TECHNICAL MEMORANDUM

TO: Mike Blumen, Blumen Consulting Group, Inc.

FROM: David Pischer, P.E.

DATE: December 2007

RE: EARTH ELEMENT TECHNICAL REPORT
NEW WHATCOM REDEVELOPMENT PROJECT
PORT OF BELLINGHAM
BELLINGHAM, WASHINGTON

INTRODUCTION

This technical memorandum provides background information to support the preparation of the earth element of the Draft Environmental Impact Statement (EIS) for the New Whatcom Redevelopment (New Whatcom) project in Bellingham, Washington.

This document describes the affected earth environment and existing geologic conditions in the vicinity of the New Whatcom site, the impacts from existing geologic conditions related to future site development under development Alternatives 1 through 4, potential mitigation measures that may be implemented to address these impacts, and significant unavoidable adverse impacts.

This document has been prepared for the Port of Bellingham (Port) and the City of Bellingham (City) to support the New Whatcom Master Development Plan and is not intended to be used beyond the master planning stage. Additional site-specific subsurface investigations and geotechnical engineering analyses should be performed as part of the specific design and permitting of infrastructure and buildings associated with future site development.

AFFECTED ENVIRONMENT

Existing Site Conditions

The following section provides information about the existing geology, soil, and groundwater conditions in the New Whatcom study area. Information regarding environmental contamination conditions in the study area is summarized in Section 3.5 – Environmental Health of the Draft EIS.

Site Description and Redevelopment Areas

The New Whatcom site includes approximately 216 acres of contiguous waterfront property in central Bellingham. The site is generally bounded by Bellingham Bay to the west, Roeder Avenue and State Street to the east, and Cornwall Avenue to the south.

For descriptive purposes, the site has been divided into 10 redevelopment areas, as shown on Figure 1; these 10 redevelopment areas are summarized below and further described in Section 2.5 of the Draft EIS.

- Redevelopment Area 1: This 51.3-acre area is bordered by the Whatcom Waterway to the south, Roeder Avenue to the east, the I & J Waterway to the north, and the Aerated Stabilization Basin and Bellingham Bay to the west.

- Redevelopment Area 2: This 22.6-acre area is bordered by the Whatcom Waterway to the north, West Chestnut Street to the east and south, and other New Whatcom site areas to the west.

- Redevelopment Area 3: This 7.7-acre area is bordered by the Whatcom Waterway to the north, the Burlington Northern Santa Fe (BNSF) railroad right-of way to the south, and other New Whatcom site areas to the west.

- Redevelopment Area 4: This 11.4-acre area is bordered by the Whatcom Waterway to the north (including a portion of the former log pond), and other New Whatcom site areas to the east, west, and south.

- Redevelopment Area 5: This 7.4-acre area is bordered by the BNSF railroad right-of way to the north, West Chestnut Street to the east, Cornwall Avenue to the south, and other New Whatcom site areas to the west.

- Redevelopment Area 6: This 6.5-acre area is bordered by the BNSF railroad right-of way to the north, Cornwall Avenue to the south, and other New Whatcom site areas to the east and west. This area contains the Puget Sound Energy (PSE) Encogen co-generation power plant.

- Redevelopment Area 7: This 9.5-acre area is bordered by Cornwall Avenue to the north, bluff areas to the south and east, and other New Whatcom site areas to the west.

- Redevelopment Area 8: This 24.4-acre area is bordered by the Whatcom Waterway to the north (including a portion of the former log pond), the BNSF railroad right-of way to the south, and other New Whatcom site areas to the east and west.

- Redevelopment Area 9: This 21.4-acre area is bordered by Bellingham Bay on the north, west, and a portion of the east, Cornwall Avenue to the south, and other New Whatcom site areas to the east and west. The northwestern portion of this area contains the Bellingham Shipping Terminal.

- Redevelopment Area 10: This 18.2-acre area is bordered by Bellingham Bay on the north and west, the BNSF railroad right-of way and adjacent bluff area to the south, and other New Whatcom site areas to the east. The western portion of this area contains the Cornwall Avenue Landfill site, and the eastern portion of this area consists of R.G. Haley Corp. property and buildings.

- Aerated Stabilization Basin: The 35.9-acre Aerated Stabilization Basin (ASB) is bordered by the Whatcom Waterway to the south, Bellingham Bay to the north and west, and other New Whatcom site areas to the east. The ASB is planned to be converted into a marina by the Port after implementing remedial cleanup action activities.

Background

The “earth element” information summarized in this document is based on a review of certain geotechnical borehole logs, subsurface investigation reports, and published sensitive area and surficial geologic maps.

The literature review included both in-house project files and outside sources. Outside sources of information included U.S. Geological Survey (USGS) maps, geologic maps from the Washington State Department of Natural Resources Division of Geology, critical area ordinance maps from the City, and other sources.

The subsurface data collected in support of this document varied across the project site in level of detail, depth of exploration, quality, usefulness, and availability. However, the level of information gathered is considered adequate for an EIS-level report and for the purposes of characterizing subsurface conditions in the study area, understanding the potential impacts, and identifying proposed and possible mitigation measures for site development.

For the purpose of discussing the geology, soils, groundwater, and geologic hazards at the New Whatcom site, some of the individual redevelopment areas have been combined, as appropriate.

Topography

The ground surface topography within the New Whatcom site is relatively flat due to historical filling behind shoreline bulkheads. The only exception pertains to the steeper slope and bluff areas located adjacent to the southeast side of Areas 2, 5, and 7, and the south side of Area 10. The existing ground surface at the site typically ranges from as low as Elevation 10 feet to about 25 feet Mean Lower Low Water (MLLW), with the adjacent bluff area extending up to about Elevation 70 to more than 100 feet MLLW south of Areas 7 and 10, respectively.

Generally, the site areas slope toward the nearby shorelines. Existing site topographic information is presented in the Stormwater Technical Report.

Geology

The surficial geologic units in the vicinity of the New Whatcom site were interpreted from the Geologic Map of Western Whatcom County, Washington (Easterbrook 1976), the Geologic Map of the Bellingham Quadrangle, Washington (Lapen 2000), and certain other investigations that have been conducted in or near the project area.

The geology in the Bellingham area has been shaped by various glacial deposits derived from the advance and retreat of the Cordilleran Ice Sheet between about 12,000 and 18,000 years ago, as well as by subsequent sedimentation and filling activities. A substantial portion of the site represents a historic beach and intertidal area along the Bellingham Bay shoreline that has been filled in the past.

A general surficial geology map is provided on Figure 2. Very few of the specific geologic units in the site vicinity have consistent boundaries or contacts, and the near-surface geology across the site can change significantly both horizontally and vertically within relatively short distances. Accordingly, general subsurface cross sections for the site have not been developed for this EIS-level report. Typical descriptions of the geologic units encountered at or in the vicinity of the project site are presented below, ordered from the deepest (oldest) units to the most shallow (youngest) deposits.

Chuckanut Formation

Bedrock that generally underlies the portion of the site south of the Whatcom Waterway consists of fractured sandstone, siltstone, and carbonaceous shale of the Chuckanut Formation. Coal seams present at depth in certain portions of the Chuckanut Formation were previously mined in the Bellingham area in the 1800s.

The Chuckanut Formation has an undulating surface that has been eroded by glaciers and water. The Chuckanut Formation is present near the ground surface and forms the bluff located south of Areas 7 and 10. The top of the Chuckanut Formation slopes downward toward Bellingham Bay. The depth to the top of the Chuckanut Formation varies significantly, and may be present at depths of more than 30 to 60 feet below ground surface (BGS) near the shoreline.

Bellingham Drift (Glaciomarine Drift)

The Bellingham Drift is typically a soft to stiff, unsorted and unstratified pebbly, sandy silt and clay material (with occasional gravel and marine shells) that was derived from rock debris that melted out of glacial ice as rising sea levels floated and melted glacial ice and deposited the material on the sea floor.

The Bellingham Drift material, also referred to as Glaciomarine Drift (GMD), varies in thickness and location within the project site. Where present, the depth to the top of the GMD varies significantly and increases toward Bellingham Bay. The GMD is occasionally present above the Chuckanut Formation, but is typically present below the outwash sand and gravel unit at the site. The thickness of the GMD exceeds 90 feet in portions of Area 1, but thins to 30 feet or less near the shoreline in Area 10 and pinches out toward the southern portion of Area 10.

Outwash Sand and Gravel

The outwash sand and gravel unit is present primarily north of the Whatcom Waterway below Area 1. This unit is primarily medium dense sand and gravelly sand mixtures deposited in the Squalicum Outwash Channel that follows the course of Squalicum Creek.

Nooksack Deposits

Nooksack deposits are fine-grained sediments deposited in Bellingham Bay by the Nooksack River, and typically consist of deposits of soft silt, sandy silt, and silty clay. The Nooksack deposits, where present, generally thicken toward Bellingham Bay and pinch out near the shoreline.

Beach Deposits

Beach deposits are present primarily south of the Whatcom Waterway and typically consist of very loose to loose, fine to medium sand with occasional shell and wood fragments deposited along the shoreline of Bellingham Bay.

Fill / Modified Land

The term "modified land" is used to describe surficial geologic conditions that have been modified by human activities such as, but not limited to: cutting, filling, grading, leveling, and shoreline protection. Fill materials are present over a significant portion of the New Whatcom site due to past shoreline filling and site development activities. Material dredged from nearby waterways was historically used to raise site grades near the waterfront. Fill materials present at the site are highly variable and may consist of sand, silt, clay, gravel, sawdust and/or wood fragments, construction debris (bricks, concrete, etc.), and mixtures of these fill materials. (Landfill refuse is also present in certain areas of the site, as discussed in the following section; fill materials include cover soils placed over the refuse.) Locally, some effort at compaction may have been made during placement of fill materials, whereas in other areas limited effort at compaction may have been made. Consequently, the relative density of the fill will vary widely and specific engineering properties of the fill materials will be very different from location to location.

Landfill Refuse

Although landfill material generally comes under the term “fill/modified land,” it has been expressly called out here to reflect municipal solid waste and other waste materials present within the historic Roeder Avenue Landfill located in the central portion of Area 1 and the Cornwall Avenue Landfill located in the western portion of Area 10.

Groundwater

The primary groundwater system at the New Whatcom site consists of a shallow, non-potable, unconfined aquifer that is tidally influenced near the shoreline areas. There are no known active uses of groundwater (from industrial or domestic wells) at the site.

Information regarding groundwater levels within the New Whatcom site was obtained from previous subsurface investigations conducted by others. Generally, groundwater has been encountered at about 3 to 12 feet BGS, with a groundwater flow direction typically toward Bellingham Bay. It is anticipated that groundwater conditions will vary depending on local subsurface conditions, the season, recent weather patterns, the tide level in Bellingham Bay, and other factors.

The New Whatcom site is not considered a critical aquifer recharge area because a significant portion of the site has been developed and covered by buildings or pavements.

Geologic Hazards

Washington State’s Growth Management Act (Chapter 36.70A RCW) requires all cities and counties to identify critical areas within their jurisdictions and to formulate development regulations for their protection. Among the critical areas designated by the Growth Management Act are geologically hazardous areas, defined as such because of their potential susceptibility to erosion, landsliding, seismic, or other geologic events, or because of their past use (i.e., landfill). These areas may not be suited for development consistent with public health and safety concerns without conducting specific studies during the design and permitting process.

The City defines and identifies geologically hazardous areas in its Environmental Critical Areas Ordinance (City of Bellingham Municipal Code 16.55.410-.460) and has developed a folio of maps of the geologically hazardous areas. In general, before development is allowed in or immediately adjacent to mapped critical areas, detailed geotechnical studies must be conducted as part of the permit process to address specific standards relating to site geology and soils, seismic hazards, and facility design.

A discussion of potential geologic hazards at the New Whatcom site is provided below.

Landslide Hazards

Landslide hazard areas may be prone to landslides and/or subsidence that could include movement of soil, fill, rock, or other geologic strata. Specific landslide hazard areas may include, but are not limited to:

- Slopes that rise at an inclination of 40 percent or more (typically with a vertical change in elevation of at least 10 feet)
- Slopes that are parallel or subparallel to planes of weakness in subsurface materials
- Marine bluffs along present and historic shorelines of Bellingham Bay
- Areas mapped by the City as a geologic hazard area with high landslide potential.

The degree of potential sloughing and sliding varies with the steepness, height, and potential planes of weakness of the slope. Steeper, higher slopes are more likely to create larger slides, whereas shorter slopes tend to produce smaller surficial sloughs. Slopes that are susceptible to movement under non-earthquake (static) conditions also present a hazard under earthquake loading conditions.

In the vicinity of the site, the bluff and steep slopes located south of Areas 7 and 10 are considered to have the highest landslide potential (see Figure 3); however, these steeper slope areas are located either outside the site boundary or within the railroad easement where development is not proposed. A general reconnaissance of the bluff and steep slope areas conducted as part of this study did not identify areas of significant slope instability that would affect future site redevelopment. Also, as part of the City's railroad relocation feasibility analysis project, a slope reconnaissance was conducted along portions of the proposed railroad realignment that pass near the toe of the existing steep slopes; that study concluded that the proposed railroad realignment would have a low risk of being impacted by slope instability (GeoEngineers 2007). A moderate landslide potential may exist along some of the steeper, unsupported shorelines at the site (primarily along portions of Areas 4, 8, and 10).

Seismic Hazards

General

Seismic hazard areas are generally defined as those areas subject to severe risk of earthquake damage as a result of ground shaking, ground rupture, soil liquefaction, or tsunamis. Ground shaking can occur far from the earthquake source, ground rupture only occurs along the active fault trace, liquefaction requires a certain combination of soil and groundwater conditions at the site, and tsunamis can occur far from a fault rupture or massive landslide in a water basin.

The general seismic hazards map for the area (see Figure 4) indicates that much of the New Whatcom site is mapped by the City as a very high seismic hazard area due to the presence of man-made fill. However, the portions of Areas 2 through 7 that are mapped as having a low seismic hazard due to relatively shallow bedrock also contain surficial fill and beach deposits. Thus, for the purpose of this EIS-level study, the entire New Whatcom site should be considered a high to very high seismic hazard area.

The USGS and other researchers continue to evaluate the presence and potential effects of fault systems in the Pacific Northwest that could affect seismic hazard assessments in the Bellingham area. Relatively recent research of the Boulder Creek fault near Kendall, Washington, the Sumas and Vedder Mountain faults near Sumas, Washington, and other fault features in northwestern Washington suggest that seismic hazards in the Bellingham area may be greater than previously estimated based on currently available USGS seismic hazard maps and data that may not adequately account for potential ground shaking from such nearby fault systems. Accordingly, seismic hazard assessments conducted during the design phase of future site improvements should use USGS seismic hazard maps and data that have been updated to reflect potential ground shaking from such nearby fault systems.

Ground Shaking and Ground Motion Amplification

The entire Puget Sound region lies within a seismically active area, and moderate to high levels of ground shaking should be anticipated during the design life of the New Whatcom project. The New Whatcom site is located over deposits of relatively soft to loose soils that may amplify earthquake ground motions at various frequencies. Consequently, the near-surface soils at the site could affect the level of earthquake ground shaking felt in the area. Certain soil deposits at the site may be subject to ground motion amplification and subsequent liquefaction during a significant earthquake event.

Seismic design using most recent design codes and generally accepted engineering standards and practices should be conducted during the design phase of the future site improvements. This includes conducting site-specific seismic analyses when appropriate and using the most recent version of the International Building Code (IBC), which contains provisions to address life safety issues and incorporates data obtained from recent seismic events in the seismic design standards.

Ground Rupture

The Puget Sound region contains numerous fault zones, and the Sumas and Vedder Mountain fault system, located northeast of Bellingham near Sumas, is currently considered the closest reported fault zone. However, due to the distance between the New Whatcom site and this fault zone, it is unlikely that ground rupture would occur at the site. Accordingly, design against actual ground surface rupture at the site during a seismic event will not be a significant part of the site-specific seismic design for future site improvements.

Liquefaction

When shaken by a significant earthquake, certain soils may lose strength and temporarily behave as if they were liquid. This phenomenon is known as liquefaction. The seismically induced loss of strength can result in loss of bearing capacity for shallow foundations, reduction in vertical and lateral deep foundation capacities, downdrag forces on deep foundations, ground surface settlement, embankment instability, sand boils, and lateral spreading. Seismically induced liquefaction typically occurs in loose, saturated, sandy material commonly associated with recent river, lake, and beach sedimentation. In addition, seismically induced liquefaction can occur in areas of loose, saturated fill.

Most areas within the New Whatcom site contain surficial fill materials and native deposits that would likely be subject to liquefaction during a major seismic event. The Washington Department of Natural Resources (WDNR) Division of Geology and Earth Resources has published liquefaction susceptibility maps for Washington. The results of the WDNR study (Palmer et al. 2004) entitled “Liquefaction Susceptibility and Site Class Maps of Washington State, By County” indicate that the majority of the site is mapped as having a high liquefaction susceptibility.

The depth and extent of potentially liquefiable soil deposits is dependent on specific soil and groundwater conditions and will be highly variable across the site. The actual magnitude and extent of soil liquefaction will depend on many factors including the duration and intensity of the ground shaking during the seismic event, and specific soil and groundwater conditions. Accordingly, a site-specific liquefaction analysis would need to be conducted during the design and permit process for future site improvements in order to estimate the expected impact due to soil liquefaction and evaluate potential mitigation measures.

Tsunamis

Tsunamis are earthquake-generated waves that occur in open water bodies. A tsunami wave can be generated by permanent ground displacements in a water basin caused by a fault rupture (or landsliding). The extent and severity of a tsunami wave will depend on many factors including site location and elevation, fault offset, ground motions, and tide stage. A tsunami could be generated by a large earthquake in the Pacific Ocean basin. The WDNR Division of Geology and Earth Resources and the National Oceanic and Atmospheric Administration (NOAA) have published estimates of tsunami inundation in the Bellingham Bay area based on computer modeling of ground deformations and waves that may be generated by a Cascadia Subduction Zone earthquake. The results of the WDNR and NOAA modeling study (Walsh et al. 2004) entitled “Tsunami Hazard Map of the Bellingham Area, Washington: Modeled Tsunami Inundation from a Cascadia Subduction Zone Earthquake” indicate that a magnitude 9.1 Cascadia Subduction Zone earthquake may result in a tsunami wave that could cause a depth of inundation of 0 to 0.5 meters (0 to 1.6 feet) in much of the New Whatcom site.

It should be noted that the study acknowledges certain limitations, with the largest source of uncertainty being the initial deformation of the earthquake, which is poorly understood. Additionally, the model run does not include the influences of changes of tides, and tide stage and tidal currents can amplify or reduce the impact of a tsunami at a specific site. Thus, the study states, "While the modeling can be a useful tool to guide evacuation planning, it is not of sufficient resolution to be useful for land-use planning."

Landfill Areas

The closed Roeder Avenue Landfill, located in the central portion of Area 1, encompasses an area of about 21.4 acres. Specific information regarding subsurface conditions and contamination levels at the landfill is contained in the Remedial Investigation/Feasibility Study (RI/FS) for the Roeder Avenue Landfill site (ThermoRetec 2001).

The closed Cornwall Avenue Landfill, located in the western portion of Area 10, encompasses an area of about 8 acres. Specific information regarding subsurface conditions and contamination levels at the landfill is contained in the Remedial Investigation/Feasibility Study (RI/FS) for the Cornwall Avenue Landfill site (Landau Associates 2003). Refuse associated with the Cornwall Avenue Landfill is present in the northwest portion of the adjacent R.G. Haley site (GeoEngineers 2006).

Landfill conditions at the Roeder Avenue and Cornwall Avenue landfills are typical of other solid waste landfill areas that have been redeveloped (e.g., the Georgia Pacific Tissue Warehouse was constructed on the Roeder Avenue landfill). Site redevelopment directly over or adjacent to these landfill areas is possible as long as the potential effects of long-term settlement, migration of methane gas and leachate, protection of existing environmental controls, and other landfill-related issues are adequately addressed as part of the site-specific design and permit process for buildings and infrastructure near these portions of the site.

Erosion Hazards

Erosion hazard areas are defined as those areas containing soils that may experience severe to very severe erosion from construction activity. The susceptibility to erosion is generally a function of soil type, topography, occurrence of groundwater seepage or surface runoff, and the built environment. The New Whatcom site is in an urban environment where the erosion hazard is considered relatively low; however, certain soil types at the site may be susceptible to erosion when disturbed by construction, particularly on slopes exceeding 15 percent (see Figure 3). This potential erosion hazard primarily applies to the bluff and steeper slope areas adjacent to the perimeter of the site, which is a relatively small area with limited planned development.

Coal Mine Hazard

Mine hazard areas are those areas potentially underlain by or affected by mine workings, such as adits, gangways, tunnels, drifts, or airshafts, and those areas of probable sinkholes, gas releases, or subsidence due to mine workings.

Coal mining was historically conducted in the Bellingham area in the 1800s. Tetra Tech, Inc. completed an extensive review of abandoned mines in the City (Tetra Tech 1984). As indicated on the coal mine hazard map (see Figure 5), the abandoned Sehome Mine is mapped by the City as a known coal mine hazard area beneath a portion of downtown Bellingham, but is mapped as an unknown hazard in the area north of Cornwall Avenue and near the southeastern portion of Areas 5 and 7 where former mine openings along the bluff have been reported (Tetra Tech 1984).

The mined coal seams present within the Sehome Mine have not been well mapped, but have been reported at depths of about 90 feet BGS at an offsite location near Railroad Avenue and Chestnut Street (BEK Purnell 1998). As part of the City's railroad relocation feasibility analysis project, a 100-foot deep boring was advanced at the top of the slope at the end of the existing East Laurel Street, and it was reported that this boring did not encounter any voids (GeoEngineers 2007).

Based on a review of currently available information, it appears that there were several historic mine openings along the bluff near the southeast portion of Areas 5 and 7, but that coal mining generally extended downward to the east below the downtown portion of Bellingham. Thus, it is likely that areas with any remaining void spaces from past coal mining activities are primarily located beyond the perimeter of the site. However, due to the potential for ground subsidence due to the presence of void spaces from past coal mining activities, a coal mine hazards evaluation should be conducted in accordance with the City's permit process for future site redevelopment within the southeast portion of Areas 5 and 7.

Site redevelopment directly over mined coal seams is feasible (as evidenced by past development in the portion of downtown Bellingham that is within the known coal mine hazard area) as long as site-specific ground improvement and/or foundation modifications are implemented when necessary.

Sea Level Rise

The potential impact of climate change (global warming) on mean sea level elevation in Bellingham Bay is difficult to accurately predict. Two Washington State agencies, the

Department of Ecology (Ecology) and the Department of Community, Trade, and Economic Development (CTED), jointly issued a study in 2006 evaluating the economic impact of climate change on the state's economy. The study (Ecology and CTED 2006) includes a discussion of potential impacts on shorelines, and indicates that rising temperatures and glacial melting are expected to raise global sea levels between approximately 4 and 40 inches from 1990 to 2100, based on projections from the Intergovernmental Panel on Climate Change (IPCC 2001). The study also indicates that, in the Pacific Northwest, rates of global sea level rise may be augmented by regional effects on the Pacific Ocean linked to atmospheric circulation patterns, which could add up to 12 inches to sea level rise projections over the 1990 to 2100 time period (based on the study's communications with the Climate Impact Group at the University of Washington in October 2006). In addition, the study acknowledges that interactions with tectonic activities will offset climate-induced sea level rise in areas with tectonic uplift (rising landmasses) and exacerbate climate-induced sea level rise in areas with tectonic subsidence (sinking landmasses). However, in the vicinity of the New Whatcom site, it appears that a significant trend toward tectonic uplift or subsidence has not been confirmed.

For the purpose of this Draft EIS analysis, a reasonable estimate of potential sea level rise in Bellingham Bay by 2100 is currently assumed to be up to approximately 2.4 feet over current levels.

IMPACTS

This section evaluates the potential effects that the existing earth environment at the site may have on redevelopment under the EIS Alternatives, as well as how the alternatives could affect the earth environment at the site. These impacts include both short-term construction impacts and long-term operational impacts. For identified impacts, some potential mitigation measures are noted in this section to supplement the discussion in the subsequent Mitigation Measures section of this document.

Specific foundation support systems to be used for onsite improvements will be determined as part of the site-specific design and permitting of infrastructure and individual buildings associated with future site development. Based on the presence of compressible, fine-grained soils and liquefiable sand deposits at the site, and the relatively high foundation loads typically associated with multi-story buildings, deep foundations (such as driven or auger-cast piles) would be required for support of the majority of these structures (heavy buildings over about two stories) under Alternatives 1 through 3. Preloading a future building site prior to construction can be used to preconsolidate compressible foundation soils and reduce post-construction settlement impacts on spread foundation systems; however, preloading would likely be effective only for lightly loaded structures (buildings under about two stories) located in site areas without significant layers of liquefiable soils. Consequently, use of preloading and spread foundation support for future buildings would likely be limited under Alternatives 1 through 3.

Landsliding and erosion hazard impacts are addressed below; however, these potential impacts generally apply only to the bluff and steeper slopes adjacent to the southern side of Area 10 (which are located either outside the site boundary or within the railroad easement where development is not proposed), and to a lesser extent to the shallower slopes along the southeastern side of Areas 2, 5, and 7.

Landfill area impacts associated with future redevelopment near the closed landfills at the site are addressed below; however, these potential impacts apply only to future site improvements near the Roeder Avenue Landfill located in the central portion of Area 1 and near the Cornwall Avenue Landfill located in the western portion of Area 10.

A general description of the potential impacts associated with future site redevelopment under the EIS Alternatives is provided below and summarized in Table 1. Impacts evaluated include those due to the effect of the earth environment on the alternative, as well as the effect of construction, operation, and maintenance of the alternative on the earth environment. An impact such as potential liquefaction of existing soils would be an example of an impact associated with the existing environment. Examples of construction-related impacts could include pile-driving noise and vibration. Long-term operational impacts would be those associated with the specific land use and are likely to be negligible and indistinguishable for the earth environment. The following discussion of impacts generally pertains to all EIS Alternatives, including the No Action Alternative.

Geologic Hazard Impacts

Geologic hazard impacts are discussed below in terms of how existing geologic conditions at the site could affect the New Whatcom Redevelopment Alternatives.

Settlement

Portions of the site are underlain by loose/soft compressible deposits. Constructing heavy structures or placing significant heights of fill (more than about 3 to 4 feet) directly on these soil types could cause varying amounts of settlement. Such settlement could potentially result in damage to structures and utilities. In order to preclude adverse settlement impacts, typical construction mitigation measures would be implemented; such measures could include using deep foundation systems for heavy structures, preloading a building site prior to construction of relatively light structures (buildings under about two stories) on spread foundations, delaying construction until most of the fill-induced settlement has occurred, and use of mechanically stabilized earth walls or lightweight fill materials for construction of bridge approach embankments (in conjunction with new bridge connections at Laurel Street, Bay Street, Commercial Street, etc.).

Landsliding / Steep Slopes

There is a moderate potential for landsliding of portions of the existing steeper slopes present along the southeastern side of Areas 2, 5, and 7 and the bluff on the southern side of Area 10, with or without redevelopment. A moderate landslide potential may also exist along some of the steeper, unsupported shorelines at the site (primarily along portions of Areas 4, 8, and 10). Landsliding could potentially be triggered by a seismic event; the natural process of stabilization of a steep slope to a flatter profile; an increase in porewater pressure from excessive rainfall that could destabilize a portion of the slope; or construction that traverses or cuts into a steep slope (especially if planes of weakness in the slope are adversely affected). The impact of landsliding is considered low given that construction that would require significant cuts into the nearby steep slope areas would not be likely under any of the EIS Alternatives, and that the stability of unsupported shoreline slopes would be evaluated and mitigated as necessary during redevelopment in these areas.

Erosion

The New Whatcom site is in an urban environment where the erosion hazard is considered relatively low; however, certain soil types at the site may be susceptible to erosion when disturbed by construction, particularly on slopes exceeding 15 percent. This potential erosion hazard primarily applies to the bluff and steeper slope areas near the eastern and southern perimeter of the site, which comprise a relatively small area with limited planned development under all alternatives. Fill material placed to construct bridge approach embankments (in conjunction with new bridge connections to improve site access) may also be susceptible to erosion; the bridge connections could be subject to future environmental review at the permit stage.

When unvegetated and/or disturbed, finer-grained soils can be subject to some degree of erosion during construction. Construction activities would include employing temporary erosion control measures and Best Management Practices to mitigate erosion impacts (see the Mitigation Measures section of this document for details).

Ground Shaking and Ground Motion Amplification

The entire Puget Sound region lies within a seismically active area, and moderate to high levels of ground shaking should be anticipated during the specific design and permit process for future site improvements. The New Whatcom site is also located over deposits of relatively soft to loose soils that may be susceptible to amplified earthquake ground motions at various frequencies. Seismic design using the most recent design codes (including the IBC) and generally accepted engineering standards and practices would be conducted during the design and permit process for future site improvements. This would include conducting site-specific seismic analyses when appropriate.

Ground Rupture

The site is not located near fault zones that could cause ground rupture in or near the planned redevelopment areas. The Sumas and Vedder Mountain fault system, located northeast of Bellingham near Sumas, is currently considered the closest reported fault zone. However, due to the distance between the New Whatcom site and this fault zone, it is unlikely that ground rupture would occur at the site. Accordingly, design against ground rupture will not need to be a significant part of the site-specific seismic design and permit process for future site improvements, and mitigation to prevent ground rupture impacts would not be required.

Liquefaction

The entire New Whatcom site may be subjected to earthquake shaking and should be considered to have a high seismic risk. There is a potential for loss of soil strength (loss of bearing capacity for shallow foundations or the reduction in lateral and vertical capacities of deep foundations), ground surface settlement, and lateral displacement of soils supporting the future structures where founded in or over liquefiable soils. The specific magnitude of settlement, soil movement, and loss of strength is a function of the soil thickness, soil quality, groundwater level, location, magnitude of the seismic event, and the specific foundation system of the structure.

Liquefaction can result in widespread structural damage of buildings and utilities if not properly mitigated. Damage caused by liquefaction can include: foundation rotation, slope failure, lateral spreading, and post-liquefaction ground subsidence (settlement).

Soil liquefaction, should it occur, would likely lead to consolidation of loose, saturated soil deposits, resulting in some surface settlement at the site. Since subsurface conditions vary across the site, overall settlement would also vary, leading to differential settlements across the site and possibly differential settlements between adjacent foundation elements. Liquefaction-induced ground settlements could cause increased downdrag loading on deep foundations.

Impacts associated with soil liquefaction can be mitigated in a number of ways, as discussed in the Mitigation Measures section of this document. Examples of possible mitigation methods include ground improvement, use of deep foundations, installing wick drains, and/or designing for potential soil liquefaction impacts. The specific mitigation measures would be determined during the site-specific design and permit process for future site improvements.

Lateral Spreading

Lateral spreading is a phenomenon where lateral ground displacements occur as a result of soil liquefaction. Lateral spreading is typically observed on very gently sloping ground or on virtually level ground adjacent to slopes. Lateral spreading tends to break the upper soil layers into blocks that progressively move downslope during an earthquake. Large fissures at the head of the lateral spread are common, as are compressed or buckled soil at the toe of the soil mass. Lateral spreading displacements can range from a few centimeters to meters, depending on the magnitude and duration of the seismic event (Kramer 1996). From accounts of recent large earthquakes, lateral spreading at waterfront facilities typically appears to be more prevalent in upland areas within about 300 feet of the shoreline; however, case histories have documented lateral spreading occurring up to about 1,200 feet from the unsupported face of a soil mass.

In the vicinity of the New Whatcom site, significant lateral spreading displacements could potentially occur during a large seismic event along shoreline portions of the site that are not protected by a suitable seawall or other structures/measures. Lateral spread displacements would generally move toward Bellingham Bay.

Lateral spreading would be specifically evaluated during the site-specific design and permit process for future site buildings located within (at a minimum) 300 feet of the shoreline.

Lateral spread displacements could cause significant forces that could result in permanent deformation of piles/drilled shafts used to support structures. Mitigation measures could include stabilizing unsupported slopes by using ground improvement techniques or installing retaining structures at appropriate depths and locations, or by designing foundation systems to resist the lateral loads due to lateral spreading.

Seismically Induced Landslides

Flow liquefaction landslides are triggered when the shear stress required for static equilibrium of the soil mass is greater than the shear strength of the liquefied soil. Because the ground surface throughout the majority of the New Whatcom site is relatively level, the shear stress required for equilibrium is relatively small; consequently, the potential for flow liquefaction landslides is considered small.

Non-liquefiable slopes can also experience slope failures as the dynamic shear stresses produced by earthquake shaking increase the load along a potential failure plane. Although the potential for deep-seated, earthquake-induced landslides along the bluff or along some of the steeper, unsupported shorelines at the site is considered relatively low, some sloughing and slope movement could occur within loose surficial materials on a slope during a large seismic event. To address the potential impact of such slope movement, mitigation measures would include conducting site-specific slope stability analyses during the design and permit process and construction of slope stabilization measures or earth retention structures that might be needed near the steeper slopes at the site.

Tsunamis

Tsunamis are earthquake-generated waves that occur in open water bodies. As discussed under Affected Environment, the results of a modeling study by WDNR and NOAA (Walsh et al. 2004) indicate that a magnitude 9.1 Cascadia Subduction Zone earthquake may result in a tsunami wave that could cause a depth of inundation of 0 to 0.5 meter (0 to 1.6 feet) over much of the New Whatcom site.

Depending on the height of any tsunami wave produced by a major rupture along the Cascadia Subduction Zone, a tsunami could potentially pose a temporary hazard at the site; however, the return period for large earthquakes along the Cascadia Subduction Zone that might generate a large tsunami is on the order of thousands of years. The potential impacts of a tsunami in Bellingham Bay include the adverse effects of temporary inundation by the tsunami wave, and damage/injury caused by debris carried by the wave. To address the potential impact of a tsunami, mitigation measures would include public notification and warnings; additionally, raising site grades for other site redevelopment purposes would also serve to mitigate this potential impact (see discussion under Sea Level Rise below).

Landfill Areas

Landfill refuse is present at the old Roeder Avenue Landfill (located in the central portion of Area 1) and the old Cornwall Avenue Landfill (located in the western portion of Area 10). The potential effects of long-term settlement, migration of methane gas from the landfills, and other landfill-related issues would need to be addressed as part of the site-specific design and permit process for buildings and infrastructure near those portions of the site. The depth and extent of refuse material at these landfills are variable. Specific information regarding subsurface conditions at these landfills is contained in the RI/FS reports for the Roeder Avenue Landfill (ThermoRetec 2001) and the Cornwall Avenue Landfill (Landau Associates 2003).

Decomposing organic landfill refuse has the potential to generate methane that could migrate off the landfill site. Methane could potentially accumulate under impervious surfaces over time if not properly mitigated, particularly in enclosed spaces associated with future buildings or utility vaults near these landfills. The potential for methane gas could also require methane monitoring when excavating and/or installing deep foundations near these landfills. Site-specific analysis at the design and permit stage will identify the need for and the suitability of specific mitigation measures to address this potential impact. These mitigation measures could include foundation ventilation systems, methane monitoring or collection systems, or gas barrier systems.

Landfill-impacted soil and leachate, where present beneath future redevelopment facilities, could also increase corrosion of underground metallic elements such as utility pipelines and steel pile foundations. Possible mitigation measures to address potential corrosion issues include selecting construction materials that are corrosion-resistant, or installing appropriate cathodic protection measures.

Coal Mine Areas

Coal mining was historically conducted in the Bellingham area. The abandoned Sehome Mine is located within the Chuckanut Formation beneath the downtown portion of Bellingham, and is mapped as potentially present at depth near the southeastern portion of the New Whatcom site, particularly in the eastern portion of Areas 5 and 7.

The potential for ground subsidence exists where underground void spaces exist at depth due to past coal mining activities. Based on a review of currently available information, it appears that there were several historical mine openings along the bluff near the southeastern portion of Areas 5 and 7, but that areas with any remaining void spaces from past coal mining activities are primarily located beyond the perimeter of the site. However, to address this potential impact for redevelopment within the southeast portion of Areas 5 and 7, a coal mine hazards evaluation should be conducted at the design and permit stage in accordance with City requirements, and site-specific ground improvement and foundation modifications should be implemented as appropriate.

Sea Level Rise

As discussed under Affected Environment, for the purpose of this Draft EIS analysis, a reasonable estimate of potential sea level rise in Bellingham Bay by 2100 is considered to be up to approximately 2.4 feet over current levels. As part of site redevelopment, site grades will be raised several feet above existing grades to facilitate construction of a gravity flow stormwater system that discharges to Bellingham Bay, to minimize unnecessary excavation work within areas of completed site remediation, and to mitigate the potential impact of a long-term sea level rise in Bellingham Bay.

Groundwater

As discussed under Affected Environment, the primary groundwater system at the New Whatcom site consists of a shallow, non-potable, unconfined aquifer that is tidally influenced near the shoreline areas. Generally, groundwater has been encountered at about 3 to 12 feet BGS, with a groundwater flow direction typically toward Bellingham Bay.

There are no known active uses of groundwater (from industrial or domestic wells) at the site, and no installation/use of any new water supply wells is included as part of future site improvements; therefore, groundwater use at the site would not change.

The New Whatcom site is not considered a critical aquifer recharge area because a significant portion of the site has been developed and covered by buildings or pavements. The planned future site improvements will typically replace existing impervious surfaces with new buildings and pavements, but site redevelopment under Alternatives 1 through 3 will result in a decrease in impervious surfaces at the site relative to existing conditions. No significant impact to the shallow aquifer is anticipated.

While some limited excavation dewatering could potentially be required for certain structures, the effect on groundwater would be temporary and localized (also see the Construction Dewatering section below). Deep foundations and ground improvement measures that could be associated with future structures at the site could potentially have some minor and localized effect on groundwater movement; however, groundwater would divert around relatively impervious foundation and ground improvement zones and these structures would not likely impact the overall groundwater flow system at the New Whatcom site.

Construction Impacts

Many of the potential impacts due to existing geologic hazards can be mitigated by implementing effective design and construction techniques or selecting appropriate foundation types during redevelopment. There are predictable impacts associated with typical construction techniques and foundation types. An example would be using a deep foundation to mitigate potential soil settlement and liquefaction. Construction of a deep foundation system would have different impacts depending on whether the deep foundation is a driven pile foundation, a drilled shaft foundation, or some other foundation type. Impacts associated with typical construction techniques are described below.

With respect to geologic hazards, there is little difference between the types of impacts associated with construction during the intermediate redevelopment stage (2016 impacts) versus the redevelopment buildout stage (2026 impacts). The difference in impacts among the EIS Alternatives primarily relate to the relative degree of construction associated with the higher-density, medium-density, lower-density, and no action alternatives. All EIS Alternatives are expected to have some level of initial and ongoing phased redevelopment as the area is changed from an industrial land use to a mixed-use redevelopment. For purposes of environmental review, it is assumed that the infrastructure projects would be generally similar for all redevelopment alternatives, although Alternative 1, the higher-density alternative, would entail the largest level of infrastructure improvements. Each of the redevelopment actions, however, will include similar forms of construction activities, such as demolition; clearing and grading; placing and compacting structural fill to raise site grades several feet above existing grades; excavating for utilities and foundations; potentially preloading certain areas to reduce settlement under lightly loaded structures; and installing deep foundations and/or implementing ground improvement for heavily loaded structures (i.e., structures higher than about two stories). Each of the alternatives includes various forms of new roadway development, marina and in-water development, and recreational development (parks and trails) that will be implemented in a limited initial phase and completed over the long term. Some of these alternatives also include the relocation of a portion of the BNSF railroad adjacent to the bluff.

Erosion during Construction

Construction associated with redevelopment under all of the EIS Alternatives could have erosion impacts on exposed soil and soil stockpiles, which could cause onsite and offsite transport of sediment. However, standard temporary erosion and sedimentation control measures and Best Management Practices (as summarized in the Mitigation Measures section of this document) would be implemented during construction to reduce the potential for erosion-related impacts.

Construction Excavations

Some amount of temporary excavation will likely be required for the construction of future structures and infrastructure, including elevator pits, new or upgraded underground utilities, and other shallow subsurface facilities. However, as part of site redevelopment, site grades will be raised several feet above existing grades to facilitate construction of a gravity flow stormwater system that discharges to Bellingham Bay, to provide mitigation of potential impacts of sea level rise, and to minimize unnecessary excavation work within areas of completed site remediation.

Without mitigation, certain excavations could potentially have an adverse impact on immediately adjacent existing (if retained) and future structures (i.e., structures within a distance equal to about the depth of the excavation), utilities, and other improvements. However, standard construction measures, such as use of properly designed and installed temporary shoring systems, would reduce the potential for such adverse impacts.

Construction Dewatering

Groundwater may be encountered within excavations at relatively shallow depths, particularly during the winter and spring months; thus, construction dewatering may be required to control groundwater flow into certain temporary excavations. However, raising site grades for other site redevelopment purposes will tend to limit the amount of excavations that extend below groundwater level.

The process of excavation dewatering could potentially cause some ground settlement and damage to adjacent utilities and structures. The radius of influence of a dewatering system is related to the amount of drawdown of the water table. Because future below-grade construction would likely be limited (currently estimated to be about 5 to 10 feet BGS or less for elevator pits), the associated excavations and degree of drawdown required would likely be relatively shallow. Site-specific analyses will determine what structures (existing or future, onsite or offsite) may be influenced by any required excavation dewatering; however, the potential for offsite impacts applies only to excavation dewatering for future redevelopment at the perimeter of the New Whatcom site. Examples of mitigation measures to control the potential impact of excavation dewatering include site-specific design at the permit stage and careful control of dewatering systems, minimizing the extent and duration of dewatering, and reinfiltration of extracted groundwater.

Extracted groundwater could potentially contain certain chemical contaminants and/or a high percentage of sediment, which might necessitate special handling, treatment, and/or disposal methods. Mitigation measures could include monitoring to assess the quality of dewatering discharges and treatment, if needed, to comply with applicable discharge permits. Also see the Environmental Health section of the Draft EIS for information on contamination and cleanup activities at the site.

Placement of Structural Fill

It is anticipated that some amount of surficial onsite soil that may need to be excavated as part of site redevelopment will be suitable for reuse as onsite fill, provided that the excavated material is properly handled and moisture-conditioned prior to placement and compaction. As part of site redevelopment, site grades will be raised several feet above existing grades to facilitate construction of a gravity flow stormwater system that discharges to Bellingham Bay, to provide mitigation of potential impacts of sea level rise, and to minimize unnecessary excavation work within areas of completed site remediation.

All structural fill and backfill material placed as part of site redevelopment should be densely compacted, which can cause vibrations and potential settlement of structures in the immediate vicinity of the construction work. Placement of significant depths of fill (more than about 3 to 4 feet) can also cause some ground subsidence that could impact existing (if retained) or future structures (onsite or offsite) in the immediate area of the fill; however, the potential for offsite impacts primarily applies only to significant fills, if any, placed for future redevelopment at the perimeter of Areas 1 and 2. Potential impacts to any structures would be mitigated by site-specific analysis and design of fill placement near any settlement-sensitive structures during the permit process.

Alternatives 1 through 3 include construction of certain bridges to connect existing roadways and enhance vehicle and pedestrian access and circulation at the New Whatcom site. While the bridge spans would likely be supported on drilled shaft foundations (a type of deep foundation), approach embankments may involve placement of fill materials over compressible soils. The height of any required bridge approach fills has not been determined, but the weight of approach fills could potentially cause some settlement and lateral loading of adjacent facilities (such as buildings, roadways, railroad corridors, and utilities) and increased downdrag loading on nearby deep foundations. These potential impacts would be mitigated by site-specific analysis during the design and permit stage for the bridge approach fills that would consider the potential settlements, lateral movements, and stability issues associated with fill placement over soft/loose, compressible materials, as well as their potential effect on nearby structures and utilities. In addition, these bridge connections could be subject to additional environmental review at the permit stage. Mitigation measures could include use of mechanically stabilized earth walls to retain and limit the width of the approach fills, use of lightweight fill materials to reduce the amount of settlement caused by fill placement, and use of geosynthetic reinforcement to help stabilize the approach fills.

Preloading

Preloading or surcharging a future building site or roadway corridor prior to construction can be used to preconsolidate compressible foundation soils and reduce post-construction settlements. However, preloading or surcharging a future building site would likely be effective only for lightly loaded structures (buildings under about two stories). Consequently, preloading or surcharging would potentially apply only to roadway corridors or lightly loaded buildings constructed on spread foundation systems.

Impacts of preloading and placing surcharge fills (placing greater amounts of fill to accelerate ground settlements) are generally associated with increased quantities of earthwork to place and remove the preload materials, and the potential for ground subsidence impacts to structures and utilities in the immediate area of the preloaded area. The potential impact of preload and surcharge fills would be mitigated by site-specific analysis and design during the permit stage, as said impacts are dependent on the depth of poor soil, the height of the preload, the proximity of existing structures and utilities, and the sensitivity of the existing structures and utilities to settlement. Mitigation measures could include constructing temporary mechanically stabilized earth walls at the edge of the preload/surcharge fills to limit the lateral extent and influence of the fill, conducting pre- and post-construction surveys of nearby structures, and monitoring of ground movements.

Deep Foundations

Based on the presence of compressible, fine-grained soils and liquefiable sand deposits at the site, and the relatively high foundation loads associated with multi-story buildings under Alternatives 1 through 3, deep foundations would be required for support of the majority of these structures (heavy buildings over about two stories).

For the purpose of this evaluation, it is assumed that the majority of the deep foundations would be driven piles due to the beneficial ground densification associated with driven displacement piles and the potential for contaminated spoils that might be associated with auger-cast piles. It is also assumed that bridge connections would likely be supported on drilled shaft foundations. Actual pile foundation types to be used for future site improvements would be determined as part of the site-specific design and permit process for individual buildings. Pile types could also include drilled piles, such as auger-cast concrete piles that are cast-in-place using a continuous-flight, hollow-stem auger, if site-specific analyses indicate that soil contamination or other site conditions do not preclude their use. If determined to be appropriate, certain structures might also be able to be supported on stone column foundation systems.

The depth of pile foundations would be determined as part of the site-specific design process for individual buildings, and would depend on various factors that include the pile type, the building loads, and site-specific soil conditions. The depth of pile foundations will vary across the site, and could vary from less than 50 feet to more than 100 feet BGS.

Driven Piles

During installation of driven piles for foundation support of structures, potential obstructions (such as logs, old piles, and other debris) may be encountered that could obstruct pile-driving and possibly result in damage to some of the new piles.

Increased levels of noise and vibration can occur within about 50 to 100 feet of pile-driving activities. Peak particle velocities within 10 to 15 feet of pile-driving can, in certain cases, exceed 2.0 inches per second (ips), gradually diminishing with distance. Structural damage can occur at peak particle velocities of 2.0 ips and greater.

Soil densification can occur with driven displacement piles when peak particle velocities approach 0.20 ips, which is generally within about 50 to 100 feet of pile-driving activities. Soil densification could potentially impact adjacent structures or utilities. The potential impact to existing or future adjacent structures or utilities is directly related to the intensity of the vibration, the diameter of the pile, the inherent density of the soil, and the sensitivity of the adjacent structure or utility to vibrations. The impact of vibrations is difficult to quantify and needs to be addressed on a case-by-case basis, but could potentially extend a short distance offsite for pile-supported structures to be located near the perimeter of the New Whatcom site.

Pile-driving case histories with similar soil conditions tend to indicate that several inches of surface settlement can occur within about 25 feet of pile-driving activities. Structures and/or utilities located within about 50 feet could potentially be impacted as a result of pile-driving activities and the associated surface settlements.

The anticipated number of deep foundation piles that could be needed for full buildout under the EIS Alternatives has been estimated based on the assumed density of the redevelopment, the anticipated building loads based on land use, and the assumption of all pile-supported structures (even for industrial buildings under Alternative 4) using piles with an allowable capacity of 100 tons. Alternative 4, the no action alternative, would require the least number of piles, currently estimated at about 3,000, due to limited industrial development under this alternative. Alternative 3, the lower-density alternative, would require the next lowest number of piles, currently estimated at about 12,000. Alternative 2, the medium-density alternative, is currently estimated to require about 18,000 piles. Alternative 1, the higher-density alternative, would require the greatest number of piles, currently estimated at about 23,000. It is assumed that pile-driving associated with construction of the site improvements under all EIS Alternatives would take place over a 20-year buildout period.

Driven piles would also likely be used during installation of a pedestrian bridge over the Whatcom Waterway, construction of the new marina in the remediated ASB, installation of new piers and floats, installation of new or upgraded shoreline bulkhead structures, and other in-water or near-shore improvements within or near the site.

Mitigation measures for pile-driving activities could include pre- and post-construction surveys of nearby buildings, monitoring of ground movements, vibration monitoring during pile installation, and use of vibratory hammers versus impact hammers when practicable. If appropriate, auger-cast piles could be used in upland areas to limit the vibration and ground settlement impacts associated with driven piles.

Drilled Shafts

Drilled shafts could potentially be used instead of driven piles for deep foundation support of certain buildings, and would likely be used to support bridge connections planned under EIS Alternatives 1 through 3 (such as the Laurel Street Bridge). Construction of drilled shaft foundations can be impacted by caving soils, soil heave, and large obstructions. The installation of drilled shafts generally does not produce significant vibrations; however, installation of temporary casings can produce a limited level of ground vibrations and localized ground settlement around the shaft construction area. Drilled shafts create large volumes of spoils and may require dewatering. Contaminated soil and groundwater that may be encountered during the installation of drilled shaft foundations might necessitate special handling, treatment, and/or disposal methods.

Potential mitigation measures for drilled shaft foundations include using casing to control caving soils and monitoring the ground surface during construction. Mitigation measures for contaminated groundwater include monitoring to assess the quality of dewatering discharges and treatment, if needed, to comply with applicable discharge permits. Contaminated soil and refuse generated during drilled shaft installation would need to be disposed of in accordance with applicable regulations. Also see the Environmental Health section of the Draft EIS for information on contamination and cleanup activities at the site.

Operational Impacts

Operational impacts associated with the earth environment at the site primarily relate to traffic vibrations near existing offsite buildings, and operation of active landfill gas control measures that may be installed as part of redevelopment near the closed landfills present in Areas 1 and 10.

Traffic Vibrations

Some level of ground vibration will result due to vehicle traffic on an expanded road and bridge network at the site, and due to operation of the BNSF railway that crosses the site. The potential vibration impact that may be felt at existing buildings is related to factors that include vehicle weight and speed, the frequency and duration of the vibrations transmitted to the ground, the inherent density of the soil, and the sensitivity of the adjacent structure or receptor(s) to traffic vibrations. The EIS Alternatives that include relocation of the BNSF railroad adjacent to the bluff could potentially result in some increased level of traffic vibration at nearby offsite buildings.

The impact of traffic vibrations is difficult to quantify, and thus needs to be addressed on a case-by-case and location-specific basis. However, traffic vibrations due to an expanded road and bridge network at the site are expected to be typical of those commonly encountered near roads and bridges in urban settings, and thus traffic vibration impacts are not anticipated to be a significant issue for any of the EIS Alternatives. Mitigation measures for traffic vibrations could include monitoring of traffic vibration levels and comparison with standard vibration levels that are perceptible to humans in nearby offsite buildings.

Landfill Gas

As previously discussed, landfill refuse is present at the old Roeder Avenue Landfill (located in the central portion of Area 1) and the old Cornwall Avenue Landfill (located in the western portion of Area 10). Methane could potentially accumulate under impervious surfaces over time if not properly mitigated, particularly in enclosed spaces associated with future buildings or utility vaults near these landfills. The potential impact of methane migration from the landfills would need to be addressed as part of the site-specific design and permit process for buildings and infrastructure near those portions of the site. Specific mitigation measures could include installation of active foundation ventilation systems and implementation of a methane monitoring program. However, the operation and monitoring of these systems is not considered a significant operational impact for any of the EIS Alternatives.

Relative Impacts by Alternative

With respect to geologic hazards, the differences in impacts between the EIS Alternatives primarily relate to the relative degree of construction associated with the higher-density, medium-density, lower-density, and no action alternatives.

Alternative 1, the higher-density alternative, represents the largest level of site redevelopment and infrastructure improvements, and results in the highest level of construction impacts. Alternative 1 assumes building heights ranging from 100 to 200 feet, and construction of approximately 7.5 million square feet of total floor space for mixed-use redevelopment over the 20-year buildout period. This alternative requires the largest number of foundation piles, currently estimated at about 23,000, and requires a large volume of fill materials, currently estimated at about 694,000 cubic yards.

Alternative 2, the medium-density alternative, represents the second highest level of site redevelopment and infrastructure improvements, and results in the second highest level of construction impacts. Alternative 2 assumes building heights ranging from 75 to 140 feet, and construction of approximately 6 million square feet of total floor space for mixed-use redevelopment over the 20-year buildout period. This alternative requires the second largest number of foundation piles, currently estimated at about 18,000, but also requires a large volume of fill materials, currently estimated at about 694,000 cubic yards. Alternative 2A assumes delayed railroad relocation and a modified roadway system, but otherwise has development impacts similar to Alternative 2.

Alternative 3, the lower-density alternative, represents the third highest level of site redevelopment and infrastructure improvements, and results in the third highest level of construction impacts. This alternative assumes building heights ranging from 75 to 100 feet, and construction of approximately 4 million square feet of total floor space for mixed-use redevelopment over the 20-year buildout period. This alternative requires the third largest number of foundation piles, currently estimated at about 12,000, and requires a slightly smaller volume of fill materials than Alternatives 1 or 2, currently estimated at about 688,000 cubic yards.

Alternative 4, the No Action Alternative, represents the lowest level of site redevelopment and infrastructure improvements, and results in the lowest level of construction impacts. This alternative assumes building heights similar to existing conditions (generally one to two stories), and construction of approximately 1 million square feet of total floor space for continued marine and industrial use over the next 20 years. This alternative requires the smallest number of foundation piles (assuming pile support for all new structures), currently estimated at about 3,000, and requires a much smaller volume of fill materials, currently estimated at about 150,000 cubic yards.

Indirect / Cumulative Impacts

Installation of a pedestrian bridge over the Whatcom Waterway, construction of the new marina in the remediated ASB, installation of new piers and floats, installation of new or upgraded shoreline bulkhead structures, and other in-water or near-shore improvements within or near the site would require the use of driven piles for foundation support and typical construction earthwork operations. Additionally, separate projects known to be proposed in or near the site area include: shipping terminal improvements (including new piers); improvements along the south side of the I & J Waterway; improvements along the north side of the Whatcom Waterway; the Bellwether on the Bay Phase II project; the 1010 Morse Square project; and the Bay View Tower project.

These other projects and separate actions may cause impacts similar to those discussed for the EIS Alternatives. However, if typical construction mitigation measures are implemented and applicable codes are followed for these other projects, no significant cumulative impacts associated with the earth environment would be encountered.

MITIGATION MEASURES

Specific foundation support systems to be used for onsite improvements will be determined as part of the specific design and permit process for infrastructure and individual buildings associated with future site development. Site-specific studies and evaluations would be conducted in accordance with City of Bellingham Municipal Code requirements and the provisions of the most recent version of the IBC, including conducting site-specific seismic analyses when appropriate. Methods are available to build out the New Whatcom site under each EIS alternative without resulting in significant unavoidable adverse impacts. Different foundation support options and their implications are summarized above in the Impacts section of this document. The mitigation measures to limit impacts from geologic hazards and foundation support options are summarized below.

Geologic Hazards

Settlement

For multi-storied structures, total and differential settlements could be accommodated by founding the structures on deep foundations, and/or by implementing ground improvement techniques. Preloading could be used to reduce total and differential settlements to within tolerable levels for roadways, utilities, and single-story structures. Alternatively, lightly loaded structures could be founded on a mat foundation with flexible utility connections that would limit the potential adverse effect of differential settlement. Mechanically stabilized earth walls or lightweight fill materials could be used for construction of approach embankments for the bridge connections at the site.

Landsliding / Steep Slopes

If any development adjacent to or on the steeper slopes near the perimeter of the site is proposed in the future, site-specific slope stability analyses prior to construction would be required and completed during the permit process. Catchment areas or retaining walls could be constructed near the base of steep slopes to temporarily retain surficial soil and debris that may slide down the slopes until that material is removed. Other slope stabilization measures or earth retention structures could be constructed as necessary.

Erosion

During construction, contractors would employ temporary erosion and sedimentation control measures and Best Management Practices to control erosion. These measures would be consistent with City regulations, and could include the following:

- Minimize areas of exposure
- Schedule earthwork during drier times of the year
- Retain vegetation where possible, especially on the steeper slopes near the perimeter of the site
- Seed or plant appropriate vegetation on exposed areas as soon as earthwork is completed
- Route surface water through temporary drainage channels around and away from disturbed soils or exposed slopes
- Use silt fences, temporary sedimentation ponds, or other suitable sedimentation control devices to collect and retain possible eroded material
- Cover exposed soil stockpiles and exposed slopes with plastic sheeting, as appropriate
- Use straw mulch and erosion control matting to stabilize graded areas and reduce erosion and runoff impacts to slopes, where appropriate
- Intercept and drain water from any surface seeps, if encountered
- Incorporate contract provisions allowing temporary cessation of work under certain, limited circumstances, if weather conditions warrant.

Ground Shaking and Ground Motion Amplification

With proper design and construction procedures, no additional mitigation measures would be required.

Ground Rupture

With proper design and construction procedures, no additional mitigation measures would be required.

Liquefaction

Ground improvement techniques or deep foundations could mitigate liquefaction impacts. Several methods of ground improvement are available, including stone columns, vibro-compaction, vibro-replacement, deep soil mixing, compaction grouting, installation of wick drains, and others. Selection of the appropriate deep foundation or ground improvement technique would be location-specific at the site and would depend on a number of factors, including the soil type, weight of structure/level of improvement required, area and depth needing improvement, proximity of existing structures, potential contaminated soil, concerns about encountering existing contamination, and cost. The specific method of ground improvement and foundation support would be determined as part of the design and permit approval process for future onsite redevelopment.

Lateral Spreading

Site-specific analysis of redevelopment planned within about 300 feet (and potentially up to about 1,200 feet) of an unsupported slope (e.g., along the shorelines at the site) would be conducted during the design and permit process to determine the appropriate mitigation and construction method. Mitigation measures could include stabilizing the unsupported slope by using ground improvement techniques, installing retaining structures at appropriate depths and locations, and potentially designing foundation systems to resist the lateral loads due to lateral spreading.

Seismically Induced Landslides

During a large seismic event, some sloughing and slope movement would likely occur within loose surficial materials on the steeper slopes near the perimeter of the site. Site-specific analysis of any redevelopment planned adjacent to or near these slopes would be completed during the design and permit process to address specific methods to mitigate potential landslide impacts. Catchment areas or retaining walls could be constructed near the base of the steeper slopes to temporarily retain surficial soil and debris that may slide down the slopes until that material is removed. Other slope stabilization measures or earth retention structures could be constructed as necessary.

Tsunamis

Depending on the height of any tsunami wave produced by a major rupture along the Cascadia Subduction Zone, a tsunami could potentially pose a temporary hazard at the site. The potential impacts of a tsunami in Bellingham Bay include the adverse effects of temporary inundation by the tsunami wave, and damage/injury caused by debris carried by the wave. To address the potential impact of a tsunami, mitigation measures would include public notification and warnings; additionally, raising site grades for other site redevelopment purposes would also serve to mitigate this potential impact.

Landfill Areas

Hazards associated with the closed Roeder Avenue Landfill (located in the central portion of Area 1) and the closed Cornwall Avenue Landfill (located in the western portion of Area 10) could be mitigated by developing a construction contingency plan specific for work in or near these portions of the site. The contingency plan should contain guidelines for handling and disposing of any contaminated materials that are encountered. Certain landfill hazards could also be mitigated by monitoring for methane when excavating adjacent to either closed landfill.

Mitigation for onsite structures would include site-specific monitoring and evaluation to determine if methane is present in the area. If present, the need for additional monitoring and installation of methane gas control measures would be evaluated. These measures could potentially include implementing a methane monitoring plan, installing subsurface gas migration barriers, or including foundation ventilation systems into the design of certain structures to mitigate against methane build-up beneath the onsite structures or within confined spaces. Also see the Environmental Health section of the Draft EIS for information on contamination and cleanup activities at the site.

Possible mitigation measures to address potential corrosion issues include selecting construction materials that are corrosion-resistant, or installing appropriate cathodic protection measures.

Coal Mine Areas

The potential for ground subsidence exists where underground void spaces exist at depth due to past coal mining activities. To address this potential impact, a coal mine hazards evaluation should be conducted at the design and permit stage in accordance with City requirements for any redevelopment within the potential coal mine hazard area near the southeast portion of Areas 5 and 7; site-specific ground improvement and foundation modifications should be implemented as appropriate.

Sea Level Rise

As previously discussed, for the purpose of this Draft EIS analysis, a reasonable estimate of potential sea level rise in Bellingham Bay by 2100 is considered to be up to approximately 2.4 feet over current levels. As part of site redevelopment, site grades will be raised several feet above existing grades to facilitate construction of a gravity flow stormwater system that discharges to Bellingham Bay, to minimize unnecessary excavation work within areas of completed site remediation, and to mitigate the potential impact of a long-term sea level rise in Bellingham Bay.

Construction Impacts

Construction Excavations

Impacts from temporary construction excavations could be mitigated through the use of properly designed and constructed excavation shoring systems.

Construction Dewatering

The impacts associated with temporary excavation dewatering depends on the required drawdown of the water table. Because site grades would be raised by several feet for other redevelopment purposes and future below-grade construction would likely be limited (currently estimated to be about 5 to 10 feet BGS or less for elevator pits), the associated excavations and degree of drawdown required would likely be relatively shallow. Site-specific analyses during the design and permit process would determine what structures may be influenced by excavation dewatering. Mitigation measures to control the potential impact of excavation dewatering include site-specific design and careful control of dewatering systems, minimizing the extent and duration of dewatering, reinfiltration of extracted groundwater, and monitoring for settlement.

Extracted groundwater may contain certain chemical contaminants and/or high turbidity, which might necessitate special handling, treatment, and/or disposal methods. Mitigation measures could include monitoring to assess the quality of dewatering discharges and treatment, if needed, to comply with applicable state and local requirements. Also see the Environmental Health section of the Draft EIS for information on contamination and cleanup activities at the site.

Placement of Structural Fill

Ground subsidence impacts could be mitigated by designing the fill to control adjacent settlements. In addition, adjacent structures/surfaces could be monitored during construction to verify that no adverse settlement occurs. Potential impacts to existing onsite structures could be mitigated by limiting the amount of fill placed within 50 feet of these structures, or monitoring the structures during construction if it is necessary to place fill within 50 feet of these structures.

It is anticipated that some amount of surficial onsite soil that is excavated as part of site redevelopment would be suitable for reuse as onsite fill, provided that the excavated material is properly handled and moisture-conditioned prior to placement and compaction.

The weight of bridge approach fills could result in settlement of the underlying deposits, which could result in settlement and lateral loading of adjacent facilities and increased downdrag loading on nearby deep foundations. These potential impacts would be mitigated by site-specific analysis during the design and permit process for the bridge approach fills that would consider the potential settlements, lateral movements, and stability issues associated with fill placement over compressible materials, as well as their potential effect on nearby structures and utilities. Mitigation measures could include use of mechanically stabilized earth walls to retain and limit the width of the approach fills, use of lightweight fill materials to reduce the amount of settlement caused by fill placement, use of geosynthetic reinforcement to help stabilize the approach fills, relocating existing utilities below or near the approach fills if they could be damaged by fill-induced settlements and lateral loads, and incorporating ground improvement measures to protect settlement-sensitive structures.

Preloading

The potential impact of preload and surcharge fills would be mitigated by site-specific analysis and design of the preload fill to control adjacent settlements. The extent of potential ground settlements and mitigation needed would be dependent on the depth of poor soil, the height of the preload, the proximity of existing structures and utilities, and the sensitivity of the existing structures and utilities to settlement. Mitigation measures could include constructing temporary mechanically stabilized earth walls at the edge of the preload fill, as needed, to limit the lateral extent and influence of the fill, conducting pre- and post-construction surveys of nearby structures, and monitoring of ground movements to verify that no adverse settlement occurs during the preload period.

Driven Piles

To limit the potential for adverse vibration impacts of pile-driving on nearby structures, vibration monitoring could be conducted during installation of test piles and selected production piles. The construction-related impacts from pile-driving may extend up to about 50 to 100 feet offsite for new onsite structures located near the perimeter of the New Whatcom site. A site-specific vibration analysis could be conducted to more precisely determine the extent of potential vibration impacts due to pile-driving. In addition, pile and pile hammer types should be matched to the specific subsurface conditions to achieve an optimal pile-driving operation, and vibratory hammers could be used instead of impact hammers, when appropriate. Pre- and post-construction inspections, ground elevation surveys, and photographic surveys of structures within about 100 feet of the pile-driving operation is recommended to help document site-specific conditions and the effectiveness of mitigation measures. If appropriate, auger-cast piles could be used to limit the vibration and ground settlement impacts associated with driven piles.

Drilled Shafts

Casings could be installed to control caving soils during drilled shaft installation for deep foundation support of bridges and certain other structures. To minimize the potential for vibration impacts from drilled shaft installation, vibration monitoring and ground elevation surveys could be conducted in conjunction with pre- and post-construction inspections and photographic surveys of settlement-sensitive structures located within about 50 feet of drilled shaft construction activities.

Spoils generated during drilled shaft installation should be disposed in accordance with applicable local, state, and federal requirements.

Significant Unavoidable Adverse Impacts

No significant unavoidable adverse impacts have been determined for the earth element of the New Whatcom EIS Alternatives.

REFERENCES

BEK Purnell Engineering. 1998. *Geotechnical Engineering Investigation Report, Proposed Railroad Avenue Parking Garage, Bellingham, Washington*. Prepared for City of Bellingham Parking Services. September 11.

Easterbrook, D.J. 1976.. *Geologic Map of Western Whatcom County, Washington*. U.S. Geological Survey Miscellaneous Investigation Series Map I-854-B.

Ecology and CTED. 2006. *Impacts of Climate Change on Washington's Economy: A Preliminary Assessment of Risks and Opportunities*. Washington State Department of Ecology and Washington State Department of Community, Trade, and Economic Development. November.

GeoEngineers. 2007. *Geotechnical Engineering Services, City of Bellingham Railroad Relocation Feasibility Analysis Project, Bellingham, Washington.* Prepared for HDR Engineering, Inc. July 17.

GeoEngineers. 2006. Draft: *Remedial Investigation/Feasibility Study Report, R.G. Haley International Corporation Site, Bellingham, Washington*. Prepared for Douglas Management Company. March 13.

IPCC. 2001. *Climate Change 2001. Working Group 1: The Scientific Basis*. Intergovernmental Panel on Climate Change. World Meteorological Organization. Geneva, Switzerland.

Kramer, S.L. 1996. *Geotechnical Earthquake Engineering*. Prentice Hall, Inc. Upper Saddle River, New Jersey. 653 pp.

Landau Associates. 2003. Ecology Review Draft: *Remedial Investigation/Feasibility Study, Cornwall Avenue Landfill, Bellingham, Washington*. Prepared for the Port of Bellingham. October 9. (Currently being updated.)

Lapen, T.J. 2000. *Geologic Map of the Bellingham 1:100,000 Quadrangle, Washington*. Washington State Department of Natural Resources, Division of Geology and Earth Resources. Open File Report 2000-5. December.

Palmer, S.P., S.L. Magsino, E.L. Bilderback, J.L. Poelstra, D.S. Folger, and R.A. Niggemann. 2004. *Liquefaction Susceptibility and Site Class Maps of Washington State, By County*. Available at http://www.dnr.wa.gov/geology/pubs/ofr04-20/. Washington State Department of

Natural Resources, Division of Geology and Earth Resources. Open File Report 2004-20. September.

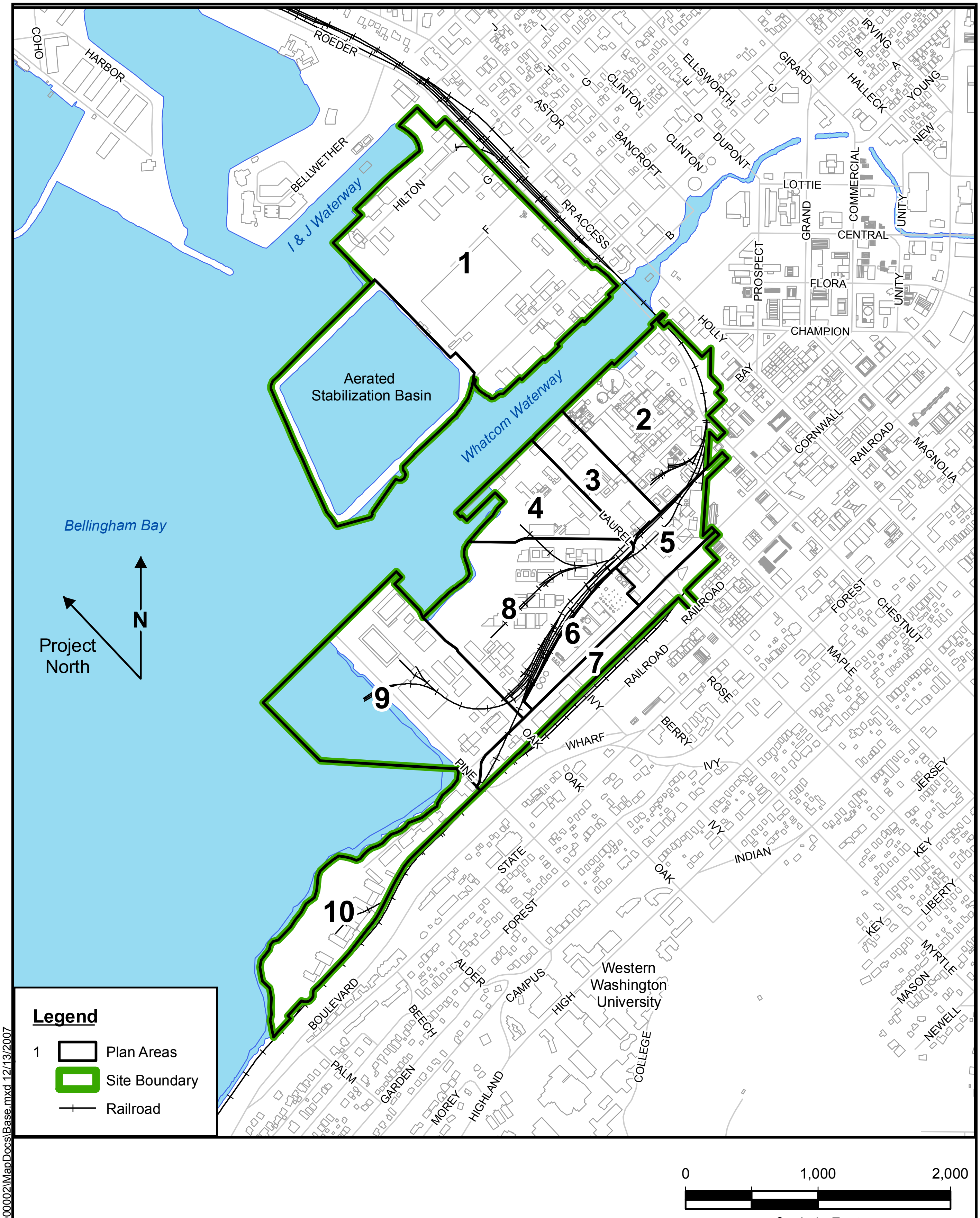
Retec. 2006. Draft Supplemental Environmental Impact Statement: *Bellingham Bay Comprehensive Strategy, Whatcom Waterway Cleanup Site*. Prepared for the Washington State Department of Ecology. October 10.

Tetra Tech. 1984. Final Report: *Bellingham Abandoned Mine Land Survey*. Prepared for the U.S. Department of the Interior, Office of Surface Mining. December.

ThermoRetec. 2001. Draft: *Remedial Investigation and Feasibility Study, Roeder Avenue Landfill, Bellingham, Washington*. Prepared for the Port of Bellingham. October 1.

Walsh,T.J., V.V. Titov, A.J. Venturato, H.O. Mofjeld, and F.I. Gonzalez . 2004. *Tsunami Hazard Map of the Bellingham Area, Washington: Modeled Tsunami Inundation from a Cascadia Subduction Zone Earthquake*. Available at http://www.dnr.wa.gov/geology/pdf/ofr04-15.pdf. Washington State Department of Natural Resources, Division of Geology and Earth Resources, and National Oceanic and Atmospheric Administration. Open File Report 2004-15. June.

ATTACHMENTS

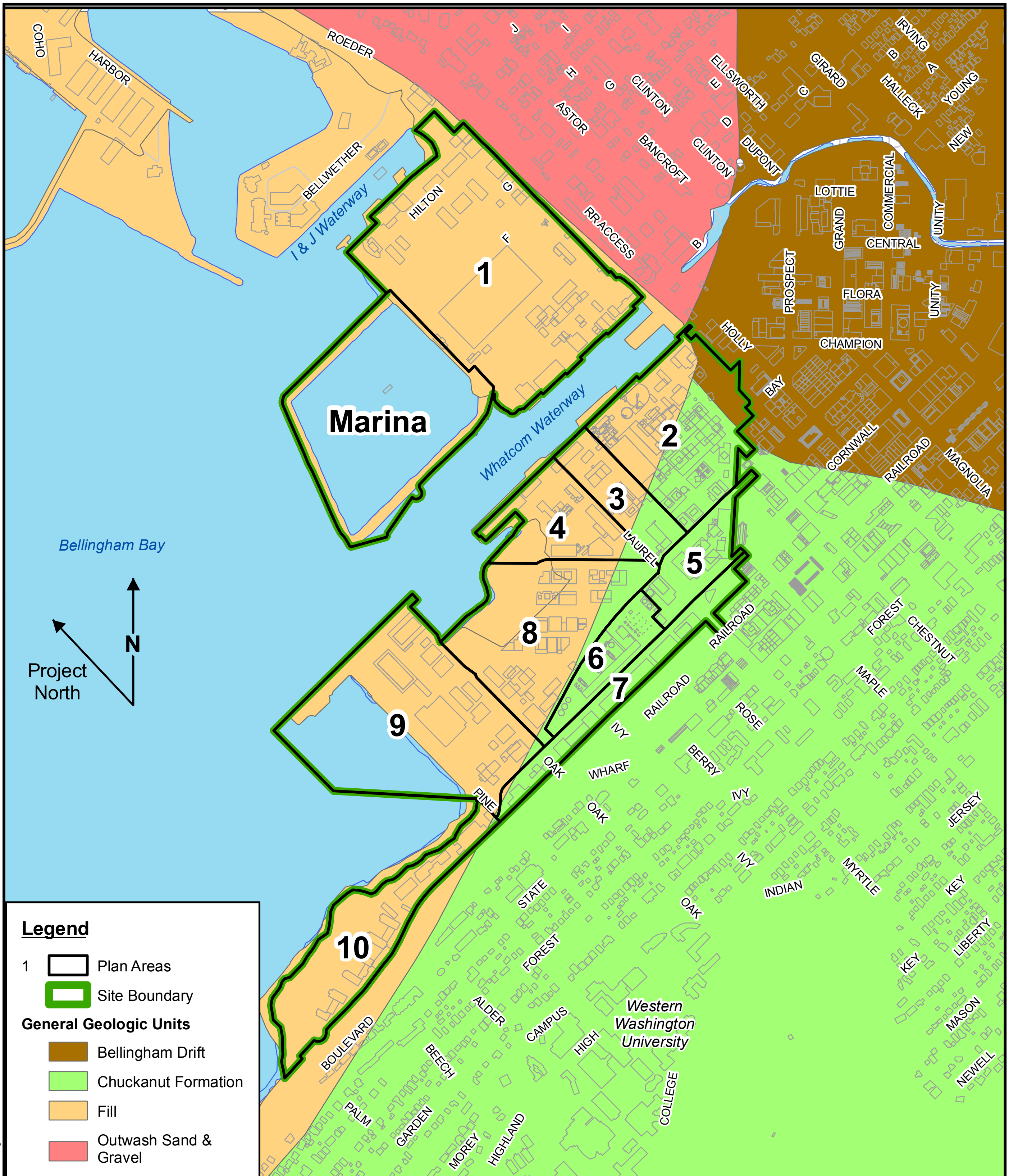


Data Source: CollinsWoerman (2007)

Y:\Projects\900002\MapDocs\Base.mxd 12/13/2007

LANDAU ASSOCIATES

New Whatcom Redevelopment Bellingham, Washington	**Site Map and Redevelopment Areas**	Figure 1

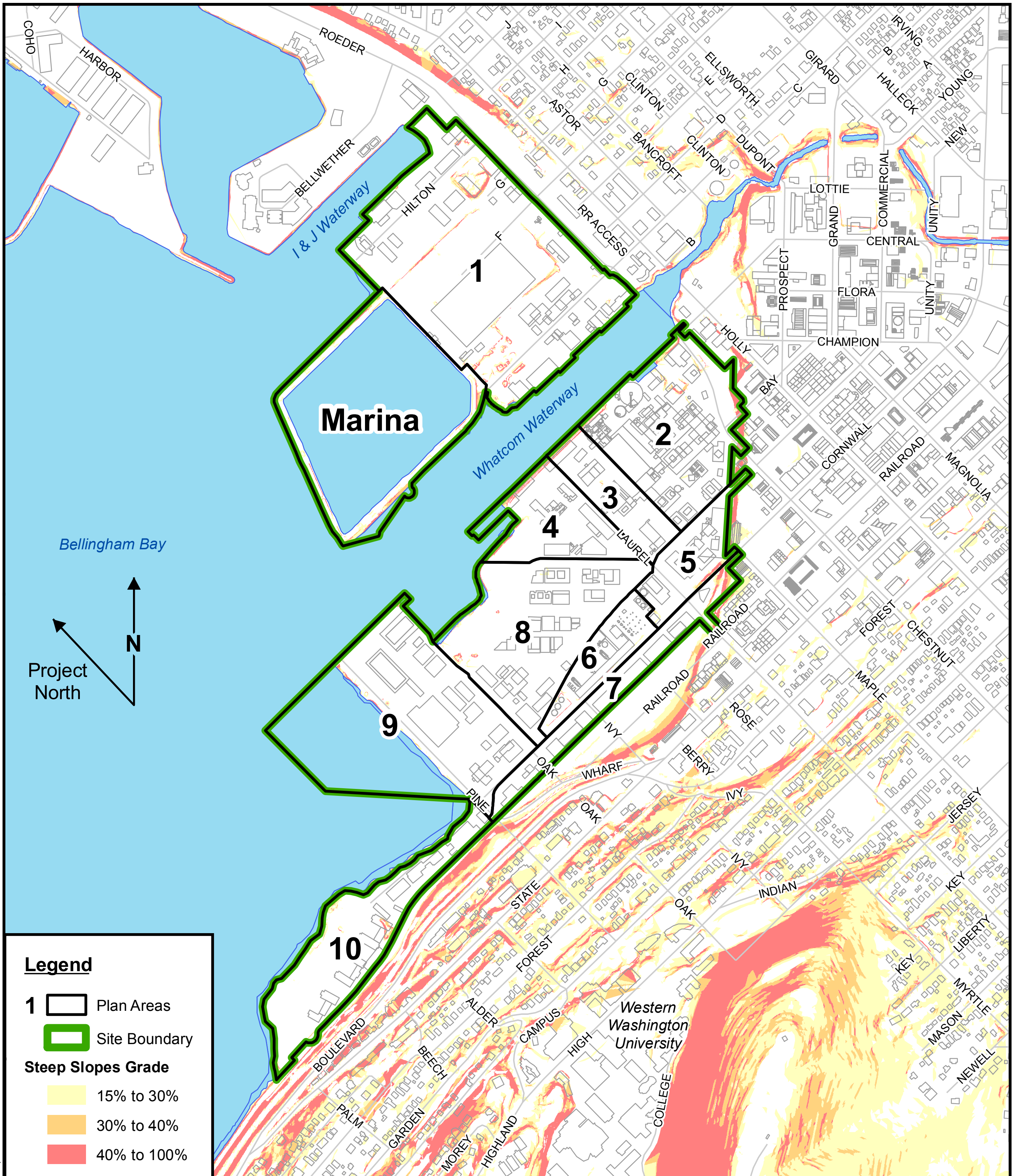


Y:\Projects\900002\MapDocs\Geologic.mxd 12/13/2007

Data Source: City of Bellingham (2007)

LANDAU ASSOCIATES

New Whatcom Redevelopment Bellingham, Washington	**General Surficial Geology**	Figure 2



0 1,000 2,000

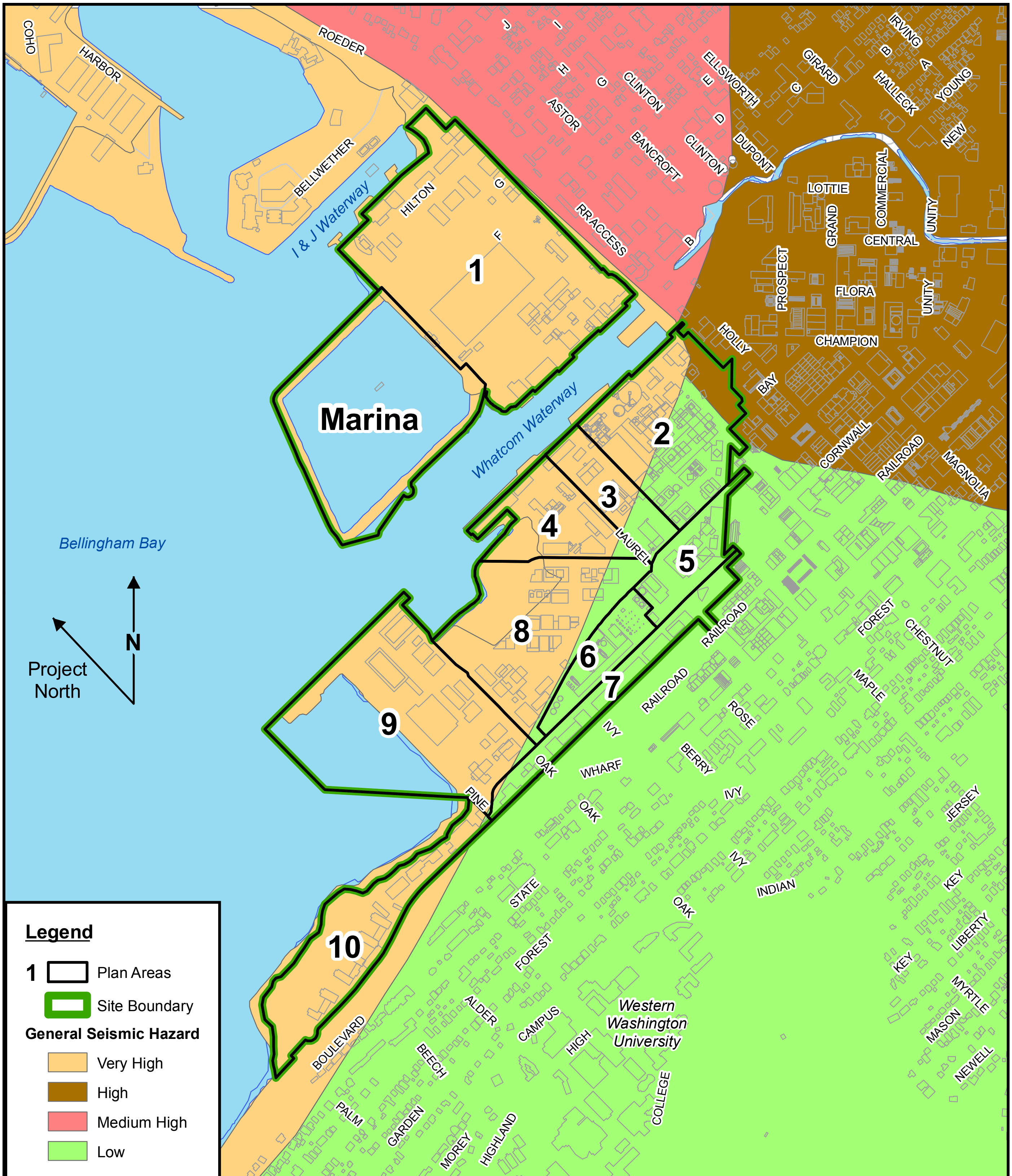
Scale in Feet

Data Source: City of Bellingham (2007)

Y:\Projects\900002\MapDocs\Slopes.mxd 11/9/2007

Landau Associates

New Whatcom Redevelopment Bellingham, Washington	**Steep Slopes**	Figure 3



0 1,000 2,000

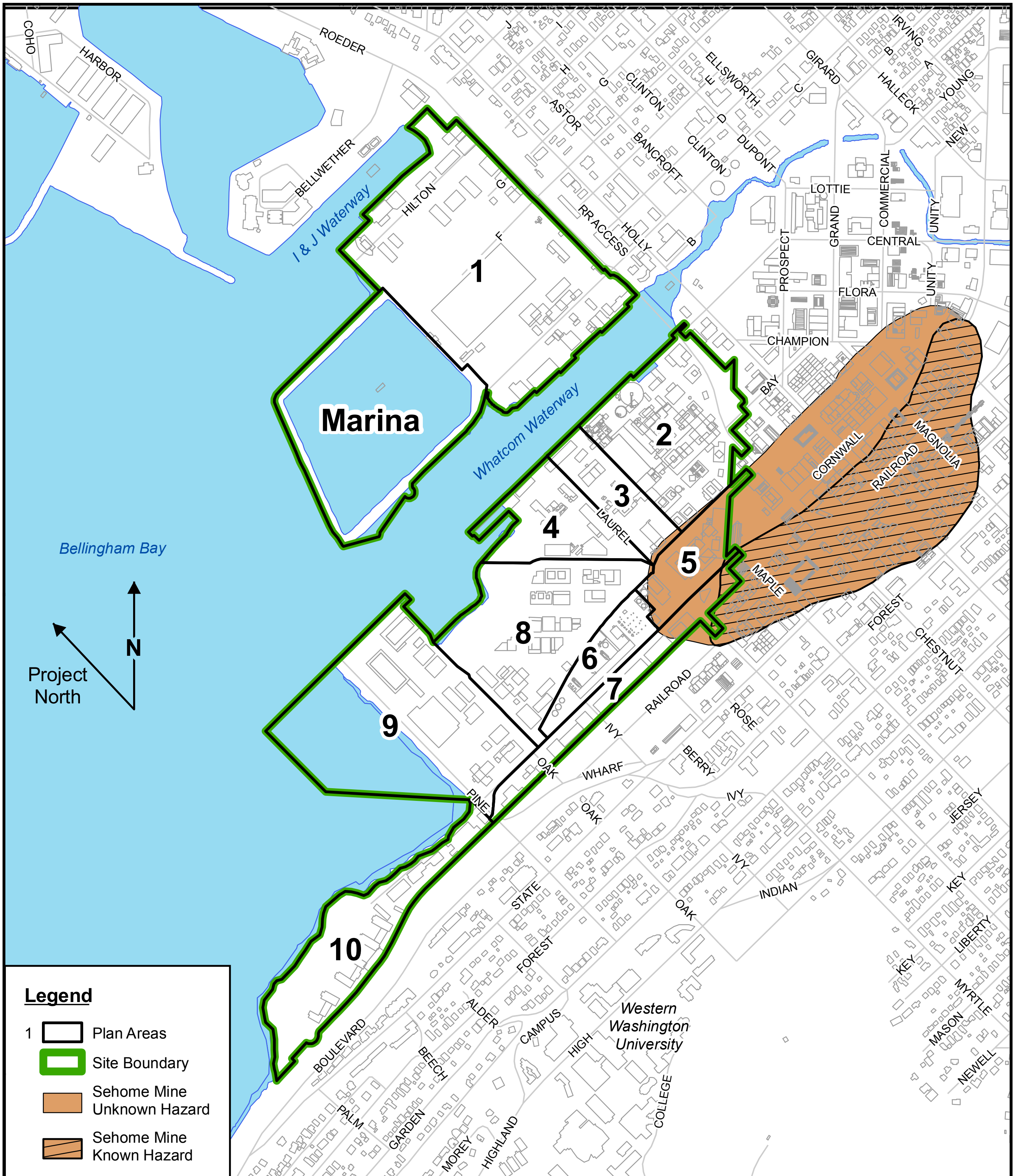
Scale in Feet

Data Source: City of Bellingham (2007)

Y:\Projects\900002\MapDocs\SeizmicHaz.mxd 11/9/2007

LANDAU ASSOCIATES

New Whatcom Redevelopment Bellingham, Washington	**Seismic Hazards**	Figure 4



0 1,000 2,000

Scale in Feet

Data Source: City of Bellingham (2007)

Y:\Projects\900002\MapDocs\CoalMine.mxd 12/13/2007

LANDAU ASSOCIATES

New Whatcom Redevelopment Bellingham, Washington	**Coal Mine Hazard**	Figure 5

TABLE 1
SUMMARY OF IMPACTS AND MITIGATION – EARTH ELEMENTS
NEW WHATCOM REDEVELOPMENT PROJECT
BELLINGHAM, WASHINGTON

Type of Impact	Impact	Mitigation
Geologic Hazard-Related Impacts		
Settlement	Potential subsidence of structures built on poor, compressible soils	Choice of foundation type (deep foundation, mat foundation, spread footings), ground improvement, foundation preparation
Landsliding / Steep Slopes	Slope movement, sloughing	Site-specific analysis and design, use of slope stabilization measures, retaining structures, or catchment areas
Erosion	Onsite/offsite transport of sediment and degradation of surface water	Implement BMPs during construction
Ground Rupture	Settlement, ground movement, and structure displacement	Design to most recent seismic design standards
Ground Motion Amplification	Amplified earthquake ground motions	Design to most recent seismic design standards
Liquefaction	Settlement, soil movement, loss of soil strength	Implement ground improvement techniques, use deep foundation systems
Lateral Spreading	Soil and structure displacement	Stabilize free face zone, implement ground improvement techniques, design structure to withstand lateral loads induced by liquefied soil
Seismically-Induced Landslides	Slope movement, sloughing	Site-specific analysis and design, use of slope stabilization measures, retaining structures, or catchment areas
Tsunami	Temporary Inundation	Raise site grades, public notification and warning
Sea Level Rise	Inundation and coastal erosion	Raise site grades
Landfill Areas	Methane gas generation and migration	Gas barrier and/or gas extraction system, and gas monitoring
Coal Mine Areas	Ground subsidence	Site-specific analysis and design, implement ground improvement or foundation modifications

Type of Impact	Impact	Mitigation
Construction Related Impacts		
Erosion	Onsite/offsite transport of sediment and degradation of surface water	Implement BMPs
Excavations	Settlement and loss of support for nearby structures and utilities	Use adequate shoring systems
Excavation Dewatering	Ground settlement, need for special handling/disposal of contaminated and/or turbid water	Controlled dewatering, monitor adjacent structures for settlement, treat/discharge effluent in accordance with applicable regulations
Placement of Fill	Ground settlement and vibration	Monitor for settlement and vibrations, use of MSE walls, use of lightweight fill
Preloading	Erosion potential, ground settlement	Implement BMPs and monitor for settlement, use of MSE walls to support preload fill
Construction/Excavation near Steep Slopes or Slide-Prone Areas	Decreased stability of slopes	Site-specific analysis and design accounting for slide potential, use of retaining structures
Driven Piles	Noise, vibration, soil densification, potential ground settlement	Size the piles, hammer, and type to match the subsurface conditions. Monitor adjacent structures for settlement and vibrations/noise
Drilled Shafts	Noise, vibration, ground settlement, large volume of spoils	Monitor adjacent structures for settlement, handle/dispose of spoils in accordance with applicable regulations