GEOTECHNICAL ENGINEERING REPORT
LOCAL IMPROVEMENT DISTRICT 98-2
CONTRACT 3 – CMC HEARTLAND AND SOUTH OXBOW GRAVITY SEWERS
FIFE, WASHINGTON

Submitted to:

TetraTech/KCM Inc.
1917 First Avenue
Seattle, Washington 98101-1027

Submitted by:

AMEC Earth & Environmental, Inc.
11335 N.E. 122nd Way, Suite 100
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March 25, 2002

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TetraTech/KCM Inc.
1917 First Avenue
Seattle, Washington 98101-1027

Attention: Mr. Doug Genzlinger, P.E.
Project Manager

Subject: **Geotechnical Engineering Report**
Local Improvement District 98-2
Contract 3 – CMC Heartland and South Oxbow Gravity Sewers
Fife, Washington

Dear Doug:

AMEC Earth & Environmental, Inc. (AMEC) is pleased to submit this report describing our geotechnical engineering evaluation for the above-referenced project. The purpose of our evaluation was to derive design conclusions and recommendations concerning site preparation, temporary dewatering, shoring and excavations, utility trench backfill, pipe crossings, and structural fill. Our scope of work comprised a field exploration, laboratory testing, analytical testing, geotechnical research, geotechnical analyses, and report preparation.

We appreciate the opportunity to be of service on this project and would be happy to answer any questions you may have.

Sincerely,

AMEC Earth & Environmental, Inc.

James S. Dransfield, P.E.
Principal

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GEOTECHNICAL ENGINEERING REPORT **9-91M-13123-0**
LOCAL IMPROVEMENT DISTRICT 98-2
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FIFE, WASHINGTON

1.0 SUMMARY

The following summary of project geotechnical considerations is presented for introductory purposes and, as such, should be used only in conjunction with the full text of this report.

- Project Description: The project consists of a total of about 11,500 feet of gravity sewer main, at depths ranging from about 10 to 25 feet below ground surface. The gravity sewer main alignment is about 1,000 feet along 54th Avenue East, roughly 1 mile across the CMC-Heartland development, approximately 1300 feet along 70th Avenue East, and 1000 feet within the South Oxbow area.

- Exploratory Methods: We explored subsurface conditions by means of 4 borings advanced along 70th Avenue East, and 10 backhoe test pits in the South Oxbow area. Subsurface conditions on the CMC-Heartland property / 54th Avenue East were based on a previous study by others. We had also advanced two borings in the vicinity of 54th Avenue East for previous studies.

- Soil Conditions: Soils underlying the sewer main generally consist of interlayered silt, sand, clay, and peat that occurred in discontinuous layers and at varying depths. In a previous sewer installation to the north along 70th Avenue E, buried trees, root wads and logs of 12 to 36 inches in diameter and lengths greater than the minimum trench width caused difficulty in trenching. These buried trees were interpreted to be associated with historic mudflows off of Mt. Rainier. We also understand that in other areas, cedar tree stumps may exist where trees were cleared for agricultural fields. Explorations made along the proposed alignment encountered occasional scattered organics, however, no buried trees were found in any of the explorations along this current alignment.

- Groundwater Conditions: Static groundwater levels measured in monitoring wells during January to February 2002 were found to range from about 2 to 6 feet below ground surface. Test pits on the CMC–Heartland property advanced during May 1998 encountered slight to minor ground water seepage in most test pits between 3 and 10 feet in depth. Significant groundwater was encountered in most CMC–Heartland test pits at depths ranging from 6 to 12 feet. Our monitoring well MW-14 at proposed Pump Station 12 had a static water level at 3.5 feet below grade in late June 2000. Our test pits across the South Oxbow area in February 2002 encountered seepage as shallow as 2 feet below grade within the low-lying oxbow, and as deep as about 10 feet in the surrounding upland areas.

- Dewatering: A temporary dewatering system will be required along major portions of the alignment due to the depth of the sewer alignment, the high water table, and the soil conditions encountered during exploration.

Temporary Sloping and Shoring: Shoring will be required in settlement-sensitive areas close to roads. Assuming soils have been properly dewatered, it may be possible to excavate safe temporary slopes (on the order of 1.5H:1V to 2H:1V or flatter) without shoring, in open field areas. If the soils are not dewatered, we have found that rapid seepage and sudden sidewall collapse will occur, with a stable repose angle of 10H:1V or flatter.

Pipe Bedding / Foundation Material: The soils at depth, even in dewatered areas, have been found to be very soft. We recommend planning on placement of 3 feet of foundation material over geotextile at the base of the trenches for stability of bedding and pipe;

On-Site Soil Considerations: Because the on-site soils are moisture-sensitive and would be readily disturbed when wet, we do not anticipate these soils will be suitable for structural fill beneath roadway areas. If the organic-rich soils are separated and the soils are allowed to drain, they may be considered for backfill above the pipe zone in non-structural areas (open fields). Ideally, earthwork would be scheduled for the summer and fall months, when drier weather will maximize the potential for reusing on-site soils and when groundwater levels will likely be at their seasonal low.

2.0 SITE AND PROJECT DESCRIPTION

The project site is an existing segment of roadway located within the City of Fife, Washington, as shown on the enclosed *Location Map* (Figure 1). Specifically, the project segment extends from approximately 1000 feet south of the Union Pacific Railroad on 54th Avenue East. From the south end of the 54th Avenue East segment, the sewer runs eastward across the currently undeveloped CMC-Heartland property for about one mile to 70th Avenue East. On 70th Avenue East, the alignment begins about 1,100 feet south of the railroad track, and continues south for another 1,300 feet. From the south end of the 70th Avenue sewer alignment, the sewer runs westward for approximately 1,000 feet through the South Oxbow area.

Both 54th Avenue and 70th Avenue presently consist of 2 traffic lanes, narrow and soft shoulders, and shallow drainage ditches. The enclosed *Site & Exploration Plan* (Figure 2) illustrate the existing alignment and associated features.

The Fife LID 98-2 has consisted of three main projects, including Contract I – Force Main, Contract 2 – Pump Stations, and Contract 3 – CMC Heartland. This report addresses Contract 3 – CMC Heartland and South Oxbow Gravity Sewers. Figure 2 illustrates the proposed sewer alignment, and our geotechnical exploration locations.

AMEC (formerly AGRA) previously conducted geotechnical studies for Contract 1, summarized in *Summary of Geotechnical Studies*, Fife LID 98-2, dated June 29, 2000. AMEC (formerly AGRA) also completed a report for Contract 2, entitled *Geotechnical Engineering Report, LID 98-2 Sanitary Sewer Improvements, Contract 2 – Pump Stations, Fife, Washington,* dated October 9, 2000. For the CMC-Heartland property, we relied on a report prepared by GeoResources, entitled: *Report, Geotechnical Engineering Services, proposed Wapato Site Development, Pierce County near Fife, Washington,* dated September 7, 1998.

The 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. Consequently, if any changes are made in the currently proposed project, we may need to modify our conclusions and recommendations contained herein to reflect those changes.

3.0 EXPLORATORY METHODS

We explored surface and subsurface conditions at the project site during December 2001. Our exploration and testing program comprised the following elements:

- A visual surface reconnaissance of the site;
- Four borings (designated B-1 through B-4) with Standard Penetration Tests, advanced along the 70th Avenue East alignment;
- Ten backhoe test pits (designated ATP-1 to ATP-10) advanced along the South Oxbow alignment;
- A review of the logs of 26 backhoe test pits (designated TP-1 through TP-26), and 6 cone penetration test probes (designated CPT-1 through CPT-5 and CPT-1B), advanced along the CMC-Heartland alignment by GeoResources, Inc. ;
- A review of two borings (designated AGRA B-3 and AGRA B-4), advanced along the 54th Avenue East alignment by AMEC (formerly AGRA) for the Contract 1 – Force Main;
- A review of one boring (designated AGRA B-14a / MW-14) advanced along the CMC-Heartland alignment by AMEC (formerly AGRA) at a location approximately 120 feet east of proposed Pump Station #12;
- Three grain size analyses, performed on selected soil samples obtained from strategic locations beneath the site;
- Seven #200 screen washes, performed on selected samples of cohesive soil obtained from beneath the site;
- Two Atterberg limit determinations, performed on selected samples of cohesive soil obtained from beneath the site;
- Thirty two moisture content determinations, performed on selected samples of cohesive soil obtained from beneath the site;
- A review of published geologic and seismologic maps and literature.

Table 1 summarizes the approximate functional locations, surface elevations, and termination depths of all pertinent subsurface explorations, and Figure 2 depicts their approximate relative locations. Appendix A of this report describes our field exploration procedures, and Appendix B describes our laboratory testing procedures.

TABLE 1
APPROXIMATE LOCATIONS, ELEVATIONS, AND DEPTHS OF EXPLORATIONS

Exploration	Functional Location	Surface Elevation (feet)	Termination Depth (feet)
B-1*	W. side of 70th Ave E., 1000 ft S. of RR Crossing	23	32.0
B-2*	W. side of 70th Ave E., 1400 ft S. of RR Crossing	23	31.5
B-3*	W. side of 70th Ave E., 1800 ft S. of RR Crossing	23	31.5
B-4*	W. side of 70th Ave E., 2350 ft S. of RR Crossing	24	31.5
AGRA B-4*	W. side of 54th Ave E., 54 ft S. of RR Crossing	25	31.5
AGRA B-14*	120 feet east of proposed Pump Station 12	21	41.5
ATP-1	South Oxbow Area: Property corner, east of oxbow	20	9.0
ATP-2	South Oxbow Area: Fence line, east of oxbow	20	9.0
ATP-3	South Oxbow Area: East side of oxbow	14	4.0
ATP-4	South Oxbow Area: West side of oxbow	16	8.5
ATP-5	South Oxbow Area: Fence line, west of oxbow	15	4.0
ATP-6	South Oxbow Area: Top of slope, west of oxbow	23	14.0
ATP-7	South Oxbow Area: Fence line, south of gravel driveway	24	14.0
ATP-8	South Oxbow Area: Field, west of brick house	24	14.0
ATP-9	South Oxbow Area: Field, north of Crowell residence	24	13.5
ATP-10	South Oxbow Area: Field, north Crowell property line	24	13.0

Elevation datum: NGVD 29; Pierce County Benchmark: VAL-44; and Temporary Benchmark: DEA #314
* Includes observation well.

The specific number, locations, and depths of our explorations were selected by AMEC and field-adjusted by AMEC in relation to the existing and proposed site features, under the constraints of surface access, underground utility conflicts, and budget considerations. We estimated the relative location of each exploration by measuring from existing features and scaling these measurements onto a layout plan supplied to us, then we estimated their elevations by interpolating between contour lines shown on this same plan. 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 utilized for this evaluation reveal subsurface conditions only at discrete locations along the project alignment and that actual conditions in other locations 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.

4.0 SITE CONDITIONS

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

4.1 Utility Conditions

Based on the roadway plans supplied to us, and information provided by utility locating services, the road areas along 54th Avenue East and 70th Avenue East include buried water and gas lines, and culverts along drainage ditches. No major utilities were identified within the CMC-Heartland or South Oxbow areas, however irrigation lines and residential service lines are present.

4.2 Surface Conditions

Alignment Surface: The roadway alignments consist of two-lane asphalt roadway. Industrial, commercial, residential, and farmland developments border the alignment. Grassy shoulders and ditches with occasional gravel or asphalt-paved access roads and driveways also border the alignment.

Topography: Surface grades along the entire alignment are relatively flat-lying. Along 70th Avenue East surface grades are generally about elevation 23 feet and rise to approximately 24 feet at the south end of the alignment. A rise in grade was noted at the 54th Avenue East railroad crossing. Topography across the CMC-Heartland and South Oxbow sites is also fairly flat-lying, with the exception of the Wapato Creek channels and other former oxbow areas. Grades in the vicinity of these current and former channels slope moderately steeply, with maximum topographic relief on the order of 10 to 15 feet.

Surface Water: The northeast portion of the CMC-Heartland property appears to drain to westward-flowing Wapato Creek. The remainder of the site appears to drain south toward the Puyallup River. Drainage ditches along 54th Avenue East and 70th Avenue East also flow south toward the Puyallup River.

4.3 Pavement Conditions

Table 2 summarizes our approximate pavement thickness measurements and soil observations recorded at each exploration location along 70th Avenue East.

TABLE 2
APPROXIMATE PAVEMENT THICKNESSES AND UNDERLYING SOILS OBSERVED IN EXPLORATIONS

Exploration	Pavement Location	Thickness (inches)		Subgrade Soil Type
		ACP	CTB	
B-1	STA. 01+90, 5 R	2"	12"	Native Silt
B-2	STA. 05+90, 5 R	2"	12"	Native Silt
B-3	STA. 10+20, 5 R	2"	12"	Native Silt
B-4	STA. 15+55, 5 R	2"	12"	Native Silt

ACP = asphalt concrete pavement
CTB = cement treated base

4.4 Soil Conditions

According to published geologic maps, soil conditions in the site vicinity are characterized by alluvium including: silt, sand and gravel deposited in stream beds, and fans; surface relatively undissected; includes some low level terraces and some lacustrine deposits. Our on-site explorations revealed somewhat variable near-surface soil conditions but confirmed the mapped stratigraphy. In general, our explorations encountered silty sands and silts, with interbedded organics and peats.

The enclosed exploration logs provide a detailed description of the soil strata encountered in our subsurface explorations. Our geotechnical laboratory tests revealed that the soils have a fines (silt and clay) content on the order of 50-96 percent, and moisture contents in the order of greater than 20% percent. We interpret most of 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 present our test results, and Table 3 summarizes these results.

TABLE 3
LABORATORY TEST RESULTS FOR NON-ORGANIC ON-SITE SOILS

Soil Type And Source	Sample Depth (feet)	Moisture Content (percent)	Gravel Content (percent)	Sand Content (percent)	Silt/Clay Content (percent)
Silty SAND (B-1/S-4)	10	26.5	0.4	85.0	14.6
Silty SAND (B-3/S-6)	20	27.0	0	63.4	36.6
SAND with silt (B-4/S-7)	25	26.0	0	92.3	7.7
SILT (B-1/S-5)	15	64.6	N/T	N/T	96.4
Silty SAND (B-1/S-6)	20	27.3	N/T	N/T	43.9
Sandy SILT (B-2/S-2)	5	41.2	N/T	N/T	77.4
Sandy SILT (B-2/S-4)	10	31.4	N/T	N/T	54.0
Sandy SILT (B-2/S-8)	30	34.1	N/T	N/T	83.1
Silty SAND (B-3/S-4)	10	29.6	N/T	N/T	15.9
Sandy SILT (B-4/S-2)	15	31.7	N/T	N/T	57.0

N/T – not tested

Buried Logs/Wood Debris

A buried log was encountered in GeoResources test pit TP-5 (on the CMC-Heartland property) at 14 to 16 feet below ground surface. No other buried logs were encountered in other exploratory test pits or borings along the subject alignment.

During 2000, construction of the deep gravity sewer along 70th Avenue East (between 20th Street East and Valley Avenue East), a log/wood debris layer was encountered. These materials are interpreted to originate from ancient flood events along the Puyallup River. We understand that trees and logs of 12 to 36 inches in diameter and lengths greater than the minimum trench width, were encountered. Additionally, tree root wads were encountered, which reportedly caused the most difficulty in trenching. We understand the top of the log/wood debris layer was encountered at about 13 feet below existing grade (elevation +5 feet), and was of variable thickness and distribution. We understand some of these logs were well preserved and had to be cut with chain saws. Chain saw blades reportedly had to be replaced frequently when cutting these logs, due to the soil in contact with the logs. Some of the logs were reported as soft and saturated and spongy. The logs were in various orientations relative to the long axis of the trench. Some of these logs could be removed or broken through with a trackhoe/ thumb, however, movement of the soil outside of the trench was observed and this was stopped due to concern for damaging adjacent utilities and other facilities.

4.5 Groundwater Conditions

Groundwater levels were measured on January 4, 2002 and again on February 28, 2002. All of our observation wells encountered groundwater at depths ranging from 2 to 6 feet below existing grades and at elevations ranging from 14 to 21 feet. Table 4 summarizes the approximate groundwater depths and elevations that we measured in our explorations and observation wells. Our explorations were performed during an extended period of alternately wet and dry weather. The groundwater

conditions present at that time may closely represent the yearly high; somewhat lower levels probably occur during the summer and early fall months, whereas higher levels probably occur during the winter and early spring months. Throughout the year, groundwater levels would likely fluctuate in response to changing precipitation patterns, off-site construction activities, and site utilization.

TABLE 4
APPROXIMATE DEPTHS AND ELEVATIONS OF GROUNDWATER ENCOUNTERED IN EXPLORATIONS

Exploration	Observation Well	Depth of Groundwater (feet)	Elevation of Groundwater (feet)	Date of Measurement
B-1	OW-1	2.0	21.0	01/04/2002
B-1	OW-1	1.65	21.35	02/28/02
B-2	OW-2	2.3	20.7	01/04/2002
B-2	OW-2	2.10	20.90	02/28/02
B-3	OW-3	4.2	18.8	01/04/2002
B-3	OW-3	3.75	19.25	02/28/02
B-4	OW-4	6.3	17.7	01/04/2002
B-4	OW-4	5.25	18.75	02/28/02
AGRA B-14a	MW-14a	5.5	17.5	06/23/2000
AGRA B-4	MW-4	10	15	11/17/99
AGRA B-4	MW-4	11.05	13.95	02/28/02

According to the contractor for the 70th Avenue East sewer between 20th Street and Valley Avenue, groundwater was observed as moderate to rapid lateral seepage into the trench originating from the organic/ log layer they encountered at about 13 feet. We understand the contractor had difficulty operating a trash pump when attempting to dewater this open excavation, due to clogging by sediment-laden water, wood splinters, and organic debris floating in the perched water.

5.0 BASELINE STATEMENTS

The following baseline statements pertain to the proposed CMC-Heartland South Oxbow gravity sewer project.

- **Baseline Statement - For baseline purposes, well preserved logs with saturated spongy exteriors, of 12 to 36 inches in diameter and lengths greater than the minimum trench width, are expected to be encountered below elevation +5 feet. These logs are expected to be encountered at random orientations. Additionally, tree root wads are expected to be encountered below elevation +5 feet. Root wads were found to cause the most difficulty in trenching and shoring. For baseline purposes, these trees and root wads form a mat of varying thickness and makeup, and are expected to be encountered within the depth of planned excavation, at a frequency of one every 20 feet on average; along the entire length of the trench. Excavation solely by track-mounted excavators will be inadequate, and supplementary stump grinding and chain saw methods must be provided.**

- **Baseline Statement - Unless groundwater levels are maintained below the bottom of the excavation, the materials in and below the bottom of the trench will pipe, heave, boil, and lead to instability of the excavation. For baseline purposes, a dewatering system capable of removing 4 to 6 gallons per minute per foot of trench will be required for excavations greater than 15 feet deep. This groundwater may originate from pervious layers within or beneath the trench, or it may occur as lateral seepage into the trench from water perched within granular or organic-rich layers. A dewatering system comprised solely of pumped dewatering wells will be inadequate, and supplementary sump and pump methods within the trench must be provided. The pumped groundwater is expected to contain suspended sediment and solids, wood splinters, and organic debris; therefore filtration and proper disposal of the discharge water must be provided. No excavation should be permitted within 2 feet of the static water table, as measured at groundwater observation wells installed at the midpoint between adjacent pumps along the trench line. Dewatering may be facilitated by installing dewatering wells and sumps along both sides of the excavation.**

- **Baseline Statement - The invert depth for major portions of the proposed gravity sewers are anticipated to be approximately 20 to 25 feet below existing ground surface. Excavation of soils throughout the project area is likely to be accomplished by trenching with large backhoes, and utilizing a trench box to control sidewall raveling, to prevent undermining of pavement, and to protect workers. With trench box methods in properly dewatered soils, ground settlement is expected to occur within a ½H:1V (Horizontal:Vertical) prism extending upward from the base of the trench box. Where existing utilities are within this prism, supplemental shoring (such as cantilevered or internally braced sheet piles or cantilevered or internally braced H-piles with lagging)**

must be provided to protect existing utilities from damage. Shoring will also be required for connections to manholes.

6.0 CONCLUSIONS AND RECOMMENDATIONS

- Improvement plans call for installation of approximately 11,500 feet of gravity sewer main, at depths ranging from about 10 to 25 feet below ground surface. The gravity sewer main alignment is about 1,000 feet along 54th Avenue East, roughly 1 mile across the CMC-Heartland development, approximately 1300 feet along 70th Avenue East, and 1000 feet within the South Oxbow area. Based on our field explorations, research, and analyses, the proposed force main construction appears feasible from a geotechnical standpoint, contingent on proper subgrade preparation and groundwater management. A summary of our findings is presented below.

- Soil Conditions: Soils underlying the sewer main generally consist of interlayered silt, sand, clay, and peat that occurred in discontinuous layers and at varying depths. In a previous sewer installation to the north along 70th Avenue E, buried trees root wads and logs of 12 to 36 inches in diameter and lengths greater than the minimum trench width caused difficulty in trenching. These buried trees were interpreted to be associated with historic mudflows off of Mt. Rainier. We also understand that in other areas, cedar tree stumps may exist where trees were cleared for agricultural fields. Explorations made along the proposed alignment encountered occasional scattered organics, however, no buried trees were found in any of the explorations along this current alignment. An exception to this was test pit TP-5 at 14 to 16 feet on the CMC-Heartland property, where organic debris (wood/logs) was reported.

- Groundwater Conditions: Static groundwater levels measured in monitoring wells during January to February 2002 were found to range from about 2 to 6 feet below ground surface. Test pits on the CMC–Heartland property advanced during May 1998 encountered slight to minor ground water seepage in most test pits between 3 and 10 feet in depth. Significant groundwater was encountered in most CMC–Heartland test pits at depths ranging from 6 to 12 feet. Our monitoring well MW-14 at proposed Pump Station 12 had a static water level at 3.5 feet below grade in late June 2000. Our test pits across the South Oxbow area in February 2002 encountered seepage as shallow as 2 feet below grade within the low-lying oxbow, and as deep as about 10 feet in the surrounding upland areas.

- Dewatering: A temporary dewatering system will be required along major portions of the alignment due to the depth of the sewer alignment, the high water table, and the soil conditions encountered during exploration.

- Temporary Sloping and Shoring: Shoring will be required in settlement-sensitive areas close to roads. Assuming soils have been properly dewatered, it may be possible to excavate safe temporary slopes (on the order of 1.5H:1V to 2H:1V or flatter) without shoring, in open field areas. If the soils are not dewatered, we have found that rapid seepage and sudden sidewall collapse will occur, with a stable repose angle of 10H:1V or flatter.

- Pipe Bedding / Foundation Material: The soils at depth, even in dewatered areas have been found to be very soft. We recommend planning on placement of 2 feet of foundation material at the base of the trenches for stability of bedding and pipe;

- On-Site Soil Considerations: Because the on-site soils are moisture-sensitive and would be readily disturbed when wet, we do not anticipate these soils will be suitable for structural fill beneath roadway areas. If the organic-rich soils are separated and the soils are allowed to drain, they may be considered for backfill above the pipe zone in non-structural areas (open fields). Ideally, earthwork would be scheduled for the summer and fall months, when drier weather will maximize the potential for reusing on-site soils and when groundwater levels will likely be at their seasonal low.

The following text sections of this report present our specific geotechnical conclusions and recommendations. WSDOT Standard Specifications and Standard Plans cited herein refer to WSDOT publications M41-10, *Standard Specifications for Road, Bridge, and Municipal Construction*, and M21-01, *Standard Plans for Road, Bridge, and Municipal Construction*, respectively.

6.1 Site Preparation

Preparation of the project site will involve temporary road closure, temporary drainage, erosion and sedimentation control, clearing, stripping, pavement removal and demolition. The paragraphs below discuss our geotechnical comments and recommendations concerning site preparation.

Temporary Drainage: We recommend intercepting and diverting any potential sources of surface or near-surface water within the construction zones before stripping begins. We anticipate that curbs, berms, or ditches placed around the work areas will adequately intercept surface water runoff. Final decisions regarding drainage systems are best made in the field at the time of construction because the selection of an appropriate drainage system will depend on the water quantity, season, weather conditions, construction sequence, and contractor's methods.

Erosion Control Measures: Because stripped surfaces and soil stockpiles are typically a source of runoff sediments, they should be given particular attention. If earthwork occurs during wet weather, we recommend that all stripped surfaces be covered with straw to reduce runoff erosion. Similarly, soil stockpiles and cut slopes should be covered with plastic sheeting for erosion protection. We also recommend that a staked silt fence be installed around the area to be disturbed. The base of the silt fence should be buried so that sediment cannot pass beneath it, and the silt fence should be inspected and maintained during the time that the site soils are exposed, on a periodic basis, and after any major rainstorm event. It may be prudent to maintain a berm and swale around the downslope side of stripped areas and stockpiles in order to capture runoff water and thereby reduce the downslope sediment transport. In addition, the stripped areas should be revegetated as soon as possible, also reducing the potential for erosion.

A temporary erosion and sedimentation control plan should be implemented, for diversion of surface water, for controlled discharge of water from excavations, for protecting soil stockpiles against erosion, and for preventing sediment transport.

Clearing and Stripping: After surface and near-surface water sources have been controlled, the construction areas should be cleared and stripped of all trees, bushes, sod, topsoil, debris, asphalt pavement, and concrete. A portion of the gravity sewer main alignment is along existing roadway. Where temporary roadway closure is planned, the entire pavement section will be removed. Where sewer construction occurs along the roadway shoulder, the first step in site preparation will consist of removal of the pavement surface. We anticipate this will mostly consist of sawcutting asphalt pavement. Our explorations along 70th Avenue East indicate that about 3 inches of asphalt will be encountered across the site, underlain by about one foot of cement-treated base, but significant variations could exist. Concrete aprons, slabs, or footings might be encountered at random locations along the alignment.

6.2 Dewatering

Our explorations encountered groundwater at depths of about 2 to 10 feet below grade (see Table 4). Consequently, most site excavations will extend below the groundwater level, depending on the actual excavation depth and time of year. Where groundwater is encountered, we recommend it be lowered below the base of the proposed excavation by temporary dewatering. Dewatering requirements will likely be reduced if construction is performed during the summer and early fall months when groundwater levels are typically at seasonal lows. The actual design of the dewatering system depth and spacing should be the responsibility of the contractor. Typical dewatering systems which would be appropriate for this site consist of a wellpoint system or a series of deeper wells with submersible pumps, possibly supplemented with pumps and sumps inside the excavation.

We recommend that groundwater levels be maintained at a depth of at least 2 feet below the base of the excavation. Such dewatering would reduce the risk of unstable conditions and disturbance of the trench bottom, thereby reducing post construction pipe settlements and providing a more stable manhole structure and pipe foundation. In these areas dewatering using a series of drilled deep wells with submersible pumps, or a system of vacuum well points will likely be required. However, it should be realized that dewatering, particularly within areas underlain by loose sands or soft clays, can cause ground settlement due to an increase in the effective weight of the dewatered soils. Dewatering-induced ground settlements are highly dependent upon drawdown and soil conditions, and are very difficult to predict. Possible effects on adjacent settlement sensitive elements should be taken into consideration, and the use of a sheetpile cutoff as a barrier to lateral seepage, recharging the groundwater outside the excavation, or alternative installation methods such as pipe boring should be considered, where appropriate. If any settlement-sensitive structures are in close proximity to deeper excavations, we recommend that the condition of the adjacent structures, roads, and any other nearby settlement-sensitive structures be documented prior to the start of construction. In addition, settlement benchmarks should be established and monitored on a regular basis during dewatering and excavation.

Well construction and water withdrawn from dewatering wells, sumps, and collected runoff will need to be handled in accordance with Washington State Department guidelines. At the termination of dewatering, all wells will need to be abandoned in accordance with WAC 173-160.

6.3 Temporary Slopes and Shoring

The invert depth for the proposed gravity sewers are anticipated to be approximately 20 to 25 feet below existing ground surface. An exception will be the South Oxbow area, where gravity sewer is expected to be in the range of 3 to 15 feet below grade. Excavation of soils throughout the project area is likely to be accomplished by open trench with large backhoes normally utilized for similar earthwork construction. We anticipate the contractor will need to utilize a trench box to control sidewall raveling, to prevent undermining of pavement, and to protect his workers. Shoring may be required where construction is limited by existing utilities or limited right-of-way. Specifically, with trench box methods in properly dewatered soils, ground settlement is expected to occur within a ½H:1V prism extending upward from the base of the trench box. Where existing utilities are within this prism, supplemental shoring (such as cantilevered or internally braced sheet piles or cantilevered or internally braced H-piles with lagging) must be provided to protect existing utilities from damage. Shoring will also be required for connections to manholes.

Temporary excavation slope stability is a function of many factors, including soil type, density, slope inclination, depth, the presence of groundwater, adjacent surcharges, and the length of time the cut remains open. Temporary slope safety should remain the responsibility of the contractor who is present at the site, able to observe changes in site soil and groundwater conditions, and monitor the performance of the excavation. In all cases, cut slope angles and shoring should conform to applicable Federal, State, and/or local guidelines. For planning purposes, we anticipate that temporary open-cut, sloping excavations within dewatered soils could be made at inclinations of 1½H:1V or flatter.

If necessary, sheetpiling shoring could be used to act as a cut-off to reduce lateral seepage into the excavations and also reduce the radius of influence of the groundwater drawdown, thereby reducing potential dewatering-induced ground settlements. Such a system would consist of driving/vibrating a row of interlocking steel sheets below the planned excavation base for trench sidewall support. The embedment of the sheets should satisfy structural and lateral stability design requirements. The sheetpile must be extended to sufficient depths to prevent "blowout" (heave) or "boiling" (piping) of the excavation base, particularly where the soils outside the sheets cannot be effectively dewatered. Due to the anticipated logs, it would likely be necessary to pre-excavate in advance of installing sheetpiles. As discussed below, drilled or driven H-piles with steel plate or timber lagging may be considered as an alternative shoring method.

Along the project alignment, sheetpiles should be designed to support active pressure distributions with an equivalent fluid pressure of 40 pounds per cubic foot (pcf) above the groundwater table and 80 pcf below the groundwater table. These values would be applicable for a cantilever sheetpile system or with up to one row of internal or external lateral bracing. For multiple rows of bracing, we recommend a rectangular lateral earth pressure of 22H in pounds per square foot, where H is the height of the cut in feet. Surcharges should be added as appropriate for construction equipment,

soil stockpiles, traffic, or other surface loading. Forty percent of the applied vertical surcharge should generally be used for lateral surcharge pressure within a 1½H:1V plane subtended up from the bottom of the sheetpiling. A minimum surcharge equivalent to 2 feet of soil should be used in all areas, with higher surcharges if necessary for areas accessible to construction equipment and activities. Passive earth pressures can be assumed to act below the base of the excavation. The uppermost 2 feet of passive earth pressure should be ignored. An allowable passive earth pressure equivalent to 300 pcf fluid pressure is recommended for lateral support (safety factor of 1.5).

As an alternative to sheet piles due to the potential difficulty of driving through logs or other organic debris, shoring using drilled or driven H-piles and steel plate or timber lagging may be considered. Drilling or driving with an impact hammer would be expected to be more effective at penetrating the wood then vibrating sheet piles. Installation of lagging between H-piles may require clearing wood obstructions with excavating equipment, chain saws, grinding, or other means. The above active pressures are assumed to act on individual H-piles, with passive pressures acting over two pile diameters. Temporary lagging may be designed to withstand 50 percent of the computed lateral earth pressures due to soil arching effects.

Shoring Plan: All excavations involve a risk of soil movement, potential delays, and damage to nearby structures. However, in our opinion, based on the soil conditions encountered in our borings, this risk could be reduced if the design considerations in this report are implemented. Nonetheless, the actual level of risk will depend on the particular shoring techniques and design criteria selected by the contractor. Consequently, we recommend that the contractor submit a shoring plan in advance of construction for review by the owner, the structural engineer, and the geotechnical engineer.

6.4 Pipe Foundation and Bedding

Based on the field explorations and the current anticipated pipe burial depths, it appears that the soils exposed at the sewer and manhole inverts will primarily be loose to medium-dense silty sand or soft to medium-stiff silt. In areas where an undisturbed, loose to medium-dense, silty sand is encountered, excavation to ½ foot below pipe invert for pipe bedding is recommended. In areas where very loose sand or soft clay/silt/peat is encountered, or where trench bottom disturbance occurs, overexcavation by as much as 2 feet (2½ feet below pipe invert) is recommended.

Pipe Bedding: We recommend using one of the following pipe bedding materials:

- *Gravel Backfill for Drains* meeting the requirement of 1998 WSDOT Standard Specification, Section 9-03.12(4); or
- *Crushed Surfacing Base Course* meeting the requirements of 1998 WSDOT Standard Specification, Section 9-03.9(3).

We recommend crushed surfacing base course (⅝-inch crushed rock) be utilized for pipe bedding only if a water-free trench conditions can be maintained. The ⅝-inch crushed rock bedding becomes difficult to compact and may provide degraded pipe support when moisture contents are

greater than 3 percent above optimum moisture due to a fines content of 7.5 percent. If the water within the trench cannot be controlled, the ⅝-inch crushed rock may be utilized with the modification that the fines content be specified at 3 percent maximum. Otherwise, we recommend gravel backfill for drains as presented above.

In all cases, the pipe bedding material should be placed to fully envelope the pipe, with minimum thickness of 6 inches under and over the pipe to ensure proper pipe support and protection during backfilling activities. Where the pipe bedding material is placed over coarse foundation material, it may be necessary to increase the thickness of bedding material under the pipe in order to fill the interstices of the foundation material with a portion of the bedding material and to ensure adequate pipe protection. In this instance, the pipe bedding material should be worked into the void spaces of the underlying foundation material by mechanical methods prior to installing the pipe.

We recommend that pipe bedding material be placed and consolidated in lift thicknesses not to exceed one-half the diameter of the pipe, or 12 inches, whichever is smaller. Following compaction of the initial bedding and installation of the pipe, bedding materials should be placed to spring-line of the pipe and consolidated by means of mechanical compaction methods. Subsequently, pipe bedding material should be placed to cover the pipe and consolidated by means of mechanical compaction methods.

At locations where trench excavation extends below groundwater level, porous pipe bedding material may tend to transmit groundwater along the pipe alignment. Contractors may choose to use low permeability pipe collars, such as controlled density fill (CDF), clay or concrete collars, to serve as a construction expedient to control groundwater flow along the trench.

Foundation Overexcavation: We anticipate ½ foot of bedding will be adequate for most of the alignment. If very soft silts, very loose sands, or organic-rich/peat soils are encountered, we recommend overexcavation by a minimum of 1 foot to a maximum of 3 feet (below the ½ foot bedding layer). If, in the judgement of the Engineer, soft/wet subgrade conditions require it, we recommend placement of a geotextile separation fabric at the base of the overexcavation, to separate the foundation material from the subsoil to provide some reinforcement and minimize loss of rock due to punching into the subsoil. The overexcavation should be backfilled with foundation material, as discussed below.

Foundation Material and Geotextiles: For foundation material, we recommend using one of the following materials:

- *Quarry Spalls* meeting the requirements of the WSDOT Standard Specification, Section 9-13.6; or
- *Shoulder Ballast* meeting the requirements of the WSDOT Standard Specification, Section 9-03.9(2).

For geotextile fabric, we recommend using a woven or nonwoven geotextile, conforming to the requirements of WSDOT 9-33.2, Table 3, *Geotextile for Separation*.

6.5 Trench Backfill

Based on the field explorations and proposed pipe burial depths, it appears that the majority of the soils excavated for the pipeline will consist of silty sands, or sandy silts, with interlayered organics. Because the on-site soils are moisture-sensitive and would be readily disturbed when wet, we do not anticipate these soils will be suitable for structural fill beneath roadway areas. If the organic-rich soils are separated and the soils are allowed to drain, they may be considered for backfill above the pipe zone in non-structural areas (open fields). Ideally, earthwork would be scheduled for the summer and fall months, when drier weather will maximize the potential for reusing on-site soils and when groundwater levels will likely be at their seasonal low.

Given this information, we recommend that the contract provisions include reuse of the on-site soils (as a bid alternate in non structural areas) to aid in quantifying the potential cost savings should this option be selected. The reuse of on-site soils should be pursued only during periods of extended dry, warm weather conditions which regionally occur during the months of June to September.

Fill Material and Settlement: The suitability of soils for compacted backfill use depends primarily on the gradation and moisture content of the soil when it is placed. As the amount of fines (that portion passing the U.S. No. 200 Sieve) increases, soil becomes increasingly sensitive to small changes in moisture content and adequate compaction becomes more difficult or impossible to achieve. Generally, soils containing more than about 5 percent fines by weight cannot be compacted to a firm, non-yielding condition when the moisture content is more than 3 percent above or below optimum moisture.

As previously discussed, soils excavated from the trench will primarily consist of native silts and sands. Replacement of the native silts and sands with "bank run" sand and gravel would likely increase the weight and produce settlement. We would recommend using imported sand backfill soils with less than 20 percent gravel for use as trench backfill to reduce the risk of pipeline settlements. We estimate that total, static pipe settlement at any location along alignment would not exceed 1 inch. Higher gravel contents may be used if larger settlements are allowed. It should be noted that the use of silty sand backfill soils or soils with more than 5 percent fines may be difficult to properly moisture condition and compact, and should be limited to use in extended dry weather conditions.

Placement and Compaction: Prior to placement of compacted backfill, the pipe bedding should be placed to a minimum of 6 inches over the top of the pipe. Pipe bedding material should be uniformly compacted along the haunches of the pipe, so that variable density bedding does not exist along the pipe. An initial lift not exceeding 18 inches in depth should be placed over a minimum of 6 inches of pipe bedding immediately above the pipe. Backfill above this initial lift should be placed in lifts not exceeding 12 inches in loose thickness. Within the top 2 feet below pavements and structures, backfill should be placed in lifts not exceeding 8 inches in loose thickness. Individual lifts should be mechanically compacted to product a firm and non-yielding condition prior to placement of additional backfill. All backfill material should be compacted to a uniform density of at least 90 percent of the modified Proctor maximum dry density (ASTM:D-1557). Within the top 2 feet below pavements and

structures, all backfill should be compacted to a uniform density of at least 95 percent of the same maximum density.

Compaction Criteria: Using the Modified Proctor test (ASTM:D-1557) as a standard, we recommend that structural fill used for various on-site applications be compacted to the following minimum densities:

Fill Application	Minimum Compaction
Roadway embankment (upper 2 feet)	95 percent
Roadway embankment (below 2 feet)	90 percent
Concrete sidewalk subgrade	90 percent
Asphaltic pavement base and subbase	95 percent
Asphaltic pavement subgrade (upper 2 feet)	95 percent
Asphaltic pavement subgrade (below 2 feet)	90 percent

Subgrade Verification and Compaction Testing: Regardless of material or location, all structural fill should be placed over firm, unyielding subgrades prepared in accordance with the *Site Preparation* section of this report. The condition of all subgrades should be verified, by a qualified geotechnical engineer or their representative before filling begins. Also, fill soil compaction should be verified by means of in-place density tests performed during fill placement so that adequacy of soil compaction efforts may be evaluated as earthwork progresses.

Soil Moisture Considerations: The suitability of soils used for structural fill depends primarily on their grain-size distribution and moisture content when they are placed. As the "fines" content (that soil fraction passing the U.S. No. 200 Sieve) increases, soils become more sensitive to small changes in moisture content. Soils containing more than about 5 percent fines (by weight) cannot be consistently compacted to a firm, unyielding condition when the moisture content is more than two percentage points above or below optimum. For fill placement during wet-weather site work, we recommend using "clean" fill, which refers to soils that have a fines content of 5 percent or less (by weight) based on the soil fraction passing the U.S. No. 4 Sieve.

CDF Strength Considerations: CDF is normally specified in terms of its compressive strength, which typically ranges from 50 to 200 psi. CDF having a strength of 50 psi (7,200 psf) provides adequate support for most structural applications and can be readily excavated with hand shovels. A strength of 100 psi (14,400 psf) provides additional support for special applications but greatly increases the difficulty of hand-excavation. In general, CDF having a strength greater than about 100 psi requires power equipment to excavate and, as such, should not be used where future hand-excavation might be needed.

7.0 RECOMMENDED ADDITIONAL SERVICES

Because the future performance and integrity of the structural elements will depend largely on proper site preparation, drainage, fill placement, and construction procedures, monitoring and testing by experienced geotechnical personnel should be considered an integral part of the construction process. Consequently, we recommend that a qualified geotechnical engineer be retained to provide the following post-report services:

- Review all construction plans and specifications to verify that our design criteria presented in this report have been properly integrated into the design;

- Attend a pre-construction conference with the design team and contractor to discuss important geotechnically related construction issues;

- Review shoring and dewatering plans to verify conformance with the construction plans and to document the contractor's procedures;

- Observe all exposed subgrades after completion of stripping and overexcavation to confirm that suitable soil conditions have been reached and to determine appropriate subgrade compaction methods;

- Monitor the placement of all structural fill and test the compaction of structural fill soils to verify their conformance with the construction specifications.

In addition to the aforementioned services, AMEC can provide inspection and testing of concrete, steel, masonry, and other structural materials. Upon request, we could submit a proposal for providing some or all of these construction monitoring, inspection, and testing services. Such a proposal is best prepared after the project plans and specifications have been approved for construction.

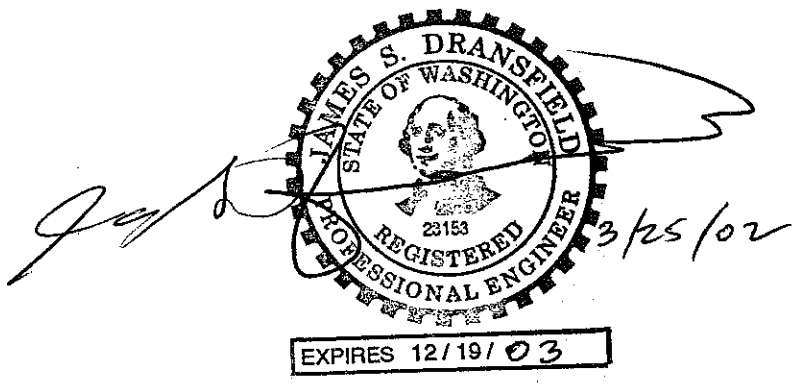
8.0 CLOSURE

The conclusions and recommendations presented in this report are based, in part, on the explorations that we performed and utilized for this study; therefore, if variations in the subgrade conditions are observed at a later time, we may need to modify this report to reflect those changes. Also, because the future performance and integrity of the project elements depend largely on proper initial site preparation, drainage, and construction procedures, monitoring and testing by experienced geotechnical personnel should be considered an integral part of the construction process. AMEC is available to provide geotechnical monitoring, soils and concrete testing, steel and masonry inspection, and other services throughout construction.

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.

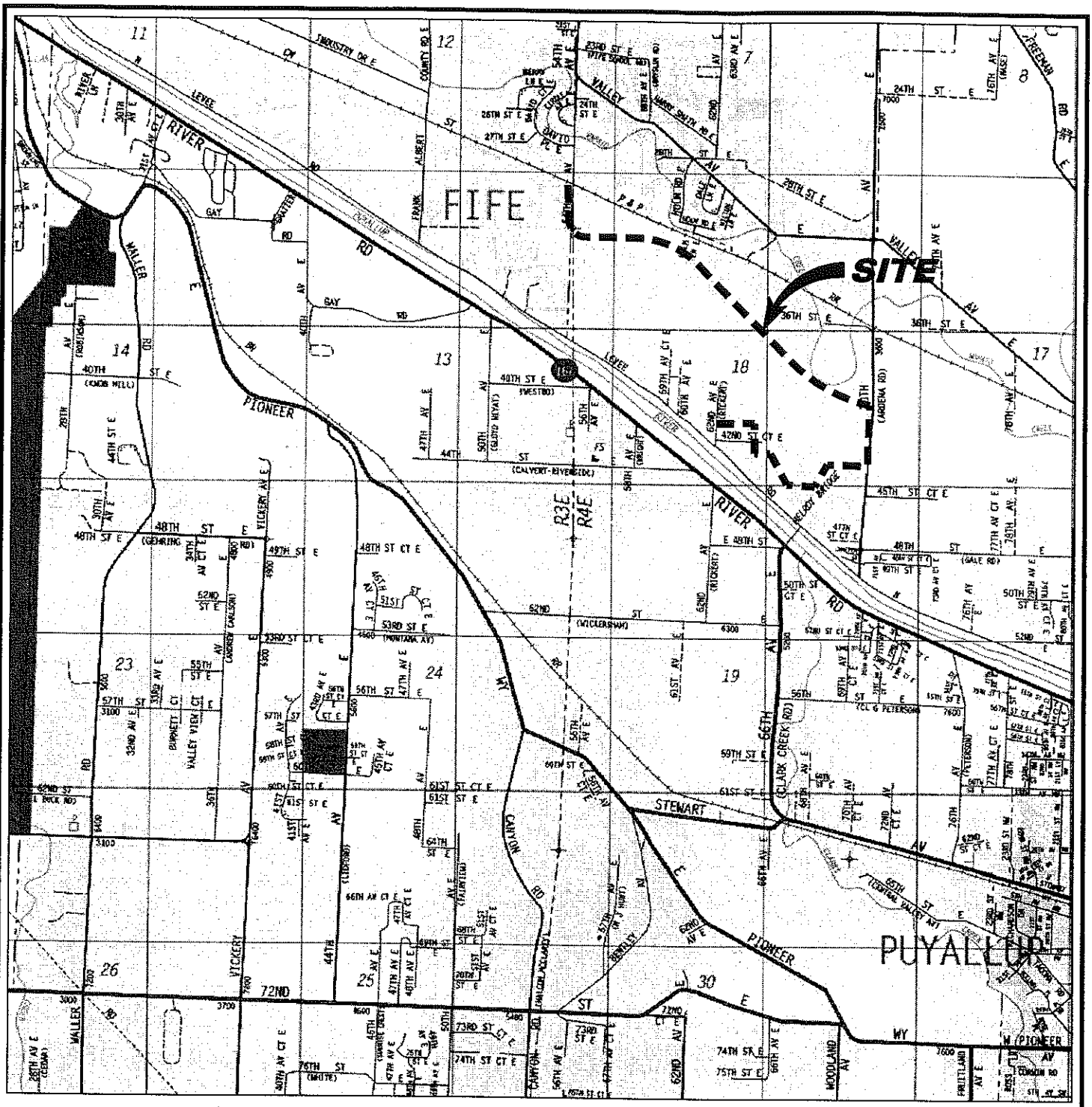
Sincerely,

AMEC Earth & Environmental, Inc.



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

FIGURES



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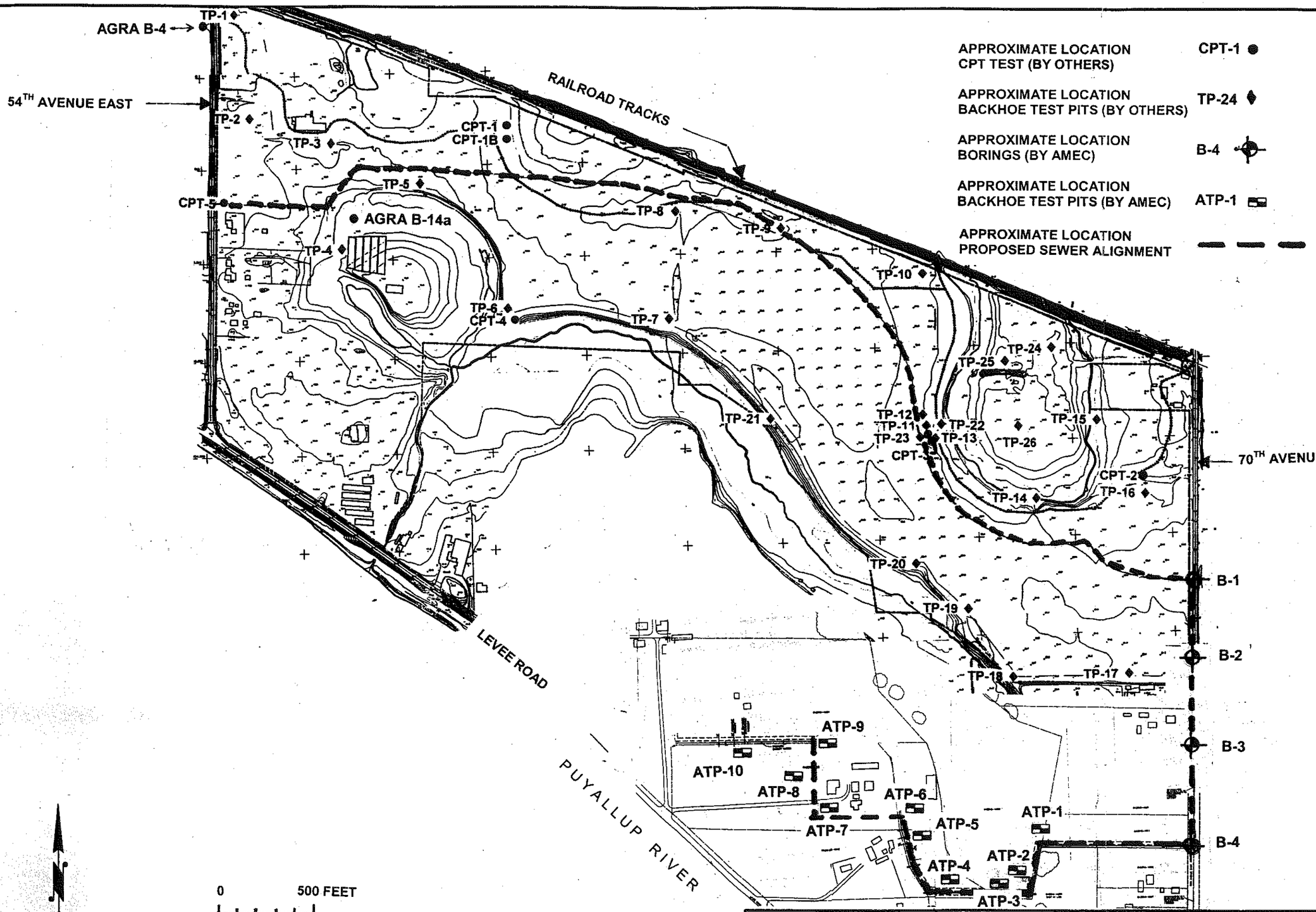
LOCATION MAP

CONTRACT 3 – CMC HEARTLAND AND SOUTH OXBOW GRAVITY SEWERS

FIFE, WASHINGTON

FIGURE 1



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SITE AND EXPLORATION PLAN

CONTRACT 3 – FIFE LID 98-2
CMC HEARTLAND AND SOUTH OXBOW GRAVITY SEWERS
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FIGURE 2