

September 12, 2005
Project No. EH04539A

Murray Smith and Associates
2707 Colby Avenue, Suite 1118
Everett, Washington 98201

Attention: Mr. Tom Perry

Subject: Hydrogeologic Assessment
Lynch Cove/North Shore Sewer Service Area Delineation
Mason County, Washington

Dear Mr. Perry:

We are pleased to present the enclosed copy of the referenced report. This report summarizes the results of our geologic and hydrogeologic evaluation of the Lynch Cove/North Shore area and offers conclusions regarding the potential for specific areas located near the community of Belfair to impact water quality in Lynch Cove.

We have enjoyed working with you on this study and are confident that the conclusions presented in this report will aid in the successful completion of your project. If you should have any questions or if we can be of additional help to you, please do not hesitate to call.

Sincerely,
ASSOCIATED EARTH SCIENCES, INC.
Everett, Washington

Charles S. Lindsay, P.G., P.E.G., P.Hg.
Principal Geologist/Hydrogeologist

Hydrogeologic Assessment

**LYNCH COVE/NORTH SHORE
SEWER SERVICE AREA
DELINEATION**

Mason County, Washington

Prepared for

Murray Smith and Associates

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HYDROGEOLOGIC ASSESSMENT

LYNCH COVE/NORTH SHORE SEWER SERVICE AREA DELINEATION

Mason County, Washington

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1.0 INTRODUCTION

Associated Earth Sciences, Inc. (AESI) has completed an evaluation of the geologic and hydrogeologic conditions of a potential sewer service area located west of the Belfair Urban Growth Area (UGA) in the Lynch Cove and North Shore areas of Lower Hood Canal in Mason County, Washington (County). The approximate location of the study area for this project is shown on Figure 1.

The Washington State Department of Health (DOH) has declared that the water quality conditions in the Lynch Cove area of Hood Canal create a severe public health hazard. Previous studies conducted in the Lynch Cove/North Shore area of the County have linked septic effluent as a potential contributor to the poor water quality conditions. The DOH's declaration is based upon the following, as documented in their letter of March 6, 2002 (Appendix A):

- On-site sewage systems at 54 of the 102 homes evaluated were either failing or suspect.
- The high ground water, soils poorly suited for on-site technology, fill, antiquated systems design, and small lot sizes make on-site sewage systems impractical or unworkable in this area.
- Runoff from failed systems flow over the ground or through saturated subsurface flow into Hood Canal. This pattern has caused the bay to be unfit for human recreation and has resulted in the closure of this part of Hood Canal for shellfish harvest.
- This problem involves a serviceable area of Hood Canal in the County.
- The problems described cannot be corrected through more efficient operation and maintenance of the existing on-site systems. Many of these are old, and all of them are on small lots with limited depth of suitable soil.

The County and their consultant, Murray Smith and Associates (MSA), are currently in the process of evaluating the feasibility of providing sewer service to the general area around Lynch Cove/North Shore in an effort to improve water quality in Lynch Cove and Hood Canal.

2.0 PURPOSE AND SCOPE

The purpose of our study was to assist the County and MSA in their evaluation of the potential sewer service area by delineating the study area into areas that have either a probable, a possible or unlikely chance for septic effluent originating in the specified areas (specifically fecal coliform bacteria) to degrade water quality in Lynch Cove. Our services involved

developing a conceptual hydrogeologic model of the Lynch Cove area and a potential impact ranking matrix that is based on the physical and land use characteristics of the study area. The conceptual hydrogeologic model was used in conjunction with the ranking matrix to delineate areas with a probable, a possible and/or unlikely chance for septic effluent to degrade water quality in Lynch Cove.

Our specific scope of services for the Lynch Cove/North Shore Sewer Service Area Delineation project is listed below.

- Data Review
 - Reviewed available geologic, hydrogeologic, and water quality information for the site and surrounding area. The data review included published reports and data from the County, the United States Geological Survey (USGS), the DOH, local health departments, other government agency reports, geologic maps of the area, and water well reports available from the Washington State Department of Ecology (Ecology).
- Developed Delineation Criteria
 - Worked with representatives of MSA and the County to develop general criteria for the delineation of the potential sewer service area. The delineation criteria included: (1) Soil Type/Septic Suitability, (2) Land Use/Lot Size, (3) Proximity to Surface Water, (4) Depth to Ground Water, and (5) Slope of the Ground Surface.
- Preliminary Assessment/Define Study Area
 - Conducted a reconnaissance of the potential sewer service area.
 - Based on the information review conducted and the results of the field reconnaissance, the approximate limits of the study area for the sewer service area feasibility assessment were defined.
- Soils Evaluation
 - Reviewed published soil survey maps for the defined study area.
 - Developed soil maps of the study area that identify soils based on their suitability for septic drainfield use.

- Geologic/Hydrogeologic Evaluation
 - Evaluated depth to ground water, ground water flow direction, and aquifer recharge/discharge areas in the study area based on published information and water well reports.
 - Developed a conceptual hydrogeologic model of the study area based on the available and field-generated geologic/hydrogeologic information.
 - Evaluated the available water quality information relative to the developed conceptual hydrogeologic model.
- Physical Site Constraints
 - Evaluated topography of the study area to identify slope of ground surface, proximity to surface waters, and other site conditions.
 - Evaluated lot sizes and densities based on County Assessor maps within the study area.
- Delineation and Documentation
 - Delineated the potential sewer service area based on soil, hydrogeologic, and water quality information reviewed/evaluated as described in the previous tasks.
 - Met with representatives of MSA and the County to discuss the delineation and the implications of land use zoning within the study area on the potential sewer service area.
 - Modified the delineated sewer service area, as appropriate, based on input regarding existing land use zoning in the study area.
 - Participated in public meetings.

3.0 SITE CONDITIONS

The study area includes the coastal area along North Shore Road (Highway 300) from near the Union River to approximately $\frac{3}{4}$ of a mile southwest to Belfair State Park, including the uplands to the north. The study area included portions of Sections 23, 24, 25, 26, 35, and 36, Township 23 North, Range 2 West, Sections 19, 20, 29, 30, and 31, Township 23 North, Range 1 West, and Sections 1 and 2, Township 22 North, Range 2 West. The approximate boundaries of the study area are shown on Figure 1.

Land use in the populated portions of the study area includes residential homes, a public school, several light industrial and retail businesses, and Belfair State Park. The highest population densities of the study area are located along the coastal lowlands and on the slope which extends from the uplands to the lowlands. Large portions of the upland areas and steep slope area, particularly the stream channels and erosional gullies, are densely wooded. Highway 300 extends from east to west along the coastal lowlands. The upland areas are accessed by several roads in the major stream drainages which extend from the coastal lowlands to the uplands.

Belfair State Park consists of picnic grounds, RV/tent camping sites with associated restroom facilities, and an RV wastewater dump. All facilities at the state park use septic drainfields for wastewater disposal.

4.0 METHODOLOGY

AESI reviewed available soil, hydrogeologic, and geologic data to gain an understanding of the existing conditions in the study area. Information reviewed included the following:

- *Water Resources and Geology of the Kitsap Peninsula and Certain Adjacent Islands* (Garling et al., 1965), USGS Water Supply Bulletin No. 18, 1965.
- *Land Use and Water Quality, Mission Creek, Little Mission Creek Sub-Basins, Lower Hood Canal* (Barnes et al., 1995), Ecology Watershed Management Section, Publication No. WQ-95-72, September 1995.
- *Union River Fecal Coliform Total Maximum Daily Load Study* (Ward et al., 2001), Ecology Environmental Assessment Program, Publication No. 01-03-038, October 2001.
- *Union River Fecal Coliform Total Maximum Daily Load, Submittal Report* (Sweet et al., 2002), Ecology Water Quality Program, Publication No. 02-10-022, June 2002.
- *Union River Fecal Coliform Water Cleanup, Detailed Implementation Plan* (Garland and Lawrence, 2003), Ecology Publication No. 03-10-066, August 2003.
- Mason County Health Department information.
- Water well reports on file with Ecology.

4.1 Field Activities

Field activities completed for the study included a visual reconnaissance of portions of the study area accessible by existing County roads. Our reconnaissance included inspection of soil

exposures along road cuts, stream channels, and landslide scarps. Mr. Michael O'Neal (2005) of the University of Washington accompanied us during a portion of our reconnaissance. Mr. O'Neal has been conducting geologic mapping in a portion of the study area for several years. His work is focused in the Lake Wooten Quadrangle in which the western portion of the study area is located. The geologic information developed by Mr. O'Neal was used in developing the geologic setting of the study area.

5.0 GEOLOGY AND SOILS

5.1 General Physiography

The County and the community of Belfair lie within what is referred to as the Puget Lowland, which is a regional north-south trending topographic trough that extends from southern British Columbia through the western portion of Washington to northern Oregon. The western portion of the study area is generally an upland that slopes to the southeast toward Hood Canal, and ranges in elevation between roughly 20 and 500 feet (Figure 1). The very eastern portion of the study area, immediately adjacent to Hood Canal, is relatively level lowland located at elevations that range from near mean sea level (msl) to approximate elevation 20 feet. All elevations presented in this report are relative to msl unless otherwise noted.

The primary surface water drainages in the study area are Mission and Little Mission Creeks (Figure 1). Other small intermittent streams and springs are located in steep, narrow canyons and gullies along the periphery of the upland area.

5.2 General Quaternary Geology

Quaternary sediments throughout the Puget Lowland were deposited during several glacial (stade) and nonglacial intervals (interstade) during the last 2.4 million years. During glacial periods, the southwest margin of the Cordilleran ice sheet flowed southeastward from British Columbia into the Puget Lowland of western Washington (Blunt et al., 1987). The most recent glacial episode in the Puget Lowland is referred to as the Fraser Glaciation.

The Fraser Glaciation consisted of multiple stades and interstades with the most recent being the Vashon Stade. The Vashon Stade represented the maximum advance of the Cordilleran ice sheet during the Fraser Glaciation. At its maximum extent (Vashon Stade), the Puget Lobe of the Cordilleran ice sheet extended to Olympia and reached a maximum thickness of several thousand feet. Retreat of the glacial ice at the end of the Vashon Stade was rapid and deglaciation of the Puget Lowland was complete by approximately 11,300 years ago (Blunt et al., 1987).

Sediments of the Vashon Stade are present over a majority of the ground surface in the study area. Exposures of older glacial and nonglacial deposits are typically limited to bluffs and incised river/stream valley walls. The Fraser glacial and nonglacial deposits in the study area

are generally underlain at depth by bedrock. A generalized geologic map of the study area is presented on Figure 2.

5.3 Study Area Geology

Michael O'Neal with the University of Washington recently completed a geologic investigation of the Lake Wooten Quadrangle, which includes a large part of the sewer service delineation study area (O'Neal, 2005). Information developed by Mr. O'Neal (2005) and published geologic information (Garling et al., 1965) were used to define the geology of the study area.

Garling et al. (1965) mapped the surficial geology in the study area as including recent alluvium, Vashon glacial deposits, and undifferentiated pre-Vashon glacial and nonglacial deposits. Recent alluvium deposits are present at the mouth of the Union River and around the several small lakes and depressions in the upland areas. Vashon recessional outwash deposits are mapped in the Union River valley and the slopes which form the walls of the valley. Vashon till is the predominant unit mapped at ground surface in the upland areas. Vashon advance outwash deposits underlie the till and are mapped at ground surface in the Mission Creek and Little Mission Creek channels, and in several steep narrow canyons, gullies, and slopes which extend from the uplands to Hood Canal. Undifferentiated pre-Vashon glacial and nonglacial deposits are mapped at ground surface in the lower reach of the Mission Creek channel. A generalized description of each major Quaternary unit in the study area is presented below.

Older Quaternary-Age Sediments (Qpf)

Older Quaternary-age sediments (undifferentiated pre-Vashon deposits) are mapped on the slopes between the uplands and the coastal lowlands, as shown on Figure 2 (O'Neal, 2005). The older Quaternary-age deposits underlie the surficial Vashon-age deposits on the uplands and are comprised of a very dense, matrix-supported mix of sand and silt with some gravel and cobbles. The dense nature of the deposits is due to a combination of compaction by glacial ice and cementation by iron and manganese oxides and hydroxides (O'Neal, 2005).

Vashon Advance Outwash (Qva)

Surface exposures of Vashon advance outwash sediments have been mapped by O'Neal (2005) on the slopes and erosional channels between the upland area and low-lying coastal areas. The base of the advance outwash deposits includes a fine-grained lacustrine unit overlain by coarser-grained sand and gravel deposited by streams emanating from the advancing ice sheet. Horizontally bedded and deltaic fan facies are present in the lower portion of the sequence where the sediments were deposited in a proglacial lake. The upper portion of the sequence is characterized by braided-stream deposits and consisted of coarser-grained sediments and cross-bedding. The advance outwash deposits are typically very dense from compaction of the sediments by the massive weight of the glacial ice. The advance outwash sequence is relatively

thin (less than 30 feet). The Vashon advance outwash deposits are generally overlain by Vashon till in the uplands of the study area (Figure 2).

Vashon Till (Qvt)

Vashon till is the primary geologic unit present at ground surface in the upland areas above Lynch Cove (Figure 2). Vashon till typically consists of a very dense, unsorted mixture of sand, gravel, and cobbles in a silt/clay matrix. These sediments were deposited beneath the advancing ice sheet. The very dense characteristic of the till is the result of compaction by the massive weight of the glacial ice. O'Neal (2005) described the till deposits as no more than a few tens of feet in thickness.

Vashon Recessional Outwash (Qvr)

Surface exposures of Vashon recessional outwash sediments have been mapped in the slopes and erosional channels between the upland areas and low-lying coastal areas (Garling et al., 1965). Recent mapping by O'Neal (2005) indicates recessional outwash deposits are also present in portions of the erosional channels in the upland areas and that the sediments mapped as recessional outwash on the walls of Mission Creek by Garling et al. (1965) are likely recent alluvial terrace deposits. Vashon recessional outwash consists of sediments deposited by meltwater streams that emanated from the retreating glacial ice. Recessional outwash deposits are generally comprised of sand and gravel with varying amounts of silt and are typically loose as they have not been compacted by the glaciers.

Recent Alluvium and Other Sediments (Qal, Qb, Qf)

O'Neal (2005) indicates surficial sediments in the coastal lowlands include Quaternary-age beach deposits (Qb), fan deposits (Qf), and alluvium (Qal). Beach deposits are mapped along the coastline and extend inward to where they co-mingle with the fan deposits emanating from the stream channels which drain the upland areas. Fan deposits consist of silt, sand, gravel, and cobbles deposited in a lobate form where streams emerge from the erosional valleys and reduced gradients result in sediment loads to be deposited. Beach deposits consist of locally well-sorted sand, gravel, cobbles, and silt, locally with shells, deposited and reworked by wave action. Alluvium is mapped on the floor of the stream channels (Figure 2). The alluvium generally consists of silt, sand, and gravel deposited by local streams.

5.4 Surface Soils

Mapped soils in the study area predominantly consist of Alderwood, Everett, and Indianola Series, as shown on Figure 3. Tidal marsh soils are mapped along the coastline in a majority of the study area. The soil types identified in study area are based on the United States Department of Agriculture (USDA), Mason County Soil Survey mapping completed by the Soil Conservation Service (SCS) (1960).

Alderwood Soils (Ab)

Alderwood soils are present in the upland portions of the study area and typically develop on till. Alderwood soils are well-drained and generally consist of gravelly sandy loam. The main limitations of Alderwood soils are depth to the cemented hardpan (till) and the seasonal perched water table (interflow). In areas of moderate- and high-density population, on-site sewage disposal systems often fail or do not function properly during periods of high rainfall because of these soil limitations.

Everett and Indianola Soils (I/E)

Everett and Indianola soils are mapped in the lowland areas, in creek channels, and on the slopes which extend from the lowlands adjacent to Lynch Cove to the uplands. Everett and Indianola soils typically develop on glacial outwash sediments typically exposed in eroded channels or on outwash plains. Everett and Indianola soils are droughty because the loose gravel and sand subsoil and substratum offer little resistance to the downward movement of water. The high infiltration rates typical of Everett and Indianola soils allow infiltrated septic effluent to travel rapidly to shallow ground water without sufficient residence time in the unsaturated zone needed to allow the natural filtering and treatment of the septic effluent.

Tidal Marsh Soils (Tn)

Tidal marsh soils are mapped in the coastal areas. Tidal marsh soil is generally composed of silt with fibrous peat and, in some cases, very fine sand. Tidal marsh soils have very limited septic effluent disposal characteristics due to the very low infiltration rates and associated shallow ground water levels which are affected by tidal influences.

6.0 GROUND WATER

Based on mapped geologic conditions and available hydrogeologic data, ground water in the study area consists of: (1) a seasonal interflow zone located on top of the Vashon till, (2) unconfined/confined aquifers in the Vashon advance outwash and older Quaternary-age deposits, and 3) an unconfined aquifer in the recent alluvial sediments located in the coastal lowland areas. Our review of the water well reports indicates a majority of the domestic water wells in the area are completed in unconfined/confined aquifers located within the older Quaternary-age deposits.

6.1 Interflow Zone

A seasonal shallow interflow zone is likely present in the weathered horizon of the Vashon till mantling the upland portions of the study area. Interflow commonly accumulates seasonally in areas underlain by the relatively low-permeability till. Water in the interflow zone is comprised of precipitation that percolates down through the relatively permeable, surficial

weathered till soils and accumulates on top of the underlying, low-permeability unweathered till surface. The interflow zone is typically relatively thin, ranging from less than 1 foot to several feet in thickness. Flow in the interflow zone follows topography flowing from areas of higher elevation to areas of lower elevation. Ground water flow direction in the interflow zone generally mimics topography and flows toward the incised stream channels and edges of the uplands. Discharge from the interflow zone is likely via diffuse seeps and springs which either enter the streams in the incised erosional channels or percolate into the soils on the slope faces or at the base of the slopes. A portion of the ground water in the interflow zones also likely percolates downward through the unweathered till to the underlying advance outwash deposits.

6.2 Vashon Advance Outwash/Older Quaternary Deposits

Ground water recharge to the advance outwash deposits and underlying older Quaternary-age sediments is almost completely from the infiltration of precipitation through the overlying surficial till layer. Direct infiltration of precipitation likely occurs in limited areas where the advance outwash sediments are exposed at the ground surface.

Garling et al. (1965) stated the regional water table is in most places below the elevation of the advance outwash deposits. Seeps and springs were observed during our field reconnaissance emanating from the contact between the advance outwash deposits and the underlying older Quaternary-age sediments indicating a potential perched ground water condition. It is likely that there are perched aquifers in portions of the advance outwash sediments and in the upper portion of the older Quaternary-age sediments which overlie a regional water table at depth. A review of the water well reports for the study area indicate that several domestic wells are completed in what appear to be perched zones in the Vashon advance outwash/older deposits. Many of the domestic wells capable of yielding large quantities of ground water are completed at deeper levels in a regional aquifer located in the older Quaternary-age deposits underlying the uplands.

Ground water in the advance outwash deposits, where present, and perched zones of the older Quaternary-age deposits likely flow from northwest to southeast with localized flow patterns toward the incised stream channels and erosional gullies in the study area. Ground water discharges from these perched zones in the form of seeps and springs in the creek channels, erosional gullies, and along the slope extending from the coastal area to the uplands. The regional ground water flow direction in the deep aquifer located within the older Quaternary-age deposits is likely to the southeast with ground water discharging as seeps and springs in lower portions of the creek channels, erosional gullies, and the slope between the coastal areas and the uplands with a significant component of discharge to Lynch Cove and Hood Canal.

6.3 Recent Alluvial Sediments

Ground water is present in the recent alluvial sediments comprised of Quaternary alluvium (Qal), Quaternary beach deposits (Qb), and Quaternary fan deposits (Qf) located in the coastal areas along the north shore of Lynch Cove. Ground water recharge to the recent alluvial

sediments is from infiltration of precipitation, and infiltration of surface water from the creeks, springs, and seeps along the slope between the coastal lowland and the uplands. Ground water flow in the recent alluvial sediments is toward Lynch Cove with discharge occurring at or slightly below msl. Some discharge in the form of seeps from the recent alluvial sediments to Lynch Cove is likely exposed during low tides. The depth to ground water in the recent alluvial sediments is shallow based on water well information and our site reconnaissance observations.

7.0 CONCEPTUAL GROUND WATER MODEL

The conceptual ground water model describes the components of the ground water systems in the study area. The components of a conceptual ground water model include three main components: (1) inputs to the ground water system, (2) flow within the ground water system, and (3) discharge from the system. Inputs to the ground water flow system in the study area include infiltration of precipitation, irrigation of developed or farmed land, and infiltration of domestic wastewater. Flow within the ground water systems in the study area includes flow in the seasonal interflow zone, Vashon advance outwash/older Quaternary sediments, and recent alluvial sediments. Discharge from the ground water flow system occurs as regional discharge to Lynch Cove and localized discharge to seeps and springs along steep slopes. The three components which comprise the conceptual ground water flow model are described below.

As previously described, the ground water system underlying the study area consists of three ground water zones, a seasonal interflow zone on the till-mantled uplands, perched zones in the Vashon advance outwash and the older Quaternary-age sediments/regional aquifer at depth in the older Quaternary age deposits, and a water table aquifer in the recent fan and beach deposits in the coastal lowlands.

Precipitation provides a bulk of the input (recharge) to the ground water system in the study area. A portion of the precipitation falling directly on cleared areas infiltrates downward; the remainder is lost to evaporation and transpiration (uptake by vegetation). These two processes are commonly combined into one term: evapotranspiration. On developed land, precipitation infiltrates in vegetated areas, minus evapotranspiration, or runs off of impervious surfaces, which ultimately infiltrate to the ground water or are conveyed via drainage ditches to surface waters. In heavily wooded areas, the tree canopy intercepts a portion of the precipitation and some is lost as surface water runoff. The remainder infiltrates into the ground and is either lost to evapotranspiration or provides recharge to the ground water system. Water applied as irrigation in the study area provides recharge to the ground water system in the same fashion as precipitation. Wastewater effluent conveyed to the ground via drainfields provides direct recharge to the ground water system, minus transpiration from vegetation. Some component of recharge to the ground water system is via infiltration of surface waters in the streams which extend from the upland to the coastal lowland.

Precipitation, wastewater, and runoff from impervious surfaces provide direct recharge to the interflow zone in the uplands and the recent fan and beach deposits in the coastal lowlands. Infiltration of surface water from streams draining the upland areas provides additional recharge to the recent fan and beach deposits. Ground water recharge to perched zones in the Vashon advance outwash and older Quaternary-age deposits is from the downward movement of ground water in the interflow zone through the till and the direct infiltration of precipitation where the till is absent. Recharge to the deep regional aquifer is from the downward movement of water in perched zones and infiltration of surface water from streams which have eroded through the till.

Ground water flow in the interflow zone generally follows surface topography and discharges as seeps and springs at the edge of the slope extending from the uplands to the coastal lowland and in the slopes of the deeply incised surface water drainages. Ground water discharge from the interflow zone provides recharge to the underlying perched zones in the advance outwash and older Quaternary-age deposits and baseflow for the streams in the study area. Perched ground water in the advance outwash deposits and older Quaternary-age sediments discharges as seeps and springs along the slope between the coastal lowlands and upland areas, and ultimately provides recharge to the ground water in the recent fan and beach deposits in the coastal lowlands via direct infiltration and discharge to streams flowing from the uplands to the coastal lowlands. Ground water in the regional aquifer discharges as seeps and springs along the lower portions of the slope between the coastal lowlands and uplands areas, and at depth to Lynch Cove. Ground water in the recent fan and beach deposits in the coastal lowlands discharges to Lynch Cove.

Ground water travel times to Lynch Cove and stream channels are generally a function of the geology/hydrogeology of the area and the proximity of the surface water. Depth to ground water in the coastal lowlands is relatively shallow and the coastal lowlands are in close proximity to Lynch Cove; therefore, the potential for this area to contribute fecal coliform to Lynch Cove is the highest. Septic systems located in close proximity to surface waters tributary to Lynch Cove also have a high potential to contribute fecal coliform due to the short travel time of ground water to the surface water body and direct conveyance of the tributary to the waters of Lynch Cove. Septic systems located in close proximity to seeps and springs which directly flow to tributary creeks also have a high potential to contribute fecal coliform to Lynch Cove. Seeps and springs which do not directly flow to surface waters tributary to Lynch Cove are less likely to contribute fecal coliform to Lynch Cove as the residence time of the fecal coliform bacteria in the ground water system is greater. Areas with a thick, unsaturated zone between the septic system and the water table and areas with a long flow path (travel time) to the ground water discharge point have the lowest potential to contribute fecal coliform to Lynch Cove.

8.0 WATER QUALITY

In 1987, the DOH downgraded the eastern end of Lynch Cove (Hood Canal near Belfair) from Approved for direct harvest of shellfish to Prohibited due to unacceptable levels of fecal coliform bacteria. The closure halted commercial harvest from 630 acres of intertidal growing area. Recreational and tribal harvest were also curtailed at Belfair State Park (about 2 miles west-southwest of Belfair on the north shore), the second most productive public oyster site in Puget Sound. Elevated fecal coliform levels have also led to the declaration of a public health hazard by the DOH for the Lynch Cove area. Studies have been conducted by Ecology, DOH, and local health agencies in an effort to determine the source of the elevated fecal coliform levels in Lynch Cove and propose possible solutions. The following is a summary of these studies.

8.1 Washington State Department of Ecology Studies

Ecology has completed studies related to fecal coliform in the Union River Basin, and Mission Creek and Little Mission Creek Sub-Basins. The Union River studies include: *Land Use and Water Quality, Mission Creek, Little Mission Creek Sub-Basins*, dated September 1995 (Barnes et al., 1995); *Union River Fecal Coliform Total Maximum Daily Load (TMDL) Study*, dated October 2001 (Ward et al., 2001); *Union River Fecal Coliform Total Maximum Daily Load Submittal Report*, dated June 2002 (Sweet et al., 2002); and *Union River Fecal Coliform Water Cleanup Detailed Implementation Plan*, dated August 2003 (Garland and Lawrence, 2003). The following is a brief summary of the Ecology studies.

The Missions Creek/Little Mission Creek 1995 study (Barnes et al., 1995) was completed to address the potential for pollution from the sub-basin to the marine waters of Lynch Cove. Results at the time of the study suggested that storm-generated fecal coliform loads from Mission and Little Mission Creeks were not an important source of fecal coliforms to the tideland at Belfair State Park. The report also concluded that conditions that minimize fecal coliform loading during heavy rain may be absent during low flow. The study concluded that the most important human source of fecal coliform contamination is likely sewage from failed on-site septic systems along the marine shoreline.

The 2001 Union River TMDL study (Ward et al., 2001) was completed to evaluate and recommend a TMDL strategy, including load allocations for fecal coliform bacteria sources on the Union River, to meet state water quality standards. The study included fecal coliform sampling in the Union River and Bear Creek. Fecal coliform levels in water samples showed a dry season concentration higher than those in the wet season suggesting that there is likely a continuous, steady component of pollution loading to the Union River and Bear Creek. Water quality data obtained in this study also indicated relatively high fecal coliform levels during the wet season when flows are dramatically higher indicating there is also a storm-related (runoff) component to loading. The study concluded pollution sources in the basin are exclusively non-point including agriculture, on-site septic systems, and post-development activities from urban development (e.g., domesticated animals).

The 2002 TMDL study (Sweet et al., 2002) was completed to establish a TMDL for fecal coliform bacteria for the Union River Watershed. The TMDL study was initiated after water quality monitoring by state and local agencies determined fecal coliform levels in the Union River had violated the Washington State Class AA standard since 1990. The TMDL study was initiated to determine the loading capacity of the river, identify non-point pollution sources of fecal coliform, and set load reductions along the stream corridor. On-site sewage system failures, inadequate agricultural and livestock practices, pet wastes and runoff from homes, highways, and commercial businesses were identified as probable sources of fecal coliform contamination.

The 2003 Union River Fecal Coliform Water Cleanup Detailed Implementation Plan (Garland and Lawrence, 2003) provides details on proposed watershed activities intended to clean up the fecal coliform bacteria contamination in the Union River. The study also summarizes potential sources of fecal coliform in the Union River Watershed. The study identified on-site sewage systems as a potential source of pollutants to the Union River if they are substandard, failing, or located near the river or a tributary.

8.2 Mason County Health Department

The Mason County Health Department (Health Department) has conducted and participated in several studies in Lynch Cove and Mission and Little Mission Creek areas with respect to water quality monitoring and source investigations. The Health Department has surveyed numerous septic systems in the study area to test for septic system failures and potential fecal coliform contamination to surface waters using visual inspection and dye testing. The Health Department concluded that failing on-site septic systems are the most likely cause of elevated fecal coliform levels in the marine waters.

9.0 SEWER SERVICE AREA RANKING MATRIX

The potential for septic effluent to impact water quality in the study area and contribute to the conditions that have led to the severe health hazard declaration is dependent on several physical characteristics of the area. Data research and detailed discussions with representatives of MSA, the County, DOH, and Ecology have led to the development of the following pertinent physical characteristics that appear to have the most control over the potential impact of septic effluent on water quality in the study area.

- Soil Type/Septic Suitability
- Land Use/Lot Size
- Proximity to Surface Water
- Depth to Ground Water
- Slope of the Ground Surface

Each of these characteristics has either a direct effect on the performance of septic systems or an effect on the ability of viable fecal coliform bacteria to travel to nearby surface water bodies. The following is a more detailed discussion of each characteristic.

9.1 Soil Type/Septic Suitability

The USDA's Natural Resources Conservation Service (NRCS) has developed a classification system which ranks soil types based on limitations that affect septic tank drainfields and/or sewage lagoons. Septic tank drainfields are defined by the USDA/NRCS as areas in which effluent from a septic tank is distributed into the soil through subsurface tiles or perforated pipes. Only the soil column between depths of 24 and 60 inches is evaluated because it represents the critical functional zone for drainfield effectiveness. These rankings include three classifications:

Not Limited: The soil has features that are very favorable for the specified use. Very good performance and very low maintenance can be expected.

Somewhat Limited: The soil has features that are moderately favorable for the specified use. The limitation could be overcome or minimized by special planning, design, or installation. Fair performance and moderate maintenance can be expected.

Very Limited: The soil has one or more features that are unfavorable for the specified use. The limitations generally cannot be overcome without major soil reclamation work, special design, or expensive installation procedures. Poor performance and high maintenance can be expected.

For the purposes of the ranking matrix, each soil type was assigned a numerical rating based on its degree of individual limitation as described by the USDA/NRCS. The rankings are based on soil properties that affect absorption of the effluent, construction and maintenance of the system, and public health. Individual limitations include filtering capacity, seepage, slope, restricted permeability, and depth to the saturated zone. The ranking values for soil type/septic suitability is shown below.

Soil Type/Septic Suitability Ranking

Septic Suitability	Very Limited	Somewhat Limited	Not Limited
Rank	10	5	1

All soil types within the study area, Alderwood series, Indianola/Everett series, and Tidal marsh (Figure 3), are very limited with respect to septic suitability.

9.2 Land Use/Lot Size

Current housing and potential future lot size was evaluated with respect to the DOH minimum lot size for on-site residential septic systems. *Washington State Administrative Code* (WAC-246-272) presents the “minimum land area requirement” for septic drainfields. The code presents two methods for the determination of the minimum lot size required. Method I bases the minimum lot size on soil type. Method II outlines a minimum lot size determination based on a written analysis of 16 specific characteristics of the proposed lot. The DOH Method I was used to develop the delineation rankings in conjunction with regional soils maps for the study area.

The DOH Method I guidelines identify the following eight soil types with regard to on-site residential septic system suitability:

- Type 1A: Very gravelly¹ coarse sands or coarser. All extremely gravelly² soils.
- Type 1B: Very gravelly medium sand, very gravelly fine sand, very gravelly very fine sand, very gravelly loamy sands.
- Type 2A: Coarse sands (also includes American Society for Testing and Materials [ASTM] C-33 sand).
- Type 2B: Medium sands.
- Type 3: Fine sands, loamy coarse sands, loamy medium sands.
- Type 4: Very fine sands, loamy fine sands, loamy very fine sands, sandy loams, loams.
- Type 5: Silt loams that are porous and have well-developed structure.
- Type 6: Other silt loams, sandy clay loams, clay loams, silty clay loams.

¹ Very Gravelly = > 35 percent and < 60 percent gravel and coarse fragments by volume.

² Extremely Gravelly = > 60 percent gravel and coarse fragments, by volume.

The DOH also lists sandy clay, clay, silty clay, and strongly cemented or firm soils as “Unsuitable for treatment or disposal.”

The glacial till-mantled uplands in the study area are generally characterized as Type 5 or 6 soils (silt loams/clay loams). The soils mapped along the shoreline are generally tidal marsh consisting of silt and some fine sand that corresponds to the DOH Type 5 or 6 soils for septic characterization. The area between the tidal marsh soils and the till-mantled uplands includes coastal areas, the slope between the lowland and uplands, and the recessional outwash ridge in the northeast portion of the study area. Soils in these areas are generally mapped as Indianola and Everett series and correspond to DOH Type 2 and 3 soils. The following ranking values have been assigned based on the DOH Method I criteria for minimum lot sizes for on-site septic systems. A map of the land use/lot size rankings is displayed on Figure 4.

Land Use/Lot Size Ranking

Lot Size Soil Type 2 and 3	< 12,500 ft ²	≥ 12,500 ft ² < 1 acre	
Lot Size Soil Type 5 and 6	< 20,000 ft ²	≥ 20,000 ft ² < 1 acre	> 1 acre
Rank	10	5	1

Lot sizes and densities are basically limited to the existing parcels within the study area. The study area is outside the Belfair UGA and land use zoning is for a minimum of 5-acre parcels. Lot sizes within the study area that are less than 5 acres are a result of plats created prior to land use zoning requirements.

9.3 Proximity to Surface Water

Proximity to surface water features was evaluated to assess the potential for septic effluent to directly enter surface waters via overland flow from failing drainfields or from ground water containing viable fecal coliform bacteria. Surface water bodies in the study area include Lynch Cove, Mission Creek, Little Mission Creek, and several unnamed drainages extending from the upland areas to the coastal lowlands. The DOH (2003) has established a distance of 200 feet as the criteria for determining if ground water has the potential to be under the influence of a surface water body. We understand that the 200-foot lateral distance was determined based on field studies and analytical testing regarding the ability of ground water to transport viable pathogens not normally found in natural ground water.

The DOH (Chapter 246-272 WAC) also provides guidelines for *Minimum Horizontal Separations* for on-site sewage systems. WAC 246-272 lists a minimum horizontal separation distance of 100 feet from the edge of the disposal component and reserve area to marine and fresh surface waters. WAC 246-272 also states “Where any condition indicates a greater potential for contamination or pollution, the local health officer or the department may increase the minimum horizontal separations. Examples of such conditions include excessively permeable soils, unconfined aquifers, shallow or saturated soil, dug wells or improperly abandoned wells.” The DOH also requires a horizontal separation of at least 200 feet between a surface water source of drinking water and a septic drainfield (WAC 246-272). Therefore, for the purposes of the ranking matrix, it was assumed that a 200-foot horizontal separation between surface water and septic drainfields is a conservative distance regarding the potential survival of pathogens in ground water. A map showing the distances to surface water bodies and their ranking is shown on Figure 5.

Proximity to Surface Water Ranking

Proximity to Surface Water	< 200 feet	> 200 feet
Rank	10	1

9.4 Depth to Ground Water

The depth to ground water is an indicator of the vertical time of travel for drainfield effluent to reach the water table. The DOH requires a minimum separation distance of 3 feet from the base of septic drainfields to ground water. Assuming that the base of the typical drainfield is located at a depth of approximately 2 feet results in a minimum separation of approximately 5 feet between ground water and the ground surface. This minimum separation is considered to be adequate to remove most pathogens from the septic effluent prior to reaching the water table for properly designed and maintained septic systems that are sited in suitable soils. Less than adequate soils and poorly designed/maintained systems decrease the ability of the unsaturated soils located beneath the drainfield to adequately treat the percolating effluent.

For the purposes of this analysis, the depth to ground water in the study area was estimated from domestic water well logs, geologic mapping, site reconnaissance, mapped surface water features, and available water level monitoring data available from the County and other state and local agencies. It should be noted that the water wells described on the domestic water well logs were not field located. Therefore, their locations should be considered approximate, which contributes to the uncertainty of the information source.

In portions of the study area that are underlain by relatively permeable soil with no obvious low-permeability zones that may perch ground water, the depth to ground water was obtained from available domestic water well reports, mapped surface water features, and available water level monitoring data. It should be noted that the depth to ground water information presented on typical domestic water well reports is generally recorded by the well driller shortly after the well has been installed. Consequently, the depth to water data represents a single spot measurement taken at any given time of the year and does not take into account seasonal variability of ground water levels. Seasonal variability of ground water levels can be as much as 10 feet in some portions of the study area.

We assumed that any reported water level measurement of less than 15 feet (recorded on the water well reports, inferred from nearby surface water features, and/or from water level monitoring data) indicates that the ground water level has the potential to be close to the ground surface during some time of the year and has a high potential to violate the DOH criteria of a minimum 3-foot-vertical separation rule between the base of the drainfield and ground water. Therefore, areas where the available information indicates that depths to ground water are 15 feet or less were considered to have a high potential to impact water quality. Areas where the

depth to water is reported to be between 15 and 30 feet were considered to have a moderate potential to impact water quality, and water level depths greater than 30 feet were considered to have a low impact potential.

As discussed previously in this report, glacial till is a very dense, complex mixture of sand, gravel, silt, and clay that was deposited at the base of the continental ice sheet as it advanced over the study area roughly 13,000 to 18,000 years ago. Glacial till has a low permeability and tends to impede the vertical migration of infiltrated precipitation. Therefore, shallow perched (water table) aquifers tend to develop on the top of the till surface. For the purposes of this analysis, we have assumed that areas that are mapped at the ground surface as glacial till or have what appears to be locally extensive, low-permeability layers (silt and clay) located within the upper 15 feet of the soil column (as identified through water well reports) have a high potential to develop shallow perched aquifers during portions of the year. These areas of perched ground water have a high potential to violate the DOH criteria of a minimum 3-foot-vertical separation rule between the base of the drainfield and ground water. Therefore, areas which are underlain by glacial till at the ground surface or have identified low-permeability zones in the upper 15 feet of the soil column will be considered to have a high potential to impact water quality. A map showing the depth to ground water zones and associated ranking is shown on Figure 6.

Depth to Ground Water Ranking

Depth to Ground Water	< 15 feet⁽¹⁾	> 15 and < 30 feet	> 30 feet
Rank	10	5	1

⁽¹⁾ Includes areas underlain by glacial till and/or low-permeability zones.

9.5 Slope of Ground Surface

The slope of the land surface is a variable in the USDA/NRCS Sewage Disposal Suitability criteria. The USDA/NRCS states excessive slope may cause lateral seepage and surfacing of sewage effluent in downslope areas. However, moderately sloping land surface facilitates the transport of infiltrated effluent away from the drainfield, thus reducing the potential for a ground water mound to occur under the drainfield. The study area includes areas of relatively steep slopes extending from the upland areas to the coastal areas and within the drainage basins of Mission Creek, Little Mission Creek, and several unnamed drainages. The Washington State DOH WAC 246-272 states on-site sewage system components shall be installed only where the slope of the ground surface is less than 45 percent (24 degrees). For the purposes of the ranking matrix, we used the following ranking values for slope. A map showing the ground surface slope areas and related ranking is shown on Figure 7.

Slope of Ground Surface Ranking

Slope of Ground Surface	> 30%	0% to 10%	11% to 29%
Rank	10	5	1

10.0 SEWER SERVICE AREA DELINEATION

The conceptual hydrogeologic model and ranking matrix were used conjunctively to delineate areas that have a probable, a possible, and/or an unlikely chance for septic effluent (specifically fecal coliform bacteria) to degrade water quality in Lynch Cove and Hood Canal. For the purposes of this analysis, we have assumed the following general definitions for the rankings:

- Probable: Likely to occur.
- Possible: Has a chance to occur.
- Unlikely: Insignificant chance to occur.

The delineated areas are based on matrix ranking scores for the five primary physical characteristics discussed in the previous sections of this report. The ranking matrix scores were developed in the following manner:

- The study area was overlain with a systematic grid that consisted of 691 relatively evenly spaced node points. This resulted in a node point occurring approximately every 400 feet in the study area.
- The grid was placed over the figures that display the primary physical characteristics of the study area.
- A ranking score for each physical characteristic was noted at each node point and totaled for a final score.
- Areas with total ranking scores equal to or greater than 36 were considered to be areas that have a probable chance of impacting Lynch Cove. A score of 36 or greater indicated that the area received a maximum score of 10 points on at least three of the five primary physical characteristics and a moderate score of 5 points on at least one of the remaining two physical characteristics.
- Areas with scores from 27 to 35 points were considered to have a possible chance to impact the water quality of Lynch Cove. A score in this range indicates that the area has received a maximum score on at least two of the physical characteristics and a moderate score on at least one of the remaining characteristics.

- Areas with scores of less than 27 points were considered to have an unlikely or insignificant chance to impact the water quality in Lynch Cove.
- The total scores at each node point were then overlain on the study area to delineate general boundaries between the probable, possible, and unlikely potential impact areas. The boundary lines between the node points were based on the surrounding ranking scores and the conceptual hydrogeologic model of the study area.

A map of the study area showing the probable, possible, and unlikely impact areas is presented as Figure 8. The following is a brief description of each area.

10.1 Probable Potential Impact Areas

The areas with a probable potential to contribute viable fecal coliform bacteria to Lynch Cove included most of the developed coastal lowland areas, areas located immediately adjacent to streams, and areas with small lot sizes. The combination of poor soils, shallow ground water, small lot size, and/or steep slopes/proximity to surface water resulted in these areas having a high probability to impact water quality in Lynch Cove and/or Hood Canal with viable fecal coliform bacteria.

10.2 Possible Potential Impact Areas

The areas identified with a possible chance to contribute fecal coliform bacteria to Lynch Cove were identified as a majority of the steep slope areas which extend from the coastal lowlands to the till-mantled uplands, including portions of the stream channels and small lot size areas (Figure 8). Areas with moderate to steep slopes could allow surface seepage and runoff from failing septic systems to surface waters via overland flow. Surface water flowing toward Lynch Cove located near failing septic systems could carry fecal coliform bacteria in drainfield effluent that is flowing overland. Areas of small lot size underlain by soils classified as limited for septic suitability and moderate depths to ground water have been identified as having a possible potential to impact Lynch Cove and/or Hood Canal with viable fecal coliform bacteria.

10.3 Unlikely Potential Impact Areas

The areas identified with an unlikely or insignificant potential to contribute fecal coliform bacteria to Lynch Cove are generally the glacial till-mantled uplands that are located away from the stream channels and have generally large lot sizes (Figure 8). The soils in the uplands are predominantly Alderbrook series, which are shown to be limited for septic drainfield construction. Septic systems in the unlikely impact areas are completed in the relatively thin, weathered till soils overlying the low-permeability unweathered till. The low vertical permeability of the till results in a relatively long travel time for fecal coliform bacteria to reach Lynch Cove via ground water recharge. Therefore, the chance for viable fecal

coliform to reach Lynch Cove via deep ground water is considered unlikely or insignificant in these areas.

11.0 LIMITATIONS

We have prepared this report for MSA and the County to assist in the delineation of a sewer service area near the community of Belfair in Washington State. The conclusions and interpretations presented in this report should not be construed as a warranty of the subsurface conditions. Our conclusions and recommendations are based on review of available geologic, hydrogeologic, soils, and water quality information, and observations of exposed site conditions. If additional information becomes available that was not reviewed for this study, that information should be made available to AESI for review.

The scope of work did not include environmental assessments or evaluations regarding the presence or absence of hazardous substances in the soil, surface water, or ground water at this site.

Within the limitations of scope, schedule, and budget, AESI attempted to execute these services in accordance with generally accepted professional principles in the fields of geology and hydrogeology at the time this report was prepared. No warranty, express or implied, is made.

We have enjoyed working with you on this study and are confident that these conclusions will aid in the successful completion of your project. If you should have any questions or require further assistance, please do not hesitate to call.

Sincerely,
ASSOCIATED EARTH SCIENCES, INC.
Everett, Washington

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12.0 REFERENCES

- Armstrong, J.E., Crandell, D.R., Easterbrook, D.J., and Noble, J.B., 1965, Late Pleistocene stratigraphy and chronology in southwestern British Columbia and northwestern Washington: Geological Society of America Bulletin, v. 76, p. 321-330.
- Barnes, J., Brummer, S., and Determan, T., 1995, Land use and water quality, Mission Creek, Little Mission Creek Sub-basins, Lower Hood Canal: Washington State Department of Ecology, Watershed Management Section, 23 p.
- Blunt, D.J., Easterbrook, D.J., and Rutter, N.W., 1987, Chronology of Pleistocene sediment in Puget Lowland, Washington: Department of Natural Resources Bulletin 77, pp. 321-351.
- Carson, R.J., Smith, M., and Foxworthy, B.L., 1975, Geologic conditions related to waste-disposal planning in the southern Hood Canal area, Washington: United States Geological Survey Map I-853D.
- Crandell, D.R., Mullineaux, D.R., and Waldron, H.H., 1958, Pleistocene sequence in the southeastern part of the Puget Sound Lowland, Washington: American Journal of Science, v. 256, p. 384-397.
- Garland, D. and Lawrence, S., 2003, Union River fecal coliform water cleanup, detailed implementation plan: Washington State Department of Ecology, Publication No. 03-10-066, 44 p.
- Garling, M.E., Molenaar, D., van Denburgh, A.S., Fiedler, G.H., and Bailey, E., 1965, Water resources and geology of the Kitsap Peninsula and certain adjacent islands: Washington State Department of Conservation Water-Supply Bulletin No. 18, 309 p.
- Gold, R., 2002, A comparative study between lidar imagery and photogrammetric approaches to identify landslides on Hood Canal in Kitsap County, WA: Senior Thesis, Whitman College, Washington.
- O'Neal, M., 2005, University of Washington, Personal communication.
- Smith, M. and Carson, R.J., 1977, Relative slope stability of the southern Hood Canal area, Washington: United States Geological Survey Map I-853-F.
- Soil Conservation Service (SCS), 1960, Soil survey of Mason County area, Washington: United States Department of Agriculture.

Sweet, S., Ward, W., Butkus, S., and Ehinger, 2002, Union River fecal coliform, total maximum daily load, submittal report: Washington State Department of Ecology, Water Quality Program, Publication No. 02-10-022, 38 p.

WAC 246-272, On-site sewage systems.

Washington State Department of Health, June 2003, Groundwater sources under direct influence of surface waters (GWI), DOH PUB #331-216.

Ward, W., Butkus, S., and Ehinger, W., 2001, Union River fecal coliform, total maximum daily load study: Washington State Department of Ecology, Environmental Assessment Program, Publication No. 01-03-038, 24 p.

APPENDIX A

Washington State Department of Health Letter