Impact of Groundwater Contamination in East Multnomah County on the Interlachen Community

by

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Acknowledgments

The members of the review panel want to thank the citizen group: Friends of Fairview and Blue Lake for having the confidence in our methods and techniques to work together on solving or resolving a serious contamination problem for the community. Chris Noble, the project manager for the citizen group, was of great help in guiding us on our review. Other local residents also played an important part in interacting with us. These include, Jane Graybill, Jean Ridings and others. Lyn Mattei also was helpful in negotiating the contract with Judy Ngai, PSU Business Office. The success of projects like this also rely on interaction with the community, which involves each resident of the area.

A special thanks goes to Mr. Robert Annear in the Civil Engineering Department for keeping the panel organized, obtaining the library of information, and maintaining the reference database.

Many organizations supplied documents to the panel for review free-of-charge as a public service. These include The Boeing Corporation, Cascade Corporation, Department of Environmental Quality, Portland Water Bureau, and Woodward-Clyde Consultants, Inc.

The library at Rockwood gladly parted with many of the documents so that they could be copied at Portland State University. We appreciate their trust in letting us use these documents as we wished.

Elizabeth Warner, Boeing Corporation, was helpful in supplying information to the panel. Bruce Gilles, DEQ, project manager of this contamination site, provided much helpful guidance to the principal investigator through both phone calls and meetings.

1. Introduction

The Friends of Blue and Fairview Lake through the Environmental Protection Agency (EPA) Technical Assistance Grant (TAG) program contracted with Portland State University faculty and staff to provide an independent review of the groundwater contamination problem at the Boeing-Cascade site in East Multnomah County. An independent consultant, Karann Brandt, of PRC Environmental Management, Inc., was also assisting the panel with the review.

The region of groundwater contamination is a 2.5 square mile region bounded by NE Halsey Blvd. to the Columbia River and NE 178th to NE 223rd (see Figure 1). The groundwater contamination is primarily of volatile organic compounds (like trichloroethylene or TCE). The approximate plume extent is shown in Figure 2 in one of the principal aquifers, the Troutdale Sandstone Aquifer (TSA).

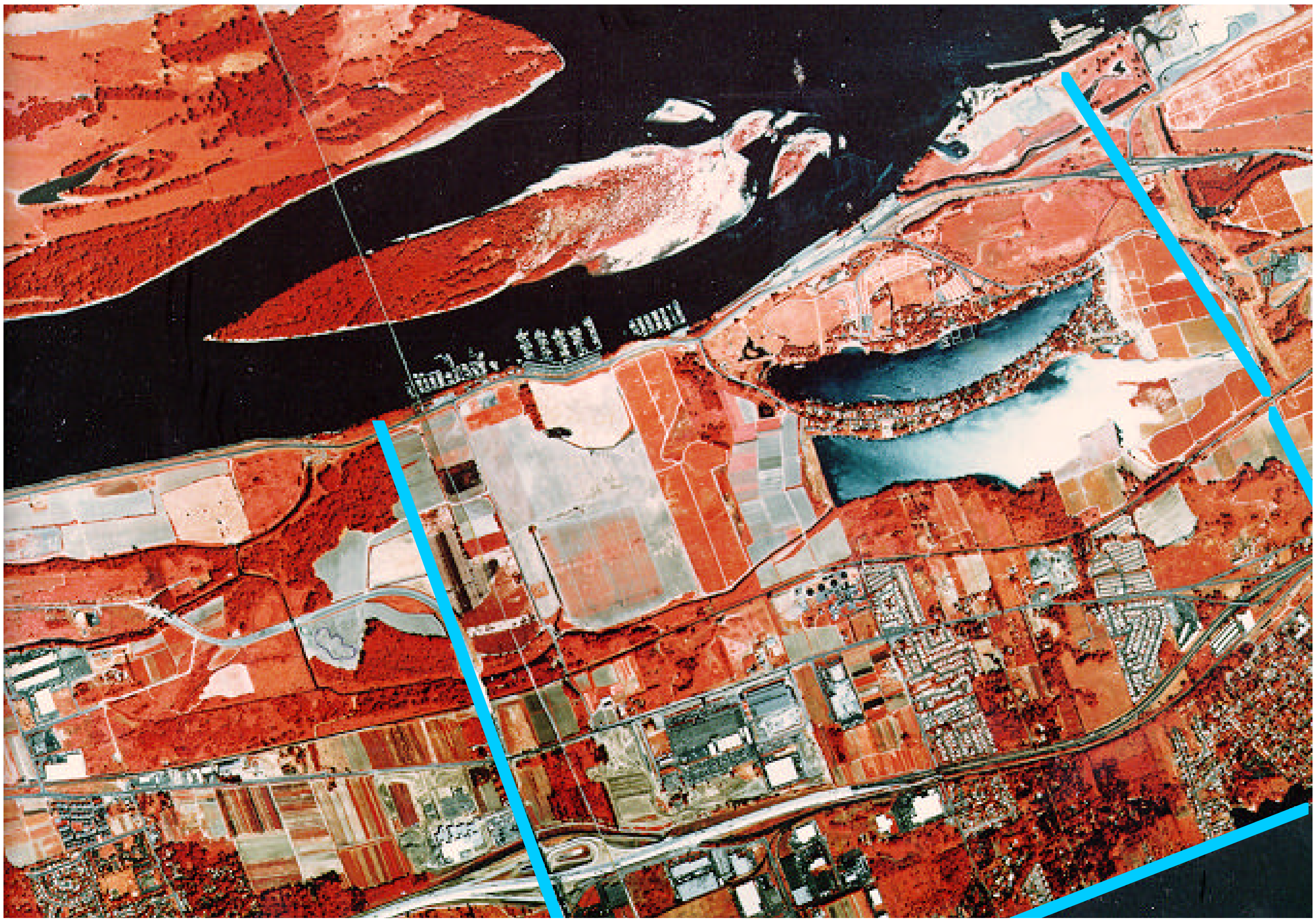


Figure 1: Study area showing Fairview Lake and Blue Lake

Since the Interlachen community in the area of Blue and Fairview Lakes uses groundwater as a community water supply and the lakes as a recreation resource, there are concerns that the groundwater contamination could seriously affect the community by contaminating their water supply and surface water bodies (Fairview Lake, Blue Lake, Columbia Slough) in their vicinity. Much work has been accomplished already by responsible parties (Boeing and Cascade Corporations and their consultants), the State of Oregon Department of Environmental Quality, and the Portland Water Bureau and its

consultants. The community was able to secure the EPA TAG to provide an independent review of the contamination problem facing their community and to assist the community in understanding the nature of the contamination problem. Issues of concern identified from this review will be recommended for incorporation in the Department of Environmental Quality's (DEQ) final Record of Decision concerning site remediation efforts. This review will help assure remediation strategies that protect groundwater and surface water for the Interlachen community will be pursued by the responsible parties.

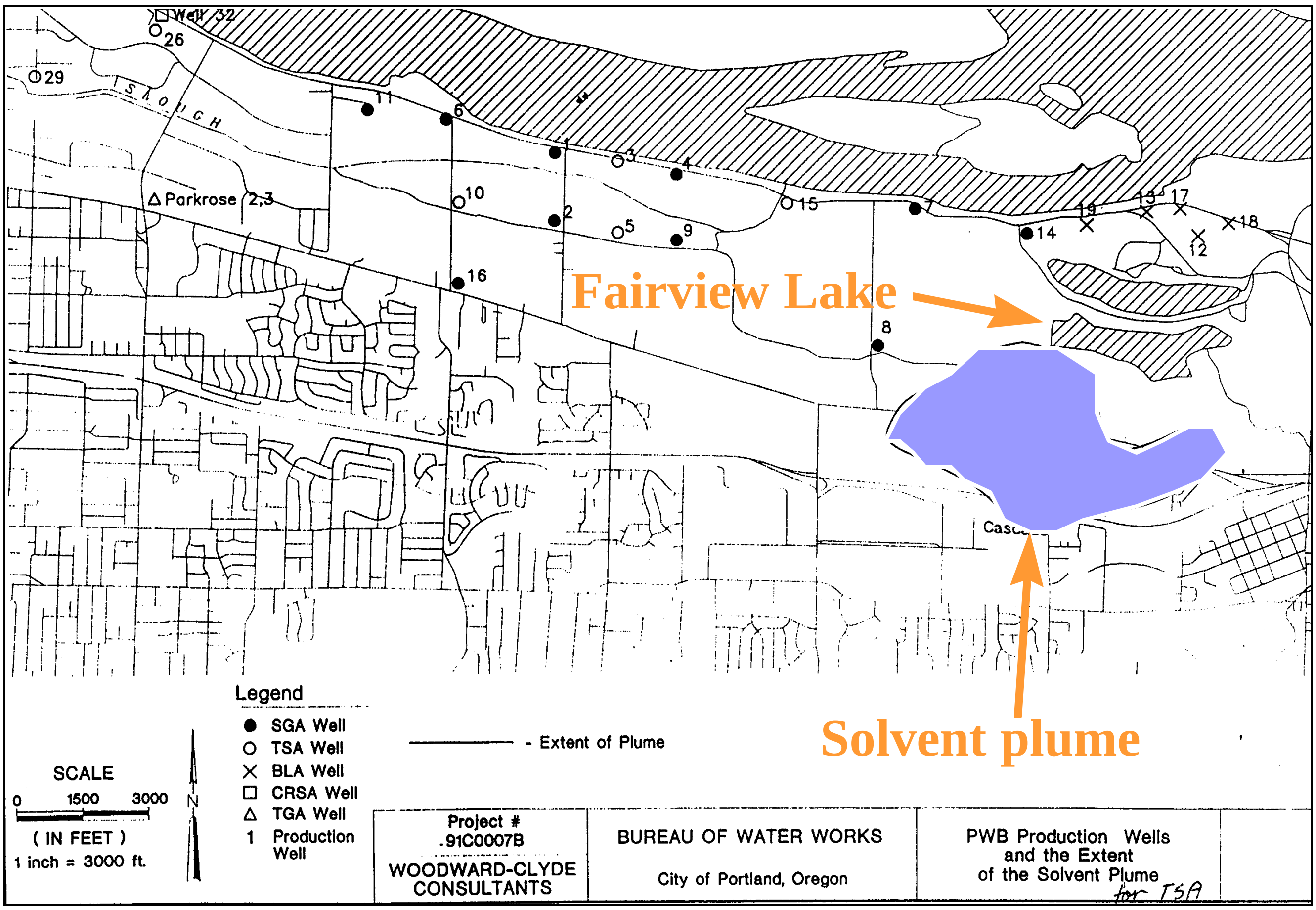


Figure 2: Schematic of TCE plume in the Troutdale Sandstone Aquifer (Woodward-Clyde).

1.1 Interlachen Community Risk

Risks to the community can be itemized as follows:

- drinking water from contaminated groundwater since their potable water supply is in the contamination area
- inhalation risk from contaminated groundwater and from air stripping towers in the community
- recreational risks associated with ingestion of contaminated surface water in the Columbia Slough or Fairview Lake or consumption of fish and other aquatic life from these surface waters

These issues will be explored by the review panel and recommendations made to minimize risk from the groundwater contamination in their community.

1.2 Philosophy of the Panel Review

The primary focus of the panel was to

- educate the community about the extent and nature of the contamination
- review and evaluate work done to-date by consultants and agencies for serious flaws that could jeopardize the community's water supply and surface water system
- offer recommendations to aide the community in protecting their water supply and surface water system

Some of the questions examined included:

- Are there enough data to draw conclusions about the nature of contamination, extent, and remediation efforts?
- Has the SGA already been contaminated? How can contamination be prevented from reaching the SGA?
- Is the mathematical model of the groundwater hydraulics and contaminant transport a good indicator of future management scenarios? Is the model calibration reasonable? How could the model be better calibrated so that conclusions of the model may be more accurate?
- Is the geologic characterization in the model by the responsible parties accurate? How does the CU1 and CU2 influence the management of this plume?
- Are the existing and proposed remediation efforts a reasonable protection to the Blue and Fairview Lake community?
- Have the risk assessments performed to-date been appropriate? Have important issues been overlooked?

The products from this panel review include this report, non-technical oriented facts and issues papers for the community, and a response to the Oregon DEQ's Record-of-Decision which is scheduled for release on September 1, 1996.

At Portland State University this review is being conducted by faculty from Civil Engineering, Geology, and Environmental Sciences and Resources. These faculty have expertise in the following areas: groundwater contamination transport and modeling, groundwater geology, geologic stratigraphy, surface water contamination transport, and environmental toxicology. The independent consultant has degrees in Biology and Civil Engineering and has experience in contamination assessment, risk management, and remedial action design.

2. Site History

The study area includes several industrial facilities which have been involved, to varying degrees, in the investigation and cleanup activities associated with the groundwater contamination. Investigations have primarily centered around Boeing of Portland, located at 19000 NE Sandy Boulevard, and Cascade Corporation, located at 2201 NE 201st Avenue, both in Troutdale, Oregon. Boeing began contamination assessment activities in 1986, after closure activities associated with a rinsate (see Glossary) impoundment revealed excessive levels of contaminants (such as chlorinated solvents and petroleum products) in groundwater monitoring wells. Cascade initiated investigations on their property in 1988 after the decommissioning of two waste coolant underground storage tanks (USTs) revealed contamination in soil and groundwater of chlorinated solvents. Since 1993, these two companies, under a Consent Order from DEQ, have been working together to address the groundwater contamination. The following is a discussion of the history of each facility.

2.1 Boeing of Portland

In 1963, the first manufacturing building, 85-001, was constructed by Electronic Specialty Company, a major subcontractor to The Boeing Company at the time. Aerial photographs taken prior to 1963 indicate that the area was primarily agricultural farmland. The property and building were occupied by several aerospace and electronic parts manufacturing companies from 1964 to 1974. During this time, the property had various owners and was divided into numerous parcels. In 1969 Electronic Specialty Company was acquired by International Controls Corporation, which in turn transferred the Portland plant to a Boeing subsidiary, Radiation International, Inc. (Boeing, 1988)

In 1974 Boeing leased the facility and began to purchase the property parcel by parcel. Other manufacturing companies subleased the west portion of the main building from 1971 to 1985. By 1979 Boeing was the sole owner of the facility property and improvements. In 1979 and 1980, Boeing constructed a wastewater pre-treatment plant, employee recreation areas, and building 85-105, used for parts assembly and storage.

From 1981 to 1984, Boeing utilized a surface impoundment for the temporary storage of rinsate from electroplating and metal finishing operations prior to transfer to the waste water treatment plant. Both the pre-treatment plant and impoundment were located directly west of building 85-001. Upon closure of the impoundment in 1985, a Detection Monitoring Program was implemented as required by DEQ. Six groundwater monitoring wells, installed around the perimeter of the impoundment, were monitored for six consecutive quarters, from January, 1986 to July, 1987. Groundwater was found to be contaminated with high levels of trichloroethylene (TCE), 1,1,1-trichloroethane (TCA), and methyl ethyl ketone (MEK). The monitoring program revealed that other point sources were suspected due to the elevated levels of contaminants detected in upgradient monitoring wells. (Landau, 1988)

Upon reviewing the interim monitoring results, DEQ initiated a monitoring program of the surrounding water supply wells and Boeing extended their monitoring to onsite water supply wells in an attempt to define the extent of contamination. Consequently, additional investigations were conducted to identify the source, nature, and extent of contamination on the site.

Reviews of historic aerial photos, interviews with Boeing employees and officials, and visual inspections of the Boeing facility property revealed numerous areas of chemical storage, historic waste disposal, and stressed vegetation which may have been areas of solvent spills, indicating contaminant releases. (Landau, 1986)

2.2 Cascade Corporation

The Cascade facility was constructed from 1955 to 1956 for the purpose of manufacturing forklift truck attachments. At that time the facility included a waterfall paint booth, a parts assembly area, a maintenance shop, an assembly area for hydraulic cylinders, two underground storage tanks (USTs) for gasoline storage, and offices. In 1961, Cascade installed a vapor degreaser near the hydraulic assembly area for the purpose of cleaning metal parts with TCE. The degreaser was used continuously until 1975 when it was removed , and TCE usage was discontinued. (EMCON, 1993)

Operations expanded to include nickel and chrome electroplating in 1963. Chrome and nickel plating operations were discontinued in 1978, but nickel plating was resumed from 1982 through 1986. (EMCON, 1993)

In 1966, another facility expansion included carburizing of forklift attachments which continued until 1985, when carburizing was replaced by purchasing tempered steel.

In 1971, two underground storage tanks were installed northwest of the production facility to store waste coolant and oils. Cascade installed a cutting bin drainage system in 1979 that collected coolant lubricant drippings from metal cuttings for transfer to the waste coolant tanks. The waste coolant tanks and cutting bin drainage system were decommissioned in 1988 under the supervision of DEQ. At that time, approximately 50 cubic yards of contaminated soil was removed and disposed of at an off site facility. In fall of the same year Cascade received a Consent Order from DEQ to conduct additional investigations into the nature and extent of contamination. (EMCON, 1995)

3. Primary Sources of Contamination

3.1 Boeing of Portland

As reported by Boeing, three processes at the facility utilized solvents: vapor degreasing, manual parts cleaning, and painting. Vapor degreasing is the process of dipping parts into a tank of solvent vapor to remove oil, grease, and metal particles. TCE was used as a vapor solvent from 1974 until 1980, when it was replaced by TCA. Manual parts cleaning used a 50-50 mixture of toluene and methyl ethyl ketone (MEK) until 1984, when another 50-50 mixture consisting of half MEK and half TCA was used. Painting operations use Toluene as a paint thinner, BMS-11-7B as a cleaner prior to painting. (Boeing, 1986)

Although records of chemical use are unavailable for the earlier years at the facility, it is assumed the operations and raw materials were the same for the previous tenants. In 1985, the use of solvents was recorded to be: 8,600 gallons of TCA in the degreaser and for manual cleaning; 600 gallons of MEK/TCA mixture; 181 gallons of Toluene and 900 gallons of BMS-11-7B which is a mixture of aromatic naptha, ethyl acetate, MEK, and isopropyl alcohol. (Boeing, 1986)

Five areas have been identified as primary sources of solvent contamination. All of the areas were included in additional soil and groundwater investigations to determine the nature and extent of contamination. However, no single source was identified as the primary source of groundwater contamination.

East Yard: This area is located at the southeast corner of building 85-001 and has been the primary location for material handling since 1968. A subsurface soil investigation revealed 4,670 parts per billion (ppb) of TCA at 12 feet below the ground surface. (Landau, 1988)

East Area: From 1968 to 1972 liquid waste was disposed along this long strip of land located 400 feet south of the East Yard area. This area may have been completely excavated during the excavation and construction of building 85-105. (Landau, 1988)

Central Area: Occasional waste disposal occurred from 1964 to 1967 along a 350-foot wide area south of building 85-001. (Landau, 1988)

West Area: This area is located 200 feet west and 400 feet north of the southwest corner of building 85-001. Liquid disposal is suspected to have occurred here from 1966 to 1972. (Landau, 1988)

Vapor Degreasers: A degreasing facility was formerly located at the northwest corner of building 85-001 from 1964 to 1968. It was believed to have leaked on at least one occasion, but soil excavation during later construction removed much of the shallow soil contamination. (Landau, 1988)

Although originally suspected as sources, the surface impoundment and TCA storage tank were determined not to be significant sources based on subsurface investigations.

3.2 Cascade Corporation

Six areas have been identified as known or suspected sources of TGA contamination at the Cascade site. All of the areas in the immediate vicinity of the main manufacturing building and, with the exception of the north ditch source area, are covered by pavement or building structures.

Of the six areas identified (see Figure 3), only the first three are suspected of being long term source areas for groundwater contamination, with the first being the most significant.

Area 1: Former Waste Coolant underground storage tanks (USTs): This area includes the former UST nest, a cutting bin storage area formerly connected to the USTs, the cutting bin drainage collection system, and the area of a former storage shed.

The USTs were used from 1971 to 1988 for spent water-based machinery coolants and waste oils. Reports were made of two accidental overflows of TCE waste from the USTs in the 1970's and of small TCE spills just outside the tank nest. (EMCON, 1996)

Degreaser waste was also reported to have been dumped in a small ditch adjacent to a storage shed near the UST nest. This ditch has also been identified as the source for contaminants within the North Ditch source area.

This area has been considered to be the primary source of TCE, its breakdown products, and petroleum hydrocarbons in the soil and groundwater, based on the concentrations detected. In addition to occasional spills and dumping, water runoff from the cutting bins and stormwater flooding of the drainage collection system also contributed to impacting the soil, groundwater, and the North Ditch source area. Recent monitoring at wells in this area have revealed significant levels of light non-aqueous phase liquid (LNAPL).

Area 2: Former Vapor Degreaser: A vapor degreaser, formerly located in the northwest portion of the production facility, is believed to be another source of contaminants in the groundwater. In addition to small spills and drips of TCE in the area, large discharges of TCE have been reported by former Cascade employees. On at least two occasions prior to the 1964 facility expansion, waste liquid from the degreasers was pumped directly onto the ground (EMCON, 1996). High contaminant concentrations in soil and groundwater to the north and west of the degreasers corroborate the historical information.

Area 3: Former Chrome Plating Facility: A chrome plating facility formerly located on the west end of the production plant was utilized from 1964 until 1978. It is suspected this area was a source of chromium and PCE due to the presence of elevated concentrations of both contaminants in the soil and groundwater in the area. PCE concentrations in the groundwater near the former chrome plating facility are 10 to 100 times higher than elsewhere on the Cascade site, indicating an independent source. (EMCON, 1996)

Area 4: North Ditch: The ditch, located on the north side of the facility property, receives stormwater runoff from the site. Impacts to the ditch are probably related to releases from the former cutting bin drainage system and overflows of the drainage collection sump conveyed by stormwater runoff. Other impacts may be related to degreaser waste disposal near the former storage shed and waste coolant USTs. Contaminants detected in the area include TCE, cis-1,2-DCE, PCE, acetone, chloroform, toluene, ethylbenzene, and chromium.

Infiltration of surface water through soil in the ditch may have contributed to impacts to groundwater. (EMCON, 1996)

Area 5: Hydraulic Line Trench: Elevated levels of TCA, TCE, and Total Petroleum Hydrocarbon (TPH) have been detected in soils near the hydraulic line trench inside the southern portion of the production facility. Structural supports near the area of contamination have restricted the removal of much of the soil. The trench was lined with a concrete containment in 1990. (EMCON, 1996).

Area 6: Vapor Degreaser Sludge and Coolant Disposal: Historical information indicates that occasional disposal of vapor degreaser sludge occurred up to 1970, near the former west end of the parking lot and outside the northwest corner of the facility (EMCON, 1996). Coolant was also reported to be disposed of on the ground northwest of the production facility. Investigations have indicated that contamination was limited to shallow soils.

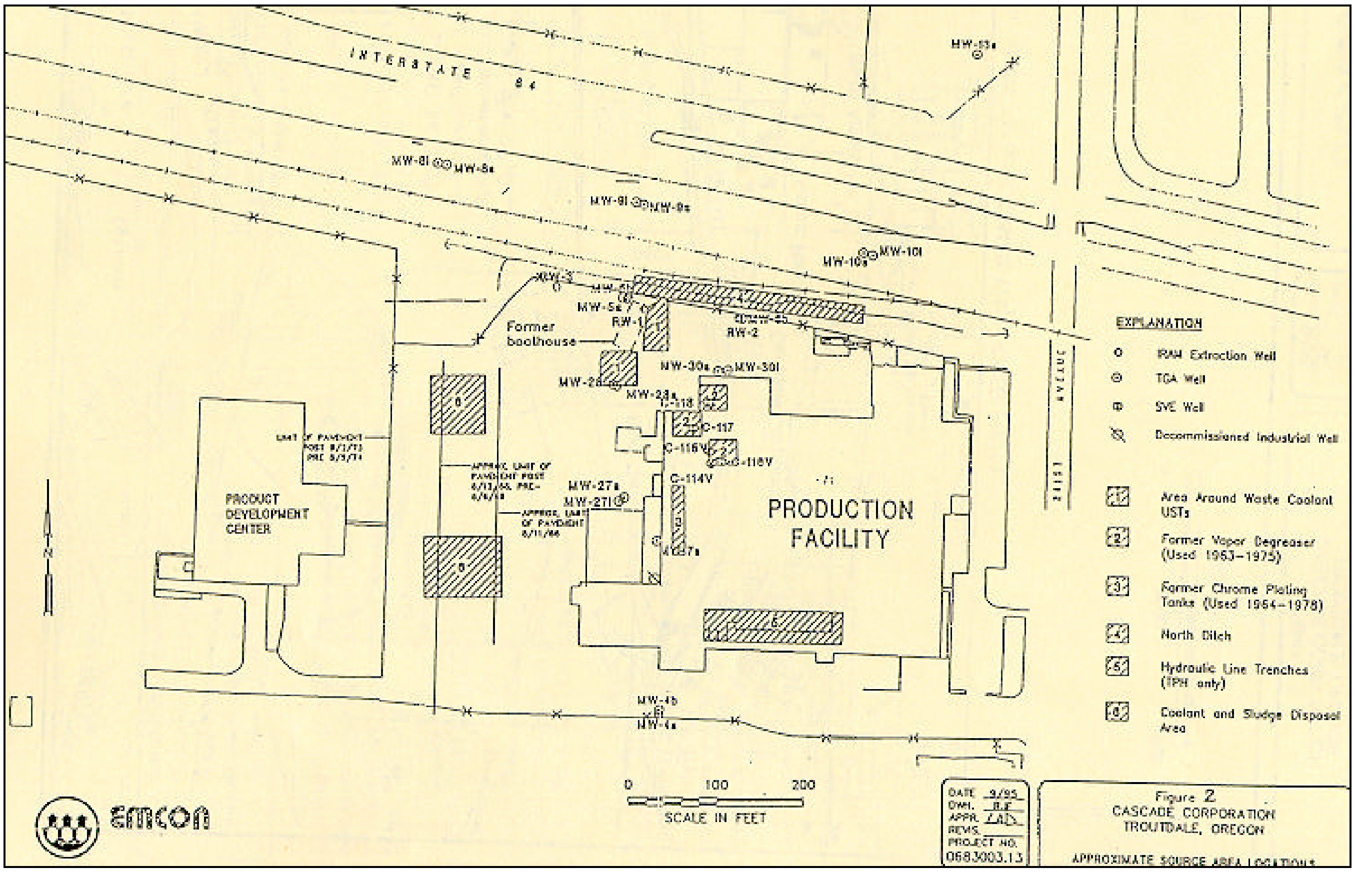


Figure 3: Cascade Corporation site.

4. Interlachen's Groundwater Supply

The Interlachen neighborhood consists of approximately 150 households which rely on groundwater produced from four wells in the area. The Lachenview well is located north of Fairview Lake, at the east end of the Interlachen community. This well, screened from 130 to 168 feet below the ground surface, is the only well which draws groundwater from the Troutdale Sandstone Aquifer (TSA). The Interlachen well (220 ft deep), screened from 201 to 216 feet below the ground surface, is located north of Fairview Lake, at the center of the neighborhood. The West Interlachen well, located north of Fairview Lake at the west end of the Interlachen community, is 261 feet deep. Both the Interlachen and West Interlachen wells draw groundwater from the Sand and Gravel Aquifer (SGA).

Blue Lake Water Coop serves about 12 houses from the Blue Lake Aquifer on the North side of Blue Lake.

The well pumps are usually operated in phases such that two of the three wells are utilized at the same time. Although the pumps are not equipped with continual reading flow meters, water usage has been estimated to be 1500-gallons per household, per week during the winter. Water use in the summer can be expected to be two times higher.

All four wells are currently operated by separate, independent water systems. A proposal has been made to unify the water systems into one public utility district owned and operated by the Interlachen community.

The Lachenview well, located the farthest from the migrating contaminant plume, is monitored by the City of Portland Water Bureau. The City collects water samples periodically and analyzes the samples for TCE and tetrachloroethylene (PCE).

5. Chemicals of Concern

The following compounds are Chemicals of Concern (COC) for groundwater (not for the soil phase). Chlorinated solvents, such as PCE and TCE, have discrete degradation pathways. The commonly accepted pathway for PCE is as follows:

PCE ⇒ TCE ⇒ trans-1,2 DCE and cis-1,2 DCE ⇒ 1,1 DCE ⇒ Vinyl chloride ⇒ CO_2

The following is a description of each COC identified in groundwater at the project site.

<u>Tetrachloroethylene (PCE)</u>
PCE is a common chlorinated solvent used in industry for the removal of grease and oil. Concentrations of PCE in on-site and off-site test borings have ranged from 55 ppb to 210 ppb. PCE has been detected in 52% of groundwater samples and 5% of surface water samples, with most detections exceeding the Maximum Concentration Level (MCL) of 5 ppb. (EMCON, 1996)

<u>Trichloroethylene (TCE)</u>
TCE , also a chlorinated solvent, was used by Cascade from 1961 to 1975 in the vapor degreasers to clean metal parts. TCE is also a degradation product of tetrachloroethylene (PCE). TCE has been detected at the highest frequency of any chemical and at elevated concentrations, both on and off-site in groundwater. Concentrations have been detected as high as 24,000 ppb in groundwater and 5,500 ppb in soil at a test boring located near the former waste coolant USTs. TCE has been detected in 79% of groundwater samples and 69% of surface water samples. (EMCON, 1996)

<u>Cis-1,2-dichloroethene (DCE)</u>

DCE, a degradation product of TCE, has been detected in 71% of groundwater samples and 60% of surface water samples. TCE concentrations frequently exceed MCL for drinking water (70 ppb) with the highest levels reaching 13,000 ppb in TGA groundwater. DCE has been detected in surface springs as well. (EMCON, 1996)

<u>Vinyl chloride</u>
Vinyl chloride, the most toxic of the degradation products of PCE and TCE, has been detected in 11% of groundwater samples, frequently above the MCL of 2 ppb (EMCON, 1996). Vinyl chloride has been found to be restricted to the area around the former waste coolant USTs and has not been detected at Shepard or Taggart Springs.

<u>Chromium</u>
Chromium, a heavy metal with an MCL of 100 ppb, has been found in 13% of groundwater samples and in the soil at elevated concentrations (1,430 ppm) near the former Cascade chrome plating plant (EMCON, 1996). Sludge waste disposal areas were also found to contain detectable levels. The chrome plating plant was operational from approximately 1963 to 1978. Neither Shepard Spring nor Taggart Spring has been impacted by chromium.

Manganese

Manganese, a heavy metal, has been found in 41% of groundwater samples, primarily in areas where Volatile Organic Compounds (VOCs) have been detected. (EMCON, 1996)

Other Compounds

Additional volatile organic compounds such as trichloroethylene (TCA), methyl ethyl ketone (MEK), and Toluene were used extensively on-site but have not been classified as COCs since these are based only on groundwater and not soil concentrations.

6. Surface Water Contamination

Various surface water bodies exist within the study area or are direct discharge points from the TSA or other drainage pathways from the study area (see Figure 4). Many, but not all, of the water bodies have been included in water quality or sediment analyses.

<u>Taggart Spring and Shepard Spring</u>

Taggart Spring and Shepard Spring discharge from the TGA north of I-84 and the Cascade facility at a flow of less than 30 gpm and 5 gpm respectively (EMCON, 1995). Taggart Spring eventually flows into Storm Drain Creek and into the Columbia Slough. Shepard Spring discharges to the TSA approximately 250-feet north of the spring emergent point. TCE and 1,2-DCE have been detected in both springs.

<u>Storm Drain Creek and East Ditch</u>

Storm Drain Creek is a tributary to the Columbia Slough located north of the Boeing facility. Water in the creek consists primarily of storm sewer runoff, groundwater from the extraction system discharge from RPW-2 at Boeing, and from Taggart Spring. No TSA connection has been identified at Storm Drain Creek.

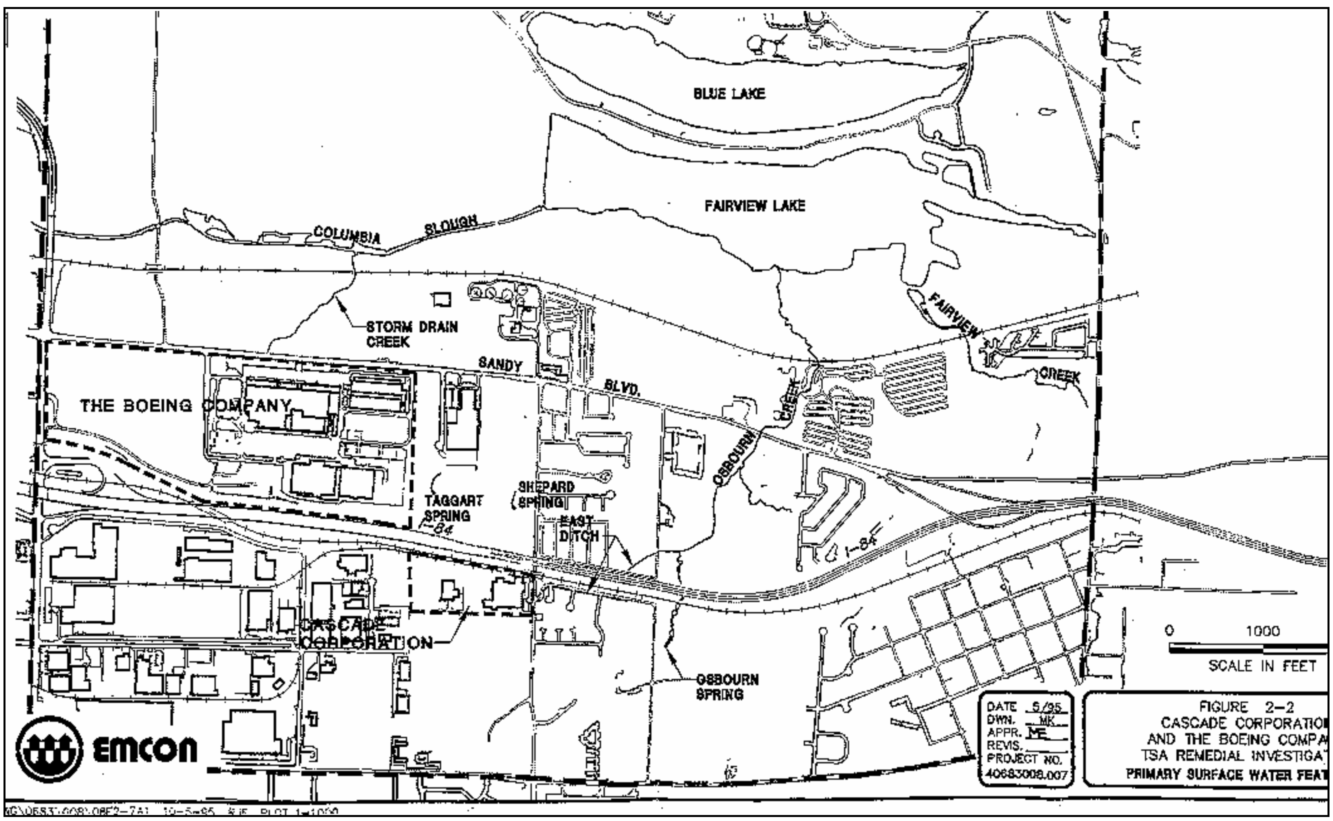


Figure 4: Surface water features in vicinity of groundwater contamination (EMCON, 1995).

East Ditch is located east of the Cascade facility and extends north under I-84 to Osbourn Creek. Runoff from Cascade and NE 201st Avenue discharges into the ditch.

Fairview Creek and Osbourn Creek

Fairview Creek flows north where it drains into the southeast corner of Fairview Lake. METRO (1994) has performed some basic water quality analyses of Fairview Creek evaluating eutrophication problems.

Osbourn Creek is fed by Osbourn Spring which is located east of NE 205th Avenue and south of I-84. Osbourn Spring discharges from the TGA. Osbourn Creek discharges to Fairview Lake at the south shore, approximately at the middle of the lake. The creek was sampled once in 1993, in two different locations along the creek, revealing non-detectable levels of contaminants-of-concern (see Section 4). (EMCON, 1995)

Both Fairview and Osbourn Creeks are fast moving streams containing cold water species such as cutthroat and rainbow trout and both are discharge points for the TSA.

Fairview Lake and Blue Lake

Fairview Lake, located at the north side of the study area, is approximately 65 acres in area and reported to be four feet deep in the summer, and contains warm water game fish such as large mouth bass. The lake has been reported to be hydrologically connected to the TSA along the south shore to a certain degree. Water levels are controlled by a levee at the west end of the lake which discharges water to the Columbia Slough. The lock is managed by the Multnomah Drainage District. Much of the water entering the lake is stormwater drainage from the cities of Fairview and Gresham. Water in the lake was sampled in two different locations, 600 feet and 1600 feet west of Osbourn Creek, in March, 1993 (EMCON, 1995). Results revealed non-detectable levels of contaminants-of-concern (see Section 4).

A study by METRO (1994) concluded that the water quality of inflows to Fairview Lake (e.g., from Fairview Creek) were not improved by the Lake.

Blue Lake, located north of Fairview Lake, has a similar surface area, but is much deeper. The lake has a direct connection to the Blue Lake Aquifer (BLA) and possibly to the TSA along the south shore. Due to its depth, Blue Lake contains species such as large mouth bass, carp, blue gill, green sunfish, black and white crappie, brown bullhead catfish, and is stocked with rainbow trout and winter steelhead.

Columbia Slough

Columbia Slough, located 1,500 feet north of the Boeing facility, is the ultimate receiving water body for much of the study area. The TSA also discharges to the Slough. The Slough is included in the City of Portland's Sediment Sampling Program, and has been included in a quarterly water quality monitoring program. Trace amounts of TCE (1.5 ppb) have been detected in water samples as recently as August, 1994. (EMCON, 1995)

7. Geologic Site Characterization

The geology of the study area in the vicinity of the plume can be considered complex. Figure 5 shows a typical geologic cross-section going approximately South to North from the Cascade area through Fairview Lake, Blue Lake, and the Columbia River. Figure 6 shows a geologic cross section through the Portland well-field going West to East parallel to the Columbia River. The predominant geologic units present are: TGA (Troutdale Gravel Aquifer), TSA (Troutdale Sandstone Aquifer), CU1 (Confining Unit 1), CU2 (Confining Unit 2), and the BLA (Blue Lake Aquifer). [See also Figure 7 showing these geologic units.] The following reviews were prepared to critique and review the geologic assumptions made by consultants involved in determining the character and nature of the groundwater pollution problem.

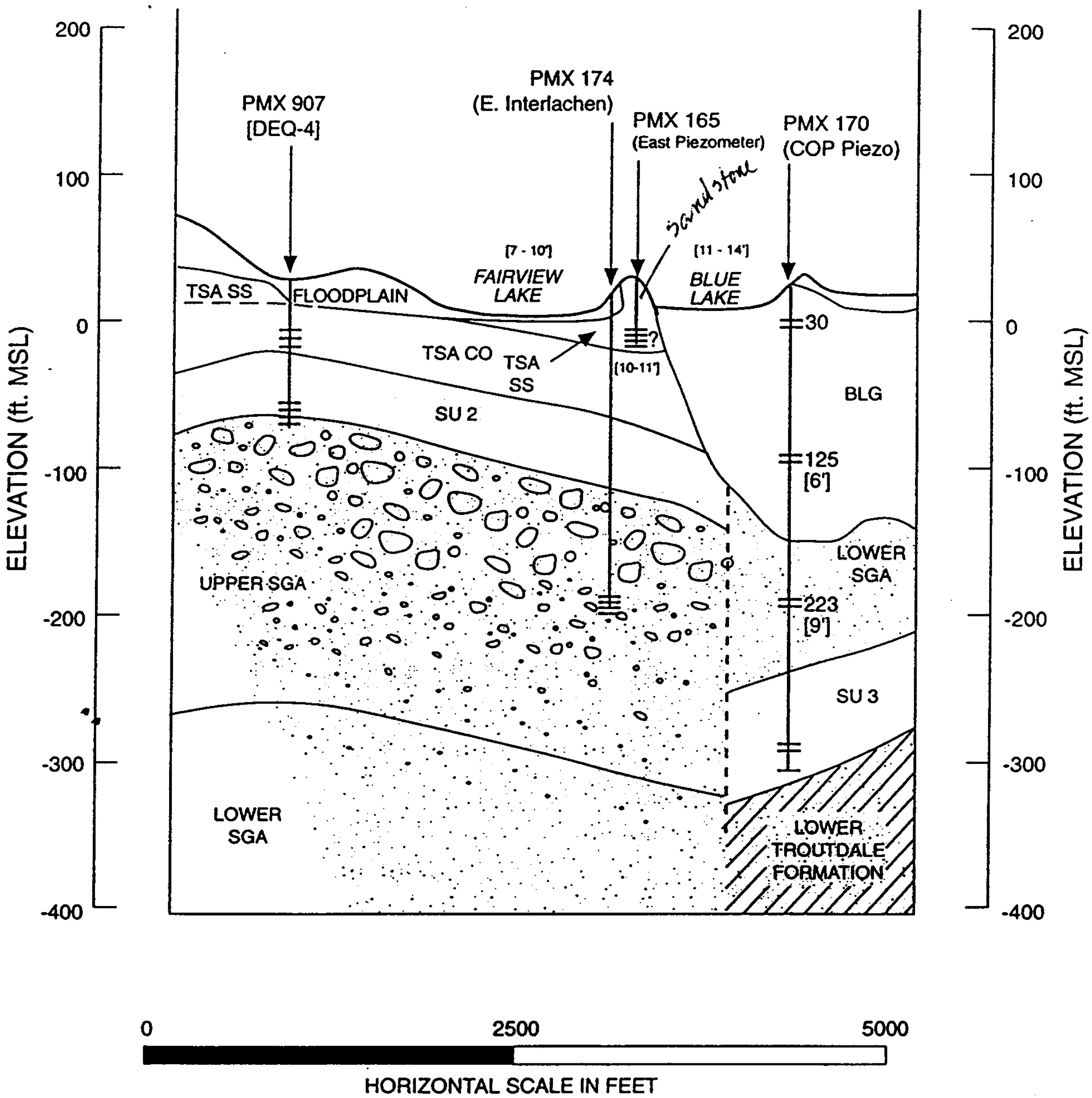


Figure 5: Typical cross-section through study area showing geologic strata.

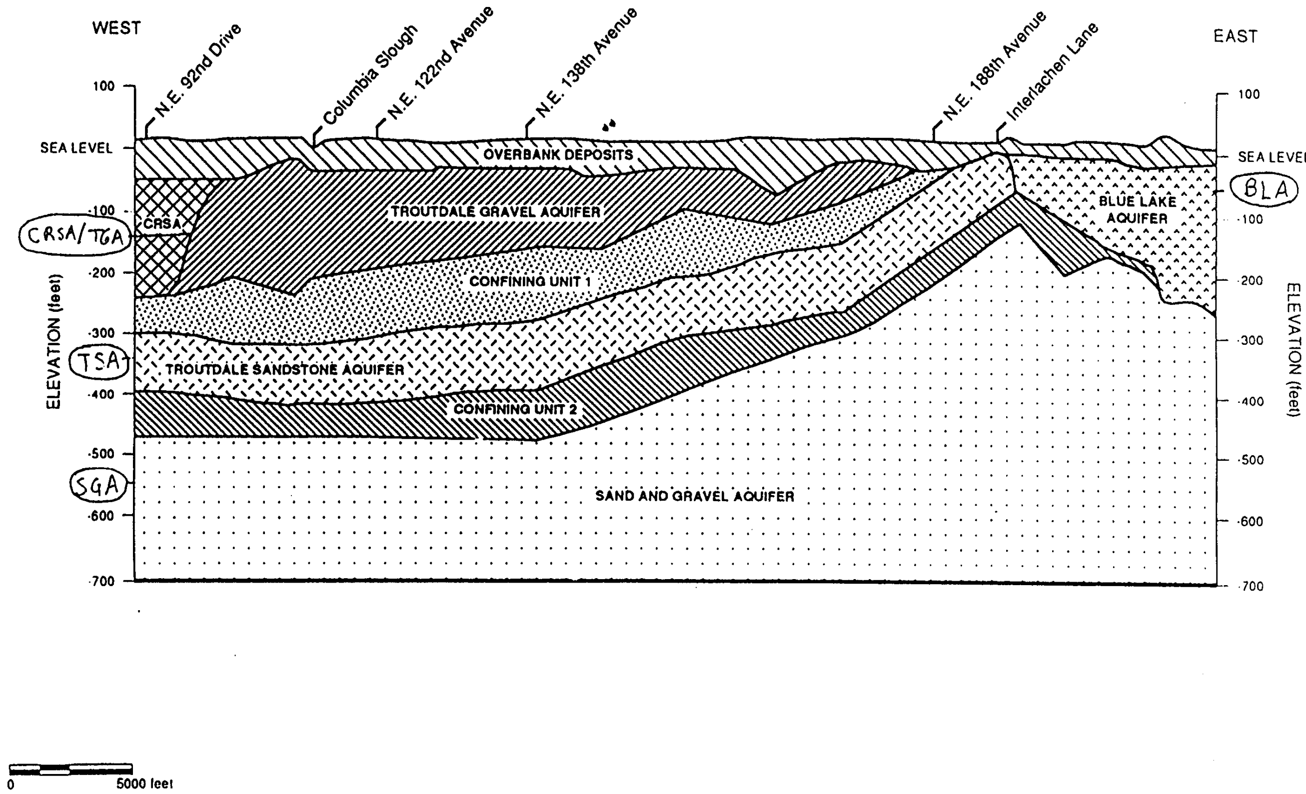
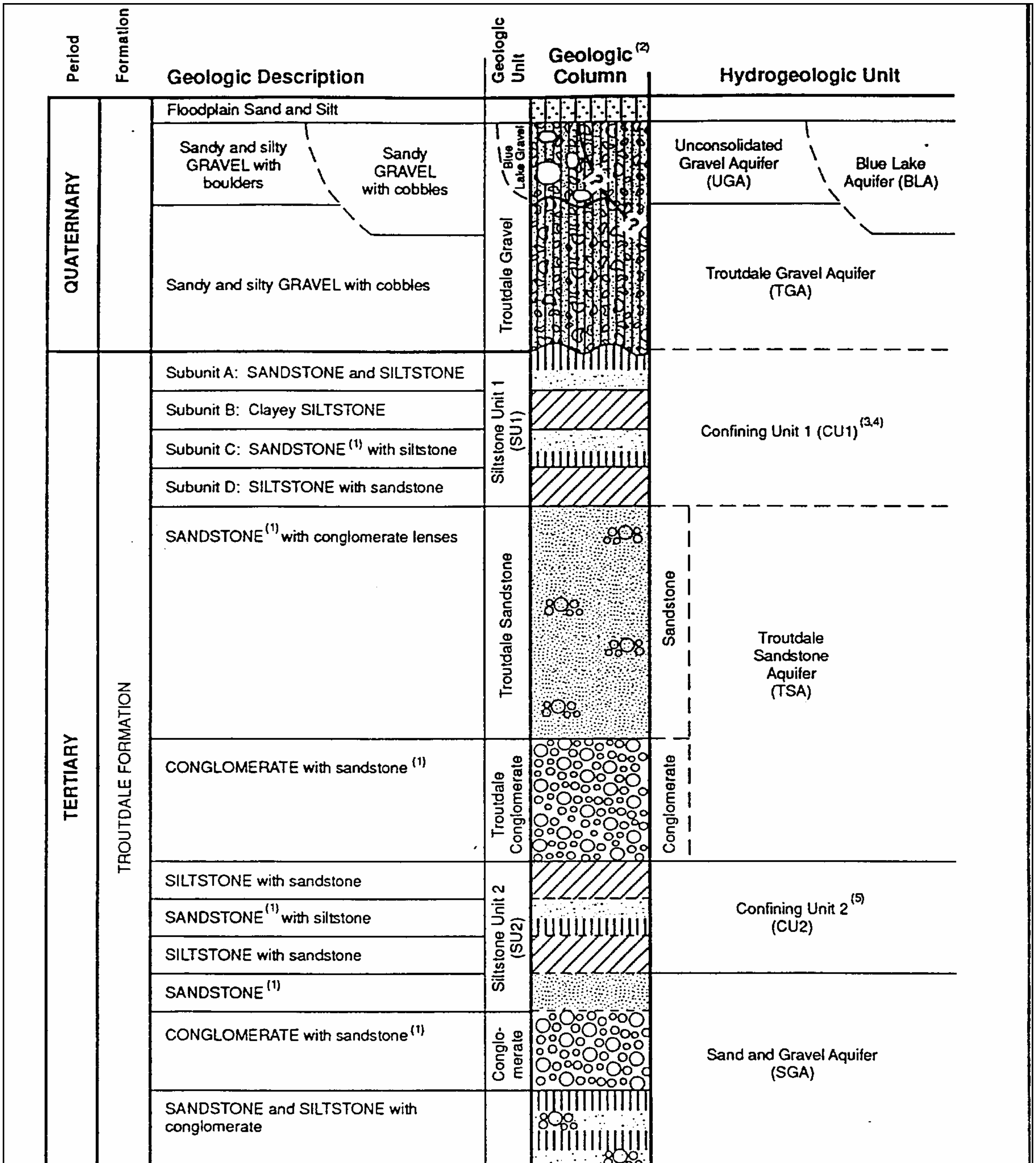


Figure 6: Geologic Strata in the Portland Wellfield area.

All of the sediments and sedimentary rocks underlying the Fairview Lake area are fluvial deposits of the Columbia River deposited on top of the Columbia River Basalt Group lava flows in the past 15 million years. The upper 500 feet of this stratigraphic section probably ranges in age from four million years, the uppermost part of the Sand and Gravel Aquifer (SGA), to 12,000 years, the unconsolidated Missoula flood sediments. River deposits tend to range from coarse gravel deposited in the high-energy channel to fine silts deposited during flooding on the shallow flood plains. The shape of fluvial deposits may be tabular in the flood plains to highly lenticular for the channel deposits of sand and gravel. Since the river's course does not remain in a fixed position over time, especially in an alluviating basin, the positions of sand bars and channel gravels migrate laterally as the sedimentary deposit thickens and earlier deposited flood plains may be dissected by flood channels or channel migration. Therefore, the stratigraphy of a fluvial system, like the Columbia River, tends to be complex, laterally variable, and quite difficult to predict and model. Sometimes the best that one can do is to group the deposits into the more permeable beds that are dominantly sand and gravel, representing the channel deposits, and the less permeable beds that are dominantly sand to clay sized sediment, representing the overbank deposits. The Fairview Lake area is basically made up of these kinds of deposits, but is further complicated by a history of periodic rapid deposition of vitric/lithic sand produced by interaction between lava flows and the river and later modification by catastrophic erosion and then deposition by the Pleistocene Missoula floods.

Geologic History

A brief geologic history summary of the various stratigraphic layers in the study area are provided to help to better understand the hydrogeologic units and predict their characteristics in ground water contaminant migration.



Notes:
1. Sandstone may contain large amounts of vitric lithic sand.
2. Geologic column is intended to represent a composite for the study area. Local variations may exist.
3. For the purposes of this report, the top of CU1 is estimated based on the depth at which the thickness of siltstone interbeds becomes greater than the thickness of sandstone interbeds. The bottom of CU1 is estimated based on the depth at which the thickness of sandstone interbeds becomes greater than the thickness of siltstone interbeds.
4. The designation of CU1 in this report is similar to designations used by EMCON (1995) but different than designations used by Landau (1995). Landau (1995) designates CU1 as being equivalent to SU1 Subunit B. CU1, as used in this report, always includes SU1 Subunit B.
5. CU2 becomes more sandy in portions of the eastern study area.

Figure 7: Geologic strata in the contamination area.

Sand and Gravel Aquifer (SGA)

The SGA was created by channel deposits of the Columbia River during slow subsidence of the Portland Basin while the river channel remained near its present position. The presence of a small percentage of exotic metamorphic and plutonic clasts and abundant quartz and mica grains in addition to the dominant basaltic cobbles, indicate that the Columbia River transported some of its load from distant headwater locations in Canada, Idaho, and Montana. The sand lenses are arkosic and poorly cemented so that the permeability of the entire sand and gravel aquifer is uniformly high. Most of the overbank, flood plain deposits at this time were located south and west where they are generally identified as the Sandy River Mudstone. The Sandy River Mudstone is micaeous and its mineral and chemical composition strongly indicates its Columbia River source, and also occurs north of the present Columbia River in Washington.

A vitric/lithic sandstone occurs near the top of the SGA, indicating that small volcanic vents located in the Cascade Range along the Columbia River had begun to erupt basaltic lava, some of which flowed into the river, chilled and fragmented to form glass sand that was carried down the river and deposited in delta-like beds into the Portland Basin. These beds are almost instantaneous deposits and were initially probably nearly continuous near the Columbia River channel, thinning rapidly westward and onto the flood plain to the south.

Confining Units 1 and 2 (CU1 & CU2)

The abrupt addition of large volumes of vitric/lithic sand to the river resulted in rapid sedimentation along the Columbia River channel in the Cascade Range and into the Portland Basin which alluviated the channel producing a braided stream and forced the river to new courses throughout the Portland Basin and covered the Sandy River Mudstone with coarser Columbia River channel deposits. The relative positions of river channel and flood plain made radical shifts during this time of episodic volcanic eruptions so the Fairview Lake area alternated between low permeability overbank silts (CU1 & CU2) to high permeability channel sands and gravel (TSA). The channel deposits during this time alternated between vitric/lithic sands during episodic volcanic eruptions that flowed into the river, upstream, and gravels containing exotic clasts, the normal load of the Columbia River. Radiometric dating of these basaltic centers along the Columbia River range from 3.7 million years to less than 1 million years. These confining units should be thought of as leaky aquitards (See Glossary). It is quite possible that they have been breached by channel cutting in places.

Troutdale Sandstone Aquifer (TSA)

The TSA actually comprises two layers, both of which are fairly permeable, that are grouped together as the TSA. The lower third of this unit is dominantly conglomerate and the upper two-thirds is vitric sandstone. This is the thickest vitric sandstone in the section, ranging over 100 feet. It is a product of volcanic eruptions of basaltic lava flows that poured into the large Columbia River, chilled and shattered to form huge amounts of glass sand. This glass sand was then carried down stream and deposited within the river channel until it was filled and then spread out onto the flood plains forming a wedge-shaped delta into the Portland Basin. The glass sand was rapidly buried and cut off from the atmosphere, as is suggested by its still black, glassy appearance in the drill holes. Where exposed at the surface, as in the ridge between Fairview Lake and Blue Lake, it takes on a brown oxidized coloration due to iron present in the rock particles. This unit is considered sandstone and is traditionally made of glass and rock particles and is thought to thin rapidly to the west and south. The upper part of the TSA contains vitric sand interfingering with the finer silts of CU1. Because of its mode of origin, the volume of sand in the bed, and rapid deposition the TSA may well be the most continuous unit in this area.

Troutdale Gravel Aquifer (TGA)

The Troutdale Gravel Aquifer media is similar to the gravels present in the lower section except it contains a greater proportion of Cascadian clasts (largely andesite) and are often less well cemented. The presence of the clasts from Cascadian volcanoes is due to a fairly rapid uplift of the Cascade Range in northern Oregon in the past 2 to 3 million years and the incision of the Columbia River and tributary streams during this time. In addition, these events were probably accompanied by the eruptions of Cascadian stratovolcanoes, which also contributed to the presence of these clasts.

Blue Lake Aquifer (BLA)

In the last 2 to 3 million years the Cascade Range in northern Oregon has been uplifting as streams were rapidly incising their channels. The Portland Basin also appears to have been rising but at a much slower rate as portions of the earlier sedimentary deposits of the valley were eroding. Interglacial rises in sea level during the Pleistocene epoch may have temporarily resulted in terrace deposits. Near the end of the Pleistocene epoch, cataclysmic floods repeatedly occurred as glacial Lake Missoula was first filled and then violently drained. Up to 100 floods poured through the Portland Basin from about 15,000 to 12,000 years ago that dramatically accelerated the erosional and depositional processes in the Portland Basin. Each flood first scoured channels as it passed through the basin and then deposited gravels (ranging in size up to 10+ ft boulders near the mouth of the Gorge) along the course of the river and finer sediments in the back water areas. Missoula floods were the likely cause of the channel into which the BLA was then deposited. The flood gravels are similar to other gravels in the area except that they contain some very large boulders, and they form a very open framework gravel that is unconsolidated and largely devoid of the finer grained matrix due to the very high energy of the flood waters. These gravels are the most permeable in the area.

Cautions for hydrologic analysis

1. Assumptions of uniformity (homogeneity) are optimistic. There are many lens-shaped beds and very few of the smaller beds can be projected with any confidence from drill hole to drill hole. This applies to both the aquifers and aquitards. The TSA is clearly described as composed of two different lithologies even though their hydrologic characteristics may be similar.

2. The determination of the presence or absence of faults and folds in these rocks is very difficult without considerable exposure or numerous drill holes. The use of small scale units to make such determinations is usually suspect. The vitric sands may offer the best chance of correlation because they are the result of an individual eruption that sent lava into the river and therefore are uniform in chemical composition, which is characteristic of that deposit. Also it is deposited almost instantaneously (in a geological sense) over a fairly broad area of channels and floodplains.

Geologic Analysis

The Troutdale Formation in the area of concern is characterized by rapid lateral and vertical variations that reflect the complex dynamics of the Columbia River as it passed from the Columbia Gorge into the Portland basin. Depending on sediment supply, subsidence rates in the basin, volcanic activity in the Cascade Range, and uplift rates in the Cascades Range the depositional system probably varied between prograding fan or fan delta and braided stream system. Displacement of one sedimentary environment by another as channels shifted across the fan or braided stream complex produces sediment geometry that is difficult to predict. At a gross scale, stratigraphic units are recognized if contacts are defined by general criteria such as "point in the stratigraphic sequence below which lithology becomes predominantly conglomerate". Such a statement does not preclude conglomerate from being present above that point, but does indicate that conglomerate becomes predominant below that point. At a more detailed scale, it is highly unlikely that thin units can be traced laterally. In addition to rapid lateral and vertical facies successions, erosional and weathering surfaces are expected to be present. The prominence of such features depends upon the length of time a particular set of conditions persisted in the depositional basin. The differences in grain size in different sedimentary environments results in differential compaction. Fine-grained sediments are more likely to undergo greater compaction than associated coarse-grained deposits. Areas where channels persisted for considerable lengths of time may occur at shallow depths in the modern setting relative to the contemporary flood plain deposits. Differential compaction may produce variations in depth of an inter-unit contact.

Associated with the development of weathering and erosion surfaces, it is likely that the water table changed elevation through time. The fluctuation of the water table encourages degradation of chemically unstable constituents in the sediments. Basalt glass, a chemically unstable and reactive constituent, is likely to be altered during alternating wetting and drying. Alteration of basalt glass to clay minerals and iron oxides and oxyhydroxides releases chemical constituents to the ground water. Mineral precipitation, especially silica phases, zeolites, and carbonate minerals, is likely to occur wherever fluids of differing composition interact. These zones of fluid mixing are likely areas for cementation and result in reduction of porosity.

The following comments require consideration in developing ground water models and predicting contaminant transport in the study area.

1) Investigations of the characteristics of confining units have treated lithology as laterally continuous. Given the characteristics of the depositional model, such an assumption appears to be difficult to support. Lateral continuity of thin lithologies is not likely.

2) An evaluation of the constraints placed on ground water models by lithologic variations in confining layers is generally lacking. Since the confining layers are viewed as important in restricting the movement of contaminants between aquifers, such an evaluation is important. The spatial variability of lithology in hydrologic units and how this variability impacts ground water models needs to be rigorously assessed. How sensitive are the models to variations in the hydrologic parameters induced by lithologic variations?

3) The abundance and mineralogy of secondary precipitated phases (cements) and the extent of alteration of primary basalt glass in stratigraphic units needs to be evaluated in light of the ability of secondary minerals to reduce porosity and provide adsorption sites for contaminants. Location of paleo water tables and weathering horizons need to be assessed in relation to cementation and variations in hydrologic properties.

4) The distribution of secondary precipitated phases and alteration of primary basalt glass needs to be assessed in the vicinity of the erosional surface that cuts deeply into the TSA and how these phases relate to the development of the ground-water mound needs to be evaluated.

5) The distribution of stratigraphic units in the area of concern may be explained by either structural development or by differential compaction and distribution of sedimentary facies. The structural interpretation is presently used to explain these patterns. However, a model based on stratigraphic concepts needs to be developed. The distribution of lithologies and unconformities in the two different approaches has implications for developing ground water models and how water may move within the deposits. Distinctions between units defined by lithologic characteristics must be clearly distinguished from those defined by hydrologic characteristics.

8. Groundwater Modeling

The East Multnomah County (EMC) groundwater models consist of a groundwater flow model and a contaminant transport model. The flow model was originally developed by Papadopulos for DEQ and was later modified and revised by EMCON and Landau for the Boeing company and the Cascade Corporation. The transport model was developed by EMCON/Landau for Boeing and Cascade. Based on the limited information presented in the model reports, the contaminant transport model in its present form is conceptually problematic and can not be reliably used to predict the future spreading and impacts of EMC groundwater contamination. The following bullet points are a summary and specific comments on some of the questionable model assumptions and their potential impacts on the conclusions obtained from the Boeing/Cascade groundwater model study.

- SGA Contamination

  The Boeing/Cascade transport model predicts that the SGA is presently not contaminated and, under large scale City of Portland (COP) pumping, a TCE plume may develop in 20 years but the maximum concentration is less than the MCL. The currently observed TCE hits in the SGA were attributed to possible cross-contamination from well bore leakage.

  It must be stressed, however, that the Boeing/Cascade groundwater model implicitly assumes that flow and transport within each of the aquifer layers is essentially horizontal and two dimensional. Vertical variations in the aquifer head and contaminant concentration within the layer are not modeled, although the interaction and variation among the layers are taken into account. This two-dimensionality assumption is acceptable if we are only interested in the general flow pattern since the flow in the EMC aquifers on a large scale is essentially horizontal. The assumption, however, is inadequate where vertical flow is significant as in the groundwater mound area, in the discharge areas near the surface water features and the partially penetrating pumping wells, and in the area where the confining units CU1 and CU2 are thin. The two-dimensionality assumption is flawed for contaminant transport in the SGA and the BLA since the plumes, if they exist, in these aquifers are inherently three-dimensional and the contamination are far from vertically mixed. The transport model predicts vertically averaged concentration within each aquifer layer. The results are not meaningful and can be misleading unless the plume fills the whole aquifer thickness. This is not the case in the SGA. The contaminant concentration immediately below the CU2 at the top of the SGA can be much higher than the predicted vertical average. Therefore, the Boeing/Cascade transport model in its present form may grossly under-predict the potential SGA contamination, especially under large scale SGA pumping.

- TSA Plume Spreading

  The Boeing/Cascade transport model predicts that, under non-pumping condition, the TSA plume will be mostly captured by surface features and, under large scale COP pumping, may reach the well fields in approximately 20 years.

It is important to stress that the transport plume model assumes that groundwater flow is steady and ignores a potentially important transport mechanism: dispersion, or plume spreading due to spatial and temporal variability in groundwater velocity caused by small-scale geological heterogeneity, intermittent pumping, tidal and seasonal groundwater level fluctuations. Simple "order of magnitude" analyses (based on a typical dispersion coefficient for a plume of the observed scale) shows that the TSA plume front may migrate much faster when dispersion is taken into account (especially during large scale COP pumping) and may reach the well fields significantly sooner than what is presently predicted.

- Model Resolution and Artificial Dilution

The grid size adopted in the groundwater model is 330 ft by 330 ft in the detailed model area and 1000 ft by 1000 ft elsewhere in the regional model area. Such a grid size can not adequately resolve the detailed land and surface water features that dictate the detailed local flow pattern in the area of critical concern. And, the coarse grid is insufficient in resolving the rapidly varying concentration plume distribution. Although further grid refinement may not change materially the general large scale flow pattern, it may affect contaminant particle tracking and transport modeling significantly. Particle tracking is often sensitive to even a small change in the curvature of head contours. Predicted concentration from a coarse grid plume transport model can be artificially diluted since the predicted concentration represents the concentration averaged over a discrete model cell volume (averaged horizontally over a 330 ft by 330 ft area and vertically over the complete aquifer thickness). Note management decisions and especially risk assessment are often made based on the maximum concentration that can be significantly higher than the predicted mean concentration from the transport model.

- TSA Response to BLA Pumping

The groundwater flow model appears to significantly over-predict the TSA drawdown in response to the 1994 BLA pumping. Boeing/Cascade deemed the model conservative and thus acceptable despite the discrepancy. However, it should be stressed, that such a model is not necessarily conservative when used to predict the rate of migration of the TSA plume. This all depends on what actually causes the discrepancy. For example, the exaggerated TSA drawdown, if caused by an underestimate of the TSA permeability, would lead to a reduced groundwater velocity and thus slow down plume migration. This is not conservative. On the other hand, the overestimate of the TSA drawdown, if caused by an underestimate of the TSA thickness, would lead to an increased groundwater velocity and thus a conservative prediction of the rate of plume migration.

- Surface Water and Groundwater Connection

The Boeing/Cascade groundwater model predicts that, under non-pumping conditions, the TSA contamination plume will be mostly captured by surface features. The validity of this conclusion depends on the aquifer and surface water connection. At the EMC site, this connection is largely controlled by the thickness and hydraulic characteristics of the sediment materials that lie at the bottom of the surface water bodies. Mathematically, this is characterized by the so called "leakance" coefficient. The selection of these leakance values is crucial in accurately simulating the impacts of these surface features on the plume migration.

In the present groundwater flow model, the leakance values are selected based on the hydraulic conductivity and thickness of the TSA. This may not be always correct. The surface features in the detailed model area are mostly underlain by the less permeable overbank sediments not indirect contact with the TSA. As a result, the actual leakance value may be significantly lower than those used in the model. The leakance can also be significantly affected by the degree of siltation at the bottom of the surface water bodies and the degree of penetration of these surface features into the aquifer layers. The best way to obtain an estimate of the effective leakance values is to calibrate the flow model to the hydrographs that explicitly reflect surface water and groundwater interaction. Graphical and quantitative comparison of the predicted and observed time hydrographs (not just the mean or heads at a particular time) in the proximity of the different surface water features can provide a significantly more accurate and unique calibration than the simple steady calibration or transient calibration at a particular time used in the present Boeing/Cascade groundwater model.

- Surface Water Recharge

In the Boeing/Cascade groundwater flow model, the surface water bodies are represented as head dependent recharge/discharge cells. Flux between surface water and groundwater is calculated as the product of the leakance and the head difference between the surface water and the underlying aquifer layer. However, these same surface water bodies were also simulated to receive direct recharge from precipitation and surface drainage. This is wrong because such a representation results in double counting of the surface water recharge! The contribution to recharge from precipitation and surface drainage in the surface water areas are already implicitly reflected in the surface water level. This incorrect representation may impact the detailed flow pattern in the proximity of the surface features and the surface water and plume interaction. According to the EMC flow model sensitivity analysis reported by Papadopulos, natural recharge appears to be by far the most sensitive parameter in controlling aquifer level and flow pattern at the site under non-pumping conditions.

- Source of Blue Lake Water

Based on the Boeing/Cascade steady flow model, the predicted aquifer level in the neighborhood of Blue Lake seems to be always smaller than the Blue Lake level. This indicates that Blue Lake discharges water to the adjacent aquifers. Where does the water in the Blue lake come from? Does the lake have a large enough surface drainage system that feeds and maintains the water level in the lake? How can one then explain the dramatic water quality (turbidity) difference between the Blue Lake and Fairview Lake?

- Model Uncertainty and Non-Uniqueness

Model prediction based on limited amount of data is necessarily uncertain, especially when they are not made full use of. The aquifer response to large scale pumping as characterized by the observed transient hydrographs at different wells and surface water bodies provides crucial information on the field scale aquifer properties, aquifer-aquifer connections, aquifer-surface water connections. The shape, the amplitude, timing of the hydrograph time curves, and the response phase lags in from well to well and from well to different surface can be all used to infer the effective aquifer structure. The Boeing/Cascade flow model appears to be calibrated only to the steady state heads or transient heads at a particular time. Model parameterization still appears rather arbitrary. Further transient calibration based on a graphical comparison of the predicted time hydrographs in all monitoring wells and piezometers in response to the different large scale pumping stress in the TSA, SGA and BLA will provide a significantly more accurate and unique calibration. The detailed calibration also provides a stringent test as to if indeed the flow model has reasonably captured the hydrogeology and the temporal and spatial aquifer dynamics at the EMC site.

Influence of Interlachen Well on Plume Migration

An "order of magnitude" estimate of the influence radius of one of the Interlachen wells is shown below. The radius of influence of the well is the distance from the well center where water is influenced by the pumping of the well. If the plume is within the vicinity of the radius of influence of the well, the plume will be influenced by the pumping. If the plume is outside that radius of influence, the well does not exert an influence on the plume migration.

Table 1: Zone-of-influence of Interlachen well.

The calculation is performed based on the following conservative assumptions
Summer time condition:

- **No rain/recharge**
- **Maximum pumping all from one TSA well**
  - **1500-3000 gallons/week/household**
  - **150 households**
  - **Total pumping rate = 0.064 MGD**
- **No lake recharge**
- **No leakage between TGA/TSA and SGA/TSA**
- **Fully well penetration into TSA**
- **Average TSA thickness = 100 ft**
- **Average horizontal hydraulic conductivity = 50 ft/day**
- **Average storage coefficient = 0.05**

Given these values, and based on the theory of well dynamics, the maximum influence radius of the Fairview well corresponding to 0.5 foot drawdown is on the order of 100-1000 ft.

Note the influence area represents the outer limit of the cone of pumping depression. It is different from the zone of contribution which is the full recharge area that includes the TSA plume area upgradient. Currently the plume is approximately 2000 ft from the Interlachen well in the TSA. Given a radius of influence of 1000 ft, the Interlachen well does not currently affect plume migration.

Evaluation of Papadopulos (1996)

Papadopulos (1996) wrote a report for DEQ to explore several remediation strategies. These strategies are included in the remediation alternatives that meet the remedial action objectives, alternatives 4 and 5, both using groundwater pump and treat technology.

The restoration times estimated based on the travel time analysis were probably overly optimistic.

First, the chlorinated contaminants such as TCE do not always travel as fast as groundwater. This is the well known retardation effect and may increase the cleanup time by a factor approximately 1.5-3, depending on the site condition.

Second, as with most groundwater contamination sites, the EMC site is extremely heterogeneous. The "randomly" distributed small scale spatial heterogeneities, though having little influence on the large scale groundwater travel time, can importantly affect the contaminant transport and transformation. Spatial heterogeneities are often the bottle-neck to remediation efforts.

Low permeability zones trap contaminants, especially those of lower solubility. Areas of small permeability are often correlated with areas with high sorptive capacity. Regions of undissolved, organic liquids (DNAPLs that may flow by gravity through saturated media to local perched zones and to the bottom the TSA-conglomerate) and contaminants adsorbed to soil may slowly release contamination to surrounding groundwater, in effect acting as in situ sources of contamination and hindering the progress of remediation attempts. Note the rate of contaminant desorption, because of the "solids effect", can be much slower than that of adsorption. The rate of reverse diffusion and desorption may well control the clean-up time frames.

Failure to recognize this could result in a gross underestimate of the length of time required to flush contaminants out of the TSA and TGA and has obvious important implications on remediation planning, design and cost analysis.

Their estimates would be good if the site is homogeneous, and the chemicals involved are 100% soluble and conservative. This is, however, not the case. In fact, heterogeneity, slow desorption and presence of dense non-aqueous phase liquid, DNAPLs, are the major reasons why most the pump and treat sites were far from as successful as predicted.

Recommendation

The present groundwater model does not have the necessary spatial resolution to address the issues facing the Interlachen community and the Portland wellfields, especially in the vertical direction. The present groundwater model did not make effective use of the available field data especially the large numbers of detailed hydrographs in response to the large-scale controlled COP pump tests.

We recommend refining the spatial groundwater model resolution, especially in the vertical direction, re-calibrate the model to the observed hydrographs (not just the mean condition or the condition at a particular time) at different wells in different aquifers and in surface water bodies in response to the different COP pump tests, and reevaluate future plume impacts on the COP well fields and the Interlachen community.

Specific biases of the model:

- the model overpredicts the efficiency of the remediation efforts, in that the expected time of remediation will probably be longer than expected
- the model underpredicts point concentrations of the plume in the SGA as a result of pumping by the COP wellfield

- the model overestimates the time the plume would take to reach the COP wells in that the plume may arrive at the wells sooner than predicted by the model

9. Remediation Efforts

Some of the "remediation" efforts have included installation and testing of resource protection wells, evaluation of hydraulic parameters by pump tests, and continued monitoring in the area. Source control on-both sites have also been implemented. The remediation efforts have been focused in the TSA, or in the TGA at each respective contamination site. The treatment systems that have been implemented by Boeing and Cascade are itemized below:

Boeing Site:

- groundwater extraction and treatment system: 13 TGA wells (Discharge of 380 gpm) with air-stripping tower only (total solvent mass removed since 3/24/89 to 3/95 was 2820 lb. (started 3/24/89) [discharge effluent to Storm Drain Creek which goes into the Columbia Slough]
- soil excavation and disposal during building of Building 85-105
- Well RPW-1 (see Figure 8 for well locations) installed N of Columbia Slough to provide hydraulic control of TSA VOC plume (6/7/93)
- Well RPW-2 installed within TSA VOC plume just south of Columbia Slough for hydraulic control of TSA plume (90 gpm) (6/94) [discharge effluent to Storm Drain Creek which goes into the Columbia Slough]
- BLA wellfield pumping for 72 days by Portland Water Bureau (8/94) and considered that the RPW-1 only helped move the plume further north and RPW-2 was good enough in capturing the VOC plume even during this pumping period of 72 days by the Portland Water Bureau, pumping at RPW-1 stopped
- new TGA extraction well Fall 1995, on-line early 1996 at a rate of 200 gpm (installed to restore off-site contamination)

Cascade Site

- North Ditch soil removal (TPH contaminated soil removed, 190 yd3, 10ft wide, 6-7 ft deep, 75 ft long, 1989)
- Oil separator removed/new one installed in 1990 - 250 yd3 of soil treated on-site (left open to air), used as fill on-site
- 3 TGA removal wells (1991-1992): RW-1 in 1991, RW-2 and RW-3 added Spring 1992 (TGA removal from 1991 to end of 1995 about 350 lb. of VOCs)
- 400 ft long 3 ft wide and up to 30 ft deep cutoff trench in the TGA down gradient from Cascade with 9 sumps to air stripper (only VOC removal) (9/95 construction finished, operation 10/18/95), to cut off flow to Shepard Spring and subsurface flow over CU1
- new well between RW-1 and RW-3 will be installed in 1996

Pumping Water to Surface Water Sites

From July 12 through July 21, 1995 the Portland Water Bureau pumped about 50 million gallons (MG) from the SGA from wells number 4, 6, 7, 9, 11, 16 into the Columbia Slough. The water quality was extremely poor: dissolved oxygen levels were about zero (even after 48 hours of pumping) (Ireland, 1995).

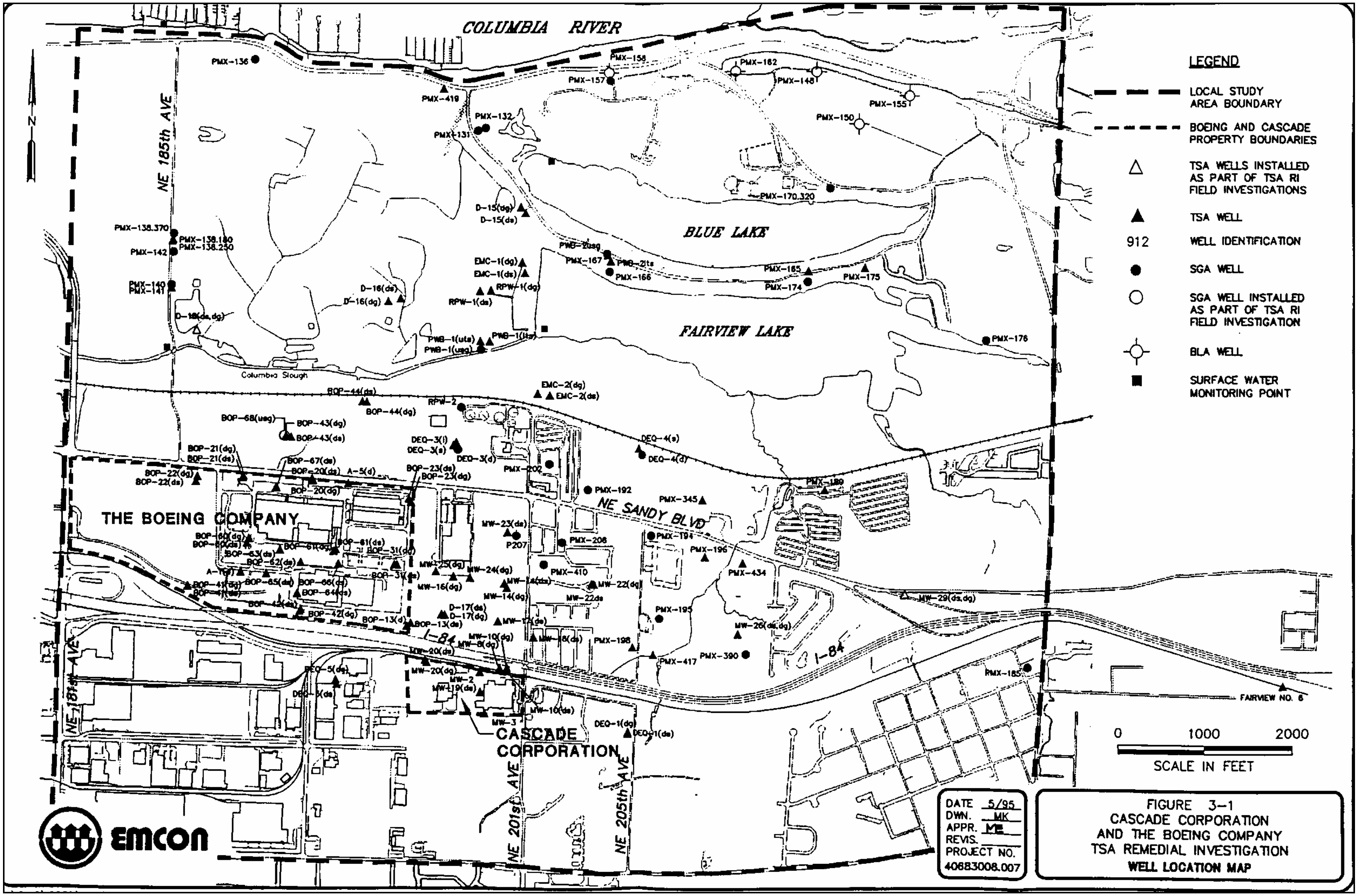


Figure 8: Well location map (EMCON, 1995).

The discharge from Boeing to the Columbia Slough from 1991 to 1992 averaged about 225 gpm (0.5 cfs or 0.0142 m3/s). These discharges have elevated levels of P because “Aqua-Mag” phosphate was used to control iron fouling on the pump-and-treat system. The only toxic organic found in the effluent was methylene chloride at 1.3 ppb and 1.1 ppb for samples taken on 12/4/91 and 9/3/91, respectively. Samples are collected and analyzed monthly. (Wells and Berger, 1994). All other VOCs were non-detects. Measurements of heavy-metals are not performed on the monthly sampling because heavy metals are not chemicals of concern from the Boeing site.

During 1992 several groundwater wells were checked for metals by Woodward-Clyde (1994). For well D-12S (owned by Boeing of Portland, aquifer UG/TGA, unconsolidated gravel, Troutdale gravel aquifer, located at NE 188th and Sandy), near the Upper Slough and Fairview Lake, elevated levels of cadmium (0.0015 mg/l, criteria was 0.0013 mg/l), copper (0.052 mg/l, criteria was 0.014 mg/l), and lead (0.033 mg/l, criteria was 0.004 mg/l) were found above drinking water limits (EPA Gold Book values, 1991). Because of heavy metals above drinking water limits from the wells in the Boeing area, a heavy metal scan is periodically recommended for the Boeing recharge to the Slough water because the wells in the vicinity of Boeing show metal contamination.

Alternatives For Future Remediation

TSA Remediation

Remediation objectives have been defined as follows:

- restore TSA to background, where possible, in reasonable time frame
- prevent ingestion of groundwater above risk levels
- protect environmental receptors
- prevent further spread of plume in the TSA
- protect groundwater quality in SGA and BLA
- allow existing uses of groundwater resources in East Multnomah County

The responsible parties have submitted to DEQ a list of alternatives for remedial action. Five alternatives were considered for the TSA cleanup as shown in Table 2.

Table 2: Proposed TSA remediation alternatives by responsible parties.

Alternative number	Description	Detailed description
1	no-action	only long-term groundwater monitoring
2	institutional controls	groundwater monitoring, restrictions on use of TSA groundwater as drinking water supply, provision of alternative water supplies, Portland Water Bureau use restrictions for its production wells
3	institutional controls and hydraulic control	Alternative 2 + TSA groundwater extraction near plume boundaries, decommission SGA wells that have well-bore leakage; restoration time 100 years
4	contaminant mass removal and hydraulic control	Alternative 3 + installation of extraction wells in areas of high VOCs, extraction from TSA and/or injection into SGA (rate of pumping: 5 aquifer pore volumes over 60 years); restoration time 50-60 years [DEQ, 1996, estimated that this would be about 85 years to remediate 85% of aquifer to MCLs]
5	contaminant mass removal and hydraulic control	Alternative 4 + additional extraction wells and increased rate of pumping; restoration time 20 years for 75% of TSA to MCLs [DEQ, 1996, estimated that this would be 24 years to restore 80% of the TSA.]

Alternatives 4 and 5 include the following 3 design goals:

- maximize contaminant mass removal (alternatives 4 and 5 would involve new pump-and-treat wells in areas where the VOC concentrations were greater than 50 ppb)
- maintain hydraulic control (containment of the plume with no Portland Water Bureau pumping, new injection and extraction wells to prevent the TSA plume from expanding beyond its present boundaries)
- SGA protection (monitoring SGA quality, eliminating vertical connections between the TSA and SGA, and creating hydraulic gradient to keep the gradient always from the SGA to the TSA)

Where would the extracted groundwater be put? There were 4 ideas:

- municipal water supply (Rockwood Water District, Gresham)
- injection into TSA and/or SGA for hydraulic control
- discharge to Columbia Slough
- irrigation/surface recharge

The issue of where the extracted water is released has largely been unexplored with regard to heavy metal or other non-VOC contaminants. This needs further scrutiny, especially if the treated water is reused in any way that the problem will spread even further.

TGA Remediation Alternatives

The remediation plans have been submitted for the TGA cleanup at Cascade only. Table 3 shows remediation alternatives proposed by Cascade for their on-site clean-up. See Figure 3 showing contamination areas.

Table 3: Proposed TGA remediation alternatives by Cascade.

Alternative number	Description	Detailed description
1	continue existing controls and monitoring	continue existing on-site remediation program; 33 years to clean up on-site plume and 14-30 years for off-site plume
2	soil vapor extraction and passive recovery	Alternative 1 + soil vapor extraction (for unsaturated areas 1, 2, and 3), passive product recovery (for saturated areas - bailers in wells to recover LNAPL in Area 1), and additional source characterization [similar clean-up times as in Alternative 1]
3	active recovery, air sparging, and groundwater extraction	Alternative 2 + 9 groundwater extraction wells followed by air-stripping, pneumatic skimmers in wells for active LNAPL recovery, air sparging (injection of air into saturated portion of aquifer followed by soil vapor extraction); even though remediation times varied, hydraulic controls were to remain in-place for 30 years
4	in-situ groundwater remediation	Alternative 3 + bioremediation system (injection of nutrients and oxygen via injection wells); even though remediation times varied, hydraulic controls were to remain in-place for 30 years
5	soil excavation	Alternative 4 + soil excavation in Area 1 (6200 yd^3 to be removed); same remediation time frames as above

Summary Of Issues With Regard To Remediation Efforts And Plans

The following points can be made about the remediation plans to-date for the Interlachen community:

- in general, the alternatives considered by the Responsible Parties were reasonable remediation approaches, of greater concern to the Interlachen community though is the TSA clean-up because it has the most immediate threat of contaminating their wellfield
- if treated water is to be re-injected or put into surface water systems, issues of heavy metal contamination have been overlooked
- current pump-and-treat systems have possibility of moving non-volatile contaminants from the Cascade site to both the Columbia Slough and Fairview Lake
- air quality was only considered when it was acknowledged that the soil-vapor extraction system for the TGA cleanup would require emissions treatment because of emission rates for vinyl chloride would exceed critieria; analysis of VOC air emissions from pump-and-treat systems has not been formally evaluated

10. Toxicity Impacts - Risk Assessment

Remedial investigations of historical groundwater contamination have revealed the presence of a number of chlorinated solvents in groundwater. Toxicological concerns focus on the potential for these contaminants to affect human populations by exposure to contaminated water supplies. Additional concerns relate to exposure of wildlife and aquatic life if groundwater contaminants impact surface waters.

Chemicals of concern for risk assessment

The principal focus of risk assessment has been on the various chlorinated solvents and their degradation products that are present in comparatively high concentrations in groundwater. Limited attention has been given to inorganic compounds that may also be of concern. Previous studies have identified more compounds of potential concern in the TGA than in the TSA, and their is very limited evidence of contamination in the SGA. Contaminants in the TGA include tetrachloroethylene (PCE) and trichloroethylene (TCE) and several degradation products. Evidence of degradation to toxic intermediates is strongest in the TGA. Production of toxic degradation products is limited for samples taken from the TSA. In general, these compounds pose potential human health risks, and the potential ecological effects are of less concern.

Inorganic contaminants of potential concern in the TGA include chromium and lead. Copper has been detected in the soil, but the source of copper in the soils and the lack of dissolved copper in surface or groundwater is inadequately described. It is unclear from the various documents if analyses included copper and other potential toxic metals since reports fail to distinguish between contaminants that were not detected and contaminants for which analyses were not done.

Groundwater contamination risk

The risk assessment for the TSA focuses on potential excess cancer risks for compounds of concern including tetrachloroethylene (PCE), trichloroethylene (TCE), cis-1,2-dichloroethene, and 1,1-dichloroethene. The risk assessment is based on conservative human exposure scenarios for both consumption of contaminated water and inhalation of VOCs released from water. The compounds examined are known to be present in the contaminated groundwater, and they pose significant potential health problems. The risk assessment correctly identifies different routes of exposure for these volatile organic compounds, including risks from contaminated drinking water and inhalation risks as VOCs are liberated from pumped groundwater. Based on the limited expected exposure of local populations to these compounds, risks are estimated to be low. Additionally, the nature of the risks (toxic vs. carcinogenic) remain equivocal, although ATSDR (1995) suggests that TCE is a probable human carcinogen.

Risk assessments do not fully account for degradation intermediates that may also be produced. For example, the risk assessment for contamination in the TSA ignores the potential risk from TCE and PCE degradation products such as vinyl chloride. Vinyl chloride has been detected (and assessed) in the TGA but not the TSA. Evaluations of public health concern by ATSDR identified vinyl chloride, among other compounds, as posing a risk to public health. Failure to detect vinyl chloride in the TSA does not mean that it is unlikely to be present in the future, regardless of which site remediation action is chosen. The time period for remediation may be sufficient for vinyl chloride production to occur. Given the probable sorption of TCE and PCE in the TGA, these compounds have limited mobility. Degradation products such as 1,2-dichloroethenes and 1,1-dichloroethene are more mobile, so it is likely that these compounds could be transported to the TSA. It should be possible to assess the probable rate of degradation to vinyl chloride in the TSA.

Surface water contamination risk

Surface water contamination by VOCs is expected to pose little ecological risk. Ecological risks are limited by the comparatively low toxicity of the chlorinated solvents and degradation products to aquatic life and wildlife. Human health risks are expected to be low because of limited contact with contaminants. Potential contamination of Fairview Lake and the Columbia Slough by the migrating plume could exacerbate other water quality problems such as BOD loading.

Chromium contamination of TGA wells has revealed concentrations as high as 172 ppb. These concentrations would be problematic for aquatic life if chromium was discharged to surface waters during remediation activities. There should be concern for enhanced risk to aquatic life if pump-and-treat systems do not adequately remove chromium since the acute and chronic water quality criteria are 16 and 11 ppb, respectively. Similarly, lead concentrations at Taggart Spring and Sheppard Spring have been measured at levels exceeding chronic criteria for protection of aquatic life. Given the evidence of toxic metals at the site, drainage ditches and discharges could pose additional ecological risks to surface waters if concentrations of chromium and lead remain near chronic water quality criteria. Uncertainty is increased by limited monitoring of some potential sources. For example, the east drainage ditch at the Cascade site (which feeds into Osborne Creek and then into Fairview Lake) has been monitored only for VOCs.

Air contamination risk

Soil vapor extraction shows that there are comparatively high concentrations of vinyl chloride present in the TGA. In addition, the human health risk models used estimate higher lifetime risks for inhalation of TCE contaminated water than for direct consumption. It is problematic to assess the risks of airborne contaminants at the site, since ambient air monitoring data are lacking. Estimating risks of airborne contaminants in more difficult that assessing risks of contaminants in water, yet the proposed remediation activities and the interim remediation actions continue to release solvents into the air. It may be possible to estimate ambient air concentrations and assess whether continued releases pose any significant risks to workers on site or area residents. Additionally, further estimation of the rate of degradation of TCE and PCE to a volatile vinyl chloride intermediate is needed to determine if vinyl chloride will be a future contaminant of concern. Given that there is evidence of degradation to vinyl chloride in the TGA and degradation to intermediates that might be expected to lead to vinyl chloride in the TSA, some additional attention to risks from vinyl chloride is warranted.

Soil contamination risk

Contamination of surficial and subsurface soils result in limited, usually inadvertent, exposure to toxic materials. Soil is not expected to be a significant source of exposure.

Recommendations

In general, risks of contaminants at the sites are limited unless the water is used for drinking or bathing. Remediation activities are needed to assure that contaminant transport is restricted, thereby minimizing off-site risks, although the present risk to human populations is low. Assessments of the rate of degradation of contaminants, uncertain carcinogens (TCE), are needed to determine if significant concentrations of degradation products such as vinyl chloride, a known carcinogen, will increase human health risks over the life of the remediation efforts. Additionally, the potential for remediation activities to add to the contaminant load in the ambient air has not been completely assessed and needs further consideration. Toxic metal contaminants present in TGA may adversely impact aquatic life in surface waters if the toxic metals are unmanaged or if remediation activities remove and subsequently discharge these toxic contaminants to surface waters. The effects of metals are not adequately represented in discussions of the remediation efforts, although presently the discharge volumes and loads are probably very small. Full scale remediation efforts might present another story, and this could be controlled by permitting.

11. DEQ Proposed Recommendations for Cleanup

An overview of the DEQ Draft Record of Decision remediation plan is presented below for the TGA cleanup at Cascade and the TSA cleanup at both Boeing and Cascade. The remediation proposal for the TGA at Boeing has not yet been submitted for review.

Troutdale Sandstone Aquifer

Goals

- Restore the TSA to protective concentrations, if feasible, in a reasonable time. If this is not feasible, minimize the extent of the TSA containing VOCs above drinking water MCLs, or $1x10^{-6}$ excess cancer risk levels if they are lower than MCLs, and provide long-term containment for areas where concentrations are above MCLs or risk-based cleanup levels.

- Prevent ingestion of TSA groundwater that contains VOCs at concentrations above MCLs or risk-based cleanup levels.

- Protect fish and wildlife by preventing discharge to surface water of groundwater that has concentrations of VOCs that may exceed ambient water quality criteria.

- Prevent the further spread of contamination in the TSA to the extent practicable.

- Protect groundwater quality in the SGA and BLA.

- Allow existing use of groundwater resources in east Multnomah County.

Recommended Cleanup

The Department of Environmental Quality recommends the alternative shown below (Alternative 5) including possible variation as described in DEQ's Alternatives 5A through 6 for the TSA contamination area. The final configuration of Alternative 5 will be determined during the remedial design and initial implementation. The goal will be to improve the cleanup time for Alternative 5 by increasing the number, location, and extraction rates from those specified in the preliminary design in the Feasibility Study and/or by adding re-injection or re-infiltration of treated groundwater to increase the flushing of contaminants from the aquifer. Figure 9 illustrates potential extraction well locations for the recommended alternative. The recommended remedy would need to be designed to meet the following criteria:

- Restore the TSA to MCL cleanup levels within 10 years of Implementation of Phase 2 of the remedy in the area north of Sandy Boulevard, east of 205th Avenue, and in the western two-thirds of the Boeing facility;

- Restore the remaining portion of the TSA to cleanup levels within 20 years of implementation of Phase 1 of the remedy;

- Control horizontal spreading of the TSA contaminated groundwater plume at all times, including during pumping of the PWB south shore well field; and

- Control vertical migration of the TSA contaminated groundwater in areas where CU2 is thin or absent and the lower TSA is contaminated at or above MCLs. This criteria would apply during operation of all the PWB SGA supply wells for 60 days annually, or 90 days annually, if PWB supply wells 7, 8, and 14 are not pumped.

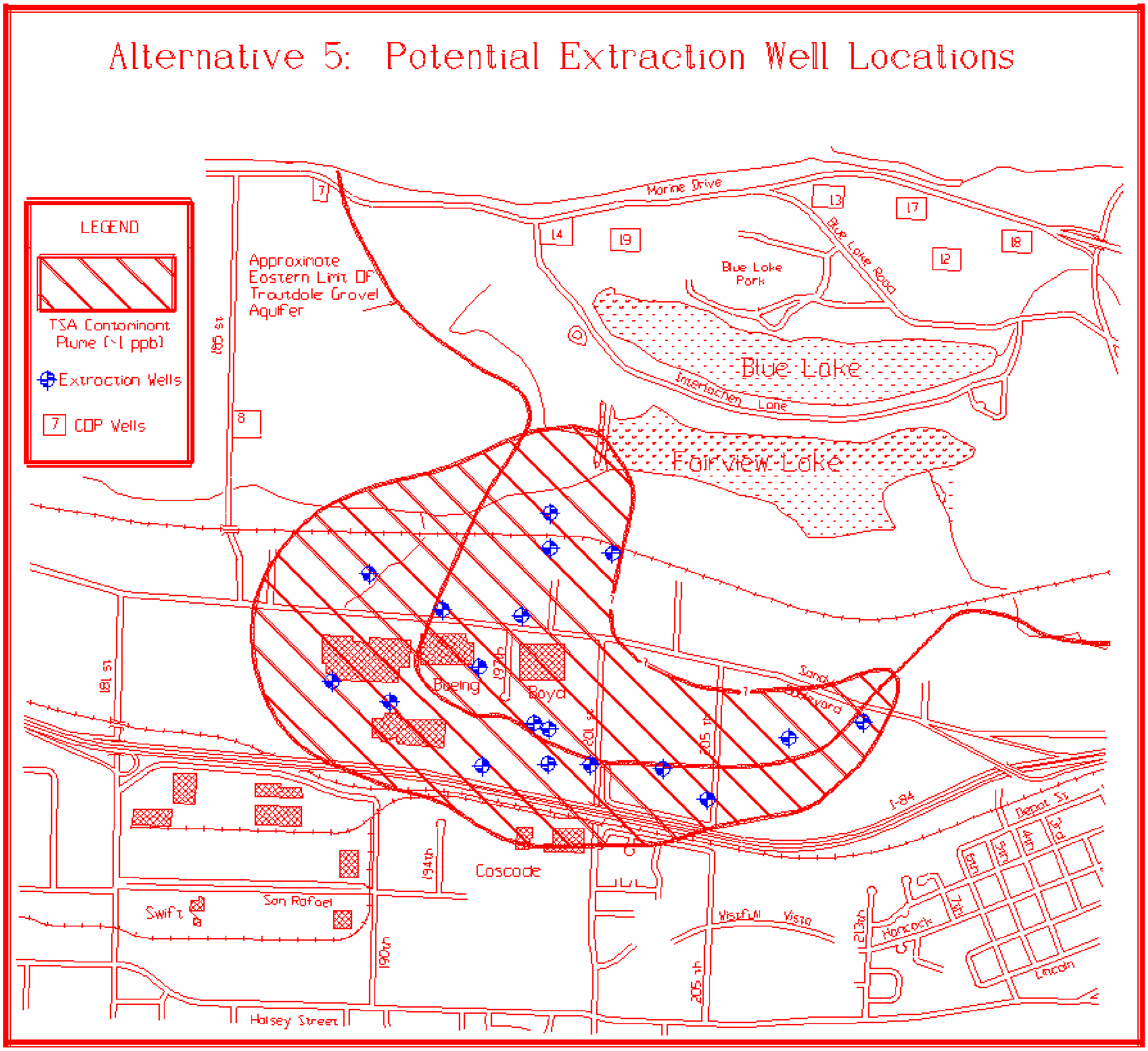


Figure 9: Remediation plan for the TSA cleanup (DEQ, 1996).

Cascade Corporation

Goals

- Restore groundwater in the TGA to the lowest protective concentrations, if feasible in a reasonable time. If this is not feasible, minimize the extent of the groundwater contamination that contains VOCs above the drinking water standard MCLs, or $1x10^{-6}$ excess cancer risk levels if they are lower than MCLs, and provide long-term containment for areas where concentrations are above MCLs or risk-based cleanup levels.

- Prevent ingestion of groundwater containing VOCs at concentrations above MCLs or risk-based cleanup levels.

- Protect wildlife by preventing groundwater discharge to surface water at VOC or chromium levels exceeding ambient water quality criteria.

- Prevent the further spread of groundwater contamination exceeding risk based protective cleanup levels.

- Reduce contaminant concentrations in and prevent contaminant migration from unsaturated zone soil to the extent necessary to achieve the groundwater cleanup levels.

Recommended Cleanup

The Department of Environmental Quality recommends the alternative shown below (Alternative 3) for the cleanup of the soil and TGA groundwater contamination at the Cascade Corporation site. The groundwater contamination in the TGA at Cascade is shown in Figure 10. Also, Figure 3 identifies the different Areas mentioned below.

- Soil remediation in Areas 1 through 3 using soil vapor extraction with possible expansion to Areas 4 through 6 based on additional soil gas monitoring for VOCs;

- Groundwater remediation, including operation of the current on-site extraction wells and off-site groundwater recovery trench, and groundwater extraction from an additional 9 extraction wells on-site;

- Air sparging in Areas 1 through 3, to promote volatilization of VOCs from soil and groundwater for recovery by the SVE system; enhanced recovery of floating product in the area of the former underground storage tanks;

- Contingency measures to provide for long-term hydraulic control of zones of groundwater contamination that cannot be cleaned up to protective levels;

- Maintenance of existing paved areas to limit the potential for future exposure to soil contamination by on-site workers; and

- Institutional controls such as deed restrictions preventing future use of shallow groundwater at the site until cleanup is achieved.

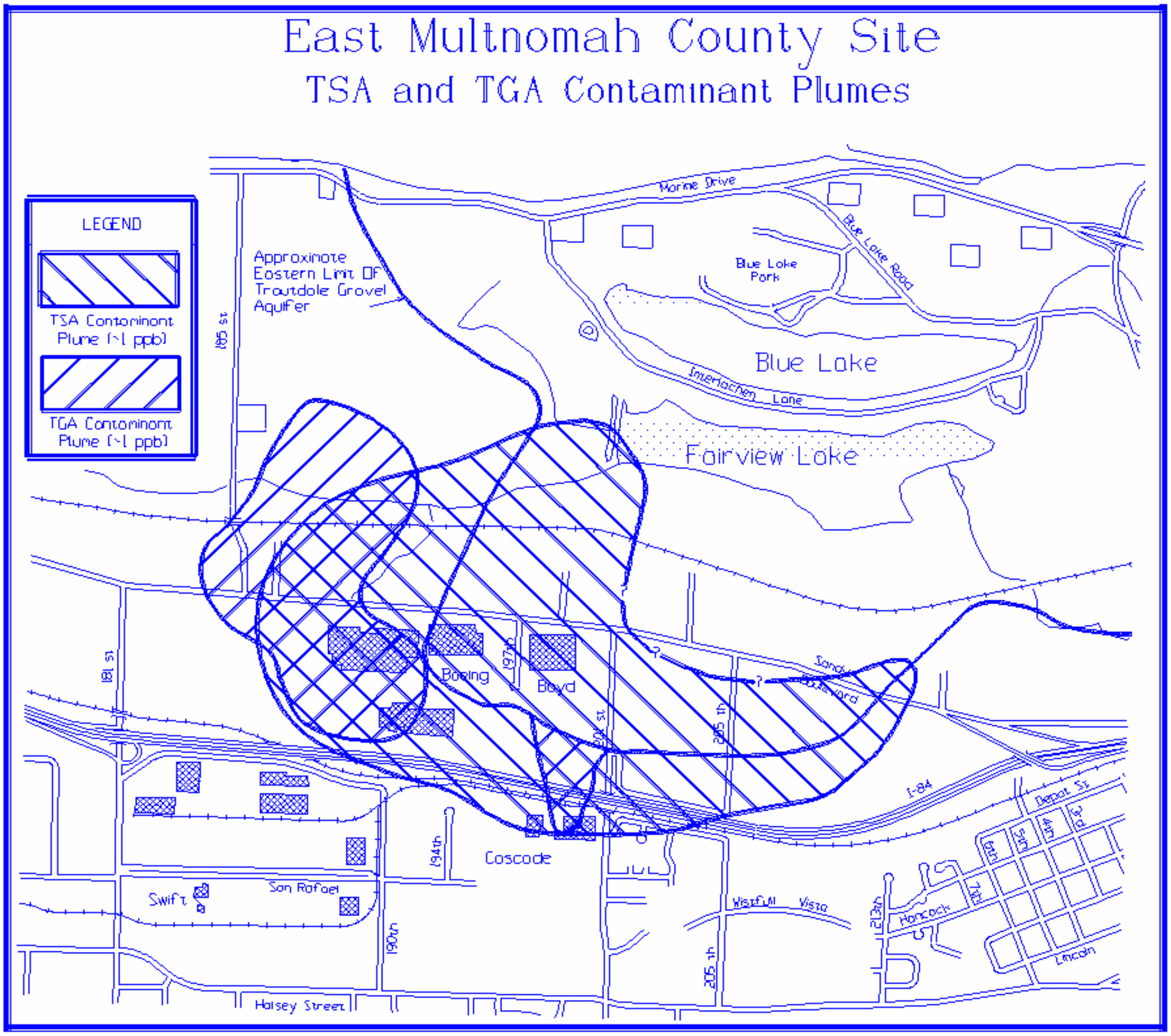


Figure 10: TSA and TGA contamination for both the Boeing and the Cascade sites (DEQ, 1996).

12. Conclusions and Recommendations

This review has generated a list of concerns for the protection of both surface and groundwater Fairview and Blue Lake communities. Several issues were raised after reviewing the Draft Record of Decision from DEQ released on September 1, 1996.

The following issues were identified by our advisory panel:

- Monitoring for Chromium and other known heavy metal contaminants should be required for treated effluents from the TGA remediation effort at Cascade and plans for heavy metal removal prior to discharge into nearby surface waters should be developed

Current on-site and off-site remediation of the TGA plume around Cascade has focused on removal of volatile organic compounds and their treatment through air-stripping towers. The current and proposed pump-and-treat systems discharge their effluent, after air-stripping, to the nearby storm drains that travel to Osbourne Creek and into Fairview Lake, or into Storm Drain Creek and into the Upper Columbia Slough. Heavy metals are not monitored even though the areas of remediation were known to have heavy metal contamination. There is a need to add heavy metals to the list of monitoring requirements and to prepare a contingency plan for removal of heavy metals if found in the effluents. Also, the loading of heavy metals to Fairview Lake and the Upper Columbia Slough may be restricted because of the Total Maximum Daily Load (TMDL) requirements currently being determined by DEQ. The present and future loading of heavy metals to nearby surface waters should be estimated, and this information should then be given to the Columbia Slough TMDL committee for evaluation.

- Inhalation of volatile organics from pump-and-treat facilities needs to be re-evaluated to determine if a public health risk exists under the proposed remediation plan

The impact of the proposed remediation plan in the Boeing-Cascade area has not been formally evaluated by DEQ for inhalation risk from the air-stripping towers. The proposed remediation plan calls for dozens and dozens of new pump-and-treat wells, increasing the magnitude of the remediation effort by from 3 to 10 times above current levels. Because of the proximity of the treatment facilities to residential areas, guidelines should be proposed by DEQ to ensure that there are no air quality risks. DEQ admitted at a September 4, 1996 public meeting that they have not formally evaluated the inhalation risk of the remediation plans. The Boeing TGA remediation plan, which has not been submitted for public review, also needs to have this level of scrutiny.

- Drinking water from the SGA aquifer wells PMX-195 and PMX-410 that have had several “hits” of TCE should be immediately removed from public consumption

A trailer park and residences near the Cascade site have had measurements of TCE in their drinking water SGA wells. These measurements have been as high 16 ppb of TCE. The Maximum Contaminant Level (MCL) for TCE is 5 ppb. Have all the residents who are drinking from this well been notified by DEQ about the possibility of contamination and what options they have to reduce the risk of ingestion of TCE or any of its more toxic by-products, such as vinyl chloride ? DEQ stated at the public meeting on 9/4/96 that SGA wells that have had “hits” of TCE are self-remediating since any contamination that seeps from the TSA to the SGA is removed by pumping from the SGA. If that is true, then DEQ must inform the residents that by drinking the water and using it, they are capturing any leakage of TCE from the TSA and removing it from the SGA. We recommend that wells PMX-195 and PMX-410 be removed from public consumption and an alternative water supply be provided.

- Recognizing that the remediation effort should proceed as fast as possible to ensure that the plume does not spread further, there have been no clear guidelines that DEQ would use to assess performance of the TSA or TGA remediation effort, nor a list of actions required if performance guidelines were not followed

This panel agrees that the proposed remediation plan is a correct approach to solving the groundwater problem in East Multnomah County and wants the implementation to proceed as fast as possible. But a clear plan by DEQ needs to be made as to what will trigger more aggressive remediation techniques. For example, the following questions need to be spelled out clearly in the DEQ Record of Decision:

- How will DEQ assess if the remediation plan is working ?
- What if the time frame for remediation seems to have lagged behind the proposed schedule, what steps will be taken, by whom, and when?
- What plans will be initiated if SGA contamination occurs, and what is the level of SGA contamination at which additional remediation steps will be started ?
- If injection for the TSA is proposed (which DEQ assumed would be the next logical step for remediation), has there been thought given to the following issues:
    - if oxygenated water (either from surface sources or recycling from air-stripping towers) were injected into the TSA, there could be both permeability (the vitric sandstone will oxidize and become more and more clogged to flow) and toxicity (TCE can now degrade to the more-toxic vinyl chloride in an aerobic environment) impacts

Before reinjection is attempted, an evaluation of the possible effects on the sandstone may need to be carried out. The TSA is made up mostly of sand-sized particles of basaltic glass that are oxidized when exposed at the surface and might easily be affected by oxygenated reinjection water. Atmospheric alteration of this basaltic glass creates clay minerals and palagonite which may greatly decrease the porosity and permeability of these deposits.

- According to the DEQ Draft Record of Decision, the computer model of the aquifer system “has been used to evaluate the effects of well pumping on the spread of contamination, to evaluate potential threats to existing well users, … and to develop cleanup options for the groundwater contamination.” The computer model has flaws that could render its use in making management decisions inappropriate.

The computer model has flaws that would make its use to formulate management decisions limited. Detailed comments about the model are shown in Section 8. This is of concern if remediation strategies hinge on the reliable prediction of the computer model. The management decisions made by DEQ must carefully show which ones are based on field data and which ones are based on the model predictions. Those that are based on the model predictions need to consider this committee’s comments about the weakness of the model and show that the remediation plan would not thereby be impacted. In general,

- the model overpredicts the efficiency of the remediation efforts, in that the expected time of remediation will probably be longer than expected
- the model underpredicts point concentrations of the plume in the SGA as a result of pumping by the COP wellfield
- the model overestimates the time the plume would take to reach the COP wells in that the plume may arrive at the wells sooner than predicted by the model

- An oversight in the Draft Record of Decision has been to propose remediation strategies without linking these strategies to surface water discharge limitations that are being formulated as a result of the TMDL process for the Columbia Slough. The TMDL process on the Columbia Slough may not allow the discharge of the pump-and-treat water to the Slough system as a result of nutrient or heavy metal loadings.

The DEQ groundwater group needs to make sure that the proposed remediation plan is a "cradle-to-grave" analysis. The disposal of the effluent from the treatment systems is assumed to be discharged into nearby surface waters, ultimately entering the Columbia Slough. The Columbia Slough is water quality limited for toxics and nutrients. Any new sources of toxics and nutrients may not be allowed or may be significantly restricted. The Record of Decision needs to factor in the cost and impact if effluent from the remediation pump-and-treat systems are not allowed to discharge to the Fairview Lake and Slough system.

- City of Portland needs to operate its wellfield with the understanding that their actions can substantially affect the plume's movement. Any unilateral pumping by the City without regard for the plume movement could endanger the existing groundwater supply of the community of Blue and Fairview Lake.

DEQ stated in its Draft Record of Decision that one objective of the clean-up was to "allow existing uses of groundwater in east Multnomah County." This includes allowing the existing uses of the Interlachen community wellfield. A recent resolution passed by the City Council on October 23, 1996 stated that the Water Bureau would attempt to stay within the DEQ pumping limit of 2.7 billion gallons in the SGA, but that the "DEQ guidelines would not operate as absolute constraints" if the City deemed it necessary to exceed those guidelines. If the City violates guidelines that move the plume and contaminate the SGA aquifer, not only would the Interlachen community water supply be threatened, but eventually the City's own well-field would be threatened. Hence, close cooperation between the City of Portland Water Bureau, the Responsible Parties, and DEQ are necessary for mitigating the impacts of the plume and preventing its further spread.

13. Glossary of Terms

The following terms are used in the report and are defined here for ease of understanding.

acetone: An intermediate chemical in industrial processes and used as a solvent for paints and lacquers. In addition its also used as a cleaning agent and has a comparatively low acute and chronic toxicity.

acute toxicity: Involving a single exposure which can elicit toxic effects, immediate effects from a single exposure. Coming speedily to a crisis, 96 hr. to 4 days

alluvial: Composed of a clay, silt, sand, gravel, or similar material deposited by a stream or running water.

aquitard: A confining (highly impermeable) bed of material which retards but does not prevent the flow of water.

arkosic: A mineral rich sandstone, coarsely grained usually pink or reddish and composed of angular or subangular grains that may be moderately well sorted.

BLA: Blue Lake aquifer (see Figures 5-7)

BMS-11-7B: metal cleaning solvent; mixture of naptha, ethyl acetate, MEK, and isopropyl alcohol

brecciated: converted into or characterized by breccia, a coarse grained clastic rock, composed of angular broken rock fragments held together by mineral cement, and having sharp edges.

carburizing: A technique to increase the hardness and strength of a low carbon steel by heating it in a carbonaceous material environment so the steel can acquire a high carbon surface layer.

clast: An individual grain or fragment of a sediment or rock, produced by the mechanical weathering of a larger rock mass.

chlorinated: compounds containing chlorine

chloroform: A chemical used as a solvent and frequently used as a dry cleaning spot remover. It can be detected by smell.

chromium: A metal used in electroplating various parts' surfaces for wear resistance. It is also used in steel alloys.

chronic toxicity: Consecutive repeated exposure over the life span of the species resulting in toxic effects, long term exposure resulting in toxic effects. continuing for a long period of time, lingering, 30-60 days for which there are no adverse effects, partial life cycles (less than 15 months) or whole life cycles.

COC: Chemicals of Concern: chemicals frequently detected in the TGA or TSA groundwater at concentrations above MCL and/or which have the potential to be detected at elevated levels due to degradation pathways of other contaminants

CU1: Confining unit 1, a region of low permeability material between the TGA and the TSA, see Figures 6 and 7

CU2: Confining unit 2, a region of low permeability material between the TSA and the SGA, see Figures 6 and 7

1,1 DCA: 1,1 dichloroethane

1,2-DCE: 1,2 dichloroethene

DEQ: State of Oregon Department of Environmental Quality

DEQ Record of Decision: The Oregon Department of Environmental Quality's proposed recommendation for cleaning up the groundwater contamination in East Multnomah County

desorption: Becoming unattached or removed from a medium either through chemical or physical processes.

DNAPL: dense non-aqueous phase liquid

EMC: East Multnomah County

ethyl benzene: Produced by reforming petroleum fractions and used in gasoline. It is also a precursor to styrene and is used with paints as well.

facies: The aspect, appearance and characteristics of a rock unit, usually reflecting the conditions of its origin, and used in differentiating the unit from adjacent ones.

feldspar: a group of abundant rocks forming minerals of formula, $MAl(Al,Si)_3O_8$ where M can equal sodium, potassium, calcium, barium, rubidium, strontium or iron.

leakance: water leaking from one aquifer into another aquifer through a confining unit

leaky aquitard: individual beds of silt and clay which are usually impermeable but have channels cut into them producing a stratum with permeable spots in it.

lenticular: Resembling in shape the cross section of a lens, especially of a double convex lens.

lithic: A synonym for lithologic, said of a medium grained sedimentary rock containing abundant fragments of previously formed rocks.

lithology: The description of rocks on the basis of such characteristics as color, mineralogic composition and grain size.

LNAPL: light non-aqueous phase liquid

Manganese: Allowing agent to improve the strength, toughness and hardness of steel.

MCL: maximum contaminant level

MEK: methyl ethyl ketone

metamorphic: mineralogical, chemical. or structural adjustment of rocks due to physical or chemical conditions imposed at a depth below the surface of weathering and cementation affect the rocks.

MG: million gallons, MGD million gallons per day

micaeous: consisting of or pertaining to mica; capable of being split into thin sheets.

P: Phosphorous

palagonite: an altered tachylyte (a volcanic glass which is normally black, green or brown in color due to abundant crystalites, and is formed from basaltic magma), brown to yellow or orange in color and found in pillow lava.

paleo: Denoting the attribute of great age. A prefix indicating a pre-Tertiary origin, and used to characterize a rock to a name which it is added.

PCE: tetrachloroethylene

piezometer: An instrument used for measuring the pressure of a fluid, such as the water level in a confined aquifer.

plutonic: Pertaining to igneous rocks formed at great depths.

ppb: parts per billion equivalently known as , micrograms per liter.

radiometric dating: Calculating the age in years of geologic materials by measuring the presence of short life radioactive elements such as Carbon-14.

rinsate: waste water produced from industrial rinsing and cooling processes

"screened" part of well: location where water is being withdrawn into the well from the surrounding aquifer.

SGA: Sand and Gravel Aquifer (see Figures 5-7)

smectite: A name used to describe a specific group of clay minerals which consist of sodium, potassium, magnesium or calcium.

sorption: The state or process of gathering or adhering to a media by adsorption or absorption.

stratigraphy: A branch of geology dealing with the classification, correlation and interpretation of stratified, or layered, rocks.

stratovolcanoes: A volcano constructed of alternating layers of lava and clastic rocks deposits ejected from the volcano.

SU1: siltstone unit 1, geologic description of a low permeability siltstone unit between the TGA and the TSA, approximately equivalent to CU1, see Figure ?

SU2: siltstone unit 2, geologic description of a low permeability siltstone unit between the TSA and SGA, approximately equivalent to CU2, see Figure ?

tabular: Said of a feature having two dimensions that are much larger or longer than the third, such as an igneous dike or a plateau.

TAG: technical assistance grant from EPA

TCA: trichloroethane

TCE: trichloroethylene

tempered steel: heat treating process/technique to increase the strength and hardness of steel and still have some ductility.

TGA: Troutdale Gravel Aquifer (see Figures 5-7)

TMDL: total maximum daily load. This is a process where DEQ allocated waste loadings from point, non-point, and background sources for water quality limited streams

toulene: A chemical used as a solvent with approximately 2/3 of usage for paints and coatings. It has similar toxicological affects to benzene.

toxicology: the study of chemicals and their effect on living organisms, the science of dealing with the effects, antidotes and detection of poisons.

TPH: Total Petroleum Hydrocarbon

TSA: Troutdale Sandstone Aquifer

UST: underground storage tank

vadose zone: The zone of aeration, a subsurface zone with water under pressure less than atmospheric including water held by capillarity and containing air or other gases. The zone is bounded on the top by the land surface and in the bottom by the zone of saturation.

vapor degreaser: device to clean metal parts: the process consists of dipping parts into a tank of solvent vapors where oil, grease, and metal particles are removed

vinyl chloride: A polymer created as result of PCE braking down several times. The direct parent of vinyl chloride is 1,1 DCE dichloroethene.

vitric: Said of pyroclastic material characteristically glassy with more than 75% glass.

VOC: volatile organic compounds

weathering: The destructive process by which earthy and rocky materials on exposure to atmospheric agents change in color, texture, composition and firmness and results in the physical disintegration and chemical decomposition of rocks.

zeolites: A generic term for a large group of white or colorless hydrous alummosilicates (A silicate with alluminum) that is similar to feldspars with sodium, calcium and potassium.

14. Questions and Answers

Citizens of the Troutdale community were asked to submit questions to the review panel for discussion. These questions are summarized below with answers provided by the review panel.

1. What is the role of Fairview Lake in terms of its influence over the Troutdale Sandstone Aquifer (TSA) and the Sand and Gravel Aquifer (SGA)? Do we need to maintain a large volume of water (about 102 surface acres) in order to keep a certain amount of hydraulic pressure that may be related to controlling plume movement?

If there is no connection between the TSA and SGA, the Lake does not influence plume migration toward the Interlachen wells. One management alternative is to keep Fairview Lake at a high elevation in the summer to retard movement of the plume. This would allow the City of Portland to pump at a higher rate without moving the plume. This is a controversial issue since the connection between the lake and the TSA and SGA has not been carefully investigated. To improve water quality in the surface water, lowering lake levels and reducing detention time may enhance the quality of the water.

2. How would dredging the lake effect the health, short-term and long term, of our water supply? What questions about dredging should we be asking now?

Dredging the lake sediments could have the following results: removal of toxic material thus restoring the quality of the Lake; removal of a low permeability barrier between the TSA and Fairview Lake thus increasing the flow of groundwater into the Lake; removal of material high in organics and nutrients could improve the trophic status of the lakes since presently the system is highly eutrophic (excessive growth of algae and aquatic plants).

3. How do we get adequate scientific PEER REVIEW to help us as we evaluate the dynamics of our environmental dilemma, i.e., sediment testing, water quality testing, etc.?

The panel is now providing that service through the EPA TAG program. But with regard to sediment testing and water quality testing, from time-to-time duplicate samples of those taken by other entities can be tested. This expense though would be borne by the community.

4. What can we do as a community to insure our citizen voice as we attempt to deal with major corporations, 3 cities, Mult. County, the Mult. Drainage District, Port of Portland and development interests while trying to protect our water supply?

Your community has already taken a first step in that direction by having a technical review panel represent them with DEQ. But in the future, probably the best way to have a good citizen voice is to *have a well-educated group of citizens. Citizens that are able to understand and articulate their concerns well can be heard. The TAG process is hopefully a step in the direction of education of the community.*

5. In what ways is the East Mult. Co. Site (EMC) similar to the Woburn, Mass. Site involving TCE in 2 local city wells? In what ways are we different ? Do we have an advantage because our site has more data available? Is the citizen/local resident able to grasp the full implication of the EMC site?

In 1990, a cooperative report from the local citizen group and the Harvard School of Public Health identified TCE as the probable cause of a variety of local health problems. TCE had been in the local drinking water for a period of several years and had been linked anecdotally to elevated incidence of leukemia.

Like the Woburn case, the local aquifers are contaminated with chlorinated solvents. Unlike the Woburn case, the contamination is less wide-spread and residents who might have been at risk have largely been removed from the contaminated water supply. The larger Interlachen population has not been exposed and would only be exposed if no remedial actions take place. While the potential for contamination of Portland Water Bureau wells still exists, it seems remote. Citizens need to understand that the present actions at the site are designed to reduce further risks of exposure to contaminants in the groundwater.

Unlike the unknown history of contamination in Woburn, MA, the EMCGC site has a fairly well-known history. Actions to limit risks were taken early, and the effects of historical contamination were restricted to a small number of people. Right now, risk to the local population is small, but clean-up and remediation activities will take several years to be effective, so citizens need to continue to monitor activities at the site to assure that contamination is being removed.

6. How do we best teach and reach the local community?

Forums, sessions before or after neighborhood association meetings. Having the site of the meetings in the community is important for reaching your neighborhood. For example, the community meeting with the review panel on October 17, 1996 was held in the community at the Lake House off Blue Lake Road. The availability of easy-to-read materials, like the "Fact Sheets," from the panel and videos of community meetings and testimony before City Council are excellent tools for teaching and educating the community.

7. Exactly what are our issues / How do we address them effectively?

The main issue that your community is facing is the protection of your drinking water supply and surface water for recreation and habitat. These can be addressed through education of the community.

8. Is it important for Interlachen to know whether or not its well head protection area (capture zone) is within the boundaries of the City of Portland's backup water supply well head protection area? What are the boundaries of the City of Portland's well head area? Is there a current map available? If Interlachen is WITHIN the Portland well head delineated area what does that mean for us? Is this area considered a Goal 5

natural resource by the Department of Land Conservation and Development? Will it be protected under Goal 5? Do we have to lobby for protection?

This was designed as a voluntary program for communities with ground water resources. The well head protection program was voluntary for communities under 10,000 in population or where a public utility district has 3,000 or less service connections, such as the Interlachen community. Since the City of Portland wellfield falls within the threshold criteria, a well head protection program is required. Doug White from the Department of Land Conservation and Development (DLCD, in Salem) is in charge of the program.

9. Will it be necessary for Interlachen to have an air stripper in place in the next 10 years to prepare for the possible hit of the advancing plume?

The necessity of an air-stripper is dependent on if the remediation plan is put into place quickly and with enough effect that the plume is captured. If the Interlachen well becomes contaminated, the community will have to decide whether to abandon the well and use another source since drinking water dependent on a pump-and-treat system could be risky.

10. From the panel's point of view, each in their respective fields of expertise, what other questions should we be asking to help us protect our drinking water supply ?

The City of Fairview, Wood Village, and Gresham discharge stormwater to the Fairview Lake area. Concerns could be raised about the water quality of that runoff. The water quality of Fairview Lake and its sediments need to be evaluated for public health assessment. Many of the questions that could be asked are highlighted in our Conclusions and Recommendations Section 12.

11. Is there a threat to the Lachenview well (east well) if it draws from 2 aquifers, the TSA and the SGA ? What are the concerns involving the close proximity of Fairview Lake to this well ?

The threat to the Lachenview well is dependent upon the success of the proposed remedial alternative. Since the Lachenview well draws water from the TSA, it is more at risk for groundwater contamination than the other Interlachen wells. Since the hydraulic relationship between the TSA, SGA, and Fairview Lake have not been adequately studied, the effects are difficult to estimate. However, as a worst case scenario contamination may reach the Lachenview well before it would infiltrate the bottom of Fairview Lake since hydraulic pumping tests in the area imply that the Fairview Lake surface water is not connected well to the groundwater system.

12, We at Interlachen are very concerned about our water quality. The solution ? The effects ? What can we do to help, if any ?

Perhaps the best strategy for the community is to be educated about the problem so that concerns of the community can be articulated to DEQ, Responsible Parties, and others who can play a part in remediation, such as the Portland Water Bureau. Close cooperation between all interested parties usually yields the best results.

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