates would improve passage conditions, enabling aquatic life to move through the watercourses and culverts present to the west of the new sheet pile wall.

This option would require purchasing the two properties east of Wishkah Road, because the sheet pile wall would eliminate access to these properties. Purchase of the properties would provide an opportunity to create habitat mitigation adjacent to the project and remove the existing structures on those properties from the active floodplain.

### *8.4.2 Level of Protection*

This option has no practical limit for the level of protection desired. The level of protection considered during this feasibility study is the 50-year Wishkah River flow, combined with the 10-year high tide event. During the design criteria phase, it was recommended by stakeholders that the top elevation of the sheet pile wall not be designed lower than 16 feet NAVD88, due to the potential consequences of it being overtopped.

### *8.4.3 Permit Considerations*

A sheet pile wall offers the advantage of a very small footprint. The sheet pile wall could be driven very near the toe of the road along much of the project area, thereby minimizing potential impacts to wetlands. The sheet pile wall would isolate a portion of the Wishkah River floodplain, but based on the modeling performed by CHE, little, if any, increase in flood water elevations would occur in the river due to installation of this alternative. The addition of regulated tide gates on the sheet pile wall would create open fish passage conditions most of the time. Some fish habitat mitigation would likely be required to offset the project impacts, which would generally be a reduction in floodplain connectivity, a reduction in available flood refuge habitat, and the presence of a hardened edge to the floodplain. It appears that a tidal slough in the finger of land to the east of Wishkah Road could be enhanced to provide most, if not all, of the mitigation.

To avoid delays and added project cost, we would recommend contacting the permitting agencies early in the design process and coordinating often as the project progresses. We would recommend using the CLEAR process described in Section 8.2.3 as a starting point to see what additional concerns and permit processes would be required.

### *8.4.4 Feasibility*

This alternative appears feasible to achieve the desired level of flood protection. It would minimally impact traffic along the road during construction and have no effect after construction. The maintenance requirements would be very low, especially if additional freeboard were added to the wall height above the design minimum elevation of 16 feet NAVD88 to compensate for potential settlement, subsidence, and sea level rise. Furthermore, raising the low spots in the road can be done quickly and provide near-term reduction of road flooding from tidal sources. Moreover, after the sheet piling has been installed, the raised road surface would help reduce the risk of flooding on the roadway due to local drainage during periods when the river level is elevated.

### *8.4.5 Cost Estimate*

A construction cost estimate was prepared for this conceptual option. Table 3 summarizes the cost estimate. For budgeting purposes, we recommend a construction budget of $5.4 million to account for contingencies, with an additional 10 percent, or $540,000, recommended for design and permitting.

### *8.4.6 Risks*

While installing a sheet pile wall to the established design height would greatly reduce the risk of flooding, if it were ever overtopped, significant erosion between the road and wall would likely result. The wall would not cause an increase in the height of flooding of the road, but it could cause a more rapid rise in flood water and increase the duration of flooding of the road and homes if the wall is ever overtopped. The likelihood of such an event is remote. No evaluation of tsunami hazards was performed as part of this project. The existing tsunami hazard map does not extend to the project site, but where it is mapped downstream, it appears that the risk of flooding from a tsunami is not any more severe than the risk of a major flood.

Tide gates would be required to prevent flood water from the Wishkah River from flowing through the drainageways in the sheet pile wall. As such, during floods, water flowing into the project area from the hills to the west would pool up until the water level in the river dropped below the level on the west side of the sheet piles. We considered the potential impact of this local drainage. There is a risk that water would fill the ditches to overflowing and create standing water in the lower areas, but it is highly unlikely that the water would accumulate to a depth that would flood the road.

The option of re-routing Wishkah Road to higher ground was considered part-way through the project. Re-routing the road would provide an alternate road for those travelling beyond the project area. The presence of bedrock outcrops and steep slopes would make it difficult to meet current road standards and greatly increase the cost of construction. This option was considered in enough detail to determine that the route, limitations, and cost make this an infeasible alternative.

## 9.0 DISCUSSION

Flooding along Wishkah road interrupts normal and emergency access and causes private property damage. Flooding has been aggravated due to roadway settlement, and it is the stated desire of Grays Harbor County to protect the road and homes from flood damage that would result from a flood at the chosen flood height. Several options were considered including do nothing, raise the roadway, a new levee, roadway relocation, and a sheet pile wall. Table 4 summarizes the concerns raised early in this project and summarizes how those concerns were addressed. Option 3: Sheet Pile Flood Wall is the only practicable option and is the recommended option to provide the selected level of flood protection. Additionally, raising the low spots in the road could be done as an early action item to reduce the frequency and depth of road flooding until the sheet pile wall can be constructed.

## 10.0 FINDINGS AND CONCLUSIONS

Due to the challenges of the soils and physical constraints in the project area, the option of constructing a sheet pile wall to an elevation that provides the desired protection level was identified as a preferred alternative that was identified and which has substantial benefits. However, to bring the project to completion requires adequate funding. AMEC recommends that Grays Harbor County move forward with the design and permitting of the sheet pile wall alternative. In addition, opportunities to purchase the properties east of the road should be pursued. This alternative should be optimized during the next phase of the project to refine the project cost estimate and attempt to reduce the cost to the extent possible while still meeting the established flood level protection criteria. If full construction funding for the sheet pile alternative is unlikely in the near term, then completion of the road improvements identified as part of that option is suggested as an early action item. However, road improvements would be an interim measure to reduce how often the road is impacted from minor flooding and would provide no reduction in flood frequency or damage to private property.

# TABLES

**TABLE 1. LIST OF DATA GATHERED**
**Kersh-Wishkah Flood Levee Project**
**Grays Harbor County, Washington**

| Source | Type | Date (MM/DD/YEAR) | Description |
|---|---|---|---|
| NOAA | Bathymetry | 9/1/1956 | Bathymetric survey of lower 2.4 miles of Wishkah River |
| USACE | Bathymetry | 2000 - 2012 | Bathymetric survey of Federal Navigation Channel |
| NOAA | Bathymetry | 2004 - 2005 | Bathymetric survey of Grays Harbor estuary |
| OR Dept. of Geology and Mineral Industries | Topography | 9/26/2009 | LIDAR survey of SW Washington |
| NOAA | Water Levels | 2/20/2004 - 12/14/2005 | Predicted and Measured Tides @ Aberdeen |
| NOAA | Water Levels | 12/19/1999 - 12/14/2009 | Predicted Tide @ Aberdeen |
| NOAA | Water Levels | 04/2004 -11/2005 | Monthly Water levels @ Aberdeen (MLLW, MHHW, etc…) |
| NOAA | Wind | 03/26/2008 - 03/28/2013 | Hourly wind speed, direction and pressure @ Westport |
| NOAA | Water Levels | 3/23/2006 - 03/28/2013 | Predicted and Measured @ Westport |
| NOAA | Water Levels | 12/19/1999 - 11/20/2009 | Predicted @ Westport |
| NOAA | Water Levels | 4/2006 - 2/2013 | Daily High/Low (Westport) |
| NOAA | Water Levels | 4/2006 - 1/2013 | Monthly Water levels at Westport (MLLW, MHHW, etc…) |
| USACE | Water Levels | 9/13/1999 -11/17/1999 | Measured @ U.S. Coast Guard Station Westport, WA |
| USACE | Water Levels | 9/12/1999 -11/17/1999 | Measured @ Aberdeen, WA |
| FEMA | Floodmap | 9/29/1986 | Panel 325 (Unincorporated Gray's Harbor County) |
| FEMA | Floodmap | 9/29/1986 | Panel 425 (Unincorporated Gray's Harbor County) |
| FEMA | Floodmap | 9/29/1986 | Panel 2 (City of Aberdeen, WA) |
| FEMA | Floodmap | 9/29/1986 | Panel 2 rev B (City of Aberdeen, WA) |
| FEMA | Report | 2/16/1990 | Flood Insurance Study: Gray's Harbor Unincorporated Areas |
| FEMA | Report | 1/1/1984 | Flood Insurance Study: City of Aberdeen |
| FEMA | Preliminary Report | 8/5/2011 | Preliminary Flood Insurance Study: City of Aberdeen |
| FEMA | Preliminary Floodmap | Not Dated | Preliminary FEMA floodmaps Gray's Harbor County 1-3 |
| NAIP | Aerial Photo | 2006 | Orthophoto,1.5 ft resolution |
| NAIP | Aerial Photo | 2009 | Orthophoto, 1 meter resolution |
| NAIP | Aerial Photo | 2011 | Orthophoto, 1 meter resolution |
| Washington Dept. of Ecology | Streamflow | 4/04/2004 - 03/28/2013 | Mean daily discharge of Wishkah River @ Nisson |
| NCDC | Wind | 1/8/1991 - 8/01/2009 | Hourly wind speed, direction and pressure @ Bowerman Field |
| Coast & Harbor Engineering | Tidal Model | 2011 | Hydrodynamic model of Grays Harbor and lower Chelalis River |
| USDA NRCS | Soils | Not Dated | Nationwide web soil survey |
| Washington Division of Geology and Earth Resources | Liquefaction | 2004 | Liquefaction Susceptibility and Site Class Maps of Washington State |
| Washington Division of Geology and Earth Resources | Site Class | 2004 | Liquefaction Susceptibility and Site Class Maps of Washington State |
| Washington DNR | Geologic Map | 1986 | Geologic Map of the Humptulips Quadrangle and Adjacent Areas |
| Grays Harbor PUD | Geotechnical Investigation | 4/17/2008 | Geotechnical investigation for substation at Wishkah Road and B Street |
| Eastern Washington University | Archaeological Monitoring | 1990 | Archaeological Monitoring of Wishkah Road |
| US Army Corps of Engineers | 1942 Aerial Photo | 1942 | Aerial photo, 1:20,000 |
| USGS | Streamstats | Not Dated | Washington StreamStats Web Application |

**TABLE 1. LIST OF DATA GATHERED**
**Kersh-Wishkah Flood Levee Project**
**Grays Harbor County, Washington**

| Source | Type | Date (MM/DD/YEAR) | Description |
|---|---|---|---|
| Grays Harbor County (GHC-GIS.org) | GIS data | Varies | Various GIS datasets (parcels, zoning, roads, hydro, jurisdiction, PLS) |
| Grays Harbor County | Wishkah Road design | 2/6/1989 | Wishkah Road design (drawing no 94311-26) |
| Grays Harbor County | Wishkah Road design | 7/11/1983 | Wishkah Road design (drawing no 94311-16) |
| Grays Harbor County | Wishkah Road design | Not Dated | Test Hole Logs - at locations shown on 94311-16 |
| AMEC Environment & Infrastructure, Inc. | Geotechnical Investigation | 2013 | Collection and laboratory testing of soil samples from three boreholes along Wishkah Road |
| Berglund, Schmidt, & Associates, Inc. | Topographic survey | 2013 | Topographic survey of road alignment and relevant nearby features from milepost 2.2 to 2.7 |
| HydroGraphix, LLC | Bathymetric survey | 2013 | Bathymetric survey of Wishkah River from its mouth to approximately river mile 5 |

**TABLE 2. PERMIT SUMMARY**
**Kersh-Wishkah Flood Levee Project**
**Grays Harbor County, Washington**

| Regulatory Agency | Point of Contact | Permit | Exemption Threshold | Timeline for Approval | Cost | Comments |
|---|---|---|---|---|---|---|
| US Army Corps of Engineers | Seattle District<br>Regulatory Branch<br>P.O. Box 3755<br>Seattle, WA 98124-3755<br>Tel: (206) 764-3495 | CWA Sec 404 | May be covered under nationwide permit (NWP) | 9-24 months for individual | $100 for individual | Applies to excavation or fill below OHWM or in wetlands<br><br>Apply with JARPA<br><br>Triggers the need for ESA, MSA, NHPA, 401, CZM compliance |
| | | Nationwide Permit (NWP) 14: Linear Transportation Projects | Individual permit required if >0.5 acre (non-tidal) or >0.33 acre (tidal)<br><br>Pre-Construction Notice if >0.1 acre, or if discharging to special aquatic site | 3-6 months for NWP | No fee for NWP | Applies to activities required for construction, expansion, modification, or improvement of linear transportation projects<br><br>Must meet National & Regional General Conditions and State Conditions |
| | | Endangered Species Act Section 7 Consultation | | | | Reviewed by Corps as part of 404 process |
| | | Magnuson-Stevens Act Essential Fish Habitat | | | | Reviewed by Corps as part of 404 process |
| | | National Historic Preservation Act Sect. 106 | | | | Reviewed by Corps as part of 404 process |
| WA Department of Ecology | Attention: Federal Permit Unit<br>P.O. Box 47600<br>Olympia, WA 98504-7600<br>Tel: (360) 407-6000 | 401 Water Quality Certification | >0.5 acre (non-tidal) or >0.33 acre (tidal)<br><br>Related to residential or commercial development | Up to 1 year for individual but usual less than 3 months<br><br>Up to 180 days for pre-certified subject to conditions | No fee | Applies whenever Sec 404 is required for excavation or fill below OHWM or in wetlands<br><br>SEPA must be completed before 401 cert decision<br><br>NWP 14 is pre-certified subject to conditions |
| WA Department of Ecology | Department of Ecology - SEA Program<br>Federal Permit Coordinator<br>Post Office Box 47600<br>Olympia, WA 98504-7600 | Coastal Zone Management (CZM) Certification | | Min 60 days (federal projects)<br><br>Min 6 months (non-federal projects) | No fee | Applies to projects with a federal nexus that occur in coastal counties (i.e., Grays Harbor County)<br><br>Ensures consistency of federal actions with State laws (SMA, SEPA, CWA, CAA, EFSEC, ORMA)<br><br>Apply with JARPA |
| Washington Department of Fish and Wildlife | PO Box 43234<br>Olympia, WA 98504-3234<br>Tel: (360) 902-2534 | Hydraulic Project Approval | | Max 45 calendar days<br><br>Max 15 calendar days if expedited | $150 | Applies to “any construction activity that uses, diverts, changes, or obstructs the bed or flow of state waters”<br><br>Apply with JARPA<br><br>Provide notice of compliance with SEPA |

**TABLE 2. PERMIT SUMMARY**
**Kersh-Wishkah Flood Levee Project**
**Grays Harbor County, Washington**

| Regulatory Agency | Point of Contact | Permit | Exemption Threshold | Timeline for Approval | Cost | Comments |
|---|---|---|---|---|---|---|
| WA Department of Ecology | Water Quality Program – Industrial Stormwater<br>300 Desmond Drive<br>PO Box 47696<br>Olympia, WA 98504-7696<br>Tel: (360) 407-6400 | NPDES Construction Stormwater | >1.0 acre of uplands and discharging to waters of the state | Min 60 days | $519-$1935 depending on acreage | Required if clearing, grading or excavating activities disturb an area of 1 acre or more of upland and will discharge to surface waters of the state<br><br>Permit (called Notice of Intent) filed electronically |
| WA Department of Natural Resources | Rivers District<br>Aquatic Region<br>601 Bond Road; PO Box 280<br>Castle Rock, WA 98611-0280<br>Tel: 360-577-2025 | Aquatic Use Authorization | | Variable; 6-12 months | $25 | Applies to any project that impacts state-owned aquatic lands<br><br>Apply with JARPA Attachment E |
| WA Department of Ecology | SEPA Unit<br>Washington Department of Ecology<br>PO Box 47703<br>Olympia WA 98504-7703<br>Tel: (360) 407-6922<br>Email: sepaunit@ecy.wa.gov<br><br>Southwest Region, Lacey:<br>Tel: (360) 407-6300 | SEPA Review | Triggered by any State or local agency decision | Variable<br><br>Must be completed before other permits are issued | | Environmental checklist: WAC 197-11-960 |
| Grays Harbor County | Grays Harbor County Department of Public Services<br>Planning and Building Division<br>100 W Broadway, Suite 31<br>Montesano, WA 98563<br>Tel: (360) 249-5579 | Grade and Fill Permit | | | Sliding scale depending on volume ($27-$1,172) | If >100 cy, project will also require SEPA review |
| Grays Harbor County | Planning and Building Department<br>100 W. Broadway<br>Suite 31<br>Montesano, WA 98563<br>Tel: (360) 249-5579 | Shoreline Master Program Permit (Exemption, Substantial Development, Conditional Use, or Variance) | Work within 200 ft of OHWM | | $956 + $256 per $20,000 valuation | "Substantial" development is defined as > $6,416 (WAC 173-27-030(8)) |
| Grays Harbor County | Planning and Building Department<br>100 W. Broadway<br>Suite 31<br>Montesano, WA 98563<br>Tel: (360) 249-5579 | Floodplain Development | Development in 100-yr floodplain | | | 100-yr floodplain determined by FEMA NFIP maps |
| Grays Harbor County | | Critical Areas Ordinance | | | | Project is most likely in a Frequently Flooded Area and/or Wetland, which may result in project not being eligible for certain permit exemptions<br><br>CAO consistency will be screened as part of review of other permits and during CLEAR application process |

**TABLE 3. ENGINEER'S OPINION OF PROBABLE CONSTRUCTION COST**
**Kersh-Wishkah Flood Levee Project**
**Grays Harbor County, Washington**

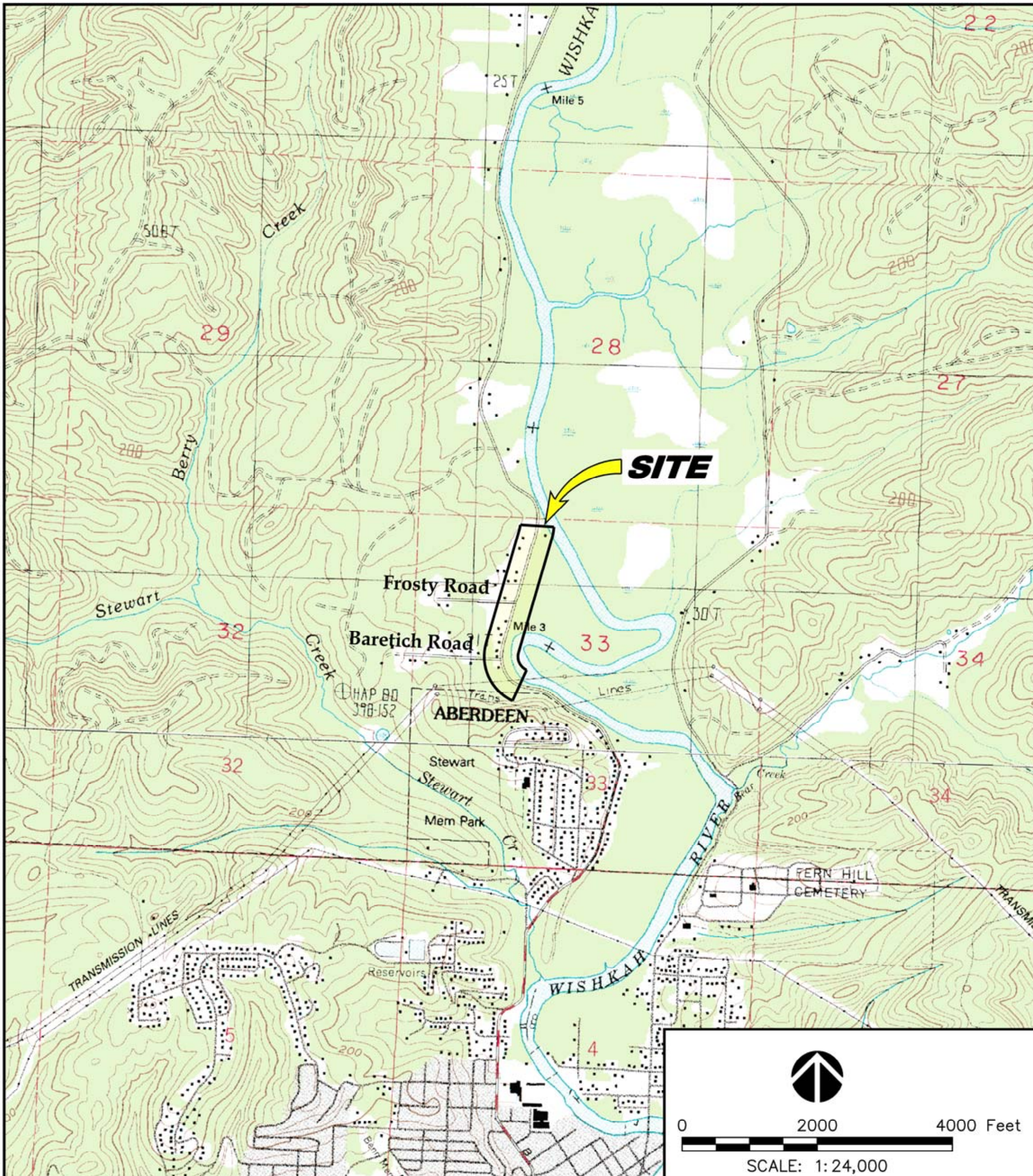
| Item No. | Item Description | Qty. | Unit | Unit Price (Thousands) | Total Price (Thousands) |
|---|---|---|---|---|---|
| 1 | Mobilization for Construction | 1 | LS | $240 | $240 |
| 2 | Temporary Erosion and Sediment Control | 1 | LS | $25 | $25 |
| 3 | Site Preparation | 1 | AC | LS | $10 |
| 4 | Road Improvements | 1 | LS | $225 | $225 |
| 5 | Stormwater Infrastructure Improvements | 1 | LS | $50 | $50 |
| 6 | Sheet Pile Wall | 68 | 1000 SF | $40 | $2,700 |
| 7 | Regulated Flap Gates, 48"x48" | 3 | EA | $60 | $180 |
| 8 | Site Stabilization | 1 | LS | $10 | $10 |
| 9 | Habitat Mitigation, including property acquisition | 1 | LS | $545 | $545 |

| | |
|---|---|
| **Construction Subtotal** | **$3,985** |
| **Contingency (25%)** | **$996** |
| **Tax (8.4%)** | **$418** |
| **Total (2013 dollars)** | **$5,400** |

**TABLE 4. ISSUES CHART**
**Kersh-Wishkah Flood Levee Project**
**Grays Harbor County, Washington**

| Concern or Issue | Comment or Resolution |
|---|---|
| The Wishkah River flows very close to one part of the road; any design solution must consider potential long-term river migration and bank erosion. | Historical aerial photos dating back to 1941 show that the present alignment of Wishkah River has been stable since that time. There is enough of a bench between the road and river and shallow enough riverbank slopes that the geotechnical engineer for this project expect significant bank erosion protection measures would be necessary. |
| Soils appear very soft in the project area, and wetlands are present along the east side of Wishkah Road. During the development of design alternatives, impacts to wetlands will be avoided to the extent possible. Where impacts are unavoidable, the project will be designed to minimize the impacts and consider likely mitigation requirements. | The alternatives that were developed for this project consider the presence of native vegetation and wetlands and strove to minimize the impacts to that. |
| There is concern that buried intact wood (logs) could prevent sheet piling, or other types of piling, from being installed to the required depth. Geotechnical investigations that do not discover the presence of wood would not preclude the possibility of encountering wood or other obstructions during construction. | Geotechnical investigations did not find any significant wood. Given the limited scope of the investigations, it is still possible that significant wood pieces could be encountered during construction. |
| The existing road is above the grade of homes on the west side of the road in some places. Raising the road could result in unfeasibly steep driveways for some homes, depending upon the level of flood protection selected. | No alternatives were selected that would create unfeasibly steep driveways for the homes. |
| There is concern that flows from the local drainages west of the project area could contribute to localized flooding if the water levels in the river are high and the rainfall has been locally heavy. | This concern has been considered in the development and analysis of the alternatives. |
| Homeowners have indicated that the major flooding events have occurred during the King Tides even when the weather pattern had been relatively dry, as during the week of November 24, 2011. | Modeling efforts associated with this project have determined that flooding can come from a number of sources. |
| The largest culvert (36-inch corrugated metal pipe) crossing the road has no flap gate, apparently due to WDFW concerns regarding fish passage. Floodwater therefore passes freely from Wishkah River through the culvert beneath the road and floods properties. Regardless of the level of proposed flood protection along the roadway, this existing culvert and others without functional tide gates must be addressed as sources of potential flooding. | During the May 16, 2013 meeting with regulators, no significant objections were raised to the possibility of adding a new tide gate though mitigation may be necessary. |
| Buildings and properties on the east side of the road would be excluded from flood protection for this project. It was mentioned that these properties should be purchased during a later phase of this project, presumably by Grays Harbor County. | No comment. |
| Buried gas and water lines are present in the project area and must be considered in the alternatives analysis. | A utility located was called prior to the survey work completed during this project. The presence of existing utilities was considered as alternatives were developed. |
| Floodwater has overtopped Wishkah Road severely enough to result in erosion on its western shoulder that required repair and maintenance. | No comment. |
| During the 1980s, Wishkah Road was raised throughout the project area. The curve at the north end of the project was also realigned slightly eastward at the same time, which left the old roadside ditch at the north end of the project in place, and created a new one about 15 feet farther east. The old ditch has been filled in by some landowners. | As discovered by the recent survey, the road has settled significantly since the 1980s work was completed. |

# FIGURES




| | | | |
|---|---|---|---|
| AMEC Environment & Infrastructure<br>11810 North Creek Parkway North<br>Bothell, WA, U.S.A. 98011-8201 | amec | CLIENT LOGO | CLIENT |
| PROJECT: KERSH-WISHKAH FLOOD LEVEE | DWN BY: JRS | DATUM: NAD83 | DATE: JUNE 2013 |
| TITLE: SITE LOCATION MAP | CHK'D BY: RSB | REV. NO.: | PROJECT NO: 3-915-17568-0 |
| | PROJECTION: WA STATE PLANE | SCALE: AS SHOWN | FIGURE No. 1 |

G:\91\17000\17568 – Kersh-Wishkah Flood Levee\17568-01a.dwg – Layout1 – Jun. 21, 2013 2:40pm – jeffrey.sanders


# Kersh-Wishkah Road Project

1942 Aerial Photo

N

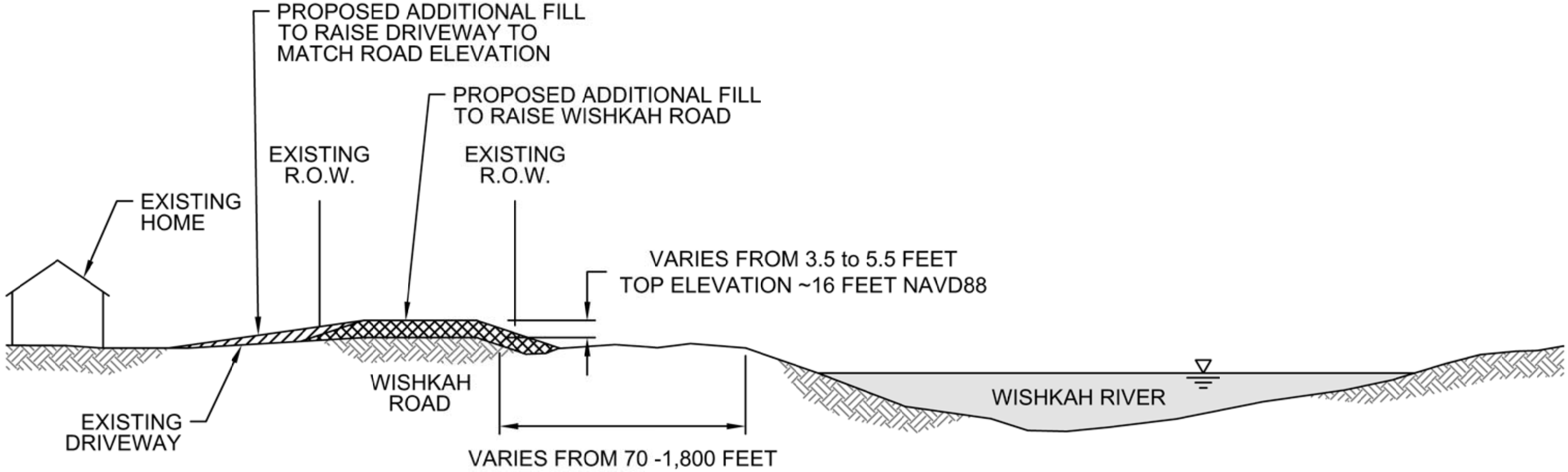
400 0 400 Feet



amec

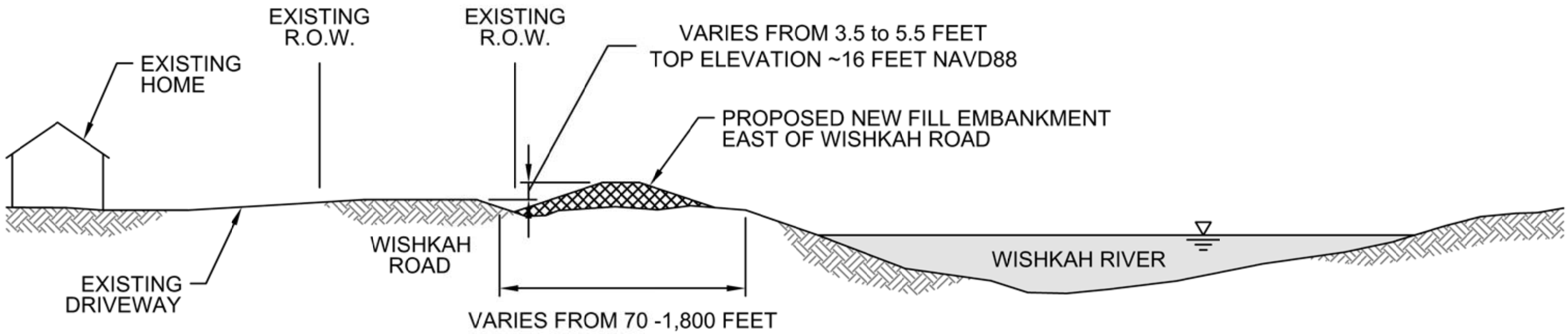
Kersh-Wishkah Road Project

2011 Aerial Photo



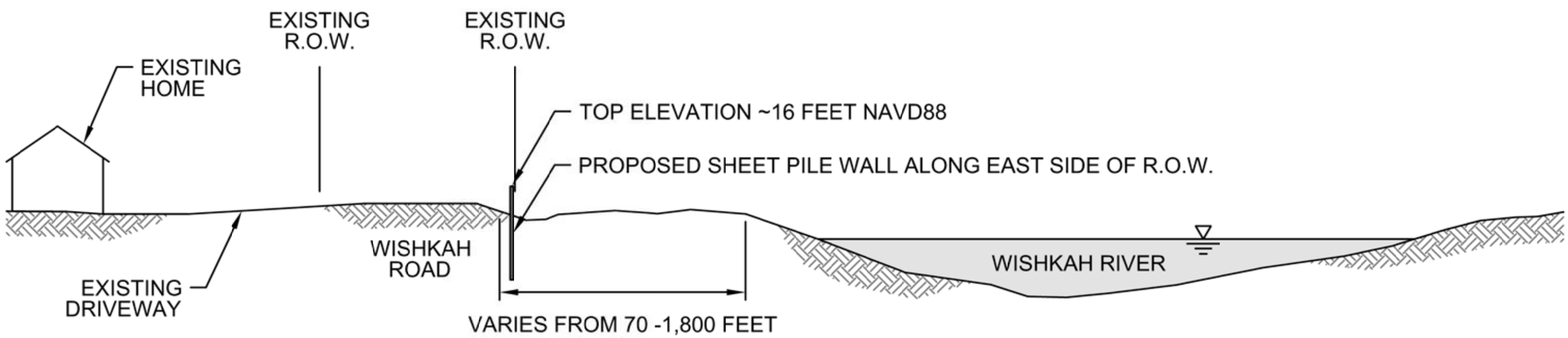

| CLIENT LOGO | CLIENT | DWN BY: JRS<br>CHK'D BY: RSB | PROJECT<br>KERSH-WISHKAH FLOOD LEVEE | REV. NO.:<br>DATE: JUNE 2013 |
|---|---|---|---|---|
| AMEC Environment & Infrastructure<br>11810 North Creek Parkway North<br>Bothell, WA, U.S.A. 98011-8201 | amec | DATUM:<br>PROJECTION:<br>SCALE: NOT TO SCALE | TITLE<br>OPTION 1<br>RAISE ROADWAY EMBANKMENT | PROJECT NO: 3-915-17568-0<br>FIGURE No. 4 |

G:\91\17000\17568 – Kersh–Wishkah Flood Levee\17568–10.dwg – Option One – Jun. 21, 2013 2:30pm – jeffrey.sanders




| CLIENT LOGO | CLIENT | DWN BY: JRS | PROJECT | REV. NO.: |
|---|---|---|---|---|
| | | CHK'D BY: RSB | KERSH-WISHKAH FLOOD LEVEE | DATE: JUNE 2013 |
| AMEC Environment & Infrastructure<br>11810 North Creek Parkway North<br>Bothell, WA, U.S.A. 98011-8201 | | DATUM: | TITLE | PROJECT NO: 3-915-17568-0 |
| | | PROJECTION: | OPTION 2<br>LEVEE | FIGURE No. |
| | | SCALE: NOT TO SCALE | | 5 |

G:\91\17000\17568 – Kersh–Wishkah Flood Levee\17568–10.dwg – Option Two – Jun. 21, 2013 2:00pm – jeffrey.sanders




| | | | |
|---|---|---|---|
| CLIENT LOGO | CLIENT | DWN BY: JRS<br>CHK'D BY: RSB | PROJECT<br>KERSH-WISHKAH FLOOD LEVEE |
| AMEC Environment & Infrastructure<br>11810 North Creek Parkway North<br>Bothell, WA, U.S.A. 98011-8201 | amec | DATUM:<br>PROJECTION:<br>SCALE: NOT TO SCALE | TITLE<br>OPTION 3<br>SHEET PILE FLOOD WALL |

REV. NO.:
DATE: JUNE 2013
PROJECT NO: 3-915-17568-0
FIGURE No. 6

G:\91\17000\17568 – Kersh–Wishkah Flood Levee\17568–10.dwg – Option Three – Jun. 21, 2013 1:59pm – jeffrey.sanders

# APPENDIX A

Kersh-Wishkah Flood Levee Project Goals and Design Criteria Memo

**Memo**

| | | | |
|---|---|---|---|
| To | Russ Esses | AMEC# | 3-915-17568-0 |
| From | Ryan Bartelheimer | cc | Kersh-Wishkah Flood Levee Project Team |
| Tel | (425) 368-0980 | | |
| Fax | (425) 368-1001 | | |
| Date | March 5, 2013 | | |

Subject Kersh-Wishkah Flood Levee Project Goals and Design Criteria

On February 21, 2013, Ryan Bartelheimer (AMEC Environment & Infrastructure, Inc.), Joel Darnell (Coast & Harbor Engineering, Inc.), and Hari Sharma (Berglund, Schmidt & Associates, Inc.) visited with Frank Kersh and Terry Willis at Frank's house and walked the Kersh-Wishkah Flood Levee Project site. We all subsequently met with you, Commissioner Cormier, and Al Smith later that evening.

The scope of work for this project identified the following goals and design criteria, which were discussed during that evening meeting:

- Gain an understanding of site specific concerns and site issues;
- Understand the frequency and ramifications of the flooding problems;
- Establish appropriate level(s) of protection for the design alternatives to achieve;
- Establish desired level of design detail to be provided; and
- Establish timeline for data gathering, performing analyses, and reporting results.

For convenience, the scope of work is reproduced as a stand-alone document and attached to this memorandum. This memorandum summarizes the discussion at the meeting regarding project objectives and limitations, specific concerns about the project, design criteria to be developed, and the anticipated project timeline.

## PROJECT OBJECTIVES

Currently, Wishkah Road is frequently flooded, at times preventing emergency responders from travelling north of Baretich Road. Therefore, the primary project objective is to reduce flooding on Wishkah Road to facilitate emergency response. A secondary benefit of the project will likely be to reduce the frequency of flooding experienced in homes and properties located west of the roadway.

## PROJECT LIMITS

The project area for flood protection is limited to an approximately 2,700-foot-long segment of Wishkah Road approximately centered at the intersection with Frosty Road. Modeling and analysis will extend beyond the project area toward the river's mouth, but detailed results will be focused on the project area only.

## SITE-SPECIFIC CONCERNS AND ISSUES

Participants at the meeting raised and discussed the following site-specific concerns regarding the project.

The Wishkah River flows very close to one part of the road; any design solution must consider potential long-term river migration and bank erosion.

Soils appear very soft in the project area, and wetlands are present along the east side of Wishkah Road. During the development of design alternatives, impacts to wetlands will be avoided to the extent possible. Where impacts are unavoidable, the project will be designed to minimize the impacts and consider likely mitigation requirements.

There is concern that buried intact wood (logs) could prevent sheet piling, or other types of piling, from being installed to the required depth. Geotechnical investigations that do not discover the presence of wood would not preclude the possibility of encountering wood or other obstructions during construction.

The existing road is above the grade of homes on the west side of the road in some places. Raising the road could result in unfeasibly steep driveways for some homes, depending upon the level of flood protection selected.

There is concern that flows from the local drainages west of the project area could contribute to localized flooding if the water levels in the river are high and the rainfall has been locally heavy.

Homeowners have indicated that the major flooding events have occurred during the King Tides even when the weather pattern had been relatively dry, as during the week of November 24, 2011.

The largest culvert (36-inch corrugated metal pipe) crossing the road has no flap gate, apparently due to WDFW concerns regarding fish passage. Floodwater therefore passes freely from Wishkah River through the culvert beneath the road and floods properties. Regardless of the level of proposed flood protection along the roadway, this existing culvert and others without functional tide gates must be addressed as sources of potential flooding.

Buildings and properties on the east side of the road would be excluded from flood protection for this project. It was mentioned that these properties should be purchased during a later phase of this project, presumably by Grays Harbor County.

Buried gas and water lines are present in the project area and must be considered in the alternatives analysis.

Floodwater has overtopped Wishkah Road severely enough to result in erosion on its western shoulder that required repair and maintenance.

Wishkah Road was previously raised in most of the project area, except for a section in the southern portion of the project area, which appears to be the lowest-lying section of road. The road was also realigned slightly eastward at the same time, which left the old roadside drainage ditch on the west side of the roadway in place, and created a new one about 15 feet farther east. The old ditch has been filled in by some landowners.

## FREQUENCY AND RAMIFICATIONS OF FLOODING

Residents indicated that Wishkah Road floods two to three times each year. During these flood events, water from Wishkah River overtops the roadway to a depth that makes it impassible and floods adjacent properties on the west side of the road. Shallow flooding is very frequent (approximately 20 times last year, according to Frank Kersh) and appears to be caused primarily by high water levels at the river mouth, driven by tidal influences.

According to residents, the worst flooding on the road has been observed in the last 5 years with a maximum depth of about 2 to 3 feet on top of the road. Water depths are even greater in adjacent homes and yards, due to their lower elevations relative to the road, with water depths of up to 4 feet in some yards. Significant flood events were noted by residents on approximately the following dates:

- December 31, 2005
- December 5, 2007
- January 1, 2009 (Frank Kersh noted worst flooding in recent times)
- November 24, 2011

Some adjacent homes have experienced water levels above the lowest floor of the dwelling.

Emergency vehicles can travel through shallow water depths, but avoid using the road when the depth of water is more than about 1 foot.

## FLOODING PROTECTION LEVELS

The design team will complete a preliminary cost/benefit analysis to determine the appropriate level of flood protection. Given the frequency of flooding noted above, we propose to consider flood levels with return periods ranging from 5 years to 100 years. Local sea level rise will be investigated and addressed as part of the cost/benefit analysis.

The County has indicated that if a sheet pile wall is constructed, the design should consider providing protection for up to the 100-year flood event.

## DESIRED DESIGN LEVEL

During the evening meeting, it was commented that the closer the project comes to being "shovel ready," the better the chances of obtaining funding for future phases of the project. The Scope of Work indicates that the alternatives will include development of a typical preliminary cross-section, conceptual design detail including scour protection (if required), and a schematic plan view alignment within Autodesk software.

## PROJECT TIMELINE

No concerns were expressed about the timeline identified in the scope of work. Bi-weekly project status calls are scheduled to occur on Mondays at 9:30 am, starting on March 11, 2013. Since no major objections or concerns were raised about the scope of work, the design team will continue with the activities identified in the scope of work in accordance with the project timeline.

# APPENDIX B

Compilation of Flood Photos in Project Area

12/31/05 3134 Wishkah Rd
SAT.

3134 Wishkah Rd.
Friday 12-30-05

3134 Wishkah Rd.
Friday 12-30-05

3134 Wishkah Rd.
Friday 12-30-05

3134 Wishkah Rd.
Friday 12-30-05

12|31|05 3134 Wishkah Rd
SAT.

1/1/09

EAST FACE - WATER UP TO FRONT DOOR

3003 WISHKAH RD. MIKE ZAWISLAK RESIDENCE

1/1/09

BARITICH FLATS

1/1/09

LOOKING N.E.

BETTY PETERSON RESIDENCE

1/1/09


FRONT DOOR
MIKE & ALYLIS ZAWISLAK RESIDENCE

BETTY PETERSON RESIDENCE

1/1/09

GARAGE SIDE ENTRY DOOR - off deck

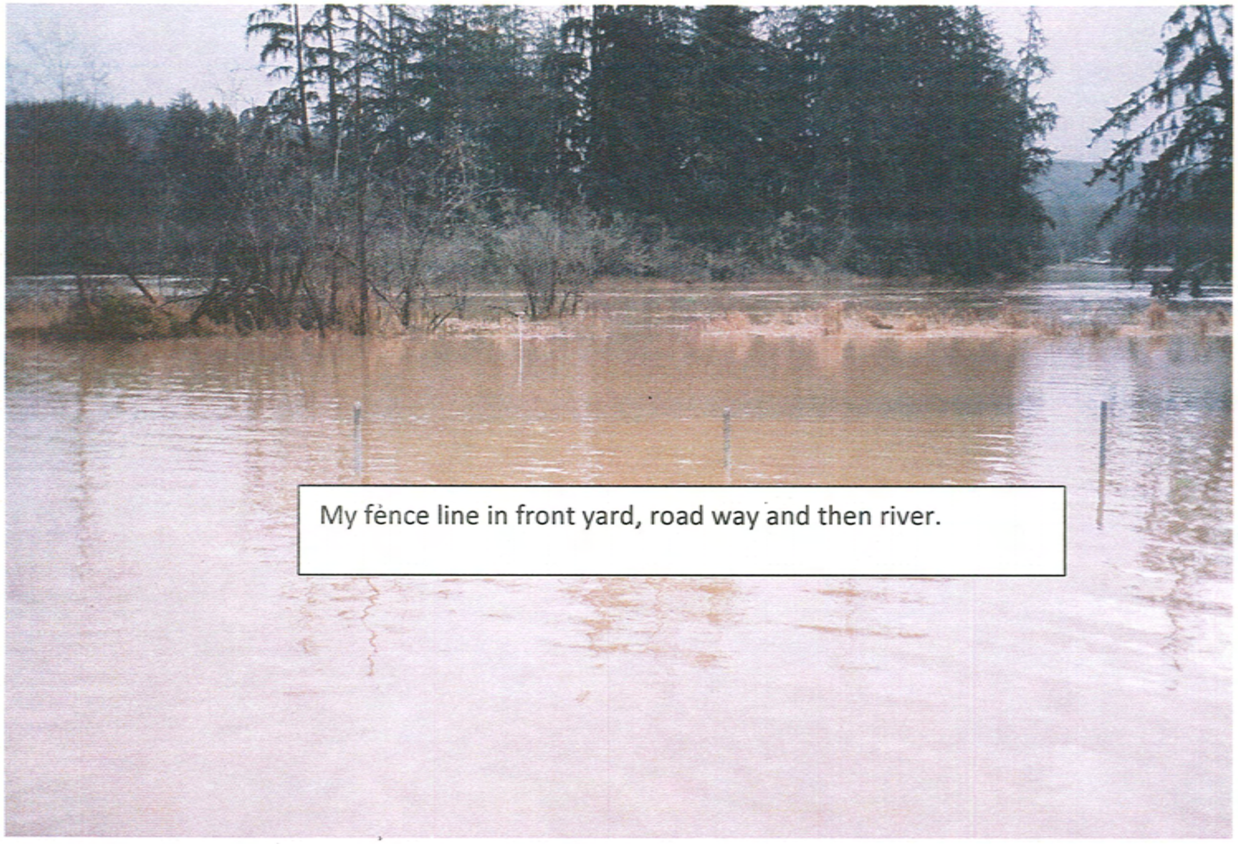
BETTY PETERSON RESIDENCE

1/1/09

STEPS FROM BACK DECK

BETTY PETERSON RESIDENCE

1/1/09



My fence line in front yard, road way and then river.

BETTY PETERSON RESIDENCE

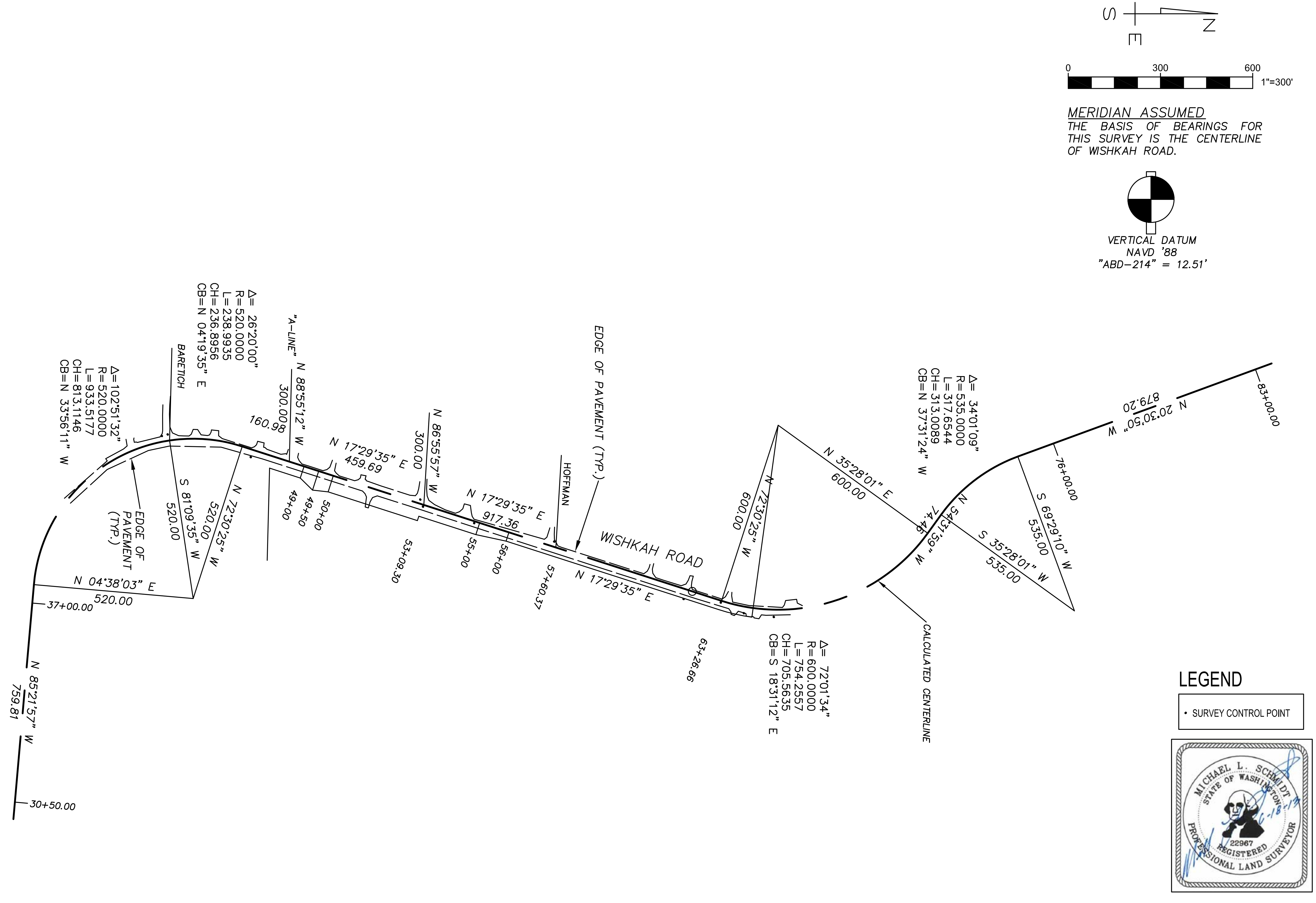
Thanksgiving

Thanksgiving-2011 King Tide

## APPENDIX C

Survey

# WISHKAH ROAD SURVEY




| BY | DATE |
|---|---|
| | |

REVISIONS

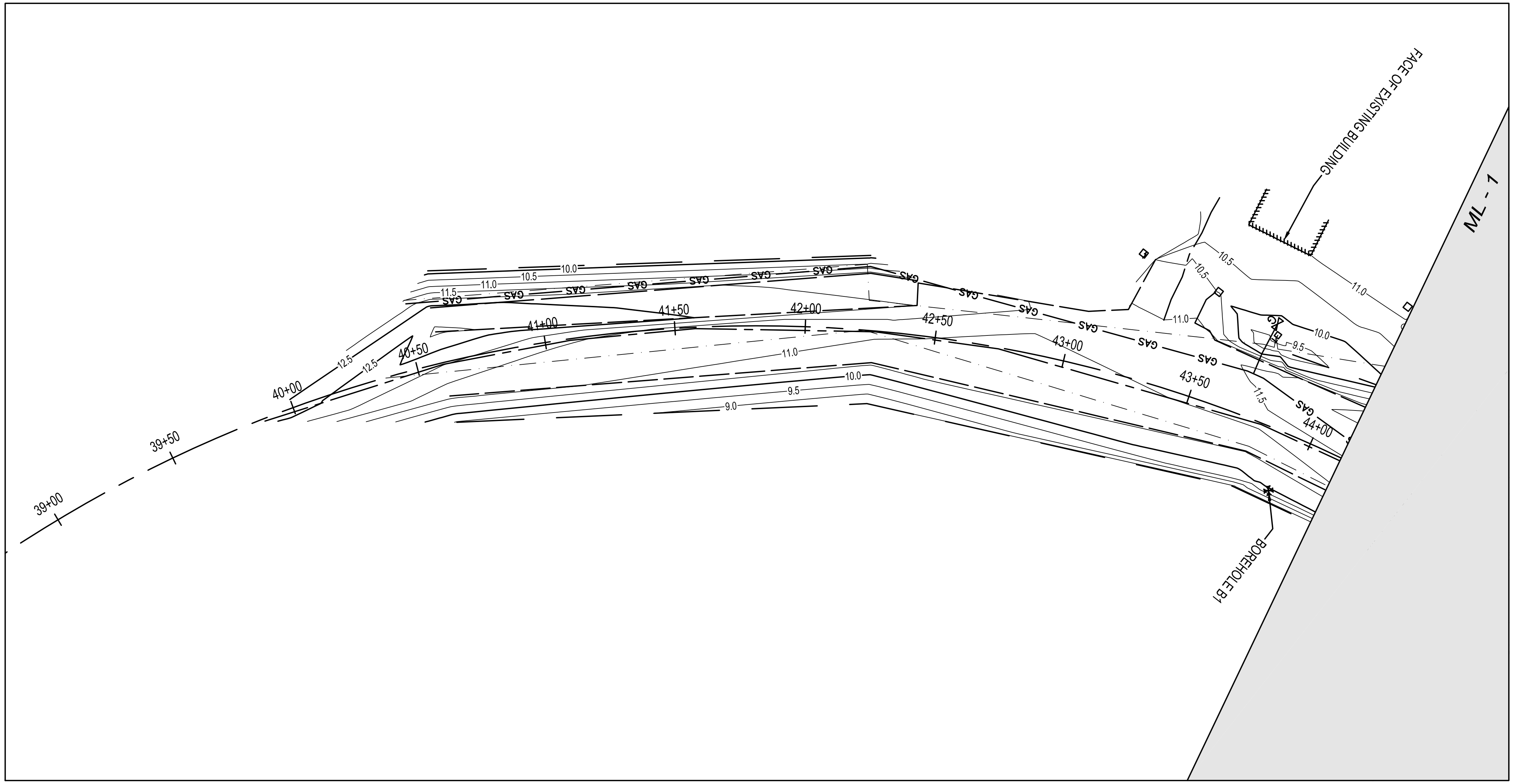
**Wishkah Road**
*Calculated Centerline*

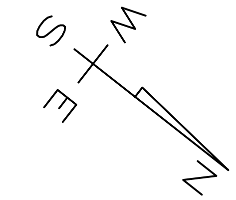
WISHKAH ROAD SURVEY
AMEC Environmental
11810 North Creek Parkway N.
Bothell, Washington 98011

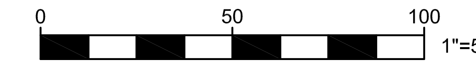
BERGLUND, SCHMIDT & ASSOC., INC.
professional engineers and land surveyors
2323 BAY AVENUE TEL.: (360)532-7630
HOQUIAM, WA 98550 FAX: (360)532-9682

JOB # :13.013
DATE: 6/12/13
SCALE: 1"=300'
DESIGNED:
DRAWN: JMK
CHECKED: MLS
APPROVED: MLS
DRAWING NO.
S-1
SHEET 1 OF 7

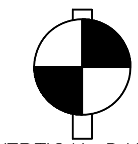
# WISHKAH ROAD SURVEY




MERIDIAN ASSUMED
THE BASIS OF BEARINGS FOR THIS SURVEY IS THE CENTERLINE OF WISHKAH ROAD.



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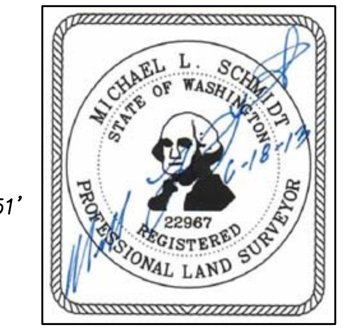
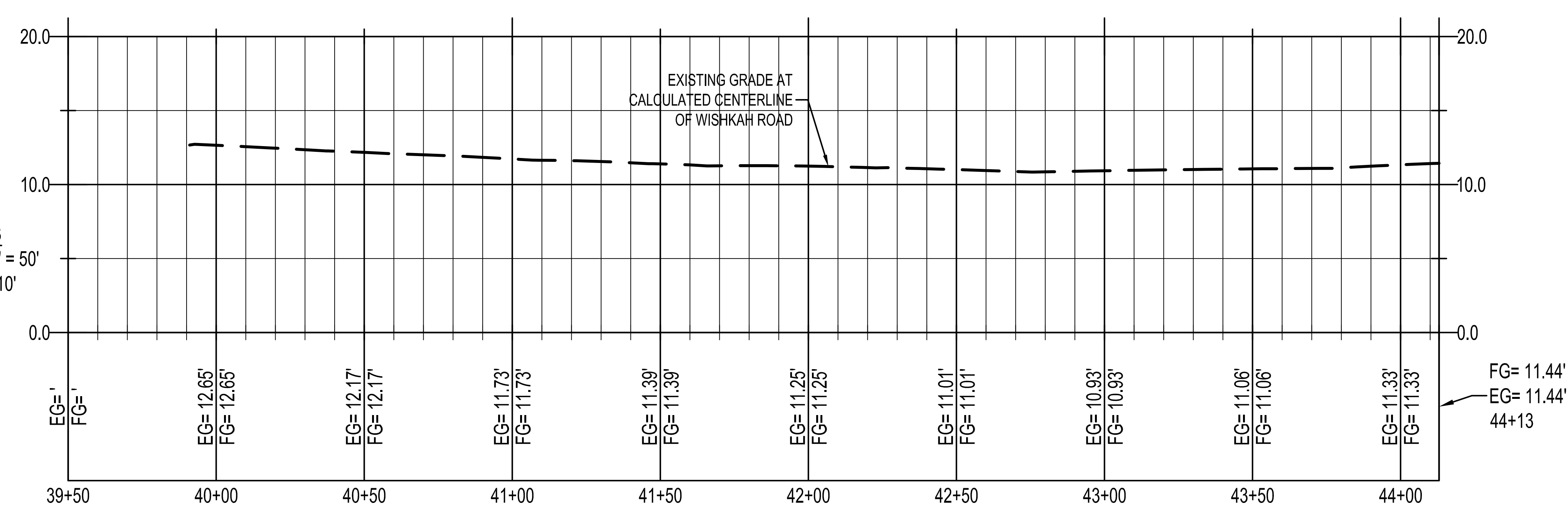



## LEGEND

- BOREHOLE LOCATION
- SURVEY CONTROL POINT
- WATER METER
- FIRE HYDRANT
- WATER VALVE
- STORM MANHOLE
- STORM INLET STRUCTURE
- POWER POLE
- SERVICE POLE
- GUY POLE
- DOWNGUY & ANCHOR
- TELEPHONE PEDESTAL
- GAS VALVE
- GAS RISER
- FENCE POST
- CULVERT
- ROAD CENTERLINE
- TELEPHONE LINE
- GAS LINE
- WATER LINE
- EDGE OF GRAVEL
- EDGE OF PAVEMENT
- GRASS MOW LINE
- FENCE
- BUILDING

EG 39+50~44+13
HORIZONTAL: 1" = 50'
VERTICAL: 1" = 10'




REVISIONS | BY | DATE

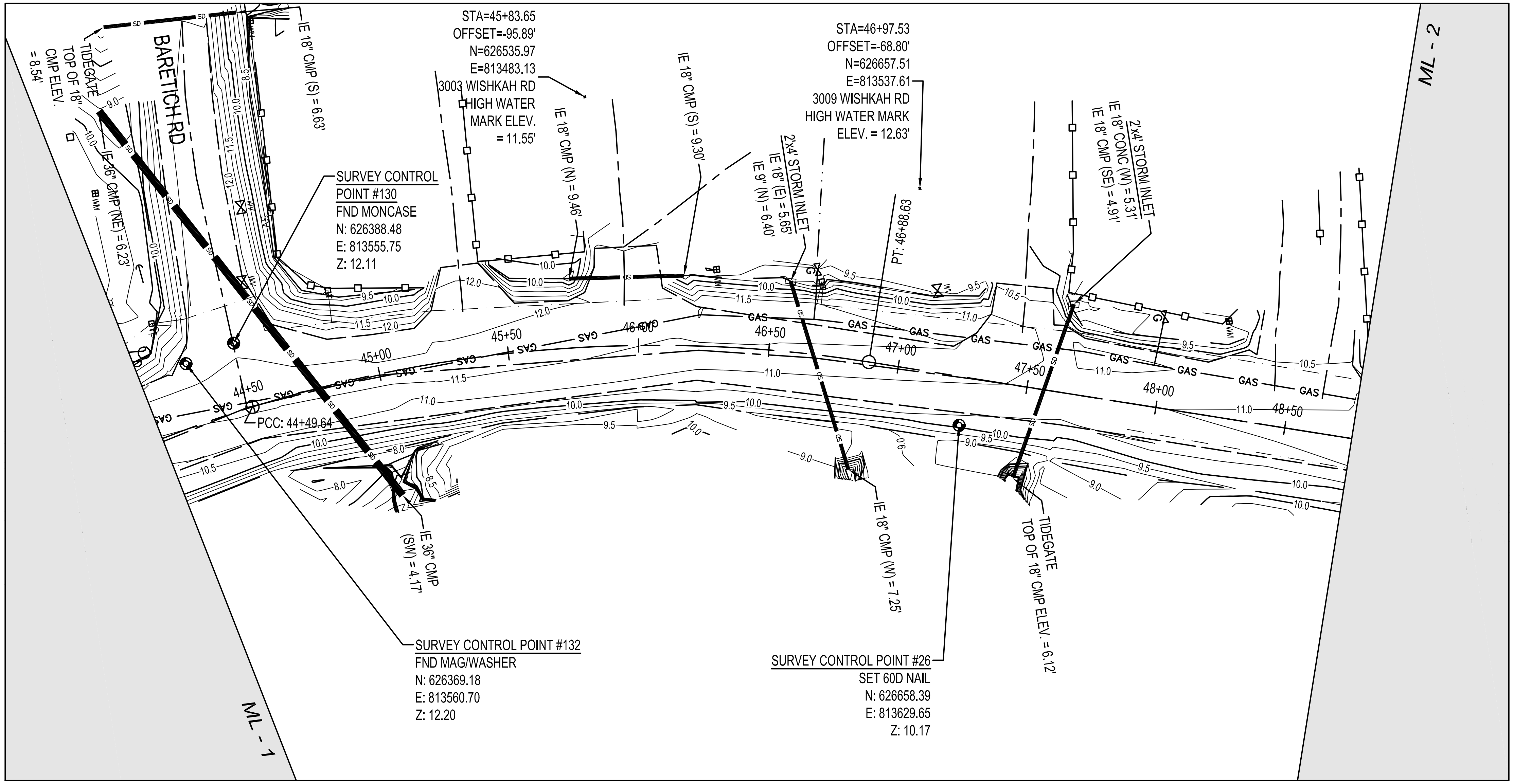
Plan/Profile
STA 39+50~44+13

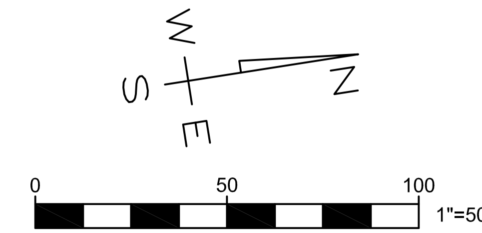
WISHKAH ROAD SURVEY
AMEC Environmental
11810 North Creek Parkway N.
Bothell, Washington 98011

BERGLUND, SCHMIDT & ASSOC., INC.
professional engineers and land surveyors
2323 BAY AVENUE
HOQUIAM, WA 98550
TEL.: (360)532-7630
FAX: (360)532-9682

JOB # :13.013
DATE:6/12/13
SCALE:1"=50'
DESIGNED:
DRAWN:JMK
CHECKED:MLS
APPROVED:MLS
DRAWING NO.
S-2
SHEET 2 OF 7

# WISHKAH ROAD SURVEY

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VERTICAL DATUM
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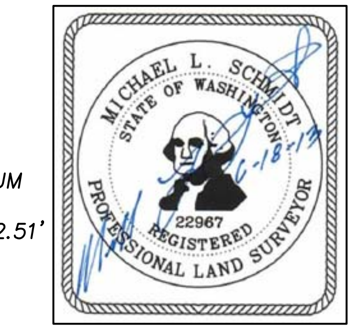


## LEGEND

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- SURVEY CONTROL POINT
- WATER METER
- FIRE HYDRANT
- WATER VALVE
- STORM MANHOLE
- STORM INLET STRUCTURE
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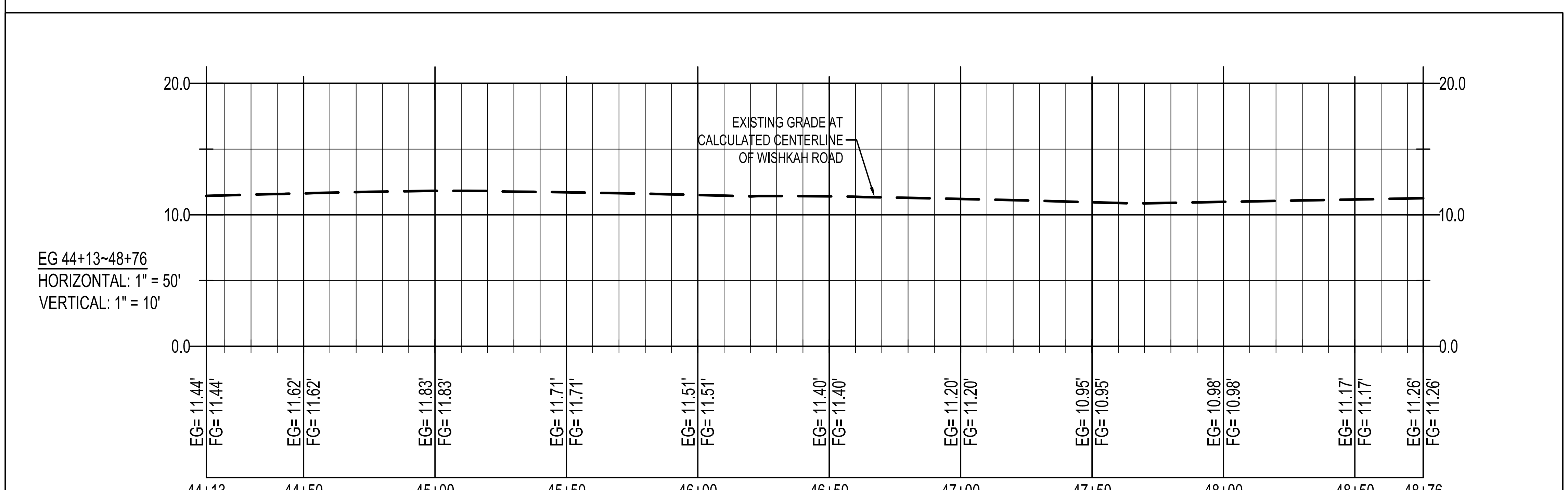
- FENCE
- BUILDING




| REVISIONS | BY | DATE |
|---|---|---|

Plan/Profile

STA 44+13~48+76

WISHKAH ROAD SURVEY

AMEC Environmental
11810 North Creek Parkway N.
Bothell, Washington 98011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professional engineers and land surveyors
2323 BAY AVENUE
HOQUIAM, WA 98550
TEL.: (360)532-7630
FAX: (360)532-9682


JOB #: 13.013
DATE: 6/12/13
SCALE: 1"=50'
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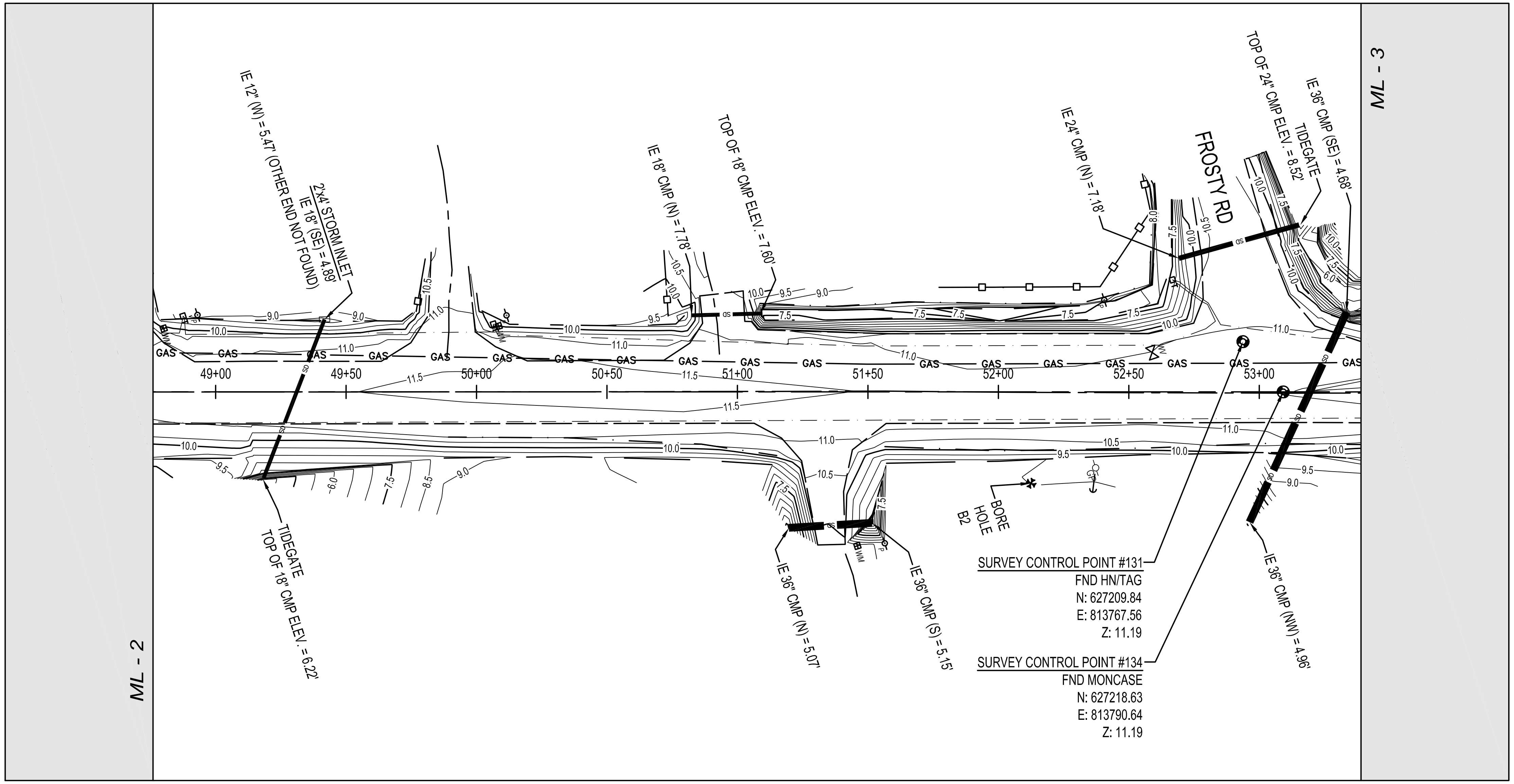
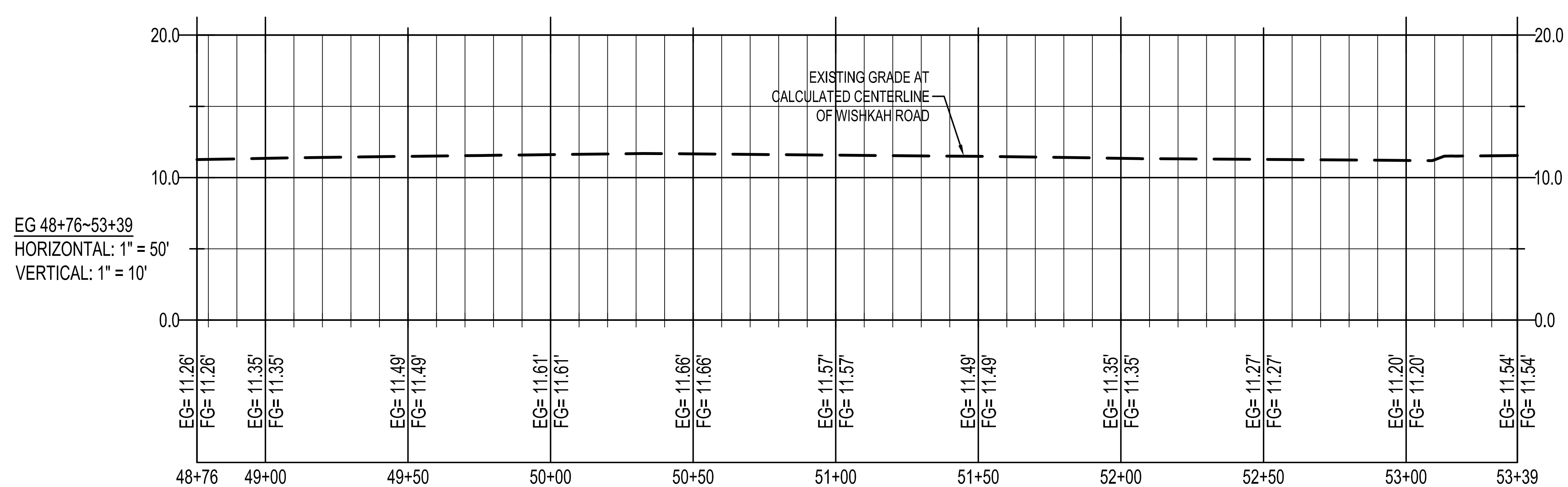
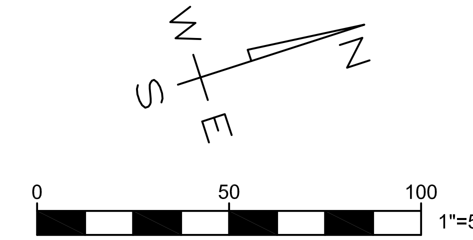
CHECKED: MLS
APPROVED: MLS
DRAWING NO.
S-3

SHEET 3 OF 7

# WISHKAH ROAD SURVEY




**MERIDIAN ASSUMED**

THE BASIS OF BEARINGS FOR THIS SURVEY IS THE CENTERLINE OF WISHKAH ROAD.

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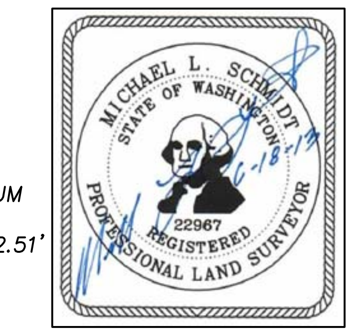


## LEGEND

- BOREHOLE LOCATION
- SURVEY CONTROL POINT
- WATER METER
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- GAS LINE
- WATER LINE
- EDGE OF GRAVEL
- EDGE OF PAVEMENT
- GRASS MOW LINE
- FENCE
- BUILDING

| REVISIONS | BY | DATE |
|---|---|---|

**Plan/Profile**
**STA 48+76~53+39**

WISHKAH ROAD SURVEY
AMEC Environmental
11810 North Creek Parkway N.
Bothell, Washington 98011


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HOQUIAM, WA 98550
TEL.: (360)532-7630
FAX: (360)532-9682


JOB #: 13.013
DATE: 6/12/13
SCALE: 1"=50'
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CHECKED: MLS
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DRAWING NO. S-4
SHEET 4 OF 7

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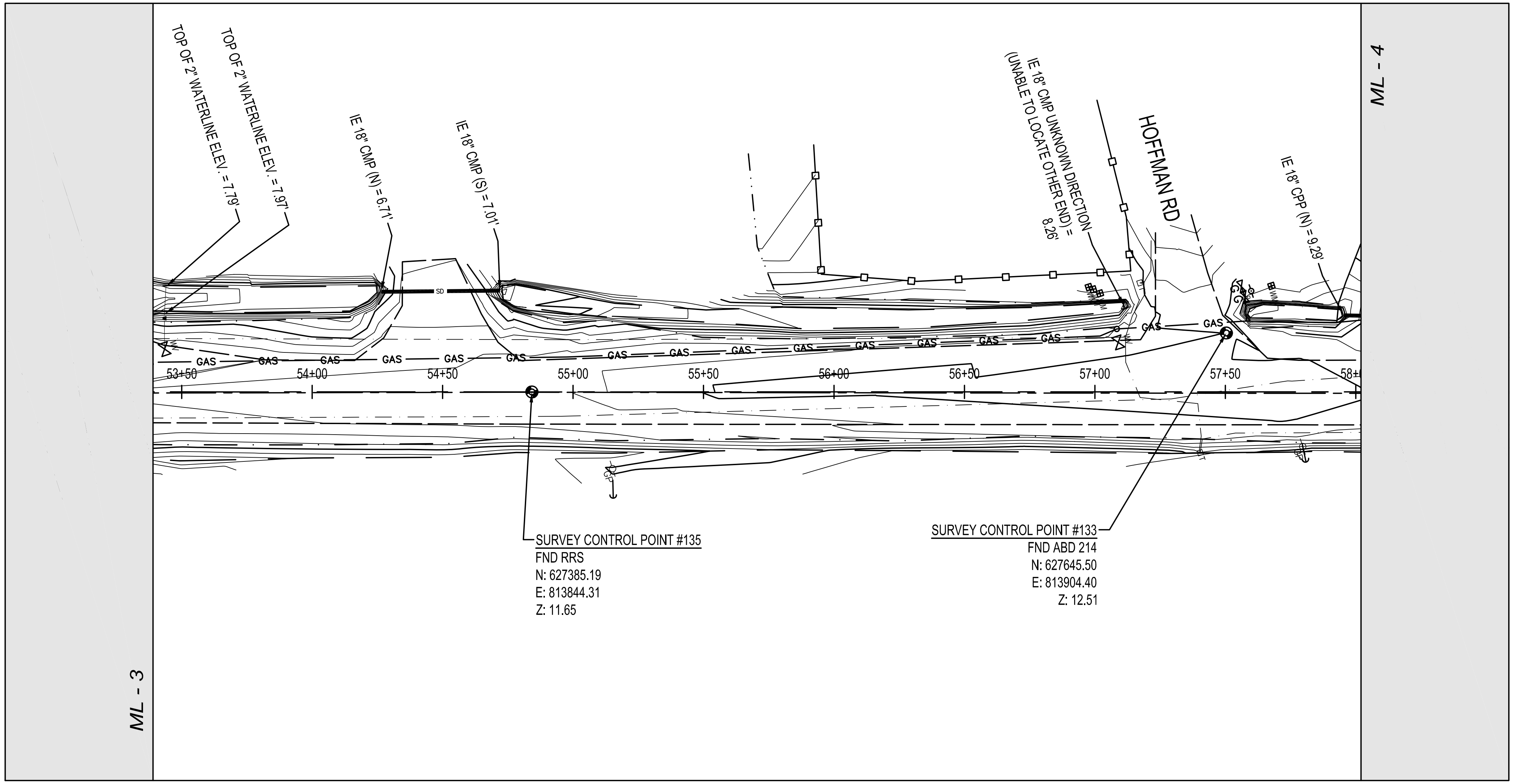


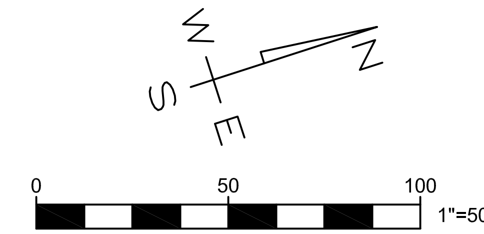


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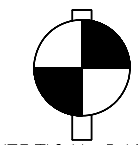

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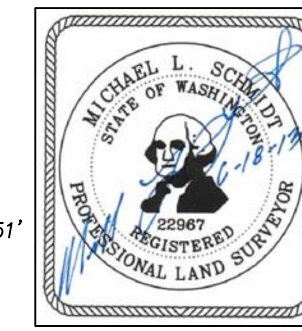


## LEGEND

- BOREHOLE LOCATION
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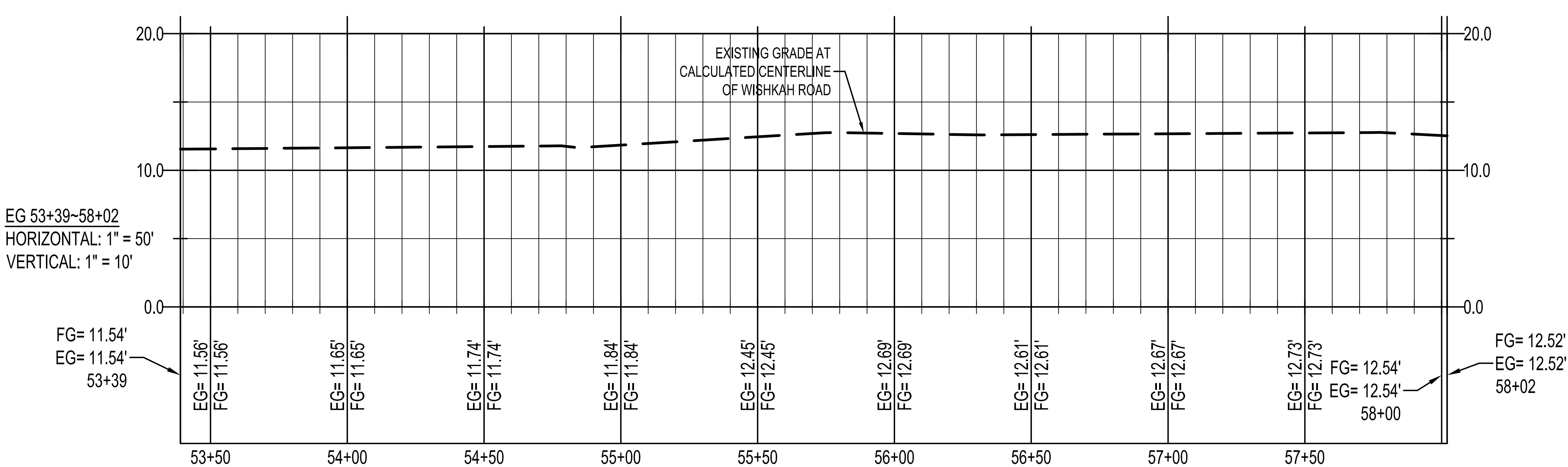


EG 53+39~58+02
HORIZONTAL: 1" = 50'
VERTICAL: 1" = 10'

REVISIONS | BY | DATE

Plan/Profile
STA 53+39~58+02

WISHKAH ROAD SURVEY
AMEC Environmental
11810 North Creek Parkway N.
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2323 BAY AVENUE
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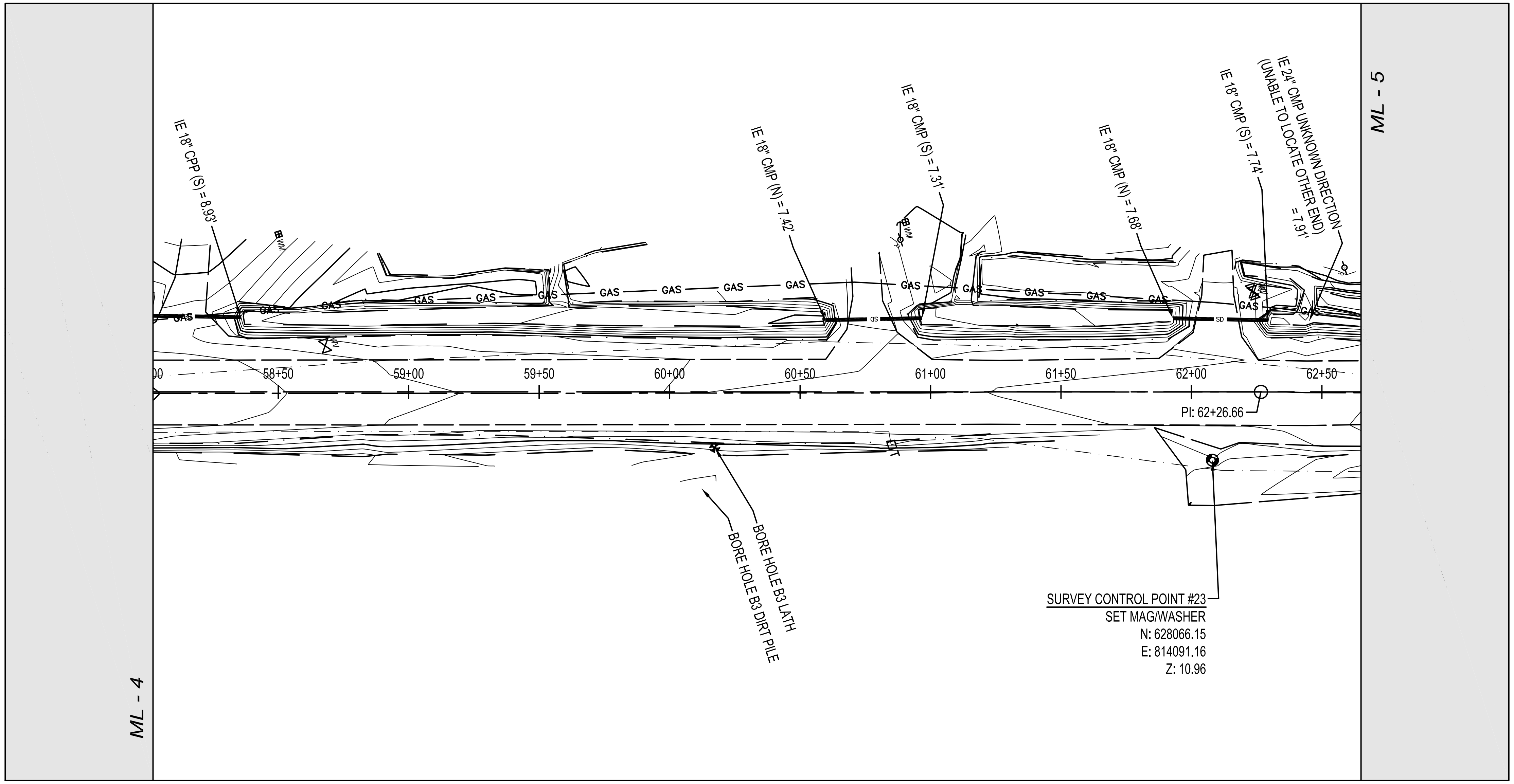
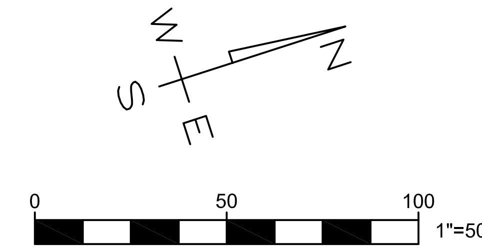
TEL.: (360)532-7630
FAX: (360)532-9682

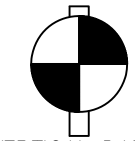
JOB # :13.013
DATE:6/12/13
SCALE:1"=50'
DESIGNED:
DRAWN:JMK
CHECKED:MLS
APPROVED:MLS
DRAWING NO.
S-5
SHEET 5 OF 7

# WISHKAH ROAD SURVEY




MERIDIAN ASSUMED
THE BASIS OF BEARINGS FOR THIS SURVEY IS THE CENTERLINE OF WISHKAH ROAD.



VERTICAL DATUM
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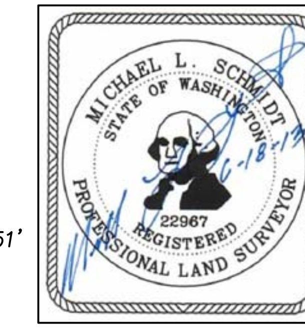


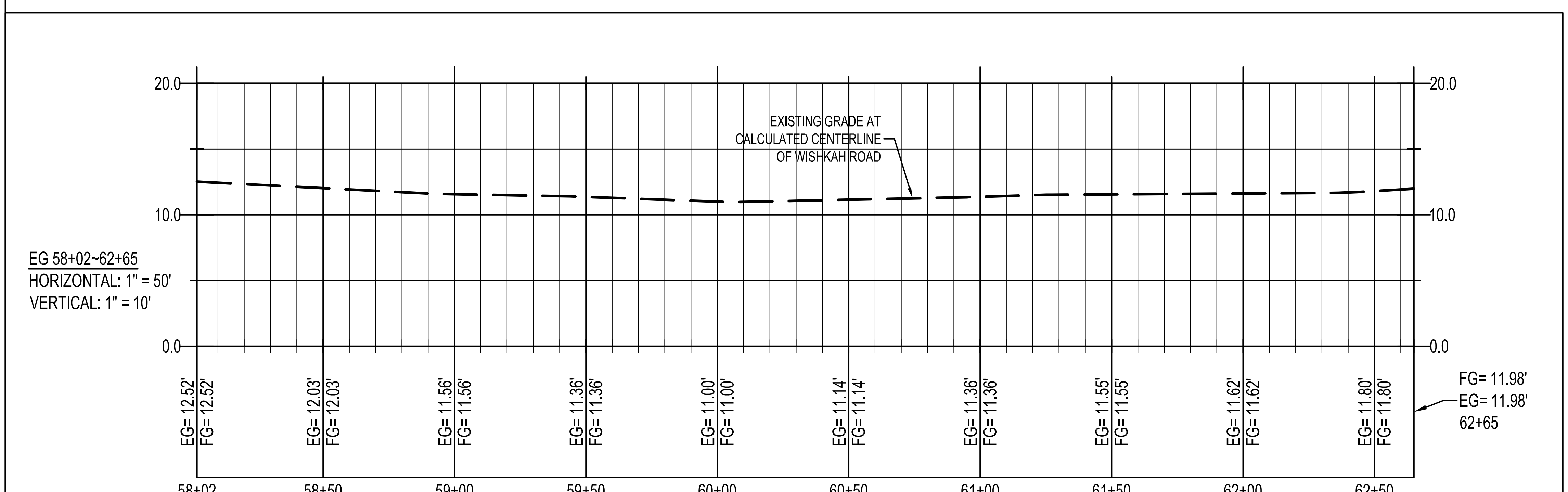


## LEGEND

- BOREHOLE LOCATION
- SURVEY CONTROL POINT
- WATER METER
- FIRE HYDRANT
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- STORM MANHOLE
- STORM INLET STRUCTURE
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- TELEPHONE LINE
- GAS LINE
- WATER LINE
- EDGE OF GRAVEL
- EDGE OF PAVEMENT
- GRASS MOW LINE
- FENCE
- BUILDING

REVISIONS | BY | DATE

Plan/Profile
STA 58+02~62+65

WISHKAH ROAD SURVEY
AMEC Environmental
11810 North Creek Parkway N.
Bothell, Washington 98011

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HOQUIAM, WA 98550
TEL.: (360)532-7630
FAX: (360)532-9682

JOB #: 13.013
DATE: 6/12/13
SCALE: 1"=50'
DESIGNED:
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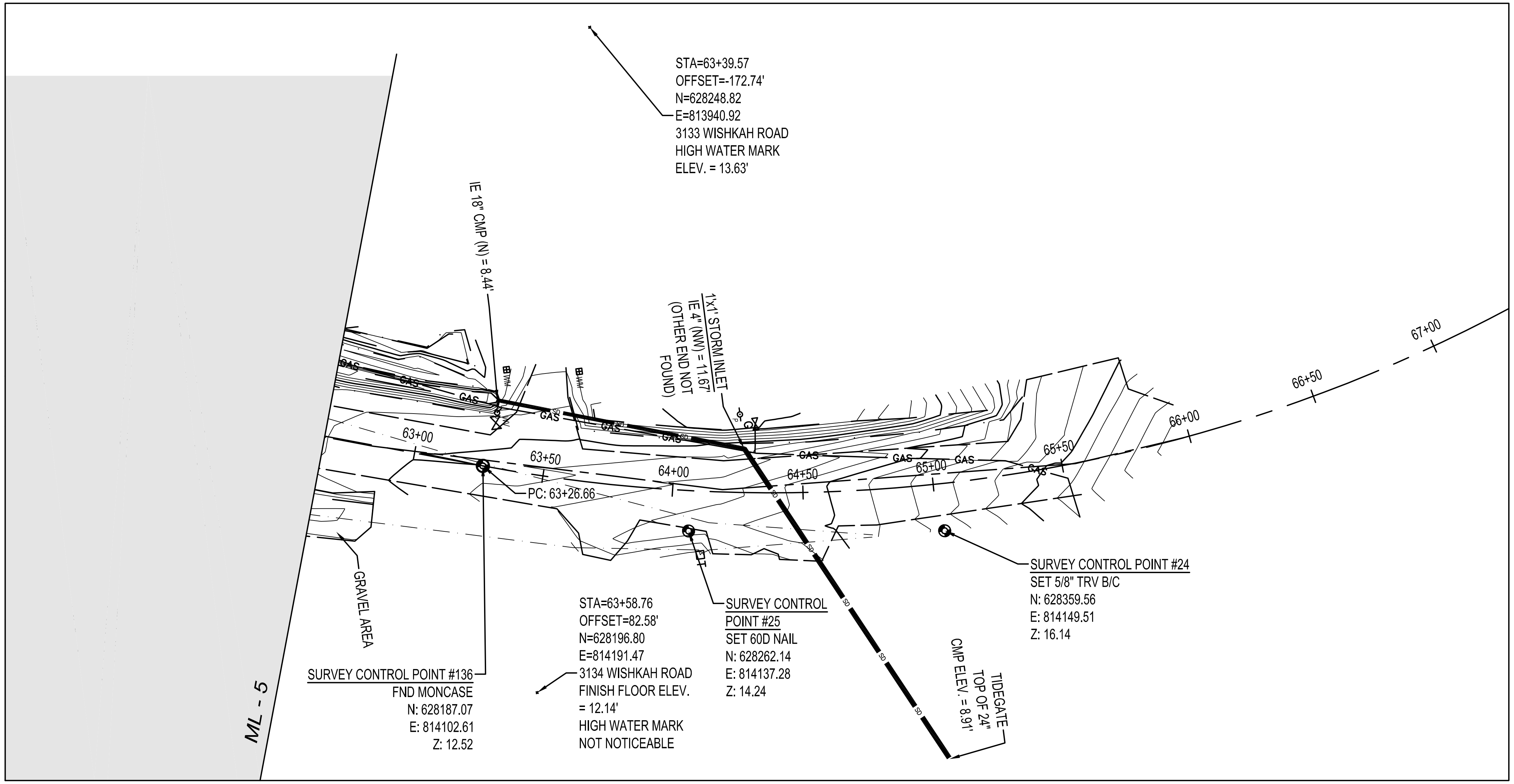
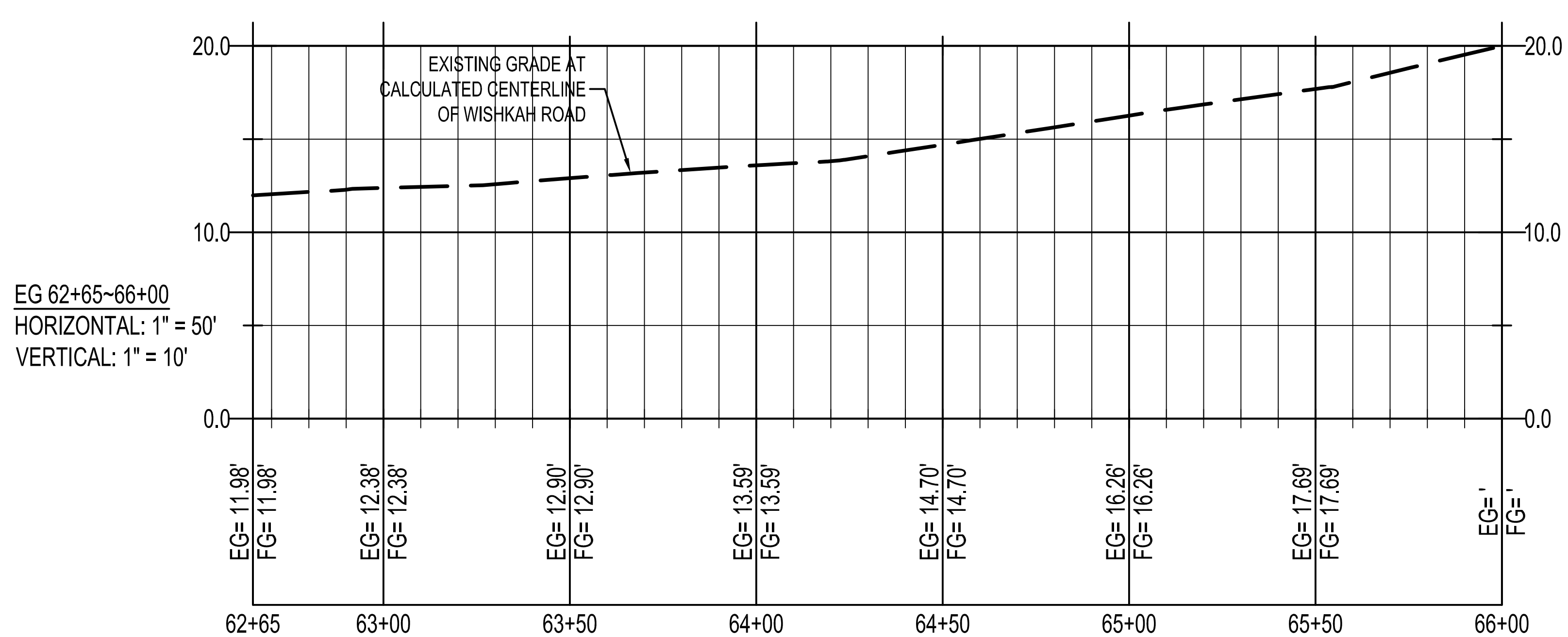
CHECKED: MLS
APPROVED: MLS
DRAWING NO.
S-6
SHEET 6 OF 7

# WISHKAH ROAD SURVEY




0 50 100
1"=50'

MERIDIAN ASSUMED
THE BASIS OF BEARINGS FOR THIS SURVEY IS THE CENTERLINE OF WISHKAH ROAD.

VERTICAL DATUM
NAVD '88
"ABD-214" = 12.51'

MICHAEL L. SCHMIDT
STATE OF WASHINGTON
22967
REGISTERED PROFESSIONAL LAND SURVEYOR

## LEGEND

- BOREHOLE LOCATION
- SURVEY CONTROL POINT
- WATER METER
- FIRE HYDRANT
- WATER VALVE
- STORM MANHOLE
- STORM INLET STRUCTURE
- POWER POLE
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- TELEPHONE LINE
- GAS LINE
- WATER LINE
- EDGE OF GRAVEL
- EDGE OF PAVEMENT
- GRASS MOW LINE
- FENCE
- BUILDING

REVISIONS | BY | DATE

Plan/Profile
STA 62+65~66+00

WISHKAH ROAD SURVEY
AMEC Environmental
11810 North Creek Parkway N.
Bothell, Washington 98011

BERGLUND, SCHMIDT & ASSOC., INC.
professional engineers and land surveyors
2323 BAY AVENUE
HOQUIAM, WA 98550
TEL.: (360)532-7630
FAX: (360)532-9682

JOB #: 13.013
DATE: 6/12/13
SCALE: 1"=50'
DESIGNED:
DRAWN: JMK
CHECKED: MLS
APPROVED: MLS
DRAWING NO.
S-7
SHEET 7 OF 7

# APPENDIX D

Geotechnical Memorandum

# GEOTECHNICAL MEMORANDUM

Kersh-Wishkah Flood Levee Project

Grays Harbor County, Washington

*Prepared for:*

**Grays Harbor County**
Montesano, WA

*Prepared by:*


**AMEC Environment & Infrastructure, Inc.**
11810 North Creek Parkway North
Bothell, Washington 98011


April 25, 2013

Project No. 3-915-17568-0

# TABLE OF CONTENTS



## TABLES



## FIGURES



## APPENDICES

April 25, 2013
Project No. 3-915-17568-0

Grays Harbor County
100 W. Broadway, Suite 31
Montesano, WA 98563

Attention: Mr. Russ Esses, PE

**Subject: Geotechnical Design Memorandum**
Kersh-Wishkah Flood Levee Project
Grays Harbor County, WA

Dear Russ:

AMEC Environment & Infrastructure, Inc. (AMEC), is pleased to submit this report describing our preliminary geotechnical evaluation for the above-referenced project. The purpose of our evaluation was to derive preliminary conclusions and recommendations concerning feasibility of constructing a floodwall or embankment at the site.

As outlined in our contract dated February 12, 2013, our scope of work was limited to field exploration, laboratory testing, and preparation of a geotechnical memorandum. This report has been prepared for the exclusive use of Grays Harbor County and their consultants, for specific application to this project, in accordance with generally accepted geotechnical engineering practice.

## 1.0 SITE AND PROJECT DESCRIPTION

The project site is a segment of Wishkah Road along the west side of the Wishkah River north of Aberdeen, Washington, as shown on the enclosed Site Location Map (Figure 1). The overall segment of Wishkah Road is about 0.5 mile in length, extending from about 400 feet south of the Baretich Road intersection, to about 850 feet north of the Hoffman Road intersection, and lies between road stationing 40+00 to 66+00. The enclosed Site & Exploration Plan (Figures 2a to 2e) illustrate these site boundaries and adjacent existing features.

We understand that a floodwall or raised embankment are being considered as options to provide flood protection for the low-lying segment of Wishkah Road and the nearby residences. The preliminary conclusions and recommendations contained in this report are based on our understanding of the currently proposed utilization of the project site, as derived from layout drawings, written information, and verbal information supplied to us. After specific floodwall or embankment locations have been established, AMEC should be retained to review the proposed layout plans, perform additional geotechnical analyses, as needed; and subsequently prepare a design-phase geotechnical engineering report for the project.

## 2.0 EXPLORATORY METHODS

We explored surface and subsurface conditions at the project site during March 2013. Our exploration and testing program comprised the following elements:

- A visual surface reconnaissance of the site;
- Three borings (designated B-1 through B-3) advanced at strategic locations along the alignment;
- Laboratory testing on representative samples, including 16 moisture content determinations, one 200-wash grain size analysis, and eight Atterberg Limit determinations;
- A review of the logs of three borings made along this segment of roadway during previous roadway realignment design work;
- A review of a geotechnical report for an electrical substation to the south of the project site; and
- A review of published geologic and seismic maps for the vicinity.

Table 1 summarizes the approximate functional locations, surface elevations, and termination depths of the AMEC borings as well as known previous borings by others within the site limits, and Figures 2a to 2e depict their approximate relative locations. The following text sections describe the procedures we used to advance the soil borings and the lab tests we ordered.

**Table 1 Approximate Locations, Elevations, and Depths of Explorations**

| Exploration | Functional Location | Surface Elevation (feet) | Termination Depth (feet below ground surface) |
|---|---|---:|---:|
| B-1 | Wishkah Road Station 43+92 & 23’ East | 9.9 | 51.5 |
| B-2 | Wishkah Road Station 52+12 & 35’ East | 9.1 | 51.5 |
| B-3 | Wishkah Road Station 60+17 & 21’ East | 9.7 | 51.5 |
| J-1* | Wishkah Road Station 68+00 & 52’ West | 41.1 | 31.5 |
| C-3* | Wishkah Road Station 57+00 & 22’ East | 10.5 | 31.5 |
| C-4* | Wishkah Road Station 61+50 & 05’ West | 11.6 | 46.5 |

Elevation datum: 1988 North American Vertical Datum (NAVD88)
* Previous borings by Grays Harbor County

The specific number, locations, and depths of our explorations were selected in relation to the existing and proposed site features, under the constraints of accessibility, underground utility locations, budget, and the level of detail needed during this phase of the project. The locations of the recent borings were surveyed by Berglund, Schmidt, and Associates and are plotted on the attached figures. The earlier borings are plotted on the attached figures using the previously established road stationing and the measured road centerline offset distance from the previous designs. Consequently, the data listed in Table 1 and the locations depicted on Figure 2 should be considered accurate only to the degree permitted by our data sources and implied by our measuring methods.

It should be realized that the explorations performed, and past boring information utilized for this evaluation, reveal subsurface conditions only at discrete locations along the project alignment and that actual conditions in other areas could vary. Furthermore, the nature and extent of any such variations would not become evident until additional explorations are performed or until construction activities have begun. If significant variations are observed at that time, we may need to modify our conclusions and recommendations contained in this report to reflect the actual site conditions.

## 2.1 Soil Boring Procedures

Our exploratory borings were advanced with a hollow-stem auger, using a track-mounted drill rig operated by an independent drilling firm working under subcontract to AMEC. An engineering geologist from our firm continuously observed the borings, logged the subsurface conditions, and collected representative soil samples. All samples were stored in watertight containers and later transported to our laboratory for further visual examination and testing. After each boring was completed, the borehole was backfilled with a mixture of bentonite chips and soil cuttings.

Throughout the drilling operation, soil samples were obtained at 5-foot depth intervals by means of the Standard Penetration Test (SPT) per ASTM:D-1586. This testing and sampling procedure consists of driving a standard 2-inch-diameter steel split-spoon sampler 18 inches into the soil with a 140-pound hammer free-falling 30 inches. The number of blows required to drive the sampler through each 6-inch interval is counted, and the total number of blows struck during the final 12 inches is recorded as the Standard Penetration Resistance, or “SPT blow count.” If a total of 50 blows is struck within any 6-inch interval, the driving is stopped and the blow count is recorded as 50 blows for the actual penetration distance. The resulting Standard Penetration Resistance values indicate the relative density of granular soils and the relative consistency of cohesive soils.

The enclosed Boring Logs describe the vertical sequence of soils and materials encountered in each boring, based primarily on our field classifications and supported by our subsequent laboratory examination and testing. Where a soil contact was observed to be gradational, our logs indicate the average contact depth. Where a soil type changed between sample intervals, we inferred the contact depth. Our logs also graphically indicate the blow count, sample type, sample number, and approximate depth of each soil sample obtained from the borings, as well as any laboratory tests performed on these soil samples. If any groundwater was encountered in a borehole, the approximate groundwater depth is depicted on the boring log. Groundwater depth estimates are typically based on the moisture content of soil samples, the wetted height on the drilling rods, and the water level measured in the borehole after the auger has been extracted.

# 3.0 SITE CONDITIONS

The following sections of text present our observations, measurements, findings, and interpretations regarding development, utility, traffic, surface, soil, groundwater, seismic, and liquefaction conditions at the project site.

## 3.1 Development Conditions

The project site is located along Wishkah Road in the Wishkah River Valley, just north of the city limits of Aberdeen, Washington. The project site is zoned R2 (General Residential) west of the road and a combination of R2 and A1 (Agricultural Use) east of the road. There are several houses and commercial buildings along the west side of Wishkah Road. On the east side of the road, there are only two parcels. The northern one, currently owned by Schultz, has a small residence and southerly one, currently owned by Sanders, has a fishing shack, but the area is otherwise undeveloped.

## 3.2 Utility Conditions

Based on the site utility locate surface markings provided by the utility locating specialists, underground utilities are limited along the eastern right-of-way of Wishkah Road. A buried telephone line is present along the entire alignment, at least up to the Schultz residence. There are overhead power lines that cross Wishkah Road, transitioning to underground power that parallels a waterline to the fishing shack. We did not observe, but assume that there are similar utilities to the residence and out buildings on the Schultz property. On the west side of the Wishkah Road right-of-way, there are underground utilities consisting of gas, telephone and waterlines. Overhead utilities consist of power and cable lines, which are present along the entire length of the alignment on the western side of Wishkah Road. A gas main apparently crosses the river and roadway at the north end of the project alignment. There are also six or more storm drain crossings beneath Wishkah Road that discharge to the river.

## 3.3 Traffic Conditions

Wishkah Road is a single lane asphaltic paved roadway, and the main road that connects Wishkah Valley with downtown Aberdeen. Traffic volume varies throughout the day. Volumes are heaviest between 6:00 to 9:00 am and 4:00 to 6:00 pm, with very light traffic flows during the remainder of the day. Speed limit is marked as 35 miles per hour (MPH), but during the day of our site visit typical speeds appeared to be closer to 45 MPH.

## 3.4 Surface Conditions

Our observations of the surface conditions were made during our site visit on March 28, 2013. The regional topography of the site can be broken down into two geographical provinces comprising the Wishkah Valley and the uplands to the west and north. The project topography in the Wishkah Valley is relatively flat. The elevation down the centerline of Wishkah Road varies from 11 to 13 feet until the northernmost 200 feet, where the elevation increases from 13 to 20 feet at the end of the alignment. Along the eastern side of Wishkah Road, the elevation below the road fill drops down to 8 to 9 feet along the south end, increasing in elevation to 17 feet at the north end of the alignment before sloping down to the river. Along the western side of Wishkah Road, the topography generally slopes upward to the west. At the north and south ends of the alignment, bedrock outcrops are exposed in the road cuts. The Wishkah Valley is narrower on the northern half of the alignment and widens to the south. The adjacent upland elevations range from 50 feet up to over 400 feet further to the west.

Vegetation along the east side of Wishkah Road in and around the drainage ditches consists mostly of low-growing vegetation, including grasses and wetland vegetation. On the drier ground away from the ditches, there is some secondary growth of conifer and alder trees with an understory of blackberry bushes, ferns, Oregon grape, salal and grasses. Vegetation along the west side of Wishkah Road is mostly associated with grasses and landscaped areas and some conifer and deciduous trees.

During our site visit, we observed surface water running in the storm drainage ditches parallel to and crossing the roadway. There are at least six storm drainage pipes that cross Wishkah Road that connect the drainage ditches allowing the stormwater to drain into the Wishkah River. All of them have flap gates on the river side of the pipe, except for the large one that crosses the intersection of Wishkah and Baretich Roads.

## 3.5 Soil Conditions

We reviewed the Washington State Department of Natural Resources Geologic Map GM-33, Geologic Map of the Humptulips Quadrangle and Adjacent Areas, Grays Harbor County, Washington (W.W. Rau 1986) to assess surface and subsurface geologic conditions. Geologic mapping shows the area to be underlain by Quaternary alluvial, lacustrine and peat deposits. The lacustrine and peat deposits are believed to have deposited as the result of temporary damming of the drainage by glacial ice sometime early in the Pleistocene Epoch. The Quaternary soil deposits are underlain by the Montesano, Astoria and Lincoln Creek bedrock formations of Tertiary age, which are generally siltstones and sandstones. According to geologic mapping, these bedrock layers have been folded and faulted beneath the project site.

Our on-site borehole explorations revealed fairly uniform near-surface soil conditions that became more variable with depth in the northern half of the alignment and generally confirmed the mapped stratigraphy. A description of the subsurface conditions by stationing is described below.

Station 40+00 to 52+00: The subsurface soils in this segment of the project alignment were investigated with borehole B-1. It penetrated 2.5 feet of sandy gravel fill soils before encountering 3 additional feet of soft clayey silt disturbed/fill soils to a depth of 5.5 feet. Beneath the road fill soils, our explorations encountered lacustrine and marsh deposits consisting of interlayers of very soft to soft elastic silts, organic silts, fat clays, organic clays and peat deposits with scattered small diameter woody debris. In borehole B-2 it appeared that these lacustrine/marsh deposits may have been penetrated at a depth of 51 feet. Below 51 feet pieces of greenish gray silty sandstone were recovered suggesting that the Tertiary Montesano Formation may have been encountered.

Station 52+00 to 66+00: The subsurface soils in this segment of the project alignment were investigated with boreholes B-2 and B-3 and previously advanced boreholes C-3 and C-4 (also borehole J-1 located about 200 feet north of the project). While previous explorations were advanced outside of the road prism that existed at the time, borehole B-3 was advanced through the prism of road fill soils. B-3 encountered 4.5 feet of loose sandy gravel fill soils. Beneath the road fill soils, all explorations encountered lacustrine and marsh deposits consisting of interlayers of very soft to soft elastic silts, organic silts, fat clays, organic clays and peat deposits with scattered small diameter woody debris. However, the thickness of these deposits varied along the alignment, starting in the south at borehole B-2 at 51 feet thick, borehole C-3 at 13 feet thick, borehole B-3 at 31 feet thick, borehole C-4 at 26 feet thick and borehole J-1 at 3 feet thick. Beneath the lacustrine/marsh deposits there is a weathered bedrock zone consisting of medium stiff to stiff soils varying in thickness from 3 to 18 feet. Our exploration B-3 also encountered the greenish gray silty sandstone recovered in our borehole B-2 at a depth of 51 feet thought to be the Tertiary Montesano Formation, at a depth of 35.75 feet. At a depth of 44 feet there was a change in drilling characteristics suggesting that we may have encountered the Tertiary Astoria Formation consisting of dark gray very stiff to hard siltstone. This contact with the extremely weak siltstone bedrock appears to be more evident in previous boreholes C-3 at a depth of 16 feet, C-4 at a depth of 44 feet and J-1 at a depth of 18 feet.

Based on our review of the available geology for the region, the undulating surface between the lacustrine/marsh deposits can be attributed to the project alignment lying along the flanks of the Cemetery Syncline and the Bear Creek Anticline. The undulating contact and weak bedrock could also be attributed to the mapped unnamed fault that cuts through the project alignment in a northeast-southwest direction.

The enclosed exploration logs provide a detailed description of the soil strata encountered in our subsurface explorations, and Table 2 summarizes the approximate thicknesses, depths, and elevations of selected soil layers. The enclosed Site Plan with Geologic Profile AA-AA' (Figures 2a-2e) illustrate our stratigraphic interpretations at selected locations along the project alignment.

**Table 2 Approximate Thicknesses, Depths, and Elevations of Soil Layers Encountered in Explorations**

| Exploration | Thickness of Fill Soils (feet) | Thickness of Lacustrine/ Marsh Deposits (feet) | Thickness of Weathered Bedrock/ Dense Soil (feet) | Depth of Bedrock/ Dense Soil (feet) | Elevation of Bedrock/ Dense Soil (feet) |
|---|---|---|---|---|---|
| B-1 | 5.5 | 46.0+ | N/E | N/E | N/E |
| B-2 | N/E | 51.0 | 0.5+ | N/E | N/E |
| B-3 | 4.5 | 31.2 | 15.8+ | N/E | N/E |
| J-1* | N/E | 3.0 | 15.0 | 18 | 26.1 |
| C-3* | N/E | 13.0 | 3.0 | 16 | -5.5 |
| C-4* | N/E | 26.0 | 18.0 | 44 | -32.4 |

Elevation datum: 1988 North American Vertical Datum (NAVD88)
N/E not encountered within depth of exploration
* Previous borings by Grays Harbor County

Our geotechnical laboratory tests revealed that the lacustrine/marsh deposits comprise over 75 percent silt and clay with a high organic/peat content. The silts are elastic and/or organic and the clays are fat and/or organic. Moisture content distributions range from 51 to 197 percent, with plastic limits ranging from 32 to 74 percent, liquid limits ranging from 67 to 170 percent, and plasticity indexes ranging from 27 to 96. No laboratory testing was performed on the recovered bedrock.

We interpret these soils to be currently above their optimum moisture contents and to be highly sensitive to moisture content variations. The enclosed laboratory testing sheets graphically illustrate our test results, and Table 3 summarizes these results.

**Table 3 Laboratory Test Results for Non-Organic On-Site Soils**

| Soil Sample | Moisture Content (percent) | Silt / Clay content (percent) | Plastic Limit (percent) | Liquid Limit (percent) | Plasticity Index (percent) |
|---|---|---|---|---|---|
| B-1/ S-2@ 10 feet | 83.4 | — | — | — | — |
| B-1/ S-4@ 20 feet | 51.9 | — | 32 | 83 | 51 |
| B-1/ S-6@ 30 feet | 79.4 | 77 | — | — | — |
| B-1/ S-7@ 35 feet | 113.6 | — | — | — | — |
| B-1/ S-8@ 40 feet | 144.1 | — | 74 | 170 | 96 |
| B-2/ S-2@ 10 feet | 113.1 | — | 47 | 75 | 28 |
| B-2/ S-3@ 15 feet | 81.3 | — | — | — | — |
| B-2/ S-5@ 25 feet | 97.8 | — | 40 | 67 | 27 |
| B-2/ S-6@ 30 feet | 197.4 | — | — | — | — |
| B-2/ S-7@ 35 feet | 88.8 | — | — | — | — |
| B-2/ S-9@ 45 feet | 79.3 | — | 38 | 83 | 45 |
| B-3/ S-1@ 05 feet | 93.3 | — | 40 | 94 | 54 |
| B-3/ S-2@ 10 feet | 98.5 | — | — | — | — |
| B-3/ S-4@ 20 feet | 115.8 | — | — | — | — |
| B-3/ S-5@ 25 feet | 94.9 | — | 43 | 113 | 70 |
| B-3/ S-6@ 30 feet | 131.6 | — | 46 | 96 | 50 |

## 3.6 Groundwater Conditions

At the time of drilling (March 2013), we did not encounter any groundwater in our borings. However, at our boring location B-1, surface water ran into our exploration suggesting that there is a perched groundwater table occurring between the prism of fill soils for the roadway and the native silt and clay soils. It should be noted that although groundwater was not encountered during drilling, the soils may just be slow to exhibit seepage due to their fine-grained characteristics. The collected soil samples exhibited high moisture contents (often at or above their Atterberg liquid limit), and it is possible that a groundwater table would be observed within a few feet of ground surface if a well was installed. Because our explorations were performed during an extended period of generally wet weather, these observed groundwater conditions may closely represent the yearly high levels; even higher levels would be expected during periods of flooding; somewhat lower levels probably occur during the summer and fall months. At all times of the year, groundwater levels would likely fluctuate in response to changes in precipitation, the stage of the Wishkah River, withdraws from nearby wells, and the use of irrigation and drain fields.

## 3.7 Seismic Conditions

For planning of floodwalls or levee embankments, we propose to follow recommendations found in the US Army Corps of Engineers Process for the National Flood Insurance Program (NFIP) Levee

System Evaluation, USACE (2010). This document states that the median annual water level shall be combined with the 1 percent annual chance exceedance earthquake (100 year return period) load for the evaluation of seismic stability.

Based on analysis of subsurface exploration logs and review of published geologic maps, we interpret the on-site soil conditions to correspond to a seismic site class E, as defined by Table 3.4.2.1-1 of the 2009 American Association of State Highway and Transportation Officials (AASHTO) manual entitled *Guide Specifications for LRFD Seismic Design First Edition*.

National Seismic Hazard Maps prepared by the USGS (2002) indicate that a peak bedrock site acceleration coefficient of about 0.1g (where g is the acceleration due to gravity) is appropriate for a 100-year return interval earthquake. The actual peak acceleration at the ground surface would be greater than the peak bedrock acceleration due to amplification through soft alluvial soils above the bedrock. According to the American Society of Civil Engineers (2010), for a Site Class E, and bedrock acceleration of 0.1g, the value will amplify by a factor of 2.5, so that a peak ground surface acceleration value of 0.25g should be used for design.

Regional mapping indicates a moderate to high liquefaction risk in Wishkah Valley soils, and very low risk in surrounding areas underlain by bedrock. Based on the fine grained nature of site soils we encountered, we would conclude the risk of liquefaction at this site is relatively low. However, these soft organic silts and peats would be subject to ground deformation and lateral spreading toward the river bank. This is expected to be minor during a 100-year return interval earthquake, but may be significant during stronger earthquake shaking.

The above methodology provides reasonable protection against floodwall/levee damage for an earthquake with a 100-year recurrence interval. The USACE Levee Design Manual EM 1119-2-1913 does not normally consider further analysis of the stability of levees for earthquakes because of the low probability of an earthquake coinciding with periods of high water. In the case of an extreme earthquake event, more extensive liquefaction and lateral spreading could occur. After any significant earthquake event, the condition of the floodwall or levee should be inspected and repairs made as necessary.

### 3.8 Settlement and Ground Subsidence Review

There are several factors that could lead to settlement at this site that should be considered in selection of a flood protection system. These are discussed in the following paragraphs.

Observed Settlement: We compared the current surveyed elevations to the finish grades for the 1989 – 1990 road realignment. Embankment fill heights for the roadway realignment project appear to have been on the order of 1 to 4 feet, and it appears that settlements of 0.5 to 2.5 feet have occurred in 23 years. The least amount of settlement was observed to coincide with shallow bedrock areas, and greatest settlements in areas of deep soft alluvial deposits. The differential settlement could be attributed to variations in fill thickness, as well as variations in the thickness and composition of underlying compressible soils. These values are considered approximate, since the precise stationing/ centerline locations may vary, and it is not known if the as-built road profile was consistent with the plans

Primary Settlement: Based on our review of apparent embankment fill heights, as well as lab test data (moisture contents and Atterberg limit data), we would expect settlement due to primary consolidation to be on the order of 20 to 30 percent of the fill height. This would account for settlements of roughly 0.3 to 1.2 feet.

Ground Subsidence: Because the very soft organic silts had measured moisture contents at or above the measured Atterberg liquid limit, these soils would be considered “underconsolidated,” and susceptible to ongoing subsidence-type settlement under their own self-weight, even without the addition of fill. Based on our experience with similar soils, the subsidence might be on the order of 0.25 to 0.5 inch per year, which could account for 0.5 to 1 foot of settlement of the area in the last 24 years.

Secondary Creep-Type Settlement: In addition to primary consolidation settlement, the organic soils are subject to long term decomposition and secondary creep-type settlement. This could account for a small portion of the observed settlement.

Earthquake-Induced Settlement: As discussed previously, the risk of liquefaction at this site is considered relatively low, however, deformation of soft organic soils under ground shaking is possible We observed such settlement in areas of organic deposits as a result of the 2001 Nisqually earthquake event.

## 4.0 CONCLUSIONS AND RECOMMENDATIONS

Improvement plans call for considering either a floodwall or a raised earthen embankment to provide added protection against flooding. We offer the following preliminary geotechnical conclusions and recommendations concerning this improvement project.

### 4.1 Feasibility of Floodwall

Based on our field explorations and research, the proposed floodwall appears feasible from a geotechnical standpoint. A sheet pile wall would appear to be the most cost-effective wall type. The wall should be designed to resist lateral earth pressures as depicted in Figure 3. The soils are amenable to installation of interlocking sheet piles installed by a vibratory hammer.

While not disclosed by our explorations, obstructions such as buried logs or stumps could be an impediment to installing sheet piles. In addition, according to Russ Esses, there may have been a corduroy road beneath the existing roadway. The northern portion of road in the project area was realigned slightly to the east in about 1989 and to the best of our knowledge the new alignment would be offset from the old corduroy road. If obstructions are encountered during installation, it would be necessary to excavate or pre-drill through them to complete the wall in the chosen alignment. The excavated area would be disturbed, and would need to be treated to provide equivalent or better lateral resistance than the soils that were disturbed or removed. This might involve backfilling the pre-excavation with a slurry sand, washed gravel, controlled density fill or similar self-compacting material, prior to resuming the sheet pile installation.

As interpreted on Figure 2c, the depth to bedrock may be relatively shallow along about 500 feet of the alignment. Based on previous borings, dense soil or bedrock was encountered at about 16 feet below grade (approximate elevation -5 feet NAVD88). While it should be feasible to embed sheet piles into weathered bedrock, the piles may encounter practical refusal on non-weathered bedrock. If sheet piles need to be embedded deeper, this may require pre-drilling at these locations.

Decisions regarding the wall height will depend on the design flood elevation, the desired freeboard above flood elevation, and anticipated long term settlement of the wall. The USACE and FEMA typically recommend a minimum 2 foot freeboard above base flood elevation, and would add to the freeboard to account for any anticipated settlement. As discussed above, subsidence over a 20-year design life for areas with no additional filling is anticipated to be on the order of 0.5 to 1 foot.

## 4.2 Feasibility of Embankment

Based on our explorations, the soils beneath the site are moderately to highly compressible. Therefore, raising the road or creating a new levee embankment would likely involve overbuilding the embankment height to accommodate predicted long-term settlements. The addition of fill during construction may also need to be staged to avoid a bearing capacity failure. These items area discussed below.

We anticipate the embankment might need to be as much as about 8 feet in height to provide flood protection with adequate freeboard. For planning, we would anticipate embankment side slopes of 2H:1V or flatter. A minimum crest width of 10 to 12 feet is recommended by the USACE Levee Design Manual to allow access during flood fighting, and to allow for embankment re-grading to long term differential settlement.

For design planning, we anticipate that an 8 foot high levee could settle on the order of 1.5 to 2.5 feet due to primary consolidation. A large portion of this primary settlement would occur within the first 6 months after filling. Therefore, the embankment should be overbuilt in anticipation of this future settlement.

Because the subgrade soils are very soft, there is a risk of a bearing capacity-type failure during fill placement if fill is placed too rapidly and to an excessive height. For planning, to avoid the risk of bearing capacity failures, we recommend staged construction such that fills not exceed 5 feet in height over a period of 1 year. In this way, the underlying soil can consolidate and gain strength prior to completion of the full height embankment.

As discussed, the fill placed during the second season would also undergo primary settlement that would mainly be completed after about 6 months. Final grading of the roadway surface should be conducted after the full embankment height has been achieved (likely during the third year).

We estimate another 0.5 to 1 foot of settlement may occur due to ongoing subsidence of the area. Differential settlement due to secondary creep or earthquake deformation may also occur over the life of the facility. To reduce the risk of differential settlement, a preload or surcharge could be included as part of the initial construction.

While overbuilding and possibly even preloading are measures that will reduce future settlement, there will continue to be a risk of some long term differential settlement. Therefore an access road should be maintained along the crest of the embankment, and topographic surveys should be conducted periodically to verify that adequate flood protection is being provided.

If the new levee embankment is placed close to the existing Wishkah Road, this new embankment load may produce settlement of Wishkah Road. The amount of settlement will decrease with increasing distance from the new embankment.

If Wishkah Road would be placed on top of the embankment, this would present logistical and practical challenges related to roadway vertical curve, grades at road intersections and driveways, the need to relocate above ground utilities and poles, and the potential for induced settlement adversely affecting buried utilities.

## 4.3 Other Considerations

For either the floodwall or the levee, the existing drainage outfalls and any utilities along the east side of the right of way will need to be protected or relocated. This includes the gas main crossing at the north end of the project alignment.

## 4.4 Design-Phase Evaluation

After the specific floodwall or levee alignment and associated structure locations have been established, we should be retained to perform a design-phase geotechnical evaluation. Such an evaluation may include advancing additional borings along the specific floodwall or embankment alignment (primarily to more accurately establish depths to bedrock), conducting laboratory tests, performing geotechnical engineering analyses, and preparing a Geotechnical Engineering Report.

# 5.0 CLOSURE

The preliminary conclusions and recommendations presented in this report are based, in part, on the explorations that we performed for this study. If our design-phase geotechnical explorations reveal significant variations in subgrade conditions, we may need to revise these conclusions and recommendations. AMEC would be pleased to submit a proposal for a design-phase evaluation after the floodwall/embankment alignment and height details have been established.

We appreciate the opportunity to be of service on this project. If you have any questions regarding this report or any aspects of the project, please feel free to contact our office.

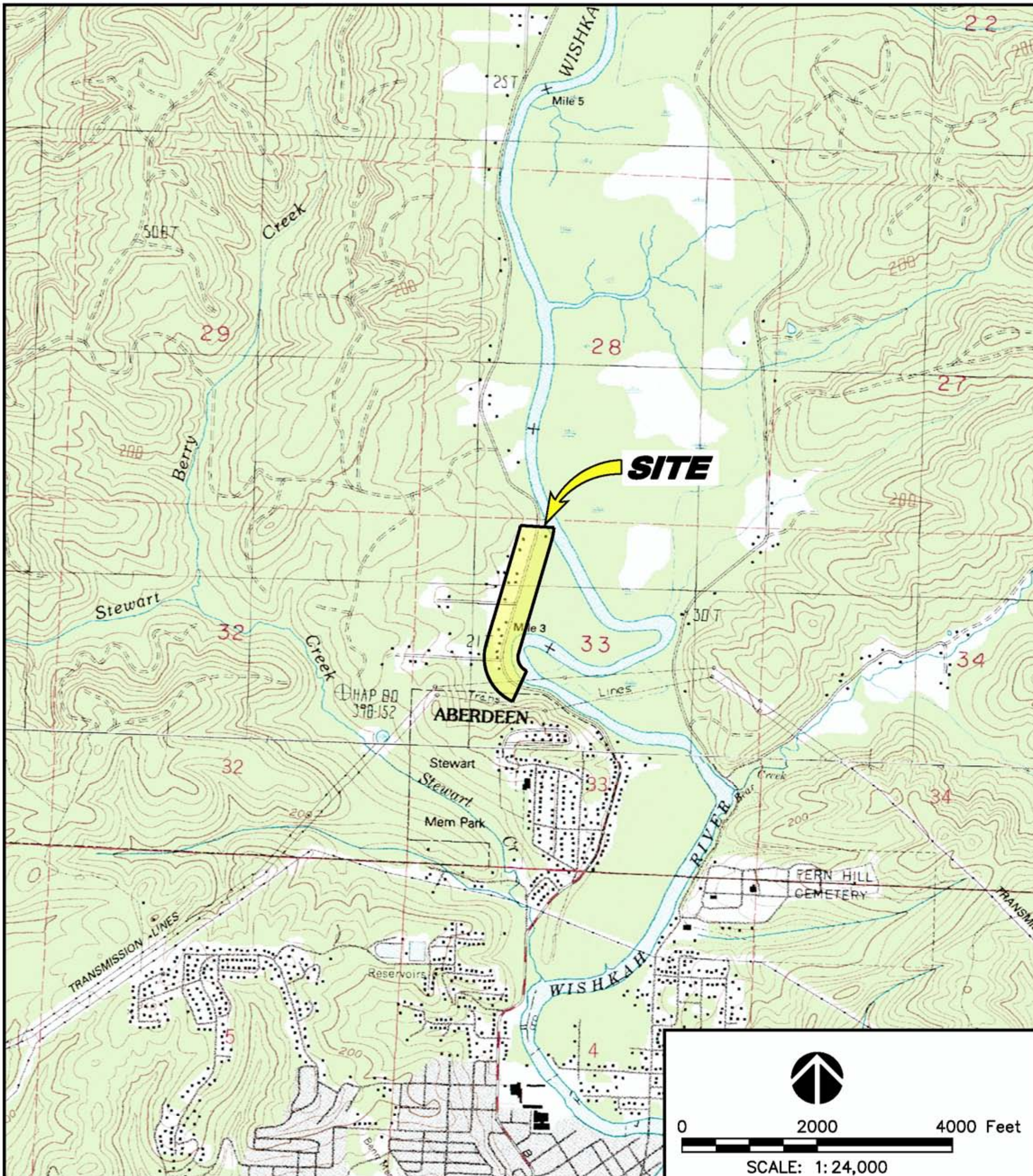
Sincerely,

**AMEC Environment & Infrastructure, Inc.**

Henry W. Brenniman, L.E.G
Senior Engineering Geologist

James S. Dransfield, P.E.
Principal Geotechnical Engineer

# FIGURES

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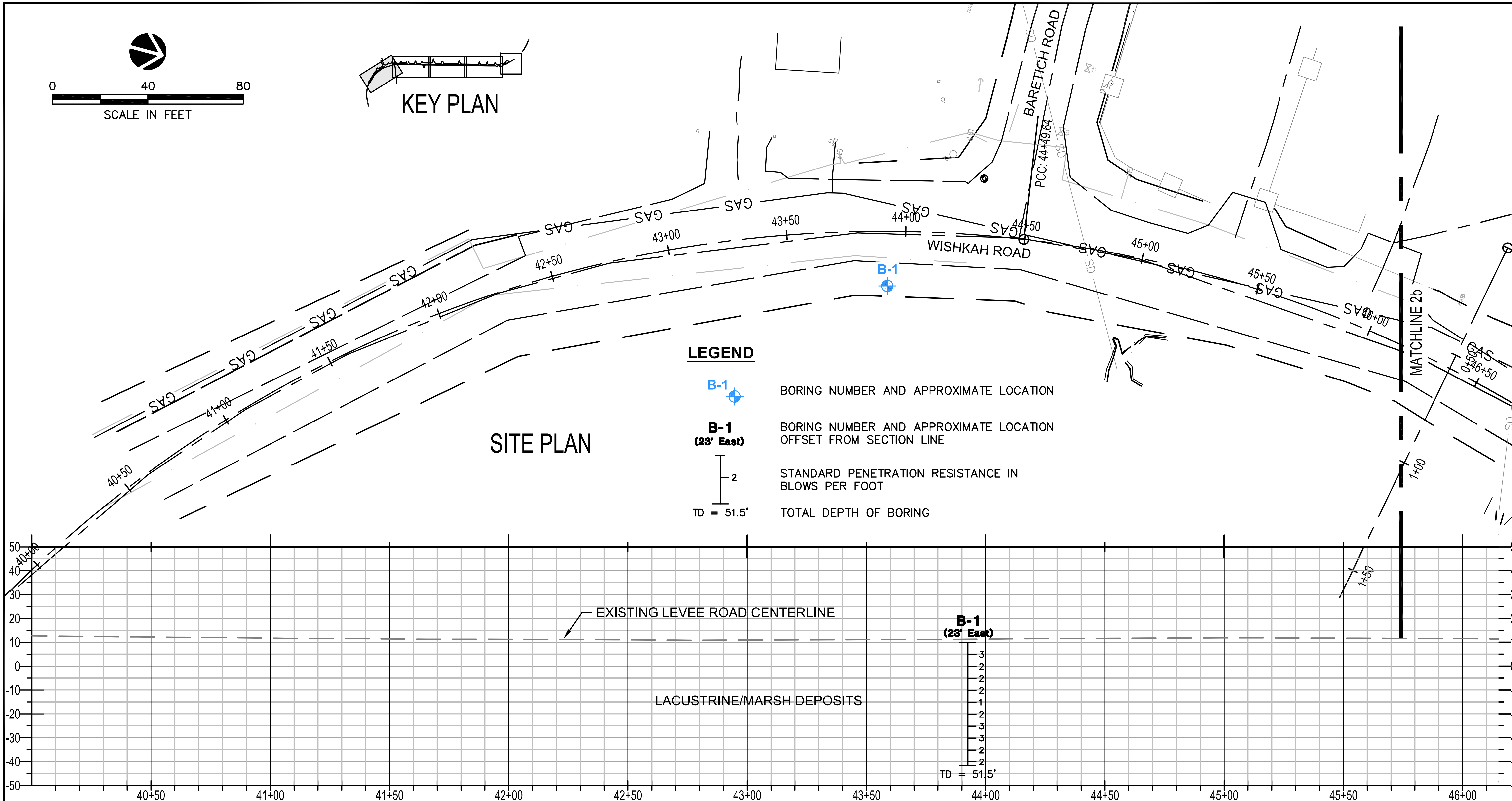
| TITLE<br>SITE LOCATION MAP | | CHK'D BY:<br>HWB | REV. NO.: | PROJECT NO:<br>3-915-17568-0 |
| | | PROJECTION:<br>WA STATE PLANE | SCALE:<br>AS SHOWN | FIGURE No.<br>1 |




PROFILE VIEW OF ROAD ALIGNMENT

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| | AMEC Environment & Infrastructure<br>11810 North Creek Parkway North<br>Bothell, WA, U.S.A. 98011-8201 | amec |
| DWN BY: JRS | PROJECT: KERSH-WISHKAH FLOOD LEVEE | DATE: APRIL 2013 |
| CHK'D BY: HWB | | PROJECT NO: 3-915-17568-0 |
| DATUM: | TITLE: SITE PLAN | REV. NO.: |
| PROJECTION: | | FIGURE No. 2a |
| SCALE: AS SHOWN | | |

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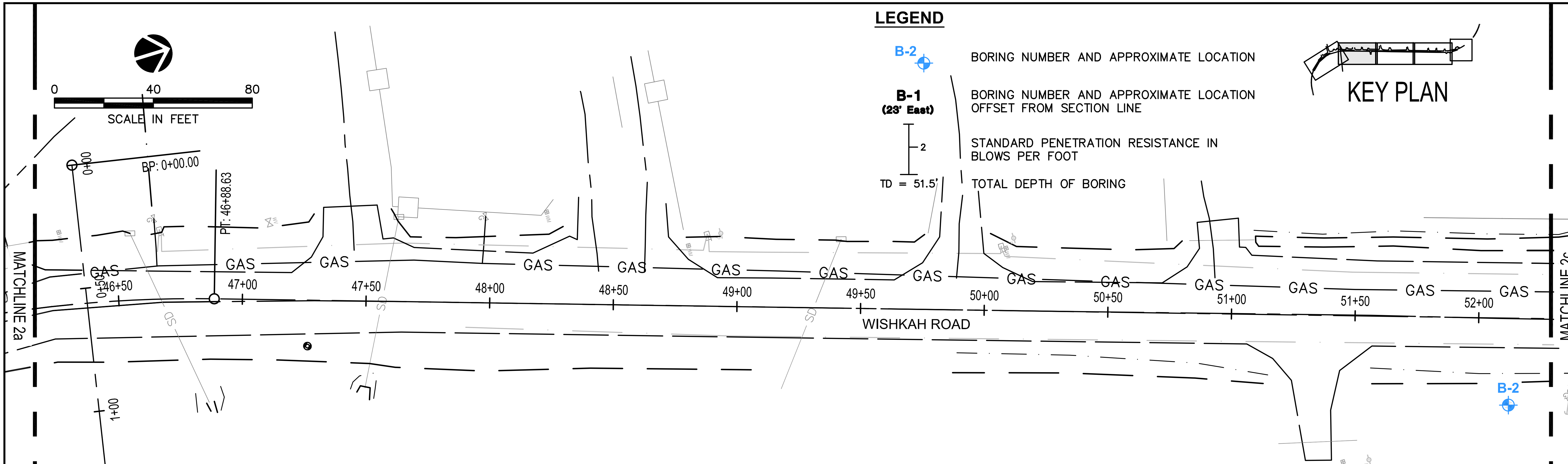
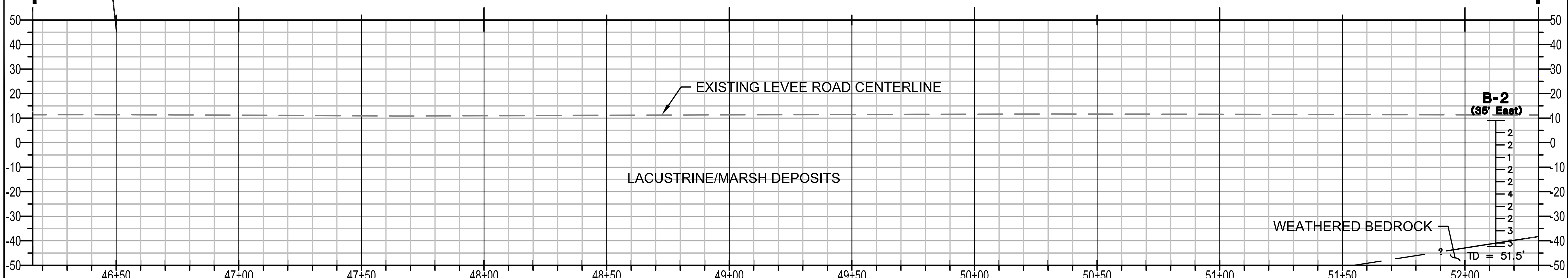



SITE PLAN




PROFILE VIEW OF ROAD ALIGNMENT

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| | | | CHK'D BY: HWB | | PROJECT NO: 3-915-17568-0 |
| | | AMEC Environment & Infrastructure<br>11810 North Creek Parkway North<br>Bothell, WA, U.S.A. 98011-8201 | DATUM: | TITLE: SITE PLAN | REV. NO.: |
| | | amec | PROJECTION: | | FIGURE No. 2b |
| | | | SCALE: AS SHOWN | | |

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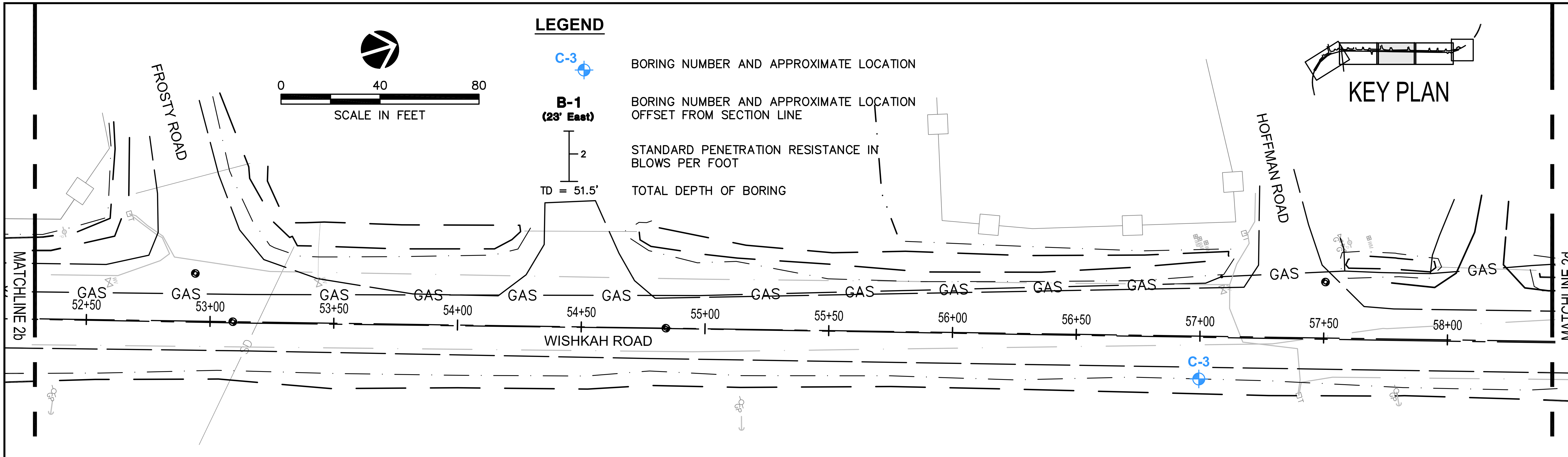
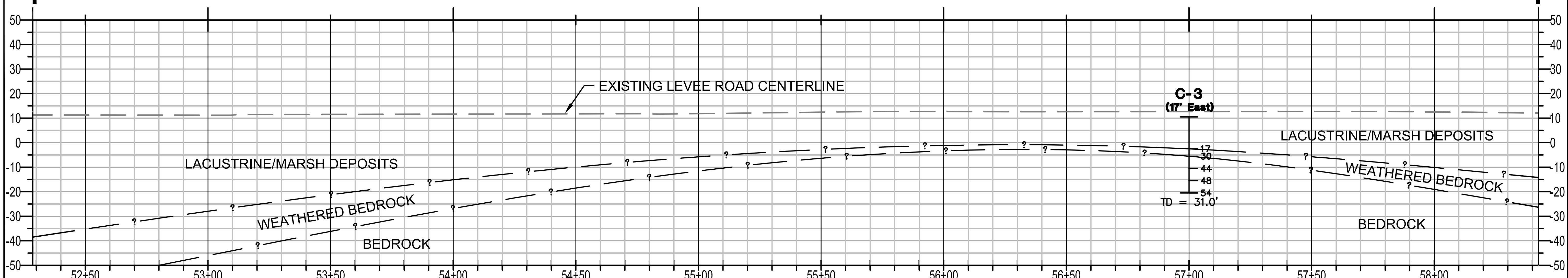



SITE PLAN




PROFILE VIEW OF ROAD ALIGNMENT

CLIENT LOGO

CLIENT:

AMEC Environment & Infrastructure
11810 North Creek Parkway North
Bothell, WA, U.S.A. 98011-8201

DWN BY: JRS
CHK'D BY: HWB
DATUM:
PROJECTION:
SCALE: AS SHOWN

PROJECT: KERSH-WISHKAH FLOOD LEVEE

TITLE: SITE PLAN

DATE: APRIL 2013
PROJECT NO: 3-915-17568-0
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FIGURE No. 2c

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## LEGEND

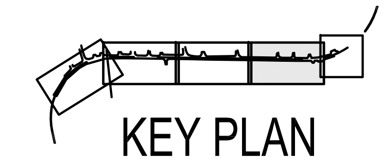
C-4 — BORING NUMBER AND APPROXIMATE LOCATION

B-1 (23' East) — BORING NUMBER AND APPROXIMATE LOCATION OFFSET FROM SECTION LINE

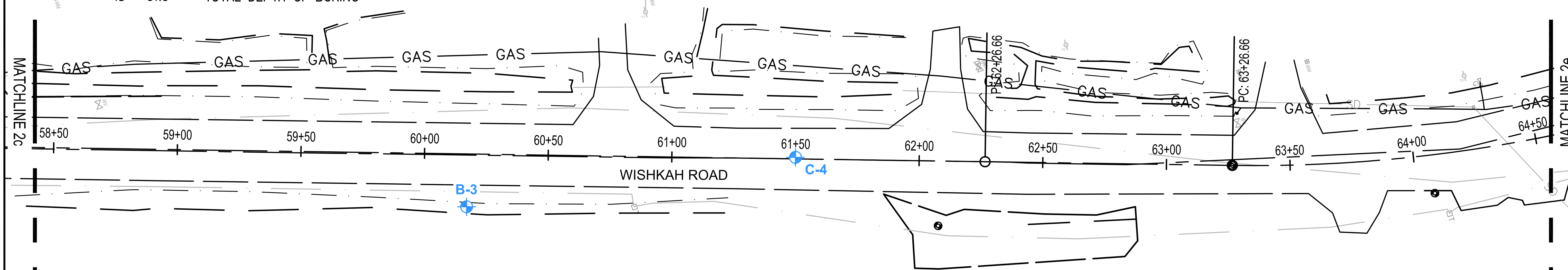
2 — STANDARD PENETRATION RESISTANCE IN BLOWS PER FOOT

TD = 51.5' — TOTAL DEPTH OF BORING

0 40 80
SCALE IN FEET



KEY PLAN

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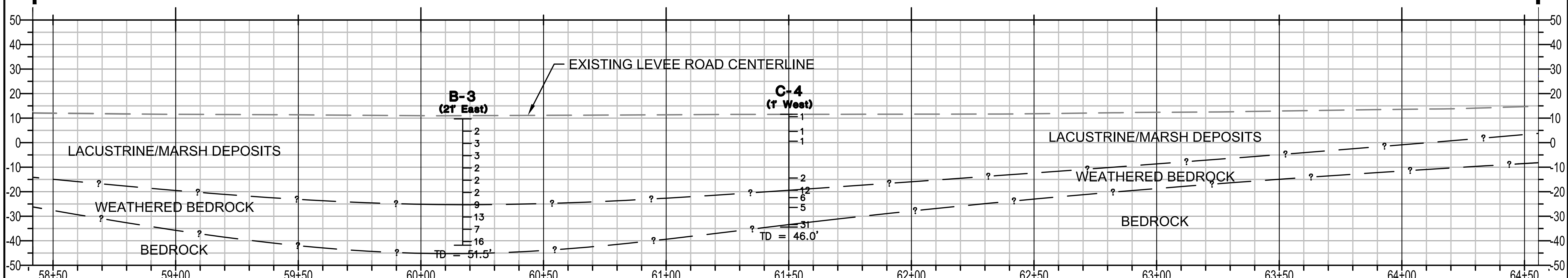


PROFILE VIEW OF ROAD ALIGNMENT

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| PROJECTION: | | FIGURE No. 2d |
| SCALE: AS SHOWN | | |

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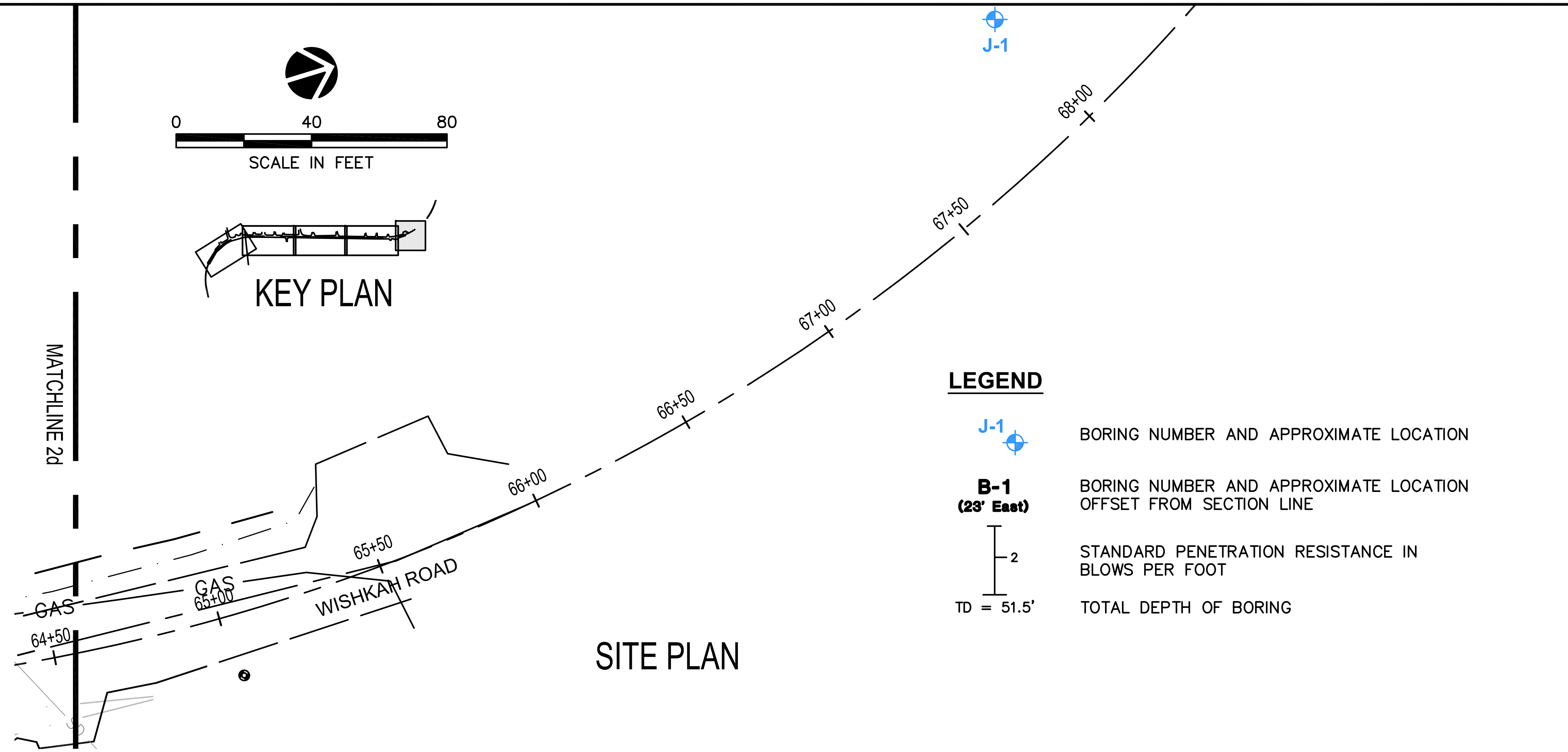


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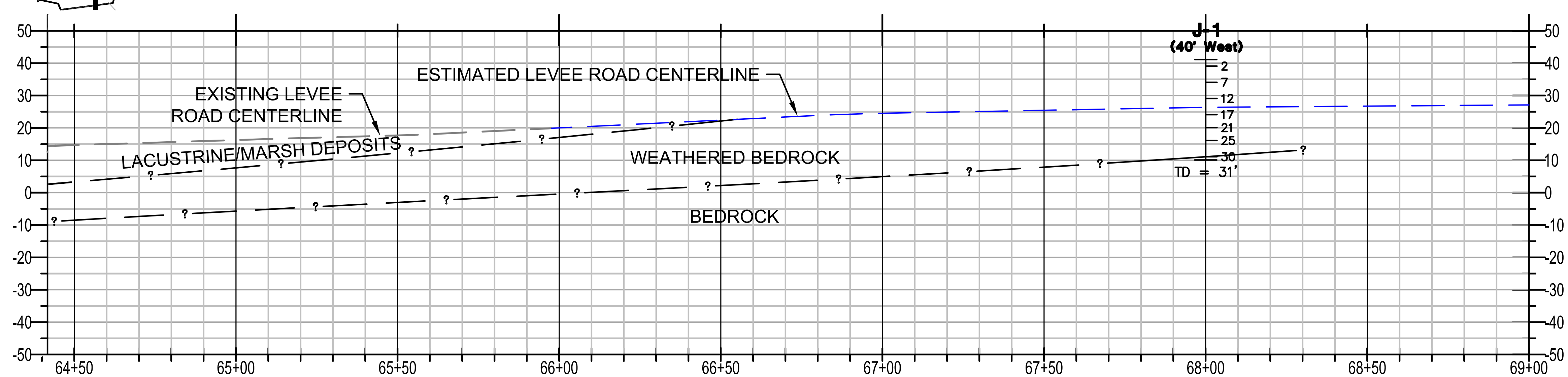


PROFILE VIEW OF ROAD ALIGNMENT

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| | amec | DATUM: | TITLE: SITE PLAN | REV. NO.: |
| | | PROJECTION: | | FIGURE No. 2e |
| | | SCALE: AS SHOWN | | |

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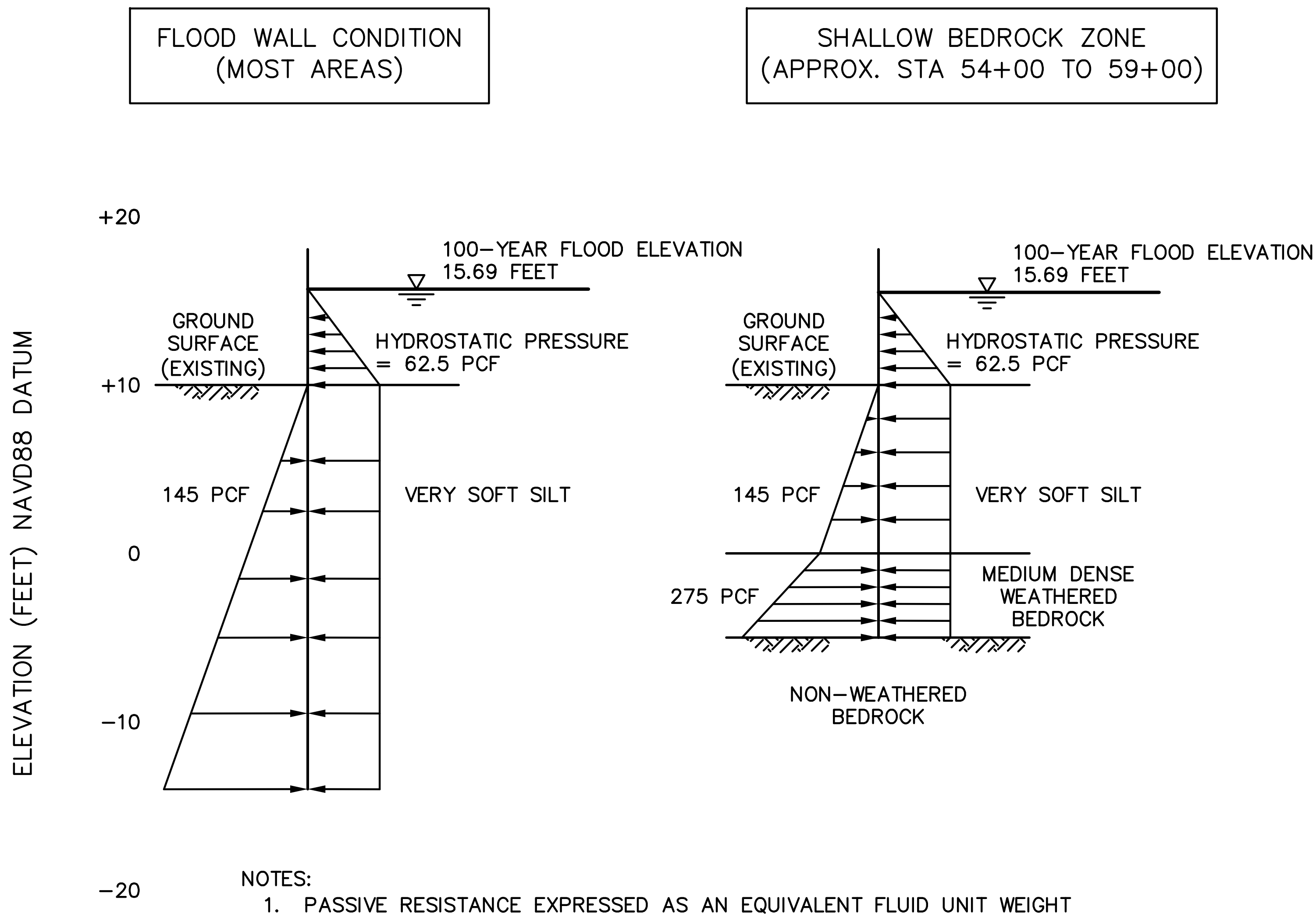



NOTES:
1. PASSIVE RESISTANCE EXPRESSED AS AN EQUIVALENT FLUID UNIT WEIGHT (ULTIMATE). AN APPROPRIATE SAFETY FACTOR SHOULD BE APPLIED.
2. THIS IS A NET PASSIVE PRESSURE (ACTIVE PRESSURE INCORPORATED).
3. PRESSURES ACT OVER FULL WIDTH OF SHEET PILING.

| | | | |
|---|---|---|---|
| CLIENT LOGO | CLIENT: GRAYS HARBOR COUNTY | DWN BY: JRS | PROJECT: KERSH-WISHKAH FLOOD LEVEE |
| | | CHK'D BY: JSD | REV. NO.: |
| | | | DATE: APRIL 2013 |
| AMEC Environment & Infrastructure<br>11810 North Creek Parkway North<br>Bothell, WA, U.S.A. 98011-8201 | amec | DATUM: NONE | TITLE: LATERAL EARTH PRESSURE DIAGRAM |
| | | PROJECTION: NAVD88 | PROJECT NO: 3-915-17568-0 |
| | | SCALE: NOT TO SCALE | FIGURE No. 3 |

G:\91\17000\17568 – Kersh–Wishkah Flood Levee\17568–05.dwg – Pressures–Level – Apr. 29, 2013 8:50am – jeffrey.sanders

## APPENDIX A

Boring Logs B-1 through B-3

PROJECT: *Kersh-Wishkah Road Levee Project* JOB No. *3-915-17568-0* BORING No. *B-1*



Soil Description

Location: Wishkah Road Station 43+92 & 23' East

Approximate ground surface elevation: 9.9 feet

| DEPTH (feet) | Soil Description | SAMPLE NUMBER | GROUND WATER | PENETRATION RESISTANCE (Blows per foot) | MOISTURE CONTENT | TESTING |
|---|---|---|---|---|---|---|
| 0 | Loose, wet, yellowish brown to brown, sandy GRAVEL with some silt (Fill) GP-GM | | N/E | | | |
| | Soft, wet, clayey SILT with with some orangish brown, sandy SILT inclusions (Fill) ML | | | | | |
| 5 | Relict Topsoil | S-1 | | 3 | | |
| | Very soft, wet, brown-gray, elastic SILT with some organics (Quaternary Lacustrine/Marsh Deposits) MH-OH | | | | | |
| 10 | Very soft wet, gray, fat CLAY with some fibrous and black organics and very thin PEAT lenses (Quaternary Lacustrine/Marsh Deposits) CH-OH | S-2 | | 2 | ● | |
| 15 | | S-3 | | 2 | | |
| 20 | | S-4 | | 2 | ● (with Plastic Limit and Liquid Limit) | 51 |
| 25 | | S-5 | | 1 | | |
| 30 | | | | | | |

PENETRATION RESISTANCE: ▲ Standard; ##/## Blows over inches; Blows per foot; △ Other

Scale: 0 10 20 30 40 50

MOISTURE CONTENT scale: 0 20 40 60 80 100 — Plastic Limit, Liquid Limit

LEGEND

- 2.00-inch OD split-spoon sampler
- N/E No groundwater encountered
- Atterberg Test (PI shown)
- 200 Wash (% fines shown)
- Moisture Content (% shown)

amec

11810 North Creek Parkway N
Bothell, WA 98011

Drilling Method: HSA Hammer Type: Cathead Date drilled: *March 20, 2013* Logged By: *HWB*

Drilled by: *Boretec*

Location: Wishkah Road Station 43+92 & 23' East
Approximate ground surface elevation: 9.9 feet

| DEPTH (feet) | Soil Description | USCS/USGS GRAPHICS | SAMPLE TYPE | SAMPLE NUMBER | GROUND WATER | PENETRATION RESISTANCE (Blows per foot) | TESTING |
|---|---|---|---|---|---|---|---|
| 30 | Fat CLAY with some fibrous and black organics, as above | | split-spoon | S-6 | | 2 | 77 (200 Wash) |
| 33 | Soft, wet, brown fibrous PEAT with interbeds of gray clayey SILT (Quaternary Lacustrine/Marsh Deposits) PT-OH | | | | | | |
| 35 | | | split-spoon | S-7 | | 3 | 114 (Moisture Content) |
| 40 | | | split-spoon | S-8 | | 3 | 144 (Moisture Content); 96 (Atterberg, PI) |
| 45.5 | Very soft, wet, gray, elastic clayey SILT (Quaternary Lacustrine/Marsh Deposits) MH-OH | | split-spoon | S-9 | | 2 | |
| 49 | Very soft, wet, gray, elastic clayey SILT with some fibrous organics to interbeds of thin PEAT lenses (Quaternary Lacustrine/Marsh Deposits) MH-PT | | split-spoon | S-10 | | 2 | |
| 51.5 | Boring terminated at approximately 51.5 feet | | | | | | |

Penetration resistance scale: 0, 10, 20, 30, 40, 50. Standard (▲), Blows over inches (#/#), Other (△).

MOISTURE CONTENT: 0, 20, 40, 60, 80, 100 — Plastic Limit, Liquid Limit

LEGEND

- 2.00-inch OD split-spoon sampler
- N/E No groundwater encountered
- Atterberg Test (PI shown)
- 200 Wash (% fines shown)
- Moisture Content (% shown)

amec

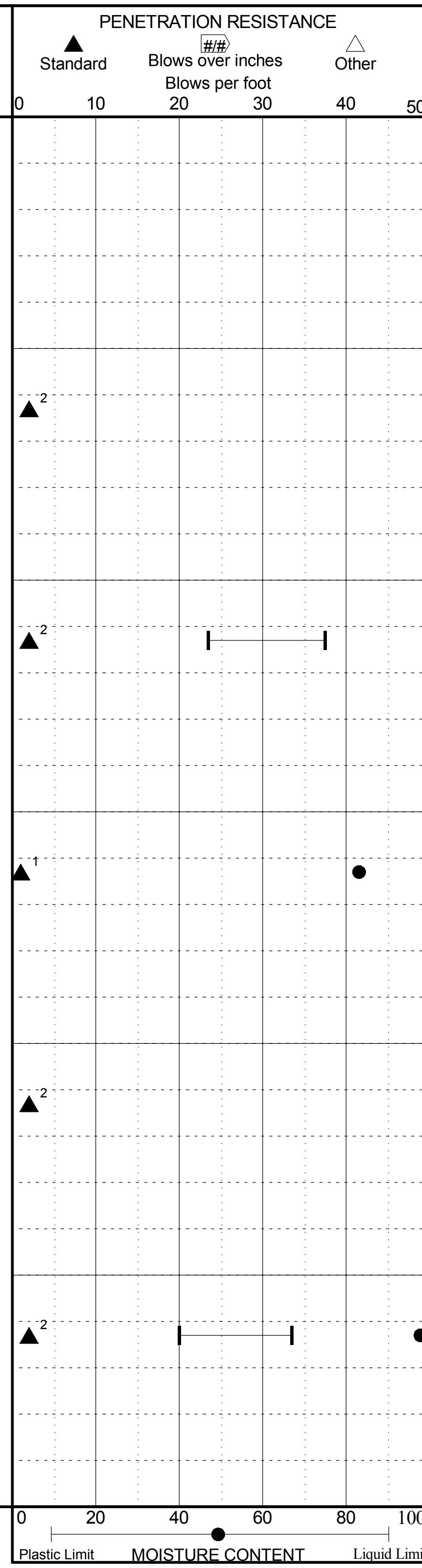
11810 North Creek Parkway N
Bothell, WA 98011

Drilling Method: HSA Hammer Type: Cathead Date drilled: *March 20, 2013* Logged By: *HWB*
Drilled by: *Boretec*

PROJECT: *Kersh-Wishkah Road Levee Project* JOB No. *3-915-17568-0* BORING No. *B-2*



| DEPTH (feet) | Soil Description<br>Location: Wishkah Road Station 52+12 & 35' East<br>Approximate ground surface elevation: 9.1 feet | USCS/USGS GRAPHICS | SAMPLE TYPE | SAMPLE NUMBER | GROUND WATER | TESTING |
|---|---|---|---|---|---|---|
| 0 | 4-inches of SOD mantling very soft, wet, gray, elastic SILT with some fibrous and black organics (Quaternary Lacustrine/Marsh Deposits) MH | | | | N/E | |
| 5 | | | | S-1 | | |
| 10 | | | | S-2 | | 113, 28 |
| 15 | | | | S-3 | | |
| 20 | Very soft, wet, gray, elastic SILT with some to abundant brown and black fibrous PEAT material through out and PEAT lens from 20.3-20.5 feet (Quaternary Lacustrine/Marsh Deposits) MH-OH-PT | | | S-4 | | |
| 25 | | | | S-5 | | 27 |
| 30 | | | | | | |




LEGEND

2.00-inch OD split-spoon sampler

N/E No groundwater encountered

Moisture Content (% shown)

Atterberg Test (PI shown)

11810 North Creek Parkway N
Bothell, WA 98011

Drilling Method: HSA Hammer Type: Cathead Date drilled: *March 20, 2013* Logged By: *HWB*

Drilled by: *Boretec*

PROJECT: *Kersh-Wishkah Road Levee Project* JOB No. *3-915-17568-0* BORING No. *B-2*

| DEPTH (feet) | Soil Description<br>Location: Wishkah Road Station 52+12 & 35' East<br>Approximate ground surface elevation: 9.1 feet | USCS/USGS GRAPHICS | SAMPLE TYPE | SAMPLE NUMBER | GROUND WATER | PENETRATION RESISTANCE (Standard ▲ Blows per foot) | TESTING |
|---|---|---|---|---|---|---|---|
| 30 | Soft, wet, brown, fibrous PEAT with pieces of wood (Quaternary Lacustrine/Marsh Deposits) PT | | | S-6 | | 4 | 197 |
| 35 | Very soft, wet, gray, elastic SILT with some inclusions of brown fibrous and black amorphous PEAT; soils look colluival from 34.5 to 36 feet (Quaternary Lacustrine/Marsh Deposits) MH-OH-PT | | | S-7 | | 2 | |
| 40 | | | | S-8 | | 2 | |
| 45 | | | | S-9 | | 3 | 45 |
| | Soft, wet, gray, elastic clayey SILT with woody organics; looks disturbed; possible landslide debris (Quaternary Lacustrine/Marsh Deposits) MH | | | | | | |
| 50 | | | | S-10 | | 3 | |
| | Moderately weathered, massive, greenish gray, extremely weak, micaceous SILTSTONE (Tertiary Montesano Formation) Tmal | | | | | | |
| | Boring terminated at approximately 51.5 feet | | | | | | |
| 55 | | | | | | | |
| 60 | | | | | | | |

Page 2 of 2

PENETRATION RESISTANCE: ▲ Standard; #/# Blows over inches; △ Other; Blows per foot (0, 10, 20, 30, 40, 50)

MOISTURE CONTENT: 0, 20, 40, 60, 80, 100 — Plastic Limit, Liquid Limit

LEGEND

2.00-inch OD split-spoon sampler

N/E No groundwater encountered

Moisture Content (% shown)

Atterberg Test (PI shown)

amec

11810 North Creek Parkway N
Bothell, WA 98011

Drilling Method: HSA Hammer Type: Cathead Date drilled: *March 20, 2013* Logged By: *HWB*

Drilled by: *Boretec*

BOTHELL_LOG FORMAT 2012 KERSH-WISHKAH ROAD LEVEE PROJECT.GPJ BOTHELL GEO 2010 B&TP.GDT 4/15/13

PROJECT: *Kersh-Wishkah Road Levee Project* JOB No. *3-915-17568-0* BORING No. *B-3*

Location: Wishkah Road Station 60+17 & 21' East
Approximate ground surface elevation: 9.7 feet

Page 1 of 2

| DEPTH (feet) | Soil Description | USCS/USGS | SAMPLE NUMBER | GROUND WATER | PENETRATION RESISTANCE (Blows per foot, Standard) | TESTING |
|---|---|---|---|---|---|---|
| 0–4.5 | Loose, wet to saturated, brown, sandy GRAVEL with trace silt (Fill) GP | GP | | N/E | | |
| 4.5–18 | Soft, wet, gray, elastic SILT with some to abundant brown fibrous PEAT throughout (Quaternary Lacustrine/Marsh Deposits) MH-OH | MH-OH | S-1 | | 3 | 54 (Atterberg) |
| | | | S-2 | | 3 | |
| | | | S-3 | | 3 | |
| 18–26.3 | Very soft, wet, gray, fat CLAY with some brown fibrous and black organics; PEAT zone from 21 to 21.5 feet (Quaternary Lacustrine/Marsh Deposits) CH-OH | CH-OH | S-4 | | 2 | 116 (Moisture Content) |
| | | | S-5 | | 2 | 70 (Atterberg) |
| 26.3–30 | Very soft, wet, light brown to brown SILT with some fibrous PEAT material throughout; PEAT lens from 31 to 31.5 feet (Quaternary Lacustrine/Marsh Deposits) OH-PT | OH-PT | | | | |

PENETRATION RESISTANCE: ▲ Standard; #/# Blows over inches; △ Other — Blows per foot 0, 10, 20, 30, 40, 50

MOISTURE CONTENT: 0, 20, 40, 60, 80, 100 — Plastic Limit, Liquid Limit

## LEGEND

- 2.00-inch OD split-spoon sampler
- N/E No groundwater encountered
- Atterberg Test (PI shown)
- Moisture Content (% shown)

amec

11810 North Creek Parkway N
Bothell, WA 98011

Drilling Method: HSA Hammer Type: Cathead Date drilled: *March 20, 2013* Logged By: *HWB*

Drilled by: *Boretec*

PROJECT: *Kersh-Wishkah Road Levee Project* JOB No. *3-915-17568-0* BORING No. *B-3*



Location: Wishkah Road Station 60+17 & 21' East
Approximate ground surface elevation: 9.7 feet

| DEPTH (feet) | Soil Description | SAMPLE NUMBER | Penetration Resistance (Blows per foot, Standard) | TESTING |
|---|---|---|---|---|
| 30 | Organic SILT with PEAT lenses as above | S-6 | 2 | Moisture Content 132; Atterberg Test PI 50 |
| 35.7 | Moderately weathered, massive, greenish gray, extremely weak, micaceous SILTSTONE (Tertiary Montesano Formation) Tmal | S-7A, S-7B | 9 | |
| 40 | Moderately to completely weathered, massive, mottled orange-brown-gray, extremely weak, micaceous SILTSTONE; blocky to highly fractured with slickensides (Tertiary Montesano Formation) Tmal | S-8 | 13 | |
| 44 | Medium stiff, moist to wet, massive, dark gray, micaceous SILTSTONE; highly milled rock with trace to some pieces of fractured rock and slickensides-fault gouge (Tertiary Astoria Formation) Ta | S-9 | 7 | |
| 47.5 | Grades to very stiff | S-10 | 16 | |
| 51.5 | Boring terminated at approximately 51.5 feet | | | |

PENETRATION RESISTANCE: ▲ Standard; #/# Blows over inches; △ Other; Blows per foot (0 10 20 30 40 50)

MOISTURE CONTENT: Plastic Limit — Liquid Limit (0 20 40 60 80 100)

LEGEND

- 2.00-inch OD split-spoon sampler
- N/E No groundwater encountered
- Atterberg Test (PI shown)
- Moisture Content (% shown)

amec
11810 North Creek Parkway N
Bothell, WA 98011

Drilling Method: HSA Hammer Type: Cathead Date drilled: *March 20, 2013* Logged By: *HWB*
Drilled by: *Boretec*

## APPENDIX B

Lab Testing Results

# MOISTURE CONTENT AND MINUS 200 WASH

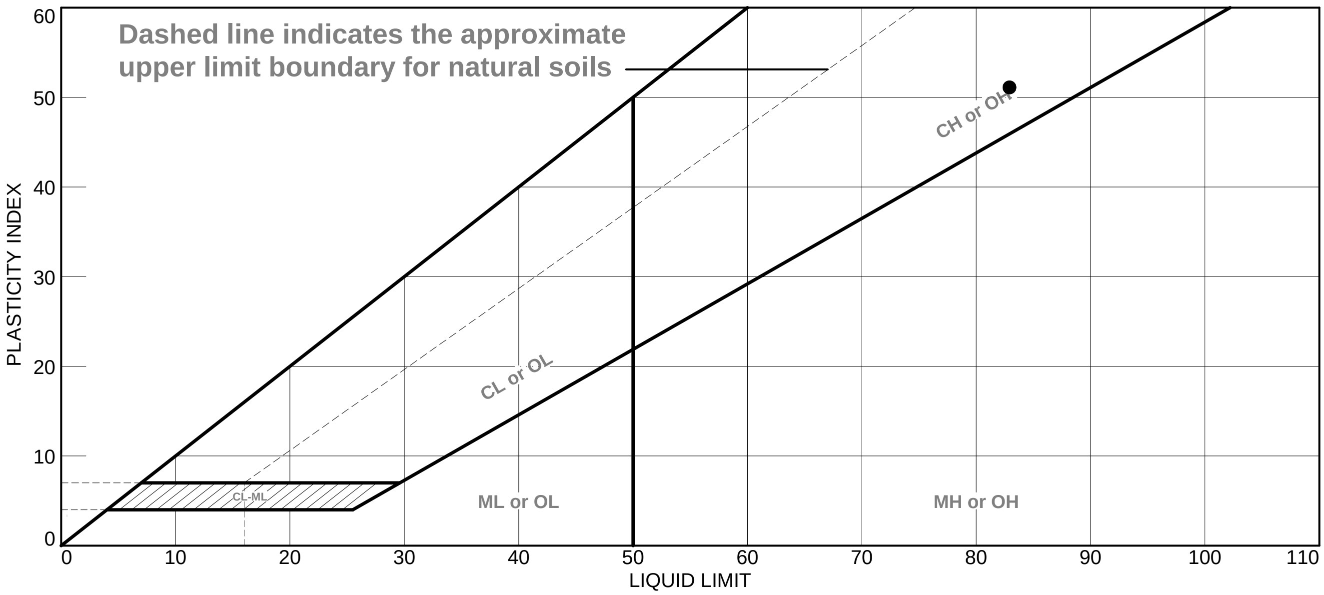
**ASTM: D2216-92, D1140-97**

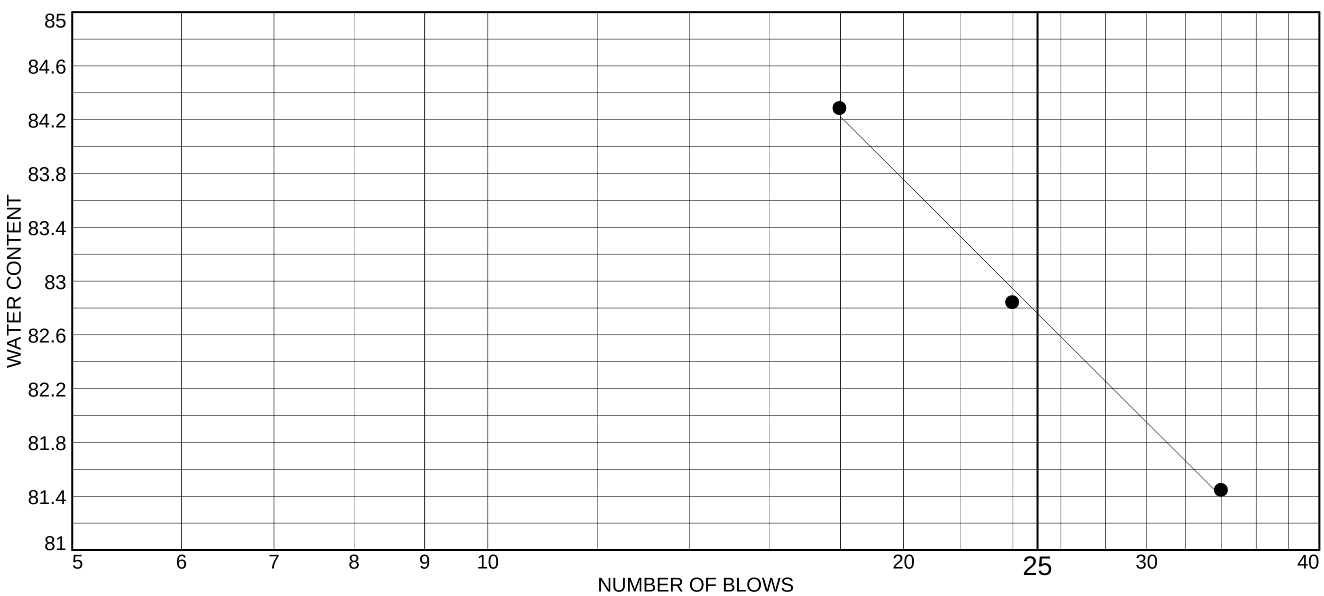
| | |
|---|---|
| Job Name: Kersh - Wishkah Road Levee Project | Client: Grays Harbor County/Amec |
| Job Number: 3-915-17568-0 | Sample Date: 3/20/2013 |
| Date: 4/3/2013 | Sampled By: Henry B. |

| ID Number: | 1002D.1 | 1002D.3 | 1002D.4 | 1002D.7 | 1002D.9 | 1002D.11 | 1002D.13 | 1002D.14 | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Exploration: | B-1 | B-1 | B-1 | B-2 | B-2 | B-2 | B-3 | B-3 | | |
| Sample Number: | S-2 | S-6 | S-7 | S-3 | S-7 | S-6 | S-2 | S-4 | | |
| Depth: | 10-11.5' | 30-31.5' | 35-36.5' | 15-16.5' | 35-36.5' | 30-31.5' | 10-11.5' | 20-21.5' | | |
| | | | | | | | | | | |
| Moisture Content: | 83.4% | 79.4% | 113.6% | 83.1% | 88.8% | 197.4% | 98.5% | 115.8% | | |
| % -200 Wash | N/A | 76.86% | N/A | N/A | N/A | N/A | N/A | N/A | | |

Terracon
Consulting Engineers & Scientists

# LIQUID AND PLASTIC LIMITS TEST REPORT




| | MATERIAL DESCRIPTION | LL | PL | PI | %<#40 | %<#200 | USCS |
|---|---|---|---|---|---|---|---|
| ● | Natural Moisture: 51.9% | 83 | 32 | 51 | | | |

**Project No.** 3915175680 **Client:** Grays Harbor County

**Project:** Kersh - Wishkah Road Levee Project

**Location:** B-1, S-4
**Sample Number:** 81131002D.2 **Depth:** 20-21.5'

**Terracon Consultants, Inc.**

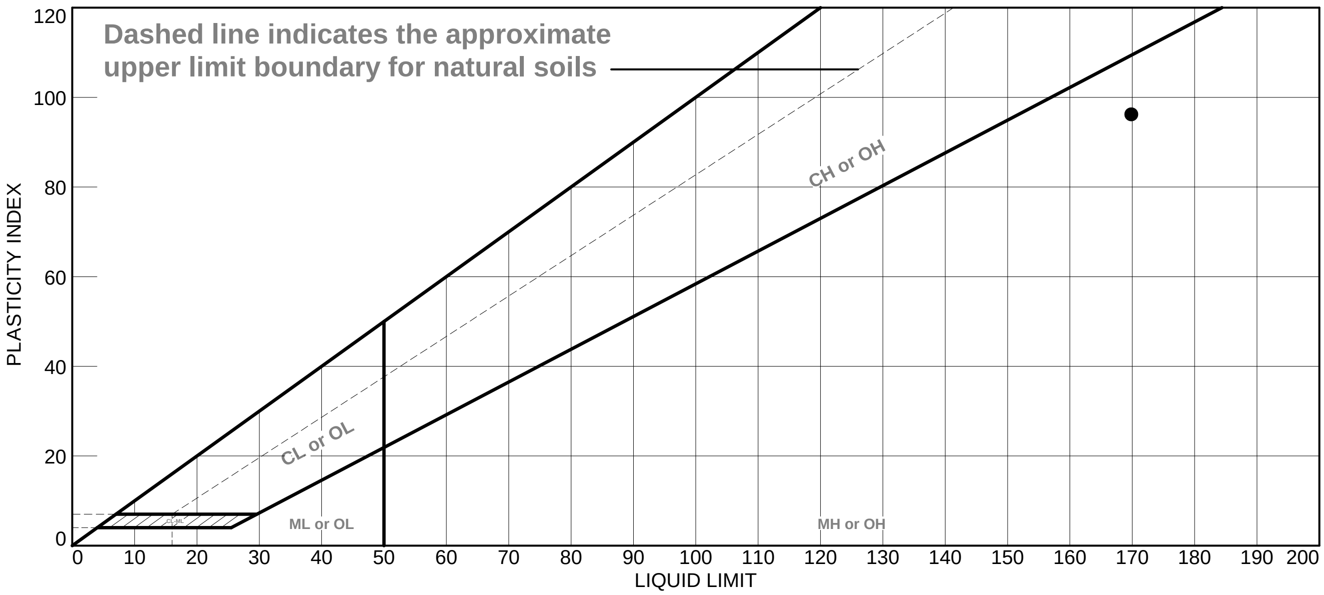
**Mountlake Terrace, WA**

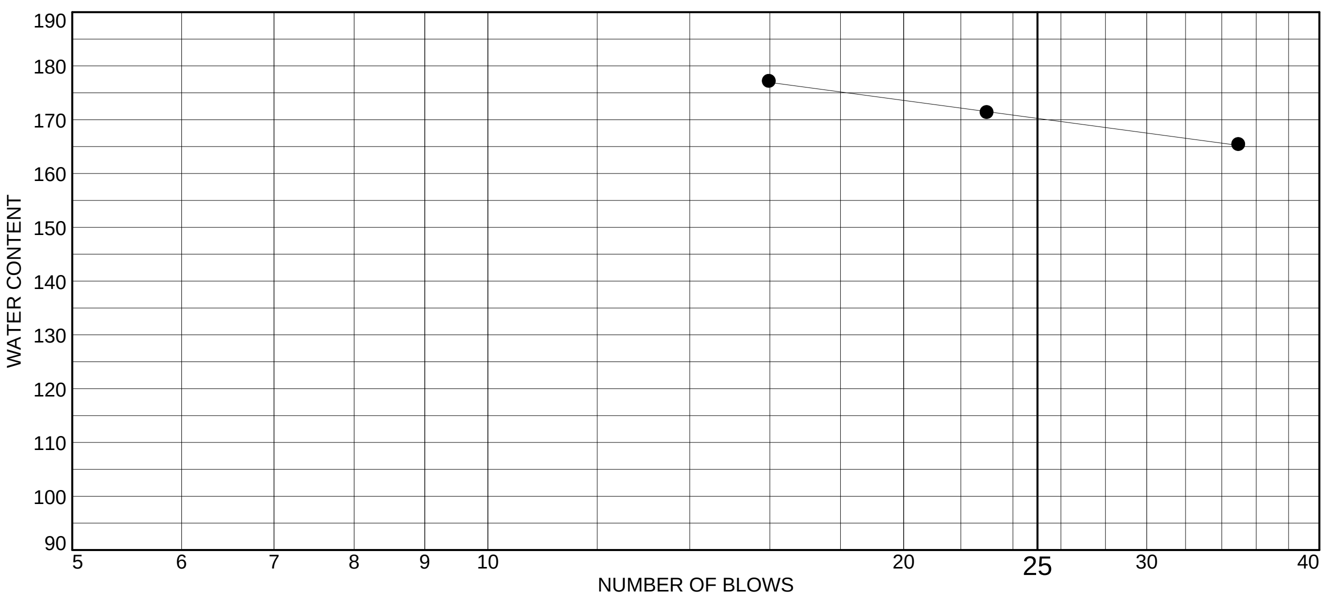
**Remarks:**

**Figure**

**Tested By:** Jeff W **Checked By:** Jeff W

# LIQUID AND PLASTIC LIMITS TEST REPORT




| | MATERIAL DESCRIPTION | LL | PL | PI | %<#40 | %<#200 | USCS |
|---|---|---|---|---|---|---|---|
| ● | Natural Moisture: 144.1% | 170 | 74 | 96 | | | |

**Project No.** 3915175680 **Client:** Grays Harbor County

**Project:** Kersh - Wishkah Road Levee Project

**Location:** B-1, S-8

**Sample Number:** 81131002D.5 **Depth:** 40-41.5'

**Terracon Consultants, Inc.**

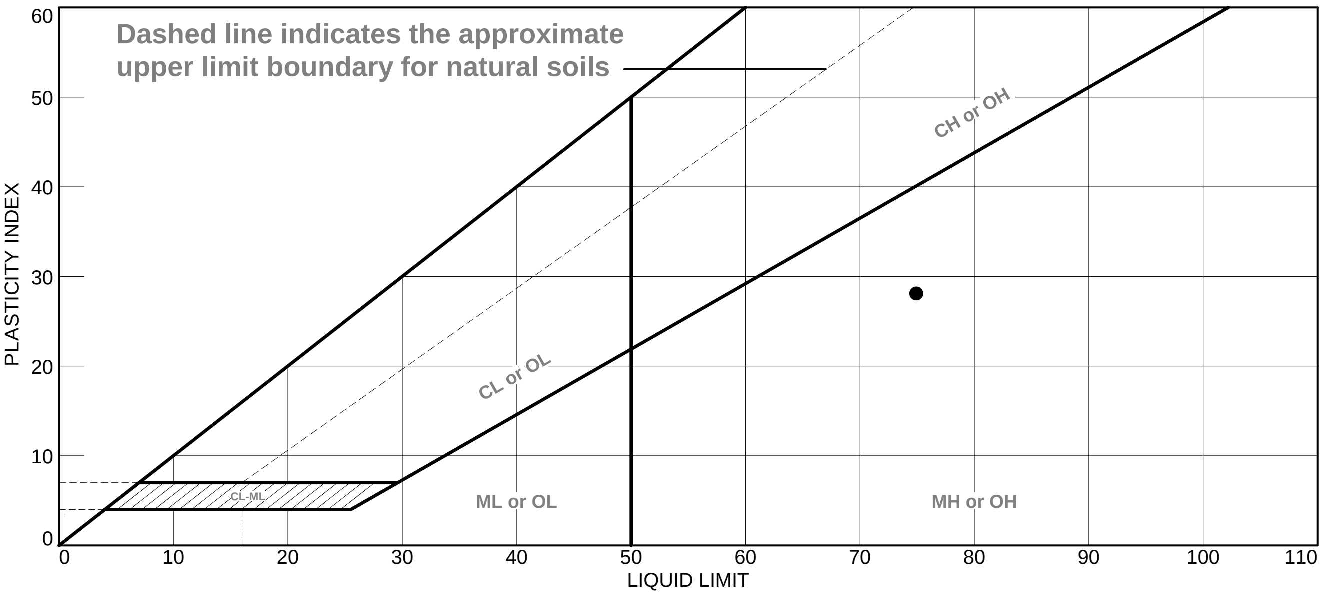
**Mountlake Terrace, WA**

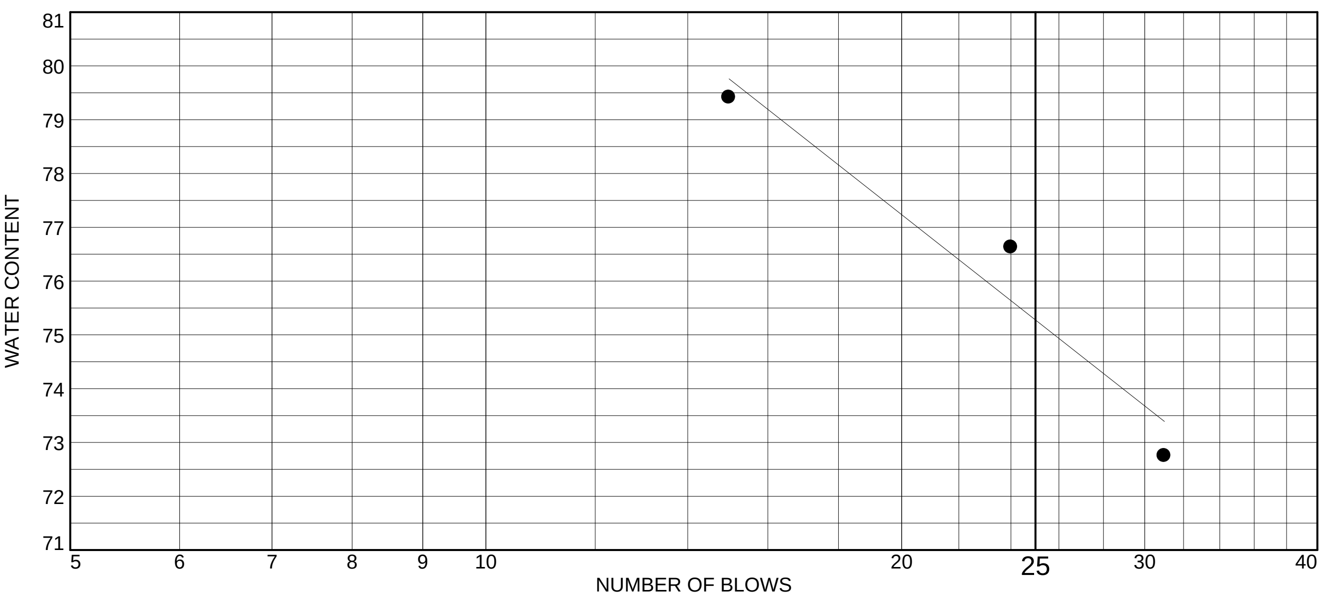
**Remarks:**

**Figure**

**Tested By:** Jeff W **Checked By:** Jeff W

# LIQUID AND PLASTIC LIMITS TEST REPORT




| | MATERIAL DESCRIPTION | LL | PL | PI | %<#40 | %<#200 | USCS |
|---|---|---|---|---|---|---|---|
| ● | Natural Moisture: 113.1% | 75 | 47 | 28 | | | |

**Project No.** 3915175680 **Client:** Grays Harbor County

**Project:** Kersh - Wishkah Road Levee Project

**Location:** B-2, S-2

**Sample Number:** 81131002D.6 **Depth:** 10-11.5'

**Terracon Consultants, Inc.**

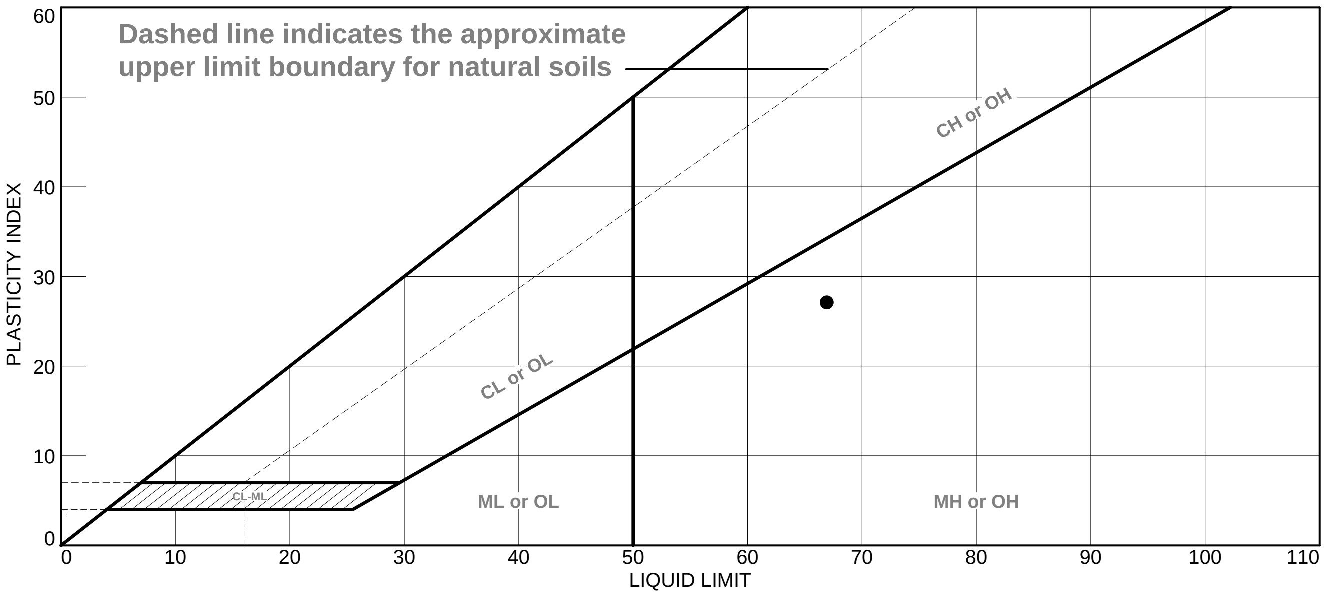
**Mountlake Terrace, WA**

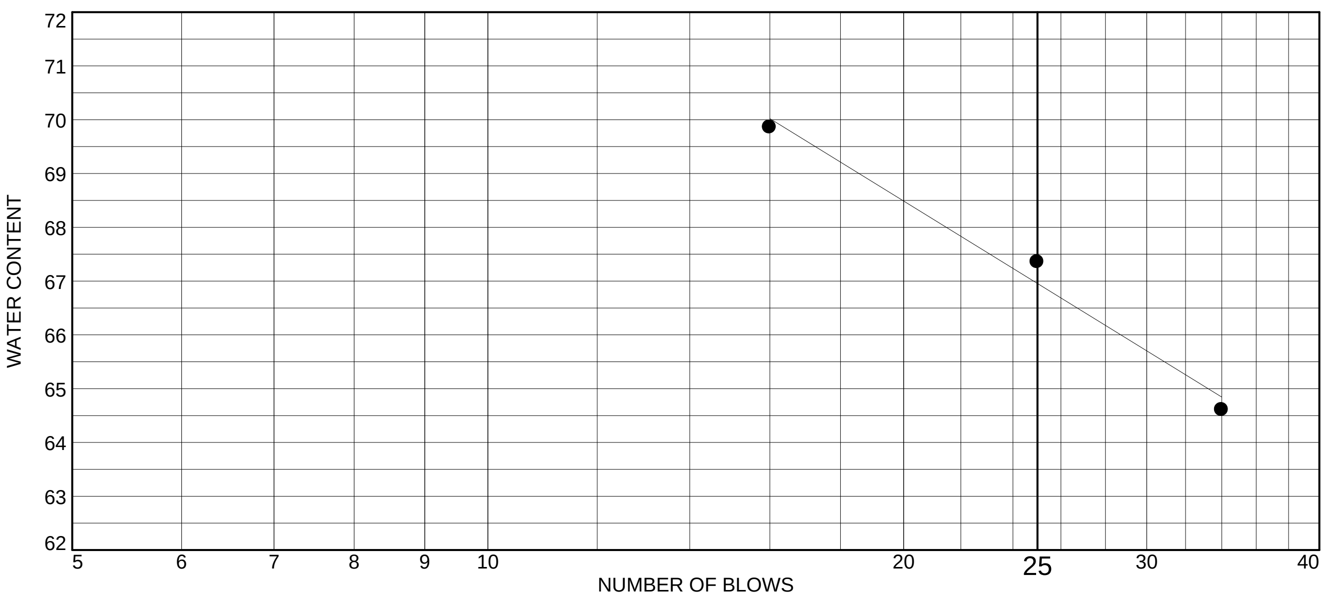
**Remarks:**

**Figure**

**Tested By:** Jeff W **Checked By:** Jeff W

# LIQUID AND PLASTIC LIMITS TEST REPORT




| | MATERIAL DESCRIPTION | LL | PL | PI | %<#40 | %<#200 | USCS |
|---|---|---|---|---|---|---|---|
| ● | Natural Moisture: 97.8% | 67 | 40 | 27 | | | |

**Project No.** 3915175680 **Client:** Grays Harbor County

**Project:** Kersh - Wishkah Road Levee Project

**Location:** B-2, S-5
**Sample Number:** 81131002D.8 **Depth:** 25-26.5'

**Remarks:**

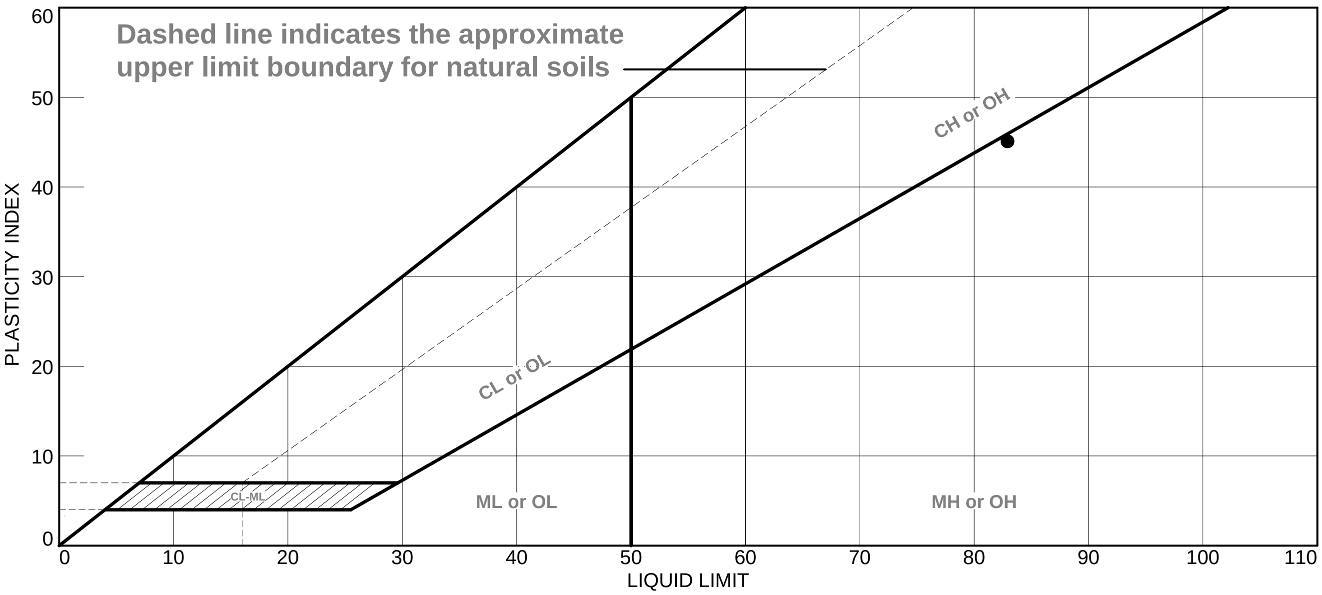
**Terracon Consultants, Inc.**

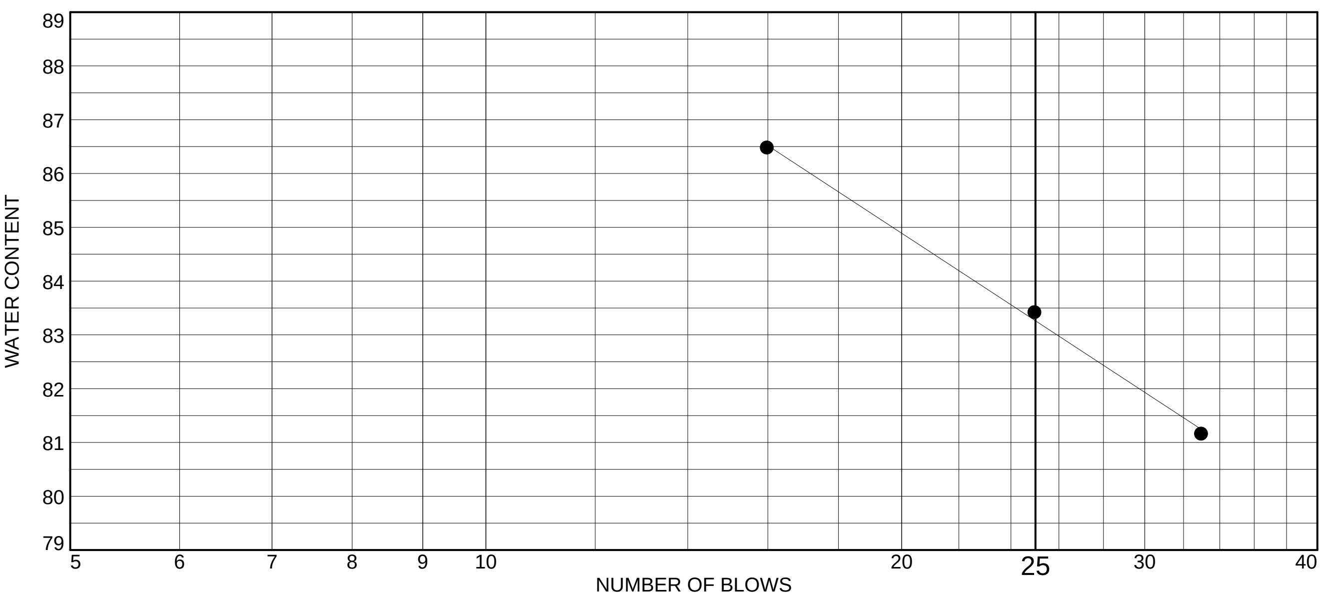
**Mountlake Terrace, WA**

**Figure**

**Tested By:** Jeff W **Checked By:** Jeff W

# LIQUID AND PLASTIC LIMITS TEST REPORT




| | MATERIAL DESCRIPTION | LL | PL | PI | %<#40 | %<#200 | USCS |
|---|---|---|---|---|---|---|---|
| ● | Natural Moisture: 79.3% | 83 | 38 | 45 | | | |

**Project No.** 3915175680 **Client:** Grays Harbor County

**Project:** Kersh - Wishkah Road Levee Project

**Location:** B-2, S-9
**Sample Number:** 81131002D.10 **Depth:** 45-46.5'

**Terracon Consultants, Inc.**

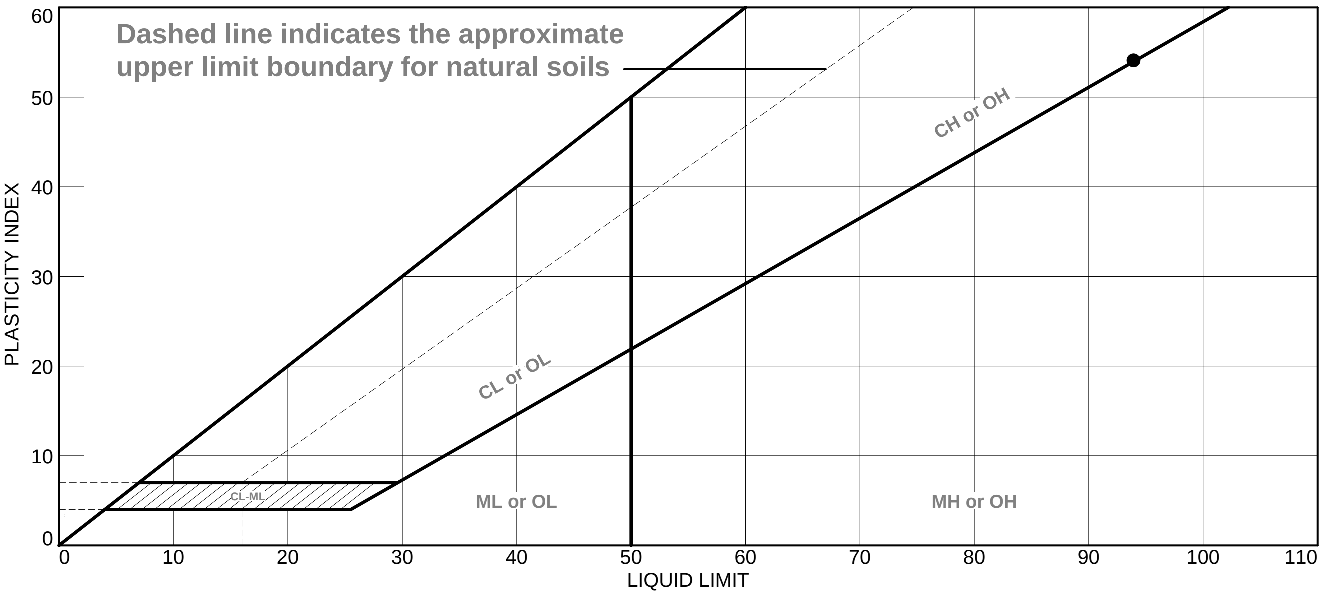
**Mountlake Terrace, WA**

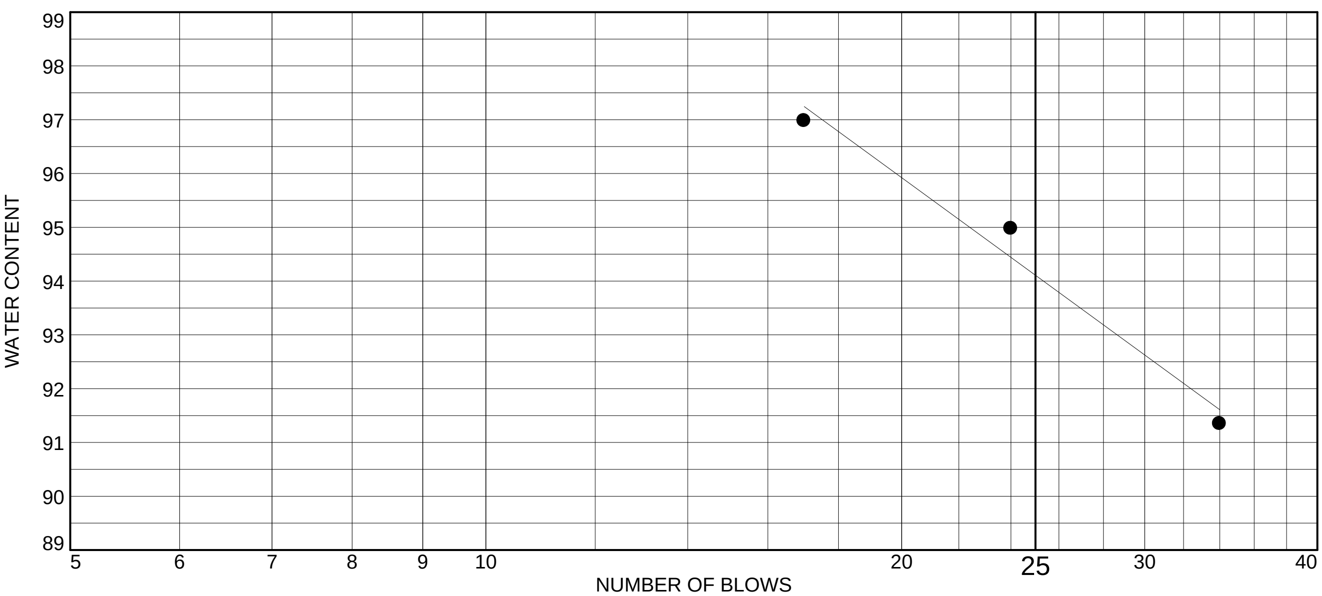
**Remarks:**

**Figure**

**Tested By:** Jeff W **Checked By:** Jeff W

# LIQUID AND PLASTIC LIMITS TEST REPORT




| | MATERIAL DESCRIPTION | LL | PL | PI | %<#40 | %<#200 | USCS |
|---|---|---|---|---|---|---|---|
| ● | Natural Moisture: 93.3% | 94 | 40 | 54 | | | |

**Project No.** 3915175680 **Client:** Grays Harbor County

**Project:** Kersh - Wishkah Road Levee Project

**Location:** B-3, S-1
**Sample Number:** 81131002D.12 **Depth:** 5-6.5'

**Terracon Consultants, Inc.**

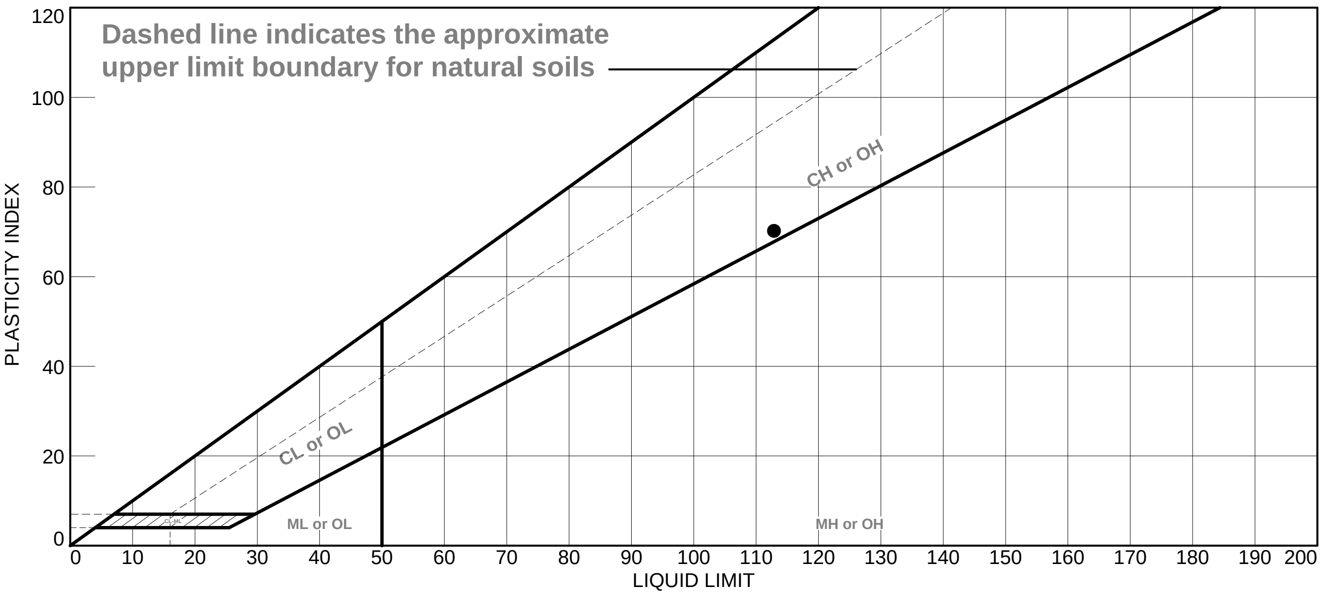
**Mountlake Terrace, WA**

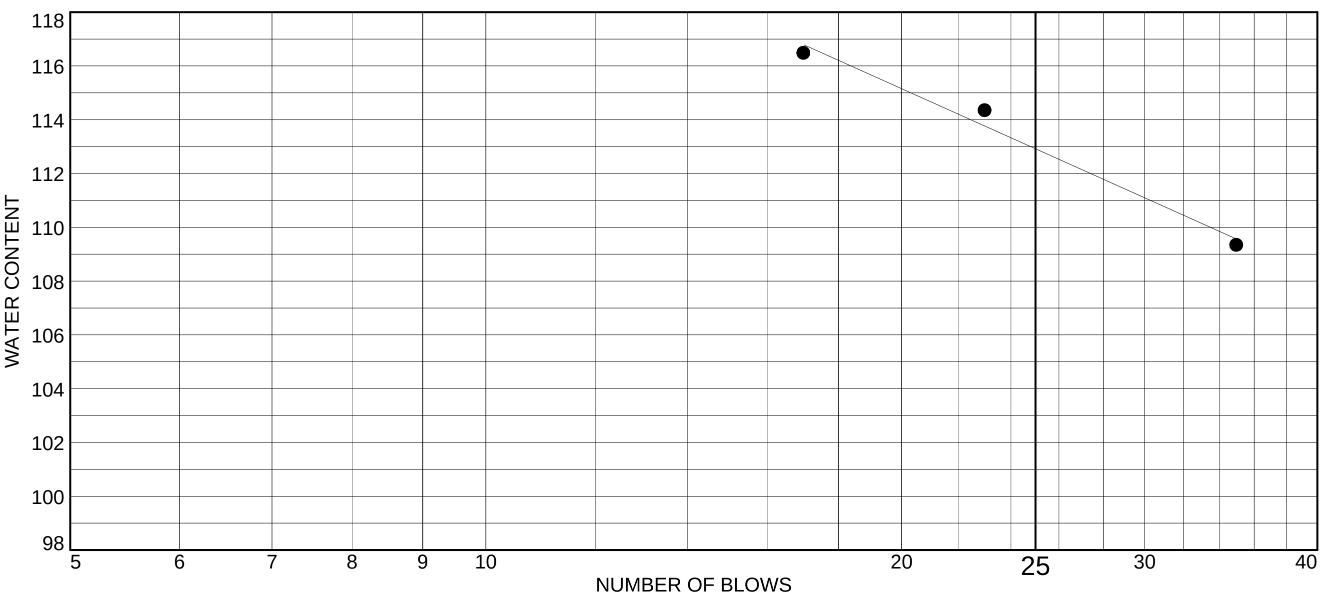
**Remarks:**

**Figure**

**Tested By:** Jeff W **Checked By:** Jeff W

# LIQUID AND PLASTIC LIMITS TEST REPORT




| | MATERIAL DESCRIPTION | LL | PL | PI | %<#40 | %<#200 | USCS |
|---|---|---|---|---|---|---|---|
| ● | Natural Moisture: 94.9% | 113 | 43 | 70 | | | |

**Project No.** 3915175680 **Client:** Grays Harbor County

**Project:** Kersh - Wishkah Road Levee Project

**Location:** B-3, S-5

**Sample Number:** 81131002D.15 **Depth:** 25-26.5'

**Terracon Consultants, Inc.**

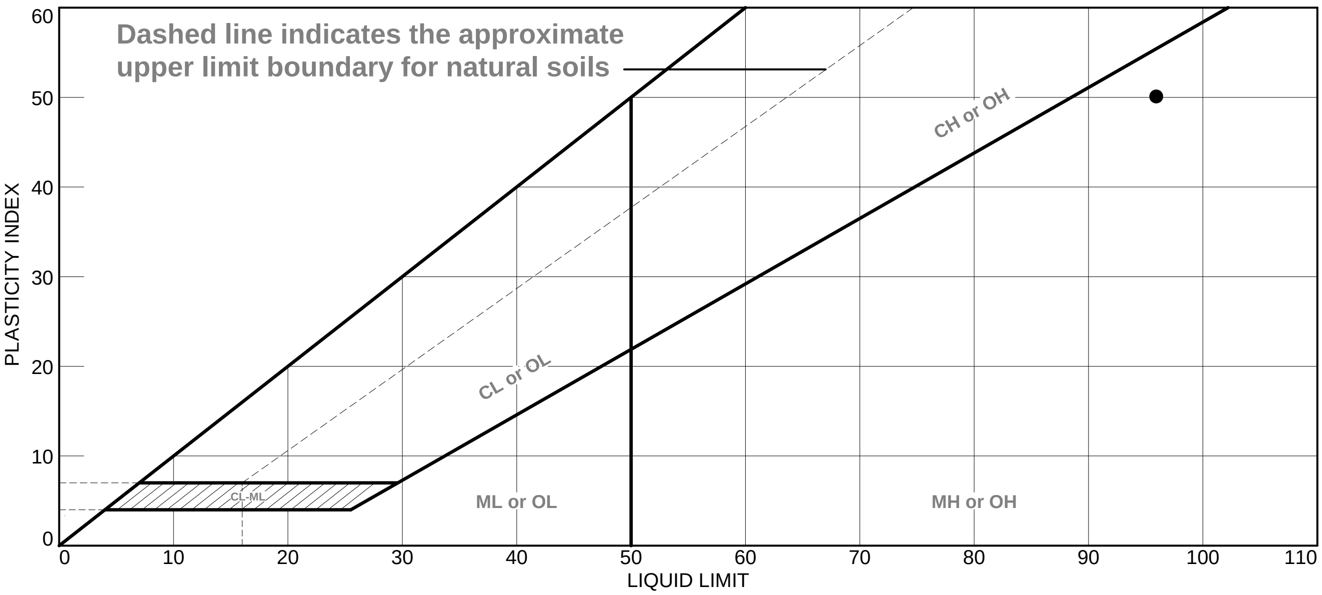
**Mountlake Terrace, WA**

**Remarks:**

**Figure**

**Tested By:** Jeff W **Checked By:** Jeff W

# LIQUID AND PLASTIC LIMITS TEST REPORT





| | MATERIAL DESCRIPTION | LL | PL | PI | %<#40 | %<#200 | USCS |
|---|---|---|---|---|---|---|---|
| ● | Natural Moisture: 131.6% | 96 | 46 | 50 | | | |

**Project No.** 3915175680 **Client:** Grays Harbor County

**Project:** Kersh - Wishkah Road Levee Project

**Location:** B-3, S-6
**Sample Number:** 81131002D.16 **Depth:** 30-31.5'

**Terracon Consultants, Inc.**

**Mountlake Terrace, WA**

**Remarks:**

**Figure**

**Tested By:** Jeff W **Checked By:** Jeff W

# APPENDIX E

Hydraulic Modeling Report

# Technical Report

## WISHKAH ROAD – KERSH FLOOD LEVEE PROJECT HYDRAULIC ANALYSIS

Prepared for:

AMEC

This report documents the engineering analysis and numerical modeling performed by Coast & Harbor Engineering to assist AMEC Environment & Infrastructure in developing and evaluating design alternatives for the Wishkah Road-Kersh Flood Levee Project. This document is not to be used for purposes of permitting, final engineering design, or for construction documents.

Prepared by:


Vladimir Shepsis, Ph.D., P.E.

COAST & HARBOR ENGINEERING

110 Main Street, Suite 103
Edmonds, WA 98020
Ph 425 778.6733
Fax 425 977.7416

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<u>FIGURES</u>

TABLES

COAST & HARBOR ENGINEERING

# Technical Report
# Wishkah Road-Kersh Flood Levee Project Hydraulic Analysis

## 1. Introduction

This technical report was prepared by Coast & Harbor Engineering (CHE) and documents engineering analysis and numerical modeling performed to assist AMEC Environment & Infrastructure (AMEC) in developing and evaluating design alternatives for the Wishkah Road-Kersh Flood Levee Project (project). The purpose of the project is to eliminate or reduce Wishkah Road flooding problems.

This work performed included compilation and review of existing information and performing numerical modeling of existing conditions and proposed design alternatives. Relevant existing data CHE reviewed included topographic and bathymetric surveys, tidal records, water level measurements, river discharge, and previous studies by others. Some of these data were briefly presented in AMEC's Technical Memorandum *Review of Existing Information* dated April 10, 2013. Upon compilation and review of the existing data, water levels and velocities at the project site were simulated with a calibrated two-dimensional (2-D) hydrodynamic model, MORPHO (Kivva, 2006). The modeling was conducted to develop design criteria, identify and evaluate feasible alternatives, and select the preferred flood protection alternative for further analysis and design.

### 1.1. Data Sources

The relevant data sources applied for analysis and hydraulic modeling are described in detail below. Unless otherwise noted, elevations refer to North American Vertical Datum of 1988 (NAVD88).

#### 1.1.1. Topography and Bathymetry

A combination of aerial LiDAR, topographic, and bathymetric surveys were compiled and applied for the engineering analysis and numerical model development. Aerial LIDAR survey data from September 26, 2009, covering the Aberdeen/Wishkah River area were provided by the Oregon Department of Geology and Mineral Industries (DOGAMI). New land surveys in the immediate project area were conducted by Berglund, Schmidt & Associates (BSA) in March 2013. These surveys included roads, ditches, water marks, culverts, tide gates, and other relevant features in and around the river floodplain. A new bathymetric survey consisting of two longitudinal profiles and numerous cross-sections along the Wishkah River was performed by HydroGraphix on March 12-13, 2013. The survey extended from the mouth of the Wishkah River to 1,500 ft upstream of the project site. Other bathymetric surveys used included those conducted in Grays Harbor by NOAA in 2004 to 2005 and one conducted by the U.S. Army Corps of Engineers (USACE) Seattle District in 2013 within the Federal Navigation Channel.

### 1.1.2. Water Levels

Water level data that were available from multiple stations in Grays Harbor and the Wishkah River were compiled, analyzed and summarized in Table 1; station locations are shown in Figure 1. The most relevant information for the project objective appears to be available from two tide measuring stations: Aberdeen NOAA Station 9441187 and Westport NOAA Station 9441102. A comparative analysis of measured data at these stations was conducted to determine if long-term tide measurements at Westport can be used to predict tides at Aberdeen using the measured anomaly. The anomaly is the difference between the measured and predicted tide. Analysis performed by CHE of data measured concurrently in 1999 by USACE showed that the anomaly signals are consistent, and the anomaly magnitude and phase between the two stations are not significantly affected by local meteorological effects. Therefore, for statistical analysis to estimate extreme tide parameters at Aberdeen, the meteorological anomaly measured at Westport was added to the predicted tides at Aberdeen.

To support the analysis and validate the models at the project site, three water level data loggers (A, B, and C) were deployed by AMEC/HydroGraphix in the Wishkah River at two locations during March of 2013 (3/12/2013 – 3/25/2013). Water level gage "A" was located at the Wishkah River mouth, and water level gages "B" and "C" were co-located approximately 1.5 miles upstream of the project site. Figure 1 shows the locations of the water level gages and data loggers with respect to the project site. Approximate tidal and vertical datum relationships at Westport and Aberdeen are provided in Table 2 per NOAA.

**Table 1. Water Surface Elevation Data Sources**

| Source | Date | Description |
|---|---|---|
| AMEC | 3/12/2013 – 3/25/2013 | Water Level Data Loggers |
| NOAA, Station 9441102 | 3/23/2006 - 03/28/2013 | Predicted and Measured @ Westport, WA |
| NOAA | 12/19/1999 - 11/20/2009 | Predicted @ Westport, WA |
| USACE | 9/13/1999 -11/17/1999 | Measured @ U.S. Coast Guard Station Westport, WA |
| NOAA Station 9441187 | 2/20/2004 - 12/14/2005 | Predicted and Measured Tides @ Aberdeen, WA |
| NOAA | 12/19/1999 - 12/14/2009 | Predicted Tide @ Aberdeen |
| USACE | 9/12/1999 -11/17/1999 | Measured @ Aberdeen, WA |

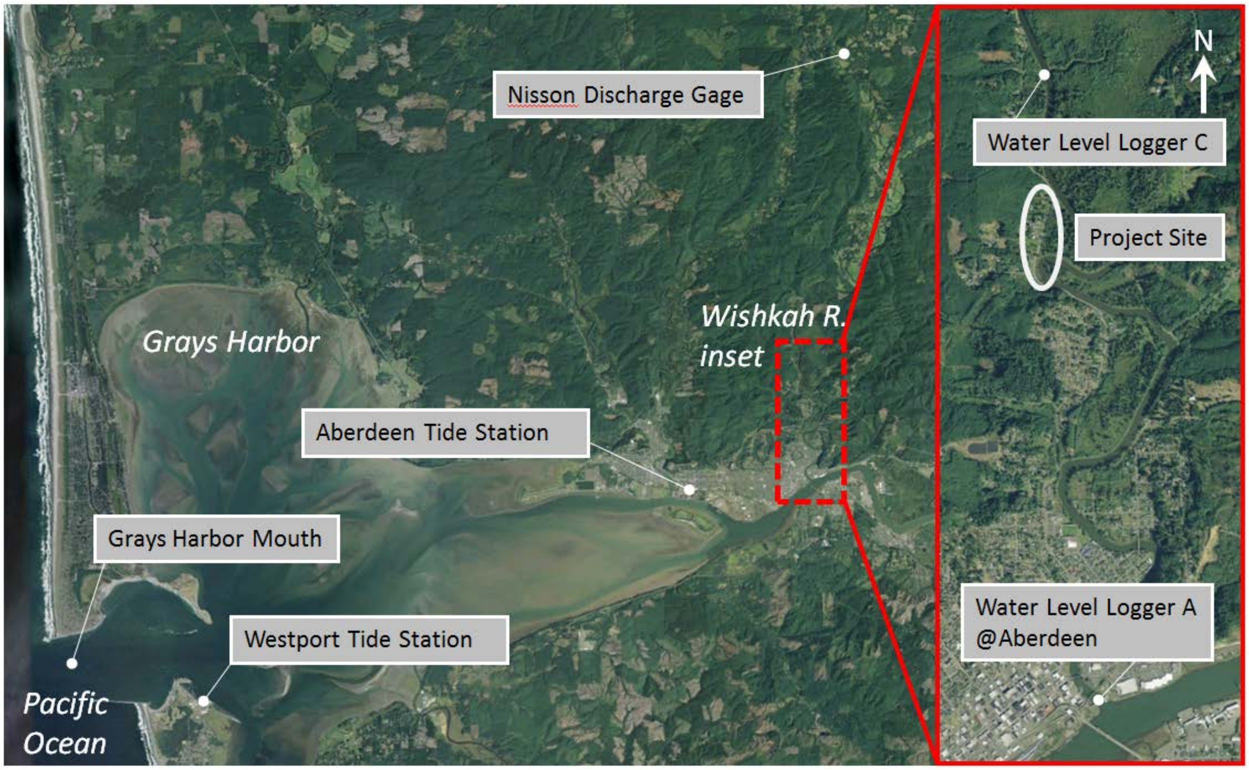


**Figure 1. Grays Harbor and Wishkah River site map showing locations of water level and discharge stations**

**Table 2. Approximate Tidal Datum Relationships at Westport and Aberdeen, WA**

| Datum | Elevation (Westport) | Elevation (Aberdeen) |
|---|---|---|
| MHHW | +7.51 feet | +8.68 feet |
| NAVD88 | 0.00 feet | 0.00 feet |
| MLLW | -1.50 feet | -1.64 feet |

### 1.1.3. Local Flooding Records

As part of the project data collection, water marks of past flood events were surveyed by BSA in March 2013. These marks were cross-referenced to photo documentation of historical flooding events provided by Frank Kersh, a long-time local resident. The collected data, including a topographic survey along the road, were superimposed and are shown in Figure 2. The figure shows the elevation of the Wishkah Road centerline (in yellow) and east shoulder (in grey) as the road progresses north in the project area. Stationing and profile were provided by AMEC. The measured high water marks are plotted as black triangles, with the associated flood date and type (if available). These data and corresponding photos (not included herein) clearly indicate that the roadway has been inundated by flood waters. Analysis of estimated tide conditions during these events points to both tidal and riverine flooding sources, and was further used by the Project Team to develop the design flood event.

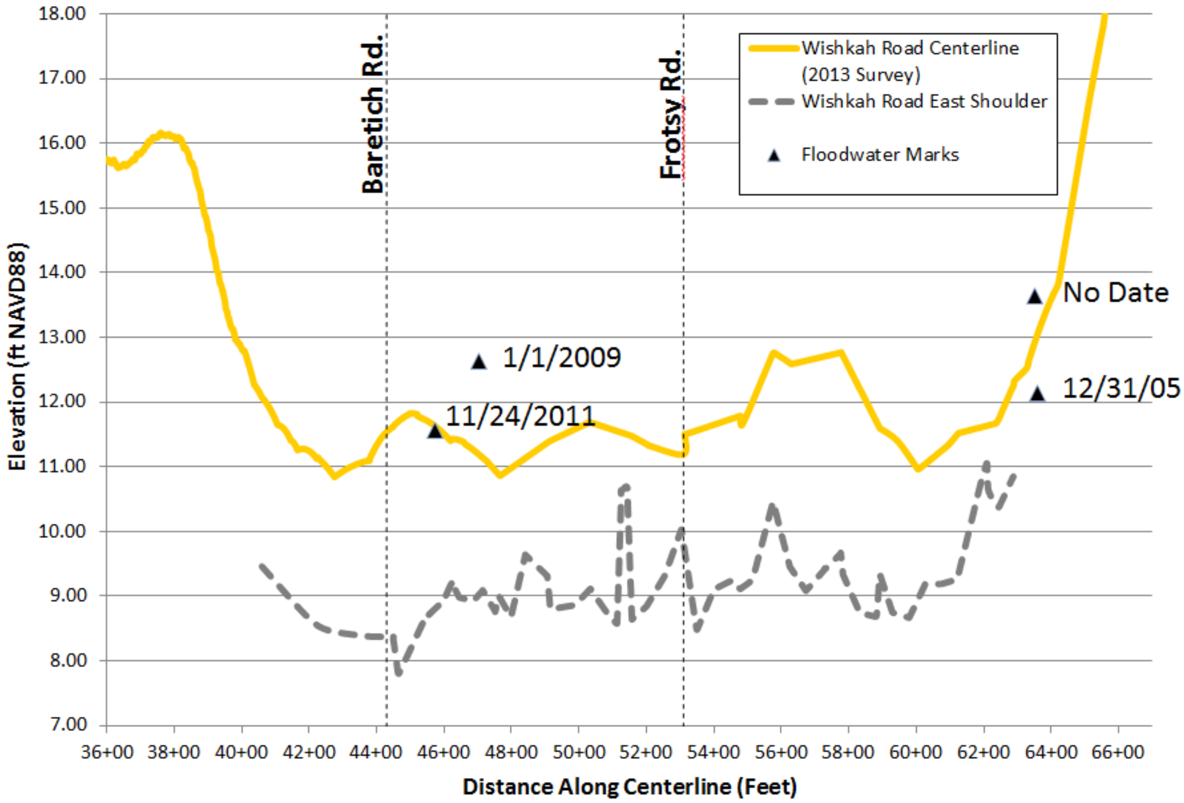


**Figure 2. Road elevations with water marks during recent floods along Wishkah Road centerline stationing, from south (left) to north (right)**

### 1.1.4. River Discharge

Wishkah River discharge data were obtained from the measurements by the Washington State Department of Ecology (DOE) at the stream gage "Nisson" located at River Mile 15.3 (11 miles upstream from the project site)[1]. The data are available from April 2005 to the present. Because river discharge from this gage is reported a distance 11 miles upstream of the project site, river discharges were extrapolated by AMEC to the boundary of the 2-D numerical model at River Mile 5. Both typical and extreme river discharge scenarios were provided by AMEC at the model boundary. For the design 50-year stream flow, AMEC estimated a discharge of 17,100 cfs.

## 1.2. Previous Studies

The FEMA Flood Insurance Study (FIS) 530057 for Grays Harbor County (FEMA 1990) was the only previous study at the project site available to CHE for review. At present, an update to the FEMA FIS is in process of development, but is not yet

[1] Chehalis River discharge at Porter, WA (USGS Station 12031000) were also downloaded and reviewed for this analysis. However, these data were not applied because Chehalis River flows have negligible effect on flooding conditions in the Wishkah River, due to the influence of Grays Harbor estuary.

published as effective.  In addition, the FEMA FIS for the City of Aberdeen, FIS 530058 (FEMA 1984), was also reviewed.  It appears that previous flood modeling for the project area was based upon analysis performed by USACE (1971).  Neither detailed methods nor the results are reported in the FIS or FEMA Flood Maps for the project site, and no published flood elevations are presented.  However, more detailed methods were applied for the Aberdeen FIS (FEMA1984).  The following table summarizes Wishkah River discharge and extreme water levels reported by FEMA at Aberdeen, WA.  For the study of Wishkah River flooding, FEMA assumed a 10-year water level in Grays Harbor, combined with the various discharges in the Table.

**Table 3. Extreme Grays Harbor water levels relative to NAVD88 and Wishkah River discharge as reported by FEMA at Aberdeen, WA (1984)[2]**

| Flooding Source | Water Surface El. (ft NAVD88) | | | Discharge (cfs) | | |
|---|---|---|---|---|---|---|
| | 10-Year | 50-Year | 100-Year | 10-Year | 50-Year | 100-Year |
| Grays Harbor | 12.3 | 13.2 | 13.5 | - | - | - |
| Wishkah River | varies | varies | varies | 12,000 | 16,500 | 18,600 |

## 1.3. Model Mesh Generation

### 1.3.1. Elevation Model

The first step in model development was generation of an elevation model for Grays Harbor and the Wishkah River.  The elevation model was generated by merging bathymetry and topography (described previously) from the mouth of Grays Harbor upstream to Cosmopolis, WA.  Manual adjustments were made as needed; where overlapping survey data were available, the most accurate data were applied and less accurate data were discarded or adjusted for consistency.

The elevation model included the lowest portion of the Hoquiam River and the lower 5 miles of the Wishkah River.  Figure 3 shows the combined topographic and bathymetric elevation model; blue colors indicate lower elevations (deeper water), and yellow and red colors indicate higher elevations (land).

A second step was performed to create the computational mesh consisting of finite triangular elements that can vary in size.  Figure 4 shows the mesh used for simulations.  Please note that areas outside of the Wishkah River, not critical to the study (such as distant portions of Grays Harbor), were not as highly resolved.  From Figure 4, it can be seen that the highest resolution (smallest computation mesh) was provided in the Wishkah River near the project site.  Smaller mesh sizes (5-10 ft) were used around the project site to resolve relevant topographic and hydrodynamic features.  The densest areas are seen on the right hand panel of Figure 3 around the project site.  These dense meshes were used to compute possible flooding on and to either side of Wishkah Road, from 600 ft south of Baretich Road to the northern portion of the project area, 1,300 ft north of Frosty Road, where Wishkah Road bends

[2] FEMA flood elevations were reported relative to NGVD29 vertical datum. To convert to NAVD88 datum, approximately 3.5 ft was added.

to the west. In the Wishkah River, the mesh size is typically around 25 ft, which is sufficient for providing adequate resolution of the river cross-section shape.

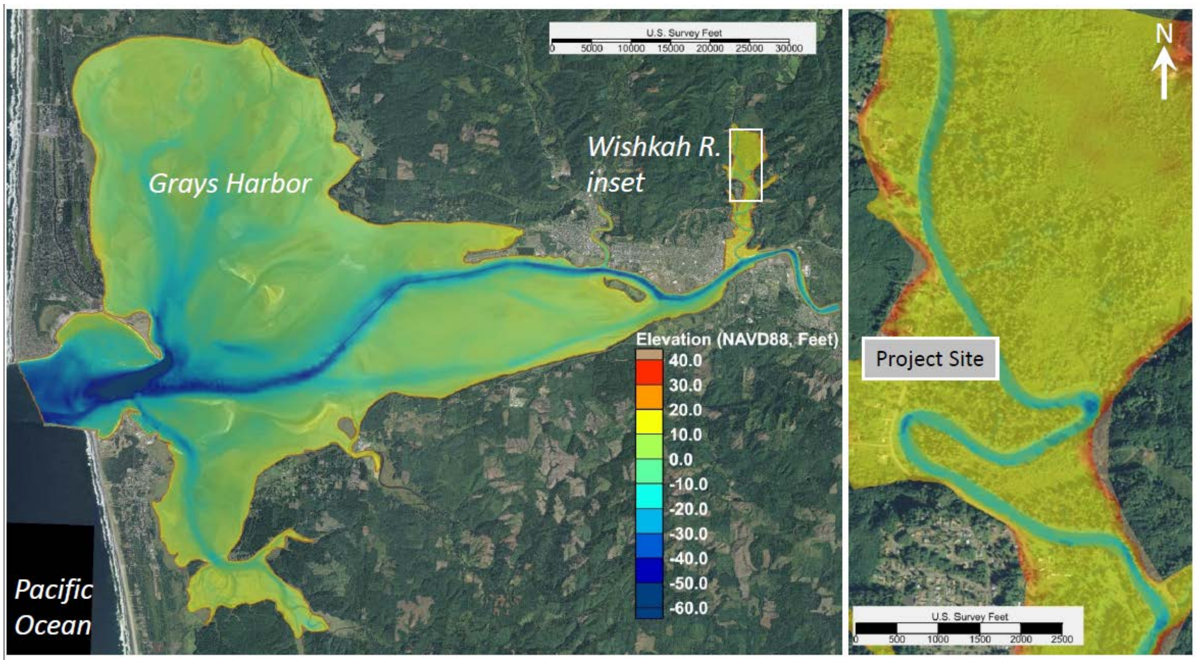


**Figure 3. Grays Harbor (left) and Wishkah River (right) elevation model. Blue colors indicate lower elevations (deeper water) and yellow and red colors indicate higher elevations (land).**

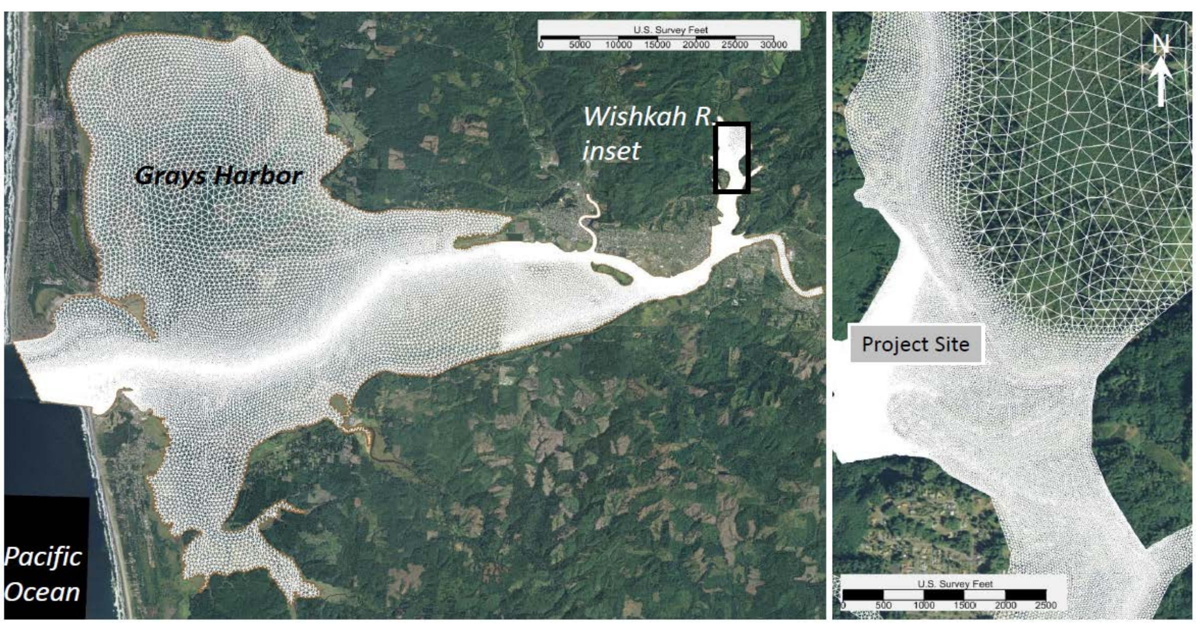


**Figure 4. Computational mesh for MORPHO model**

### 1.3.2. Roughness

In the MORPHO model, bottom roughness is parameterized by the Manning's Coefficient, the so-called "n" value.  For this analysis, two coefficients were applied: one for flow in the river channel, and one for floodplain areas outside the river channel.  The above-referenced USACE (1971) flooding study for the Wishkah River used a range of Manning's values (0.02 to 0.168) in order to calibrate their model. For this study, bottom roughness in the river channel was parameterized with a Mannings "n" value of 0.02.  Because overland flooding flow encounters many more obstacles such as trees, ground vegetation, and structures, bottom roughness for overland flow was parameterized with a Manning's coefficient of 0.08, which according to the U.S. Forestry Service Forestry Sciences Laboratory (U.S. Forest Service, 2013) is appropriate for floodplains with trees and undergrowth.

## 1.4. Model Validation

### 1.4.1. Input

To validate the MORPHO hydrodynamic model, simulations were performed for the time period when AMEC's water level data loggers were deployed in the Wishkah River (March 13-25, 2013).  Measured water surface elevations at NOAA Station at Westport were applied as the boundary conditions at the mouth of Grays Harbor. Estimated Wishkah River discharge upstream model boundary was determined by the extrapolation method of the time series from the DOE's Nisson gage described in Section 1.1.4.   Boundary conditions (e.g. model input) for the model validation case are plotted in Figure 5, where the dotted black line is the water surface elevation at Westport, and the solid dark blue line is the extrapolated discharge in the Wishkah River at the model boundary[3].

[3]As discussed above, the Chehalis River flows were not included in the simulations due to minimal influence on extreme flood conditions in the Wishkah River.

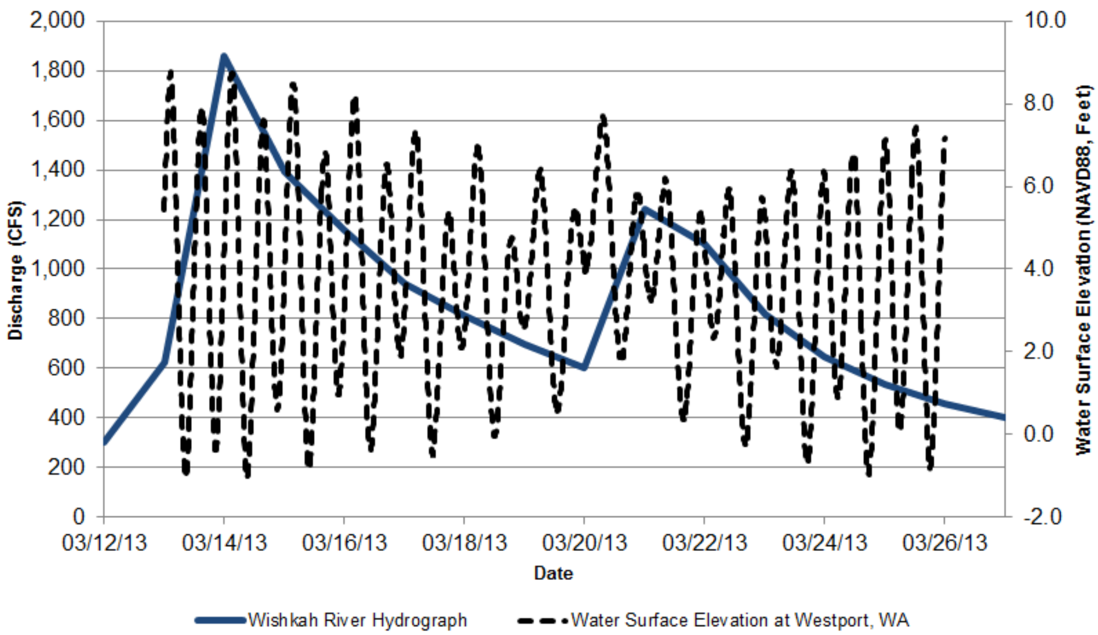


**Figure 5. Water surface elevation at Westport (dotted black line) and Wishkah River discharge (solid dark blue line) are model boundary conditions**

At the onset of the simulation, boundary input water levels and discharge were gradually ramped up over a 12-hour period, from zero to the value at the conclusion of the 12-hour ramping period. Initial water surface elevations in the modeling domain were coded to match the water surface elevation at the Grays Harbor boundary at the end of the ramp time (12 hours).

### 1.4.2. Measured and Modeled Water Levels

Simulated model water surface elevations are compared in Figure 6 to the measured water levels at data logger C located just upstream of the project site (see Figure 1). Figure 6 shows that the modeled water surface elevation (red) compares well to the measured water surface (black dashed line). The grey circle identifies the time of the model snapshot provided in Figure 7. The water levels match well and phase is resolved; these indicate the model simulates tide and river discharge interaction properly. A snapshot of the 2-D model simulation is shown in Figure 7, where the red colors represent higher velocities, the blue colors indicate slower velocities, and the black arrows show the direction of depth-averaged flow. This figure corresponds to 6 a.m. on March 15, 2013, in Figure 6. The modeling domain boundary is plotted as a white line in Figure 7, which approximately follows the 17.0-ft contour line. Note that in the snapshot and throughout this simulation, the river stayed within its banks and did not flood the roadway. The model did, however, simulate realistic wetting of the marsh/floodplain area near the roadway shoulder. Therefore, based upon comparison with measured water levels and site observations, the model is considered to be validated for typical flow conditions

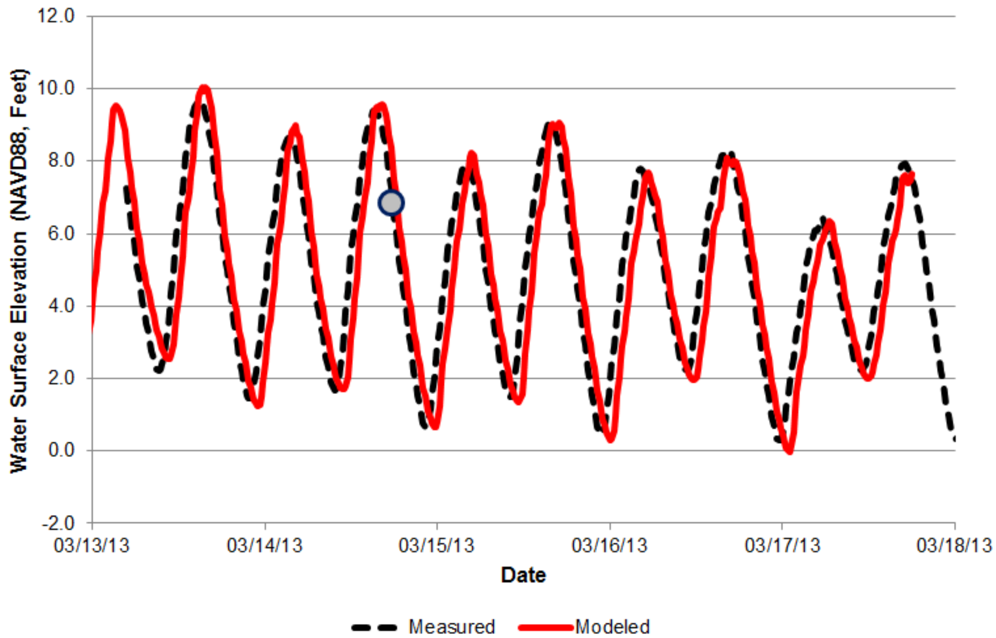


**Figure 6. Time series of measured (dashed black line) and modeled (solid red line) water surface elevations at Water Level Logger C, near the project site, over approximately five days in March 2013**

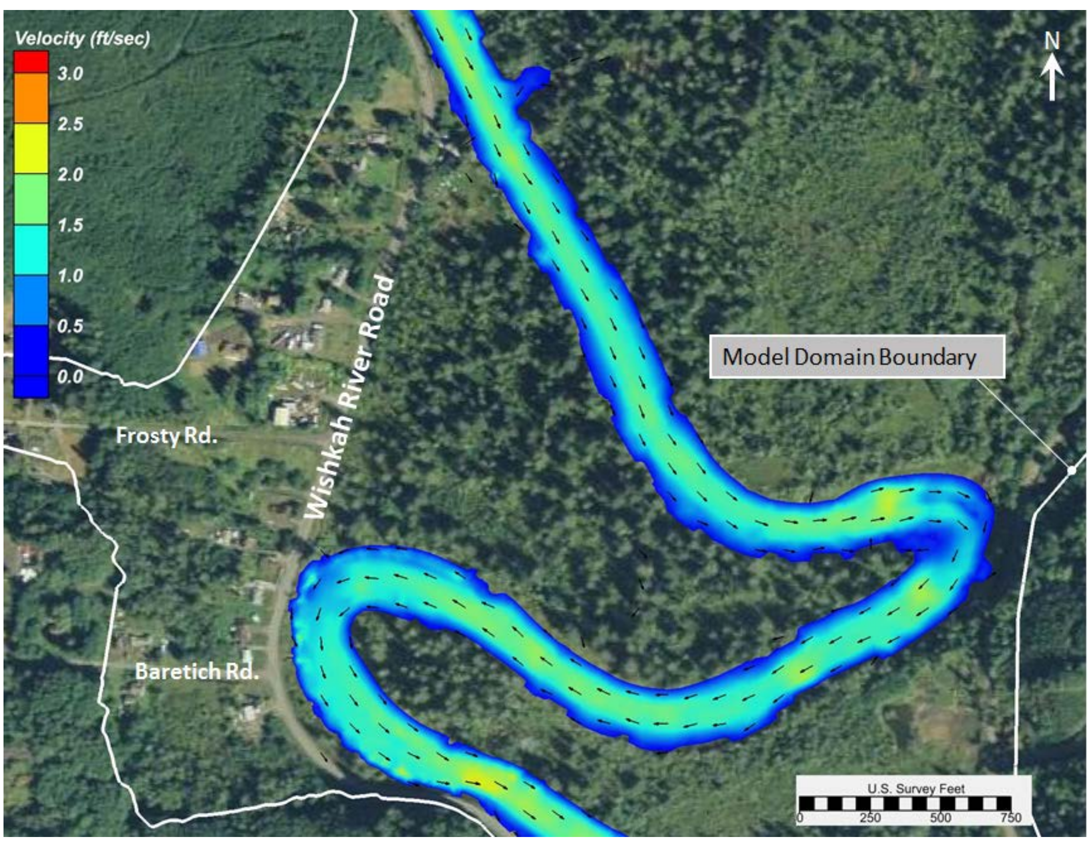

**Figure 7. Snapshot of model simulation velocities for the calibration case at 6 a.m. on March 15, 2013 (water surface elevation shown in time series plot in Figure 6)**

## 2. Model Results

Upon successful validation of the model, as described in the previous section, extreme flooding scenarios were evaluated and simulated to support analysis of flood protection alternatives. The following sections summarize the key findings of this analysis.

### 2.1. Design Criteria

Past studies (FEMA, USACE) and analysis conducted herein indicate that extreme flooding is caused by high river discharge combined with high tides. A range of design criteria (tide levels and river discharge) were considered by the project team. These included the 10-, 50-, and 100-year water surface elevation in Grays Harbor (see Table 3) and Wishkah River discharge ranging from the 50- to 100-year events. Upon comparison and analysis of potential design criteria and previous studies, it was agreed that the design flood event for numerical analysis and alternatives development would be the 10-year water level (tide) in Grays Harbor, combined with the 50-year Wishkah River discharge. Such a combination of extreme tide and discharge events has a very low probability of occurrence during any given year; and likely has less than a 1 percent annual chance of occurrence.

### 2.2. Existing Conditions

#### 2.2.1. Input

The design flood event was simulated in two different ways; steady-state and dynamic. In the steady-state simulations, a constant water surface elevation equal to the 10-year return period water level (tide) reported by FEMA for Grays Harbor (12.3 ft, NAVD88) was applied and a constant river discharge (17,600 cubic feet per second (cfs) as determined by AMEC) was simulated. In the dynamic simulations, time-varying water surface elevation (tide) and river discharge were applied. The 50-year return period hydrograph was developed by AMEC, and applied with a peak flow of 17,600 cfs. The peak of the hydrograph was phased to correspond with a peak water surface elevation (high tide) of 12.3 ft. This tidal time series input was constructed from actual high tides measured in Grays Harbor at Westport. Figure 8 shows tidal elevations at the model boundary (black dotted line), and the 50-year Wishkah River discharge (solid blue line).

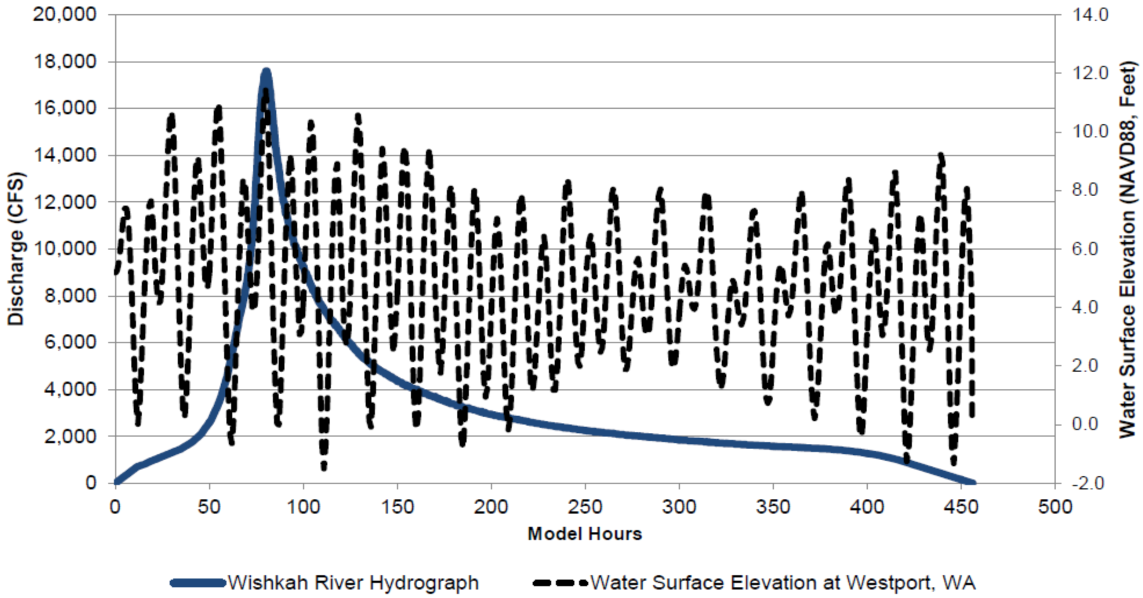


**Figure 8. 10-year water surface elevation time series at Westport (dashed black line), and 50-year Wishkah River discharge volume (solid dark blue line) applied for dynamic simulation**

### 2.2.2. Results

Model results from both the steady-state and dynamic simulations of the design flood event indicate flooding in the project area. Peak water surface elevations vary across the project site, as depicted in Figure 9 for the dynamic and steady-state model results. In Figure 9, the solid yellow line is the roadway centerline surface provided by AMEC, the solid dark blue line is the peak dynamic water surface elevation, and the solid light blue line is the peak steady-state water surface elevation. From these simulations, the model indicates that much of the roadway would be inundated by 3 to 4 ft of water during the design flood event.

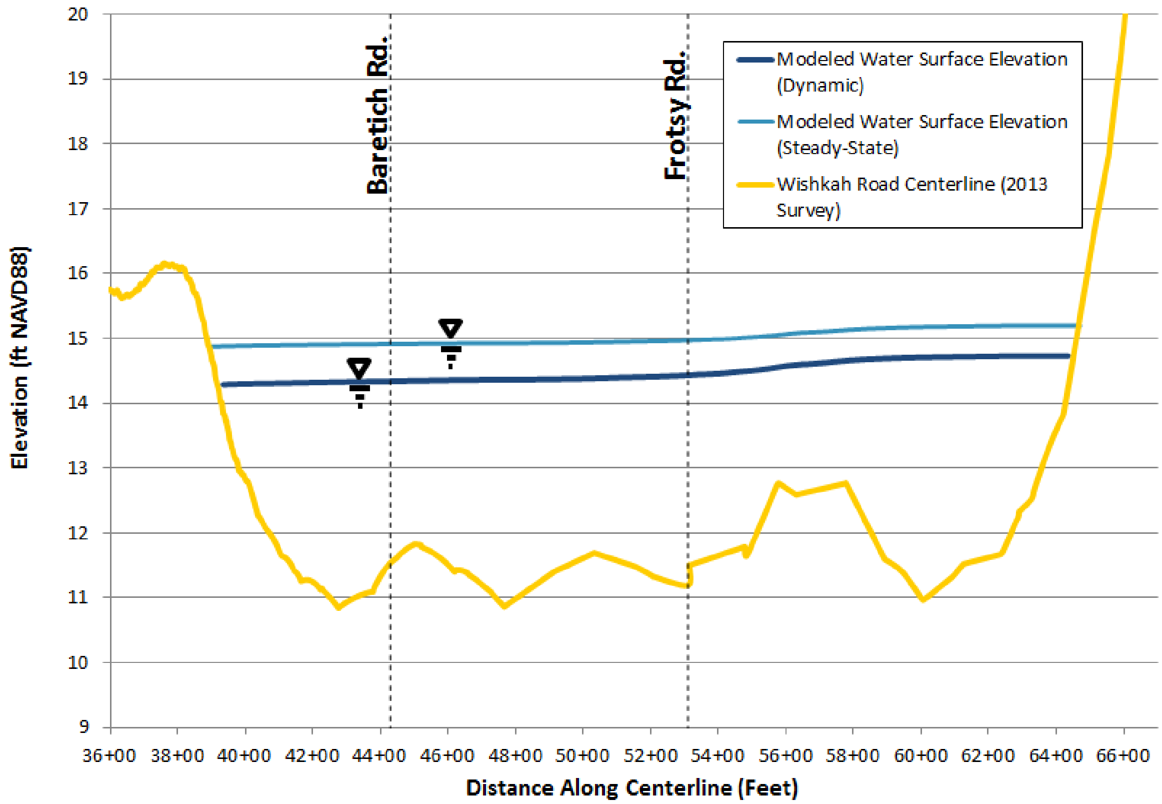


**Figure 9. Water surface elevations along centerline of Wishkah Road at peak flood for existing conditions steady-state and dynamic simulations. Roadway centerline (solid yellow) elevations provided by AMEC are also plotted.**

Figure 10 shows a snapshot of model velocities associated with the peak flood water surface elevation in the project area for the existing conditions steady-state simulation, where blue colors represent low velocity, brighter colors represent higher velocities, and black arrows represent the direction of the depth-averaged flow. Model results are extracted at the virtual model gages (red dots at upstream and Baretich Road locations) and are provided for comparison with proposed conditions in the next section.

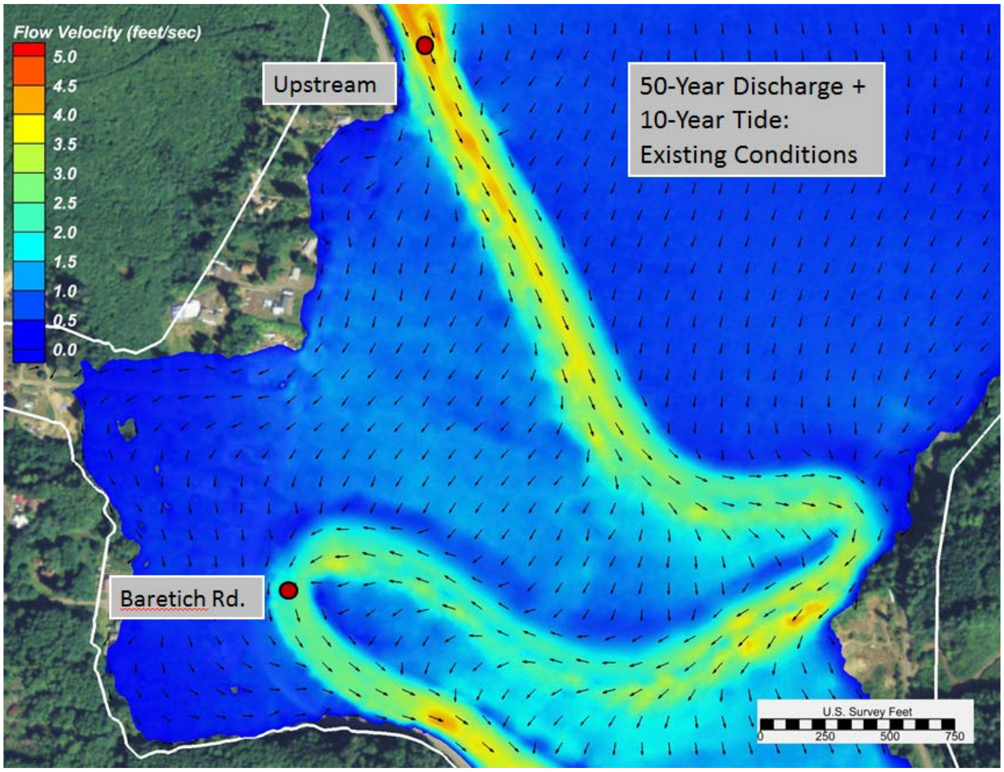


**Figure 10. Snapshot of design flood event for existing conditions steady-state model, showing flow velocities and wetted extent. Blue colors represent lower flow velocities, yellow colors represent higher velocities, and black arrows represent flow direction.**

## 2.3. Proposed Alternatives

Based upon the modeling results for the steady-state simulation summarized above for the existing conditions, alternative designs were developed to protect Wishkah Road from inundation during the design flood event. Multiple flood protection alternatives were considered by the project team. Modeling was performed only for the preferred sheet pile wall alternative; results are summarized below.

### 2.3.1. Input

To simulate the proposed floodwall alternative in the model, the identical hydrodynamic model inputs were applied as described above for the existing conditions model. In the same manner, two modeling methods were performed; steady-state and dynamic. The proposed floodwall was parameterized by a series of high-resolution mesh elements with a uniform top elevation of 16.5 ft along the proposed floodwall alignment. Figure 11 depicts the existing and proposed elevation models for comparison. The proposed floodwall alignment is indicated by the dashed red line just to the east of Wishkah Road. No other changes were made to the elevation model or model input for the proposed alternative simulations.

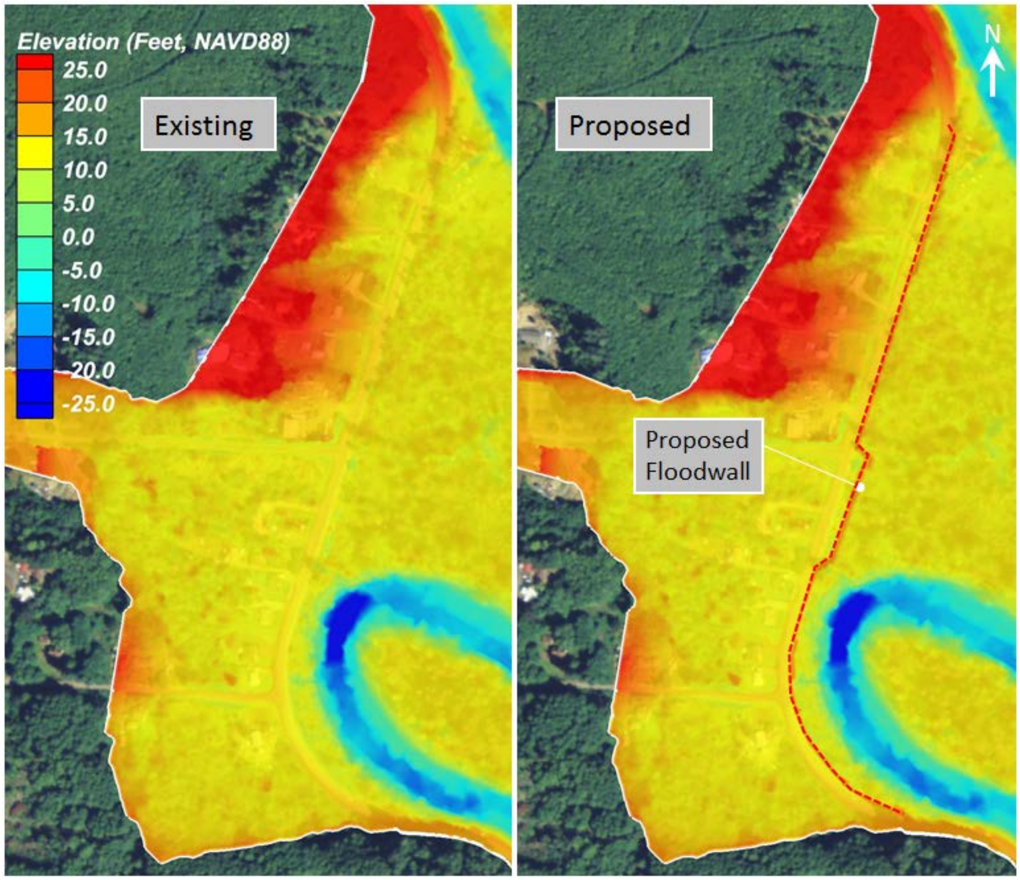


**Figure 11. The elevation model of exisiting conditions and parameterization of flood wall (dashed red line) in elevation model for proposed condtions**

### 2.3.2. Results

Figure 12 shows a snapshot of model velocities associated with the peak design flood water surface elevation in the project area for the proposed conditions steady-state simulation. In the figure, the blue colors represent low velocity; brighter colors represent higher velocities, and black arrows represent the direction of the depth-averaged flow. Figure 12 shows the proposed conditions and is compared with Figure 10, which shows the existing conditions. From the comparison, it is clear that the proposed floodwall layout and elevation prevents inundation of the project site due to combined river and tidal flooding for the design event. Please note that the modeling assumes that all culverts and outfalls crossing the floodwall are fully sealed during the flood event, and that the modeling does not take into account local rainfall runoff behind the floodwall.

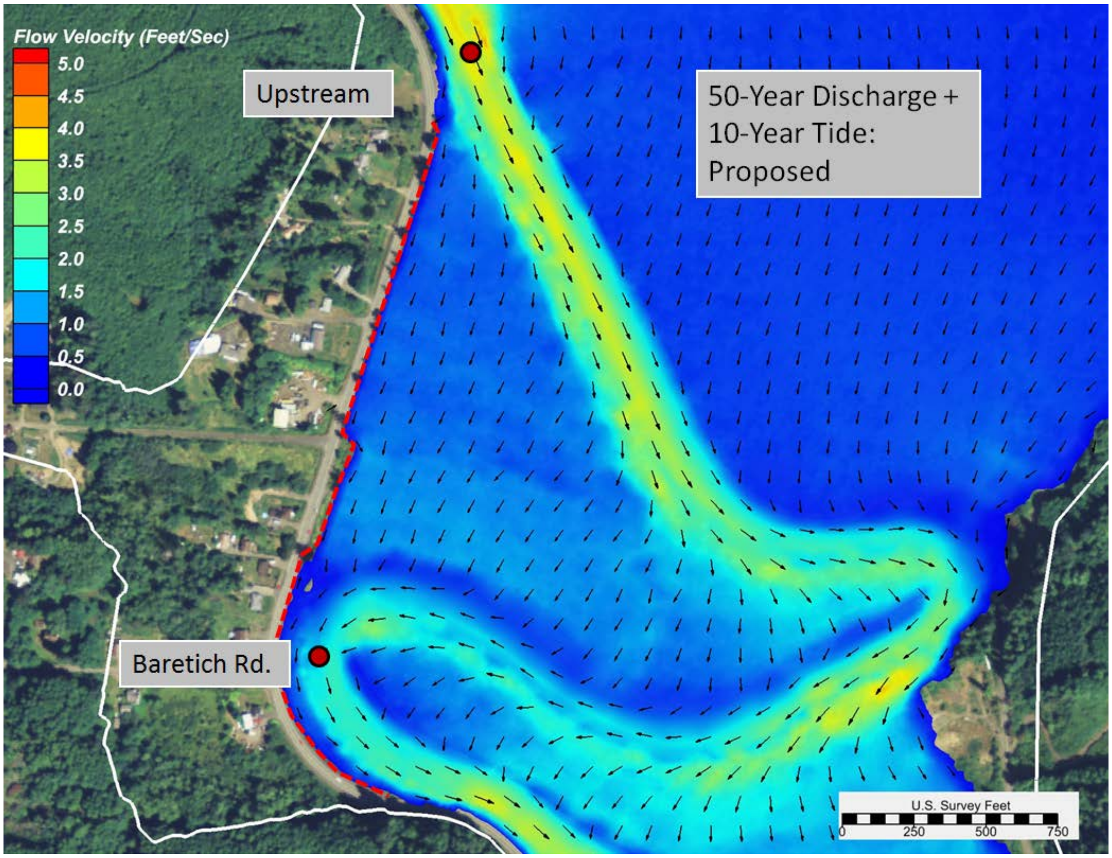


**Figure 12. Snapshot of design flood event for proposed conditions steady-state model, showing flow velocities and wetted extent. Blue colors represent lower flow velocities, yellow colors represent higher velocities, and black arrows represent flow direction.**

The analysis was conducted to determine possible effects from the proposed floodwall on peak water surface elevations in the river and for AMEC's use in evaluating drainage issues behind the floodwall. For this purpose, peak water surface elevations at the virtual gage locations in Figure 12, as well as two other locations shown in Figure 1, are compared in Table 4. The table shows that downstream of the site, in Aberdeen and in the harbor mouth near Westport, no changes in peak water surface elevations are expected with the proposed floodwall alternative. The table also indicates some slight increase (0.06 ft) in peak water surface elevation near the project site. It is likely that such a slight difference may be attributable to model accuracy. A more detailed analysis of potential rise due to the floodwall should be investigated in subsequent studies during the next phase of the project.

**Table 4. Peak water surface elevations for existing and proposed conditions at selected points in the model for dynamic simulations**

| Location | Water Surface Elevation, feet NAVD88 | |
|---|---|---|
| | Existing | Proposed |
| Grays Harbor Mouth | 11.46 feet | 11.46 feet |
| Aberdeen Data Logger C | 12.27 feet | 12.27 feet |
| Baretich Road | 14.33 feet | 14.37 feet |
| Upstream of Site | 14.79 feet | 14.85 feet |

To support AMEC's evaluation of localized flooding on the protected side of the floodwall due to local runoff, a time series of water surface elevations for the dynamic modeling results of proposed conditions were extracted at Baretich Road. Figure 13 provides the duration of time that water levels exceed the given elevations for the design flood. From the figure it can be determined the duration that localized flooding would be unable to drain during the flood event.

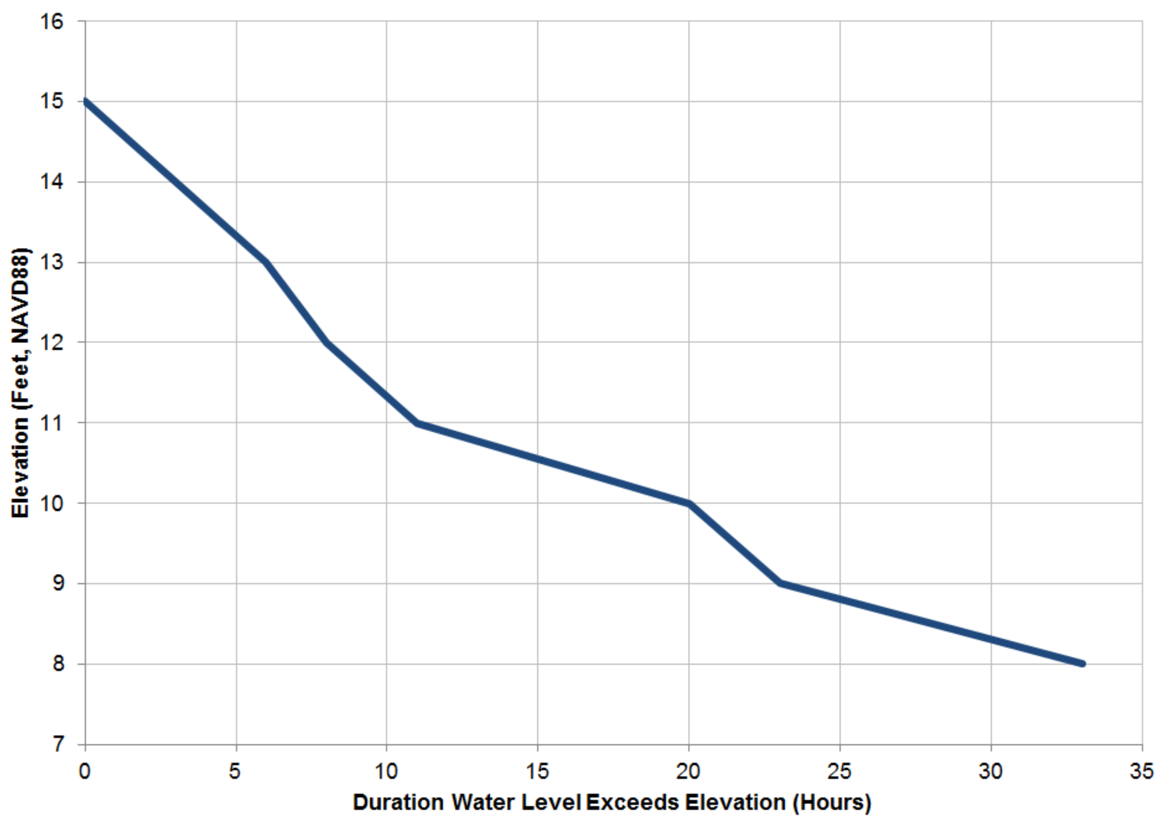


**Figure 13. Duration of flooding in hours as a function of river elevation for Wishkah River Road at Baretich Road**

In consideration of potential scour along the east (waterward) side of the floodwall, depth averaged velocities were extracted from the model for the design flood event along the proposed floodwall alignment. From the model, depth averaged velocities in the main river channel vary depending on river stage and location, and may exceed 5.0 ft/sec. The model also shows that flow velocities along the proposed floodwall are much smaller, with peak velocities ranging from 0.5 to 1.0 ft/sec. The distance of the floodwall from the existing main river channel (more than 1,000 ft in some areas) and resulting relatively slow shallow flow over the floodplain cause these low velocities. The joint occurrence of the extreme high tide and peak river discharge also has a damping effect on depth average flow velocities, because of the elevated water surface elevations. The highest model velocities along the proposed floodwall occurred near Baretich Road, where the main river channel flow is closest to the existing roadway. Comparison of velocities for the existing and proposed floodwall conditions showed no measurable increase in velocities for the design flood event.

Given the relatively low model velocities for the design flood (less than 1 ft/sec), it appears that potential scour risk is low and scour protection is not warranted for the proposed floodwall alignment and existing river channel configuration. Scour at the proposed floodwall is a function of local velocity (shear stress) and soil properties.

More detailed analysis and numerical modeling will be required during the next phase of the project to evaluate potential scour and bank erosion risk from a larger scale of geomorphic processes, such as channel river channel meandering. Future river meandering may expose the floodwall to higher velocities, and thus, the potential for scour may increase, particularly at the north end of the project and in the vicinity of Baretich Road. If the risk of scour is determined to be critical by this future analysis, then standard measures for scour protection should be anticipated. Floodwall areas at high risk can then be designed with suitable scour protection, or portions of the at-risk floodwall can be designed structurally (e.g., greater sheetpile embedment) to withstand river meandering and associated scour effects.

# 3. Conclusions

Engineering analysis and numerical modeling were performed to develop and evaluate design alternatives for Wishkah Road flooding protection. Existing studies and data were reviewed and used, as applicable, to support this effort. Based upon previous studies, engineering analysis, and measurements of recent high water marks, it was determined that flooding at the site is caused by both high tides and high discharge events in the Wishkah River, or a combination thereof. To evaluate flooding effects at the project site, the 2-D numerical model MORPHO was applied and validated using local water surface elevation measurements from March of 2013.

Prior to developing alternatives, a range of extreme events were considered, based upon previous FEMA studies, including various combinations of high tide and Wishkah River discharge. For alternatives analysis and development, the project team selected a design flood event that combined the 10-year water level (tide) in Grays Harbor with the 50-year Wishkah River discharge. This design flood event was first simulated for existing conditions with both steady-state and dynamic model input.

Simulations of existing conditions indicate that water depth on the road centerline in some areas may reach three to four feet during the design flood event. To protect the roadway from flooding, the project team developed a number of alternative protection concepts. A vertical sheetpile floodwall was selected by the project team as a preferred alternative. The proposed alternative was numerically modeled and evaluated for the design flood conditions. Modeling results provided for peak water surface elevations and duration of high water levels confirmed the technical feasibility of a vertical floodwall (preferred alternative) to protect Wishkah Road from flooding by the Wishkah River.

Model velocities along the proposed floodwall are relatively low, compared to flows in the main river channel. Therefore, it appears that scour protection along the full length of the floodwall is not warranted for the existing river channel conditions. CHE recommends that large-scale river geomorphology and channel meandering be investigated in the next phase of the project to define the appropriate criteria for floodwall design and scour protection at the north end of the project and in the vicinity of Baretich Road.

In addition, CHE notes that effective flood protection and project feasibility ultimately require addressing local drainage behind the floodwall and installation of functional tide gates on all culverts crossing the wall, as evaluated by AMEC.

## 4. References

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USACE. 1971. Wishkah River, Washington, Water Surface Profiles, Drawing E-S-4-4.

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## APPENDIX F

Hydraulic Project Approval, 1986

071-OYB-010507-R

# HYDRAULIC PROJECT APPROVAL

(R.C.W. 75.20.100)

August 26, 1986

(Applicant should refer to this date in all correspondence)

PAGE 1 OF ____ PAGES

DEPARTMENT OF GAME
600 Capitol Way North
Olympia, Washington 98504
(206) 753-5897

| | |
|---|---|
| [10] LAST NAME / FIRST: Grays Harbor County Public Works | [18] CONTACT PHONE(S): |
| [1] 1 2 3 4 | [2] [3] 70949 |
| [19] STREET OR RURAL ROUTE: P. O. Box 511 | |
| CITY: Montesano, Washington / STATE / ZIP: 98563 | [7] 027 [8] C (A B C D) [9] WRIA 22 |
| [12] WATER: Unnamed Tributaries / TRIBUTARY TO: Wishkah River | [14] 91 [15] [16] F G [17] 01 |
| [13] QUARTER SECTION / SECTION: 33 / TOWNSHIP: 18N / RANGE (E-W): 9W / COUNTY: Grays Harbor | [11] TYPE OF PROJECT: Culvert Extension |

**TIME LIMITATIONS:** [5] THIS PROJECT MAY BEGIN September 1, 1986 [6] AND BE COMPLETED BY December 31, 1987

THIS APPROVAL IS TO BE AVAILABLE ON THE JOB SITE AT ALL TIMES AND ITS PROVISIONS FOLLOWED BY THE PERMITTEE AND OPERATOR PERFORMING THE WORK.

The person(s) to whom this approval is issued may be held liable for any loss or damage to fish life or habitat which results from failure to comply with the provisions of this approval.

Failure to comply with the provisions of this approval is a gross misdemeanor, possibly punishable by fine and/or imprisonment.

The Departments reserve the right subject to the holders opportunity to a hearing to contest agency actions as provided by the Administrative Procedure Act, chapter 34.04 RCW, to make additional restrictions or conditions or revoke the approval when new information shows such action is necessary by the departments for the protection of fish life.

These departments cannot be held liable for any property damage which might occur as a result of this project, except where damages are proximately caused by actions of the departments.

This approval pertains only to the provisions of the Fisheries and Game Codes. Additional authorization from other public agencies may be necessary for this project.

1. Work that will involve direct contact in the water will be schedule between June 1 to September 30, 1987.
2. Work on mitigation sites as identified in mitigation plan that can be separated from state waters may be constructed during the operational period of this permit.
3. Culvert extensions shall not restrict the free movement of fish at any life stage.
4. Wetlands losses that contributed to state waters will be protected as per an approved mitigation plan.
5. Road construction fills shall not appreciably offset water quality of the Wishkah River system and shall be approved by appropriate water quality variance permits.

DEPARTMENT OF GAME [signature] for DIRECTOR

GAM 111 (Rev. 9/77) -771- 3

# APPENDIX G

Kersh-Wishkah Flood Levee Review of Existing Information

**Memo**

| | | | |
|---|---|---|---|
| To | Russ Esses | AMEC# | 3-915-17568-0 |
| From | Ryan Bartelheimer | cc | Kersh-Wishkah Flood Levee Project Team |
| Tel | (425) 368-0980 | | |
| Fax | (425) 368-1001 | | |
| Date | April 10, 2013 | | |

Subject Kersh-Wishkah Flood Levee Review of Existing Information

The goals and design criteria for the Kersh-Wishkah Flood Levee project were previously documented in a memorandum dated March 5, 2013. Since then, the design team has endeavored to gather available information that could be useful in developing or evaluating alternative strategies to reduce flooding along Wishkah Road. This memorandum summarizes the readily available information that has been reviewed and provides a list of recently gathered data that have been acquired to fill known data needs.

## REVIEW OF EXISTING DATA

The following information was collected and reviewed as specifically described below:

- Landowner petition and accompanying materials: *viewed at Frank Kersh's house. Of particular interest were dated photos of different homes along Wishkah Road during various flood events.*
- Anecdotal information on flooding history, road settlement, and road maintenance and Public Works records: *reviewed, including documents, photos (Kersh), road department records, and 1980s design, which will be compared to the topographic survey and road repair records.*
- Soils and geologic maps and accompanying information: *obtained and reviewed soils, geology, seismic, and hazard classification.*
- Parcel boundary maps, records, and markers: *gathered by the surveyor.*
- Historic photos: *viewed photos of floods and aerial photos dating back to 1942.*
- Road, infrastructure, and utilities: *utility locate service called and then surveyed.*
- Maps: *Grays Harbor County GIS data sets downloaded from ghc-gis.org. The data sets include parcel, zoning, roads, hydro, jurisdiction, and PLS (public land survey).*
- Flood maps and profiles: *obtained from FEMA.*

- Topography: *data gathered, including USGS topography, FEMA LiDAR.*
- Bathymetry: *gathered historic bathymetric survey data.*
- Tidal modeling: *compiled existing modeling data produced by Coast & Harbor Engineering, including 3D and 2D hydrodynamics.*
- River modeling: *no existing model is readily available for Wishkah River.*

The specific data acquired and the sources are listed in more detail in Table 1.

## ADDITIONAL DATA GATHERED

In addition to reviewing existing data, additional data were acquired as part of this project to fill gaps and support the engineering analysis. This information is in various stages of being finalized, but all of the field work has been completed. The additional acquired data include:

- Topographic survey – A topographic survey was conducted addressing roads, ditches, utilities, high water marks (as observed in the photos viewed at Frank Kersh's house), culverts, tide gates, and other relevant features. Field work was performed by Berglund, Schmidt, and Associates as a subconsultant to AMEC.
- Bathymetric survey – A bathymetric survey was performed at numerous cross-sections in the Wishkah River from its mouth to just upstream of the project site, along with longitudinal profiles in the same area. Field work was performed by HydroGraphix as a vendor to AMEC.
- Geotechnical investigation – Three borings were advanced along the east edge of the road prism. Soil samples were taken and are being analyzed in a laboratory to determine their engineering properties. Field work was overseen by AMEC, and performed by Boretec.
- Water level loggers – Two water level loggers were deployed during the bathymetric survey and for about 10 days afterward to collect water elevations near the mouth of the river and at a point located upstream of the project site. AMEC-owned equipment was deployed and retrieved by HydroGraphix.

A detailed list of the data gathered is shown in Table 1.

**Table 1 - List of Data Gathered for Kersh-Wishkah Flood Levee Project**

| Source | Type | Date (MM/DD/YEAR) | Description |
|---|---|---|---|
| NOAA | Bathymetry | 9/1/1956 | Bathymetric survey of lower 2.4 miles of Wishkah River |
| USACE | Bathymetry | 2000 - 2012 | Bathymetric survey of Federal Navigation Channel |
| NOAA | Bathymetry | 2004 - 2005 | Bathymetric survey of Grays Harbor estuary |
| OR Dept. of Geology and Mineral Industries | Topography | 9/26/2009 | LIDAR survey of SW Washington |
| NOAA | Water Levels | 2/20/2004 - 12/14/2005 | Predicted and Measured Tides @ Aberdeen |
| NOAA | Water Levels | 12/19/1999 - 12/14/2009 | Predicted Tide @ Aberdeen |
| NOAA | Water Levels | 04/2004 -11/2005 | Monthly Water levels @ Aberdeen (MLLW, MHHW, etc…) |
| NOAA | Wind | 03/26/2008 - 03/28/2013 | Hourly wind speed, direction and pressure @ Westport |
| NOAA | Water Levels | 3/23/2006 - 03/28/2013 | Predicted and Measured @ Westport |
| NOAA | Water Levels | 12/19/1999 - 11/20/2009 | Predicted @ Westport |
| NOAA | Water Levels | 4/2006 - 2/2013 | Daily High/Low (Westport) |
| NOAA | Water Levels | 4/2006 - 1/2013 | Monthly Water levels at Westport (MLLW, MHHW, etc…) |
| USACE | Water Levels | 9/13/1999 -11/17/1999 | Measured @ U.S. Coast Guard Station Westport, WA |
| USACE | Water Levels | 9/12/1999 -11/17/1999 | Measured @ Aberdeen, WA |
| FEMA | Floodmap | 9/29/1986 | Panel 325 (Unincorporated Gray's Harbor County) |
| FEMA | Floodmap | 9/29/1986 | Panel 425 (Unincorporated Gray's Harbor County) |
| FEMA | Floodmap | 9/29/1986 | Panel 2 (City of Aberdeen, WA) |
| FEMA | Floodmap | 9/29/1986 | Panel 2 rev B (City of Aberdeen, WA) |
| FEMA | Report | 2/16/1990 | Flood Insurance Study: Gray's Harbor Unincorporated Areas |
| FEMA | Report | 1/1/1984 | Flood Insurance Study: City of Aberdeen |
| FEMA | Preliminary Report | 8/5/2011 | Preliminary Flood Insurance Study: City of Aberdeen |
| FEMA | Preliminary | Not Dated | Preliminary FEMA floodmaps Gray's Harbor County 1-3 |
| NAIP | Aerial Photo | 2006 | Orthophoto,1.5 ft resolution |
| NAIP | Aerial Photo | 2009 | Orthophoto, 1 meter resolution |
| NAIP | Aerial Photo | 2011 | Orthophoto, 1 meter resolution |
| Washington Dept. of Ecology | Streamflow | 4/04/2004 - 03/28/2013 | Mean daily discharge of Wishkah River @ Nisson |
| NCDC | Wind | 1/8/1991 - 8/01/2009 | Hourly wind speed, direction and pressure @ Bowerman Field |
| Coast & Harbor Engineering | Tidal Model | 2011 | Hydrodynamic model of Grays Harbor and lower Chelalis River |
| USDA NRCS | Soils | Not Dated | Nationwide web soil survey |
| Washington Division of Geology and Earth Resources | Liquefaction | 2004 | Liquefaction Susceptibility and Site Class Maps of Washington State |
| Washington Division of Geology and Earth Resources | Site Class | 2004 | Liquefaction Susceptibility and Site Class Maps of Washington State |
| Washington DNR | Geologic Map | 1986 | Geologic Map of the Humptulips Quadrangle and Adjacent |
| Grays Harbor PUD | Geotechnical Investigation | 4/17/2008 | Geotechnical investigation for substation at Wishkah Road and B Street |
| Eastern Washington University | Archaeological Monitoring | 1990 | Archaeological Monitoring of Wishkah Road |
| US Army Corps of Engineers | 1942 Aerial Photo | 1942 | Aerial photo, 1:20,000 |
| USGS | Streamstats | Not Dated | Washington StreamStats Web Application |
| Grays Harbor County (GHC-GIS.org) | GIS data | Varies | Various GIS datasets (parcels, zoning, roads, hydro, jurisdiction, PLS) |
| Grays Harbor County | Wishkah Road | 2/6/1989 | Wishkah Road design (drawing no 94311-26) |
| Grays Harbor County | Wishkah Road | 7/11/1983 | Wishkah Road design (drawing no 94311-16) |
| Grays Harbor County | Wishkah Road | Not Dated | Test Hole Logs - at locations shown on 94311-16 |

The pre-existing data that have been collected, along with the additional information generated by this project, primarily topographic, bathymetric, and geotechnical data, are sufficient to perform the tasks identified in the existing scope of work, dated February 7, 2013.

We anticipate that additional information will need to be gathered during future phases of this project in order to provide the additional details that will be needed to fully design the project and obtain the necessary permits. Those details would more appropriately be described at the end of this phase of the project, after the alternatives are developed and evaluated, and the best alternative is chosen.