MEMORANDUM

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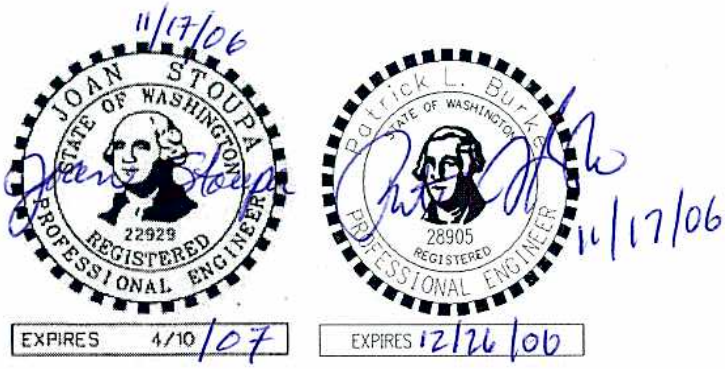
Brightwater Treatment Plant



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DATE:	October 9, 2006
SUBJECT:	Treatment Plant Approach to Seismic Design

Introduction

Building codes establish engineering and design standards to protect public safety. Because the Puget Sound region is a seismically active area, our building codes contain requirements to ensure structures are engineered to withstand earthquakes.

King County's Brightwater Treatment Plant, including Snohomish County Public Utility District's (PUD) substation, will be built to seismic standards that exceed the current minimum standards for wastewater facilities in the Pacific Northwest. Brightwater is a modern facility, designed to exceed the latest standards for seismic design. The design provides for the highest level of protection in the King County system. Brightwater design meets or exceeds applicable building code standards by 25 percent based on site-specific seismic shaking hazard analysis.

Brightwater is being designed to survive minor and moderate level earthquakes without structural damage. The facilities will not collapse in major level earthquake.

Key components of Brightwater design and operation will protect public health and safety in the event of an earthquake include:

- Significant structural reinforcement to water holding tanks, beyond what is required by seismic design codes. This means more steel reinforcement to withstand damage.
- Isolating individual water holding tanks with shut-off valve to prevent major leakage
- Designing nonstructural features such as pipes to withstand shaking and prevent major damage
- Using flexible couplings on piping systems will to reduce potential for pipe leaks
- Preventing the mixing of alkaline and acidic chemicals by separating chemical storage buildings by 1,200 feet, equipping chemical storage facilities with secondary containment systems and designing site grading and separate storm water control systems to capture flows to prevent mixing and off-site discharge.
- Providing access to repair damaged tanks
- Providing on site and offsite emergency and auxiliary power
- Locating stormwater ponds and foreground landforms down slope from the treatment plant to capture any leaked materials, preventing offsite discharge of spilled materials in the unlikely event of a major earthquake event on or near the Route 9 site
- Developing an emergency response plan and training staff to respond to earthquakes on or near the Route 9 site.

Approach to Seismic Design

The design of the Brightwater Treatment Plant, including above ground buildings, liquid and solids holding tanks, the Snohomish PUD substation, and nonstructural elements such as mechanical and electrical systems, will be designed to comply with the recommendations of the 2003 International Building Code (IBC 2003), with Washington State amendments, or more stringent structural design standards, depending on the type of structure or system. Both structural and nonstructural components of the plant will be designed to resist the forces associated with predicted levels of ground shaking in accordance with accepted seismic design standards, and in addition, site-specific spill containment design will be incorporated that further reduces the risk of offsite discharges should ground shaking or ground fault rupture occur.

IBC 2003, with Washington State amendments, is the governing code for design of all structures. It has been adopted by the State of Washington and Snohomish County. While IBC 2003 forms the basis of design, wastewater treatment plants include other structures that are not specifically addressed by the IBC. For example, the American Concrete Institute

(ACI) standards (ACI, 2001) and documents published by the American Water Works Association (AWWA, 1996 and 2005) are used to design concrete liquid and solids holding tanks. The design of these tanks is typically governed by crack control requirements to resist leakage. Sufficient reinforcing steel is placed in the walls and slabs to limit crack width such that the structure is considered water tight. Meeting these crack control requirements provides strength greater than that required to resist earthquake forces.

In addition to the requirements of the IBC 2003, King County conducted a site-specific probabilistic seismic hazards analysis (PSHA) (discussed later in this memorandum) that considered the most up-to-date information relative to the understanding of seismicity within the greater Puget Sound and Brightwater site area. This PSHA analysis resulted in King County adopting ground shaking design criteria for the Brightwater project that are 25 percent greater than the requirements of the IBC code.

The following sections describe how these seismic codes, the PSHA, and site-specific spill containment designs will be incorporated in the Brightwater treatment plant design.

International Building Code 2003

Seismic Provisions of IBC 2003

The seismic provisions in the IBC 2003 are based on the 2000 edition of the National Earthquake Hazards Reduction Program (NEHRP) *Recommended Provisions for Seismic Regulations for New Buildings and Other Structures* (Federal Emergency Management Agency, 2001). NEHRP provides up-to-date criteria for design and construction of buildings that may be subject to earthquake ground motions. These criteria are applicable anywhere in the United States.

The purpose of the seismic provisions in the IBC 2003 is to provide minimum building design standards for structures in order to maintain public safety of building occupants during a very strong earthquake. Structures designed in conformance with the IBC 2003 will, in general, be able to resist the following:

- Minor level of earthquake ground motion (shaking) without damage
- Moderate level of earthquake ground motion without structural damage, but possibly experience some non-structural damage
- Major level of earthquake ground motion of intensity equal to the strongest earthquake, either experienced or predicted, for the building site, without collapse, although buildings may sustain structural and nonstructural damage

An important concept associated with seismic design codes is that of “life safety.” The building codes provide minimum design criteria for structures that take into account the need to protect the health, safety, and welfare of the general public by minimizing the earthquake-related risk to life, and for essential facilities, by minimizing damage such that these facilities have an improved capability to function during and after a design level earthquake. “Life safety” does not, however, mean that the building will not sustain some damage. Rather, it indicates that any damage that occurs is not expected to result in loss of life. The IBC 2003 and other seismic design reference documents do not take into account economic losses in the event of an earthquake; their focus is purely life safety and protection of the public.

One way the IBC 2003 provides for life safety is to specify different structural design criteria based on a building's use, intended occupancy, and intended level of operation following an earthquake. The IBC 2003 has established three Seismic Use Groups with differing design criteria as described in the following section. It is important to note that Seismic Use Group I is intended to provide life safety. Structures assigned to Seismic Use Group II or III are designed to a higher seismic standard, thus they are expected to suffer less structural and non-structural damage during an earthquake.

Seismic Use Groups

In the IBC, buildings are assigned to Seismic Use Group I, II, or III as well as to Importance Factor Category I, II, III, or IV. The Seismic Use Group takes into account the intended occupancy and use of the structure and the intended level of operation of the building following an earthquake. The Importance Factor Category is based on the potential to pose risk to life safety if a structure should fail; it is used to determine what the seismic load should be. Structures that would pose greater risk are assigned to a higher category and, therefore, are designed to be more resistant to the design level earthquake.

In accordance with the IBC 2003, water and wastewater treatment facilities are assigned to Seismic Use Group II and structures containing highly toxic materials (as defined by IBC Section 307) are assigned to Seismic Use Group III. The Seismic Use Groups are as follows:

- **Seismic Use Group I:** A structure assigned to this group is one that is not assigned to either Group II or III. It is designed to provide life safety when subjected to the maximum expected level of shaking. However, it may not be operational following an earthquake.
- **Seismic Use Group II**: A structure assigned to this group would result in a public hazard if it were to collapse. Structures assigned to this use group would be expected to have less damage than those assigned to Group I but more damage than those assigned to Group III. The level of damage likely would require restrictions to use or operations until repairs are made.
- **Seismic Use Group III:** A structure assigned to this group is required for post-earthquake recovery or contains substantial quantities of hazardous materials. It is designed to prevent collapse, provide life safety, and remain operational following an earthquake that produces the maximum expected level of shaking.

Consistent with IBC 2003 requirements, the majority of Brightwater facilities are assigned to Seismic Use Group II and the chemical storage and odor control structures are assigned to Seismic Use Group III (Table 1). For structures that are a combination of water-holding tanks and buildings, the IBC assigns a Seismic Use Group based on the intended use of the structure.

Table 1. IBC 2003 Seismic Use Groups for Brightwater Facilities

Seismic Use Group II	Seismic Use Group III
Plant Operations and Maintenance Building	Headworks/Primary Odor Control
Main Substation	Aeration/MBR Odor Control
Community-Oriented Building	Chemical Storage Facilities
Headworks	Solids Odor Control
Grit Removal	Snohomish PUD substation
Headworks Truck Loadout Building	
Sedimentation Support Building	
Primary Sedimentation	
Primary Effluent Screens	
Aeration Basin	
MBR Basins	
Reclaimed Water	
Solids Building	
Digestion Building	
Energy and Cogeneration Building	

Site-Specific Probabilistic Seismic Hazard Analyses

The IBC 2003 requires structures in most parts of the United States, including the Puget Sound area, to be designed to resist the effects of earthquake-induced ground motion. The estimated level can be based on the U.S Geological Survey (USGS) national hazard maps or on a site-specific probabilistic seismic hazard analysis (PSHA). The IBC allows a PSHA to be used to provide the most up-to-date information about a site when there has been a significant change in the understanding of causes, locations, or frequencies of earthquakes in an area and existing USGS national hazard maps may no longer represent the most current seismic information.

King County conducted a site-specific PSHA to determine the level of shaking that could occur at the Route 9 site based on the current understanding of potential seismic source mechanisms that could affect the site. The site-specific PSHA was conducted to take into account recent findings that strands of the Southern Whidbey Island Fault (SWIF) were found near and underlying the northern portion of the Route 9 treatment plant site and the postulated Lineament X in the southern portion of the site. The PSHA developed earthquake ground motions that could occur at the site considering the potential occurrence of earthquakes on these newly discovered strands. Other sources of potential ground shaking in the Seattle region, such as the Seattle Fault, were also explicitly incorporated into the PSHA. The results of this site-specific PSHA were used to develop seismic criteria for the design of the proposed Brightwater Treatment Plant facilities.

The PSHA estimated that a peak level of ground shaking of 0.65 times the acceleration of gravity (g) could be expected to result from the maximum considered earthquake. This level of ground shaking most likely would be associated with a large magnitude earthquake occurring on the SWIF. This level of shaking is nearly 4 times the level of shaking felt by people in the area during the 2001 Nisqually earthquake and nearly 25 percent greater than the levels of shaking determined on the basis of current IBC 2003 national hazard maps.

King County adopted the more conservative seismic design criteria as determined from the PSHA, resulting in design criteria for the Brightwater structures that exceed the IBC 2003 codes for life safety. In February 2006, King County transmitted to Snohomish County PUD the structural design criteria for the site, including the PSHA site-specific seismic design criteria, for their review and adoption as the design criteria for the PUD-designed substation. Snohomish County PUD accepted the site-specific seismic design criteria and has proceeded with the design of the substation in accordance with this criteria.

Support for Nonstructural Elements

Support systems for architectural, mechanical, electrical, and other nonstructural systems and for components and elements attached to the buildings and liquid-holding structures will be designed to withstand sliding and overturning forces due to earthquake shaking in accordance with IBC Section 1621. This section of the code requires adequate lateral bracing of pipes, pumps, motor control centers, and other systems to minimize damage due to earthquake-induced ground shaking. Examples of nonstructural seismic bracing include adequate anchor bolts for equipment and lateral bracing for process piping. The addition of this bracing and structural support increases resistance to earthquake forces that may cause equipment to overturn or pipes to rupture and help ensure the facility can remain operational or sustain minimal damage from an earthquake.

Other Measures to Limit and Mitigate the Effects of a Major Earthquake

A number of measures are being taken beyond the requirements of IBC 2003 to reduce the effects on treatment plant facilities of strong ground shaking or fault offsets. One of the most important measures is to shut down the influent pump station (IPS) to stop pumping flow to the treatment plant if an earthquake were to occur. The IPS will be monitored and controlled from the treatment plant, and standard operating procedures will require immediate shutdown of the IPS should an earthquake be felt or observed on the Route 9 site. Shutdown of the IPS will allow time to inspect facilities for damage before restarting the plant, thereby limiting the potential for leakage from damaged facilities. Other measures are discussed in the following sections.

Designing Water-Tight Liquid Holding Tanks

The majority of the structures at the Brightwater Treatment Plant will be liquid-holding tanks. They will be designed in accordance with American Concrete Institute's *Code Requirements for Environmental Engineering Concrete Structures* (ACI, 2001) to be water tight by limiting the size of cracks allowed to develop in the structure under normal loading. For Brightwater, where all the liquid-holding tanks are concrete structures reinforced with steel, the reinforcing steel specified for crack control provides additional strength beyond that which would be required by code for seismic design.

In addition, most liquid-holding tanks will be either below grade or partially buried in very dense, low-permeability soils. Burying the tanks will tend to minimize the loss of tank contents should a tank be damaged by either strong ground shaking or fault offset.

Buried structures designed to meet crack control requirements for water tightness generally have performed well in earthquakes. There is evidence of such performance in the 1989 Loma Prieta and 1994 Northridge earthquakes. Only one case was identified where a tank joint at a wastewater treatment plant failed during the Northridge earthquake, releasing water into a gallery. Based on observations following these and other earthquakes, damage is typically limited to piping connections between tanks and to ancillary equipment.

Isolating Individual Tanks

To minimize impacts from earthquake damage to facilities, individual liquid-holding tanks would be isolated with shutoff valves and gates. These valves would allow the contents of individual piping systems and tanks to be isolated from the system if upstream or downstream damage occurs. Sufficient redundancy would also be available within the treatment process so that individual tanks and conveyance structures could be taken off line while still providing treatment where flows bypass the damaged unit.

Designing Flexible Piping Systems

Piping systems will be designed to be flexible where they connect to structures. Flexible piping systems allow relative movement between the liquid-holding tanks and the piping systems during strong ground shaking. This flexibility minimizes the potential for pipe leaks where pipes enter the basins.

Following American Society of Civil Engineers Guidance

Structural and nonstructural systems on the plant site will be detailed in accordance with the latest recommendations in the American Society of Civil Engineers guidance document for the seismic design of wastewater treatment plants (Heubach, 2002). This guidance document provides detailed checklists for structural and nonstructural systems. These checklists are based on observations of damage from past earthquakes, thereby introducing past performance experience into the design process.

Designing Chemical Storage Areas to Prevent Mixing of Chemicals

Several chemicals are used in the wastewater treatment and odor control processes. These chemicals would be kept on the Brightwater Treatment Plant site in large bulk chemical storage, handling, and distribution facilities located near the Disinfection Building and near the Headworks / Primary Odor Control Building. In addition, small quantities of chemicals would be stored in the Headworks / Primary Odor Control Building, the Aeration / MBR Odor Control Building, and the Solids Odor Control Building (see Figure 1).

Design of the chemical storage, handling, and distribution facilities for the Brightwater Treatment Plant will be in compliance with federal, state, and local codes and guidelines and industry standards, including the Occupational Safety and Health Administration (OSHA, 2000) and Federal Risk Management (EPA, 2000) plans, the International Fire Code (IFC) (International Code Council, 2003b), and the Chlorine Institute’s recommendations for prevention of mixing sodium hypochlorite with acids (Chlorine Institute, Inc., 2000).

As previously stated, chemicals would be stored in bulk quantities at two containment areas at the Brightwater Treatment plant. Alkaline chemicals (sodium hydroxide and sodium hypochlorite) would be stored just north of the Disinfection Building near the north end of the plant. Acidic chemicals (ferric chloride, polyaluminum chloride, and citric acid) would be stored just south of the Headworks/Primary Odor Control Building near the south end of the plant.

Chemicals will be stored in fiberglass tanks with each tank having a capacity up to 18,000 gallons each. Four alkaline tanks will be provided for a total of 72,000 gallons of bulk storage; similarly, four acid tanks will be provided with a total of 64,000 gallons. Each bulk storage area will be provided with secondary containment consisting of a concrete wall surrounding the tanks to provide containment of the chemicals should one of the tanks fail. Should the secondary containment fail, chemicals would flow to and be contained in different stormwater detention system as discussed below.

The IFC requires only 20 feet of separation between storage areas for alkaline and acidic chemicals; however, the two chemical storage facilities on the Brightwater Treatment Plant site would be approximately 1,200 feet apart. The 1,200 feet of separation between the alkaline and acidic chemical storage areas would prevent mixing of the two classes of chemicals in the highly unlikely event that both facilities and their respective secondary containment facilities were to fail in an earthquake. In addition, the grading downslope from the two chemical storage areas will be designed to direct any potential spills to separate stormwater detention ponds and each pond that could receive chemical spills will contain a shutoff valve to prevent discharge of the chemicals from the ponds. The stormwater detention system is described below.

Stormwater Detention System

As stated above, a stormwater detention and treatment system will be provided for the Brightwater Treatment Plant on the Route 9 site. The system will be located "down slope" from the liquid and solids processing and chemical storage facilities and provide a significant amount of emergency spill containment in the unlikely event of a major earthquake on or near the Route 9 site and the even more unlikely event of a major earthquake occurring immediately following a major rainfall event in the area.

The stormwater system will consist of five earthen ponds designed to capture stormwater runoff and provide treatment prior to discharge to Little Bear Creek. The stormwater system will be designed in accordance with state and local codes and guidelines. Finished grading of roadways and other areas within the plant site will direct stormwater to catch basins for conveyance to the detention ponds. Low points will be provided in the grading along the west road (see Fig 1) to direct flows directly into the detention ponds should the catch basins be plugged or their capacity otherwise exceeded. In addition, high points will be provided along the west road to ensure that acid and alkaline chemicals would be discharged to separate detention ponds to avoid mixing.

Detention ponds have been sized to hold stormwater generated up to the 50-year rainfall event on the site, per Snohomish County and Washington State Department of Ecology standards. The ponds are designed with approximately 5 feet of storage with an additional foot between the normal discharge elevation and the emergency spillway crest elevation. Approximate volumes in the detention ponds are shown in Table 1.

Table 1, Stormwater Detention Volumes

Detention Pond	**Detention Volume to Normal Discharge (MG)**	**Additional Volume to Emergency Overflow (MG)**	**Total Volume (MG)**
A	1.04	0.29	1.33
B	1.66	0.46	2.12
C	1.08	0.33	1.41
D	0.82	0.26	1.08
E	1.30	0.39	1.69
Total (MG)	5.90	1.73	7.63
MG = million gallons			

Detention ponds that would receive the bulk of spillage from process tankage or chemical containment areas (Ponds A, B, and D) will contain a shut off valve or gate to allow isolation of contents in the ponds and prevent discharge to Little Bear Creek.

Providing Easy Access for Repair of Damaged Tanks

Sumps and access hatches are being incorporated into the design of tanks and pipe galleries for the Brightwater Treatment Plant to allow easy access for dewatering of tanks if they should be damaged by an earthquake or need to be taken out of service. A strategy for dewatering these below ground facilities will be documented in the operations manual for Brightwater. This strategy will include specifying the types of dewatering pumps, making the pumps available for immediate use, and establishing the procedure for disposal of tank contents.

Providing Emergency and Auxiliary Power

Emergency and auxiliary power sources will be made available in the event that both power feeds to the plant site were severed. There will be access to approximately 1 megawatt of power produced by portable generators from other King County facilities. Both the portable generators and the auxiliary power will provide enough power for primary treatment and disinfection prior to discharge to Puget Sound if both power feeds were out of service.

Initially, the emergency power would consist of one onsite essential services generator with 48 hours of diesel fuel supply capable of supplying critical life safety services and, if treatment facilities and the effluent tunnel remained operational, the ability to provide power for limited preliminary and primary treatment before discharge to Puget Sound. Provisions will be made in the design to add auxiliary power in the future. In addition, King County can provide portable generators from other locations.

Plant Underdrain System

Areas beneath the liquids and solids processing facilities will be provided with a passive underdrain system that are designed to assure groundwater will not apply uplift or lateral pressure on the facilities. Underdrains will consist of a series of perforated six inch diameter pipes, typically spaced 30 feet apart (with many at 20 and 25 foot spacing, and some as close as 10). Manholes will be installed alongside treatment plant roads to collect the underdrain water from beneath the tankage and convey it through non-perforated pipe to the western boundary of the site for discharge. The system is considered passive in that it will operate by gravity, with no pumps required.

The underdrain system manholes will allow access for sampling and testing to determine if leakage is occurring following an earthquake. In the highly unlikely scenario of a major event that would cause damage to process tankage, the manholes provide access and a location for manually plugging the underdrains to prevent discharge of spilled contents underlying soil which may eventually connect to Little Bear Creek.