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Report to the City
of Blaine on
Wellhead protection

97190748 program

WASHINGTON STATE
DEPARTMENT OF
ECOLOGY

Report to:

City of Blaine
Blaine, Washington

Wellhead Protection Program

Prepared by:

Golder Associates
Redmond, Washington

Funded in Part by the Washington State Department
of Ecology Through the Centennial Clean Water Fund

In Association with:

Adolfson Associates, Inc.
Seattle, Washington

and

EARTH TECH
Bellevue, Washington

November 25, 1996

Golder Associates Inc.

4104-148th Avenue, NE
Redmond, WA 98052
Telephone (206) 883-0777
Fax (206) 882-5498

Golder Associates

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EXECUTIVE SUMMARY

This document is a draft Wellhead Protection Plan (WHPP) prepared for the City of Blaine. Wellhead protection is a federally-mandated, State-implemented program designed to protect ground water-based drinking water supplies. The program is managed in Washington by the Washington State Department of Health (WDOH). The intent of the Wellhead Protection Program (WHPP) is to protect potable ground water supplies through resource management strategies aimed at pollution prevention. The Blaine WHPP will operate in conjunction with the Blaine Ground Water Management Program (GWMP), which has been approved by the Washington Department of Ecology (Ecology), and is currently being implemented. The region covered by the GWMP includes the Wellhead Protection Study area, and the intent is to build from the GWMP and refine the information to specifically address protection of the City wells from contamination.

Public water purveyors have primary responsibility for developing and implementing local wellhead protection programs. Because of the purveyors often limited jurisdictional control, integration and coordination with state, county and local agencies involved in water-resource issues is essential.

The Blaine area is a growing urban/rural community that relies solely on ground water for drinking water purposes. Currently, the City of Blaine supplies water to most residences within the City limits, and to several areas outside of the City limits. In addition, the City of Blaine currently wholesales water to the Birch Bay Water District and Bell Bay Jackson Water Associates. Protection of the ground water supply is critical to the City, its residents, and others that rely on the water supply.

The following executive summary discusses the main components and results of the WHPP.

Hydrogeology and Delineation of Wellhead Protection Areas (WHPAs)

The hydrogeologic conditions of the Boundary Upland Area were evaluated based on previously existing data, and on studies of the Boundary Upland area, including installation of monitoring wells, water level and water quality data collection, and a geophysical survey. From the hydrogeologic data, a conceptual model of the hydrogeologic system was derived to aid in the delineation of the WHPA's for the City wells.

The Boundary Upland area consists of three general aquifer systems; a Perched Aquifer System; a Shallow Aquifer System; and a Deep Aquifer System. The Perched Aquifer System is restricted to the upper portions of the Boundary Upland, and provides adequate quantities of ground water in some cases for domestic use. The Shallow Aquifer System is the most heavily utilized aquifer system of the Boundary Upland area, and is tapped by most of the deeper domestic wells and all but two of the City wells. The Deep Aquifer system occurs at a depth of between 600 and 750 feet bgs, and is separated from the Shallow Aquifer System by 400 to 500 feet of low permeability silt and clay. This aquifer system is tapped by City Wells No. 1 and No. 2.

It appears, based on aquifer recharge estimates, that additional wells could be developed in the Shallow Aquifer System without significant adverse consequences on ground water levels. Baseflows to Dakota Creek could potentially be effected by significant additional development of the Shallow Aquifer System. However, it is important to note that any adverse effects on the flows of Dakota Creek will likely occur along the tidally-influenced reach of the creek (Figure 1-1), which is exempt from the stream closure rule under WAC 173-501-030. Based on the recent pumping test of replacement Well No. 1, it is estimated that the Deep Aquifer is capable of sustaining as much as 2,000 to 3,000 gpm. Evaluation of the drawdown response to longer-term pumping (currently being collected) is required to refine the estimated long-term yield of the aquifer. Development of the Deep Aquifer has several advantages over further development of the Shallow Aquifer including less potential impact on streamflows and other water rights, and a greater potential yield per well.

Wellhead Protection Area Delineation

A WHPA is defined as the surface and subsurface area surrounding a well, wellfield, or spring that supplies a public water supply through which contaminants are likely to pass and eventually reach water well(s) (Department of Health, 1995). From the conceptual hydrogeologic model described briefly above, the WHPAs were delineated through a combination of hydrogeologic mapping techniques and ground water modeling. The hydrogeologic mapping technique identified the potential area of contribution, or recharge area of the City wells. The ground water model was subsequently used to evaluate Time of Travel (TOT) zones associated with the City wells.

In the State of Washington, wellhead protection areas are defined primarily based on the 1-, 5-, and 10-year TOTs of ground water to the well(s). The 1-year TOT zone, for example, represents the area around a well or wellfield in which a contaminant moving at the same rate as ground water would reach the well or wellfield within 1 year. These TOT zones are used to define aquifer management regions around a well or wellfield where specific management strategies/ordinances are implemented to reduce the potential for ground water contamination. The capture zone area for each of these TOT's is progressively larger for increasing TOT. Consequently, management strategies are typically tailored to these TOT's, with the most restrictive approaches within the 1-year TOT zone, moderately restrictive within the 5-year TOT zone, and least restrictive within the 10-year TOT zone. TOT zones do not take into account the time it may take for a contaminant to move from ground surface to the aquifer. In some cases, this vertical time of travel is sufficiently long that it should be taken into account in the delineation of the WHPAs.

The Shallow Aquifer System and the Deep Aquifer System were modeled separately to obtain the estimated 1-year, 5-year, and 10-year TOT's associated with all of the City wells. The results show that, due to the limited recharge area of the shallow City wells (Boundary Upland area), any contaminant released in the Boundary Upland area could potentially reach the wells within a relatively short time, generally less than 5 years.

The vertical travel time from ground surface to the Shallow Aquifer System and the Deep Aquifer system was also evaluated as part of the wellhead delineation process. This evaluation suggested that the time it may take for a contaminant to reach the Shallow

Aquifer System could be short, and therefore, should be assumed to be instantaneous as suggested by WDOH. In contrast, the time that it would take for a contaminant at ground surface to reach the Deep Aquifer System was estimated at 240 years. Therefore, with regard to the Deep Aquifer wells a WHPA is not recommended.

Due to the small difference between the 10-year TOT's and the 5-year TOT's, and the degree of uncertainty in the hydrogeologic conditions, it is recommended that management strategies consistent with a 5 -year TOT be adopted throughout the WHPA, and that a 10-year WHPA not be designated.

The recommended 1-year and 5-year WHPA's are shown on Figure 5-1. The recommended WHPA's generally correspond with the 1-year and 5-year TOT's, but were refined to reflect jurisdictional and property boundaries in order to provide a rational basis for implementation of the wellhead protection measures. The proposed 5-year WHPA is designated the "Blaine WHPA".

Present Water Quality

The current ground water quality within the Boundary Upland is generally good. Nitrate concentrations within the Boundary Upland area are currently well below the Maximum Contaminant Level (MCL) of 10 mg/L. However, the pervasive nature of nitrate detected in wells within the Boundary Upland area is of concern to the City, because the Boundary Upland area is the primary recharge area of the City wells. A trend of increasing nitrate concentrations in some of the City wells raises concern over future development of the Boundary Upland area.

Inventory of Potential Contaminants

A sanitary survey of the Blaine Watershed was conducted to evaluate the condition of the City wells, and the susceptibility to contamination due to possible vandalism. The survey revealed that the City wells are susceptible to contamination or damage by vandals as a result of equipment/housing and security deficiencies.

An inventory of potential contaminant sources within the Blaine WHPA established the presence of seventeen active underground storage tanks at seven sites, and seven permitted RCRA facilities. RCRA facilities generate 220 pounds or more of hazardous waste or 2.2 pounds or more per month of extremely hazardous waste. Several other potential sources of contamination were identified within the Blaine WHPA, including sand and gravel quarries, septic systems, stormwater disposal, solid waste disposal, possible household hazardous wastes, agricultural and forestry activities, roadside spraying, and abandoned or improperly designed domestic wells.

A one-day traffic survey of H-street truck traffic revealed that most of the truck traffic is associated with the shopping center between Grant Avenue and Ludwick Avenue, and is generally confined to the present City limits. A few trucks transporting construction materials and dairy products traveled along H-street through the Blaine WHPA towards

Lynden and Sumas. A large amount of truck traffic passes through the western portion of the Blaine WHPA along Truck Route SR 543 in the vicinity of City Wells No. 7 and No. 8.

Contamination Potential

A quantitative assessment of contamination potential from the various sources of potential contaminants identified during the surveys was conducted through a nitrate loading analysis and an EPA risk ranking analysis. The purpose of this assessment was to establish a framework for developing effective contaminant source management and risk reduction strategies.

A conservative nitrate loading analysis was conducted specifically to evaluate potential future development scenarios of the Boundary Upland area. Three generalized development scenarios were evaluated, the results of which suggest that nitrate levels could increase to between roughly 2 and 4 mg/L, for high density sewered development or moderate density (one house per acre) unsewered development. The sources of nitrate considered in the analysis were from septic systems and lawn/garden fertilizers. The primary outcome of the analysis as part of the WHPP, however, is that any future development of the Boundary Upland area should be accompanied by specific strategies to reduce the potential of impacting groundwater quality.

The results of the EPA risk ranking evaluation indicates that the greatest risk to the City wells may be from illegal dumping in the sand and gravel quarries of the Boundary Upland area. Ranked second is transportation spills in the Boundary Upland area (along H-street). Septic systems under present density are ranked third, followed by underground storage tanks, which are ranked fourth. Any future USTs placed in the Boundary Upland area could potentially be a much greater threat to the City wells than the threat posed by the existing USTs.

A significant threat to the City wells that was not addressed through the risk ranking evaluation is that of vandalism and well/equipment deficiencies within the Blaine Watershed.

Ground Water Quality Management

Watershed System Upgrades

The City has taken several measures recently to improve the Watershed water supply system, including attaching flow meters to most of the wells, and other equipment upgrades. However, additional well and equipment upgrades are needed in order to properly track wellfield performance and to protect the water supply from vandalism.

Contaminant Source Management/Risk Reduction Program

The contaminant source management/risk reduction programs presented in the report builds on the management strategies proposed by the Blaine GWMP. The WHPP, in many respects, is viewed as an adjunct to the Blaine GWMP. Specific contaminant source management strategies, which are either consistent with those proposed by the GWMP or an augmentation thereof, are recommended in the WHPP. These recommendations stem from the results of the contaminant source inventory and traffic survey, in conjunction with the ranking of the potential contaminant sources.

Specific management strategies are recommended for sand and gravel mining, septic systems, solid waste facilities, stormwater disposal, underground storage tanks, commercial hazardous wastes, household hazardous wastes, agricultural practices, roadside spraying, abandoned wells, transboundary impacts, and impacts from future land use. Table 9-1 provides a matrix of the recommended management strategies.

Spill Response Plan

Management/risk reduction strategies representing the basic components of the Spill Response Plan are listed. The recommended management strategies involve providing emergency management teams with the locations of the City wells, and requiring that the emergency response teams notify the City of any incident that might adversely impact any of the City's wells. Other recommended strategies are listed to promote the development and maintenance of an effective spill response program plan for the Blaine WHPA.

Public Outreach

Protection of the City's wells to a large extent will be accomplished through voluntary compliance by the public rather than through regulatory controls. Therefore, public outreach should be an important component of the Blaine WHPP. This may involve door-to-door surveys or mailing out questionnaires to residences within the WHPA to raise awareness and document potential sources of contamination (abandoned wells, for example). Information concerning use of household hazardous wastes, lawn and garden fertilizers, and pesticides could be disseminated to residences within the WHPA. Another approach to public involvement would be developing a curriculum for schools in the Blaine School District, covering fundamentals of ground water, water quality risk factors, and ground water management strategies.

Contingency Plan and Additional Ground Water Development Options

The City's existing Water Supply Emergency Response Action Plan (WSERAP) provides adequate contingency options for emergency and short term water deficits, and should be adopted for use as part of this WHPP. However, additional long-term strategies are required in order to meet present and projected peak day demands, and to ensure that an adequate supply of water will be available in the event that one or more of the City wells becomes contaminated.

Several options, including development of the Deep Aquifer, an intertie with Surrey water or Birch Bay, reuse, and system upgrades appear viable to meet future demands and contingencies. A well in the Deep Aquifer may be capable of yielding between 800 and 1,500 gpm or more, based on available data, and as such could potentially satisfy projected peak day demands through year 2015. Additional wells may be required, however, to provide total demand under worst case conditions if other options are not pursued. The intertie with Surrey could provide adequate emergency and short-term supply demands depending on the agreement that can be made with Surrey. The intertie with Birch Bay would be viable only if a proposed pipeline from Ferndale to Birch Bay is completed or if a new water treatment plant is constructed. The recommended way to meet projected demands and provide adequate contingencies is to pursue a combination of a new ground water supply and water reuse and system upgrades to meet normal system demands, and an intertie with Surrey to provide emergency/short term supplies when needed.

Development of the Deep Aquifer System appears to be an attractive option available to the City for increasing its ground water supply, because the Deep Aquifer is not susceptible to contamination, water rights may be more easily acquired, and the yield from a single well in the Deep Aquifer could be sufficient to make up the current and projected water supply deficit. Additional data on the character of the Deep Aquifer, is currently being collected before proceeding with development. If results prove positive, and ongoing negotiations with Ecology for additional water rights are successful, a new deep well could be constructed by the end of 1997, assuming funds are available and the system demand remains as projected in this report.

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1. INTRODUCTION

Wellhead protection is a federally-mandated, State-implemented program designed to protect ground water-based drinking water supplies. The Federal mandate is provided under Section 1428 of the 1986 Safe Drinking Water Act Amendments; and the State Wellhead Protection Program is managed by the Washington State Department of Health (WDOH). The intent of the State's Wellhead Protection Program (WHPP) is to protect potable ground water supplies through resource management strategies aimed at pollution prevention. The State WHPP operates in conjunction with other State and Local programs, such as the Ground Water Management Program, Aquifer Protection Program, Critical Aquifer Recharge Area (CARA) Protection Program, and State point and non-point pollution control programs. A Ground Water Management Program (GWMP) for the general Blaine area has been approved by the Washington Department of Ecology (Ecology), and is currently being implemented. The region covered by the GWMP includes the Wellhead Protection Study area, and the intent is to build from the GWMP and refine the information to specifically address protection of the City wells from contamination. The Blaine WHPP will form part of the City of Blaine Water System Plan (WSP), and several portions of this document will be referenced or included in the WSP.

In July of 1994, the Washington Administrative Code (WAC 246-290) was modified to include mandatory wellhead protection measures for all Group A public water systems in the state using wells or springs for water supply purposes. Public water purveyors have primary responsibility for developing and implementing local wellhead protection programs. Because of the purveyors often limited jurisdictional control, integration and coordination with state, county, and local agencies involved in water-resource issues is essential. However, a key aspect of wellhead protection is the emphasis on local control. The nature of wellhead protection is such that local conditions, whether geologic or political, are key in developing functional management strategies to protect a well or wells supplying drinking water.

The Blaine area is a growing urban/rural community that relies solely on ground water for drinking water purposes. Currently, the City of Blaine supplies water to most residences within the City limits, and surrounding community. In addition, the City of Blaine currently wholesales water to the Birch Bay Water District and Bell Bay Jackson Water Association. Protection of the ground water supply is critical to the City, its residents, and others that rely on the water supply.

The Wellhead Protection Program for the City of Blaine was initiated by the City of Blaine. The program is being funded by the City, with a matching grant from Ecology's Centennial Clean Water Fund.

1.1 Study Area

The study area comprises approximately 14 square miles in northwestern Whatcom County, Washington, near the City of Blaine (Figure 1-1). The general study area is bounded to the north by the border between Whatcom County and British Columbia; on the west by

Drayton Harbor, on the south by southern flank of the Boundary Upland; and on the east by the topographic divide separating the Dakota Creek watershed from the Bertrand Creek Watershed.

The area of primary interest is the Boundary Upland area (Figure 1-1), which is the primary recharge area of the City wells. Activities such as spills and land-use within the Boundary Upland area could potentially lead to contamination of the City wells. The Boundary Upland is an 8 square mile plateau area elongated east-west located along the U.S.-Canadian Border at elevations of between 200 and 500 feet above mean sea level (amsl). To the south and west of the Boundary Upland lies generally flat to gently sloping topography at elevations of between 0 and 100 feet amsl. Dakota Creek flows east to west in the lowland area south of the Boundary Upland, and discharges into Drayton Harbor, as shown in Figure 1-1.

Six of the City's nine wells are located in the Blaine Watershed, which is located approximately 2.5 miles east of the City along the southern flank of the Boundary Upland. Two producing City Wells (Wells No. 7 and 8) are located within the City limits along the western flank of the Boundary Upland. The City also owns a well near the eastern end of Boblett Street, Well No. 9. Well No. 9 is currently not in use, but will be put in use in the future, once water rights for the well are secured. Figure 1-2 shows the City well locations, along with domestic wells of interest to this study. Table 1-1 summarizes the construction and other details of the City wells. Table 1-2 summarizes pertinent aspects of selected domestic wells in the area, and selected well logs are presented in Appendix A.

The northern boundary of the study area is the US/Canadian border. Although the border in part follows the topographic divide between the Dakota Creek watershed of Whatcom County and the Campbell River of British Columbia, the border does not delineate an independent study area for hydrological purposes. As a result, data has been collected from British Columbia to gain an overall understanding of the hydrology and hydrogeology for the Blaine WHPP.

1.2 Background

The three jurisdictional entities in the general study area are the City of Blaine, unicorporated Whatom County, and Langely District Municipality. The jurisdictional boundaries are shown in Figure 1-3. Figure 1-3 also shows the location of a the East Blaine annexation, a 1,200 acre parcel located in the Boundary Upland area along the U.S-Canadian border. Much of the work presented in this report relates to the future development of the Boundary Upland area, either under present zoning restrictions or future zoning restrictions that may accompany the annexation.

The Blaine Watershed and seven of the City's nine wells are technically within the Whatcom County jurisdiction. However, the City owns the Watershed parcel, and access to the Watershed, and activities within the Watershed are controlled by the City. The City and Whatcom County have established a good working relationship, in part through the planning and implementation of the GWMP.

Blaine is a major population center in Whatcom County supporting a permanent population of about 3,940 persons within the Urban Growth Area. It is projected that the population of the City will grow to 7,800 by 2015. The remainder of the general Blaine area is rural residential and/or agricultural. The rural residential population is seasonal with greatest population during the summer months when the population can exceed 10,000 persons. The area is currently undergoing relatively rapid development. One of the major issues surrounding water resource management in the study area is the interplay of growth and water resource development. Although the presence of sufficient ground water resources to meet the needs of the City has been determined from past studies, additional water rights need to be secured, and the existing and future supplies need to be managed properly and protected to ensure an adequate and safe water supply for the community.

Concerns regarding ground water quality that have arisen include:

- **Zoning/Density in the Boundary Upland area**: Increased development utilizing septic systems, and other land use activities in the Boundary Upland area may result in increased concentrations of nitrate and other contaminants in ground water. Elevated nitrate concentrations have been previously noted in the Boundary Upland area and in some of the City's wells. The annexation of a large portion of the Boundary Upland (Figure 1-3), and the expansion of the sewer system to portions of the Boundary Upland may reduce the potential for future nitrate contamination. However, coordinated jurisdictional control over land-use in the Boundary Upland area is important with regard to future wellhead protection;

- **Sand and Gravel Quarries**: Several gravel quarry operations (active and non active) exist in the Boundary Upland area. Abandoned quarries all to often become prime locations for illegal dumping of household and sometimes industrial hazardous wastes. Due to the location of the quarries in the primary recharge area of the Boundary Upland aquifer system, there is concern regarding the potential affects of illegal dumping on ground water quality;

- **Transportation**: One of the wells serving the City of Blaine (Well No. 7) is directly adjacent to the truck route on SR543. A traffic-related spill of hazardous materials could jeopardize the well and is a concern with regard to public health. Present and potential future transportation of hazardous materials along H-Street in the Boundary Upland area is a significant concern, since this area is the primary recharge area of the City wells;

- **Underground Storage Tanks**: There are several known underground storage tanks (UST's) in the close proximity of City Wells No. 7 and 8. These UST's predominately contain petroleum products. Several cases of well contamination due to leaking UST's have been reported in the literature, and is a concern that has prompted the development of the State WHPP;

- **Stormwater/Urban Run-off**: Increased development of the Boundary Upland may alter the quantity and quality of the ground water recharge that feeds the aquifers and sustains the City (and domestic) ground water supply. This issue is of present concern for the two City wells (No. 7 and 8) that are located within the City limits (Figure 1-3). The planned future development of the Boundary Upland area is also an area of concern with regard to ground water quality and stormwater/urban runoff ;

- **Abandoned/Improperly Sealed Wells:** Approximately 100 domestic wells exist in the Boundary Upland area, some of which may not have properly constructed surface seals. This may allow contaminated surface water to enter the wells and aquifer. In addition, there may be open abandoned wells in the Boundary Upland area that may be transmitting contaminated surface water into the aquifer; and

- **Miscellaneous Activities:** Miscellaneous activities which include hobby farming in the Boundary Upland and road-side spraying activities are of concern with regard to the potential affects on ground water quality.

1.3 Objectives and Scope

The objectives of the Blaine WHPP, are as follows:

- Develop and document a technical hydrogeologic evaluation of the Boundary Upland area using existing and newly collected data;

- Perform wellhead protection area (WHPA) delineations for the City wells;

- Perform a contaminant source inventory and evaluate land use within the WHPA's;

- Perform a sanitary survey of the Blaine Watershed wells to identify potential well security problems, and well construction, housing, and equipment deficiencies related to the prevention of well contamination;

- Identify and rank potential threats to ground water quality within the WHPA's;

- Summarize existing management strategies that are being implemented as part of the GWMP that will aid in the protection of the City's water wells; and recommend additional management strategies (or alternatives) that will reduce the threat of contaminating the City wells;

- Outline needed water supply system improvements within the Watershed required to prevent well contamination and aid in managing the water supply;

- Develop a spill response plan;

- Develop a Watershed Operations Plan to aid City personnel in the collection of well and wellfield performance and ground water conditions needed for ground water supply management purposes, and to ensure the wells and the Watershed are secured from unauthorized access; and

- Develop a contingency plan to address the potential for future groundwater contamination, including options for future ground water supply development to meet the present and projected future water supply demands of the City.

This report is organized as follows:

- Section 1 presents an introduction and scope of work;
- Section 2 presents a summary of the data and analysis that were available for this study;
- Section 3 presents the hydrogeologic setting and conceptual hydogeologic model;
- Section 4 presents a discussion on the delineation of the wellhead protection areas;
- Section 5 summarizes the hydrogeologic conditions and presents the recommended WHPA's;
- Section 6 presents an evaluation of the present ground water quality conditions, and historic water quality trends;
- Section 7 describes present land-use and presents the results of the contaminant source inventory, and also the results of a sanitary survey of the City wells within the Blaine Watershed;
- Section 8 presents an evaluation of the current and future ground water contamination potential;
- Section 9 presents recommended Blaine Watershed System upgrades, summarizes existing ground water management strategies of the Blaine GWMP, and presents additional ground water quality management procedures to further reduce the ground water contamination potential; presents the basic components of a Spill Response Plan, and recommended strategy needed to develop and implement the plan; and presents a discussion on public involvement;
- Section 10 presents a contingency plan to meet short-term and long-term water supply demands of the City;
- Section 11 presents a summary of the water quality, contamination issues, and management strategies;
- Section 12 presents conclusions and recommendations; and

- Section 13 presents references.

Selected well logs are presented in Appendix A. Appendix B presents water quality information. Appendix C present WHPA delineation modeling results. Appendix D presents analysis results of potential ground water nitrate concentrations associated with various Boundary Upland development scenarios. Appendix E presents the worksheets of the EPA contaminant risk analysis used to rank land-use practices and contaminant sources with regard to potential ground water contamination. Appendix F presents a Watershed Operations Plan. Appendix G presents presents portions of the water supply contingency plan. Appendix H presents sample contaminant source control notification letters to agencies and businesses; and Appendix I includes comments received on the Draft WHPP and the response to the comments.

2. SUMMARY OF DATA AND ANALYSES

This section presents a review and summary of the existing data sources, data quality, and data products available from previous studies that were used in developing the WHPP for the City of Blaine. Also presented in this section is an overview of the data collection activities that were undertaken specifically for this WHPP.

2.1 Existing Data Sources

The previously existing data sources used in developing the WHPP are presented below:

Golder Associates Inc.

Installation and Pump-Testing of a Deep Well at the Boblett Street Site, Blaine, Washington, 1991. This report summarized the drilling and pump-testing of a production/test well installed near the east end of Boblett Street (Well No. 9). The work described in this report was carried out in order to assess the feasibility of developing a municipal ground water supply at the site.

Report on the Geophysical Logging and TV Inspection of Blaine Wells No. 1 and No. 2, 1992. This work was part of the data collection activities designed to provide a better understanding of the hydrogeology within the Blaine Ground Water Management Area (Boundary Upland area), and to determine the occurrence and quality of ground water.

Report on Rehabilitation and Pump Testing of Blaine City Well No. 2, 1992. This report summarized the rehabilitation work and pump testing of City Well No. 2. It also contained estimates of the long-term potential yield of the well, recommendations for rehabilitation or replacement of Well No. 1, and estimated yield from the deep aquifer tapped by both wells.

Blaine Ground Water Management Program, 1995. This report presented a detailed description of the hydrogeology, water quality, ground water resources, and land uses of the Blaine GWMA. This report provided the basis for the development of a strategy to protect the ground water resources within the general Blaine area, as part of the Blaine GWMP. The report incorporated information from several studies conducted in British Columbia, as well as available studies of the Blaine area. During the development of the GWMP, the Ground Water Advisory Committee (GWAC) analyzed the existing approaches for managing ground water to identify any deficiencies in those systems. Alternatives for addressing each deficiency were developed and evaluated. Ultimately, a recommended set of alternatives were selected. These alternatives constitute the Preferred Program as recommended by the GWAC.

EMCON Studies

Evaluation of Aquifer Vulnerability, Proposed East Blaine Annexation Area, 1992. This study performed a focused ground water assessment, using existing information, to evaluate the current and future vulnerability of local aquifer systems based on hydrogeologic and land use conditions. The modeling results indicated that nitrate loadings from onsite sewage treatment systems could have a significant impact on water quality in the shallow aquifer regardless of the development scenario.

Draft Hydrogeological Characterization Study East Blaine Annexation Area, 1994. This study was undertaken as a follow up to the Evaluation of Aquifer Vulnerability, Proposed East Blaine Annexation Area (EMCON 1992), to address additional data collection and analysis needs identified by the Blaine City Council.

Hammond, Collier & Wade - Livingstone Associates Inc.

Comprehensive Water System Plan for City of Blaine, Washington, 1982. This report outlined the findings and conclusions reached during a study of the City of Blaine's Water System, and proposed immediate and long-range improvements to meet the present and future needs of the City to the year 2000 and beyond.

URS Consultants

1989 Water System Plan Update, City of Blaine, Washington, 1989. This document updated the City of Blaine Comprehensive Water System Plan dated July, 1982 (Hammond, Collier & Wade - Livingstone Associates), as adopted by the Blaine City Council.

Shannon & Wilson Inc.

Potential Ground water Supply, Blaine, Washington, 1975. This was a study of ground water supply potential in the western half of the Blaine Watershed. The ground water supply potential in this area was determined to a depth of approximately 700 feet. The eastern half of the watershed was thought to possess as much potential as the western half.

Re-evaluation of Ground water Resources within the Blaine Watershed, Blaine, Washington, 1986. This letter provided an updated evaluation of the Blaine Watershed ground water resource development potential. Based on the new data, the available quantity of ground water resources beneath the watershed was interpreted to be less than was estimated in 1975.

Installation and Testing of the City of Blaine Well 19 and Point Roberts Water District No. 4 Test Well, 1987. Two 12-inch diameter wells were installed in the City of Blaine Watershed to investigate the ground water supply potential. A production well (Well 6, formerly known and Well No. 19) was installed for the City of Blaine and a test well (Well 20) was installed for Point Roberts Water District No. 4.

Mark S. Sandal, Western Washington University

Water Balance and Hydrostratigraphy of the Dakota Creek Watershed, Whatcom County, Washington, 1990. Water balances were computed for the time periods June 1952 to May 1953 and June 1989 to May 1990. The computation of water balances for the two time periods separated by 37 years provided an opportunity to assess the influence of changes in land use on water supply and streamflow in the region. Gaging was re-established as part of the evaluation of the water balance for Dakota Creek.

Economic and Engineering Services Inc.

City of Blaine Water System Plan, 1994. This Water System Plan provided recommendations needed to improve existing water system deficiencies, meet future growth requirements, and ensure compliance with state and federal regulatory requirements.

Harding Lawson Associates

Hydrogeologic Investigation Report South Langley Golf Course and Residential Community, Langley, Columbia, 1994. This study identified the baseline hydrogeologic and water quality conditions associated with the site, located in the Boundary Upland area, north of the border. The investigation performed at the site indicated that the shallow water-bearing zone has moderate to low permeabilities, and that ground water flow in this zone is in a northerly direction.

Washington State Department of Ecology

Well logs available from Ecology were used to evaluate the hydrogeologic conditions of the study area.

Environment Canada

Well logs available from British Columbia were used in determining the hydrogeologic conditions north of the study area.

2.2 Recent Data Collection Activities

The data presented in the reports described above are, in general, of good quality and provide information needed to evaluate many aspects of the WHPP. However, previous studies were largely confined to the Blaine Watershed, with the primary exception of the Blaine GWMP and the studies conducted by EMCON.

Specific additional hydrogeologic information that was needed to develop the WHPP were:

- The nature and extent of hydrostratigraphic units within the Boundary Upland area, (e.g., thickness, hydraulic conductivity of aquifers and materials overlying aquifers);
- A better understanding of ground water elevations and flow directions beneath the Boundary Upland, including the location of the ground water divide;
- The directions of ground water flow from areas of recharge to the City wells;

- A better understanding of the ground water quality in the primary recharge area (the Boundary Upland area); and

- A better understanding of the amount and spatial distribution of ground water recharge.

To provide some of the above information, EMCON performed the following work in the Boundary Upland area:

- Installed two monitoring wells (MW-1 and MW-2) (Figure 1-2) to collect geologic samples and water level data;

- Collected additional ground water level data from twelve domestic wells to better determine water level conditions in the Boundary Upland area;

- Sampled six domestic wells to aid in determining the ground water quality characteristics of the Boundary Upland area; and

- Performed a electrical resistivity (transient electromagnetic) geophysical survey (survey was conducted by Geo Recon on EMCON's behalf) to better define the hydrogeologic conditions of the Boundary Upland area.

Golder Associates performed the following additional hydrogeologic work in the Boundary Upland area:

- Collected water level data from six domestic wells in 1995 to further refine the ground water conditions in the Boundary Upland area; and

- Collected a second round of ground water samples from the wells sampled previously by EMCON in order to identify any seasonal water quality changes.

The installation and pump testing of a replacement well for Well No. 1, conducted by Golder Associates under a separate contract with the City, provided a better understanding of the geology of the Blaine Watershed area, and provided a much clearer understanding of the hydraulic properties of the deepest aquifer utilized by the City.

Information on potential contaminant sources and land-uses within the study area was also collected by Adolfson Associates, Inc. as part of this study, as detailed in Section 7 of this report, along with a sanitary survey of the Blaine Watershed conducted by Golder Associates.

The following section describes the present understanding of the hydrogeologic conditions of the study area, based on the assimilation of all of the previously available data, and the newly collected data.

3. HYDROGEOLOGIC SETTING

The hydrogeologic setting of the Boundary Upland and surrounding areas forms the basis for delineating wellhead protection areas and developing strategies for aquifer protection. The hydrogeology of the study area is complex. Complexities arise from the topographic, and hydrogeologic conditions that control ground water flow in the Boundary Upland. The data collected for the GWMP and WHPP provide a more complete understanding of the area, but some uncertainty remains. The scope of the WHPP is not intended to address all of the uncertainty associated with the hydrogeology of the Boundary Upland. The intent of the WHPP, rather, is to propose conservative, consistent, and manageable strategies for wellhead protection purposes. In order to do this, a simplified hydrogeologic model must be developed to allow WHPA delineation.

The purpose of this section is to summarize the geology and hydrogeology of the Boundary Upland and surrounding areas, and to outline a simplified conceptual model used to develop the WHPA's.

3.1 Geology

A major structural trough is located beneath the Boundary Upland area and the Fraser Lowland of British Columbia (Mathews, 1972). The northern boundary of the trough occurs approximately 20 miles north of the international border. The eastern border occurs approximately 30 miles east of Drayton Harbor; and the southern border occurs near Bellingham, Washington, approximately 15 miles south of the international border. The trough appears to be at least 1,100 feet deep in places based on a well (TP-7SEC6 #26) located just north of Blaine at Peace Arch Park (Figure 1-2). This well was drilled to a depth of 1,112 feet below ground surface (bgs) without encountering bedrock. Bedrock, however, has been encountered at a depth of 457 feet bgs (borehole 40N01E-11Q) approximately 1 mile to the south of the Boundary Upland.

The trough was gradually filled, first with fluvial sediments transported by rivers from the inland mountains, then by marine, fluvial, and glacial sediments of Quaternary age associated with the glacio-climatic episode of the last 1.8 million years (Halstead, 1986). Isostatic adjustments related to glacial advances and retreats, combined with eustatic changes in sea level produced vertical fluctuations of shoreline position of up to 650 feet during the last 1.8 million years (Armstrong, et al., 1965). This has resulted in considerable variability in the characteristics of the sediments filling the trough.

The Quaternary geology of the Blaine Boundary Upland area consists of glacial deposits of the Fraser Glaciation and Pre-Fraser glacial and non-glacial deposits. Little is known of the Pre-Fraser deposits (over roughly 22,000 years old) which typically occur at depths greater that 300 feet (Halstead, 1986). This is because only limited surface exposures of the Pre-Fraser sediments exist, and only a few wells in excess of 300 feet deep exist in the Blaine area. The Fraser Glaciation consisted of two glacial advances known as the Vashon and Sumas Stades which have occurred within the last 22,000 years. The two glacial advances are separated by a period of glacial retreat known as the Everson Interstade. The Vashon deposits consist of a sand and gravel outwash deposit of up to 45 feet thick known as the Esperance Sand, and a 10 to 30 feet thick till deposit known as the Vashon Drift, which consists of unsorted clay, silt, sand, and gravel. As the Vashon glacier retreated, the area was invaded by the sea, and the Everson Interstade sediments were deposited. The Everson Interstade deposits consist of the 15 to 25 feet thick Kulshan glacio-marine drift, the Deming sand (up to 30 feet thick), and the Bellingham glacio-marine drift (up to 70 feet thick) (Easterbrook, 1976). The deposits consist of interbedded fossiliferous stony clays, stony silt, till-like mixtures, marine clay, deltaic sand and gravel, fluvial and lacustrine clay, silt, sand, gravel, and peat. In the Boundary Upland area, wave action has reworked Bellingham drift deposits removing most of the fines. This has resulted in a sand and gravel deposit which mantles the Boundary Upland with a thickness of up to 10 feet (Easterbrook, 1976). During the waning stages of the last glacial period, a small glacial re-advance, known as the Sumas Stade, deposited glacial outwash in the Sumas area (Easterbrook, 1976; Armstrong et al., 1965. Fine-grained outwash sediments (roughly 20 to 30 feet thick) of the Sumas outwash extend as far west as Drayton Harbor.

3.2 Hydrogeology

Halstead (1986) devised a classification scheme for hydrostratigraphic units of the Fraser Lowland of British Columbia to provide a framework for evaluating the hydrogeologic conditions of the area. Due to the close geographic locality and similar geologic history, the classification system was adopted with some revision for the Blaine GWMA (Golder, 1995). The convention used in the GWMP is also used in this study to describe the hydrogeology with some additional revision based on an updated understanding of the hydrogeology.

The convention used in defining the hydrostratigraphic units is presented in Section 3.2.1 below, followed by a detailed discussion of the hydrostratigraphy of the Boundary Upland area in Section 3.2.2. Section 3.2.3 discusses ground water levels and directions of flow. Section 3.2.4 presents a discussion of ground water resources of the Boundary Upland area, and a conceptual model of the hydrogeologic system, derived from the evaluation of the available data is presented in Section 3.3.

3.2.1 Definition of Hydrostratigraphic Units

The convention devised by Halstead (1986) to describe the hydrogeology of the Fraser Lowlands of British Columbia is presented below along with the modified definitions of the hydrostratigraphic units used for this study. The modified definitions of the hydrostratigraphic units are summarized in Table 3-1.

Hydrostratigraphic Unit A/B

Two separate hydrostratigraphic units (A and B) were recognized by Halstead in southern British Columbia. These units included clay, peat, stony clay and silty clays as well as sandy silts, and silty sands with marine shells. The proportion of clay was 10% to 50%; silt, 35% to 75%; and sand, 5% to 60%. These materials are often reported on Canadian drillers logs as "sticky-stony clay". Unit A was differentiated from Unit B on the basis of the abundance of shells. The material is described as mainly glacio-marine in origin, deposited following the retreat of the Vashon glacier during the Everson Interstade.

Although Everson Interstade deposits are present within the Boundary Upland area, there is insufficient data to differentiate between these units on the basis of shell content. Thus, the two units have been lumped together as Unit A/B for the purposes of this study.

Hydrostratigraphic Unit C

Hydrostratigraphic Unit C, as described by Halstead, consists mainly of glacio-fluvial sand and gravel deposited by meltwater streams. Where these streams entered the sea, large deltas formed, which upon isostatic rebound, have been elevated above present sea level. Halstead indicates that this unit overlies Unit B (based on his definition), and forms unconfined aquifers capable of yielding large quantities of ground water. The geologic units associated with Unit C, according to Halstead include parts of the Bellingham Drift and the Sumas Drift. Halstead also includes the Esperance Sand within Unit C, which is a glacial outwash sand and gravel deposited during the advance of the Vashon glacier. The Esperance Sand, however, is believed to occur largely as a confined aquifer within the Boundary Upland area, and for the purposes of this study, is not classified as Unit C based on its close association with glacial till (see description of Unit D below).

In the GMWP study, Unit C was divided into four subunits, based on depth and location within the GWMA. The subdivisions of Unit C, however, are not used in this study in order to simplify the classification system. Further Unit C4 as described in the GWMP as the permeable sediments in the deep aquifer penetrated by City Wells No. 1 and No. 2 has been reclassified as a new hydrostratigraphic unit (Unit F).

Hydrostratigraphic Unit D

Hydrostratigraphic Unit D, as described by Halstead, includes tills together with sands and gravels deposited by a variety of glacial processes. The tills consist of a heterogeneous mixture of clay, silt, sand, gravel, and boulders. Halstead includes the Vashon Drift and older pre-Vashon glacial drifts within this hydrogeologic unit.

For the purposes of this study, the definition of Unit D is similar to that of Halstead's in that it includes glacial till. However, water-bearing glacial outwash sand and gravel which is associated with the till, in particular, the Esperance Sand, is also included within Unit D. The definition of Unit D has been further refined for the WHPP to include what is believed to be Vashon-aged or younger glacial sediments. Unit D is differentiated from Unit C by its association with sediments which appear to be till, or other closely related glacial deposits. The low permeability till-like materials included within Unit D tend to be relatively thin (5 to 15 feet thick) in comparison to the glacial outwash sediments, which may be capable of supplying moderate quantities of ground water to wells.

Hydrostratigraphic Unit E

Unit E, based on Halstead's description, is comprised of marine sediments interbedded with estuarine and fluvial deposits consisting of fine sand, silt, and clayey silts. Within this unit, Halstead includes sediments deposited during the Olympic non-glacial interval which occurred during pre-Vashon times. Halstead notes that all wells drilled to depths greater than about 300 feet bgs within the Fraser Lowland of British Columbia have encountered these sediments.

For the purposes of this study, clays and silty clays of Pre-Vashon glacio-marine origin may be included along with the fine sand, silt, and clayey silt, of non-glacial origin.

Hydrostratigraphic Unit F and G

Halstead characterized Unit F as consolidated bedrock.

Due to the presence of deep permeable sediments encountered by City Wells No. 1 and No. 2, which were not identified by Halstead, Unit F has been re-classified as permeable fluvial or glacio-fluvial sand and gravel of Pre-Vashon age, and Bedrock has been classified as Unit G.

3.2.2 Characteristics and Distribution of Hydrostratigraphic Units

Based on the past hydrogeologic investigations conducted by Golder and others, and on the recent studies of the Boundary Upland area (EMCON, 1995; GeoRecon, 1994; and Harding Lawson, 1994), the hydrostratigraphic units described above are grouped into three major aquifer systems. The aquifer systems consist of a shallow perched aquifer system, a shallow semi-confined to confined aquifer system, and a deep confined regional aquifer system. A description of the aquifer systems and the distribution of each of the hydrostratigraphic units within and between the aquifer systems area presented below.

Perched Aquifer System

The shallow perched aquifer system is confined to the Boundary Upland area, and consists of several small, laterally discontinuous water-bearing zones classified as Unit C perched on lower permeability sediments of Unit A/B, as illustrated in cross sections B-B', C-C', and D-D' (Figures 3-2, 3-3, and 3-4). The Perched Aquifer System generally occurs at depths of between 10 to 180 feet bgs, which corresponds with an elevation of between 200 and 380 ft above mean sea level (amsl).

The hydraulic properties of these small unconfined perched aquifers has been investigated to some degree by Harding Lawson (1994) for the South Langely Golf Course, British Columbia, and are mainly of low to moderate permeability. Yield of the individual water-bearing units is generally low, but sufficient in some cases for domestic water supply purposes.

The ground water does not have any dominant major cations and anions, and has a low concentration of dissolved solids (based on a sample collected from the Leer well in 1990, see Appendix B). The low concentration of solids stems from the lack of time that the water has been in contact with soil particles, which relates to its recent recharge. The major ion chemistry of the ground waters of the Boundary Upland area is represented using a piper diagram, presented in Figure 3-5. The major ion chemistry of ground water depends on the history of the ground water with respect to the travel time, and the type of geologic materials that the ground water passes through. As such, it provides a unique signature that can be used to compare ground waters of similar or different histories. As shown in Figure 3-5, the ground water chemistry of the Perched Aquifer differs from that of the Shallow Aquifer System and the Deep Aquifer System.

Shallow Aquifer System

The Shallow Aquifer System, in general, lies directly beneath the Perched Aquifer System as depicted in Figures 3-2 to 3-4. The Shallow Aquifer System consists of a complex mixture of water-bearing Units C and D interbedded within low permeability Unit A/B. This aquifer system occurs at depths of between 100 and 300 feet bgs in the central portions of the Boundary Upland, and at depths of between 60 and 160 feet bgs along the southern and western flank of the Boundary Upland, corresponding to an elevation of between -150 and 250 ft amsl.

As shown in cross section A-A', the thickness and character of Units C and D vary significantly within the Boundary Upland area. Unit C is up to 100 feet thick places, and apparently absent in places. Figure 3-1 further illustrates that Unit D is up to 150 feet thick in places, and may pinch out to the southeast of the Blaine Watershed. Cross sections C-C' and D-D' show that both Units C and D pinch out between the Boundary Upland and Dakota Creek and Drayton Harbor to the south and southwest. Since the Shallow Aquifer System is comprised of Units C and D, it appears from Figures 3-3 and 3-4 that the Shallow Aquifer System is primarily confined to the general Boundary Upland area.

The Shallow Aquifer System is generally semi-confined to confined in the Boundary Upland area. The estimated transmissivity of Units C and D that comprise the Shallow Aquifer System averages between 1,000 and 3,000 ft^2/day, but varies from 50 to 14,000 ft^2/day within the Boundary Upland area. The Shallow Aquifer System is the primary aquifer system within the Boundary Upland area. It is capable of yielding moderate quantities of water in certain localities. Most of the deeper domestic wells within the Boundary Upland area are installed the Shallow Aquifer System. In addition, all of the City wells, with the exception of Wells No. 1 and No. 2, are installed within the Shallow Aquifer System.

The water from the Shallow Aquifer System is classified as a calcium bicarbonate type of water. The type of water differs markedly from that of the Perched Aquifer System and the Deep Aquifer System, as illustrated in Figure 3-5. Within the water-bearing units (C and D) of the Shallow Aquifer System itself, however, there appears to be no difference in water chemistry, as further illustrated in Figure 3-5. This suggests that there is a high degree of hydraulic communication between the two water-bearing units of the Shallow Aquifer

System, but much less, if any, communication between the Shallow and Deep Aquifer Systems.

Deep Aquifer System

Beneath the Shallow Aquifer System and overlying the Deep Aquifer System are roughly 400 to 600 feet of low-permeability sediments (Unit E), as illustrated in cross sections A-A′, B-B′, and D-D′ (Figures 3-1, 3-2, and 3-4). The Deep Aquifer System consists of two to three generally thin (2 to 20 feet thick) layers of sand and gravel, defined as Unit F. The Deep Aquifer system occurs at depths of between 600 and 750 feet bgs in the Blaine Watershed area, which translates to an elevation of between -450 to -560 feet msl. Interbedded with Unit F are additional layers of Unit E sediments. The lateral extent of the sediments of Unit F is unknown, because they have only been encountered within the Blaine Watershed, and possibly at a location roughly 0.5 miles to the southwest (School well), as shown in Figure 3-4. As shown in Figure 3-4, the Deep Aquifer System may extend beneath the lowland areas southwest of the Boundary Upland area, possibly as far west as Drayton Harbor. Towards Dakota Creek and Drayton Harbor, up to 500 feet of low-permeability sediments of Units A/B and E may overly Unit F as depicted in the cross sections.

Previous thinking was that the Deep Aquifer (Unit F) was of limited lateral extent, because it was not encountered by test wells TH-1 and No. 20 installed in the western and southeastern portions of the Watershed, respectively. However, based on the results of the recent drilling and testing of replacement Well No. 1, it appears that the test wells were not drilled deep enough to encounter the aquifer.

City Well No. 2 taps the shallowest known layer of Unit F at a depth of 634 to 644 feet bgs. The transmissivity of this layer was estimated at 700 ft^2/day (Golder, 1992). The pumping test of replacement Well No. 1 (completed between 708 and 726 ft bgs in Unit F) indicates that the aquifer has a transmissivity of about 3,000 to 5,000 ft^2/day, and the 24-hour test revealed no indication that the aquifer was of limited extent. The pumping test suggests that the aquifer is capable of yielding a moderate to large quantity of water (2,000 to 3,000 gpm). However, additional testing is required to confirm this interpretation.

The chemistry of this water (a sodium bicarbonate type) differs substantially from that of the waters from the Shallow Aquifer System, suggesting a more distant recharge source, and a different flow system (Figure 3-5). The ground water is higher in total dissolved solids (TDS of about 360 mg/L) (Table B-1, Appendix B) than ground water from the Shallow Aquifer, in addition it has higher sodium and chloride concentrations (about 35 to 66 mg/L, and 30 to 47 mg/L, respectively). The water chemistry of Well No. 2 and replacement Well No. 1, in contrast, are very similar, indicating that these two wells are within the same aquifer system.

3.2.3 Ground Water Levels and Directions of Flow

3.2.3.1 Ground Water Levels

The ground water levels within the Boundary Upland vary considerably due to the presence of perched ground water. Ground water levels associated with the small perched layers within the Perched Aquifer System may vary from near ground surface to roughly 180 feet bgs, depending on the location and depth of the confining units on which the water is perched. Fully saturated conditions exist in the underlying Shallow Aquifer System. Figure 3-6 shows the approximate ground water elevations within the Shallow Aquifer System. This map was constructed using the most recently available water level data, supplemented with older data where recent data were lacking.

From previous studies, water levels in Units C and D, which comprise the Shallow Aquifer System appear to be similar along the southern flank of the Boundary Upland. Because the water level contours in Figure 3-6 do not strictly represent the water levels within a single specific water-bearing zone (unit), the ground water elevation map technically should be viewed as a generalized water level map, rather than a water-table map or a potentiometric surface map.

As shown in Figure 3-6, water levels are highest near the center of the Boundary Upland where they approach 280 ft amsl. The water levels decrease towards the flanks of the Boundary Upland where they occur at 100 feet amsl, or less. In the vicinity of the Watershed, the water levels appear to be lower (55 to 80 feet msl) than the water levels in the adjacent areas. This is expected due to pumping of the City wells within the Watershed.

The water level conditions of the Deep Aquifer System are not depicted on Figure 3-6. Recently collected water levels from the Deep Aquifer System show that the water levels within the Watershed is approximately 60 to 70 feet amsl. The water levels in the Deep Aquifer System are greater than in the overlying shallow aquifers in the immediate Watershed area, as suggested by the geophysical investigation of old Well No. 1 conducted in 1992. The geophysical investigation showed that water from the Deep Aquifer System was flowing up the well casing and into the Shallow Aquifer System (the well was perforated across both units).

3.2.3.2 Directions of Ground water Flow

The Boundary Upland is the primary ground water recharge area within the general Blaine area, as illustrated by the elevated water level conditions of the Boundary Upland as described above. Some of the precipitation occurring on the Boundary Upland infiltrates downward, providing recharge to the perched zones. Some of the water that perches onto the lower-permeability drift deposits migrates laterally and issues forth as springs along the flanks of the Boundary Upland area. The remaining ground water continues downward to provide recharge to the Shallow Aquifer System.

Once the recharge water reaches the water table, it moves radially out from the central Boundary Upland region to the margins of the Boundary Upland area, as depicted in Figure 3-6. A ground water divide exits in the central Boundary Upland area. Ground water recharge occurring north of this boundary will flow northward into British Columbia, and ground water recharge occurring south of the boundary flows southward. Figure 3-6 shows the location of the ground water divide, assuming that it corresponds with the surface topographic divide. At the present time, however, insufficient data exists to determine the exact location of the ground water divide.

The Deep Aquifer System is believed to be recharged from more distant highland areas outside of the Boundary Upland area. This is because of the observed upward direction of flow from the Deep Aquifer to the Shallow Aquifer in the Blaine Watershed area, which is opposite to what would be expected if the Boundary Upland was the recharge area of the Deep Aquifer. Also, the major ion chemistry of the ground water from the Deep Aquifer differs substantially from the ground water chemistry of the Shallow Aquifer, as discussed earlier, suggesting a different recharge area for the Deep Aquifer ground water.

3.2.4 Ground Water Resources

This section presents a discussion and evaluation of the ground water resources within the Boundary Upland area, based on the current understanding of the hydrogeology, water quality, and estimates of ground water recharge.

Two of the three aquifer systems, the Shallow and the Deep Aquifer Systems, in the Boundary Upland area have sufficient yields for municipal supply purposes. The Perched Aquifer System is not capable of supplying sufficient water for municipal purposes. The Shallow Aquifer System receives primarily all of its recharge from the Boundary Upland, whereas the Deep Aquifer System receives most, if not all, of its recharge from outside the Boundary Upland area. Ground water resources of the Shallow Aquifer System and the Deep Aquifer are discussed below.

3.2.4.1 Shallow Aquifer System

Recharge to the Shallow Aquifer System has been estimated at between 7 and 20 inches per year, which translates to 230 to 660 gpm per square mile per year (Golder, 1995). The total recharge area of the City wells is estimated at between 3.2 and 3.9 square miles (see Section 3.3.1), which translates to a total recharge available to the City wells of between 736 gpm and 2,570 gpm.

Current annual average withdrawals by the City of Blaine wells from the Shallow Aquifer System (Wells No. 3, 4, 5, 6, 7, and 8) is estimated at between 600 to 800 gpm. Presently, there is no indication that the Shallow Aquifer is being over stressed by the City wells (i.e. water levels or pumping yields have not been dropping), and it appears that additional wells could be developed in the Shallow Aquifer System without significant adverse consequences on ground water levels. Ultimately, future withdrawals must be less than overall recharge to sustain ground water discharge to tributaries to Dakota Creek. However, it is important to note that any adverse effects on the flows of Dakota Creek will likely occur along the tidally-influenced reach of the creek (Figure 1-1), which is exempt from the stream closure rule under WAC 173-501-030. Any future City wells between the Watershed westward towards Drayton Harbor will not affect flows within the regulated reach of Dakota Creek. It is believed that if the ground water resource is managed properly, future ground water withdrawals from the Shallow Aquifer System could increase to between 30 to 50 percent of annual recharge without significant adverse effects on the hydrologic system.

One disadvantage of any further development of the Shallow Aquifer System is that these aquifers are far more susceptible to contamination than the Deep Aquifer. This is discussed further in the Contingency Plan, discussed in Section 9 and presented in Appendix G.

3.2.4.2 Deep Aquifer System

Recharge to the Deep Aquifer System is believed to be from deep underflow from British Columbia. The amount of recharge has not been determined at this time. However, it is known that City Wells No. 1 and No. 2 have yielded a considerable quantity of water from this aquifer for a period of over 65 years. In the past, prior to well deterioration, Wells No. 1 and 2, have reportedly yielded as much as 800 and 300 gpm, respectively. Prior to the recent replacement of Well No. 1, Well No. 1 had been pumped at a rate of 400 gpm. Well No. 2 is presently being pumped at a rate of 200 gpm. Based on the recent pumping test of replacement Well No. 1, it is estimated that the Deep Aquifer is capable of sustaining as much as 2,000 to 3,000 gpm. Replacement Well No. 1 is capable sustaining up to 800 gpm. Evaluation of the drawdown response to longer-term pumping is required to refine the estimated long-term yield of the aquifer.

Development of the Deep Aquifer has several advantages over further development of the Shallow Aquifer including less potential impact on streamflows and other water rights, and a greater yield potential per well. However, the Deep Aquifer has an elevated concentration of sodium at between 30 and 66 mg/L) Sodium is presently not regulated by the State. If sodium becomes regulated in the future, its possible that blending of the water from the Deep Aquifer with water from the Shallow Aquifer may be required. Further discussion of water quality is presented in Section 6.

3.3 Hydrogeologic Conceptual Model

This section presents a review of the pertinent aspects of the hydrogeology of the Boundary Upland area, and presents the conceptual hydrogeologic model that is used to delineate the wellhead protection areas presented in Section 4.

Three aquifer systems exist in the Boundary Upland area, the shallow perched aquifer system, a shallow confined to semiconfined aquifer system, and a deep regional confined aquifer system. The Perched Aquifer System provides only minor quantities of water for domestic use. The Shallow Aquifer System provides most of the ground water to the deeper domestic wells, and City Wells 3, 4, 5, 6, 7, and 8. The Deep Aquifer System provides ground water to City Wells 1 and 2, and possibly to the "School" well (Figure 3-4). Each of the aquifer systems are comprised of hydrostratigraphic units of varying hydraulic properties, as presented in cross sections (Figures 3-1 and 3-4) and described in Table 3-1.

The Perched Aquifer System is comprised of low permeability sediments of Unit A/B interbedded with perched water-bearing zones (Unit C). The Perched Aquifer System is limited to the Boundary Upland area at elevations above 200 ft amsl. The Shallow Aquifer System underlies the Perched Aquifer System at elevations of between -150 and 250 ft amsl, and may be separated from the Perched Aquifer System in places by low-permeability sediments (Unit A/B). The Shallow Aquifer System is comprised of laterally discontinuous water-bearing Units C and D, which are interbedded within Unit A/B. Low permeability sediments of Unit E, which are up to 400 to 600 feet thick separate the Shallow Aquifer System from the Deep Aquifer System. The Deep Aquifer System in comprised of two to three water-bearing units designated Unit F that are interbedded within low-permeability sediments of Unit E.

The general character of the hydrogeology of the Boundary Upland is presented in the cross sections in Figures 3-1 to 3-4. The pertinent characteristics of the Shallow Aquifer System and the Deep Aquifer System are presented below. The Perched Aquifer System is not considered further, because it is not a major aquifer system, and none of the City wells are completed within it.

3.3.1 Shallow Aquifer System

Aquifer Properties

- The thickness of the water-bearing units (Unit C and D) vary greatly, and are laterally discontinuous. The thickness ranges from less than 30 ft to approximately 100 ft in Unit C. Unit D is less than 20 ft thick to approximately 150 ft thick,

- Pump tests indicate that the transmissivity of the water-bearing units vary from roughly 50 ft^2/d to as much as 14,000 ft^2/d. In general, the transmissivity of the water-bearing units in the immediate vicinity of the City wells is between 1,000 and 3,000 ft^2/d. The transmissivity varies laterally relative to the changes in thickness and sediment grain size of the water-bearing materials. The storativity (water storage capacity) of the water-bearing units is estimated to vary from about $2x10^{-4}$ to 0.01, depending on the confining nature of the water bearing unit.

Ground Water Level Conditions

- Locally semi-confined, and confined zones exist within the Shallow Aquifer System. Ground water level elevations in the Boundary Upland area vary from over 280 ft msl in the central Upland area to 100 ft msl or lower along the margins of the Boundary Upland area, as shown in Figure 3-6.

Directions of Ground Water Flow

- The general direction of ground water flow is from the high water levels in the central Boundary Upland area to the south and north perpendicular to the ground water divide. Because of limited ground water level data from the central Boundary Upland area, the location of the ground water divide is uncertain, but may coincide with the surface topographic divide. Ground water occurring south of the ground water divide flows southward to the lower water levels in the Custer Trough area, and westward toward Drayton Harbor (Figure 3-6). With the exception of ground water in the vicinity of Well No. 7 (12th St.) and Well No. 8 (Lincoln Park), only the ground water occurring south of the divide can potentially reach the City wells. This is an important consideration with regard to developing WHPA's for the City wells. Ground water north of the divide and the Canadian Border in the vicinity of the Wells No. 7 and 8 may provide a small amount of recharge to these wells, because the wells are located near the axis of the east-west oriented ground water divide (Figure 3-6);

- Downward flow from the shallower water-bearing units within the central Boundary Upland Area provides recharge to the deeper water-bearing units within the Shallow Aquifer System. Along the margins of the Boundary Upland, ground water flow may be upward from the deeper water-bearing units to the shallower water-bearing units within the Shallow Aquifer System. Due to the laterally discontinuous nature of the water-bearing units within the Shallow Aquifer System, and the general lack of laterally continuous low-permeability horizons separating water-bearing units, a high degree of vertical hydraulic communication exists between the water-bearing units of the Shallow Aquifer System;

- Within the Boundary Upland area, the horizontal hydraulic gradient varies from 0.027 in the western area, to 0.043 near the Blaine Watershed. The average horizontal hydraulic gradient in the Boundary Upland area is approximately 0.035. Insufficient data are available to determine the vertical hydraulic gradient.

Ground Water Recharge and Inter-Aquifer Communication

- The average annual recharge occurring within the Boundary Upland has been previously estimated at between 7 and 20 inches (16 to 45% of the total precipitation), which is equivalent to 230 to 660 gallon per minute (gpm) per square mile of recharge area per year (Golder, 1994). Some of this recharge may flow laterally along perched zones within the Perched Aquifer System, and discharge to springs along the flanks of the Boundary Upland. The remaining recharge will flow downward to the Shallow Aquifer System A study from EMCON (1995) suggests that the potential for recharge is greater in the western half of the Boundary Upland area than in the eastern half because of soil conditions.

- The is little if any hydraulic communication between the Shallow Aquifer System and the Deep Aquifer System. The two aquifer systems are separated by 400 to 600 feet of low permeability silt and clay (Unit E). An upward hydraulic gradient appears to exist between the Deep Aquifer System and the Shallow Aquifer System with in the Blaine Watershed, as observed during an investigation of City Well No. 1 (Golder, 1992). This suggests that the Boundary Upland Area is not providing recharge to the Deep Aquifer System.

- The present area contributing ground water recharge to the City wells is estimated at between 3.2 and 3.9 mi^2, based on hydrogeologic mapping techniques. Based on the estimated range of the recharge area and the potential recharge per unit area as described above, the total annual ground water recharge from precipitation potentially available to the present City wells (not including Wells 1 and 2, which are installed in the Deep Aquifer System and which receive recharge from outside of the study area) is estimated to range from 736 gpm to 2,570 gpm.

3.3.2 Deep Aquifer System

Aquifer Properties

- The water-bearing units of the Deep Aquifer System are from 0 to 20 ft thick. Three layers of water-bearing materials (Unit F) appear to be present within the Blaine Watershed. Well No. 2 taps Unit F at a depth of between 634 and 644 ft bgs. Replacement Well No. 1 taps Unit F between 631 and 634 and again between 706 and 728 ft bgs. The lateral extent and character to the Deep Aquifer System is unknown. The recent 24-hour pumping test did not indicate that the aquifer pinched out laterally, but additional longer-term testing is needed;

- Pump tests indicate that the transmissivity of the Unit F varies from roughly 700 ft^2/d to as much as 5,000 ft^2/d. The storativity (water storage capacity) of the water-bearing unit is estimated to at roughly $2x10^{-4}$. Additional testing is required to determine storativity.

Directions of Ground Water Flow

- The direction of ground water flow in the Deep Aquifer System is uncertain, but is thought to be west to southwest towards Drayton Harbor.

- The horizontal hydraulic gradient in Unit F is presently unknown, but is estimated at 0.0027 ft/ft, based on the static water level of 70 feet bgs (120 feet amsl) in replacement Well No. 1, and assuming the static water level is 0 ft amsl at Drayton Harbor, which is 3.5 miles southwest of replacement Well 1.

Ground Water Recharge

- The annual amount of recharge to the Deep Aquifer System is presently unknown. Additional long-term water-level data are required to determine aquifer recharge;

- The Deep Aquifer System is interpreted to be recharged as part of a deep regional ground water flow system outside (northeast ?) of the study area.

4. WHPA DELINEATION

4.1 Introduction

This section provides a description of the methods available for WHPA delineation, followed by a discussion of the method selected, its application and results.

A WHPA is defined as the surface and subsurface area surrounding a well, wellfield, or spring that supplies a public water supply through which contaminants are likely to pass and eventually reach water well(s) (Department of Health, 1995). In the State of Washington, wellhead protection areas are defined primarily based on the 1-, 5-, and 10-year time of travel (TOT) of ground water to the well(s). The 1-year TOT zone, for example, represents the area around a well or wellfield in which a contaminant moving at the same rate as ground water would reach the well or wellfield within 1 year.

These TOT zones are used to define aquifer management regions around a well or wellfield where specific management strategies/ordinances are implemented to reduce the potential for ground water contamination. The capture zone area for each of these TOT's is progressively larger for increasing TOT. Consequently, management strategies are typically tailored to these TOT's, with the most restrictive approaches within the 1-year TOT zone, moderately restrictive within the 5-year TOT zone, and least restrictive within the 10-year TOT zone.

There are two assumptions in the TOT-based capture zone method that should be recognized. One assumption is that the contaminant will move through an aquifer at the same rate as the ground water. However, many contaminants (especially metals) typically move at a slower velocity than ground water depending on the specific characteristics of the contaminant. Fate and transport calculations can be used to estimate the rate of transport of a particular contaminant in relation to the rate of ground water flow. However, this approach is generally not used to define WHPA's, because WHPA's are not specific to a single type of contaminant, but rather apply to all potential contaminants that may exist within the TOT zone. The TOT approach is conservative and is, therefore, appropriate for planning purposes and developing management strategies.

The other assumption is that a contaminant released at ground surface would reach the aquifer instantaneously. Depending on the geologic conditions and the depth to the aquifer, the vertical travel time could vary from months to several tens of years. Unless significant evidence exists suggesting that substantial time would be required for a contaminant to reach the aquifer, the State Wellhead Protection Program recommends that the conservative assumption be made that the vertical travel time is instantaneous (Department of Health, 1995). This is often appropriate, even when a low permeability layer separates the aquifer from ground surface, because improperly sealed wells may provide a direct pathway for contaminants at the surface to the aquifer.

4.2 WHPA Delineation Methods

A number of methods of differing sophistication can be used in the derivation of WHPAs. A summary of the methods is provided below.

- **Calculated Fixed Radius method** (CFR) is the simplest approach and is based on a simple water balance formula. This method does not require knowledge of the aquifer characteristics, except for porosity. The well capture zone derived from this method simply consists of a circular area surrounding the wellhead. No consideration is given to the regional hydraulic gradient, or aquifer boundaries. This method is inappropriate for the Blaine Boundary Upland area, because of the complexity of the hydrogeology of the area.

- **Hydrogeologic Mapping** involves mapping the aquifer boundaries, particularly recharge areas, in relation to the wells of interest. A qualitative assessment of ground water can provide general information on the source of water to wells and its direction of flow. Hydrogeologic mapping is often carried out to some extent for any WHPA analysis, and can generally be used to determine the ultimate recharge areas of the aquifer. However, it cannot be used to determine time-based (TOT) well capture zones, because these require consideration of ground water flow rates and aquifer properties.

- **Conventional Analytical Modeling** takes into account the basic aquifer characteristics, such as transmissivity, aquifer thickness, and hydraulic gradient. Analytical modeling most often assumes steady state conditions and can be used to calculate capture zones to the boundary of the hydrogeologic system. An example of a commonly-used analytical model is the U.S. EPA WHPA code.

- **Sophisticated Analytical Modeling** techniques have recently been developed that can take into account boundary conditions and variable aquifer recharge conditions, in addition to the basic aquifer characteristics, such as transmissivity, aquifer thickness, and hydraulic gradient. TWODAN is one such model developed by Fitts (1995). This model is a two-dimensional analytical ground water flow model developed to evaluate ground water flow and to delineate WHPA's. The program is capable of solving large numbers of analytical solutions to model diverse irregular boundary conditions, and is more sophisticated than other analytical models such as the U.S. EPA WHPA code.

- **Numerical Ground water Flow Modeling** is the most sophisticated method used to delineate WHPA's. Ground water flow models are often used for complex systems composed of irregular aquifer boundaries and multiple wells. A numerical ground water flow model incorporates the hydraulic characteristics and boundary conditions of the aquifer and uses a "particle tracker" to numerically simulate the rate and direction of "particles" of ground water moving through the system. The accuracy of a WHPA derived from a numerical ground water flow model, however, is a function of how well the ground water flow model can simulate observed conditions of the ground water flow system. This, in turn, is a function of how much data are available to develop the model, and the complexity of the ground water flow system. When data are limited, a less sophisticated WHPA delineation method may be more appropriate than a numerical ground water model.

The proposed WHPA's for the Boundary Upland presented in this report are based on a combination of hydrogeologic mapping and TWODAN analytical modeling, as described above. The description and results of the hydrogeologic mapping and modeling are presented in the following sections.

4.3 Hydrogeologic Mapping

Hydrogeologic mapping provides a method for determining ground water flow directions and general areas of recharge. This information is in turn required as a preliminary step to ground water modeling.

Hydrogeologic mapping was performed for the Blaine Boundary Upland area based on the conceptual hydrogeologic model presented in Section 3.3. The first step was to construct a ground water level map based on the most recent water level data. Using the basic concepts of ground water flow, the directions of ground water flow were determined, and the potential recharge area to the City wells installed in the Shallow Aquifer System were mapped out. An estimate of the maximum recharge area is shown in Figure 3-6. This recharge area was chosen based on the assumption that the ground water divide occurs near the Canadian Border. This assumption is conservative with respect to WHPA delineation, and appropriate because of the uncertain location of the ground water divide. The estimated recharge area of the City wells, with the exception of City Wells No. 1 and No. 2, which are installed in the Deep Aquifer System, encompasses between 3.2 and 3.9 square miles. Specific TOT designations are not associated with the hydrogeologic mapping approach, and additional work as described in the following section was needed to delineate the WHPA's.

Insufficient data exists to determine the recharge area of the Deep Aquifer System (Unit F) via hydrogeologic mapping.

4.4 Ground Water Modeling

Analytical modeling is a useful tool for evaluating ground water flow, and understanding the aquifer system and how contaminants may be transported through the system. It is important to realize that a ground water model is simply a tool for hydrogeologic analysis. It is rare that a ground water model can accurately simulate or predict ground water conditions in all portions of the aquifer system. This is particularly true of the Boundary Upland area, because of its complexity. However, the analytical ground water modeling technique used in this case is more accurate than most of the other available methods for WHPA delineation, as described in Section 4.2, with the exception of numerical ground water modeling. A numerical modeling technique was not chosen in this case due to the limited data available.

The primary objective of the modeling is to simulate each aquifer system and develop WHPA's for planning purposes. The model can be modified in the future to re-evaluate WHPA's in the event of changes in the location and amount of ground water withdrawals, or if significant additional hydrogeologic data becomes available. If sufficient data becomes available in the future, a three-dimensional numerical ground water flow model that can represent each water-bearing zone in the system individually could be considered to further refine the WHPA's, and for evaluating and managing the ground water supply. The following section describes the reasons for selecting TWODAN for delineating the WHPA's, and some of the program's capabilities.

4.4.1 Selection of Ground Water Model and Model Capabilities

The modeling approach used for delineating WHPA's for the City wells using TWODAN was chosen based on the conceptual understanding of the hydrogeologic system. Uncertainties with regard to the aquifer properties were also taken into account in the selection of the model including the following:

- The hydrogeologic system of concern consists of two multi-layered aquifer systems, the Shallow Aquifer System and the Deep Aquifer System. The Shallow Aquifer System consists of laterally discontinuous water-bearing units, and the stratigraphy and thickness of these units are not well known. Little is known of the lateral extent and character of the Deep Aquifer System;

- Locally semi-confined to confined water-bearing units exist within the Shallow Aquifer System, and the ground water-levels associated with each unit throughout the Boundary Upland area cannot at the present time be fully determined. Available ground water level measurements are mostly from Unit C in the western portion of the Boundary Upland. The only available ground water level data from the Deep Aquifer System is from City Wells No. 1 and No. 2.;

- A study by EMCON (1995) concludes that recharge is nonuniform within the Boundary Upland area.

The use of TWODAN provides better results than less sophisticated approaches (U.S. EPA WHPA code, for example), as described in Section 4.2, recognizing that the data are insufficient for developing a more complex three-dimensional numerical model that could potentially more closely represent the complex nature of the ground water flow system.

TWODAN has the following capabilities:

- Spatially variable recharge or leakage can be represented. A uniform recharge or leakage can be assigned to the entire model domain. Different recharge or leakage rates occurring locally can be represented by circular domains of any assigned radius;

- Confined or unconfined aquifer systems can be modeled;

- Variations in aquifer properties (thickness, transmissivity, storativity, and porosity) can be incorporated as appropriate throughout the model domain;
- Injection and pumping wells can be simulated;
- Rivers and lakes can be represented using linesinks with specified discharge or constant heads;
- Impermeable/resistant boundaries of any configuration can be modeled; and
- Variable well-pumping scenarios can be simulated.

Not all of the above features were required to model the Boundary Upland hydrogeologic system.

The advantages of the TWODAN method over conventional numerical methods are its simple input, accuracy, speed, lack of a fixed grid, and direct graphical output. Prior to use, the model was subjected to internal performance review according to protocols required under ISO 9000 certification, and modeling results were compared with results generated using the U.S. EPA WHPA code.

4.4.2 Modeling Approach

Due to the lack of hydraulic connection between the Shallow Aquifer System and the Deep Aquifer System, each aquifer system were modeled separately, using the approach described below.

Shallow Aquifer System

The Shallow Aquifer System is comprised of a complex three-dimensional, multi-layered, laterally discontinuous set of water-bearing units, as shown is the cross sections presented in Figures 3-1 through 3-4. Each water-bearing unit could potentially be represented numerically or analytically as an equivalent aquifer with uniform thickness and constant hydraulic properties, based on the estimated average thickness and hydraulic properties of the laterally discontinuous unit. The equivalent aquifer model, once calibrated to available water level conditions, could then be used to estimate the average rate of ground water flow through the water-bearing unit. An additional complicating factor of the Shallow Aquifer System, however, is the interaction of the water-bearing units, and the amount of ground water that passes between them. Given the discontinuous nature of the individual water-bearing units, it is possible that more ground water is transmitted between an overlying and an underlying water-bearing unit than occurs laterally within each water-bearing unit. Given the uncertainties associated with the lateral extent and character of the water-bearing units within the Shallow Aquifer System, it was determined that the most appropriate way to model the Boundary Upland hydrogeologic system is to represent the entire Shallow Aquifer System as a single aquifer of uniform thickness and laterally constant aquifer properties.

The equivalent aquifer model, as described above, was used to estimate the average rate of ground water flow through the aquifer system. This is an appropriately conservative approach, because if a contaminant release occurs within the WHPA, it is assumed that wells installed in the deeper water-bearing units are just as likely to be contaminated as the shallower wells.

The equivalent aquifer system approach used in this study is designed to represent the aquifer system as closely as possible given the available data. In this case, a three-dimensional multiple-layered system was transformed and represented by a two-dimensional, single-layer confined aquifer. The key idea is that the average ground water flow rate within the actual ground water flow system can be estimated by modeling the equivalent single aquifer system.

Deep Aquifer System

Little is known of the characteristics of the Deep Aquifer System, including the direction of flow and the hydraulic gradient. As a result, the approach taken in modeling the TOT's for the Deep Aquifer System was to assume that the aquifer characteristics observed at replacement Well No. 1 is representative of the aquifer as a whole. In addition, a range of potential directions of flow and hydraulic gradients was assumed, as described in the following section.

4.4.3 Assumptions

The key parameters which determine the rate of ground water flow are transmissivity and hydraulic gradient. The following sections describe how the key parameters of the representative system were calibrated and satisfied, as well as assumptions, and model results.

The key assumptions are summarized as follows:

Shallow Aquifer System

- The model domain includes the Boundary Upland area in the U. S. and part of Canada, and the immediate surrounding areas westward to Drayton Harbor;

- Based on the average thickness of aquifers tapped by the City wells, and considering the discontinuous nature of the water-bearing units the comprise the Shallow Aquifer System, an average thickness of the equivalent aquifer system contributing ground water to the wells was assumed to be 30 ft;

  The bottom elevation of the equivalent aquifer was set at -50 ft msl to represent the aquifers within the Boundary Upland which have elevations varying from about -100 ft (bottom of Unit D) to above 100 ft msl (Unit C in the Boundary Upland);

- Based on the estimated recharge rate of between 230 to 660 gpm/mi^2/yr (Golder, 1995) an equivalent average recharge rate of 470 gpm/mi^2/yr within the Boundary Upland area was assumed. This equates to a total average annual recharge rate of 3,770 gpm for the total Boundary Upland area of approximate 8 mi^2;

- A greater average recharge rate was applied in the western half (500 gpm/mi^2/yr) of the Boundary Upland area in comparison to the eastern half (450 gpm/mi^2/yr), because the potential for recharge is greater in the western half of the Boundary Upland area than the eastern half (EMCON, 1995);

- The ground water level near Drayton Harbor was assumed to be 0 ft msl, to provide a reference point elevation required by TWODAN; and

- The effective porosity of the aquifer system was assumed to be 0.25.

Deep Aquifer System

- The model domain includes the Boundary Upland area in the U. S and an extended portion of Canada, and the immediate surrounding areas westward to Drayton Harbor;

- The thickness of the aquifer averages 20 feet, as observed at the replacement Well No. 1;

- No recharge from precipitation occurs within the TOT zones, and all recharge occurs as lateral flow from outside of the model domain. This was done to reflect the low potential of significant recharge to the deep aquifer from downward leakage through the extensive thickness of low permeability materials that overly the aquifer;

- The direction of flow is assumed to be west to southwest, with a hydraulic gradient of between 0.001 and 0.003, based on the observed static water level conditions at Replacement Well No. 1 and assuming that the static water level at Drayton Harbor, located 3.5 miles to the southwest is at 0 ft amsl.;

- The ground water level near Drayton Harbor was assumed to be 0 ft msl, to provide a reference point elevation required by TWODAN; and

- The effective porosity of the aquifer system was assumed to be 0.25.

4.4.4 Model Calibration

Shallow Aquifer System

Aquifer transmissivity (and to a lesser degree, aquifer recharge) was adjusted to calibrate the ground water flow model to the measured ground water elevations in the Boundary Upland area. Eight ground water level measurements were used in the calibration process. For the final calibrated model, the simulated ground water levels were matched as close as possible to the observed ground water levels. The calibrated model was then used to predict the 1-, 5-, and 10-year TOT zones for each of the shallow City's wells. The targeted water level elevations used for model calibration and the simulated ground water elevations derived from the calibrated model are summarized in Table C-1. Table 1-2 presents a summary of the well construction.

Recharge was accounted for in TWODAN by applying it near the ground water divide using a series of circular domains with diameters of between 1,600 to 2,000 ft. These circular areas did not encompass all of the Boundary Upland area. Consequently, the modeled recharge was concentrated nearer the ground water divide and the center of the Boundary Upland area than it may be in reality. This approach was necessitated by the way TWODAN handles recharge. However, the result is a somewhat conservative over-estimate of the size of the WHPA's, because the actual rate of ground water flow near the central Boundary Upland area would be somewhat less than that calculated in the model.

Through the model calibration process, the average aquifer transmissivity of the Boundary Upland ground water flow system was estimated at 495 ft^2/d. This estimated average aquifer transmissivity is consistent with the transmissivity calculated from pumping tests of City wells (1,000 to 3,000 ft^2/d) recognizing that these aquifers are laterally discontinuous. The calibrated average aquifer transmissivity of 495 ft^2/d was used to model the 5-year and 10-year TOT's. However, this transmissivity was not used to calculate the 1-year TOT's, because the aquifer transmissivity is known to be higher than the average aquifer transmissivity near the City wells.

The geometric mean of the calibrated average aquifer transmissivity and the average transmissivity at the City wells was chosen to reflect the trend of decreasing transmissivity away from the City wells. The geometric mean of wellfield transmissivity (about 2,000 ft^2/d) and regional transmissivity (495 ft^2/d) is about 1,000 ft^2/d. This value is a reasonable intermediate between the wellfield transmissivity and the regional transmissivity, that better represents the ground water flow conditions within the 1 year TOT.

Deep Aquifer System

Model calibration for the deep aquifer was limited to matching the water level at Well No. 1, because additional water levels in the deep aquifer were not available.

4.5 Model Results

Modeling results for the current pumping conditions and possible future pumping conditions are presented in the following sections.

4.5.1 Well Capture Zones/WHPA Delineation - Current Conditions

Under current conditions, the City wells were assumed to be pumping at the following reported or assumed maximum year-round pumping rates:

Well ID	Pumping Rate (gpm)
No. 1	800
No. 2	200
No. 3	210
No. 4	300
No. 5	450
No. 6	170
No. 8 (Lincoln Park)	300
Total	2,430

Well No. 7 (12th St. well) was not included due to its current infrequent use. Each of the TOT capture zones is presented below and the area of the capture zones is summarized in Table C-2.

4.5.1.1 1-year TOT Capture Zone

Shallow Aquifer System

The composite 1-year TOT zones are shown on Figure C-1. In the Blaine Watershed, the 1-year TOT capture zones of Wells No. 3, No. 4, No. 5, and No. 6. coalesce and cover a total area of 283 acres. The TOT zone extends northward and eastward from the wells to just outside the boundaries of the Blaine Watershed. For Well No. 8, the 1-year TOT capture zone has an area of 64 acres occurring around the well and extending eastward. Due to the distance between Well No. 8 and the Watershed wells, the respective 1-year TOT capture zones do not overlap.

Deep Aquifer System

The composite 1-year TOT zones for City Wells No. 1 and No. 2 are shown on Figure C-2. The TOT zone extends northward and eastward from the wells a distance of approximately 4,200 feet, and covers and area of 287 acres.

4.5.1.2 5-year TOT Capture Zone

Shallow Aquifer System

The composite 5-year TOT capture zone is shown in Figure C-1. In the Blaine Watershed, the 5-year TOT capture zone for City Wells No. 3, No. 4, No. 5, and No. 6 coalesces and covers an area of 1,089 acres. The TOT extends an average distant of roughly 6,000 feet to the north and northeast to the center of the Boundary Upland area where the ground water divide is present. For Well No. 8, the 5-year TOT capture zone has an area of 293 acres. Well No. 8's 5-year TOT extends eastward a distance of roughly 4,000 feet from the well. Due to the distance between Well No. 8 and the Watershed wells, the respective 5-year TOT capture zones do not overlap.

Deep Aquifer System

The composite 5-year TOT zones for City Wells No. 1 and No. 2 are shown on Figure C-2. The TOT zone extends northward and eastward from the wells a distance of approximately 13,500 feet, and covers and area of 2,150 acres.

4.5.1.3 10-year TOT Capture Zone

Shallow Aquifer System

The composite 10-year TOT capture zone is shown in Figure C-1. In the Blaine Watershed, the 10-year TOT capture zone for City Wells No. 3, No. 4, No. 5, and No. 6 coalesces and covers an area of 1,421 acres. The TOT extends an average distant of roughly 7,000 feet to the north and northeast to the center of the Boundary Upland area where the ground water divide is present. For Well No. 8, the 10-year TOT capture zone has an area of 390 acres. The Well No. 8 10-year TOT extends eastward a distance of roughly 4,500 feet from the well. Due to the distance between Well No. 8 and the Watershed wells, the respective 10-year TOT capture zones do not overlap.

Figure C-1 illustrates that there is only a relatively small difference in the sizes of the 5-year and 10-year TOT's of the shallow aquifer wells. This is because of the close proximity of the ground water divide in the Boundary Upland area to the City wells. In general, the figure illustrates that the recharge area of the shallow City wells is close to the wells, and that any contaminant releases in the Boundary Upland area could potentially reach the shallow City wells within a relatively short time, generally less than 5 years.

Deep Aquifer System

The composite 10-year TOT zones for City Wells No. 1 and No. 2 are shown on Figure C-2. The TOT zone extends northward and eastward from the wells a distance of at least 19,500 feet, and covers and area of at least 4,000 acres.

For the deep City wells (No. 1 and 2), there is a significant difference between the 5-year and 10-year TOT; the area of these TOT's are considerably greater than the equivalent TOT's are for the shallow aquifer wells. However, as discussed in Section 4.6 below, the vertical time of travel of a contaminant will be significantly greater than is the case for the shallow aquifers. Therefore, the contamination potential of the deep City wells is not accurately reflected by the size of the TOT's. The potential for contaminating the deep City wells is considerably less than the potential for contaminating the shallow wells, as described in later sections of this report.

4.5.1.4 Zone of Contribution

Shallow Aquifer System

The total zone of contribution or recharge area of the shallow City wells was discussed in Section 4.3, and the results are presented in Figure 3-6. The area shown in Figure 3-6 was derived based on the uncertainty of the hydrogeologic characteristics of the Boundary Upland area, and reflects what is believed to be a conservative estimate of the total area contributing ground water to the shallow City wells. In recognition of the limited nature of the recharge area of the shallow City wells (generally confined to the Boundary Upland area), and the uncertain hydrogeologic characteristics of the aquifers within the Boundary Upland area, we feel that it is prudent to consider the entire potential area of recharge in addition to the TOT modeling results to establish the WHPA's.

Deep Aquifer System

Presently, the zone of contribution of the deep City wells is unknown, but is likely northeast or east of the Boundary Upland area in British Columbia. Additional work is needed to determine where the Deep Aquifer System is being recharged.

4.5.2 Well Capture Zones/WHPA Delineation - Future Conditions

Under future conditions, the City wells were assumed to be pumping at the following reported maximum year-round pumping rates, including Well No. 7 (12th St.) and the proposed production well at the Boblett St. site (City Well No. 9):

Well ID	Pumping Rate (gpm)
No. 1	800
No. 2	200
No. 3	210
No. 4	300
No. 5	450
No. 6	170
No. 7 (12th St.)	320 (Periodical pumpage: assuming 1/3 of the rate in the model)
No. 8 (Lincoln Park)	300
No. 9 (Boblett St)	200
Total	2,737

Each of the TOT capture zones for the Shallow Aquifer System are presented below and the area of the capture zones were summarized in Table C-3. No future pumping change was assumed for the Deep Aquifer System, and therefore, the Deep Aquifer System TOT's are the same as under the assumed present pumping conditions.

4.5.2.1 1-year TOT Capture Zone

Shallow Aquifer System

The composite 1-year TOT zones are shown on Figure C-3. In the Blaine Watershed, the 1-year TOT capture zones of Well No. 3, No. 4, No. 5, and No. 6 coalesce and cover a total area of 282 acres. The TOT zone extends northward and eastward from the wells to just outside the boundaries of the Blaine Watershed. For Well No. 9 (Boblett Site well), the 1-year TOT capture zone has an area of 43 acres. Well No. 9's 1-year TOT zone extends roughly

1,500 feet to the northeast of the well. For Well No. 8, the 1-year TOT capture zone has an area of 65 acres. Well No. 8's 1-year TOT zone extends roughly 1,300 feet to the east of the well. The 1-year TOT zone for Well No. 7 (12th St.) has an area of 21 acres, and occurs in a circular area surrounding the well.

Due to the distance between Wells No. 7, 8, and 9 and the Watershed wells, the respective 1-year TOT capture zones do not overlap.

4.5.2.2 5-year TOT Capture Zone

Shallow Aquifer System

The composite 5-year TOT capture zone is shown in Figure C-3. In the Blaine Watershed, the 5-year TOT capture zone for City Wells No. 3, No. 4, No. 5, and No. 6 coalesces and covers an area of 1,085 acres. The TOT extends an average distant of roughly 6,000 feet to the north and northeast to the center of the Boundary Upland area where the ground water divide is present. For Well No. 9, the 5-year TOT capture zone has an area of 172 acres. Well No. 9's 5-year TOT zone extends roughly 4,000 feet to the northeast of the well. For Well No. 8, the 5-year TOT capture zone has an area of 286 acres. Well No. 8's 5-year TOT extends eastward a distance of roughly 4,000 feet from the well. The 5-year TOT zone for Well No. 9 has an area of 114 acres, and occurs in a semi-circular area surrounding the well. The capture zone does not extend farther to the northeast, due to the presence of Well No. 8, which intercepts the ground water flowing to the southwest before it reaches Well No. 7. Due to the distance between Wells No. 7, 8, and 9 and the Watershed wells, the respective 5-year TOT capture zones occur as three non-coalescing areas.

4.5.2.3 10-year TOT Capture Zone

Shallow Aquifer System

The composite 10-year TOT capture zone is shown in Figure C-3. In the Blaine Watershed, the 10-year TOT capture zone for City Wells No. 3, No. 4, No. 5, and No. 6 coalesces and covers an area of 1,428 acres. The TOT extends an average distant of roughly 7,000 feet to the north and northeast to the center of the Boundary Upland area where the ground water divide is present. For Well No. 9, the 10-year TOT capture zone has an area of 183 acres. Well No. 9's 10-year TOT zone extends roughly 4,200 feet to the northeast of the well to the ground water divide. For Wells No. 7 and 8, the 10-year TOT capture zone has an area of 629 acres. Wells No. 7's and 8's 10-year TOT extends eastward a distance of roughly 4,500 feet from the wells. Due to the distance between Wells 7, 8, and 9, and the Watershed wells, the respective 10-year TOT capture zones occur as three non-coalescing areas. However, due to potential variations in the hydrogeologic conditions in the Boundary Upland area, the 10-year TOT's may in fact coalesce. This must be considered in the delineation of the WHPA's.

As discussed under the current pumping conditions section above, Figure C-3 illustrates that there is only a relatively small difference in the sizes of the 5-year and 10-year TOT's of the shallow aquifer wells. This is because of the relatively close proximity of the ground water divide in the Boundary Upland area to the City wells. In general, the figure illustrates that the recharge area of the City wells is close to the wells, and that any contaminant releases in the Boundary Upland area could potentially reach the City wells within a relatively short time, generally less than 5 years.

4.5.2.4 Zone of Contribution

Shallow Aquifer System

The present total zone of contribution or recharge area of the shallow City wells was discussed in Section 4.3, and the results were presented in Figure C-3. Due to the potential of increased pumping in the future, the future zone of contribution may be larger than the present zone of contribution, because more ground water will be drawn toward the City wells.

In recognition of the limited nature of the recharge area of the shallow City wells (generally confined to the Boundary Upland area), and the uncertain hydrogeologic characteristics of the aquifers within the Boundary Upland area, we feel that it is prudent to consider the entire potential area of recharge in addition to the TOT modeling results to establish the WHPA's.

4.6 Vertical Time Of Travel Component

TOT-based capture zones assume that a contaminant released in a WHPA capture zone would reach the water table instantaneously. This is not always the case. Contaminants introduced at the ground surface can be adsorbed to the soil particles and dispersed and diluted as they move down to the aquifer through infiltration. The vertical component of travel time depends on the hydraulic property and thickness of the unsaturated zone and the type of contaminant. In this study, vertical travel time was calculated assuming that the contaminants are non-adsorptive using Darcy's Law. The vertical travel time of ground water is controlled by the least permeable layer of the unsaturated zone.

Within the Blaine Boundary Upland, the controlling layer for the vertical travel time is the confining layer Unit A/B. Assuming that Unit A/B has a hydraulic conductivity of 2.8×10^{-3} ft/day (average for glacial till, Freeze and Cherry, 1979, Page 29), a porosity of 0.25 and a thickness ranging from 20 to 40 ft, and that the vertical hydraulic gradient is 1, the vertical travel time is estimated to range from 5 years to 10 years. There is a degree of uncertainty associated with the vertical travel time. First, Unit A/B is interbedded with water-bearing Unit C. Due to the presence of lenses and perched zones, there may be direct channels for contaminants to move into the Shallow Aquifer System. Secondly, there are about 100 wells in the study area which may provide possible direct pathways for contaminants to reach the aquifer, if the wells do not have properly installed surface seals. Therefore, the vertical travel time may vary from days to years. For planning purposes, in this case, we feel that it is most appropriate to assume an instantaneous vertical travel time for the shallow City wells.

The vertical travel time of a contaminant to the Deep Aquifer System (Unit F) is controlled by the overlying confining layer Units A/B and E. The vertical travel time to the deep aquifer was roughly estimated at 240 years based on the following assumptions:

- Units A/B and E have a hydraulic conductivity of 2.8x10^{-3} ft/day (average for glacial till, Freeze and Cherry, 1979, Page 29);
- The porosity is 0.25;
- The thickness of Units A/B and E overlying Unit F is 500 ft; and
- The vertical hydraulic gradient is 0.5 ((280ft-45ft)/500ft), estimated based on the maximum water levels observed in the Boundary of 280 ft amsl, and an estimated pumping water level of the Deep Aquifer System of 45 feet amsl.

The estimate of vertical travel time to the Deep Aquifer System is believed to be conservative, in part because the vertical hydraulic gradient is less than that assumed, except for possibly the central Boundary Upland area. The actual vertical travel time could be considerably greater than that calculated.

Due to the vertical time of travel that would be required for a contaminant to reach the aquifer, in combination with the lack of deep wells that could serve as conduits, we believe that it is reasonable in this case to consider the vertical travel time in defining the WHPA's for the Deep Aquifer and Wells No. 1 and No. 2.

5. SUMMARY OF HYDROGEOLOGIC CONDITIONS AND RECOMMENDED WHPA'S

5.1 Overview of Data

The hydrogeologic conditions of the Boundary Upland Area were evaluated based on previously existing data, and on studies of the Boundary Upland Area that were conducted specifically to address wellhead protection issues. Work recently conducted in connection with the WHPP included the installation of two deep monitoring wells, the collection of several rounds of water level data, the collection of two rounds of water quality data, and a geophysical survey. Additional work conducted by Golder Associates that is relevant to the WHPP, included the installation and pump testing of a replacement well for City Well No. 1. This work provided a better understanding of the geology of the Blaine Watershed area, and in addition, provided a much clearer understanding of the hydraulic properties of deepest aquifer utilized by the City, and the potential for additional ground water development.

5.2 Hydrogeologic Conditions

A conceptual model of the hydrogeologic system was derived from the available data to aid in the delineation of the WHPA's for the City wells. The conceptual understanding of the geologic conditions of the Boundary Upland area furthers the work conducted as part of the GWMP (Golder, 1995). The Boundary Upland area consists of three general aquifer systems; a Perched Aquifer System; a Shallow Aquifer System; and a Deep Aquifer System. The Perched Aquifer System is restricted to the upper portions of the Boundary Upland, and provides adequate quantities of ground water in some cases for domestic use. The Shallow Aquifer System is the most heavily utilized aquifer system of the Boundary Upland area, and is tapped by most of the deeper domestic wells and City Wells No. 3, 4, 5, 6, 7, 8, and 9. This aquifer system is comprised of laterally discontinuous water-bearing units with varying hydraulic properties. The Shallow Aquifer System appears to pinch out to the southwest between the Boundary Upland area and Dakota Creek, as illustrated in Figures 3-3 and 3-4. The Deep Aquifer system occurs at a depth of between 600 and 750 feet bgs, and is separated from the Shallow Aquifer System by 400 to 500 feet of low permeability silt and clay. This aquifer system is tapped by City Wells No. 1 and No. 2, and may possibly be tapped by the "School Well" (Figures 1-2, and 3-4). Based on recent pumping test results of a replacement well for Well No. 1, the Deep Aquifer System tentatively appears capable of yielding up to 2,000 to 3,000 gpm or more, and is an attractive option for further development by the City.

5.3 Ground Water Resources

The City of Blaine is currently withdrawing an average of between 600 and 800 gpm from the Shallow Aquifer System, and there are no indications that the aquifer is being over stressed. It appears, based on aquifer recharge estimates, that additional wells could be developed in the Shallow Aquifer System without significant adverse consequences on ground water levels. Baseflows to Dakota Creek could potentially be effected by significant additional development of the Shallow Aquifer System. However, it is important to note that any adverse effects on the flows of Dakota Creek will likely occur along the tidally-influenced reach of the creek (Figure 1-1), which is exempt from the stream closure rule under WAC 173-501-030.

Recharge to the Deep Aquifer System is believed to be from deep underflow from British Columbia. The amount of recharge has not been determined at this time. However, it is known that City Wells No. 1 and No. 2 have yielded a considerable quantity of water from this aquifer for a period of over 65 years. Based on the recent pumping test of replacement Well No. 1, it is estimated that the Deep Aquifer is capable of sustaining as much as 2,000 to 3,000 gpm. Evaluation of the drawdown response to longer-term pumping is required to refine the estimated long-term yield of the aquifer. These data are currently being collected by City personnel.

Development of the Deep Aquifer has several advantages over further development of the Shallow Aquifer including less potential impact on streamflows and other water rights, and a greater yield potential per well.

5.4 Wellhead Protection Area Modeling

Once the conceptual hydrogeologic model described briefly above was developed, wellhead delineation work began using hydrogeologic mapping techniques to map the potential area of contribution to the City wells. This potential area of contribution defines the ultimate area of interest with regard to protecting the shallow City wells from contamination, since any contaminant released within this area can potentially contaminate one or more of the shallow City wells. The potential area of contribution shown in Figure 3-6 reflects the uncertainty in the hydrogeologic conditions, particularly the location of the ground water divide than runs east-west along the Boundary Upland area. To provide a conservative estimate of the area of contribution to the shallow City wells, the ground water divide was assumed to run along the U.S.-Canadian Border, which is somewhat north of the topographic divide in the Boundary Upland area.

The hydrogeologic mapping results, along with the conceptual hydrogeologic model, provided the basis for developing a ground water model of the Boundary Upland and surrounding areas. The ground water model was used to evaluate the time of travel to the City wells of any potentially released contaminants within the recharge area. Time-of-Travel zones (TOT) provide the basis for wellhead protection delineation in the State of Washington.

Based on the conceptual model of the hydrogeologic system and the amount of data available for model development and calibration, it was determined that the Shallow Aquifer System which is comprised of several water-bearing units, could best be represented as an equivalent single aquifer having hydraulic properties equivalent to the average hydraulic properties of the aquifer system. This approach is conservative in that deeper City wells, such as Wells No. 5 and No. 6, are assumed to have an equal probability of contamination as the shallower City wells, such as Wells No. 3 and No. 4. The Deep Aquifer System was also represented and modeled as a single aquifer. Due to the lack of data available from the

Deep Aquifer, the aquifer properties were assumed to be equivalent to the properties calculated from the recent pumping test of replacement Well No. 1.

5.5 Modeling Results

The TOT capture zones determined from the models of the Shallow and Deep Aquifer Systems under present conditions are shown in Figures C-1 and C-2. Figure C-3 presents the TOT's for the Shallow Aquifer System under assumed future conditions. Future conditions for the Deep Aquifer System were assumed to be equivalent to the present conditions.

The vertical travel time from ground surface to the Shallow Aquifer System underlying the Boundary Upland was evaluated. As suggested by WDOH, it was decided that it is most appropriate in this case to assume an instantaneous vertical travel time. This is because of the uncertainty associated with the vertical travel time as a result of variable hydraulic properties of the sediments at depths of less than 300 feet in the Boundary Upland area. Furthermore, up to 100 domestic wells may be present in the Boundary Upland area. If some of these wells do not have properly installed surface seals, they can act as a conduit allowing contaminated surface water direct access to the aquifer.

The vertical travel time from ground surface to the Deep Aquifer System was roughly estimated at 240 years (base on conservative assumptions). Due to the considerable vertical time of travel that would be required for a contaminant to reach the Deep Aquifer, in combination with the lack of deep wells that could serve as conduits, we believe that it is reasonable in this case to consider the vertical travel time in defining the WHPA's for the Deep Aquifer and Wells No. 1 and No. 2.

Figures C-1 and C-3 illustrate that the recharge area of the shallow City wells is close to the wells, and that any contaminant released in the Boundary Upland area could potentially reach them within a relatively short time, generally less than 5 years. Due to the small difference between the 10-year TOT's and the 5-year TOT's, and the degree of uncertainty in the hydrogeologic conditions, we recommend that management strategies consistent with a 5 -year TOT be adopted throughout the WHPA, and that a 10-year WHPA not be designated.

With regard to the Deep Aquifer and City Wells No. 1 and 2, a WHPA is not recommended due to the considerable time required for a contaminant to reach the aquifer. However, further study to identify the recharge area of the deep well is warranted, as well as the installation of a deep monitoring well upgradient of Wells No. 1 and No. 2 to provide early warning of potential contamination.

The recommended WHPA's are presented in the following section.

5.6 Recommended Wellhead Protection Areas

The recommended 1-year WHPA's are shown on Figure 5-1. The recommended 1-year WHPA's generally correspond with the 1-year TOT's, but were refined to reflect jurisdictional and property boundaries in order to provide a rational basis for implementation of the wellhead protection measures. The 1-year WHPA's are also somewhat larger than the 1-year TOT's in order to take into account some of the inherent uncertainty in the hydrogeologic conditions.

The proposed 5-year WHPA, designated the "Blaine WHPA", is also shown in Figure 5-1. The Blaine WHPA takes into account the overall recharge area of the shallow wells and the uncertainty in the hydrogeologic conditions, as well as the TOT zones derived from the modeling. The area of the Blaine WHPA in Figure 5-1 was developed, in part to reflect jurisdictional and geographic boundaries (roads, streets, etc.) to aid in implementation of wellhead protection measures.

It is important to recognize that the WHPA's in Figure 5-1 are recommended based on the basic principles outlined above. The City, in cooperation with the other jurisdictions should modify the boundaries of the WHPA, if needed, in order to ensure that the boundaries of the WHPA are set in such a way as to allow affective implementation of wellhead protection strategies.

6. WATER QUALITY EVALUATION

This section presents a general discussion of ground water contamination issues and processes, followed by an evaluation of current ground water quality of the Boundary Upland area and the City wells.

6.1 Overview of Contaminant Hydrogeology

Ground water contamination can be defined as artificially induced degradation of natural ground water quality, which may impair the use of the water, and create a human health hazard. Contaminant types can be broadly classified into inorganic chemicals, organic chemicals, microbiological contaminants, and radionuclides. Inorganic chemicals include metals and nitrate. Organic chemicals include petroleum products, pesticides and herbicides, chlorinated solvents, and other miscellaneous organic compounds. Microbiological contaminants include bacteria, particularly coliform bacteria, viruses, and giardia. Table 6.1 presents a general breakdown of contaminant categories and characteristics of typical contaminants.

There are a large number of potential sources of ground water contamination, which are broadly grouped into point sources and non-point sources based on the areal extent of the contaminant source. Point sources include underground storage tanks (UST's), landfills, construction activities, mining activities, and agricultural activities (animal feed lots, dairy). Non-point sources include agricultural use of fertilizers, pesticides and herbicides, septic systems, and urban runoff. The division between point and non-point sources is gradational. For example, depending on the number and areal extent of septic drainfields, septic systems could be classified as either a point or a non-point source.

The transport of a contaminant from the ground surface to an aquifer is a highly complex subject, dependent on a number of hydrogeologic and chemical parameters. It is beyond the scope of the WHPP to evaluate specific transport pathways for all contaminants of concern. Rather, the objective of the WHPP is to provide a general technical framework for planning purposes and for more detailed future analyses as required. The following summary of general contaminant behavior is included to briefly discuss significant transport parameters associated with the various contaminant categories.

In general, there are two important properties to recognize in contaminant transport from the ground surface to ground water:

- Sorption reactions with soil particles (particularly organic matter) are important in controlling the migration rate and concentration of contaminants in both the unsaturated and saturated portions of the sub-surface. In some cases, these processes significantly retard the rate of contaminant migration, and may significantly attenuate the concentration. As such, the plume for a retarded contaminant may expand more slowly and the concentration may be less than for a non-reactive contaminant; and

- The solubility of the contaminant is important in the concentration of the contaminant since it determines how easily the contaminant dissolves in water. A given volume of contaminant with a high solubility is more likely to attain a high concentration in ground water than a similar quantity of a low-solubility compound.

Table 6-2 contains a list of several contaminants and their respective travel times across a 1,000-foot pathline in a granular aquifer similar to the aquifer found in the Boundary Upland area. Table 6-2 shows that travel times range over orders of magnitude depending on the type of contaminant.

The concentration of a contaminant is usually referenced to an MCL established by state or federal agencies based on toxicity and risk to human health. These MCL's are the standards by which the severity of contamination are assessed, and are in many, but not all, cases the established criteria for clean-up actions at contaminated sites. For ground water protection studies, protection of the aquifer is often based on a level lower than the MCL as a target water quality which the community strives to maintain. Table 6-3 summarizes current State of Washington primary drinking water standards (MCL's) for inorganic and organic contaminants.

Water quality aspects of interest with regard to human health, and the fate and transport of contaminants in ground water are discussed in the following sections.

Major Cations/Anions

In general, the major cations and anions do not pose a threat to human health and are not generally considered contaminants. At high concentrations, some ions, such as chloride, sulfate and sodium, may cause a health risk. A secondary MCL for chloride (250 mg/L), and sulfate (250 mg/L) exists. However, an MCL for sodium has not been established by the state or the U.S. EPA. An MCL for sodium may or may not be established in the future.

Metals

Elevated metals may cause a variety of health problems associated with accumulation of metals in body tissue. The transport and fate of trace metals is complex, due to their tendency to form complexes with inorganic and organic anions, which changes their potential solubility and transport characteristics accordingly, and due to their sensitivity to the specific conditions of the subsurface (pH, pE, and redox environment). Adsorption processes may also strongly influence the mobility of trace metals. For example, in some ground water, many of the trace metals are strongly adsorbed, which reduces the dissolved concentrations significantly.

Nitrate

Nitrate contamination, in general, has been attributed to agricultural practices, septic systems, nitrogen fertilizers and urban run-off. Elevated nitrate concentrations pose a health risk, particularly to infants and small children, from a condition known as methemoglobinemia. A primary MCL of 10 mg/L exists for nitrate. In some cases nitrate in ground water originates as nitrate-containing wastes or fertilizers applied to the ground surface. Nitrate may also originate from organic nitrogen which occurs naturally or is incorporated into the soil by human activities. A process called denitrification often occurs in the soil zone (and ground water system) when organic matter is abundant and reducing conditions exist. Denitrification in the soil zone can remove large amounts of nitrate under certain conditions. Once nitrate reaches the water table, however, it is highly mobile (does not react or absorb to soil particles) and does not transform or break down readily unless denitrification occurs in the absence of dissolved oxygen.

Organic Chemicals

Organic chemicals are becoming an increasingly problematic contaminant in ground water. They include petroleum products (gasoline, diesel oil), solvents, pesticides and herbicides. The health risk of organic contaminants range considerably. Many are toxic to the nervous system or vital organs and others are carcinogens. One of the common behaviors of most organic chemicals is their occurrence in multiple phases. During migration from a surface source to the water table, organic chemicals can partition into three distinct phases, occurring in:

- Soil pores and soil solids as a residual;
- Soil gas as a vapor; and
- Pore water and ground water as a dissolved phase.

Thus, a given quantity of contaminant released to the subsurface has a very complex pathway from its source to ground water. Many organic contaminants are volatile and a portion of a spill on the ground surface will "evaporate" into the atmosphere. A spill may migrate downwards in a liquid phase and mix with ground water at the water table. Water infiltrating through contaminated soil may "pick up" contaminants present in the soil. A fluctuating water table may also pick up contaminants in this manner.

Organic contaminants can be broadly classified according to their non-aqueous behavior into Light Non-Aqueous Phase Liquids (LNAPL) and Dense Non-Aqueous Phase Liquids (DNAPL). These distinctions are important to the fate and transport of organic contaminants in ground water.

As the name implies, LNAPL is lighter than water, and, when present in ground water, often floats at the water table. LNAPL contaminants include gasoline, oils, and greases. The most prevalent potential LNAPL contaminant with regard to the City wells is gasoline. Gasoline is a complex mixture of over 200 different hydrocarbon compounds. Of these compounds, soluble aromatics typically comprise more than 95 percent of the dissolved constituents. As a result, the dissolved components typically associated with gasoline contamination are normally dominated by the aromatics benzene, toluene, ethylbenzene, and xylene (BTEX).

As the name implies, DNAPL is denser than water, and, when present in ground water, often sinks below the water-table. Below the water table, DNAPL in large quantities may migrate to the bottom of the aquifer or perch on stratigraphic heterogeneities within the aquifer. If present as a free-product liquid phase below the water table, DNAPL can be a continuing source of dissolved ground water contamination lasting many decades. DNAPL contaminants include solvents used for cleaning and degreasing of metal parts. Common components of solvents include trichloroethylene and trichloroethane. Tetrachloroethylene (PCE) is commonly used in dry cleaning processes.

6.2 Available Water Quality Data

Ground water quality data are available from a number of wells within and adjacent to the Boundary Upland area. For the purposes of the WHPP, a ground water quality monitoring network was established within the Boundary Upland area of Blaine, Washington, and British Columbia, Canada by EMCON of Bothell, Washington. The network consists of six domestic wells as shown on Figure 6.1. In addition to these six domestic wells, ground water quality data were previously collected in 1990 and 1991 from eleven other domestic wells, three test wells, and four City of Blaine municipal water wells as part of the Blaine GWMP (Golder, 1995). Other data are available from the City wells which was collected as part of the water quality monitoring program for Class A Drinking Water Systems. Tables 1-1 and 1-2 summarize. the available well construction information of the wells used for sampling.

Specifically, the water quality data available for this study are summarized as follows:

- Water quality data from eight City wells recorded periodically from 1956 to 1993 (Table B-1). Analytes included general physical characteristics, dissolved inorganic constituents, and metals;

- Four quarterly rounds of water quality samples taken in 1990 and 1991 during the GWMP from the three test wells, four City wells, and eleven domestic wells (Table B-2). Analytes included general physical characteristics, dissolved inorganic constituents, metals, total coliform, and total organic halides (TOX); and

- Two rounds of water quality samples recently taken for the WHPP from the three test wells and six domestic wells (Table B-3). Analytes included general physical characteristics, dissolved inorganic constituents, metals, total coliform, and total organic carbon (TOC).

6.3 Summary Of Previous Studies And Regional Ground Water Quality

As part of the Blaine GWMP (Golder, 1995), a regional ground water quality analysis was conducted based on water quality data from the City wells, test wells, and eleven domestic wells. This section presents a brief summary of the regional ground water quality characteristics.

The regional water quality data are summarized in part in Tables B-1 and B-2, and presented by a Piper diagram (Figure 3-5). The Piper diagram indicates that calcium and magnesium are generally the predominant cations, and bicarbonate, represented by alkalinity, is generally the predominant anion. Ground water from the Perched Aquifer System does not have a clear dominant ion chemistry, whereas the ground water from the Shallow Aquifer System is classified as a calcium bicarbonate type of water. The water from the Deep Aquifer is classified as a sodium bicarbonate type of water, due to its higher sodium concentration in comparison to calcium (Figure 3-5).

Overall, pH values range from 7.4 to 8.4, which is within the range of acceptable pH established by the WDOH. The water varies from soft to moderately hard, with total dissolved solids (TDS) concentrations ranging from 93 to 130 mg/L.

The shallow waters of the Perched Aquifer (Leer) differ from other waters within the Boundary Upland area, due to their close proximity to ground surface and short residence times within the subsurface. No dominant anions or cations are present, stemming from the short residence time of the ground water, and the resulting low ion concentration.

The water quality of the Shallow Aquifer System, in general, is good. However, nitrate concentrations of up to 2 mg/L have been detected in some of the wells (Boettcher, Leer, Colacurcio, Aller, and City Wells No. 3 and No. 4 that tap the shallowest water-bearing zones (Unit C) of the Shallow Aquifer System. Nitrate concentrations are less in the deeper water-bearing zones of the Shallow Aquifer System, including Unit D. Manganese concentrations may be higher in Unit D, and is near the Secondary MCL of 0.05 mg/L in some cases.

The ground water within the Deep Aquifer (City Wells No. 1 and No. 2) has a higher sodium concentration (about 35 to 66 mg/L) and chloride concentration (30 to 47 mg/L) in comparison to the Shallow Aquifer System in the area.

In summary, the water quality within the general Blaine area appears to be good. However, the concentrations of nitrate in Unit C of the Shallow Aquifer System are elevated above background levels (up to 2 mg/L). The elevated nitrate concentrations in the Boundary Upland area raises concerns over the impacts of future land use activities on the quality of the City ground water supply.

6.4 Ground Water Quality Sampling

To determine the current ground water quality within the Boundary Upland area, two rounds of ground water samples were conducted as part of the WHPP. In the first round, six domestic wells were sampled by EMCON on October 24, 1994, and in the second round, six domestic wells and the three test wells (GWMP-1, -2, and -3) were sampled by Golder Associates on June 5 and 6, 1995. All the wells sampled are located in the Shallow Aquifer System of the Boundary Upland.

Samples were collected in accordance with the "Quality Assurance Plan for the Blaine Ground Water Wellhead Protection Program" (QA/AC), presented in the Work Plan (Golder, 1995). The samples from the domestic wells were collected from faucets closest to the wells. Water was allowed to run for at least 5 to 10 minutes before the samples were collected. The samples from the test wells were collected from spigots at the wellheads. The test wells were purged from one to three wellbore volumes before the samples were collected. Temperature, specific conductance, pH, and turbidity were monitored prior to sampling. All field instruments were calibrated according to manual instructions, as required in the QA/QC Plan.

The samples were analyzed for the following constituents:

Calcium
Sodium
Potassium
Magnesium
Iron
Bicarbonate
Nitrate-N
Sulfate
Chloride
Silica
Manganese
Hardness.
Total Organic Carbon (TOC)
Total Coliform
Total Dissolved Solids (TDS)

The samples were analyzed by Columbia Analytical Laboratory for the first sampling round and by Laucks Testing Laboratories, Inc. for the second sampling round.

As required in the QA/QC plan, the samples were tracked via Chain of Custody forms from the field to the laboratory. The quality of the data were evaluated according to the QA/QC plan. The laboratory reports were clear and legible, and the analytical laboratories used appropriate EPA methods with the exception of the coliform analysis method used during the second sampling round. Laucks Testing Laboratories, Inc. used a method with a detection limit of 2/100ml for coliform for Wells #6, #37, and GWMP-1 instead of 1/100ml which is the State drinking water standard. The laboratory QC reports and Method Blank reports were provided. A field duplicate sample was also used to validate the water quality data.

6.5 Present Ground Water Quality Of The Boundary Upland Area

This section provides a discussion of the present water quality characteristics of the Boundary Upland area. The water quality data collected for this purpose are summarized in Table B-3, in addition to the data collected previously from other wells within the Boundary Upland area included in Tables B-1 and B-2. Section 6.6 provides a discussion of water quality trends.

6.5.1 Physical Characteristics and Major Inorganic Constituents

Specific-conductance values ranged from 110 (Well #6) to 210 umhos/cm (GWMP-1) and total dissolved solid (TDS) values ranged from 78 (Well #6) to 140 mg/L (GWMP-1). These values fall within the range of most ground water. The specific conductance and TDS in the test wells are generally higher than those in the domestic wells suggesting a longer residence time within the subsurface.

pH values ranged from 5.8 (Well #37) to 8.1 (GWMP-3) and temperature ranged from 9.8 (Well #28) to 18°C (Well #54). The pH of 5.8 is somewhat less than the State recommended range of between 6.5 and 8.5. The hardness ranged from 46 (Well #6) to 80 mg/L as $CaCO_3$ (Well #37), which is considered soft to moderately hard (Todd, 1979).

From the water quality data listed in Table B-3, bicarbonate (48 to 100 mg/L), represented by alkalinity, is the predominant anion, and calcium (10 to 21 mg/L), magnesium (4.6 to 9.2 mg/L), and sodium (5.8 to 8.6 mg/L) are the predominant cations. Bicarbonate, calcium, magnesium, and sodium are common elements in natural water, and, with the possible exception of sodium, have no associated health effects. None of these constituents are currently regulated by WDOH. However, sodium may be regulated in the future.

6.5.2 Nitrate

The concentration of nitrate in the Boundary Upland from the recently collected samples ranged from undetectable (<0.2 mg/L) to 1.7 mg/L (Table B-3). Nitrate was detected in six of the nine wells. Nitrate was not detected in Well #37, GWMP-2, and GWMP-3.

Nitrate was also detected in five of the 14 previously sampled wells in the Boundary Upland (Table B-2). The concentration of nitrate ranged from 0.2 mg/L (Aller well) to 1.9 mg/L (Leer well). Nitrate was detected in all but one of the samples collected from the central Boundary Upland area (Berg well, depth 237 feet). Nitrate concentrations of about 1 mg/L have also been found in City wells No. 3 and No. 4 (Tables B-1, B-2). Figure 6-2 shows a map of nitrate concentrations in the Boundary Upland area. The nitrate concentrations in Figure 6-2 are the highest concentrations measured to date.

6.5.3 Coliform

Large populations of coliform bacteria occur naturally in the intestinal tracts of all warm-blooded animals. Coliform bacteria usually are not harmful in and of themselves, but are used as an index of fecal coliform pollution since they are numerous, and the test is easy and inexpensive. Large counts of any fecal coliform bacteria, indicate other pathogenic organisms may be present. The Washington State primary drinking water standard for total coliform is one colony-forming unit (CFU) in 100 milliliters of water 1/100ml.

Total coliform within the Boundary Upland was detected in only one of the recently sampled wells (Well #28). The October 24, 1994 sample contained 1/100 ml, and the June 5, 1995 sample contained 38.4/100 ml (Table B-3).

One of the 14 previously sampled wells (Leer Well) also detected coliform bacteria 5/100ml (Table B-2).

6.5.4 Turbidity

Turbidity is not a concern with regard to human health, but is regulated for municipal systems for aesthetic and industrial-use reasons. Turbidity can affect sample analysis results for metals such as iron and manganese, when the water samples are not filtered (as was the case for this study). Acidizing the samples as required for analysis may release iron and manganese present as colloidal/sorbed particulates into the ground water, thus increasing the metal concentrations above the actual dissolved concentrations. The secondary drinking water standard for turbidity is 1 Nephelometric Turbidity Units (NTU).

Turbidity from the second round of sampling on June 5-6,1995 ranged from 0.4 (Well #3) to 1.6 NTU (Well #30). Turbidity was not measured during the first sampling round. Only one of the wells sampled in the Boundary Upland (Well #30) contained slightly elevated turbidity levels. Due to battery failure, turbidity was not measured for test well GWMP-1, which had elevated turbidity during the 1990 and 1991 sampling rounds.

Many of the samples collected during the GWMP were slightly turbid: five of the ground water samples collected during the Oct.-Nov., 1990 sampling round, four samples during the second sampling round, seven samples during the third, and three during the fourth exceeded 1 Nephelometric Turbidity Units (NTU). The highest turbidity reported (18 NTU) was for the sample collected from GWMP-1. The other samples averaged about 1 to 2 NTU. Fine sand and silt was interpreted to have been responsible for the elevated turbidity. The open-casing type of completion for most of the domestic wells is a possible explanation for the slightly elevated turbidities, and incomplete development is the likely reason for the elevated turbidity in GWMP-1.

6.5.5 Iron and Manganese

Iron and manganese are regulated by secondary drinking water standards. The MCL is 0.3 mg/L for iron, and 0.05 mg/L for manganese. The concentration of iron ranged from undetectable to 0.85 mg/L in GWMP-1. Iron exceeded the secondary MCL in one of the nine wells sampled (GWMP-1). The concentration of manganese ranged from undetectable to 0.6 mg/L (GWMP-1). All GWMP wells contained manganese greater than the secondary MCL of manganese.

From the previous water quality data (Table B-2) in the Boundary Upland and its surrounding area, iron and manganese appear to correlate moderately well with the turbidity of the samples. This indicates that some of the iron and manganese was derived from particulate matter, and thus may not reflect the true dissolved iron and manganese concentrations. It does appear, however, that somewhat elevated iron and manganese concentrations exist throughout much of the Boundary Upland. In half of the 14 wells sampled, iron concentrations exceeded the State secondary standards during at least one of the four sampling rounds. Locations of elevated manganese concentrations are similar in most of the cases to locations of elevated iron concentrations.

6.5.6 Chloride

Chloride has a secondary drinking water standard with an MCL of 250 mg/L. For the ground water sampled within the Boundary Upland area, the concentration of chloride ranged from 2 mg/L (Well #28, #6, GWMP-1, and GWMP-2) to 4 mg/L (Well #37). No elevated chloride concentrations were detected from the previously sampled wells (Table B-2), and the chloride concentrations of ground water within the Boundary Upland are well below the MCL.

A recent water quality sample collected from replacement Well No. 1 indicated that the chloride concentration of the deep aquifer ground water is 33 mg/L, which is well below the MCL. Some concern with regard to chloride concentrations of deeper wells exists, because many deeper wells in Whatcom County have elevation chloride (and sodium) concentrations.

6.5.7 Organic Compounds

For the analysis of organic compounds, a composite measure of organic constituents was used: total organic carbon (TOC). TOC is used to track the overall organic content of water. This method is technologically simple and economically more attractive than measurement of individual compounds. TOC is useful in the general comparison of water supplies, in identifying pollution sources, and in helping to determine when additional, more specific analyses might be required.

The TOC concentration of the ground water within the Boundary Upland ranged from undetectable (<1 mg/L) in most wells to 2.1 mg/L (GWMP-2). This range falls within in the concentrations of most ground waters (American Water Works Association, 1990) and, therefore, is not an indication of ground water contamination. Based on the current concentration of TOC, no additional analysis of specific organic compounds is believed to be necessary.

6.5.8 Sulfate

Sulfate has a secondary drinking water standard of 250 mg/L. The concentration of sulfate from the water sampled in the Boundary Upland ranged from 2 mg/L (GWMP-2) to 11 mg/L (Well #30). The sulfate concentration ranged from undetectable to 12 mg/L (City Well No. 6) in the previously collected water quality samples. The concentrations of sulfate in the ground water in the Boundary Upland and its surrounding area are well under the State secondary standards.

6.5.9 Sodium

Sodium currently has not been assigned an MCL by WDOH. However, due to health concerns associated with sodium and heart disease, WDOH currently requires that sodium concentrations be monitored in Class A drinking water systems. The concentration of sodium in the water sampled in the Boundary Upland ranges from 4 mg/L to 18 mg/L. A recent water quality sample collected from replacement Well No. 1 indicated that the sodium concentration of the deep aquifer ground water is 66 mg/L which is relatively high, and may be of concern to people on low-sodium diets. Blending of waters could possibly be required in the future if an MCL of less than 60 mg/L is established by WDOH.

6.6 Water Quality Trends

The following sections evaluate water quality trends in the Boundary Upland area.

6.6.1 Seasonal Trends

In general, only minor differences in water quality between the two recently collected sampling rounds were observed, with the exception of coliform in Well #28. These minor differences may be attributed to laboratory accuracy limitations. Sampling for the GWMP in 1990 and 1991 (four rounds) also did not reveal any significant seasonal water quality changes. The differences in coliform concentrations of the recently collected samples of Well #28 is discussed further below.

Well #28 located in the northern Boundary Upland of B.C., Canada had a trend of increasing total coliform from 1/100ml in October 1994 to 38.4/100ml in June 1995. The timing and magnitude of the samples suggests a seasonal trend of increasing coliform during times of increased surface water runoff and ground water recharge coincident with seasonal precipitation. Additional monitoring would be required to confirm this interpretation.

The well log of Well #28 did not specify whether or not a sanitary seal was installed. Absence of a surface seal may be the reason for the presence of coliform.

6.6.2 Long-Term Trends

From the available data, a long-term trend of increasing nitrate is evident. No other long-term water quality changes were evident from the available data.

Nitrate concentrations have been detected in the Boundary Upland area at between 0.2 mg/L and 1.9 mg/L. Insufficient data are available from the domestic wells to determine a trend in nitrate concentrations. However, (old) City Well No. 1 (previously tapping the Shallow Aquifer System) and City Well No. 4 have a clear trend of increasing nitrate concentrations. The concentration of nitrate in (old) Well No. 1 increased from less than 0.2 mg/L in 1990 to 1.0 mg/L in 1993. The concentration of nitrate in City Well No. 4 increased from 0.3 mg/L in 1979, to 1.1 mg/L in 1990, and to 1.2 mg/L in 1993. This supports that there is an ongoing deterioration of ground water quality in the area but all nitrate concentrations are less than the MCL of 10 mg/L.

6.7 Summary and Conclusions

The current ground water quality within the Boundary Upland area is generally good and potable based on the available water chemistry data. The water is generally soft to moderately hard, with iron and manganese concentrations approaching the secondary limits established by WDOH in some cases. The secondary limits for iron and manganese were established primarily for aesthetic reasons, and elevated concentrations are not a threat to human health.

Nitrate concentrations within the Boundary Upland area are currently well under the MCL of 10 mg/L (maximum detected nitrate concentration is less than 2.0 mg/L). However, the existence of widely detectable nitrate concentrations in the primary ground water recharge area of the City wells, and the trend of increasing nitrate concentration in some of the City wells raises concern over future development in this area. Coliform bacteria is also present in at least two of the wells in the Boundary Upland area. Contaminants such as coliform and nitrate can pose serious health risks when MCLs are exceeded. These trends underscore the importance of developing and implementing the WHPP. The concentrations of these and other contaminants can be controlled if future development is properly planned and an appropriate monitoring program is maintained, which is the aim of the WHPP.

7. INVENTORY OF POTENTIAL SOURCES OF CONTAMINATION

This section presents the results of a sanitary survey of the Blaine Watershed, and a land-use and contaminant source inventory of the Blaine WHPA. The sanitary survey consisted of an onsite inspection of the Watershed and the wells within the Watershed, as described in Section 7.1 below. The land-use and contaminant source inventory consisted of collecting available State and Local records on potential contaminants, and conducting a one-day traffic survey and windshield survey of the Blaine WHPA, as described in Sections 7.2 and 7.3.

7.1 Sanitary Survey of the Blaine Watershed

A sanitary survey of the Blaine Watershed was performed in order to evaluate the conditions of the wells within the Watershed, and the susceptibility of the wells to contamination due to well construction deficiencies, and possible vandalism. The City wells located outside of the Watershed area were not examined as part of this investigation, because information provided by the City indicates that they are not deficient or vulnerable to vandalism.

The sanitary survey consisted of the following activities:

- A visual inspection of each of the City wells and the surrounding areas to document:
    1. Visible well construction deficiencies;
    2. The presence or absence of properly functioning flow meters, and water-level access ports;
    3. General pump house conditions as it relates to protecting the wells from contamination; and
    4. Security of the wells and pump houses from unauthorized access.
- A review of the existing logs of the City wells to evaluate proper construction and screen slot-size, and the presence or absence of properly designed surface seals;
- An evaluation of the potential for unauthorized access to the Watershed; and
- An interview with Bill Duffy, City Water and Sewer Manager, regarding potential deficiencies of the City wells and security deficiencies.

The survey of sanitary conditions in the Blaine Watershed was conducted on October 16, 1995 by a Golder Associates Hydrogeologist. The results of the survey are presented below.

A discussion of recommended system upgrades, based on the survey results, is presented in Section 9.

7.1.1 Well No. 1

Well No 1 (original well) is housed in a small wooden building with a partial concrete floor. The building is in poor condition, with holes along the base of the walls, and a door comprised of heavy-gauge wire mesh with a wood frame. Small animals have easy access to the building. The door is secured with a padlock, however, the door itself could easily be broken through or torn from its hinges. The pump is an oil lubricated line shaft turbine, with an electric motor. A partially blocked access port is present for water level monitoring purposes. A small diameter sounder can be used to measure water levels. However, there is no sounding tube in the well, and City personnel have reportedly lost sounders in the past. Due to potential loss of the sounder, City personnel reportedly no longer attempt to measure the water levels in the well. The well log for Well No. 1 does not indicate a surface seal has been installed.

A small concrete reservoir is located near Well No. 1, which is used to trap and remove sand pumped from Well No. 1 before it can enter the water supply. The top of the concrete reservoir is even with the ground surface. Although access to the reservoir is secured with a metal covering and padlocks, it is not water tight, and surface water could potentially overtop the reservoir and enter the water supply in the event of flooding. The City has scheduled to remove the sand trap in 1996.

On the morning of October 17, 1995, a large tree fell on the top of the well house, damaging the roof and upper portion of one of the walls. The pump motor and wellhead were not damaged. Although the well did not have to be taken out of service, this incident underscores the need for an adequate reserve water supply to meet system demands when failures occur.

A replacement well for Well No. 1 has recently been drilled and pump tested. Once the replacement well is online, the City intends to take the old Well. No. 1 out of service and have it properly abandoned and sealed.

7.1.2 Well No. 2

Well No. 2 is not secured in a pump house or surrounded by a fence. The well head is comprised of a 10-inch diameter casing fitted with a conventional cast iron and rubber-packer well cap. The top of the casing is approximately one foot above ground surface. The well cap is in poor condition, and duct tape has been used to cover openings, including the access port for water levels. There is no sounding tube in the well due to the limited annular space between the pump column and well casing, and water level measurements cannot easily be made without jeopardizing the sounder. The conduit for the pump wires is broken off of the well cap, and may pose an electrical hazard. The electrical panels for the submersible pump are located adjacent to the well in a locked metal cabinet. Well No. 2 reportedly has a surface seal installed to 10 feet bgs.

Well No. 2 is located approximately 4 feet from the Watershed access road, and is vulnerable to being hit or damaged by passing vehicles. A small barricade has been placed next to the well to serve as a warning.

7.1.3 Well No. 3

Well No. 3 is housed in a metal building located in a localized topographic depression, where surface water may accumulate during storms and flooding. There is a concrete floor in the building, however, it has been partially broken in order to replace some piping. Several small holes are located in the siding, allowing access by animals. The entrance to the well house is secured with a standard door and padlock. The well is completed with a line shaft turbine pump with an electric motor. Well No. 3 is a flowing artesian well. When the well is shut off, ground water reportedly comes up around the outside of the casing and flows over the ground surface away from the well house. This occurs either due to a lack of a surface seal or a severely damaged surface seal. No surface seal is noted on the log. No access port for water level measurements was noted.

The well itself is in poor condition, and currently cannot be pumped at the permitted water right capacity. The City is currently investigating the possibility of transferring water rights from Well No. 3 to a new deep well.

7.1.4 Well No 4

Well No. 4 is not housed in a building and is not fenced in. The well head consists of a 10-inch diameter casing with a standard cast iron well cap. The casing is about one foot above a four feet square concrete slab. The well is equipped with a submersible pump.

The well itself is reportedly in poor condition, and currently cannot be pumped at the permitted water right capacity. Pump life in the well is reportedly short (B. Duffy, personal communication). The reason for the short pump life is unclear, but most likely stems from sand pumping as a result of improper well construction. The log of Well No. 4 indicates that no surface seal was installed.

7.1.5 Well No. 5

Well No. 5 is housed in a wooden building with holes in the walls stemming from recent piping changes. The building has a concrete floor. Access to the well is through a locked door. The well has a sounding port and airline, however, the condition of each was not determined. The well is completed with a line shaft turbine pump and electric motor. It is not known if Well No. 5 has a surface seal, based on a review of the well log. This well is reportedly the most trouble-free of the wells in the Watershed.

7.1.6 Well No. 6

Well No. 6 is completed with a submersible pump and a pitless adapter. A standard cast iron well cap is fitted to the well casing. The well site is not fenced in, and is slowly being overgrown with blackberries and other bushes. The electrical controls for the well and flow meter are located in a small building about 100 feet away. No access port was noted. However, an observation well is located nearby, which can be used for water level monitoring purposes. The observation well is comprised of an eight inch diameter casing with a welded steel cap with an access port. The well is not secured with a locking access port or fence. A surface seal extending to 30 feet bgs is noted on the log.

No problems were reported with the operation of Well No. 6.

7.1.7 General Comments of Watershed Security and Operation

From the survey, it is clear that unauthorized access to the Watershed and the wells poses a significant risk to the City water supply. The Watershed entrance gate is reportedly kept locked to prevent vehicle access at night, and when City personnel are not onsite. However, access to the Watershed area otherwise is generally unrestricted, although the area is posted. Three of the six wells within the Watershed are not secured by buildings or fenced in adequately, allowing easy access for vandals. Vandals could easily damage equipment stored in the Watershed area, and they could damage or contaminate the wells by dropping objects or substances into the wells.

Chlorine used for chlorinating the water supply is stored in a central location in a locked cinderblock building near Well No. 1 and the reservoir. The building is in good condition, and as long as proper precautions are taken to ensure it remains locked, no substantial threat is posed by the chlorine stored in the Watershed.

The gravel pits east of Wells 3 and 4 were also inspected for potential sources of contamination as part of a cursory inspection of the Watershed. The pits are not "active", but the City periodically removes minor amounts of material from the pits. One piece of equipment from the gravel pit operation remains, but no other evidence of former or illegal activities was noted.

7.2 Land Use

The Blaine WHPA includes three land-use jurisdictions: the City of Blaine, Whatcom County, and the Langley District Municipality (Figure 1-3). Within the City of Blaine, land use is regulated under provisions of Title 17 of the Blaine Municipal Code. This portion of the code includes zoning and subdivision regulations designed to further the goals and policies described in the City's Comprehensive Land Use Plan. The Whatcom County portion of the Blaine WHPA includes portions of the Birch Bay-Blaine planning subarea. Zoning and subdivision regulations that implement provisions of the subarea plans are included in Title 20 of the Whatcom County Code. Current Whatcom County zoning is shown in Figure 7-1, and current City of Blaine zoning is shown in Figure 7-2. Table 7-1 summarizes the City zoning codes.

Land use within the City of Blaine portion of the WHPA is predominantly single-family residential and commercial. Commercial areas exist primarily near the intersection of H Street and the Truck Route (State Route (SR) 543). Additional commercial establishments are located near the Truck Route (SR 543) border crossing. Limited light industrial development is located on Boblett Street near the airport. Land use within the unincorporated Whatcom

County and British Columbia portion of the WHPA is predominantly rural residential and forest.

The area within the Blaine WHPA is zoned for low density residential (UR-1, R-5, and R-10); however, the majority of the area is located within the City's proposed Urban Growth Area (UGA). The extension of municipal water and sewer service to the new annexation area may facilitate a higher density of development.

7.3 Contaminant Source Inventory and Traffic Survey Results

This section provides a summary of the most significant or potential sources of contaminants associated with ground water quality in the Blaine WHPA (Figure 7-3). As part of this study, a database of the present UST's and chemical handlers has been developed, as presented in Tables 7-2 and 7-3. The potential sources of contamination discussed in this section are ranked according to their threat of contaminating the City wells in Section 8, and Wellhead Protection Area management strategies are identified for ground water protection purposes are described in Section 9.0. Sample notification letters to businesses located within the Blaine WHPA and to agencies having jurisdiction over portions of the WHPA are included in Appendix H.

Data collection efforts concerning known and potential sources of contamination that exist within the Blaine WHPA focused on existing and historical land uses. Data sources reviewed include:

- Washington Department of Ecology (Ecology) Underground Storage Tank list;
- Ecology Confirmed and Suspected Contaminated Sites list;
- US Environmental Protection Agency (USEPA) Comprehensive Environmental Response, Compensation, and Liability Information System (CERCLIS) list;
- USEPA Resource Conservation and Recovery Act (RCRA) list;
- City/County zoning and comprehensive plan maps;
- Whatcom County gravel pit location maps;
- Blaine Ground Water Management Program Background Report of Hydrogeology, Land Use, and Water Use (Golder Associates, Inc., 1990);
- Blaine Ground Water Management Program (Golder Associates, Inc. and Adolfson Associates, Inc., 1995);
- Drayton Harbor Watershed Report (Puget Sound Cooperative River Basin Team, 1991);

- Drayton Harbor Watershed Management Plan (Whatcom County Council of Governments, 1995);
- Whatcom County Hazardous Materials Transportation Study (Gage-Johnson, 1994); and
- Whatcom County Hazardous Waste Management Plan (Running Associates, 1991).

In addition to the data sources described above, a windshield survey and a one-day traffic survey of H Street were conducted.

Following is a summary of the known and potential contaminant sources obtained during the data search and traffic survey.

7.3.1 Known Contaminant Releases

The Washington Department of Ecology (Ecology) maintains a list of confirmed and suspected contaminant release sites (e.g., leaking underground storage tanks) in Washington State. There are no facilities within the Blaine WHPA on the list.

The Blaine Department of Public Safety responds to hazardous material release incidents within the City limits. In the City portion of the WHPA, very few hazardous material spills have been recorded. The type of spills that have occurred in this area have been related to vehicle accidents and have resulted in the release of less than five gallons of gasoline (Captain Wishert, personal communication, 1996).

Hazardous material incident response in the county portion of the Blaine WHPA is conducted by Fire District 13. Hazardous material incident response information in the county is not in a form that is readily available. However, according to the District 13 Fire Chief, no major hazardous material spills have been noted in the Blaine WHPA during his 35 year tenure (Chief Joubert, personal communication, 1995).

The Washington State Patrol maintains hazardous material release information for District 7 which includes all of Snohomish, Skagit, and Whatcom Counties. The State Patrol is the incident command agency for the City of Blaine and Whatcom County; however, incident release information for only Whatcom County is not readily available. All District 7 incident response records are kept in one location; identifying incidents only in Whatcom County would be labor intensive.

During 1995, 122 minor incidents were recorded in District 7 (Snohomish, Skagit, and Whatcom Counties). Of these, 40 represented a potential concern to ground water quality. The remaining incidents were related to explosives or gases and did not represent a threat to ground water. Of the 40 incidents that represented a concern to ground water, 23 were diesel fuel releases, 7 were gasoline releases, and 10 were listed as "other chemicals" which are typically corrosives (Sergeant Glass, personal communication, 1995). The incidents are also classified by road type. Of the 122 incidents recorded in District 7 in 1995, 16 occurred on the Interstate system, 34 occurred on state highways, 66 occurred on county roads/other areas, and 6 were not identified.

7.3.2 Potential Contaminant Sources - Stationary Sources

Potential contaminant sources within the Blaine WHPA from stationary (fixed location) sources are summarized below.

7.3.2.1 Sand and Gravel Mining

Sand and gravel mining operations may potentially affect ground water quality by removing surface layers and reducing the amount of material over the aquifer. Contamination may occur because of the infiltration of hydrocarbons (e.g., oil, grease, diesel) that spill or leak from heavy equipment used in the quarrying process. Quarrying may also affect runoff and infiltration patterns in the area and may thus affect the rate and distribution of ground water recharge. In addition, abandoned, unreclaimed sand and gravel mines have historically invited illegal disposal of solid and hazardous wastes.

Several sand and gravel operations, both present and historic, are located within the Blaine WHPA and are shown on Figure 7-3. It is reported that many of the sand and gravel mining operations in the WHPA are small scale and operationally intermittent in nature. However, information regarding the actual size of the operations and amount of material withdrawn is not readily available (Goldthorp, personal communication, 1995).

7.3.2.2 Sewage Disposal

The City of Blaine sewer system serves the western portion of the WHPA. Sewer service is available to residents within the city limits of Blaine (Figure 1-3). Recently, the City's sanitary and stormwater systems were separated (Puget Sound Cooperative River Basin Team, 1991). This was done in part to reduce the potential for sewage overflow into Semiahmoo Bay during storm events. The stormwater system has been rerouted through much of the downtown area to discharge directly to Drayton Harbor (refer to the Stormwater Disposal discussion below). There is a remote possibility of leaking sewer pipelines in localized areas; however, there have been no reports of leaking sewer lines within the Blaine WHPA (Golder Associates, Inc., 1995).

The unincorporated portions of the Blaine WHPA are served primarily by on-site sewage systems, primarily septic tank and drainfields (subsurface absorption systems). These systems typically serve single family residences. Based upon 1993 aerial photograph interpretation, there are an estimated 200 residences within the Blaine WHPA served by on-site sewage systems. The greatest density of on-site sewage systems appears to be located east of the Blaine City limits in the vicinity of Allan Street and Harbor View Drive (refer to Figure 7-3).

Conventional on-site sewage systems typically consist of a septic tank and a subsurface absorption system. The septic tank receives the wastewater flow from a residence or building prior to its entry to the subsurface absorption system. The septic tanks serves three principal functions. It separates solid portions of the waste stream from the residual liquid known as effluent, provides storage for solid portions, and provides an environment for anaerobic decomposition of solids. Effluent passes from the septic tank to the subsurface absorption system where, under ideal circumstances, it is assimilated and treated within the soil column.

When properly sited, designed, and constructed, on-site sewage systems can be a satisfactory long-term form of wastewater disposal. However, when poorly designed and improperly operated, such systems can adversely affect both surface and ground water quality. Contaminants typically present in domestic septic tank effluent include bacteria, viruses, nitrates, and phosphates. Other contaminants that may be present in residential wastewater include cleaning agents and paint solvents. Nitrate is generally considered the most significant contaminant found in domestic wastewater because it is not usually attenuated or removed in the soil profile. Nitrate and bacterial contamination in ground water may be present in areas of relatively high on-site sewage system density and permeable soils.

7.3.2.3 Solid Waste Disposal

The City of Blaine operates a small road construction waste landfill located near the corner of Allan Road and D Street within the WHPA (labeled L-1 on Figure 7-3). This facility is restricted to official City use only. Historically this facility has been the site of illegal disposal of solid waste debris; however, the site is now fully secured with fences and a locked gate (Golder Associates Inc., 1995).

7.3.2.4 Stormwater Disposal

The quality of stormwater runoff varies with land use. Typically, runoff from industrial areas contain high concentrations of metals and hydrocarbons. Commercial land uses, particularly those with parking lots, generate runoff high in particulates containing metals and other pollutants. The most prevalent metals are typically lead, copper, zinc, and chromium associated with automobile operation. Runoff from residential and agricultural areas can also contain metals, in addition to nitrates, phosphorous, pesticides, herbicides, and coliform bacteria.

Stormwater within the City of Blaine is collected in a storm sewer system and discharged to Drayton Harbor. Some of the stormwater is likely to directly infiltrate to the ground water and may present a concern to ground water quality. Stormwater within the county and British Columbia portions of the WHPA is conveyed via ditches and infiltrates directly into the ground surface, or discharges to natural drainage courses.

7.3.2.5 Biosolids Application

The communities of Birch Bay, Blaine, Lynden, Everson, Nooksack, and Sumas (BBLENS) operate two cooperative wastewater treatment plant biosolids (sludge) utilization sites outside of the Blaine WHPA. Biosolids can represent a source of nutrients and metals to ground water. However, there are no known biosolids application sites, present or historic, within the WHPA. It is possible that unknown and/or abandoned sites may be present within the Blaine WHPA, but this is believed to be unlikely.

7.3.2.6 Underground Storage Tanks

Underground storage tanks can represent a significant threat to ground water, particularly old or poorly designed/poorly installed tanks. Underground storage tanks typically hold a variety of petroleum products including leaded and unleaded gasoline, diesel fuel, lubricating oil, fuel oil, and waste oil. Leakage from underground storage tanks is often difficult to detect. In addition to direct leakage from underground storage tanks, releases can occur from tank loading spills, and leakage from associated piping.

According to Ecology records, there are at least 17 active underground storage tanks in operation at seven sites in the Blaine WHPA, most of which are at automobile service stations and contain gasoline (Figure 7-3). The year of installation and type of material contained in each tank is listed in Table 7-2. As indicated in Table 7-2, the tanks within the Blaine WHPA were installed from 1960 to 1991. As noted above in Section 7.3.1, leaking underground storage tanks have not been reported within the Blaine WHPA.

These numbers do not include home heating oil tanks for which records are not available. The Whatcom County Assessors office does not differentiate between oil and other types of heat. Therefore, a door-to-door or telephone survey would be the only way to obtain information regarding heating oil tanks. Since much of the area was developed in the 1970's, it is likely that many heating oil tanks in operation within the Blaine WHPA have been in operation for over 20 years. In a study conducted in 1984, it was noted that the average life span of an underground storage tank is 17 to 18 years (Brown and Caldwell, 1986). An American Petroleum Institute Survey found that after 20 years of operation, nearly 90 percent of all tanks surveyed had leaked or failed. It should be noted that most of the tanks noted in the survey were of single-wall steel construction (Brown and Caldwell, 1986). Installation techniques, soil corrosivity, size of the tank, and the material stored are important factors in determining an individual tank's probability of failure.

Leaking underground home heating oil tanks may present a threat to ground water quality. However, heating oil's chemical constituents have a low potential for migration through the soil, and both federal and state regulations adopt a less aggressive approach to the regulation of underground heating oil tanks. Currently there is not enough information available to assess if home heating oil tanks represent a problem. There are no records of documented leaking home heating oil tanks within the Blaine WHPA.

7.3.2.7 Commercial/Industrial Hazardous Waste

Hazardous wastes from commercial and/or industrial establishments can be introduced to underlying ground water through several pathways. Inadvertent or intentional discharges to on-site sewage systems or stormwater disposal systems and direct discharges to exposed ground surfaces can eventually migrate to ground water.

Currently there are seven facilities within the Blaine WHPA that are permitted under the federal Resource Conservation and Recovery Act (RCRA) and one facility that is conditionally exempt (Table 7-3 and Figure 7-3 for locations). To require permitting under RCRA, a generator must produce 220 pounds per month of hazardous waste or 2.2 pounds per month of extremely hazardous waste. Facilities that generate less than that amount are considered "conditionally exempt" from regulation, but are expected to ensure proper handling and disposal of such wastes even though not directly regulated.

The City of Blaine Department of Public Safety and Whatcom County Fire District 13 do not require permits for businesses using hazardous materials. Reviews are conducted of new businesses; however, there are no specific hazardous material requirements other than the provisions of the Uniform Fire Code.

7.3.2.8 Household Hazardous Wastes

A survey conducted as part of the Whatcom County Hazardous Waste Management Plan (May 1991) indicated that approximately one-half of all Whatcom County residents generate household hazardous waste. The Whatcom County Hazardous Waste Management Plan was developed to manage moderate-risk hazardous waste generated in Whatcom County. The goals of the plan include: educating residents and businesses about the use and disposal of hazardous materials, educating consumers about less hazardous product'alternatives, providing a means of disposal of hazardous materials, and assigning responsibility for management of the waste to the waste generators.

Household hazardous wastes can enter the wastewater stream when residues from cleaning and paint products or quantities of unwanted chemical substances are poured into a sink or toilet for disposal. Household hazardous wastes can also infiltrate to the ground water system through direct or inadvertent discharge of materials directly to the ground surface or through storm drainage systems. When discharged to an on-site sewage system, household hazardous wastes may pass through the system and migrate to underlying ground water. While wastes from any single residence are not likely to have detectable impacts on underlying ground water, the cumulative effects of numerous residences may be significant. Many people are unaware that common household products often contain chemical compounds that can represent an environmental or even public health hazard if improperly handled.

7.3.2.9 Agricultural and Forestry Activities

Adverse surface and ground water quality impacts from agricultural activities may result from improper animal waste disposal practices, pesticide use, and fertilizer use. Agricultural areas are located throughout the unincorporated county portion of the Blaine WHPA, including horse and/or cattle grazing on pastures and forestry.

Forest practices which may adversely affect surface and ground water quality include timber harvesting, road building and maintenance, post harvest activities such as machine slash piling, and fertilizer and herbicide applications. These activities can cause increased sediment loads in local streams and chemical contamination of ground water. There are several large managed forest areas in the Blaine WHPA, particularly in the north eastern portion of the WHPA.

Potential ground water contaminants from hobby farms include nitrogen releases from fertilizers and animal wastes. The precise number of hobby farms located within the Blaine WHPA has not been determined; however analysis of aerial photographs and field surveys indicate that this may be as many as 10 farms. Hobby farms appear to be scattered throughout the Blaine WHPA, however, larger hobby farms were noted along the length of Harvey Road and on Boblett Road. Identified hobby farms are shown on Figure 7-3.

Pesticides and fertilizers applied to farms can leach into shallow ground water. There are no large scale agricultural crop farms located within the Blaine WHPA; however, there are several large forestry areas.

7.3.2.10 Roadside Spraying

Roadside weed control is performed by the Whatcom County Public Works Department for all maintained county roads, and by the City of Blaine for all roads within the City limits. The Whatcom County Public Works Department uses an integrated roadside vegetation management program for roadside weed control. This program substitutes biological, mechanical, and/or manual removal techniques for vegetation control where appropriate and/or necessary. Whatcom County Ordinance 91-44 designates several sensitive areas where chemical control of roadside vegetation is prohibited. These environmentally sensitive areas are identified as "Chemical Usage Restriction" areas.

Pesticides typically used along the county roadway rights-of-way in the unincorporated portions of the Blaine WHPA include: Round-up, Garlon, Telar, Vanish, and Rodeo (Hudson, personal communication, 1995). The type of pesticide and amount used is specifically targeted to the kind of control necessary.

7.3.2.11 Abandoned Wells

Although not actually a source of contamination, the methods used to construct a water well can have a significant impact on ground water quality. For instance, unless a well is sealed properly, the casing can act as a conduit for pollutants originating at the ground surface to travel to the underlying aquifer. Additionally, if a well penetrates more than one aquifer unit, water from the various units can mix. If the water from one aquifer unit is contaminated, contaminants can be introduced to the other aquifer units.

Well logs were obtained from Ecology in an attempt to identify possible abandoned or poorly constructed wells in the Blaine WHPA. Ecology has record of 67 wells constructed within the Blaine WHPA. Based upon aerial photograph interpretation, it is estimated that there are approximately 200 residences located within the unincorporated portion of the Blaine WHPA. This may represent over 100 wells some of which may have been poorly constructed.

7.3.2.12 Cemeteries

Little is known about the potential effect of cemeteries on ground water. Potential threats to ground water from cemeteries may include chemicals, bacteria, viruses, and metals from decomposing corpses and caskets. The embalming process uses formalin composed of formaldehyde, methanol, glycerin, borax, and water. Approximately 1/2 gallon of formalin is used to embalm each body. Bacteria and viruses are not believed to represent a concern since nutrients and oxygen are not present for the bacteria to survive and multiply. Viruses in both embalmed and non-embalmed bodies will eventually die out because they require a viable host to reproduce.

Embalming fluids and other materials may infiltrate to ground water depending on such factors as soil type, topography, the geology encountered, and the depth to the water table. Generally, the deeper the water table, the more opportunity exists for contaminant removal by soil and geologic deposits.

One small cemetery is located within the Blaine WHPA on H Street west of the intersection of Harvey Road (Figure 7-3).

7.3.3 Potential Contaminant Sources - Transportation Hazards

Transportation-related hazardous material spills that occur on roadways in the Blaine WHPA can present a threat to ground water quality if the spilled materials infiltrate and enter the ground water system. Thus, in the event of an accident involving trucks and cargo vans, large amounts of fuel may be released, in addition to the potential threat from the cargo being transported.

Information relating to roadway-specific accidents is not available in a form that lends itself to interpretation with respect to determining hazardous material spills. Refer to Section 7.3.1 above for further detail regarding incident response.

7.3.3.1 H Street Truck Traffic Survey

To better evaluate the risk of transportation-related hazardous materials spills along the main east-west corridor through the Blaine WHPA, a one day survey of H Street was conducted on November 14, 1995. H Street parallels the northern boundary of the Blaine Watershed. The survey was conducted from 6:00 a.m. to 4:00 p.m. near the intersection of H Street and Ludwick Avenue. During this period, approximately 81 trucks traveled on H Street.

The majority of the trucks traveling along H Street consisted of cargo vans transporting supplies to the shopping center, located on H Street between Grant Avenue and Ludwick Avenue, from the Truck Route (SR 543) (refer to Figure 7-3 for roadway locations). Tanker trucks transporting gasoline products did not travel past the two service stations located near the intersection of H Street and the Truck Route (SR 543). A few trucks transporting construction materials and dairy products traveled through the Blaine WHPA on H Street from the Truck Route (SR 543) to their businesses located on the Guide Meridian in Lynden.

7.3.3.2 Designated Truck Routes

Designated truck routes typically have a higher number of trucks traveling on them than do arterial streets within the Blaine WHPA. Greater truck traffic generally corresponds to a higher quantity of hazardous materials being transported on the roadways and, therefore, a higher rate of accidents involving hazardous materials. The majority of hazardous materials incidents in Washington are transportation-related rather than occurring at a fixed facility (Gage-Johnson, 1994).

The Truck Route (SR 543) is the only designated truck route through the Blaine WHPA. Records are not kept as to the number of trucks using this route and crossing the Canadian border. However, based upon observations during site visits, the number of trucks using this route is substantial.

A hazardous materials transportation study was conducted in 1994 for the Whatcom County Local Emergency Planning Committee to determine the truck haul routes and materials being transported throughout Whatcom County (Gage-Johnson, 1994). The hazardous material haul routes identified in that report do not pass through the Blaine WHPA. While amounts of hazardous materials have not been quantified, according to Whatcom County Department of Emergency Management, considerable amounts of petroleum products, industrial chemicals, and munitions are being transported over the Truck Route (SR 543) (Clement, personal communication, 1995).

8. CURRENT AND FUTURE GROUNDWATER CONTAMINATION POTENTIAL

A quantitative assessment of contamination potential is desirable to develop a ranking of contaminant types and contaminant sources discussed in the previous section. However, quantifying contamination potential or risk to public health is difficult from both a technical standpoint and from a public communication/ acceptance standpoint. To provide a framework for quantifying risk, two approaches were used: 1) nitrate loading analysis; and 2) EPA Risk Ranking Analysis. These approaches focused on the potential contaminants that are believed to be the most significant threats to the City wells as it related to developing WHPA management strategies. Vandalism is not considered in this ranking, because the City can reduce the potential of vandalism through system upgrades and security measures outside of the scope of the WHPP.

The nitrate loading analysis is presented in Section 8.1, the EPA Risk Ranking Analysis is presented in Section 8.2, and conclusions are discussed in Section 8.3.

8.1 Nitrate Loading Analysis

This section describes an analysis of potential nitrate concentrations in ground water that may result from septic systems and lawn fertilization. These analyses were done for current land use in the Boundary Upland area, and for three scenarios representing possible future land use.

8.1.1 Introduction

The nitrate contaminant loading analysis is an evaluation of how much nitrate is necessary to cause an undesirable concentration in a well. The undesirable concentration has been conservatively assumed to be one-half the MCL for a nitrate, or 5 mg/L. This level is termed an "action level". The concentration of a contaminant in a well is dependent on the amount of mixing with "clean" ground water flowing through the aquifer. Nitrate is the contaminant that has been of noted concern, and as such it was used as an "indicator" contaminant to evaluate specific land-uses or activities that occur or may occur in the Boundary Upland area.

The nitrate loading analysis focused on three scenarios for possible future development on the Boundary Upland: 1) unsewered development on five-acre parcels; 2) unsewered development on one-acre parcels; and 3) sewered development on one-quarter acre parcels. Each scenario was evaluated for its potential impact on ground water quality. Nitrate contamination sources were grouped into two categories: fertilizer application, and septic systems. Other sources such as hobby farms or animal wastes have not been included in this analysis, but their impact on water quality is believed to be minimal at this time.

8.1.2 General Approach

A simple mixing model was developed to evaluate the potential impacts to the City wells from future development of the Boundary Upland. Future development will potentially increase the nitrate concentrations in ground water through lawn fertilizer applications and septic drain field output. The mixing model is based on the model presented by Frimpter et. al. (1990) for predicting the effects of land use on water quality.

The total load of nitrate that enters the ground water in the Boundary Upland area, expressed as kilograms per year (kg/yr), was estimated from the following equation:

$$L = (A_f * R_f * L_f) + (F * C_s) + C_b$$

where

L is the total nitrate load as nitrogen (kg/yr);
A_f is the area fertilized (ft^2);
R_f is the fertilizer (nitrate) application rate (lbs/1,000 ft^2/yr);
L_f is the nitrate leaching rate to ground water (percent);
F is the septic system flow (gal/day);
C_s is the potential septic nitrate as nitrogen concentration (mg/L); and
C_b is the natural background nitrate concentration (natural load multiplied by recharge rate).

Notice that all of the parameters must be multiplied by appropriate unit conversion factors to obtain the result in kg/yr.

The objective of the mixing model is to estimate nitrate concentrations in the production wells. The predicted future nitrate concentrations in the wells were calculated based on the source load of nitrate and the volume of ground water recharge to the wells from the Boundary Upland. The volume of ground water with which the nitrate loads are mixed is controlled by the amount of recharge occurring in the Boundary Upland. The predicted total future concentration is calculated by dividing the nitrate load by the estimated recharge volume, as follows:

$$C = L/(R * 1{,}000{,}000)$$

where

C is the nitrate concentration in the well water (mg/L);
L is the nitrate load (kg/yr); and
R is the recharge volume (L/yr).

The total load of nitrate that enters ground water in the Boundary Upland does not enter the City wells, because recharge exceeds the wellfield pumping rate. As a result, some of the nitrate load bypasses the wells along with the excess recharge.

8.1.3 Model Input Parameters

This section describes the parameters that are used in the mixing model, and a brief description of the data that were used in the analysis.

Ground Water Recharge and Pumping Rate

The present ground water recharge volume is estimated at 3.30+0.9 L/yr (1,660 gpm), which is the mean of the estimated range of recharge discussed in Section 3.2.4.1. It is assumed that recharge does not change under future conditions. The average annual pumpage rate is assumed to be 1.79E+09 L/yr (about 900 gpm). The average pumping rate was based on the estimated current annual water demand. This was assumed to be constant for all of the scenarios.

Fertilizer Application

Since the future land use of the Boundary Upland is expected to be residential, a nitrate source will be fertilizer application to lawns. Nitrate load depends on lawn size, fertilizer application rate, and the rate of nitrate leaching to ground water, which vary greatly from region to region and from home to home. There is no site-specific information regarding lawn size and nitrate leaching, and local fertilizer application rates. Frimpter et. al. (1990) tabulated lawn sizes, application rates for fertilizer, and the proportion of nitrate leached to ground water for a nitrate loading study in Massachusetts. The estimated fertilizer application rates ranged from 2 to 3 lbs/1,000 ft^2/yr nitrate (as nitrogen), and between 10 and 60% is assumed to be leached to ground water. He also estimated septic tank flow and septic effluent nitrate concentrations. These data are used in this study. Other nitrate loading data are presented in Golder (1991), METRO (1982), and USEPA (1983).

Septic Discharge

The septic discharge from households in unsewered areas will contribute to the nitrate load. Due to the lack of the site-specific information, septic discharge rates and nitrate concentration are assumed based on the data of Frimpter et. al. (1990). The estimated septic system discharge ranges from 50 to 70 gallons per day per person, with an estimated nitrate concentration of 30 to 40 mg/L. An estimated 2.5 persons occupy each housing unit.

Background Concentration

Nitrate concentrations in the Boundary Upland are generally less than 1.0 mg/L, ranging from less than the detection limit (0.2 mg/L, domestic well #30) to 0.7 mg/L (domestic well #3), with the exception of 1.7 mg/L detected in domestic well #54 (see Section 6). A background concentration of 1.0 mg/L is assumed in the model. This was conservatively estimated based on the upper end of the observed range of values. The background nitrate concentrations are likely due to a combination of fertilizer application and septic discharges from existing sources in the Boundary Uplands, and from natural organic nitrate sources in the recharge area.

8.1.4 Solution

The mixing model equations were coded into a spreadsheet (Microsoft EXCEL) for solution. Because of the uncertainty in the range of values for the input parameters, a risk-based, or probabilistic approach was used to estimate the nitrate loading. The program CRYSTAL BALL was used with EXCEL to allow for a range and distribution of values to be used for each input parameter.

The distribution for each parameter is shown in Appendix D. As shown, each parameter was assigned a triangular distribution over the range of expected values. The triangular distribution represents the probability of attaining a certain value for each parameter. Hence, the most likely value has the highest probability of being obtained, while the minimum and maximum values have the lowest probability. The ranges in input parameters were taken from Frimpter et al. (1990) and are summarized below:

Lawn Fertilizer

> **Nitrate Application via Fertilizer** Nitrate application ranged from 2 to 3 pounds per 1000 ft^2 per year, with likeliest rate of 2.5 pounds per 1000 ft^2 per year.
>
> **Fertilized Area** The fertilized area was estimated to range from 5,000 to 6,000 ft^2 per lot, with a most likely value of 5,500 ft^2.
>
> **Nitrate Leached to Ground Water** Nitrate leached to ground water ranged from 10 to 60 percent of the nitrate applied, with the most likely rate of 35 percent.

Septic Systems

> **Septic Flow** In areas of septic flow (i.e., unsewered areas) the rate of septic flow ranged from 50 to 70 gallons per day per person. The likeliest value was 60 gallons per day per person. 2.5 persons were assumed for each housing unit in the model.
>
> **Nitrate Concentration** The nitrate concentration of septic effluent was estimated to range from 30 to 40 mg/L, with a most likely value of 35 mg/L.

The future development of the Boundary Upland was estimated based on the proposed zoning of the 1,200 acre annexation parcel, and the existing zoning for the remainder of the Boundary Upland. The maximum allowable area of development was estimated to be 80 percent of the total land area for both the annexed area and Boundary Upland. This factor accounts for the land that cannot be developed due to land-use restrictions, or is used for roads or easements. A simulation was also done for the present land-use, to compare the model results with actual present conditions to verify the assumed background concentrations. The simulations used are described below:

- The current use was simulated assuming 200 houses with septic systems;

- A potential future growth scenario was the annexation area zoned at 1 house per 5 acres with the remainder of the Boundary Upland zoned at 1 house per 10 acres, all with septic systems. A total of 262 houses were used; and

- Another potential future growth scenario was the annexation area zoned at 1 house per acre, with septic systems, with the remainder of the Boundary Upland zoned at 1 house per 10 acres, all with septic systems. A total of 1,030 houses were used; and

- The last scenario was the annexation area zoned at 4 houses per acre, served by sewers, with the remainder of the Boundary Upland zoned at 1 house with septic systems per 10 acres. A total of 3,910 housing units were used.

The analysis of nitrate loading used a Monte Carlo sampling approach to obtain a solution. The approach used in a Monte Carlo simulation is to compute the solution repeatedly, while each time substituting different but possible values in the specified range for each of the input parameters. In this analysis, each simulation was run for 5,000 trials. The results of this analysis consist of many values representing the possible range of nitrate loading, based on the input parameters. The estimated values form a probability distribution centered about the most likely value of nitrate loading. This approach offers a way to assess the degree of uncertainty associated with the estimates of nitrate loading, given the inherent uncertainty of the factors contributing to nitrate loading, such as fertilizer application rates and septic discharge.

8.1.5 Results

Appendix D contains the calculation tables used for each scenario. Table 8-1 presents a summary of the estimated effects of nitrate loading in the Boundary Upland on ground water quality in the production wells, based on the mixing model.

The results of the Crystal Ball simulation also have a range of values. The uncertainty of the results is based on the uncertainty of the input parameters. The results in Table 8-1 are given for three probability-levels as follows:

- A 90% probability-level indicates that the expected concentration was less than the value shown in 90% of the simulations;

- A 10% probability-level indicates that the expected concentration was greater than the value shown in 90% of the simulations; and

- A 50% probability-level indicates that the expected concentration was greater or less than the value shown in 50% of the simulations. This is the expected value for the simulation, recognizing that it is equally likely to be higher or lower.

8.1.5.1 Present Conditions

Two hundred houses were used in this analysis based on the approximate number of houses in the Boundary Upland identified from air photos. The results of the analysis using the present conditions in the Boundary Uplands area are similar to present nitrate concentrations in domestic and City wells. The nitrate concentrations ranged from 0.5 to 0.65 mg/L, with a most likely value of 0.57 mg/L. The estimated range compares well with the assumed background concentration of 1 mg/L used in the calculated development scenarios.

8.1.5.2 Unsewered Development on Five-Acre Parcels

In this scenario, the nitrate load comes from fertilizer application and septic sources. In this analysis, 262 houses were used. The predicted future concentration of nitrate in City wells ranges from 1.66 mg/L (10%) to 1.85 mg/L (90%), with a mean of 1.76 mg/L (50%). The concentration is less than the "action level" nitrate concentration of 5 mg/L.

8.1.5.3 Unsewered Development on One-Acre Parcels

In this scenario, the number of houses increased to 1,030 units. The nitrate load in this scenario also comes from a combination of fertilizer use and septic sources. The predicted future concentration of nitrate in production wells ranges from 3.71 mg/L (10%) to 4.5 mg/L (90%), with a mean of 4.11 mg/L (50%). The concentration is less than the "action level" nitrate concentration of 5 mg/L.

8.1.5.4 Sewered Development on One Quarter-Acre Parcels

This scenario has the highest number of houses at 3,910 units. For sewered development, the nitrate source is from fertilizer application to lawns alone. Table D-4 shows that the predicted future concentration of nitrate in production wells ranges from 2.68 mg/L (10%) to 4.79 mg/L (90%), with a mean of 3.74 mg/L (50%). The expected concentration is less than the "action level" nitrate concentration of 5 mg/L.

The conclusions and recommendations resulting from the nitrate loading analysis are presented in Section 8.3.

8.2 EPA Ranking Methodology

The EPA ranking methodology for contamination risks is based on the likelihood and severity of well contamination (EPA 1991). The likelihood of well contamination is a function of the likelihood of release at the source and the likelihood of reaching the well.

The severity of well contamination is a function of release quantity, contaminant attenuation, and toxicity. This approach is a simplified form of risk assessment that uses limited data to develop the relative risk of various potential contaminants. This method requires some knowledge of the hydrogeology, but can be implemented by competent non-hydrogeologists for planning purposes. The basic methodology assumptions, and limitations of the method are presented in Appendix E, which is taken directly from the US EPA document.

The ranking methodology was used independently of the contaminant load analysis to provide a preliminary ranking of point source hazards associated with underground storage tanks (UST), abandoned gravel quarries used for illegal dumping, septic systems, and transportation hazards (spills of hazardous substances). Through the use of the EPA risk approach, the overall contamination potential of sources are ranked in order to provide a framework for establishing priorities with regard to wellhead protection efforts.

The following general hydrogeologic properties were used in the EPA methodology:

Parameter	Range in EPA Screening
Depth to Aquifer	50-850 feet
Unsaturated Hydraulic Conductivity	10^{-5} to 10^{-3} cm/sec
Ground Water Velocity	3,300 to 33,000 ft/yr

The hydraulic properties used in the screening are fixed ranges in the risk assessment and are considered accurate and not subject to change.

Potential point sources closest to the City well(s) determined from the contaminant source inventory was evaluated using the EPA methodology, including UST's and chemical handlers identified within the WHPA. An important parameter in the EPA methodology is the distance of a source from the well. In several cases, a number of point sources were lumped into the same ranking assessment based on their similar distance from a well. Similarly, for transportation spills, two of the production wells in the WHPA are less than 1,000 feet from a major arterial or Interstate and, in terms of a screening level risk assessment, the distance to a transportation hazard is similar for both wells.

The second important parameter is the type of contaminant, which affects the toxicity, persistence, and degradation scores used in the risk assessment. For UST sources, benzene is the contaminant used for scoring; for septic systems, nitrate was used. For transportation spills, eight different contaminants were evaluated for two different wells: sulfuric acid, benzene, a chromium-methanol mix, methanol, chloroform, lead and two mixtures of volatile organic compounds (VOC Mix). The contaminants assumed for the illegal dumping in gravel quarries analysis were arsenic, iron, and dichloromethane.

The resultant score of a given contaminant source for a given well is ranked numerically from negative 200 to positive 10. Scores greater than zero are high risk sources. Scores between zero and -4 are considered moderate risk sources, and scores less than -4 are considered low risk sources. The relative ranking of sources is valid regardless of its actual score, which provides a means of ranking among low or moderate risk sources.

In this analysis, the EPA Risk Ranking Method was conducted for Wells No. 3, 4, 5, 6, 7, and 8. Wells No. 1 and 2 were not considered because they are both screened in the Deep Confined Aquifer System, which is overlain by approximately 700 feet of glacial sediments. Additionally, the Boundary Upland area is not the recharge area for these wells. The risk to these wells was considered to be very low.

The results of the screening are summarized on Table 8-2. There are no high risk (score greater than 0) sources in the WHPA. There are two moderate risk sources (score between 0 and -4) in the WHPA. One of the medium risk sources is illegal dumping in abandoned gravel quarries, associated with Wells No. 3, 4, 5, 6, and 8. The dumping analysis assumed a quarry size of 5 acres. The dumping risk decreases when a quarry size of 1 or 0.5 acres is used in the analysis, however, the risk is still classified as medium. Transportation corridors and the associated spill risk also pose a medium risk to Wells No. 3 and 4. The transportation risk associated with Well No. 7 is low. The risk from septic systems and associated nitrate contamination is low for all wells. The risk from underground storage tanks is very low for Wells No. 7 and 8. The scores from underground storage tanks are all less than -100.

The overall risk ranking in the WHPA for the four different contaminant sources are summarized in Table 8-3. As shown in Table 8-3, the highest risk to ground water is from landfills (abandoned gravel quarries used for dumping). Spills associated with transportation corridors are ranked as the second greatest risk. The risk from septic systems is ranked third, while the overall risk from UST's is the lowest.

8.3 Conclusions

The results of the nitrate loading analysis in the Boundary Uplands area indicate that:

- Nitrate loading and nitrate concentrations in wells are dependent on a variety of factors, including application rate and volume of fertilizer, nitrate leaching rate, and septic system density and nitrate content;

- Future land use in the Boundary Upland area has the potential to increase nitrate levels somewhat in ground water from increased fertilizer applications on lawns and increased septic system density; and

- The estimated increases in nitrate concentrations are dependent on the lot size and whether the area is sewered or not. The nitrate concentrations are inversely related to lot size, and directly proportional to the septic system density. It has been assumed that recharge will not change under future conditions. If future development were to reduce recharge, nitrate concentrations would correspondingly increase.

The results of the nitrate loading simulation for the one-quarter acre lot size are probably overestimated for several reasons. The analysis assumed that all of the annexation area was developed with a house on each one-quarter acre lot, with a lawn size of 5,000 to 6,000 ft^2.

This is likely an overestimate of the actual future development density, and an overestimate of the actual lawn size associated with the lot size. The development reportedly will be a "Cluster" type of development, where large tracks of open land are left undisturbed. In this case, the actual number of units will be less, and the lawn sizes could also be smaller than assumed in the model. The analysis overall, however, suggests the need for reasonable management strategies to prevent adverse nitrate level increases.

The risk of increased nitrate contamination can be reduced through Best Management Practices (BMP) for residential fertilizer applications and for maintaining groundwater recharge. This might include recommending the use of slow release fertilizer in the annexed area, public education efforts in fertilizer application rates and timing, and stormwater infiltration requirements for new developments.

The results of the EPA Risk Ranking Analysis for wells in the Boundary Uplands and WHPA are:

- The greatest potential risk to wells is from old gravel quarries that are used as landfills. The risk from this sources is moderate;

- A hazardous material spill along a transportation corridor presents a moderate to low risk of ground water contamination; and

- The risk from septic systems is low, and the risk from underground storage tanks is very low.

The results of the EPA Risk ranking analysis and the nitrate loading analysis are similar in many ways. Both suggest a relatively low risk of ground water contamination in the Boundary Upland area under present conditions. The nitrate loading analysis, however, indicates that future development at one or one-quarter-acre lot size has the potential of increasing nitrate concentrations in ground water in the future, unless reasonable management practices are initiated in the future.

Future zoning in the Boundary Uplands area is anticipated to be residential. The risks associated with the other sources should not appreciably increase in the future with residential zoning. Considerable risk of ground water contamination would likely result if portions of the Boundary Upland were zoned for commercial or industrial use.

9. GROUND WATER QUALITY MANAGEMENT

This section presents recommended system upgrades, management strategies, and spill response strategies to meet the objectives of the WHPP. Section 9.1 presents recommended system upgrades of the Blaine Watershed wells and equipment needed to allow better management of the water supply, and to reduce the potential of contamination of the City wells as a result of vandalism. Section 9.2 presents the recommended contaminant source management/risk reduction program and strategies needed to develop a spill response plan, and Section 9.3 presents the recommended public outreach program. A matrix summarizing the recommended management and spill response strategies is included as Table 9-1.

9.1 Recommended System Upgrades

Recent efforts by the City has substantially improved conditions of the water supply system within the Blaine Watershed. However, based on a survey of the Watershed, as summarized in Section 7, additional system upgrades are required to ensure compliance with well construction and water supply regulations, to prevent vandalism and possible well contamination, and to allow for proper collection of data needed for managing and protecting the ground water supply.

In addition to the recommended system upgrades presented in this section, a Watershed Operations Plan has been written (Appendix F) as a guide for City staff responsible for the water system maintenance. All too often for public and private water systems, well performance, water level conditions, and pumping rates, are not documented on a regular basis. As a result, proper management of the ground water supply is hampered. The Watershed Operations Plan presented in Appendix F further provides guidelines for proper water quality sample collection, and general guidelines to be followed to ensure the security of the Watershed and wells. This plan, in combination with the system upgrades recommended below will provide the means necessary for the City to manage the water supply properly, and to minimize its potential for contamination.

System upgrades will be made either through the City's capital improvement program, or through normal maintenance by City Staff. Most of the relatively inexpensive improvements will be made by the City staff, some of which have already been made, as presented below. The recommended system upgrades are divided into well construction and equipment upgrades and security upgrades, as described in the following sections.

9.1.1 Recommended Well Construction and Equipment Upgrades

Several of the wells require upgrading or replacement. Well No. 1 has been replaced since the draft WHPP was published. Efforts are currently underway to exchange water rights for Well No. 3 with water rights from a deeper well. If this effort proves successful, Well No. 3 will be replaced with a new deeper well. Prior to the release of the draft WHPP, Well No. 4 was reported to have been pumping at less than its historic capacity and allocated water right, and the lifespan of submersible pumps in the well was short. This well should be inspected to determine if it can be rehabilitated. If it cannot be rehabilitated, consideration should be given to replace it with a properly constructed well. Since releasing the Draft WHPP, a new pump has been installed in Well No. 4.

All City wells now have flow meters attached including Well No. 6, which was fitted with a flow meter since the draft WHPP was published.

All wells should have a dedicated access port equipped with a 3/4 to one-inch diameter sounding tubes for water level measurement purposes. Several of the wells have access ports, but they are not equipped with sounding tubes. The tubes are necessary to ensure that accurate water level readings can be taken without losing the sounder in the well. An airline can also be used for water level monitoring, however, airlines are not as accurate as an electric sounder and require the use of a portable compressor. An airline should be installed in Well No. 2, because the small diameter of the well prevents the installation of a sounding tube. The top of the sounding tube should be marked with a permanent, easily identified measuring point as a reference point to prevent measurement error, and be securely capped to prevent foreign material from entering the well.

Concrete pads should be present around each well to allow for a smooth, stable working surface and to provide an additional means of preventing surface water from entering the wells. The pad should be gently sloped away from the well to allow water to drain away from the well. Well No. 2 has no pad, and several of the other wells have broken or damaged pads.

Since the draft WHPP was published, sampling taps have been installed on the wells so that water-quality samples can be easily obtained.

Well caps on Well No. 2 needs to be upgraded to ensure that foreign material cannot enter the wells. A new well cap has recently been installed on Well No. 4. Proper electrical fittings are needed to prevent short circuits and protect personnel working on the wells. The well caps should also allow for easy access to the well for water level monitoring purposes, while preventing unauthorized access.

9.1.2 Recommended Security Upgrades

The Watershed and wells need to be protected from unauthorized access. Public access to the watershed is generally unrestricted, and several of the wells are not enclosed in buildings or by fencing. The wellheads can either be protected with a building or with fencing. Buildings are recommended where the wells are equipped with a motor-driven line shaft pump. The building will protect the motor from weather and other damage. Wells equipped with electric submersible pumps can be fenced in. The electrical panels for these pumps and other equipment that could potentially be damaged by vandals should be also be enclosed within the fence, or preferably housed in weatherized buildings. The electrical panels should, at a minimum, be weatherproof. Fencing and buildings should not restrict access to the wells in the event the pump needs to be removed or serviced. Buildings should be constructed with roof hatches to allow access to the pump for removal if needed. Fences should be fitted with gates large enough to allow access by service equipment.

The sand trap adjacent to Well No. 1 should also be fenced if it will be used after the replacement well is on line, otherwise, it should be decommissioned.

Well No. 2 is located immediately adjacent to the well field access road. In conjunction with a concrete pad and fencing or a building around the well, the road should also be realigned so that it is not immediately adjacent to the well. Alternatively, protective barriers such as concrete-filled metal posts, can be placed around the well to prevent damage by vehicles.

9.2 Contaminant Source Management/Risk Reduction Program

This section describes the proposed contaminant source management strategies developed for the Blaine WHPP. These strategies are intended to address the most significant contaminant sources or potential sources identified through the contaminant source inventory characterized in Section 7 and prioritized through the risk quantification process described in Section 8.

A summary of the existing state and local programs that are involved with some aspects of contaminant source management in the Blaine WHPA is provided in Table 9-2. The contaminant source management strategies recommended in this section seek to build upon these existing programs.

Formulation of the Blaine WHPP contaminant source management strategies within the context of the previously completed Blaine Ground Water Management Program (GWMP) was an important facette of the WHPP planning process. Since the WHPP is essentially an adjunct to GWMP, the contaminant source management strategies developed for the WHPP incorporate a number of the ground water protection measures proposed by the GWMP.

9.2.1 Integration with the Blaine Ground Water Management Program

The Blaine GWMP characterized existing contaminant source control programs and clarified source control responsibilities. It also identified deficiencies in existing contaminant source control programs and provided recommendations for program improvements. These accomplishments have greatly facilitated development of the WHPP.

A number of the preferred alternative management strategies recommended by the Blaine GWMP have been incorporated into the WHPP. Those management strategies are described below under the appropriate contaminant source categories. The WHPP should provide additional impetus for the implementation of those strategies through the Accelerated Implementation Task of this project.

While the GWMP and the WHPP are closely interrelated, there are significant differences in the two programs regarding the:

- Size of the resource protection area;
- Nature of contaminant source inventory procedures; and
- Focus of source control strategies.

For example, while the Blaine Ground Water Management Area (GWMA) encompasses essentially the entire northern half of the Dakota Creek Watershed, the Blaine WHPA includes only those portions of the watershed that overlie ground waters contributing to the City's wells. Thus, the Blaine WHPA represents a only a limited portion of the GWMA.

Contaminant source inventories conducted as part of the GWMP consisted of general characterizations of land use and contaminant sources that potentially affect ground water quality. In contrast, development of the WHPP involved a much more thorough, site specific inventory.

Finally, the source control strategies developed for the Blaine GWMP are somewhat general in nature, being aimed at protecting ground water quality for all beneficial uses in the Blaine GWMA. Strategies developed for the WHPP focus exclusively on protection of ground water used by the City of Blaine for public water supply purposes. In recognition of that fact, several management strategies initially considered under the Blaine GWMP were deferred to the Wellhead Protection planning effort because their primary emphasis was protection of the City's wells rather than ground water resources in general, and thus were more appropriately addressed as WHPP elements.

9.2.2 Recommended Contaminant Source Management Strategies - Stationary Sources

The following recommended management/risk reduction strategies have been developed based on an assessment of existing contaminant sources within the Blaine WHPA. To the extent possible with available information, the relative risk associated with each contaminant source type or class discussed below is quantified in Section 8.

The following recommended management/risk reduction strategies represent a composite of a portion of the Preferred Alternatives from the Blaine GWMP and a number of additional strategies that have emerged during the course of the project. The recommended management/risk reduction strategies are listed below by contaminant source type or class.

9.2.2.1 Sand and Gravel Mining

Recommended Management Strategies:

1) The City of Blaine should seek implementation of the following Preferred Alternative from the Blaine GWMP concerning sand and gravel mining:

> Whatcom County should modify its definition of Aquifer Recharge Areas to include all public water system Wellhead Protection Areas (GWMP Alternative SM.4).

Modifying the Whatcom County's definition of Aquifer Recharge Areas to specifically designate public water system Wellhead Protection Areas as Aquifer Recharge Areas will help ensure that the county's special surface mining development and performance standards, contained in Whatcom County Code Chapter 20.73, will be extended to all portions of the Blaine WHPA that lie within unincorporated Whatcom County. The development and performance standards currently apply to most, but not all, existing and new surface mines in the Blaine WHPA (Goldthorp, 1995).

2) The risk quantification exercise conducted in Section 8 resulted in the identification of inadvertent or deliberate releases of contaminants in surface mines as the most serious potential threat to ground water quality in the Blaine WHPA. Thus, the City of Blaine should assign high priority to pursuing implementation of the following Preferred Alternative from the Blaine GWMP concerning sand and gravel mining:

> Whatcom County Public Works should develop requirements for fencing or other methods of restricting access to abandoned gravel pits (GWMP Alternative SM.5).

9.2.2.2 On-Site Sewage Disposal

Recommended Management Strategies:

1) The City of Blaine should seek implementation of the following Preferred Alternative from the Blaine GWMP concerning existing on-site sewage systems:

> The Whatcom County Health Department should investigate the feasibility of establishing a system for designating existing on-site sewage systems as either conforming or non-conforming from a ground water protection perspective. These designations would be applied to systems reviewed by the health department for loan approval (FHA, VA, etc.). The non-conforming designation would pertain primarily to gravity fed on-site sewage disposal systems installed in Type 1 soils (or Type 1 conditions) as defined in Chapter 246-272 WAC. Assistance to property owners in upgrading non-conforming systems could be provided through the State Revolving Loan program recommended as part of the *Drayton Harbor Watershed Management Plan* (GWMP Alternative OS-E.3).

2) The City of Blaine should seek implementation of the following Preferred Alternative from the Blaine GWMP concerning new on-site sewage systems:

> The Whatcom County Health Department should evaluate the efficacy of its on-site sewage disposal system regulations in protecting ground water quality and, if appropriate, prepare modifications to such regulations (GWMP Alternative OS-N.4).

3) Under WAC 246-272-15501, between January 1, 1995 and January 1, 2001, all local health departments in Washington State are required to develop and implement an on-site sewage system operation and maintenance program. Implementation is to

begin with regions designated by the State Board of Health as Areas of Special Concern, including public water system WHPAs'.

The City of Blaine should request that the Whatcom County Health Department to expedite implementation of its on-site sewage system operation and maintenance program in the Blaine WHPA. Additionally, the City should request that the health department include provisions for ground water protection in the operation and maintenance program. For example, instructional materials associated with the program should stress the need to avoid the disposal of chemical products in on-site sewage systems and to not use solvent based septic tank cleaners.

9.2.2.3 Solid Waste Facilities

Recommended Management Strategies:

1) The City of Blaine should pursue implementation of the following Preferred Alternative from the Blaine GWMP concerning solid waste facilities:

> When developing its WHPP, the City of Blaine should request the Whatcom County Board of Health to implement more stringent landfill design requirements than those currently found in Chapter 173-304 WAC or to consider outright prohibition of solid waste or construction and demolition debris landfills within delineated public water system WHPAs' (GWMP Alternative SW.3).

2) Should the City of Blaine annex currently unincorporated areas that are located within the WHPA, it should preclude the possibility of solid waste or construction demolition debris landfill siting in those areas through zoning code amendments.

9.2.2.4 Stormwater Disposal

Recommended Management Strategies:

1) The following is a Preferred Alternative of the Blaine GWMP concerning stormwater management:

> The Blaine Ground Water Advisory Committee supports efforts by Whatcom County to develop a new stormwater management ordinance incorporating Ecology's *Stormwater Management Manual for the Puget Sound Basin* and encourages the county to establish a preference for stormwater infiltration in those instances where soils are capable of accepting the hydraulic loading from stormwater and adequate contaminant removal can be afforded prior to stormwater reaching ground water (GWMP Alternative SWM.2).

Passage of the *Whatcom County Development Standards, Chapter 2, Stormwater Management* by the Whatcom County Council appears to have satisfied this management strategy.

9.2.2.5 Underground Storage Tanks

Recommended Management Strategies:

1) The City of Blaine should seek implementation of the following Preferred Alternative from the Blaine GWMP concerning management of underground storage tanks that are exempt from regulations under the Ecology Underground Storage Tank (UST) program administered under Chapter 90.76 RCW and Chapter 173-360 WAC:

> The Whatcom County Council should provide direction and funding to the Whatcom County Fire Marshal and the Whatcom County Health Department to conduct an evaluation of problems associated with underground storage tank management in Whatcom County. The evaluation will focus on developing a consolidated approach to underground storage tank management which will adequately address public safety, public health, and environmental quality concerns.
>
> Upon completion of the evaluation, the fire marshal and the health department will provide the Whatcom County Council with a comprehensive report containing the following:
>
> - An estimate of the level of funding, manpower, and additional statutory authority necessary for effective implementation of Whatcom County Ordinance No. 91-053 (the local regulation governing tanks which are exempt under Ecology UST Program);
> - A proposed fee schedule which would provide stable, long-term funding for implementation of Ordinance No. 91-053;
> - A plan for fuel industry participation in efforts to identify the location of existing underground storage tanks and to implement a tank tagging program;
> - A data management plan for compiling tank location and spill reporting records;
> - An assessment of the advisability of local assumption of the Ecology underground storage tank program; and
> - A plan for coordination among agencies which currently participate or will participate in the management of underground storage tanks in Whatcom County as well as a recommendation for lead agency status (GWMP Alternative UST.2).

2) The City of Blaine should negotiate a memorandum of agreement with the Washington Department of Ecology to arrange for the City to be notified of any applications for new underground storage tanks within the Blaine WHPA, or any repairs or removals of underground storage tanks within the WHPA.

3) The City of Blaine should consider conducting a door-to-door survey of home heating oil tanks within the WHPA. This survey could be combined with efforts to identify abandoned wells and to characterize agricultural activities recommended elsewhere in this section (See Section 9.3, Public Outreach).

9.2.2.6 Commercial Hazardous Wastes

Recommended Management Strategies:

1) The City of Blaine should augment educational efforts conducted as part of the *Whatcom County Hazardous Waste Management Plan* by conducting a City sponsored technical assistance program which will disseminate information to commercial facilities within the WHPA concerning proper disposal of hazardous wastes and reduced usage of hazardous materials. As with the public outreach program described subsequently in Section 9.3, the technical assistance program could utilize reference and educational materials already developed by the county, such as the Recommended Management Practices for Small Quantity Generator Waste. Questions or problems requiring special expertise could be referred to Whatcom County's moderate risk waste reduction consultation service. The purpose of the program would not be to duplicate the county's efforts, but to help direct facility owners and operators to existing sources of information concerning hazardous materials handling practices and waste reduction, recycling, and disposal.

The technical assistance program could be integrated with the contaminant source notification process required under the WDOH Wellhead Protection Program guidelines. As the Blaine Department of Public Works notifies owners/operators of commercial facilities of their presence within a WHPA, Public Works will be presented with an opportunity to ensure that the facility owners/operators are aware of the technical support resources available from Whatcom County Solid Waste Division and the Whatcom County Health Department.

9.2.2.7 Household Hazardous Wastes

Recommended Management Strategies:

1) The City of Blaine should augment educational efforts being conducted as part of the *Whatcom County Hazardous Waste Management Plan* (Running and Associates, 1991) by conducting a City sponsored public outreach program intended to disseminate information concerning proper disposal and/or reduced usage of household and lawn and garden chemicals to residents of the Blaine WHPA (See also: Section 9.3 Public Outreach). The outreach program could utilize the existing Recommended Management Practices for Household Hazardous Waste already formulated by the

county and can build upon existing management structures such as the county's "Smart Shopper" waste reduction education program.

Because it would be focused solely on the Blaine WHPA, the City sponsored public outreach program would be much more effective in communicating with residents within the WHPA than efforts undertaken as part of the *Whatcom County Hazardous Waste Management Plan,* which target the county as a whole.

It will be essential to coordinate the outreach program with the Whatcom County Health Department and Whatcom County Solid Waste Division to ensure that it does not duplicate or conflict with efforts associated with the *Local Hazardous Waste Management Plan.*

9.2.2.8 Agricultural Practices

Recommended Management Strategies:

1) Agricultural activities in the Dakota Creek and California Creek Basins were addressed in the *Drayton Harbor Watershed Action Plan* prepared by the Whatcom County Council of Governments (1993). The agricultural management strategies recommended by the watershed action plan were also adopted as part of the Blaine GWMP. The City of Blaine should incorporate the following Preferred Alternative of the Blaine GWMP concerning agricultural management strategies into its WHPP:

> Support full implementation and complete funding of the recommendations of the *Drayton Harbor Watershed Action Plan* relating to agricultural practices (GWMP Alternative AG.2).

Among the recommended actions of the *Drayton Harbor Watershed Action Plan* are the following:

- Implementation of a program for distributing information regarding best management practices for noncommercial farms regarding animal keeping, animal waste disposal, and fertilizer and pesticide handling. This program will involve personal visits to non-commercial farms by "Watershed Masters" volunteers trained by Washington State University Cooperative Extension.

- Establishment of a State Revolving Fund Loan account for non-commercial farms to support implementation of best management practices. The loan fund account will be administered by the Whatcom County Health Department.

- Support the current zoning (Title 20, Whatcom County Zoning Ordinance) requirements concerning animal (livestock) keeping on parcels smaller than 10 acres, add language to the zoning ordinance clarifying the role of property owners in implementing animal keeping best management practices for protection of ground and surface water quality, and develop the capability to enforce the animal keeping provisions of the zoning ordinance.

- Use Centennial Clean Water Funds to support a staff position at the Whatcom County Conservation District to be engaged exclusively with implementation of the agriculture related recommendation of the *Drayton Harbor Watershed Management Plan.*

- Collaborate with Ecology, the State Conservation Commission, and other agencies to develop options for providing a stable funding base for the Whatcom County Conservation District.

- Explore potential commercial uses of animal waste solids for such purposes as crop fertilizer, soil conditioner, and energy generation.

- Coordinate with the Whatcom County Conservation District and Soil Conservation Service to ensure that conservation plans continue to be implemented on all commercial farms in the Drayton Harbor Watershed.

- Inventory commercial farms in the California Creek drainage to identify and provide assistance to those operations which are in need of a commercial farm management plan.

2) The City of Blaine should conduct a survey of farms that have been identified through the WHPP's contaminant source inventory to accurately characterize risks to ground water associated with agricultural activities. The survey should include an inventory of leachable pesticide use and fertilizer use as recommended by the Blaine GWMP.

The agricultural activity survey could be integrated with other surveys recommended in this section including abandoned wells and home heating oil tank surveys, as well as with public outreach efforts recommended in Sections 9.3.

3) Should the agricultural activity survey described in the previous management strategy indicate that monitoring is needed, the City of Blaine should consider the following Preferred Alternative of the Blaine GWMP in the development and implementation of its public water supply monitoring program:

> Recommend that the City of Blaine, as part of its comprehensive ground water monitoring program, conduct monitoring specifically designed to determine the extent of ground water impacts from existing agricultural activities (GWMP Alternative AG.3).

9.2.2.9 Roadside Spraying

Recommended Management Strategies:

1) The City of Blaine should seek implementation of the following recommendation of the Blaine GWMP regarding roadside spraying:

> The Whatcom County Public Works Department should request the Whatcom County Council to designate the region upgradient from the Blaine Watershed as a Sensitive Geographical Area, within which chemical vegetation control will not be allowed (GWMP Alternative PN.4).

Whatcom County Ordinance No. 91-44 designates a number of "Sensitive Geographic Areas" within the county where use of herbicides for roadside vegetation control is not allowed including: the Lake Whatcom Watershed, Lummi Island, North Fork Road, Cornell Creek Road, and all areas within the jurisdiction of the Whatcom County Shorelines Management Program. Extending such a designation to the Blaine WHPA will significantly reduce the risk of possible pesticide contamination.

9.2.2.10 Abandoned Wells

Recommended Management Strategies:

1) The Blaine GWMP contained the following preferred alternative:

> The Whatcom County Health Department should examine the feasibility of assuming those elements of the state well construction and abandonment program which the Department of Ecology (Ecology) may delegate to local governments under provisions of Substitute House Bill 2796 of the 1992 legislative session (amendments to Chapter 18.104 RCW). Should local assumption of the applicable program elements be deemed feasible and in the public interest, the health department should provide the Blaine Ground Water Advisory Committee with an implementation schedule, an estimate of funding needs, and recommendations concerning funding sources (GWMP Alternative WCA.2).

Whatcom County Health Department subsequently gained approval from Ecology to assume responsibility for the well sealing and decommissioning program and is in the process of implementing that program (Blake, 1995). The City of Blaine should offer assistance to the Whatcom County Health Department in the implementation of the well sealing and decommissioning program within the Blaine WHPA. Specifically, the City may aid in identifying improperly abandoned wells and in disseminating information concerning proper well maintenance, including maintaining areas around well casings free of contaminant sources.

2) The City of Blaine should consider conducting a door-to-door survey within the WHPA for purposes of locating abandoned wells. This survey could be combined with similar efforts recommended above for home heating oil tanks and agricultural practices.

3) The City of Blaine, in cooperation with the Whatcom County Health Department, should prepare an informational pamphlet regarding well abandonment

requirements and well maintenance practices for dissemination during the door-to-door survey and/or to be made available at city offices and at community events.

9.2.2.11 Transboundary Impacts

Recommended Management Strategies:

1) The City of Blaine should implement the following alternative of the Blaine GWMP regarding improvements in transboundary cooperation in controlling contaminant sources that potentially affect ground water:

> The City of Blaine should develop a mechanism for ongoing communication with the Langley District Municipality and the Surrey District Municipality concerning transboundary ground water issues. Participation of the Whatcom County Planning Department will be sought since Whatcom County maintains land use authority over much of the Blaine GWMA (GWMP Alternative TI.3).

9.2.2.12 Impacts from Future Land Use

Under the proposed Whatcom County Comprehensive Plan and the Blaine Comprehensive Plan, it is projected that the population of the City of Blaine will grow by more than 5,100 between 1990 and 2015, rising to a total of about 7,800. To accommodate that growth, the City of Blaine has identified a proposed Urban Growth Area (UGA) under provisions of the state Growth Management Act. It should be noted that the proposed UGA boundaries have recently been invalidated by the Western Washington Growth Management Hearings Board. As a result, boundary locations of the proposed UGA may be modified in the future. Since possible future modifications are uncertain, this WHPP will refer to the invalidated UGA as the "proposed" UGA. The northern half of the proposed UGA lies within the delineated WHPA of Blaine Wells No. 1, 2, 3, 4, 5, 6, and 9. Thus, effective management of land use activities and contaminant sources within the proposed UGA is an essential element in safeguarding the quality of the City's water supply.

The proposed UGA is currently under the land use jurisdiction of Whatcom County; however, portions of the proposed UGA have been annexed by the City. The remainder of the proposed UGA will likely be annexed to the City at some time in the future. Annexation will provide the City with an opportunity to strengthen contaminant source control measures within its WHPA and to greatly increase the level of surveillance of activities that might contaminate or pollute the City's water supply.

The Blaine Comprehensive Plan assigned the following land use designations to portions of the proposed UGA lying with the Wellhead Protection Area: Planned Residential, Resource Protection, Low Density Residential, Median Density Residential, and Commercial. The distribution of these land use designations, described below, is demonstrated in Figure 9-1.

Planned Residential Designation. The area designated as Planned Residential represents the portion of the proposed UGA that has been annexed by the City of Blaine and is referred to as the East Blaine Annexation. It consists of approximately 1,200 acres in a long east-west trending band lying between H Street and the Canadian Border.

Development standards that the City of Blaine intends to apply within the East Blaine Annexation are indicative of the level of protection that the City intends to afford to ground water in other portions of the proposed UGA once they are annexed. Under the Planned Residential designation, permitted uses are limited primarily to residential planned unit developments and a few types of commercial development, generally, commercial classes that represent a low risk of ground water contamination. Up to 4 dwelling units per acre are permitted in planned unit developments provided that public sewer and water service is provided.

Stormwater collection (quality) and retention (quantity) facilities in planned unit developments are required to comply with Ecology's *Stormwater Management Manual for the Puget Sound Basin.* In addition, proponents of planned unit developments must prepare an aquifer protection plan. After reviewing the plan, the City of Blaine will place conditions intended to minimize potential ground water contamination on the final approval of any planned unit development.

Although planned unit developments result in higher development densities than the five and ten acre minimum lot sizes currently allowed under the county's existing R-5 and R-10 zones, respectively, from a ground water protection perspective, planned unit developments offer a number of advantages over lower density development. Planned unit developments require extension of municipal sewer service which helps to limit or preclude installation of additional on-site sewage systems. Similarly, such developments promote extension of City water which helps limit installation of additional individual wells. Additionally, because planned unit developments involve clustering of residential units, substantial amounts of open space are created. This allows retention of areas to facilitate preservation of wetlands, stream corridors, and aquifer recharge areas in an open state.

However, the higher densities associated with planned unit developments may pose a disadvantage with respect to potential nitrate contamination of underlying ground water. As part of the risk analysis conducted in Section 8, a nitrate loading evaluation was performed using several different land use scenarios for the unincorporated portions of Blaine's Urban Growth Area:

- Unsewered development on five-acre parcels (essentially, build-out with present zoning),
- Unsewered development on one acre parcels, and
- Sewered development on one-quarter acre parcels.

The loading evaluation indicated that, with either of the latter two scenarios, elevated nitrate concentrations could be observed in ground waters within the City's WHPA.

Contamination associated with the "unsewered development on one acre parcels" scenario would result from a combination of on-site sewage disposal systems and lawn fertilizers. However, this scenario is improbable since neither the City of Blaine nor Whatcom County are likely to allow substantial development of the area without provision of urban levels of utility services, including public sewers. Therefore, the "sewered development on one-quarter acre parcels" scenario represents a much more plausible growth projection for the area. Nitrate contamination associated with this scenario would result primarily from lawn fertilizers associated with residential development.

It should be noted that assumptions used in the loading evaluation were conservative and, thus, likely resulted in an overstatement of the potential for nitrate contamination associated with the "sewered development on one-quarter acre parcels" scenario.

For example, the conservative assumption was to use a relatively large average lawn size of 5,500 square feet. Although the average amount of fertilizer applied to each square foot of lawn is the same regardless of total lawn size, the larger the average lawn size the larger the total per lot application of fertilizer. Since planned unit developments are clustered, average lot size will be only 6,000 to 7,000 square feet per unit, limiting the size of lawn and landscaped areas to well below the 5,500 square foot average used in the loading evaluation.

Resource Protection Designation. Immediately south of the East Blaine Annexation is an approximately 1,400 acre portion of the proposed UGA designated under the Blaine Comprehensive Plan as Resource Protection lands. This designation applies to currently unincorporated areas that are adjacent to the City's Watershed (Wells No. 1, 2, 3, 4, 5, and 6). Should this area be annexed, allowable development density would be limited to one unit per 10 acres. However, City water and electricity are generally available within this area, and with the sewer extensions planned to serve the East Blaine Annexation to the north, sewer service will become increasingly available.

Low Density Residential, Median Density Residential, and Commercial Designations. The remaining portions of the proposed UGA that lie within the WHPA are designated under the Blaine Comprehensive Plan as Low Density, Median Density, or Commercial. In aggregate, these designations apply to about 460 acres in an area bounded on the north by H Street, on the south by Sweet Road, on the east by approximately Harvey Road, and on the west by Odell Road. Land use in this area could affect Blaine Well No. 9 (Boblett Street well). Should these areas be annexed to the City, ground water protection measures similar to those discussed above under the Planned Residential designation will be applied through the City's critical areas ordinance.

Recommended Management Strategies:

1) The City of Blaine should consider updating and strengthening the Aquifer Recharge Area provisions of its Natural Resource Lands and Critical Areas Management Ordinance (Chapter 16.12) based upon the findings of the Blaine WHPP.

2) The City of Blaine should establish a special permit and review process as well as specific performance standards for proposed development and redevelopment in the WHPA.

3) The City of Blaine should adopt Aquifer Recharge Area sand and gravel mining performance standards similar to those found in Whatcom County Code Chapter 20.73.

4) The City of Blaine should adopt the proposed City stormwater ordinance (the City stormwater management plan has already been adopted).

5) The City of Blaine should implement measures to reduce nitrate loading to ground water associated with future development in the East Blaine Annexation and the remaining portions of the Urban Growth Area that lie within the WHPA. This includes extension of public sewer systems and use of cluster development where practicable. It may also include distribution of fertilizer best management practices (BMPs) for ground water protection developed by the Washington State University Cooperative Extension Service. The City could assist in distribution of those BMPs as part of the public outreach program described in Section 9.3.

9.2.3 Recommended Contaminant Source Management Strategies - Transportation Hazards

The following recommended management/risk reduction strategies represent the basic components of the City of Blaine WHPP transportation spill response plan. Those basic components include:

- Ensuring that the Blaine WHPA is recognized by incident response officials as an area of special significance requiring careful consideration when developing spill containment and remediation plans;

- Encouraging development of a spill response program plan specifically for the Blaine WHPA by the Whatcom County Department of Emergency Management (DEM) and the Whatcom County Local Emergency Planning Committee;

- Testing of the spill response program plan through regular exercises involving spill response agencies;

- Maintaining inventories of equipment and supplies necessary for prompt action to protect the City's wells; and

- Placing signs along major transportation corridors identifying the boundaries of the WHPA.

Fully implemented, the recommended management strategies listed below will incorporate these transportation spill response plan components. It is anticipated that substantial progress towards implementation of the recommended management strategies will occur during the Accelerated Implementation Task of the project. That task will involve continuation of coordination that is already in progress between the project team and the Whatcom County DEM.

Recommended Management Strategies:

1) The City of Blaine should implement the following recommendation of the Blaine GWMP concerning transportation related spills:

> The Blaine Public Works Department should provide the Whatcom County Department of Emergency Management with information concerning the locations of the City's wells and the areas recharging those wells for incorporation into the county's emergency management data base system (GWMP Alternative HS.2).

Providing the Whatcom County Department of Emergency Management with information concerning the locations of the City of Blaine's wells and recharge areas will allow the department to incorporate that information into its permanent data base management system. DEM can then make that information available to spill response agencies in the event of a hazardous materials incident occurring in the general vicinity of Blaine. In addition, arrangements can be made for DEM to directly notify the Blaine Public Works Department of hazardous materials incidents with the potential for affecting a Blaine public water supply well or wells.

2) The City of Blaine should implement the following recommendation of the Blaine GWMP concerning transportation related spills:

> The Blaine Public Works Department should provide the Washington State Patrol, local fire authorities, and other emergency response agencies with information concerning the locations of the City's wells and the areas recharging those wells. In addition, the Public Works Department should request that the response agencies provide direct notification to the City of any incident that might adversely impact any of the City's wells (GWMP Alternative HS.2A).

3) The City of Blaine should request that the Whatcom County DEM and the Whatcom County Local Emergency Planning Committee develop a spill response program plan for the Blaine WHPA similar to the Lake Whatcom Spill Response Program Plan. Such a plan would help ensure prompt and efficient response to contaminant releases in the WHPA.

4) As an element of the plan developed under the previous recommended management strategy, request the Whatcom County DEM, Blaine Department of Public Safety, and Washington State Patrol to schedule routine (every one to two years) spill response exercises with a scenario involving a highway transportation spill potentially affecting a City of Blaine well or wells. This scenario would be best

suited to the Truck Route (State Route 543), which potentially affects Wells No. 7 and 8, and to portions of H Street that are upgradient from the watershed, which potentially affects the Watershed wells.

5) The City of Blaine should conduct an inventory of equipment at its disposal for response to a release of hazardous materials. This includes excavating equipment, dump trucks, portable pumps, booms, pads, etc. The City will confer with Whatcom County DEM and the Blaine Department of Public Safety concerning the availability of such equipment and the availability of operators that have received training for operation of equipment during spill response actions in accordance with Washington Industrial Safety and Health Act (WISHA) standards.

6) The City of Blaine should evaluate the feasibility of placing large signs along the truck route (State Route 543) and H Street at the approaches to the WHPA identifying the area boundaries and providing instructions concerning actions to take in the event of a transportation spill.

As part of the feasibility evaluation, the City and the consultant team should confer with the Whatcom County Emergency Services, Whatcom County Public Works, and the State Department of Transportation regarding specific wording of the signs and any size or height limitations.

9.3 Public Outreach

To a large extent, protection of the City of Blaine's wells will be accomplished through voluntary compliance by the public rather than through regulatory controls. Thus, public outreach should be an important component of the Blaine WHPP. The most effective means of public outreach would involve direct contact with residents and businesses in the Blaine WHPA.

A number of the recommended management strategies described above involve door to door surveys for such purposes as identifying abandoned wells, determining agricultural practices, and locating home heating oil tanks and on-site sewage systems. As proposed above, those surveys could be combined into a multi-purpose land use canvassing effort. The land use survey would focus on approximately 170 to 200 residences within the WHP Area that lie outside the Blaine City limits. These residences generally utilize individual wells and on-site sewage systems and may involve hobby farming activities.

A less costly alternative to a door-to-door survey would be to mail out a questionnaire to all residents in the WHPA; however, previous experience with this type of outreach mechanism in other communities suggests that the response rate would be relatively low.

The door-to-door land use survey would serve to raise the awareness of residents within the Blaine WHPA concerning the importance of underlying ground water and would promote appreciation of the cause and effect relationship between land use and ground water quality. It would also present opportunities to directly distribute information to residents concerning proper practices for household hazardous waste disposal, lawn and garden fertilizer and pesticide use, well decommissioning, and home heating oil tank abandonment. A similar approach to dissemination of information and best management practices is also recommended for owners/operators of commercial establishments.

Another approach to public involvement would be to develop curriculum packages for schools within the Blaine School District. This could involve development of three packages: one each for the elementary school, middle school, and high school. The packages would demonstrate the fundamentals of ground water (e.g., a small scale constructed aquifer), explain water quality risk factors and contaminant pathways, and introduce ground water management strategies. Application of the curriculum package should be timed to coincide with the release of a feature article (or articles) in *The Banner*.

Additionally, printed educational or support materials developed for the residential population, business community, and schools should be available at City offices and disseminated at community events.

10. CONTINGENCY PLANNING AND FUTURE GROUND WATER DEVELOPMENT

The previous section discussed ways to prevent or minimize ground water contamination. This section discusses what can be done in the short-term and the long-term if contamination occurs despite efforts to prevent it. This section further focuses on ways to enhance the City's water supply to meet present and future demands, under both normal operating conditions and in the event of contamination.

A contingency plan for alternate supplies in the event of well or well field contamination is a required part of the WHPP, as specified in WAC 246-290-135. The primary objectives of the contingency plan presented in this section are to:

1. Document existing well capacities and projected system demands;

2. Summarize the City's existing Water Supply Emergency Response Action Plan (WSERAP) and incorporate it as part of the proposed contingency plan;

3. Evaluate the ability of the existing system to meet demands if City wells become contaminated;

4. Identify potential sources of water that will enhance the present water supply and offset the impact of aquifer contamination, and estimate the costs associated with the purchase and/or delivery of the selected supply option(s); and

5. Identify emergency procedures for response to aquifer contamination.

The existing water system capacity and projected demand is discussed in Section 10.1. The City's WSERAP is summarized in Section 10.2. Analysis of the impacts of contamination on the systems ability to meet demand is presented in Section 10.3. An evaluation of long-term contingency options is presented in Section 10.4, and recommended short-term and long-term contingency options are presented in Section 10.5.

10.1 Existing System Capacity and Projected System Demands

The existing well capacity, based on the most recent estimates provided by the City, is summarized in Table 10-1. As shown in the table, the City has eight wells, with a maximum combined capacity of approximately 2,450 gpm. Note that the wells of similar depths and localities are grouped together in the table to reflect their equal susceptibility to contamination from the same source or event. The assumption is made, for purposes of evaluating various contamination scenarios, that if one of the wells within the group becomes contaminated, the remaining wells within the group have a high likelihood of also being contaminated. The City wells are divided into four groups as follows:

- Deep Aquifer Wells No. 1 and No. 2 with a combined capacity of 800 gpm;

- Watershed Unit C Wells No. 3 and No. 4 with a combined capacity of 410 gpm;
- Watershed Unit D Wells No. 5 and 6 with a combined capacity of 620 gpm; and
- Western Boundary Upland Wells No. 7 and No. 8 with a combined capacity of 620 gpm.

Preliminary demand projections for years 1995, 2000, 2005, 2010, and 2015 are shown in Table 10-2. Table 10-2 shows the projected annual average day demands, the summer average day demands, and the peak day demands. Note that the demand drops somewhat from year 1995 to year 2005, and then increases gradually to year 2015. This trend occurs due to the phasing out of wholesale distributions to Birch Bay Water District by the year 1998, followed by a gradual increase in demands stemming from City growth projections through year 2015.

As shown in Tables 10-1 and 10-2, the present total well capacity is greater than the projected average day and summer average day demands through the year 2015. However, the present total well capacity is less than the present and projected peak day demands. This illustrates that the system capacity needs to be expanded, and that if wells become contaminated in the future, it will be difficult to meet peak day demands.

10.2 Summary of Existing Water Supply Emergency Response Action Plan

Due to the present water system's inability to meet peak day demands, as described above, the City has had to deal with water shortages in the past. The City has consequently developed a Water Supply Emergency Response Plan (Appendix G) for times of shortage. This WSERAP is also useful for handling shortages stemming from well contamination, as described in this report, and it is recommended that the plan be adapted as part of the WHPP contingency plan.

The plan has multiple stages designed to handle progressively more serious conditions with respect to meeting system demands. The defined Action stages of the plan are as follows:

Stage I - Minor Shortage Potential System storage remains below 70% of total capacity for over 24 hours, or a minor loss of capacity;

Stage II - Moderate Shortage Potential System storage remains below 50% of total capacity for over 24 hours, and weather forecasts predict continuing trend of warmer, drier than normal conditions, or a loss of 25% of the well capacity;

Stage III - Serious Shortage System storage remains below 35% of total capacity for over 24 hours, system inflows continue to be low, and weather forecasts predict a continuing trend of warmer, drier than normal conditions, or a loss of 50% of the well capacity;

Stage IV - Severe Shortage Same conditions as in Stage III in addition to equipment or system failure that severely reduces system supply; or if system storage drops below 20% of total capacity for over 24 hours; and

Stage V - Critical Emergency When customer demands and system pressure requirements cannot be met and major reductions in water use are required.

Measures in the WSERAP to handle water shortages vary from curtailment of non-essential operating system water uses, such as water line flushing, to public notification and voluntary conservation, to enforcement actions, as detailed in Appendix G. Specific Action stages required to meet some of the well contamination scenarios evaluated are discussed in the following section.

10.3 Analysis of Potential Contamination Scenarios and Resulting Impacts

The impacts of various contamination scenarios with regard to meeting system demands was evaluated in order to determine how well the existing WSERAP can deal with likely contamination events in the short-term, and what actions will be required in the long term to ensure that an adequate supply of water will be available to those who depend on City water. The analysis was conducted in recognition of the susceptibility of the City wells to contamination, as discussed in Section 8. Based on that analysis, City Wells No. 3 and 4 (Watershed Unit C wells) are most susceptible to contamination; City Wells No. 7 and No. 8 (Western Boundary Upland wells) and Wells No. 5 and No. 6 (Watershed Unit D wells) are nearly equally susceptibility to contamination; and the Deep Aquifer wells (Wells No. 1 and No. 2) are least susceptible to contamination.

It is assumed that if an aquifer is contaminated, it would be necessary to stop production from the associated wells as worst case. Table 10-3 shows the resulting impacts ceasing production from the well groups for the years of projected water demands. The table is organized based on which wells will most likely be contaminated. Specific contamination scenarios evaluated included:

- Contamination of Watershed Unit C wells;
- Contamination of Western Boundary Upland wells;
- Contamination of Watershed Unit D wells;
- Contamination of all Shallow Aquifer Wells (all of the above); and
- Contamination of the Deep Aquifer wells.

The evaluation was made in terms of the capability of meeting annual average day demands, summer average day demands, and annual peak day demands, as summarized in Tables 10-3a, 3b, and 3c, respectively.

As shown in Table 10-3a, no supply deficit is predicted under any of the contamination scenarios with regard to meeting annual average day demands. Consequently, no contingency is needed for meeting these demands.

As shown in Table 10-3b, the supply deficit for summer average day demands is very small for the contamination scenarios. These theoretical deficits are within the range of accuracy of the demand projections, and as such are not considered significant. Any future deficit associated with summer average day demands could be met with minor demand reductions consistent with Stage I of the WSERAP (see Appendix G).

As described in Section 10.1, present and future peak day demands cannot be met by the present City water supply, and any potential future contamination could worsen the problem. With no curtailment of peak demand, it would be necessary to replace up to approximately 2,200 gpm by the year 2015, and a minimum of approximately 800 gpm by year 2000 (see Table 10-3) if contamination occurs. Examination of Table 10-3c for peak day demand deficits for single well group contamination scenarios reveals that the maximum deficit (1,954 gpm) is approximately 50% of the year 2015 peak day demand projection of 3,604 gpm. This means that the City would have to invoke Action Stage III of the WSERAP. The reduced peak day demand will approximately equal the available supply since Action Stage III assumes a 35% loss of well capacity (see Appendix G).

Examination of the other projected year demands in Table 10-3c reveals that Action Stage II to III procedures would be required during peak day demands to handle water shortages associated with the various contamination scenarios. Providing for all of the Shallow Aquifer wells being out of service in 2015 would require procedures beyond Action Stage III.

10.4 Evaluation of Long-term Contingency Options

The City's existing WSERAP provides adequate contingency options for emergency and short term water deficits. However, additional long-term strategies are required in order to meet present and projected peak day demands, and to ensure that an adequate supply of water will be available in the event that one or more of the City wells becomes contaminated.

The City's water supply capacity needs to be increased by 1,150 gpm to meet year 2015 peak day demands at full system capacity. Additional capacity is required to meet peak day demands when the system is not at full capacity, which can either stem from contamination or equipment failure. In all, it is estimated that the City's present water supply capacity needs to be increased by between 2,000 and 3,000 gpm to be capable of meeting peak demands during times of reduced system capacity.

Long-term strategies to enhance the water supply include:

- Drilling new wells;
- Pursuing an intertie with the Surrey water system;

- Upgrading the system to maximize the existing water rights;
- Evaluating water reuse for golf courses;
- Conservation; and
- An intertie with Birch Bay.

Each of these options are described below.

10.4.1 New Wells

10.4.1.1 Shallow Aquifer System

The City has applied for water rights for two new wells (Wells No. 9 and No. 10) located near the east end of Boblett Street (Figure 1-2 and on Exhibit 3-1 (modified), Appendix G). The potential yield from Wells No. 9 and No. 10 is estimated to be approximately 200 and 100 gpm, respectively. Well No. 9 was completed in 1992 at a depth of between about 250 and 300 feet bgs within the Shallow Aquifer System (Unit D). Well No. 10 has not been drilled. However, if water rights can be secured, Well No. 10 would be completed in a previously identified water-bearing unit at a depth of between 100 and 180 feet bgs at the site of Well No. 9. Source approval from WDOH must be obtained in accordance with WAC-246-280-130 before Wells No. 9 and No. 10 can be put into service.

Assuming that water rights are obtained for Wells No. 9 and No. 10, the water supply system would be increased by about 300 gpm. This would only partially offset the present and future water deficit. Furthermore, the potential for these wells to be contaminated in the future is as high as it is for the other wells installed in the Shallow Aquifer System.

Further development of the Shallow Aquifer System, in general, is less attractive in the long-run than further development of the Deep Aquifer System, because:

1. Wells installed in the Shallow Aquifer System have limited yields, generally no more than 200 to 300 gpm, and therefore, several wells would be required to increase system capacity adequately; and
2. Wells installed in the Shallow Aquifer System are more susceptible to contamination.

10.4.1.2 Deep Aquifer System

Development of the Deep Aquifer System appears to be the most attractive option available to the City for increasing its ground water supply for the following reasons:

1. The Deep Aquifer is much less susceptible to contamination than the Shallow Aquifer System, because it is protected by 400 to 500 feet of low-permeability sediments;

2. The likelihood of acquiring water rights from the Deep Aquifer is judged to be greater than from the Shallow Aquifer System due to the absence of other wells installed in the Deep Aquifer, and the lack of hydraulic continuity with surface waters (most notably, Dakota Creek);

3. The yield of a single large-diameter well installed in the Deep Aquifer could be as high as 800 to 1,500 gpm or more, which is much higher than any well installed in the Shallow Aquifer is capable of producing. Furthermore, one well in the Deep Aquifer could make up a large proportion of the present supply deficit; and

4. An additional deep well(s) could be located within the Blaine Watershed, which could reduce costs associated with site acquisition and piping.

As noted in previous sections of this report, however, the extent, hydraulic characteristics, and potential yield of the Deep Aquifer System needs further evaluation before proceeding with development. Specific recommendations regarding acquiring additional data are presented in Section 12.

10.4.2 Intertie with Surrey

Water system interties between Blaine and Surrey are not new. In the early 1980s, there was an intertie in the vicinity of the Peace Arch, which supplied water to Surrey. Apparently, this was discontinued due to Blaine's need for all its supply. In addition, there was once an intertie in the vicinity of the existing truck customs area (Route 99 USA and 176th Street, Canada — see Figure 1 in Appendix G).

Contact with Surrey's Utility Division indicates that there is potential for a new intertie which could be used to provide an emergency water supply to both utilities as conditions require. Preliminary discussion indicates that functionally it would not be a problem for Surrey to supply several hundred gpm to Blaine. Supply replacement for all future conditions will require significantly more than several hundred gpm (minimum of 800 gpm to a maximum of 2,200 gpm; see Table 10-3). The actual amount that Surrey can provide will only be determined after detailed discussions and negotiation with Surrey. Furthermore, before an intertie could be planned, it will be necessary to acquire the approval of both municipalities.

From discussions with both Surrey and Blaine staff, it is recommended that the best location for an intertie would be in the vicinity of the truck customs area. This area is supplied by 16-, 14-, and 12-inch transmission piping, and the southern end of the 14-inch and the east-west run of 12-inch is approximately 600 feet north of the border. These Surrey pipelines are shown on Figure 1 in Appendix G.

Directly south of the border, in Blaine's 320 Zone, is a portion of an 8-inch loop. Supply from Surrey could enter this 8-inch pipeline into the 320 Zone and then be admitted into the 171 Zone via existing pressure reducing stations. Water in the 171 Zone would then be distributed throughout the entire system.

The recommended intertie is shown on Figure 2 in Appendix G. A new 12-inch pipeline would connect to the existing 12-inch in Surrey, travel south approximately 600 feet, cross the border, and then connect to the existing 8-inch pipeline in the Blaine system. A pump station will be required to lift water into the 320 Zone, along with a pressure reducing function to allow water to be supplied from Blaine to Surrey.

10.4.3 Water Re-Use

The City is currently evaluating ways of re-using water for golf course irrigation purposes. Initial estimates are that the projected day demands could be reduced by up to 400 gpm. Peak day demands could possibly be reduced by as much as 800 gpm over the long-term associated with water re-use of a second golf course.

10.4.4 Maximizing Existing Water Rights

Currently, several of the City's wells are no longer capable of providing their righted amounts, including Wells No. 3, 4, and 8. The City is currently upgrading or replacing wells to re-establish righted water quantities.

10.4.5 Conservation

In an emergency situation which requires a shutoff of a wellfield, non-essential water uses must be restricted, preferably by voluntary conservation measures. Users can reduce consumption by limiting activities such as industrial processes, landscape irrigation, laundry, washing cars, etc. The City should make an effort to educate consumers about conservation techniques prior to contamination incidents. The level of conservation should be in accordance with the appropriate Action stage, as outlined in the WSERAP in Appendix G.

Long term conservation measures (in addition to water re-use, as described above) can also be utilized in concert with other contingency options. However, conservation alone will not eliminate water deficits during peak demand periods. As the Action Stages increase (see Appendix G), it will be more difficult to invoke such measures. High Action Stages are not recommended for long term contingency purposes unless absolutely necessary.

10.4.6 Birch Bay Intertie

It would be possible to pump water from the Birch Bay system into the Blaine system if a pumping station was installed in the vicinity of Dakota Creek at the point of discharge to Birch Bay. For emergency or short-term conditions, the pump could be a skid-mounted unit, with connections being temporarily made via fire hydrants and hose, or direct connection to the buried pipe. The pump head would be required to overcome the difference in service gradients of the two systems.

Since Blaine presently supplies water to Birch Bay, the only supply available would be from the 3 million gallons (mg) of storage in the Birch Bay system, plus the 3.65-mg storage in the

Blaine system. This is only a viable supply option for minimal amounts of water. This storage supply could probably be utilized realistically for no more than a few days.

The intertie becomes much more viable if Birch Bay adds the Nooksack River (via the Ferndale and PUD treatment plants) as another supply. Then, it would be practical to increase the supply to Blaine to meaningful levels via, either a temporary pump station, as previously described, or a permanent station that is intended for long-term emergency use. The City of Ferndale is presently conducting a study of such an intertie. Provision of additional water via such an intertie could involve enlargement of both the Ferndale and PUD water treatment plants in addition to the interconnecting pipeline between Ferndale and Birch Bay.

10.5 Recommended Supply Replacement Options

10.5.1 Emergency and Short-Term

The recommended emergency and short-term supply replacement option is conservation in accordance with the City's WSERAP in Appendix G. The appropriate Action Stage would be selected to reduce the amount of demand to equal or exceed the lost supply due to a contaminated well(s) being taken out of service.

There is essentially no capital cost associated with this option. However, effort by the City staff will be required to implement and manage the selected Action Stage, similar to the effort that has been used in the past to implement the WSERAP during summer water shortages.

10.5.2 Long-Term

All of the options mentioned above would improve the City's water supply in the future. By replacing or upgrading some of the City's wells, it's possible to enhance the City's water supply by up to 400 to 450 gpm. However, the actual amount of water that can be gained in this matter depends on budgetary constraints and the variable yield of wells in the Shallow Aquifer System. For example, recent efforts to replace Well No. 3 have gone unsuccessful due to the sporadic nature of the water-bearing units of the Shallow Aquifer System. Further, in the long-run, development of the Deep Aquifer is believed to be a more attractive option than further development of the Shallow Aquifer, as explained further below. The cost of this option has not been estimated at the present time.

The option of re-using water to irrigate golf courses is viable and should be pursued by the City. Water re-use, however, will not reduce future demands enough to match the existing supply capacity, and other measures will need to be pursued in conjunction with water re-use. The cost associated with this option was not estimated.

Additional development of the Deep Aquifer System would involve a large-diameter (12 to 16 inches) well or wells installed to a depth of about 750 feet bgs. A single well may be capable of yielding between 800 and 1,500 gpm or more, based on available data, and as such could potentially satisfy projected peak day demands through year 2015 when the system is at full capacity. More wells may be required, however, (if other measures are not taken) to provide the total demand of 2,200 gpm above present system capacity under the worst case condition shown in Table 10-3. Development of the Deep aquifer must be done under recognition of its elevated sodium concentration, and the potential that sodium concentrations may be regulated by the state in the future. If an MCL for sodium of 40 mg/L, for example, is established by the State, its possible that only roughly three quarters of the City's water supply could be taken from the Deep Aquifer, without violating the MCL. Additional monitoring is required to determine what the sodium concentration of the deep aquifer is, and how it may change over time. The estimated project cost per well, including well, submersible pump and column, electrical systems, and wellhouse, is $230,000.

The intertie with Surrey will require construction of approximately 700 feet of 12-inch pipeline, a 2,200-gpm pump station, and connections to the two systems. The actual permitted rate of withdrawal will depend on Surrey and may be less than 2,200 gpm. The estimated project cost for this option is $160,000.

Depending on the amount of supply Surrey will make available, it may be that a combination of an intertie with Surrey, water reuse and minor systems upgrades and one new deep well will be required to provide the total supply deficit under worst case conditions. As previously indicated, this can only be determined after the details of the intertie are pursued with Surrey, as well as further details on the water reuse option.

At the present time, the status of the proposed pipeline from Ferndale to Birch Bay or the proposed PUD treatment plant is uncertain. Therefore, the Birch Bay Intertie option will not be considered further until it becomes clear that the pipeline will be constructed.

11. SUMMARY OF WATER QUALITY, CONTAMINANT SOURCES, POTENTIAL RISK, AND RISK MANAGEMENT STRATEGIES

This section presents a summary of the water quality, results of the contaminant source inventory and risk ranking, the proposed risk management strategies and spill response plan, and the contingency plan. Each are discussed in the following sections.

11.1 Present Water Quality

The current ground water quality within the Boundary Upland is generally good. The water is generally soft to moderately hard within iron and manganese concentrations approaching the State secondary MCL's. Secondary MCL's for iron and manganese were established primarily for aesthetic reasons, rather than human health reasons.

Nitrate concentrations within the Boundary Upland area are currently well below the MCL of 10 mg/L. However, the pervasive nature of nitrate detected in wells within the Boundary Upland area is of concern to the City, because the Boundary Upland area is the primary recharge area of the City wells. A trend of increasing nitrate concentrations in some of the City wells raises concern over future development of the Boundary Upland area. The intent of the WHPP is to provide a vehicle for controlling future development in the Boundary Upland area in such a way as to minimize potential adverse effects on ground water quality.

11.2 Inventory of Potential Contaminants

A sanitary survey of the Blaine Watershed was conducted to evaluate the condition of the City wells, and the susceptibility to contamination due to possible vandalism. The survey did not reveal specific sources of contamination, but it did reveal that the wells are susceptible to contamination or damage by vandals as a result of equipment/housing and security deficiencies.

A review of the present and possible future land use and zoning maps indicated that land use within the City of Blaine portion of the WHPA is single-family residential and commercial. Land use within the unincorporated Whatcom County and British Columbia portion of the WHPA is predominantly rural residential and forest. These types of land uses are typically less detrimental to ground water quality than commercial or industrial land uses, for example.

An inventory of potential contaminant sources within the Blaine WHPA established the presence of seventeen active underground storage tanks at seven sites, and seven permitted RCRA facilities. RCRA facilities generate 220 pounds or more per month of hazardous waste or 2.2 pounds or more per month of extremely hazardous waste. Several other potential sources of contamination were identified within the Blaine WHPA, including sand and gravel quarries, septic systems, stormwater disposal, solid waste disposal, possible household hazardous wastes, agricultural and forestry activities, roadside spraying, and abandoned or improperly designed domestic wells.

The one-day traffic survey of H-street truck traffic revealed that most of the truck traffic is associated with the shopping center between Grant Avenue and Ludwick Avenue. A few trucks transporting construction materials and dairy products traveled along H-street through the Blaine WHPA towards Lynden and Sumas. A large amount of truck traffic passes through the western portion of the Blaine WHPA along Truck Route SR 543 in the vicinity of City Wells No. 7 and No. 8.

11.3 Contamination Potential

A quantitative assessment of contamination potential from the various contaminant sources identified during the surveys was conducted through a nitrate loading analysis and an EPA risk ranking analysis. The purpose of this assessment was to establish a framework for developing effective contaminant source management and risk reduction strategies. Not all of the potential sources of contamination can readily be quantified, however, and management strategies must be developed based on this recognition.

The nitrate loading analysis was conducted specifically to evaluate potential future development scenarios of the Boundary Upland area. The analysis evaluated three generalized development scenarios: unsewered development at 1 unit per 5 acres; unsewered development at 1 unit per acre; and sewered development at 4 units per acre. The source of nitrates evaluated were from septic systems and lawn fertilizers. The results of the analysis suggest that nitrate levels could increase to roughly 1.8, 4.1, and 3.7 mg/L, respectively for development at one unsewered unit per five acres, one unsewered unit per acre, and four sewered units per acre. It would appear from this analysis that high density sewered development and lower density unsewered development could potentially increase nitrate concentrations somewhat. The primary outcome of the analysis as part of the WHPP is that any future development of the Boundary Upland area should be accompanied by specific strategies to protect ground water in the Shallow Aquifer System. Activities in the Boundary Upland Area are not expected to adversely affect the water quality of the Deep Aquifer System.

The results of the EPA risk ranking evaluation indicates that the greatest risk to the City wells may be from illegal dumping in the sand and gravel quarries of the Boundary Upland area. Ranked second is transportation spills in the Boundary Upland area (along H-street). Septic systems under present density are ranked third, followed by underground storage tanks, which are ranked fourth. The fourth ranking of UST's may seem surprising. However, the closest wells to the USTs, No. 7 and No. 8, tap water-bearing zones underlying up to 200 feet of low-permeability sediment. Since petroleum products are LNAPL's (lighter than water), they have a low probability of migrating downward to the aquifers tapped by the wells. Any future UST's placed in the Boundary Upland area could potentially be a much greater threat to the City wells (primarily Wells No. 3 and No. 4) than the threat posed by the existing UST's.

A significant threat to the City wells that was not addressed through the risk ranking evaluation is that of vandalism and well/equipment deficiencies within the Blaine Watershed. Unlike other potential sources of contamination, the water supply could be contaminated in a very short time as a result of these deficiencies, and may not be detected immediately. In recent years, the City has substantially improved the condition of the Watershed wells, and consequently, the threats of contamination have been reduced. However, additional work needs to be done to fully secure the Watershed water supply. City Wells No. 7 and 8 that lie outside the Watershed are in relatively good condition, and are not susceptible to vandalism.

11.4 Ground Water Quality Management

Watershed System Upgrades

The City has taken several measures recently to improve the Watershed water supply system, including attaching flow meters to most of the wells, and other equipment upgrades. The City has also recently drilled a replacement well for Well No. 1, which was in extremely poor condition, and was producing from several different water-bearing zones in violation of State regulations. Additional well and equipment upgrades are needed. Well No. 2 needs to be protected from possible damage due to its close proximity to the Watershed access road (it is not housed in a building), and wiring and other equipment needs repair or replacement. Well No. 4 needs to be rehabilitated or replaced. Other upgrades and repair of the housing and wellheads are needed to prevent surface waters or foreign matter from entering the wells. In addition, sounding tubes and access ports need to be installed in all of the wells (some, but not all are adequately equipped) in order to properly track wellfield performance. Since the Draft WHPP was published, the City staff has made several repairs and improvements of the water system.

Watershed and well security needs to be upgraded substantially. Some of the wells can be accessed easily by vandals, and foreign materials or contaminants can be put in the wells. The wells need to be adequately secured such that equipment or wells cannot be damaged.

Contaminant Source Management/Risk Reduction Program

The contaminant source management/risk reduction programs presented in the report build on the management strategies proposed by the Blaine GWMP. The WHPP, in many respects, is viewed as an adjunct to the Blaine GWMP. Specific contaminant source management strategies, which are either consistent with those proposed by the GWMP or an augmentation thereof, are recommended in the WHPP. These recommendations stem from the results of the contaminant source inventory and traffic survey, in conjunction with the ranking of the potential contaminant sources presented in Section 8.

Specific management strategies are recommended for sand and gravel mining, septic systems, solid waste facilities, stormwater disposal, underground storage tanks, commercial hazardous wastes, household hazardous wastes, agricultural practices, roadside spraying, abandoned wells, transboundary impacts, and impacts from future land use. Table 9-1 provides a matrix of the recommended management strategies.

Spill Response Plan

Management/risk reduction strategies representing the basic components of the Spill Response Plan are listed. The recommended management strategies involve providing emergency management teams, including the Washington State Patrol, and local fire authorities, with the locations of the City wells, and requiring that the emergency response teams notify the City of any incident that might adversely impact any of the City's wells. Further, it is recommended that the City request that Whatcom County Department of Emergency Management and the Whatcom County Local Emergency Planning Committee to develop a spill response program plan for the Blaine WHPA. Routine spill response exercises should be conducted on a regular basis. An inventory of equipment useful for emergency response should be conducted by the City, and large signs along transportation corridors identifying the Blaine WHPA should be considered.

Public Outreach

Protection of the City's wells to a large extent will be accomplished through voluntary compliance by the public rather than through regulatory controls. Therefore, public outreach should be an important component of the Blaine WHPP. This may involve door-to-door surveys or mailing questionnaires to residence within the WHPA to raise awareness of the residence and document potential sources of contamination (abandoned wells, for example). Information concerning use of household hazardous wastes, lawn and garden fertilizers, and pesticides could be disseminated to residence within the WHPA as part of this program. Another approach to public involvement would be developing a curriculum for schools in the Blaine School District, covering fundamentals of ground water, water quality risk factors, and ground water management strategies.

Contingency Plan and Additional Ground Water Development Options

The City's existing Water Supply Emergency Response Action Plan (WSERAP) provides adequate contingency options for emergency and short term water deficits, and should be adopted for use as part of this WHPP. However, additional long-term strategies are required in order to meet present and projected peak day demands, and to ensure that an adequate supply of water will be available in the event that one or more of the City wells becomes contaminated.

The City's water supply capacity needs to be increased by 1,150 gpm to meet year 2015 peak day demands at full system capacity. Additional capacity is required to meet peak day demands when the system is not at full capacity, which can either stem from contamination or equipment failure. In all, it is estimated that the City's present water supply capacity needs to be increased by between 2,000 and 3,000 gpm to be capable of meeting peak demands during times of reduced system capacity.

Several long-term options are available including development of the Deep Aquifer, an intertie with Surrey or Birch Bay, water reuse, and maximizing the existing water rights to meet future demands and contingencies. A well in the Deep Aquifer is expected to be capable of yielding between 800 and 1,500 gpm or more, based on available data, and as such could potentially satisfy projected peak day demands through year 2015. Additional wells may be required, however, to provide total demand under worst case conditions if other options are not implemented. The intertie with Surrey would require construction of approximately 700 feet of 12-inch pipeline, a 2,200-gpm pump station, and connections to the two systems. The actual permitted rate of withdrawal would depend on Surrey and may be less than required for worst case conditions. The intertie with Birch Bay would only provide a viable emergency alternative water supply if the proposed pipeline from Ferndale to Birch Bay is constructed or if a new PUD treatment plant is built. Water reuse and system upgrades could potentially reduce demands and enhance the water supply, which in turn would reduce the intertie demand, and may reduce the number of new wells required to one deep well.

The recommended way to meet projected demands and provide adequate contingencies is to pursue a combination of new ground water supply and water reuse and system upgrades to meet normal system demands, and an intertie with Surrey to provide emergency/short term supplies to augment the City's supplies when needed.

Development of the Deep Aquifer System appears to be an attractive option available to the City for increasing its ground water supply, because the Deep Aquifer is not susceptible to contamination, water rights may be more easily acquired, and the yield from a single well in the Deep Aquifer could be sufficient to make up the current and projected water supply deficit. Additional data on the character of the Deep Aquifer, however, needs to be collected before proceeding with development as described in Section 12.

12. RECOMMENDATIONS

The following recommendations are made based on the results of this draft WHPP:

- Following finalizing this WHPP, proceed with implementation of the measures outlined in the WHPP, including the public outreach program , completion of a spill response plan, and a SEPA check list for the proposed program. As part of the public outreach program, consideration should be given to conduct a door-to-door survey of residences within the WHPA;

- Continue the collection of additional data to refine and verify the ground water supply potential of the Deep Aquifer. Water level and pumping rate data presently being collected from the deep City wells should be analyzed to determine aquifer transmissivity and storativity. These data should also be analyzed to determine whether or not the aquifer is of limited extent and whether or not it is being recharged, such that the long-term aquifer yield can be determined. Water quality data should also be collected to track any potential changes in water quality that could impact the quality of the City's water supply. Sufficient data should be available by the fall or early winter of 1996 such that the long-term potential yield of the aquifer can be determined. Data analysis will be provided to the City in a separate report.

- Continue efforts to fully secure the Watershed and upgrade Watershed wells and water supply equipment to prevent vandalism, and improve the water supply system.

- Begin dialog with Surrey to investigate the possibility of an intertie that could be by both Surrey and the City of Blaine for short-term/emergency water supply purposes;

- Further evaluate water reuse options for golf course irrigation purposes; and

- Consider installing a large-diameter well in the Deep Aquifer, pending the results of the ongoing testing of the existing deep wells. If water rights can be secured through ongoing negotiations with Ecology, a new deep well could be installed by the end of 1997 subject to other factors that may influence system demand.

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TABLES

TABLE 1-1

SUMMARY OF CITY OF BLAINE WELLS

Well Owner/ Name	Map Location ID	Township, Range, Section T-R-S	Well Depth (ft bgs)	Measuring Point (ft)	Approxi. Ground Surface Elevation (ft)	Depth to Water (ft)	Water Table Elevation (ft)	Screen Depth (ft bgs) (or bottom of well)	Aquifer (Hydro. Unit)	Casing Diameter (in)
No. 1	No. 1	40N-1E-4	746	NA	190	NA	NA	50-746	F	12
New Well No. 1	New Well No. 1	40N-1E-4	733	NA	190	NA	NA	706-726	F	12
No. 2	No. 2	40N-1E-4	648	NA	190	NA	NA	456-641.5	F	8
No. 3	No. 3	40N-1E-3	65	NA	210	NA	NA	65-75	C	8
No. 4	No. 4	40N-1E-3	98	NA	240	NA	NA	NA	C	8
No. 5	No. 5	40N-1E-4	310	NA	160	NA	NA	265-280	D	8
No. 6	No. 6	40N-1E-4	261	NA	170	NA	NA	245-259	D	12
No. 7	No. 7	41N-1E-32	200	NA	150	NA	NA	177-200	D	12
No. 8	No. 8	41N-1E-31	247	100	NA	NA	NA	NA	D	12
No. 9	No. 9	40N-1E-5	303	NA	170	NA	NA	271.5-296.3	D	12
GMWP-1	GMWP-1	41N-1E-32	278	11.62	240	132 (6/6/95)	96.4	176-186	C	8
GMWP-2	GMWP-2	40N-1E-3	303	2.42	160	73.7(6/5/95)	83.9	83.5-88.5	C	8
GMWP-3	GMWP-3	40N-1E-5	299	1.67	170	86.4 (6/5/95)	81.9	148 - 158	C	8

NA = Not Available

* Accuracy roughly ± 15 feet

Well locations shown on Figures 1-2 and 6-1

TABLE 1-2

SUMMARY OF MONITOR AND DOMESTIC WELLS

Well Owner/Name	Map Location ID	Township, Range, Section T-R-S	Well Depth (ft bgs)	Casing Stickup (ft)	Ground Surface Elevation (ft)	Depth to Water (ft) (Sept-Oct 1994)	Water Table Elevation (ft)	Screen Depth (ft bgs) (or bottom of well)	Aquifer (Hydro. Unit)	Casing Diameter (in)
Monitoring Wells										
MW-1	MW-1	41N-1E-34	217	1.9	410.3	129.8	280	221	C	6
MW-2	MW-2	41N-1E-34	397	NA	NA	NA	NA	NA	NA	NA
Washington Wells										
John Notle	29	40N-1E-3	180	2.8	340	147.8 (10/94)	189.4	163-168	C	6
Albert Boursaw	15	40N-1E-3	187	1.3	406.6	160.35 (10/95)	246	186.6	C	6
Scott Freeman	30	40N-1E-4	254	2.6	345.3	-	-	254.3	C	6
Mark Waslohn	54	40N-1E-3	212	1.5	456.2	206.5 (6/5/95)	248.2	212.2	C	6
Joe Miller	37	40N-1E-5	98	1.29 (6/6/95)	270	71.08 (6/6/95)	197.63	93-98	C (Perched)	6
Doug Connelly	6	40N-1E-2	148.6	3.4 (6/6/95)	369.98	102.27(6/6/95)	264.31	133.6-148.6	C	8
John & Kelly Wood	Wood	40N01E-4Q	66	NA	65	23 (12/27/91)	42	No Screen	C (Perched)	6
Walter Berg	Berg	40N01E-3C	237	NA	400	202.5 (12/27/91)	197.5	No Screen	C	6
Roger Boettcher	Boettcher	40N01E-4F	178	NA	NA	NA	NA	172-178	C	6
Warren Aller	Aller	40N01E-10A	140	NA	300	97.5 (12/27/91)	202.5	No Screen	C	6
Dan Colacurcio	Colacurcio	40N01E-2D	184	NA	450	164.9 (7/31/91)	285	178-184	C	6
Hilda Leer	Leer	40N01E-35Q	23	NA	410	10 (12/27/91)	400	No Screen	C	6
Wells in Canada										
R.J. Harvey	28	092G-007-2.1.1	150	0.8	325.1	109.75(6/5/95)	214.55	143.3-150.5	C	6
Ian Garrioch	13	092G-007-1.2.2	130	1.9	251.2	100.3 (10/94)	151	130.2	C	6
Garry Storsley	23	092G-007-2.1.1	108	1.15	170.7	64.75 (10/94)	106	100-105	C	6
Owen Quinn	3	092G-007-2.1.1	300	0.8	427.7	203.18 (10/94)	224	300.2	C	6
Owen Quinn	25	092G-007-2.1.1	456	0.5	411.3	190.25 (10/94)	221	233.3-244.3	C	6

NA = Not Available

* Accuracy to ± 15 feet

Well locations shown on Figures 1-2 and 6-1

TABLE 3-1

SUMMARY OF HYDROSTRATIGRAPHIC UNITS

Hydro Unit	Geological Description	Elevation Range (amsl)	Thickness(ft)	Hydraulic Properties	Water Level	GW Potential	Water Quality
A/B	Stony clay and stony silt.	May be interbedded with C above 200 ft amsl	Variable	Aquitard	NA	Aquitard	NA
C	Sand and gravel of fluvial or glacial-fluvial origin.	Above -150 ft	0-100	Confined and semi-confined: T=50 to 14,000 ft^2/d, S=2x10^{-4} to 0.01	about 280 to 100 ft msl in BUL and 80 to 55 ft msl in adjacent areas. Up to 500 ft amsl in perched zones.	Relatively high	Good
D	Glacial till and outwash sand and gravel.	Between -150 and 25 ft	0-150 ft	Confined: T=50 to 14,000 ft^2/d, S=2x10^{-4} to 0.01	about 280 to 100 ft msl in BUL and 80 to 55 ft msl in adjacent areas	Relatively high	Good
E	Mainly silt and clay of marine or glaciomarine origin.	About -450 to 50 ft	400-600 ft	Aquitard	NA	Aquitard	NA
F	Sand of fluvial or glacial-fluvial origin.	About -560 to -450 ft	0-20	Confined: T=700 ft^2/d to 5,000 ft^2/d S=2x10^{-4}	about 60 to 70 ft msl	Between 2,000 to 3,000 gpm*	High sodium
G	Bedrock		Unknown	Bedrock	Unknown	Low	Unknown

*Based on recent testing, but further testing is needed.
BUL = Boundary Upland
NA = Not applicable

TABLE 6-1

GENERAL CONTAMINANT CATEGORIES AND COMMON CHARACTERISTICS

Category	Typical Contaminants	Typical Source/Activity	Comments
Major Cation/Anions	Chloride Sulfate Sodium	Landfills Mining	No primary drinking water standards.
Metals	Lead Chromium Arsenic Zinc	Landfills Mining Urban run-off Metal Plating	Generally high sorption coefficients-contaminant tend to sorb to soil particles.
Nitrate	Nitrate as N	Agriculture Septic Uraban Run-off	Conservative transport - no retardation or transformation, once in groundwater. Denitrification may occur in subsurface.
Organics - LNAPL	Benzene Toluene Ethylbenzene Xylene	UST's - Gasoline Industrial Activity Urban Run-off	Lighter than water - tends to float on water table. High potential for biodegradation or transformation.
Organics - DNAPL	Trichloroethylene (TCE) Tetrachloroethylene (PCE)	Solvents Dry Cleaning Manufacturing	Denser than water - tend to sink in aquifer. Complex transport pathways.
Organics-Pesticides/Herbicides	Atrazine Simazine 2,4-D Silvex	Agriculture Residential/Commercial Application	Both DNAPL and LNAPL characteristics.

TABLE 6-2

REPRESENTATIVE TRAVEL-TIMES OF SELECTED CONTAMINANTS

Contaminant	Travel Time (years)
Benzene	7.6
Ethylbenzene	13.4
Toluene	15.9
p-Xylene	27.2
m-Xylene	202
o-Xylene	17.6
Trichloroethylene	2.3
Tetrachloroethylene	14
1,1,1-Trichloroethane	15
PCB	3,334
Arsenic	1.37
Iron	170.3
Lead	254.8
Zinc	128.1
Nitrate	1.37

Travel Time for 1,000 foot path length

hydraulic conductivity = 200 ft/day
porosity = 0.2
hydraulic gradient = 0.002
Groundwater velocity = 1.37 yrs

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WASHINGTON STATE PRIMARY DRINKING WATER STANDARDS

Contaminant	MCL (mg/L)
Inorganic Chemicals	
Antimony	0.06
Arsenic	0.05
Asbestos	7 million fibers/liter (longer than 10 microns)
Barium	2.0
Beryllium	0.004
Cyanide	0.2
Nickel	0.1
Lead	0.05
Copper	1.3
Asbestos	7 MFL
Cadmium	0.005
Chromium	0.1
Fluoride	4.0
Mercury	0.002
Nitrate (as N)	10.0
Nitrate plus Nitrite (as N)	10.0
Nitrite (as N)	1.0
Selenium	0.05
Thallium	0.002
Organic Chemicals	
Benzene	0.005
Carbon Tetrachloride	0.005
para-Dichlorobenzene	0.075
1,2-Dichlorobenzene	0.005

WASHINGTON STATE PRIMARY DRINKING WATER STANDARDS

Contaminant	MCL (mg/L)
1,1-Dichloroethylene	0.007
1,1,1-Trichloroethane	0.20
Trichlorethylene	0.005
Vinyl Chloride	0.002
o-Dichlorobenzene	0.6
cis-1,2-Dichloroethylene	0.07
trans-1,2-Dichloroethylene	0.1
1,2-Dichloropropane	0.005
Ethylbenzene	0.4
Monochlorobenzene	0.1
Styrene	0.1
Tetrachloroethlyene (PCE)	0.005
Toluene	1
Xylenes (total)	10.0
Dalapon	0.2
Di(ethylhexyl)adipate	0.4
Di(ethylhexyl)phthalate	0.006
Dichloromethane (Methylene chloride)	0.005
Dinoseb	0.007
Diquat	0.02
Endothall	0.1
Endrin (current = D.0002)	0.002
Glyphosate	0.7
Hexachlorobenzene	0.001
Hexachlorocyclopentadiene (HEX)	0.05

WASHINGTON STATE PRIMARY DRINKING WATER STANDARDS

Contaminant	MCL (mg/L)
Oxamyl (vydate)	0.2
PAHs (Benzo(a) pyrene)	0.0002
Picloram	0.5
Simazine	0.004
TCDD-2,3,7,8 (Dioxin)	3 x 10-8
1,2,4-Trichlorobenzene	0.07
1,1,2-Trichloroethane	0.005
Pesticides/PCBs	
Alachlor	0.002
Atrazine	0.003
Carbofuran	0.04
Chlordane	0.002
2,4-D	0.07
Dibromochloropropane (DBCP)	0.0002
Ethylene dibromide (EDB)	0.00005
Heptachlor	0.004
Heptachlor epoxide	0.002
Lindane	0.002
Methoxychlor	0.04
PCBs	0.005
Oxaphene	0.003
2,4,5-TP (Silvex)	0.05
Trihalomethanes	0.10
Total Trihalomethanes	(pCi/L)
Radium 226	3

WASHINGTON STATE PRIMARY DRINKING WATER STANDARDS

Contaminant	MCL (mg/L)
Combined Radium 226 and Radium 228	5
Gross Alpha Particle Activity (excluding uranium)	15
Note: The State of Washington has not established MCL's for copper, lead, or sodium.	

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TABLE 7-1 (Page 1 of 2)

SUMMARY OF CITY OF BLAINE ZONING CLASSIFICATION

Symbol	Zone	Uses	Minimum Lot Size (1) Square Feet	Minimum Setback (2)			Minimum Lot Width	Maximum Percent Coverage	Height Limit
				Front	Side	Rear			
M	Manufacturing	Manufacturing	N/A	15′	20′	20′	60′	N/A	50′ (3)
MC	Marine Commercial	Marine related industrial enterprises	N/A	10′(3)	(3)	(3)	N/A	70%/50%	40′/25′ (4)
MR	Marine Recreation	Mixed Use Commercial activities emphasizing tourism/recreation	N/A	10′(3)	(3)	(3)	N/A	80% Area A (5) 30% Area B	25′/40′ (4)
MPR	Marine-Planned Recreation	Mixed Use Commercial activities emphasizing tourism	See Zone Master Plan (6)	See Zone Master Plan (6)			See Zone Master Plan (6)	90% Area A (5) 40% Area B	45′/40′ (4)
CB	Central Business	Retail sales and service, public uses	N/A	N/A	N/A (3)	N/A (3)	N/A (3)	100%	N/A
HC	Highway Commercial	Highway oriented retail sales and service	N/A	15′/20′ (3)	10′(3)	10′(3)	50′	60%	35′
R/O	Residential/ Office Zone	High Density residential and non retail office. Max. 32 units/acre	6,000/1,500 for each additional unit	20′	8′	20′	50′	60%	35′
RH	Residential High Density	High Density residential Max. 32 units/acre	6,000/1,500 for each additional unit	20′	8′	20′	50′	60%	35′
RM	Residential Medium Density	Medium Density residential Max. 12 units/acre	6,000(1 unit) 7,500(2 units) 12,000(3 unit) 15,000(4 unit)	20′	8′	20′	50′	40%	35′
RL	Residential Low Density	Low Density single family detached Max. 6 units/acre	7,200	25′	8′	30′	70′	35%	30′
RR	Residential-Recreation	Recreation oriented low density single family detached	16,000	25′	10′	3′	100′	25%	30′

TABLE 7-1 (Page 2 of 2)

SUMMARY OF CITY OF BLAINE ZONING CLASSIFICATION

Symbol	Zone	Uses	Minimum Lot Size (1) Square Feet	Minimum Setback (2)			Minimum Lot Width	Maximum Percent Coverage	Height Limit
				Front	Side	Rear			
RPR	Residential-Planned Recreation	Recreation oriented mixed density/type residential	See zone Master Plan (6)	See Zone Master Plan (6)	See Zone Master Plan (6)	See Zone Master Plan (6)	See Zone Master Plan (6)	See Zone Master Plan (6)	See Zone Master Plan (6)
PC	Planned Commercial	Commercial Shopping Center	5 acres	Site Plan Review Chapter 17.54			N/A	Site Plan Review Chapter 17.54	Site Plan Review Chapter 17.54
R	Rural	Rural residential	12,000	35′	15′	30′	100′	25%	30′

(1) For purposes for calculating area for lot size, the area is measured as the space available less all public rights-of-way.
(2) Setbacks from road are from right-of-way line.
(3) See text/Uniform Building Code.
(4) See Shoreline Management Master Program.
(5) Impervious Surface.
(6) Master Plan required for this overlay zone.

TABLE 7-2

UNDERGROUND STORAGE TANK LISTING

Map ID #

U-1, R-1 BLAINE SCHOOL DISTRICT #503 1112 FIR AVENUE BLAINE, WA 98230

Tank ID	Installed	Size (gallons)	Status	Substance Stored
1	1964	10,000 to 19,999	Exempt	Heating fuel
2	1964	111 to 1,100	Exempt	
3	1964	111 to 1,100	Exempt	Used oil/waste oil
4	1974	111 to 1,100	Operational	Unleaded gasoline
5	1974	111 to 1,100	Operational	

U-2 BLAINE SCHOOL DISTRICT CAMPUS 1055 H STREET BLAINE, WA

Tank ID	Installed	Size (gallons)	Status	Substance Stored

U-3 CITY OF BLAINE MUNICIPAL AIRPORT 1373 BOBLETT STREET BLAINE, WA 98230-0490

Tank ID	Installed	Size (gallons)	Status	Substance Stored
1N	1972	10,000 to 19,999	Operational	Aviation fuel
2S	1972	10,000 to 19,999	Operational	Aviation fuel

U-4, R-3 GENERAL SERVICES ADMINISTRATION 1590 H STREET BLAINE, WA 98230-9670

Tank ID	Installed	Size (gallons)	Status	Substance Stored
1	1960	1,101 to 2,000	Operational	Unleaded gasoline
2	1975	111 to 1,100	Operational	Leaded gasoline

U-5 STARVIN SAMS #12 1350 H STREET BLAINE, WA 98230-9760

Tank ID	Installed	Size (gallons)	Status	Substance Stored
1	1964	10,000 to 19,999	Unknown	Leaded gasoline
2	1964	10,000 to 19,999	Unknown	Unleaded gasoline
3	1964	10,000 to 19,999	Unknown	Unleaded gasoline
#1	1988	10,000 to 19,999	Operational	Leaded gasoline
#2	1988	10,000 to 19,999	Operational	Unleaded gasoline
#3	1988	10,000 to 19,999	Operational	Unleaded gasoline

U-6, R-8 TEXACO #63-076-1553 1503 H STREET BLAINE, WA 98230

Tank ID	Installed	Size (gallons)	Status	Substance Stored
1REG	1991	10,000 to 19,999	Operational	Leaded gasoline
2SUPER	1991	10,000 to 19,999	Operational	Unleaded gasoline
3UNL	1991		Operational	Unleaded gasoline
4DIESEL	1991	10,000 to 19,999	Operational	

U-7 YORKYS GROCERY #7 1307 BOBLETT BLAINE, WA 98230-9748

Tank ID	Installed	Size (gallons)	Status	Substance Stored
1.NE	1983	20,000 to 29,999	Operational	
2.SE	1983	20,000 to 29,1000	Operational	
3.NW	1983	20,000 to 29,1001	Operational	Leaded gasoline
4.SW	1983	20,000 to 29,1002	Operational	Unleaded gasoline

TABLE 7-3

RESOURCE CONSERVATION RECOVERY ACT SITE LISTING

Map ID #	Facility ID	Facility Name	Address	City	County	ST ZIP Code	Systems
R-1, U-1	WAD988518627	BLAINE SCHOOL BUS GARAGE	1112 FIR AVENUE	BLAINE	WHATCOM	WA 98230	RCRIS
R-2	WA8153200185	USDOJ DEA BORDER CROSSING BLAINE	PACIFIC HWY BORDER CROSSING	BLAINE	WHATCOM	WA 98230	RCRIS
R-3, U-4	WA2470000066	USGSA BLAINE BORDER PATROL HDQ	1590 H STREET	BLAINE	WHATCOM	WA 98230	RCRIS
R-4	WA0470000530	USGSA PACIFIC HWY BORDER STA	PACIFIC HWY BORDER STATION	BLAINE	WHATCOM	WA 98230	RCRIS
R-5	WA0001013549	PAYLESS 2882	1733 H STREET	BLAINE	WHATCOM	WA 98230	RCRIS
R-6	WAD988486874	A S RADIATOR WHSE	1635 BOBLETT STREET	BLAINE	WHATCOM	WA 98230-3174	RCRIS
R-7	WA0000016071	NORTHWEST PODIATRIC LAB INC	1091 FIR AVENUE	BLAINE	WHATCOM	WA 98230-9702	RCRIS
R-8, U-6	WAD988503280	TEXACO SS 63232553	1503 H STREET	BLAINE	WHATCOM	WA 98320	RCRIS

SUMMARY OF NITRATE LOADING ANALYSIS

Land-Use Scenario	Predicted Nitrate Concentration in Wells (mg/L)		
	10%*	50%*	90%*
Current Conditions[a]	0.50	0.57	0.65
One-Acre Parcels[a]	3.71	4.11	4.50
Five-Acre Parcels[a]	1.66	1.76	1.85
One Quarter-Acre Parcels[b]	2.68	3.74	4.79

*Probability

a. Assumes unsewered housing.

b. Assumes sewered housing on one quarter-acre parcels, the rest of the area unsewered.

TABLE 8-2

SUMMARY OF EPA RISK RANKINGS

Well Name	Category	Description	Compounds	Overall Risk	Ranking	Risk Level[b]
3 & 4	Landfill[a]	West of Watershed	Arsenic, Dichloromethane, Iron	-1.3	1	M
	Transportation	Highly mobile and persistent compounds	Methanol, Chromium/Methanol mix, Sulfuric Acid	-5.9	3	L
	Transportation	Highly toxic compounds	Chloroform, Lead, Organic Mix[c]	-2.9	2	M
5 & 6	Septic Systems	0-0.125 mi radius	Nitrates	-17.4	2	L
	Septic Systems	0.125-0.25 mi radius	Nitrate	-17.6	2	L
	Septic Systems	0.25-0.50 mi radius	Nitrate	-17.8	2	L
	Septic Systems	0.50-1 mi radius	Nitrate	-17.6	2	L
	Septic Systems	1-3 mi radius	Nitrate	-17.3	2	L
	Landfill[a]	East of Watershed	Arsenic, Dichloromethane, Iron	-1.9	1	M
7	UST	7 tanks within 0.25 mi radius	Benzene	-104.7	2	L
	Transportation	Highly mobile and persistent compounds	Methanol,Benzene, Organic Mix[d]	-7.3	1	L
8	Septic Systems	0.25-0.50 mi radius	Nitrate	-8.8	2	L
	Septic Systems	0.50-1 mi radius	Nitrate	-8.5	2	L
	Septic Systems	1-3 mi radius	Nitrate	-8.2	2	L
	Landfill[a]	D Street and Allen	Arsenic, Dichloromethane, Iron	-2.4	1	M
	UST	General Services Admin.	Benzene	-105.2	3	L
	UST	Texaco, H Street	Benzene	-105.9	3	L

a. Assumes material dumped in abandoned quarry.
b. Risk Levels: L, Low; M, Medium; and H, High.
c. 1,2 dicholorobenzene
d. Acetone and methl ethyl ketone

TABLE 8-3

OVERALL LANDUSE/CONTAMINANT HAZARD RANKING

Rank	Hazard
1	Landfills
2	Transportation
3	Septic Systems
4	Underground Storage Tanks

BLAINE WELLHEAD PROTECTION PROGRAM - MANAGEMENT STRATEGY MATRIX

CONTAMINANT SOURCE TYPE	PROPOSED MANAGEMENT STRATEGY	RESPONSIBLE PARTY	PURPOSE OF STRATEGY	IMPLEMENTATION STATUS (1)
Sand and gravel mining	Modify definition of Aquifer Recharge areas to include all public water system WHPA	Whatcom County Planning and Development Services Whatcom County Council	Extend requirements of WCC Chapter 20.73 (ground water performance standards) to all sand and gravel mining operations	GWMP Alternative SM 4
Sand and gravel mining	Develop requirements for restricting access to abandoned sand and gravel mines	Whatcom County Planning and Development Services Whatcom County Council	Prevent illegal dumping of hazardous materials by fencing potential disposal areas	GWMP Alternative SM-5
On-site sewage systems	Establish non-conforming system designation for conventional on-site systems installed in Type 1 soils	Whatcom County Health Department	Encourage homeowners and lending institutions to upgrade on-site sewage systems at time of sale or refinancing	GWMP Alternative OS-E.3
On-site sewage systems	Evaluate ground water protection provisions of current regulations and prepare modifications if needed	Whatcom County Health Department	Verify that regulations being applied to new systems in the WHPA are adequate in protecting vulnerable ground waters.	GWMP Alternative OS-N.4
On-site sewage systems	Expedite implementation of on-site system operation and maintenance program in the Blaine WHPA	Whatcom County Health Department	Promote care of on-site systems operating in WHPAs (considered "Areas of Special Concern" in the State Board of Health On-Site Sewage Regulations)	To be pursued in accelerated implementation task

(1) Strategies identified as GWMP Alternatives were originally developed as part of the Blaine Ground Water Management Program. Implementation plans were previously developed for these alternatives and are under consideration by Whatcom County.

BLAINE WELLHEAD PROTECTION PROGRAM - MANAGEMENT STRATEGY MATRIX

CONTAMINANT SOURCE TYPE	PROPOSED MANAGEMENT STRATEGY	RESPONSIBLE PARTY	PURPOSE OF STRATEGY	IMPLEMENTATION STATUS (1)
Solid waste facilities	Implement special standards for solid waste or demolition debris landfills, or consider outright prohibition of landfills	Whatcom County Health Department	Landfills represent high risk land uses and may not be appropriate land use in a WHPA	GWMP Alternative SW.3
Stormwater runoff	Support adoption of county stormwater management ordinance	Whatcom County Council	Ordinance will incorporate BMPs for treatment and infiltration of stormwater	GWMP Alternative SWM 2. Implemented by Whatcom County Council
Underground storage tanks	Conduct evaluation of problems associated with implementation of local regulations governing underground storage tanks (USTs) that are exempt from the Ecology UST program	Whatcom County Council Whatcom County Health Department Whatcom County Fire Marshal	Determine funding and authority needed to fully implement Whatcom County Ordinance No. 91-053	GWMP Alternative UST 2
Underground storage tanks	Negotiate memorandum of agreement with Ecology to be notified of installation, repair, or removal of tanks.	City of Blaine	Such an agreement will improve surveillance of underground storage tanks.	To be pursued as part of accelerated implementation task
Commercial hazardous wastes	Augment county business education programs for hazardous substances by implementing technical assistance program	City of Blaine	The contaminant source notification requirements under Wellhead Protection provide the city with an opportunity to assume an active role in dissemination of information concerning hazardous materials/wastes	To be pursued as part of accelerated implementation task

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BLAINE WELLHEAD PROTECTION PROGRAM - MANAGEMENT STRATEGY MATRIX

CONTAMINANT SOURCE TYPE	PROPOSED MANAGEMENT STRATEGY	RESPONSIBLE PARTY	PURPOSE OF STRATEGY	IMPLEMENTATION STATUS (1)
Household hazardous waste	Conduct an outreach program to disseminate information concerning proper disposal and/or reduced usage of household and lawn and garden chemicals	City of Blaine	Since the city has a vested interest in land use activities occurring within the WHPA, they should assume responsibility for disseminating BMP information to property owners	To be pursued as part of accelerated implementation
Agricultural practices	Support full implementation and complete funding of the recommendations of the Drayton Harbor Watershed Action Plan relating to agricultural activities	Whatcom County Conservation District Soil Conservation Service Others	The Drayton Harbor plan addressed the major known water quality problems associated with agriculture in the Dakota and California Creek basins	GWMP Alternative AG.2
Agricultural practices	Conduct survey of farms identified through the contaminant source inventory of the Blaine Wellhead Protection Program	City of Blaine	Survey results can be used to determine if monitoring needed, and to establish monitoring parameters. Results can also be used to design public outreach programs	To be pursued as part of accelerated implementation.
Agricultural practices	Should survey of agricultural practices indicate that monitoring is indicated, implement monitoring program for Watershed wells	City of Blaine	Monitoring could identify incipient water quality problems and indicate the need for implementing regulatory controls on agricultural activities	GWMP Alternative AG.3

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TABLE 9-1

BLAINE WELLHEAD PROTECTION PROGRAM - MANAGEMENT STRATEGY MATRIX

CONTAMINANT SOURCE TYPE	PROPOSED MANAGEMENT STRATEGY	RESPONSIBLE PARTY	PURPOSE OF STRATEGY	IMPLEMENTATION STATUS (1)
Roadside spraying	Designate area upgradient of the Blaine Watershed as a "Sensitive Geographical Area" under Whatcom County Ordinance 91-44.	Whatcom County Public Works Whatcom County Council	Roadside vegetation control in Sensitive Geographical Areas must be accomplished through non-chemical means	GWMP Alternative PN.4
Abandoned wells	Conduct a survey to identify location of suspected improperly abandoned wells within the WHPA	City of Blaine	The survey will target well owners for educational activities concerning proper well abandonment requirements	To be pursued as part of accelerated implementation
Abandoned wells	In cooperation with the Whatcom County Health Department, prepare educational pamphlet regarding well abandonment requirements and well maintenance practices	City of Blaine	The pamphlet would be distributed to well owners in the WHPA identified through the well survey	To be pursued as part of accelerated implementation
Transboundary Impact	Develop mechanism for ongoing communication with Langley and Surrey	City of Blaine Whatcom County Planning and Development Services	Communication would focus on water quality and quantity problems that may traverse the international boundary	GWMP Alternative TI.3

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BLAINE WELLHEAD PROTECTION PROGRAM - MANAGEMENT STRATEGY MATRIX

CONTAMINANT SOURCE TYPE	PROPOSED MANAGEMENT STRATEGY	RESPONSIBLE PARTY	PURPOSE OF STRATEGY	IMPLEMENTATION STRATEGY (1)
Future land use	Strengthen Aquifer Recharge Area provisions of the Natural Resource Lands and Critical Areas Management Ordinance of the City of Blaine	City of Blaine	Findings of the WHPP provide critical information needed to enhance ground water protection measures. Such information should be used to strengthen the city ordinance	To be pursued as part of accelerated implementation
Future land use	Establish a special permit and review process as well as performance standards for new development in WHPA	City of Blaine	Such processes and standards will assist in improving the level of protection afforded to the WHPA	To be pursued as part of accelerated implementation
Future land use	Adopt surface mining performance standards similar to those found in WCC Chapter 20.73	City of Blaine	The performance standards include extensive measures intended to protect ground water quality	To be pursued as part of accelerated implementation
Future land use	Adopt proposed city stormwater management ordinance	City of Blaine	The city has adopted a stormwater management plan, but needs to adopt the implementing standards	To be pursued as part of accelerated implementation
Future land use	Implement measures to reduce nitrate loading in East Blaine Annexation	City of Blaine	Potential nitrate contamination can be averted through extension of public sewers, use of cluster development, and dissemination of BMPs	To be pursued as part of accelerated implementation

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BLAINE WELLHEAD PROTECTION PROGRAM - MANAGEMENT STRATEGY MATRIX

CONTAMINANT SOURCE TYPE	PROPOSED MANAGEMENT STRATEGY	RESPONSIBLE PARTY	PURPOSE OF STRATEGY	IMPLEMENTATION STATUS (1)
Transportation hazards	Provide Whatcom County Department of Emergency Management with information concerning the locations of the city's wells and the areas recharging those wells	City of Blaine Whatcom County Department of Emergency Management	Emergency Management would incorporate such information into its data management system and relayed to alert first responders in the event of a hazardous materials incident. In addition, Emergency Management could alert city personnel of such incidents	To be pursued as part of accelerated implementation
Transportation hazards	Provide Washington State Patrol, local fire authorities, and other emergency response agencies with information concerning the city's wells and the areas recharging those wells	City of Blaine	Information would assist emergency response agencies in determining appropriate response protocols for hazardous materials incidents	To be pursued as part of accelerated implementation
Transportation hazards	Develop a spill response plan for the Blaine WHPA	Whatcom County Department of Emergency Management City of Blaine	Such a plan will help ensure prompt and efficient response to contaminant releases within the WHPA	To be pursued as part of accelerated implementation

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BLAINE WELLHEAD PROTECTION PROGRAM - MANAGEMENT STRATEGY MATRIX

CONTAMINANT SOURCE TYPE	PROPOSED MANAGEMENT STRATEGY	RESPONSIBLE PARTY	PURPOSE OF STRATEGY	IMPLEMENTATION STATUS (1)
Transportation hazards	Schedule spill response exercises involving a highway transportation incident potentially affecting a city well	Whatcom County Department of Emergency Management City of Blaine State Patrol others	Spill response exercises would allow spill response protocols to be routinely tested and modified as necessary	To be pursued as part of accelerated implementation
Transportation hazards	Conduct inventory of equipment and materials available to respond to a hazardous material release	City of Blaine	A regularly update inventory would expedite acquisition of necessary equipment and materials during an emergency	To be pursued as part of accelerated implementation
Transportation hazards	Study feasibility of placing large signs on truck routes providing instructions concerning actions to be taken in the event of a spill	City of Blaine Washington Department of Transportation	Placement of signs may result in faster reporting of incidents and could reduce emergency response time	To be pursued as part of accelerated implementation

(1) Strategies identified as GWMP Alternatives were originally developed as part of the Blaine Ground Water Management Program. Implementation plans were previously developed for these alternatives and are under consideration by Whatcom County.

Blaine Wellhead Protection Program Ground Water Protection and Management Responsibility Matrix

	WA Dept. of Agriculture	WA Dept. of Ecology	WA Dept. of Health	WA Dept. of Transportation	WA State Patrol	Conservation District/ Cooperative Extension	Whatcom County Dept. of Emergency Management	Whatcom County Fire Marshal	Whatcom County Health Department	Whatcom County Planning and Development Services	Whatcom County Public Works	Blaine Planning Department	Blaine Dept. Public Safety	Blaine Public Works	Fire District 13
<u>Agriculture</u>															
Develop Farm Management Plans						P(o)									
Disseminate Soil and Water Conservation BMPs						P(o)									
Regulate Animal Waste Disposal		P(m)				S(o)									
<u>Hazardous Materials/Wastes</u>															
RCRA Generators Management		P(m)													
Small Quantity Waste Generators Management (Conditionally Exempt from RCRA)									P(m)		S(m)				
Household Hazardous Waste Management									P(o)*		P(o)*				
Above Ground Hazardous Material Storage								P(m)							
Enforcement Directed Remedial Response		P(m)													
Direct Remedial Response		P(m)													

P = Primary Responsibility
S = Secondary Responsibility
(de) = Responsibility delegated to WCHD by Ecology
(dh) = Responsibility delegated to WCHD by DOH under Joint Operating Agr
(j) = Responsibility may be delegated to WCHD by DOH under Joint Operating Agreement
(m) = Program or activity legally mandated
(o) = Program or activity undertaken at agency's option
* = Responsibility Divided in Accordance with Jurisdictional Authority

Golder Associates

Golder Associates

Whatcom County Wellhead Protection Program Ground Water Protection and Management Responsibility Matrix	WA Dept. of Agriculture	WA Dept. of Ecology	WA Dept. of Health	WA Dept. of Transportation	WA State Patrol	Conservation District/ Cooperative Extension	Whatcom County Dept. of Emergency Management	Whatcom County Fire Marshal	Whatcom County Health Department	Whatcom County Planning and Development Services	Whatcom County Public Works	Blaine Planning Department	Blaine Dept. Public Safety	Blaine Public Works	Fire District 13
Land Use															
Conduct Comprehensive Land Use Planning										P(m)*		P(m)*			
Enforce Zoning Codes										P(m)*		P(m)*			
Administer Aquifer Recharge Area Ordinance										P(m)					
SEPA										P(m)*		P(m)*			
On-Site Sewage Disposal															
Permitting <3,500 Gallons Per Day Systems									P(m)						
Permitting 3,500 to 14,499 Gallons Per Day Systems			P(m)						(j)						
Permitting 14,500 Gallons Per Day Systems		P(m)													
Failing System Identification/Compliance									P(m)						
Oversight of Operation and Maintenance									P(m)						
Pesticide Use															
Registration/Regulation of Pesticides	P(m)														
Pesticide Applicator/Dealer Licensing	P(m)														

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Pesticide Use (continued)															
Pesticide Use Monitoring	P(m)														
Regulation of Commercial Fertilizer	P(o)														
Public Water Systems															
Group A Public Water System Regulation/Monitoring			P(m)						S(dh)						
Group B Public Water System Regulation/Monitoring			S(m)						P(dh)						
Reclaimed Water															
Permitting Reuse of Reclaimed Water		S(m)	P(m)												
Solid Waste															
Solid Waste Planning		S(m)							S(m)	S(m)	P(m)				
Solid Waste Handling/Facility Permitting		S(m)							P(m)						
Biosolid Site Permitting		S(m)							P(m)		S(m)				
Stormwater Management															
Regulation of Stormwater Disposal System Design										S(m)	P(m)*			P(m)*	
Conduct Stormwater Capital Facilities Projects											P(m)*			P(m)*	

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Transportation Spills															
Highway Roadway Design				P(m)*							P(m)*			P(m)*	
Spill Response - Coordination/Planning							P(m)								
Spill Response - Incident Command					P(m)										
Spill Response - Support		S(m)		S(m)			S(m)				S(m)		P(m)	S(m)	S(m)
SARA Title III Implementation							P(m)						S(m)		
Underground Storage Tanks															
Construction/Operation - RCRA Subtitle i		P(m)													
Construction and Operation - RCRA Exempt								P(m)							
Wastewater Treatment															
Sewer Facility Planning										S(m)*	P(m)*	S(m)*		P(m)*	
Sewer Facility Operation											P(m)*			P(m)*	
Conduct Sewer Pretreatment Program											P(m)*			P(m)*	
Water Quality Studies/Monitoring															
Ground Water		S(o)	S(o)												

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Whatcom County Wellhead Protection Program Ground Water Protection and Management Responsibility Matrix

Whatcom County Wellhead Protection Program Ground Water Protection and Management Responsibility Matrix	WA Dept. of Agriculture	WA Dept. of Ecology	WA Dept. of Health	WA Dept. of Transportation	WA State Patrol	Conservation District/ Cooperative Extension	Whatcom County Dept. of Emergency Management	Whatcom County Fire Marshal	Whatcom County Health Department	Whatcom County Planning and Development Services	Whatcom County Public Works	Blaine Planning Department	Blaine Dept. Public Safety	Blaine Public Works	Fire District 13
Water Quality Management Planning															
State Wellhead Protection Program Implementation			P(m)												
Local Implementation of Wellhead Protection Programs															
Water Pollution Control															
Enforcement of Water Pollution Control Act		P(m)													
Issuance of State Waste Discharge Permits		P(m)													
Issuance of National Pollution Discharge Elimination System Permits		P(m)													
Well Construction and Abandonment															
Licensing Drillers		P(m)													
Regulation of Well Sealing and Decommissioning		S(m)							P(de)						
Regulation of Other Well Construction Activities		P(m)													

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TABLE 10-1

WELL CAPACITY AND AQUIFER DATA

Well Group*	Well ID Number	Pump Capacity (gpm)	Aquifer Source And Description
Deep Aquifer	1	600 (based on estimate for new well)	These wells' water source is the Deep Aquifer (Unit F), which is greater than 600 ft deep. It appears to be recharged from a source area other than the Boundary Upland. It is confined and protected from contamination by 400 to 500 ft of relatively impermeable overlying marine silt and clay sediments.
	2	200	
	Total Capacity	800	
Watershed Unit C	3	210	These wells' water source is Unit C of the Shallow Aquifer System, and are less than 100 feet deep. Their recharge is from precipitation over the Boundary Upland, and the wells are susceptible to contamination.
	4	200	
	Total Capacity	410	
Watershed Unit D	5	450	These wells' water source is Unit D of the Shallow Aquifer System, and are 250 to 300 feet deep. Recharge is from percolation through the overlying water-bearing units in the Boundary Upland area. Unit D is semi-confined in the Watershed area and is protected to some degree from contamination by overlying silt and clay sediments.
	6	170	
	Total Capacity	620	
Western Boundary Upland	7 (12th Street)	320	These wells' water source is Unit C or D of the Shallow Aquifer System, and are 250 to 300 feet deep. Recharge is from percolation through the overlying water-bearing units in the Boundary Upland area to the east. The unit tapped by No. 7 and 8 is semi-confined to confined and is protected to some degree from contamination by up to 200 feet of overlying silt and clay sediments.
	8 (Lincoln Park)	300	
	Total Capacity	620	
Total Wellfield	Total Capacity From All Wells	2,450	

ells are grouped based on their close proximity and depth of completion, which equates to their equal susceptability to contamination from a single event or source.

TABLE 10-2

PROJECTED WATER DEMANDS, GPM

Year of Projection	1995	2000	2005	2010	2015
ANNUAL AVERAGE DAY	1,200	1,167	1,097	1,097	1,125
SUMMER AVERAGE DAY	1,458	1,458	1,402	1,438	1,514
PEAK DAY	3,257	2,854	3,160	3,215	3,604

Source: Preliminary Data from Water System Plan (currently being updated).

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TABLE 10-3

WATER SUPPLY CAPACITY SCENARIOS

TABLE 10-3A
SURPLUS OR (DEFICIT) SUPPLY FOR ANNUAL AVERAGE DAY DEMANDS (gpm)

Contaminated Well Group(s)	Wells Taken Out of Service	Lost Capacity (gpm)	Remaining Well Supply Capacity (gpm)	1995	2000	2005	2010	2015
Watershed Unit C	3 & 4	410	2,040	840	873	943	943	915
Watershed Unit D	5 & 6	620	1,830	630	663	733	733	705
Western Boundary Upland	7 & 8	620	1,830	630	663	733	733	705
Deep Aquifer	1 & 2	800	1,650	450	483	553	553	525
Shallow Aquifer System	3, 4, 5 & 6 or 3, 4, 7 & 8	1,030	1,420	220	253	323	323	295

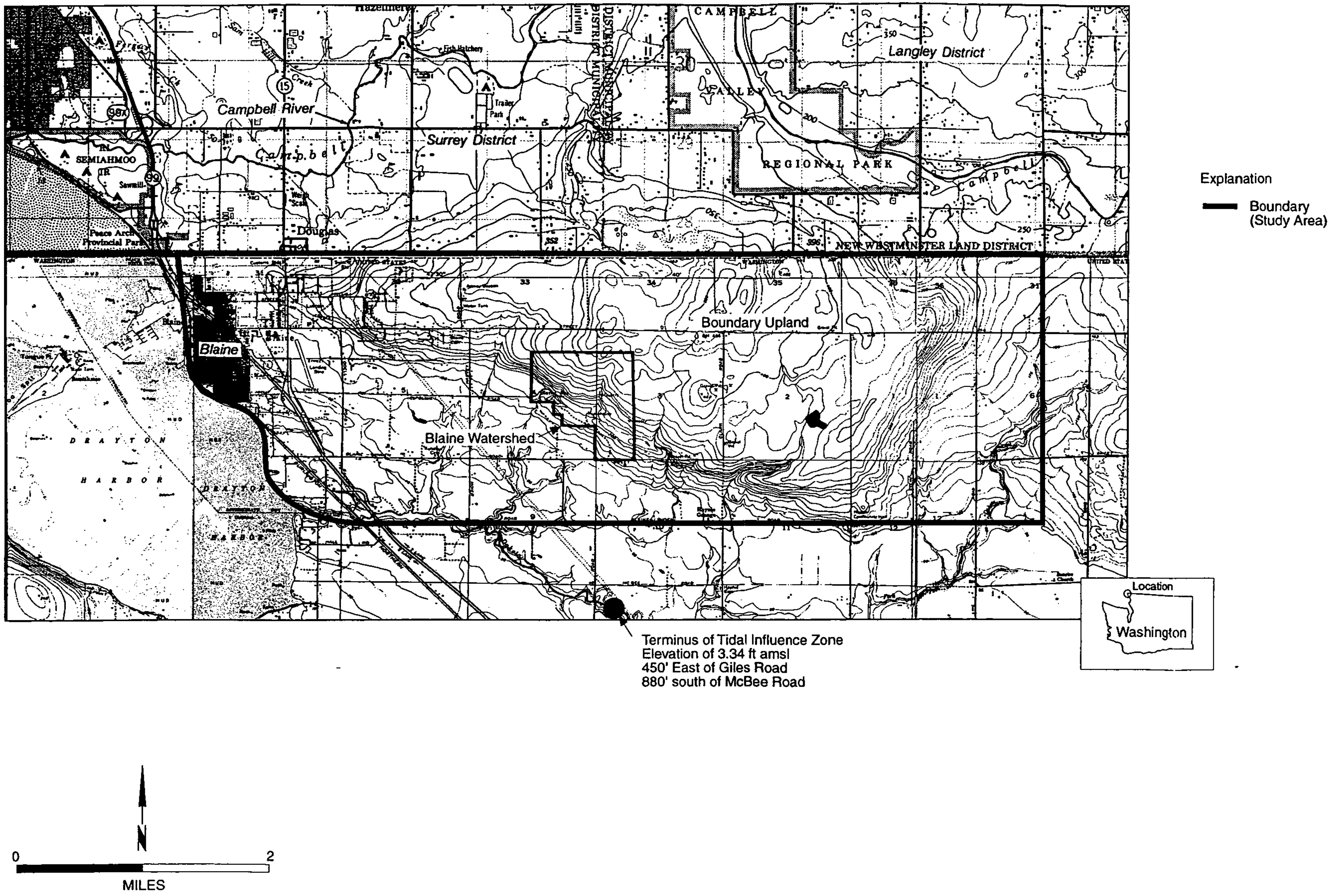
TABLE 10-3b
SURPLUS OR (DEFICIT) SUPPLY FOR SUMMER AVERAGE DAY DEMANDS (gpm)

Contaminated Well Group(s)	Wells Taken Out of Service	Lost Capacity (gpm)	Remaining Well Supply Capacity (gpm)	1995	2000	2005	2010	2015
Watershed Unit C	3 & 4	410	2,040	582	582	638	602	526
Watershed Unit D	5 & 6	620	1,830	372	372	428	392	316
Western Boundary Upland	7 & 8	620	1,830	372	372	428	392	316
Deep Aquifer	1 & 2	800	1,650	192	192	248	212	136
Shallow Aquifer System	3, 4, 5 & 6 or 3, 4, 7 & 8	1,030	1,420	(38)	(38)	18	(18)	(94)

TABLE 10-3C
SURPLUS OR (DEFICIT) SUPPLY FOR PEAK DAY DEMANDS (gpm)

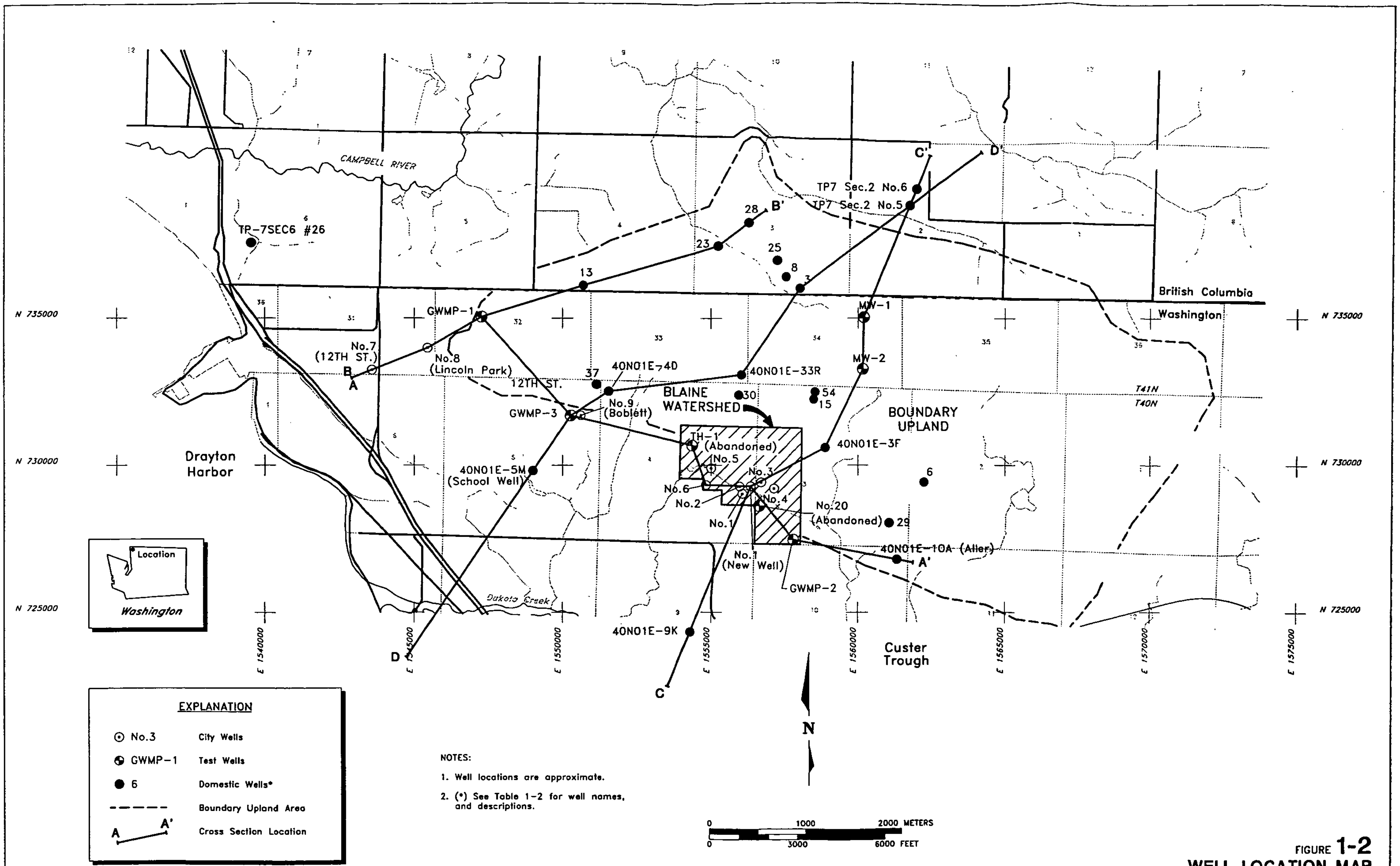
Contaminated Well Group(s)	Wells Taken Out of Service	Lost Capacity (gpm)	Remaining Well Supply Capacity (gpm)	1995	2000	2005	2010	2015
Watershed Unit C	3 & 4	410	2,040	(1,217)	(814)	(1,120)	(1,175)	(1,564)
Watershed Unit D	5 & 6	620	1,830	(1,427)	(1,024)	(1,330)	(1,385)	(1,774)
Western Boundary Upland	7 & 8	620	1,830	(1,427)	(1,024)	(1,330)	(1,385)	(1,774)
Deep Aquifer	1 & 2	800	1,650	(1,607)	(1,204)	(1,510)	(1,565)	(1,954)
Shallow Aquifer System	3,4, 5 & 6 or 3, 4, 7 & 8	1,030	1,420	(1,837	(1,434)	(1,740)	(1,795)	(2,184)

FIGURES



Terminus of Tidal Influence Zone
Elevation of 3.34 ft amsl
450' East of Giles Road
880' south of McBee Road

FIGURE **1-1**
STUDY AREA
BLAINE/WHPP/WA



NOTES:

1. Well locations are approximate.
2. (*) See Table 1-2 for well names, and descriptions.

FIGURE **1-2**

WELL LOCATION MAP

CITY OF BLAINE/BLAINE WHPP/WA

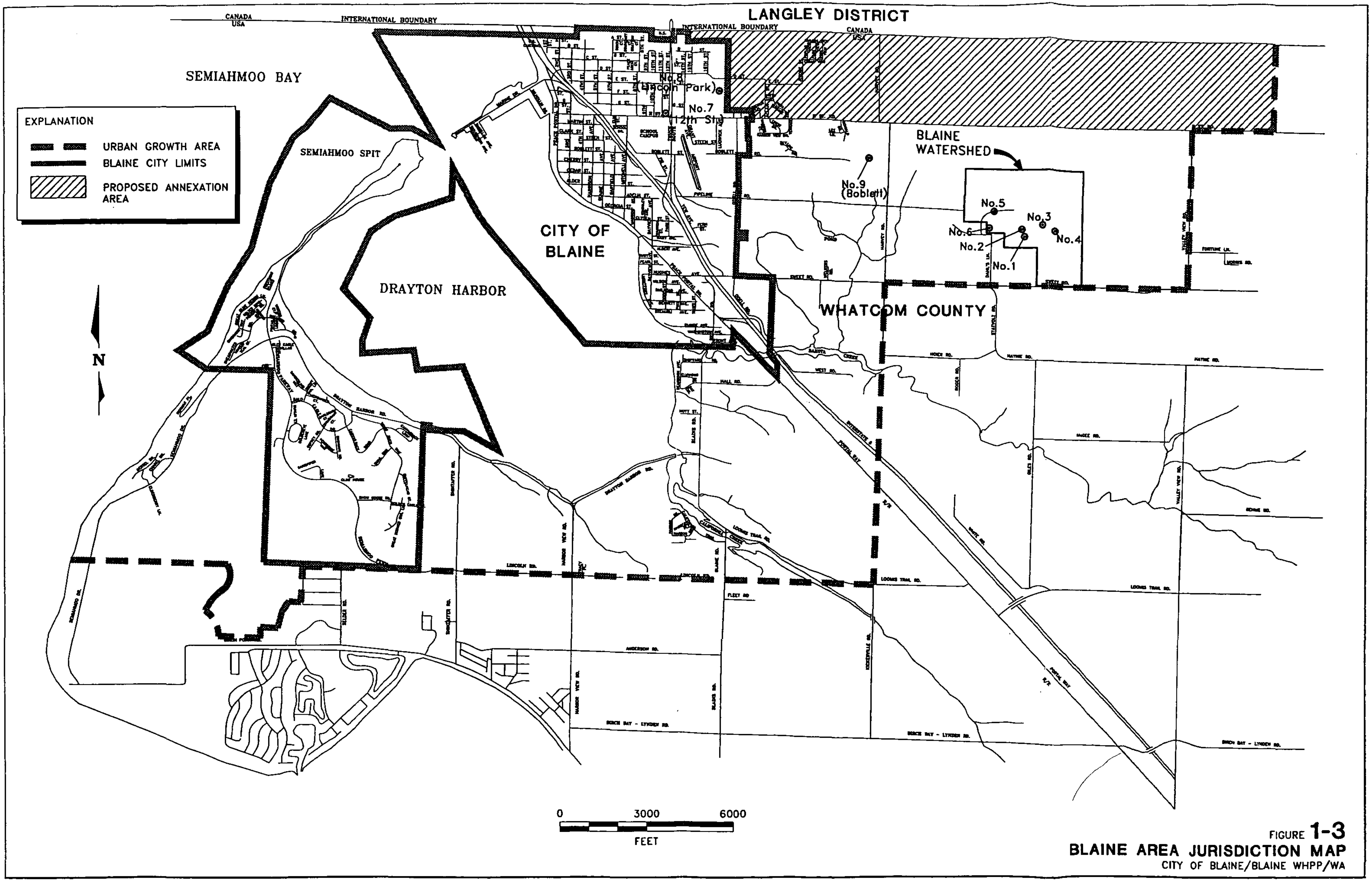


FIGURE **1-3**

BLAINE AREA JURISDICTION MAP

CITY OF BLAINE/BLAINE WHPP/WA

C:\DPT\9431673\107\63745 2-28-96 15:03 xrf: NONE

Golder Associates

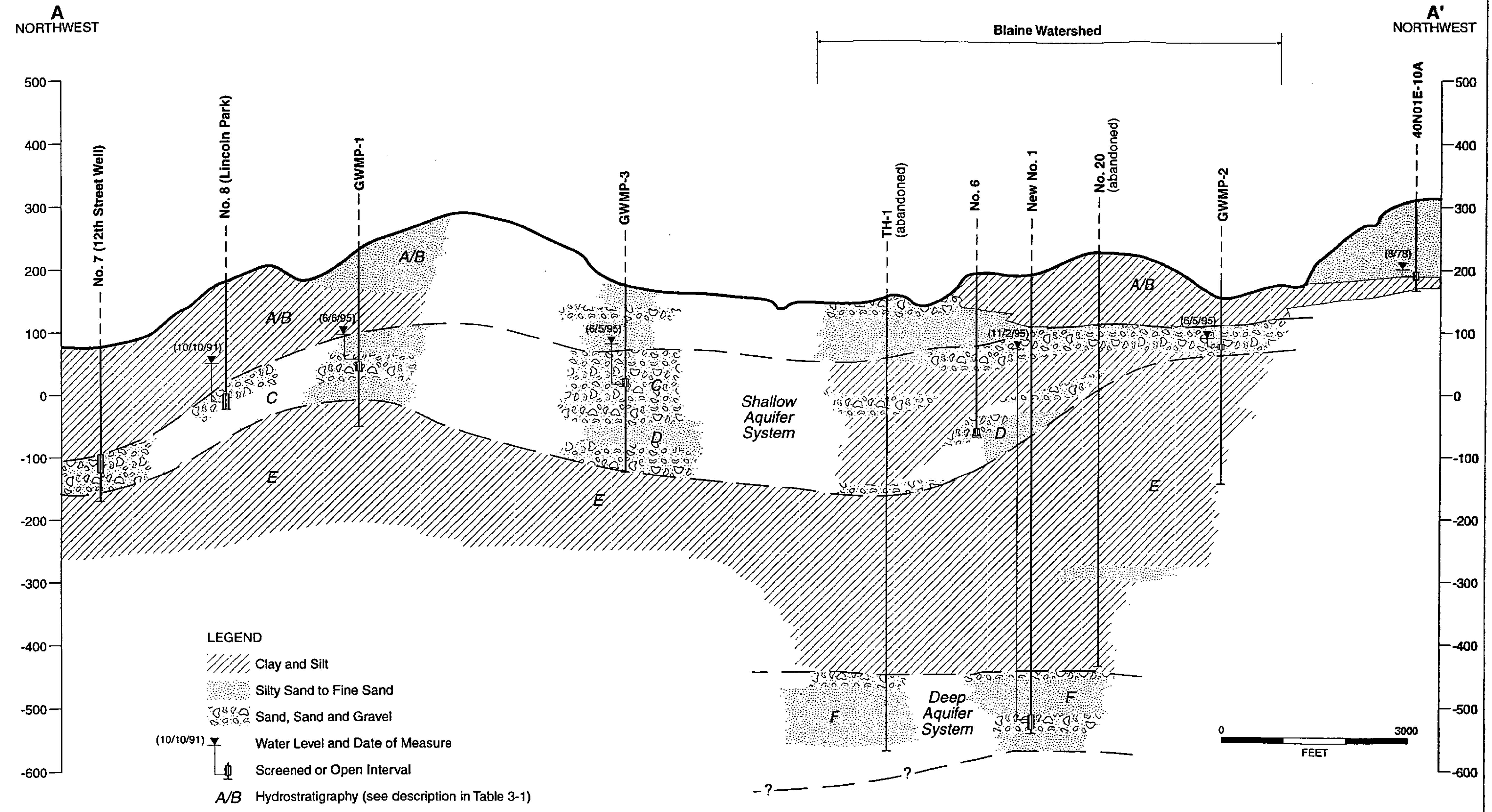


FIGURE **3-1**
CROSS SECTION A-A'
BLAINE/WHPP/WA

PROJECT NO. 943 1673.107 DRAWING NO. 65074 DATE 2/29/96 DRAWN BY CB

Golder Associates

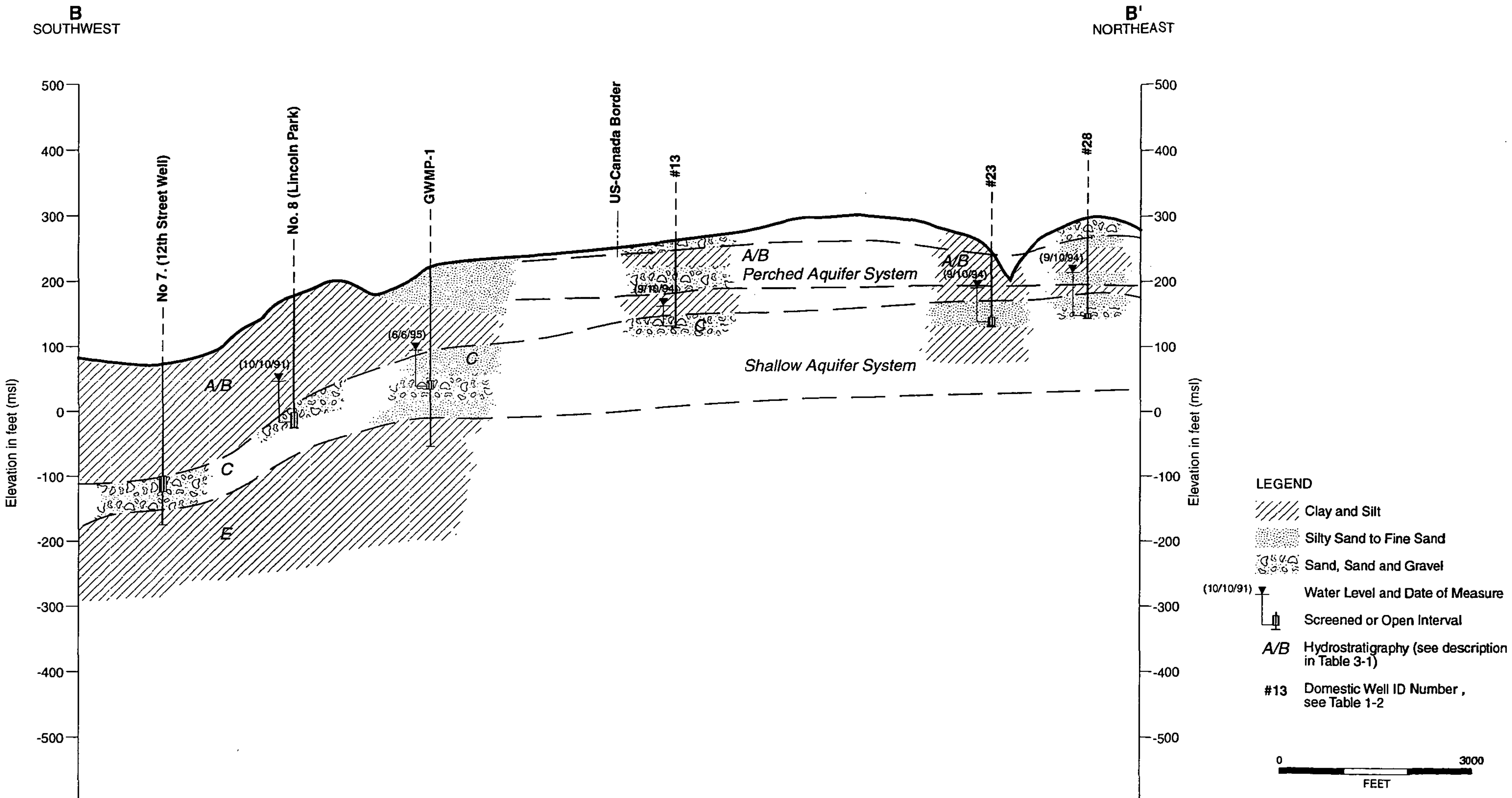


FIGURE **3-2**

CROSS SECTION B-B'

BLAINE/WHPP/WA

PROJECT NO. 943 1673.107 DRAWING NO. 65075 DATE 2/22/96 DRAWN BY CB

Golder Associates

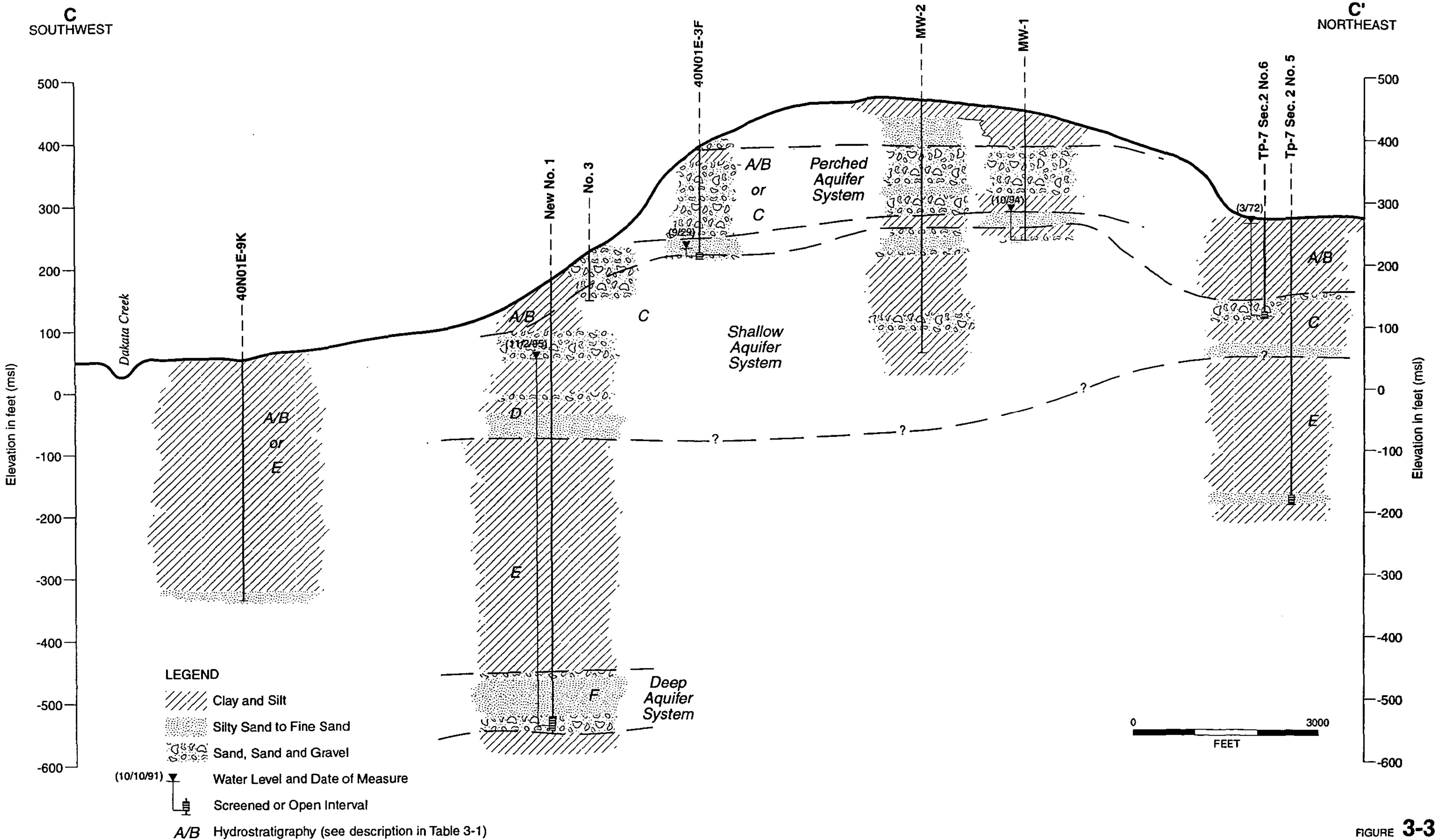


FIGURE **3-3**
CROSS SECTION C-C'
BLAINE/WHPP/WA

PROJECT NO. 943 1673.107 DRAWING NO. 65076 DATE 2/23/96 DRAWN BY CB

Golder Associates

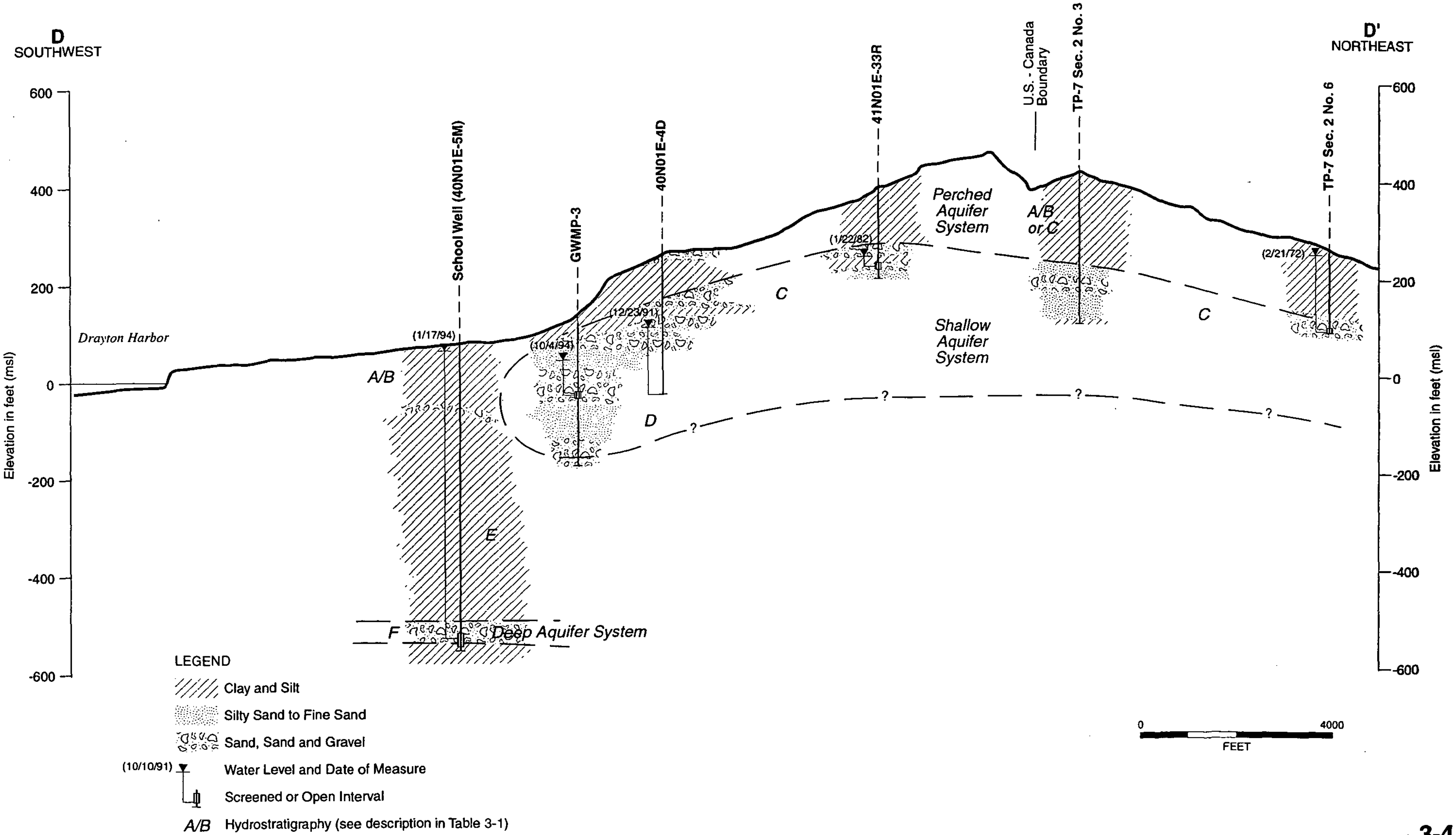
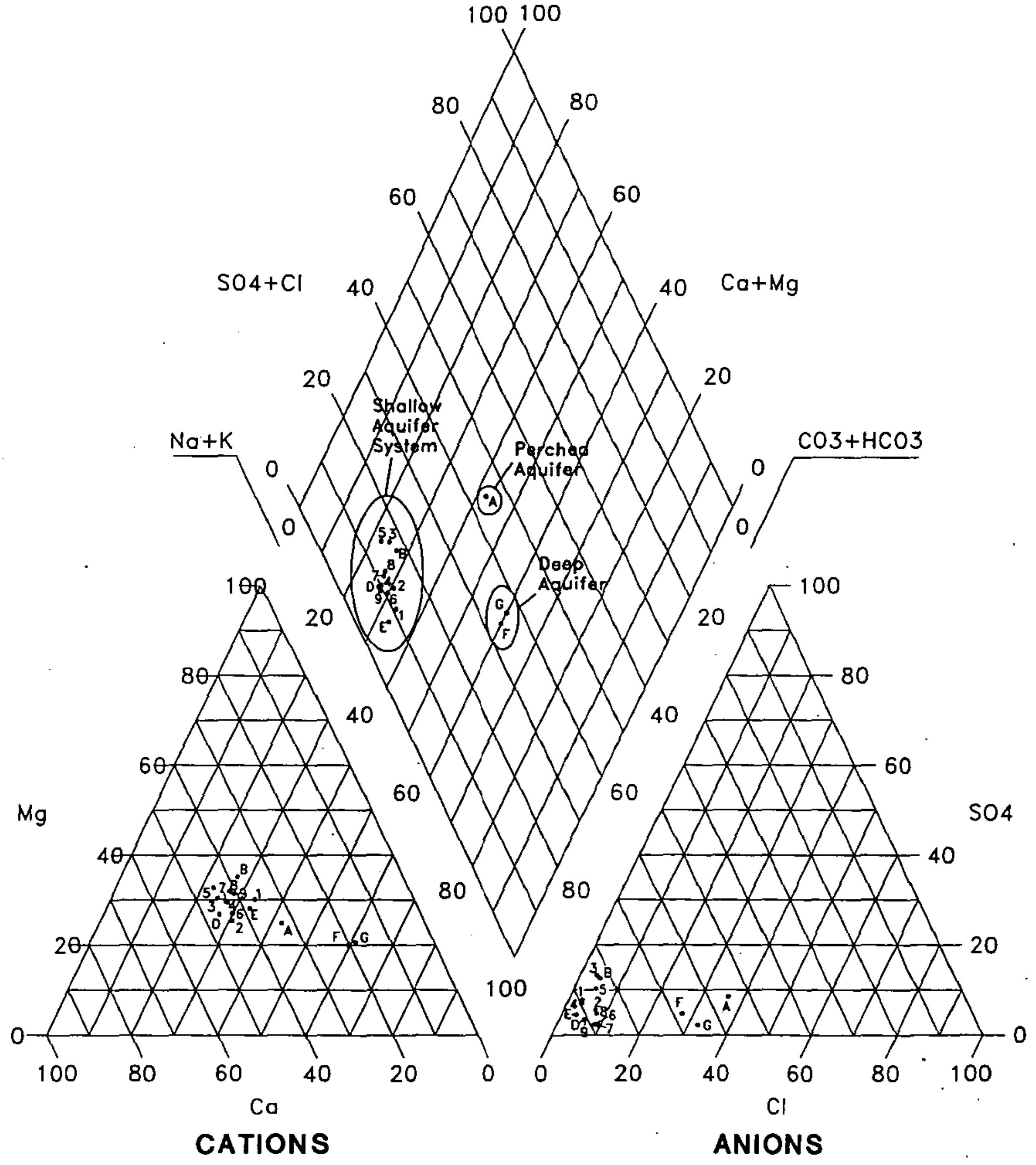


FIGURE **3-4**
CROSS SECTION D-D'
BLAINE/WHPP/WA



SAMPLES:		INTERPETED UNIT:
1	Well No. 7	(D)
2	Well No. 8	(D)
3	Well No. 6	(D)
4	Well No. 4	(C)
5	GWMP–1	(C)
6	GWMP–2	(C)
7	GWMP–3	(C)
8	Boettcher	(C)
9	Colacurcio	(C)

SAMPLES:		INTERPRETED UNIT:
A	Leer	(Perched)
B	Berg	(C)
D	Aller	(C)
E	Well No. 9	(D)
F	Well No. 1	(F)
G	Well No. 2	(F)

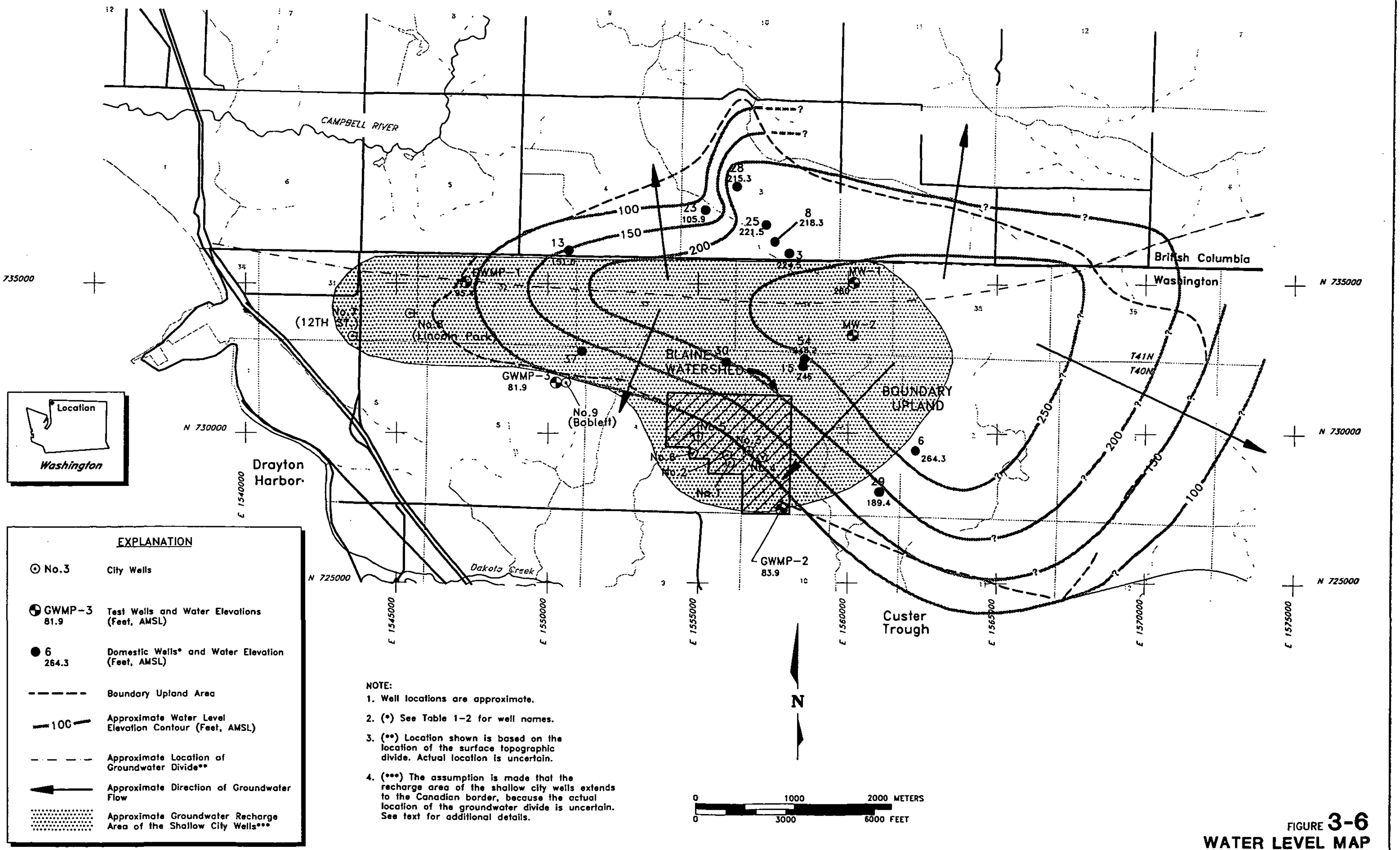
NOTES:

1) Samples collected October and November 1990, samples F and G were collected in May 1992.

FIGURE **3-5**

WATER QUALITY COMPARISON: PIPER DIAGRAM

CITY OF BLAINE/BLAINE WHPP/WA



NOTE:

1. Well locations are approximate.
2. (*) See Table 1-2 for well names.
3. (**) Location shown is based on the location of the surface topographic divide. Actual location is uncertain.
4. (***) The assumption is made that the recharge area of the shallow city wells extends to the Canadian border, because the actual location of the groundwater divide is uncertain. See text for additional details.

FIGURE 3-6
WATER LEVEL MAP
CITY OF BLAINE/BLAINE WHPP/WA

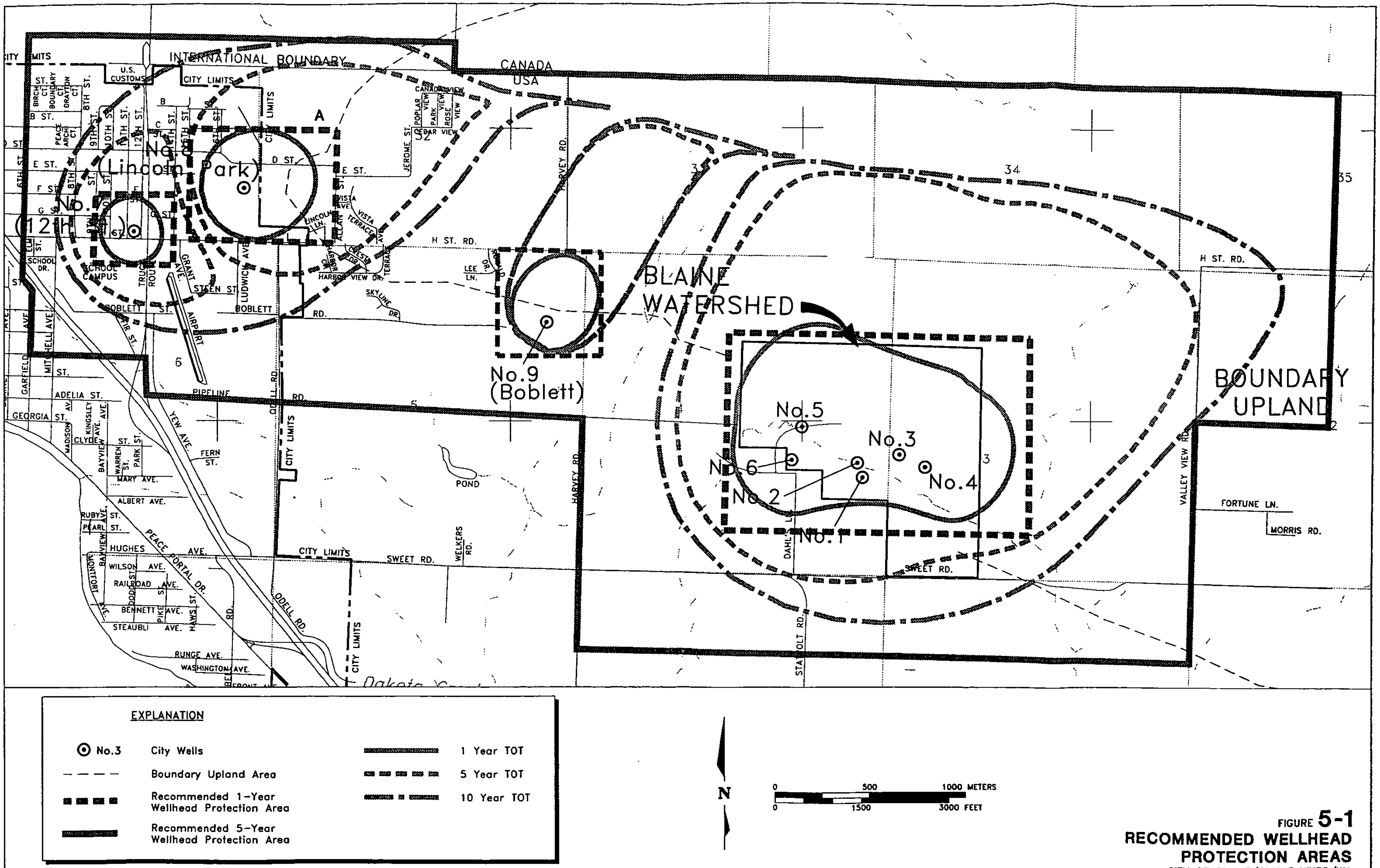
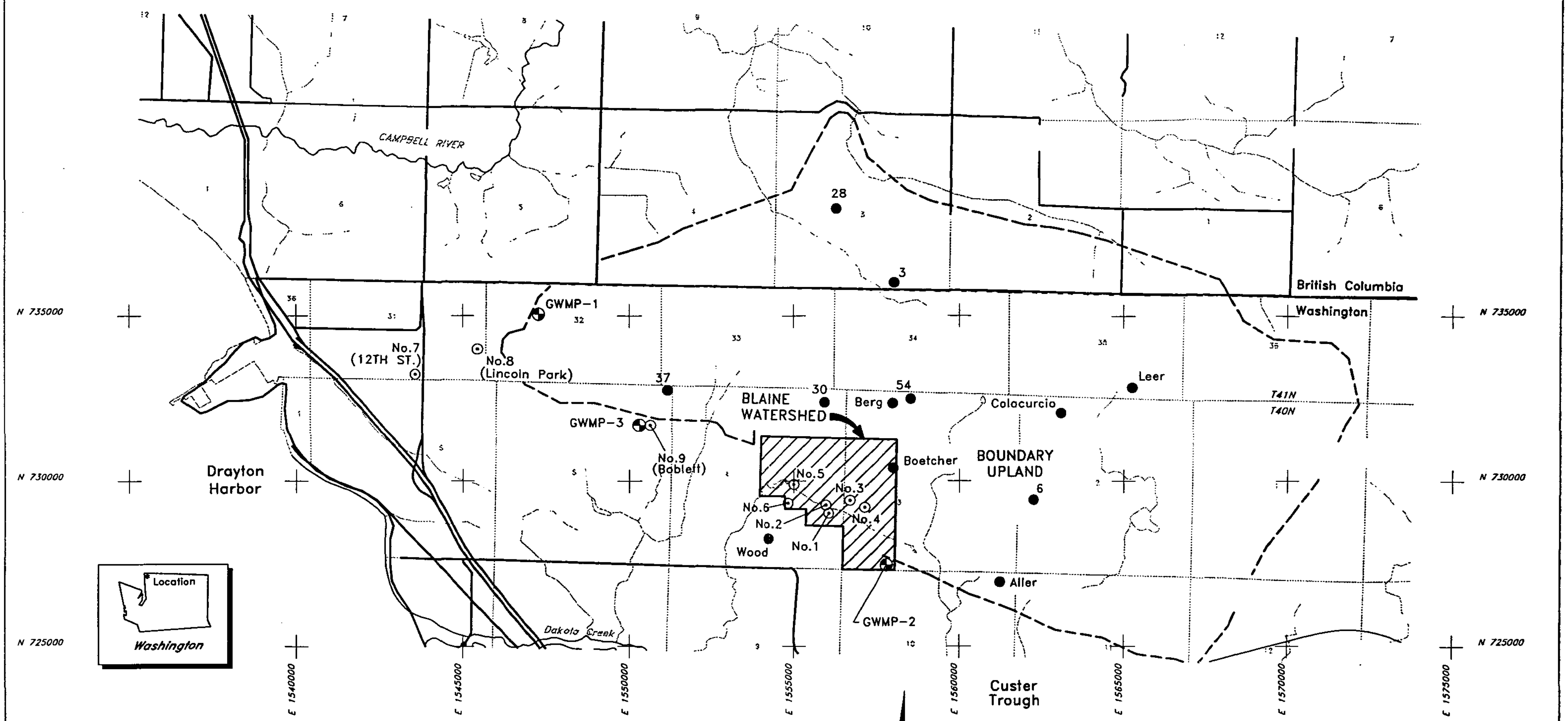


FIGURE **5-1**
RECOMMENDED WELLHEAD PROTECTION AREAS
CITY OF BLAINE/BLAINE WHPP/WA

Golder Associates



EXPLANATION

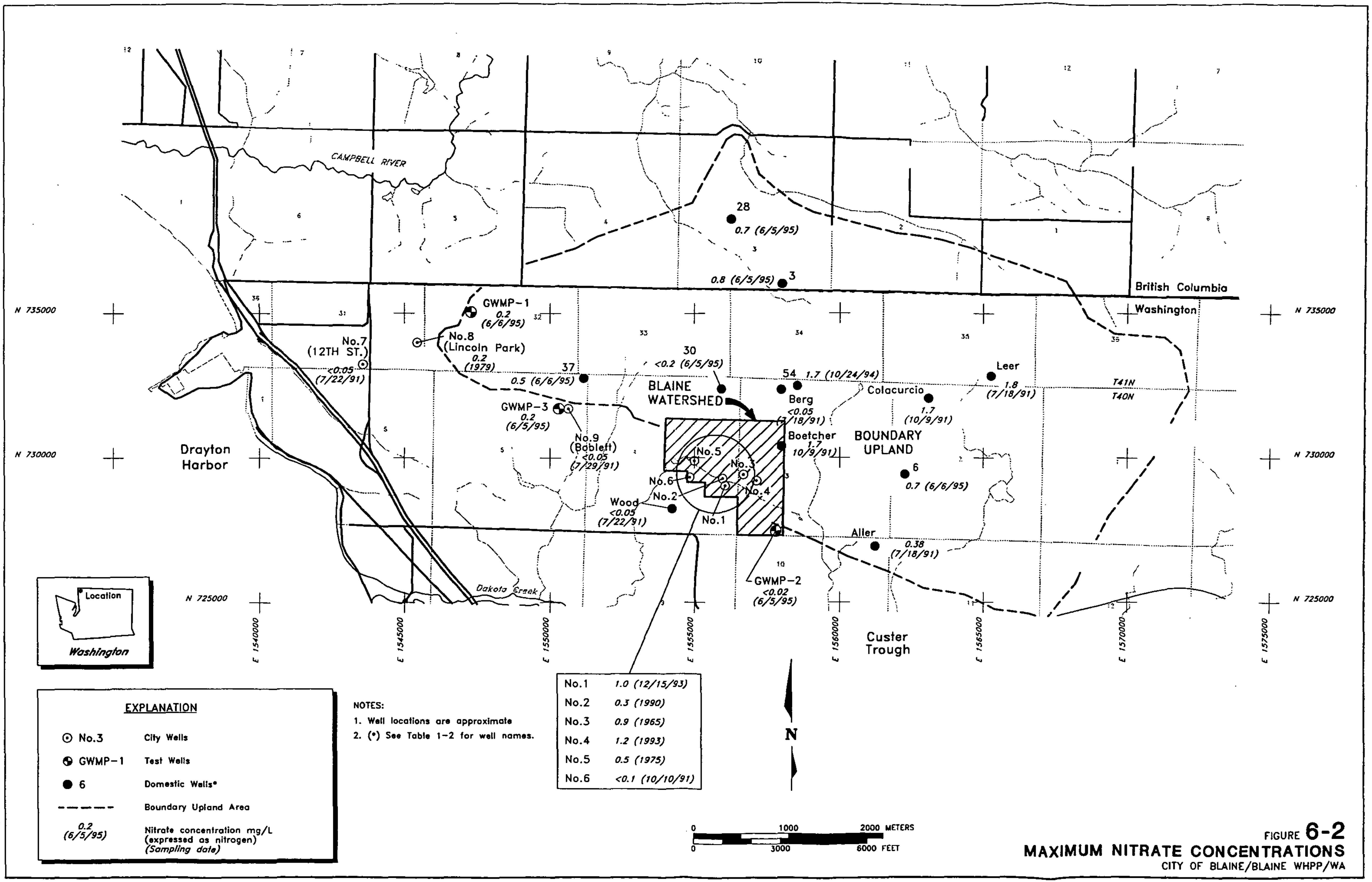
⊙ No.3	City Wells
GWMP-1	Test Wells
● 6	Domestic Wells*
– – – – –	Boundary Upland Area

NOTES:
1. Well locations are approximate
2. (*) See Table 1-2 for well names.
3. WHPP monitoring wells include all numbered wells and GWMP-1, GWMP-2, AND GWMP-3.
4. GWMP monitoring wells included all named domestic wells, GWMP-1, GWMP-2, GWMP-3, and City wells No.4, No.6, No.7, and No.8.

FIGURE **6-1**

WATER QUALITY MONITORING NETWORK

CITY OF BLAINE/BLAINE WHPP/WA



No.1	*1.0 (12/15/93)*
No.2	*0.3 (1990)*
No.3	*0.9 (1965)*
No.4	*1.2 (1993)*
No.5	*0.5 (1975)*
No.6	*<0.1 (10/10/91)*

EXPLANATION

⊙ No.3	City Wells
GWMP-1	Test Wells
● 6	Domestic Wells*
— — — —	Boundary Upland Area
0.2 *(6/5/95)*	Nitrate concentration mg/L (expressed as nitrogen) *(Sampling date)*

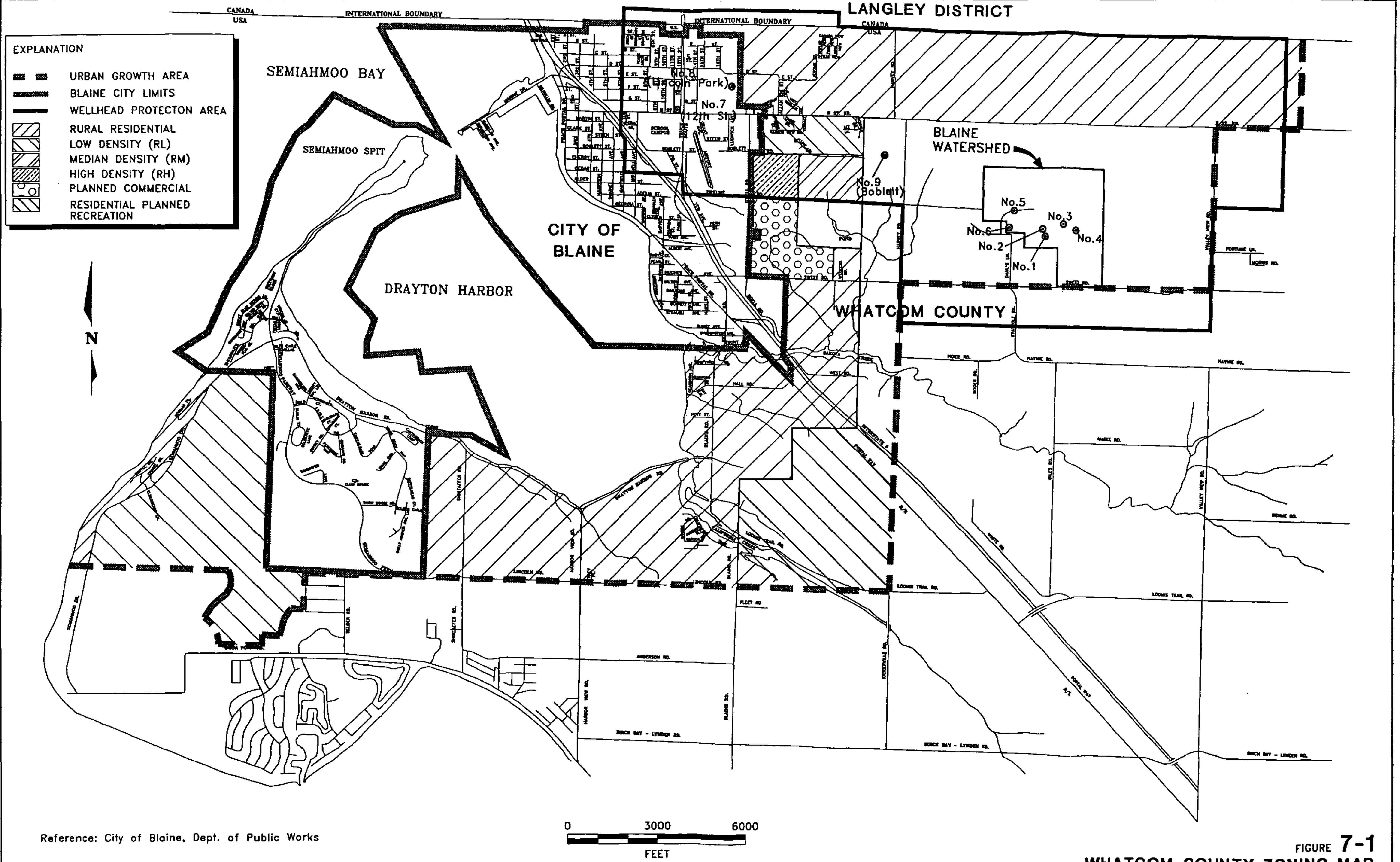
NOTES:

1. Well locations are approximate
2. (*) See Table 1-2 for well names.

FIGURE **6-2**

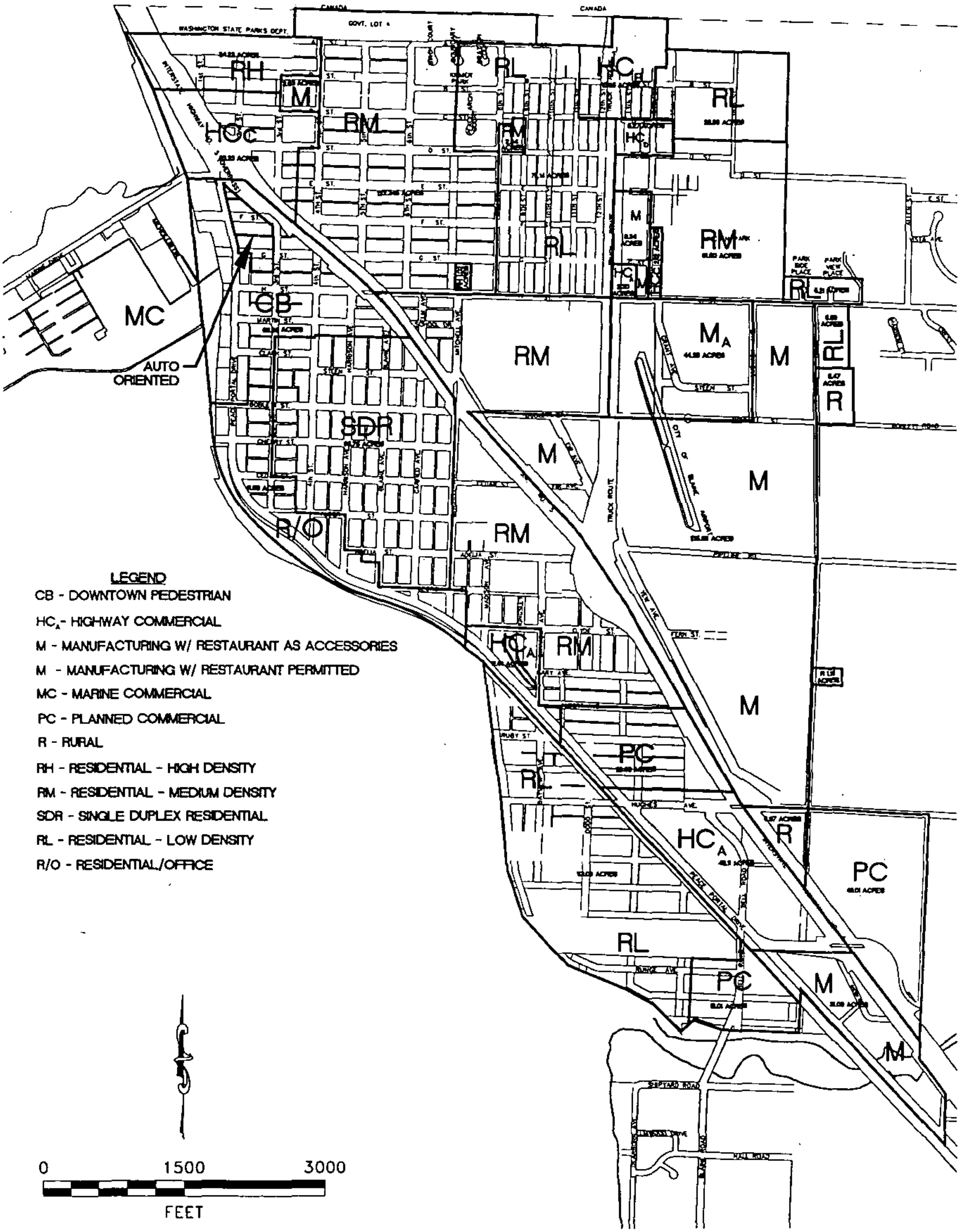
MAXIMUM NITRATE CONCENTRATIONS

CITY OF BLAINE/BLAINE WHPP/WA



Reference: City of Blaine, Dept. of Public Works

FIGURE 7-1
WHATCOM COUNTY ZONING MAP
CITY OF BLAINE/BLAINE WHPP/WA



REFERENCE: CITY OF BLAINE, DEPT. OF PUBLIC WORKS

FIGURE **7-2**

CITY OF BLAINE ZONING MAP

CITY OF BLAINE/BLAINE WHPP/WA

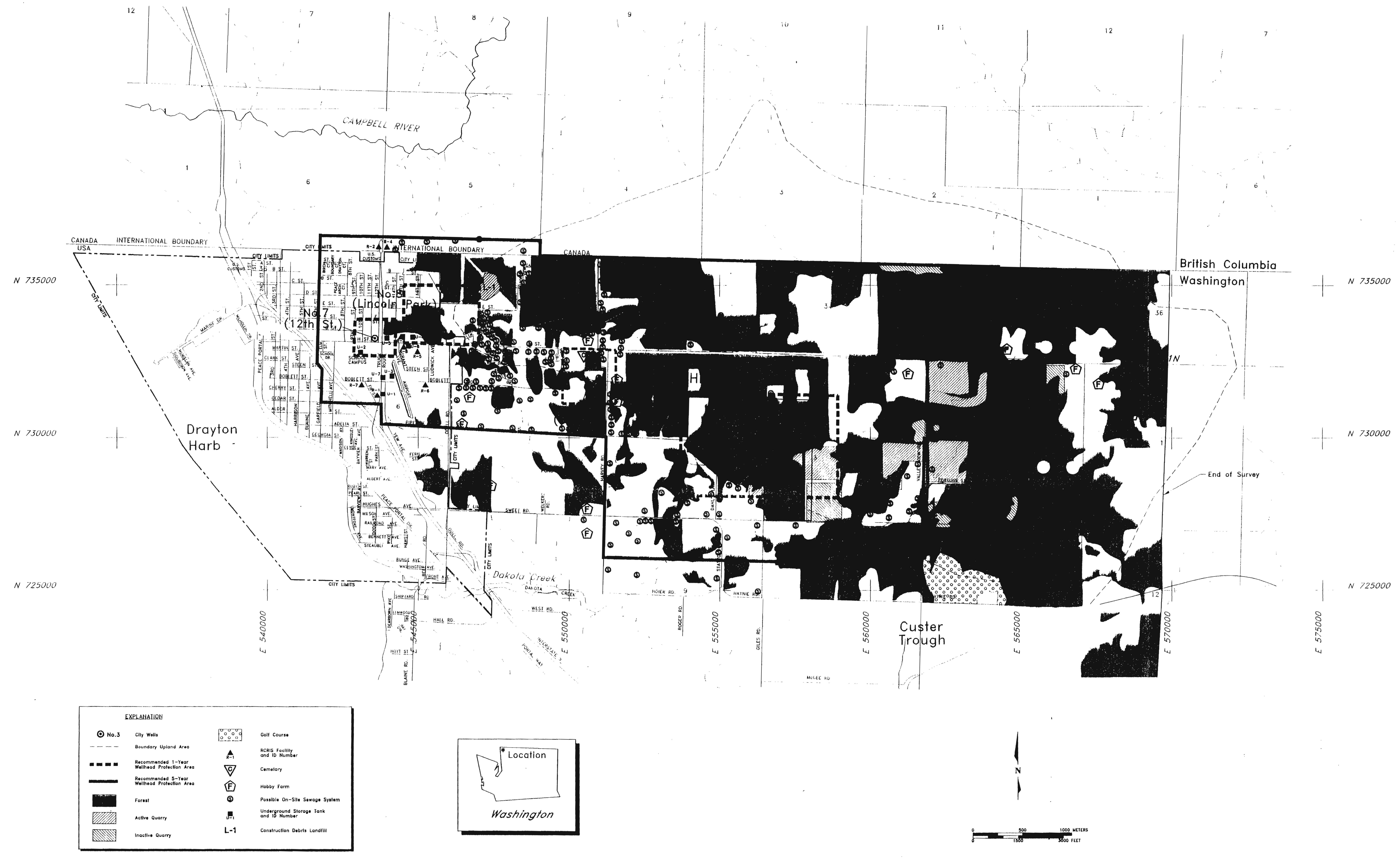


FIGURE 7-3
POTENTIAL CONTAMINANT SOURCES
CITY OF BLAINE/BLAINE WHPP/WA

Golder Associates

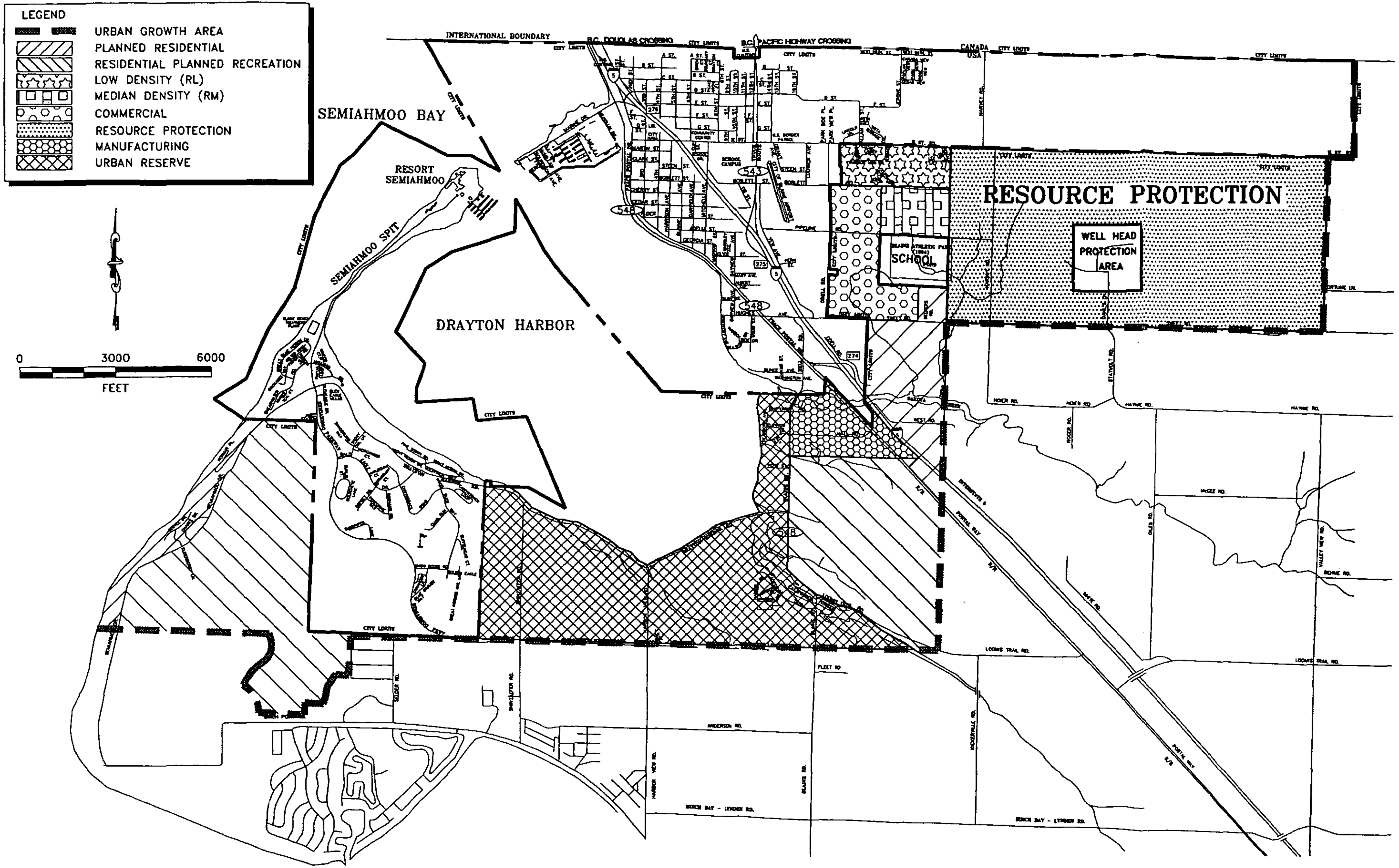


FIGURE **9-1**

FUTURE LAND USE MAP

BLAINE/WHPP/WA

C:\DPT\SDSKPROJ\9431673\107\63980 9-20-96 17:33 xrf: NONE

Golder Associates

APPENDIX A

SELECTED WELL LOGS

CITY OF BLAINE
WELL LOGS

Loc. A - Well #1

Well #1

DRILLED - 1926

LOG OF WELL FOR CITY OF BLAINE.

From 1 ft. to 5 ft.,	Gravel	5.ft
5 ft. to 97 ft.,	Blue clay	92 ft.
97 ft. to 98 ft.,	cement gravel	1 ft.
98 ft. to 100 ft.,	blue clay	2 ft.
100 ft. to 104 ft.,	cement gravel	4 ft.
104 ft. to 117 ft.,	hard pan with a little gravel in it	13 ft.
117 ft. to 139 ft.,	soft cement gravel	22 ft.
139 ft. to 230 ft.,	hard cement gravel	91 ft.
230 ft. to 235 ft.,	blue clay	5 ft.
235 ft. to 255 ft.,	shale	20 ft.
255 ft. to 304 ft.,	blue clay	49 ft.
304 ft. to 319 ft.,	shale	15 ft.
319 ft. to 366 ft.,	clay	47 ft.
366 ft. to 375 ft.,	sandy blue shale	9 ft.
375 ft. to 408 ft.,	cement gravel	33 ft.
408 ft. to 414 ft.,	hard blue shale	6 ft.
414 ft. to 480 ft.,	cement gravel	66 ft.
480 ft. to 553 ft.,	brittle blue shale	73 ft.
553 ft. to 635 ft.,	rocks and clay	82 ft.
635 ft. to 644 ft.,	sand	9 ft.
644 ft. to 683 ft.,	boulders and clay	39 ft.
683 ft. to 691 ft.,	soft sandy clay	8 ft.
691 ft. to 699 ft.,	boulders and blue clay	8 ft.
699 ft. to 709 ft.,	boulders and gravel, with a little clay	10 ft.
709 ft. to 740 ft.,	sand and gravel, with a little silt or clay	31 ft.
740 ft. to 746 ft.,	cement gravel	6 ft.
	Bottom of well	746 ft.

12" casing down 185 ft.
8" casing 695 ft. down, and perforated from 550 ft to 695 ft., and from 420 ft. to 480 ft.
3" casing cut off at 180'8"
56 ft. of perforated 6" casing in the hole, the bottom of it is 734 ft. down.
All measurements taken from the platform 3 ft. above the ground level.

Copied for [illegible] 3/26/74
[illegible]

Replacement Well #1

PROJECT: Blaine/Well 1 Replacement/WA

PROJECT NUMBER: 953 1144.106

WATER WELL LOG Well 1

WELL LOCATION: Blaine Watershed

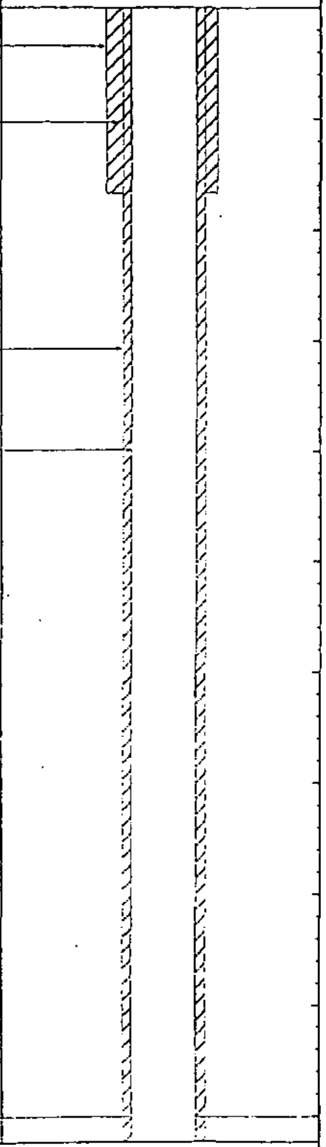
SHEET 1 **OF** 8

DATUM: MSL

BORING DATE:

DEPTH FEET	BORING METHOD	SOIL PROFILE				SAMPLES		WELL CONSTRUCTION
		DESCRIPTION	USCS	GRAPHIC LOG	ELEV DEPTH	NUMBER	TYPE	DESCRIPTION
0		No samples collected 0-40'			0.0			
								16" Casing
10								Neat Cement Grout
20								
30								12" Casing
40		40'-80' Olive gray (5Y 3/2) CLAY, little silt, sticky (GLACIAL TILL/DRIFT)			40.0	1		10" Casing
50	Cable Tool					2	Grab	
60						3		
70								
80		80'-115' Grayish black (N2) to grayish olive green (5GY 3/2) to light gray (N8) GRAVEL, with little to some sand or cobbles, trace clay or silt, gravel and cobbles, subangular to subrounded, lithologically heterogeneous			80.0	4		
						5		
						6		
90						7		
						8		
						9		
100						10		

WELL CONSTRUCTION DIAGRAM



DRILL RIG: Cable Tool

DRILLING CONTRACTOR: Charon Drilling

DRILLER: T Michaelson

LOGGED: M Kirsch/M Birch

CHECKED:

DATE:

Golder Associates

PROJECT: Blaine/Well 1
Replacement/WA

PROJECT NUMBER: 953 1144.106

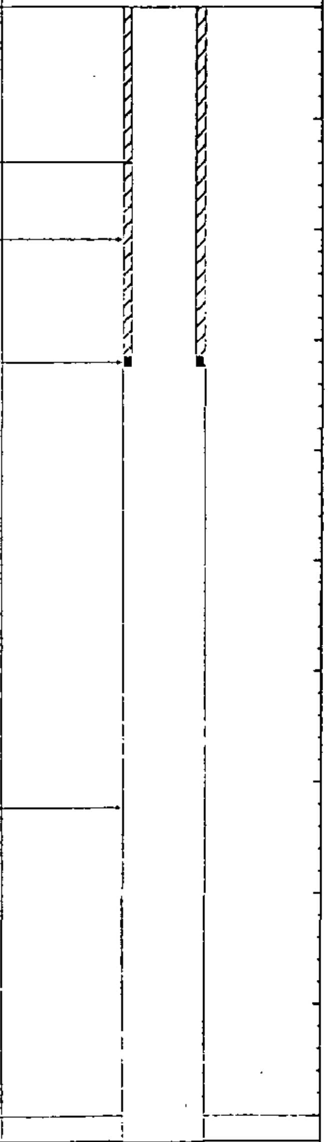
WATER WELL LOG Well 1

WELL LOCATION: Blaine Watershed

SHEET 2 **OF** 8

DATUM: MSL

BORING DATE:



DEPTH FEET	BORING METHOD	SOIL PROFILE DESCRIPTION	USCS	ELEV. DEPTH	SAMPLES NUMBER	SAMPLES TYPE	WELL CONSTRUCTION DESCRIPTION
100 110	Cable Tool				10 11 12 13 14 15 16	Grab	10" Casing
120		115'-122.5' Dense, olive gray (5Y 3/2), medium to coarse SAND, angular GRAVEL, little to some silt/clay (GLACIAL TILL/DRIFT)		115.0	17		12" Casing
		122.5'-130.0' Olive gray (5Y 3/2) to light olive gray (5Y 5/2), fine to coarse SAND, little gravel, broken, angular fragments (OUTWASH)		122.5	18 19 20		
130 140 150 160 170 180		130.0'-183.0' Olive gray (5Y 3/2) to medium dark gray (N4) CLAY with some SAND, little gravel, sticky (TILL) gravel decreases downhole thin sand lense, water level rises in casing sand lense		130.0	21 22 23 24 25 26 27 28 29 30		Packer 12" Casing
190		183.0'-195.0' Light olive gray, coarse to medium grained SAND and GRAVEL, little silt		183.0	31 32 33		
200		195.0'-217.0' Light olive gray, coarse to medium SAND and SILT, little to some gravel		195.0	34		

DRILL RIG: Cable Tool

DRILLING CONTRACTOR: Charon Drilling

DRILLER: T. Michaelson

LOGGED: M. Kisch/M. Bech

CHECKED:

DATE:

Golder Associates

PROJECT: Blaine/Well 1
Replacement/WA

PROJECT NUMBER: 953 1144.106

WATER WELL LOG Well 1

WELL LOCATION: Blaine Watershed

SHEET 3 **OF** 8

DATUM: MSL

BORING DATE:

		SOIL PROFILE				SAMPLES		WELL CONSTRUCTION	
DEPTH FEET	BORING METHOD	DESCRIPTION	USCS	GRAPHIC LOG	ELEV. DEPTH	NUMBER	TYPE	DESCRIPTION	DIAGRAM
200	Cable Tool	196.0'-217.0' Light olive gray, coarse to medium SAND and SILT, little to some gravel				34	Grab		
						35			
210						40			
						41			
		217.0'-522.0' Olive gray, fine to medium grained, SILTY SAND, trace to little clay, little to trace gravel			217.0				
220						42			
230						43			
						44			
								12" Casing	
240						45			
						46			
250						47			
						49			
260						49			
						50			
270						51			
						52			
280						53			
						54			
290						55			
						56			
300						57			

DRILL RIG: Cable Tool

DRILLING CONTRACTOR: Charon Drilling

DRILLER: T Michaelson

LOGGED: M Kksch/M Birch

CHECKED:

DATE:

Golder Associates

PROJECT: Blaine/Well 1
Replacement/WA

PROJECT NUMBER: 953 1144.106

WATER WELL LOG Well 1

WELL LOCATION: Blaine Watershed

SHEET 4 **OF** 8

DATUM: MSL

BORING DATE:

DEPTH FEET	BORING METHOD	SOIL PROFILE DESCRIPTION	USCS	GRAPHIC LOG	ELEV. DEPTH	SAMPLES NUMBER	SAMPLES TYPE	WELL CONSTRUCTION DESCRIPTION	WELL CONSTRUCTION DIAGRAM
300		CLAY and SILT				57			
						58			
310						59			
						60			
320						61			
						62			
330						63			
						64			
340						65		12" Casing	
						66			
350	Cable Tool					67	Grab		
						68			
360						69			
						70			
370						71			
						72			
380						73			
						74			
390						75			
						76			
400						77			

DRILL RIG: Cable Tool

DRILLING CONTRACTOR: Charon Drilling

DRILLER: T Michaelson

LOGGED: M Kisch/M Birch

CHECKED:

DATE:

Golder Associates

PROJECT: Blaine/Well 1
Replacement/WA

PROJECT NUMBER: 953 1144.106

WATER WELL LOG Well 1

WELL LOCATION: Blaine Watershed

SHEET 5 **OF** 6

DATUM: MSL

BORING DATE:

DEPTH FEET	BORING METHOD	SOIL PROFILE DESCRIPTION	USCS	GRAPHIC LOG	ELEV. DEPTH	SAMPLES NUMBER	SAMPLES TYPE	WELL CONSTRUCTION DESCRIPTION	WELL CONSTRUCTION DIAGRAM
400		CLAY and SILT				78			
						79			
410						80			
						81			
420						82			
						83			
430						84			
						85			
440						86		12' Casing	
						87			
450	Cable Tool					88	Grab		
						89			
460						90			
						91			
470						92			
						93			
480						94			
						95			
490						96			
						97			
500						98			

DRILL RIG: Cable Tool

DRILLING CONTRACTOR: Charon Drilling

DRILLER: T Michaelson

LOGGED: M Kisch M Birch

CHECKED:

DATE:

Golder Associates

PROJECT: Blaine/Well 1
Replacement/WA

PROJECT NUMBER: 953 1144.106

WATER WELL LOG Well 1

WELL LOCATION: Blaine Watershed

SHEET 6 OF 8

DATUM: MSL

BORING DATE:

DEPTH FEET	BORING METHOD	SOIL PROFILE DESCRIPTION	USCS	ELEV. DEPTH	SAMPLES NUMBER	TYPE	WELL CONSTRUCTION DESCRIPTION	DIAGRAM
500 510 520	Cable Tool	Olive gray SILT and CLAY, trace fine to coarse sand, trace gravel		500.0	99 100 101 102 103	Grab		
		522.0'-528.0' Olive gray SILT and CLAY, little to some fine to medium sand		522.0	104			
530 540 550 560 570		528.0'-576.0' Olive gray SILT and CLAY, trace fine to medium sand, trace gravel		528.0	105 106 107 108 109 110 111 112 113 114		12" Casing	
580		576.0'-584.0' Olive gray, fine to coarse SAND, little to some silt		576.0	115			
590 600		584.0'-631.0' Olive gray SILT, with little to some fine to coarse sand, little fine gravel		584.0	116 117 118 119			

DRILL RIG: Cable Tool

DRILLING CONTRACTOR: Charon Drilling

DRILLER: T Michaelson

LOGGED: M Kisch/M Birch

CHECKED:

DATE:

Golder Associates

PROJECT: Blaine/Well 1
Replacement/WA

PROJECT NUMBER: 953 1144.106

WATER WELL LOG Well 1

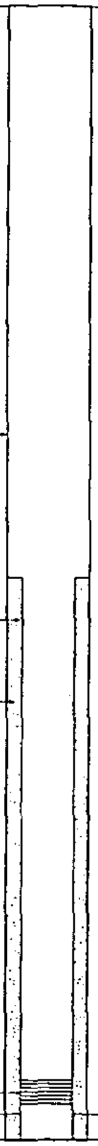
WELL LOCATION: Blaine Watershed

SHEET 7 **OF** 8

DATUM: MSL

BORING DATE:

DEPTH FEET	BORING METHOD	SOIL PROFILE				SAMPLES		WELL CONSTRUCTION	
		DESCRIPTION	USCS	GRAPHIC LOG	ELEV. DEPTH	NUMBER	TYPE	DESCRIPTION	DIAGRAM
600	Cable Tool					119	Grab		
						120			
610						121			
						122			
620						123			
						124			
630						125 126			
		631.0'-634.0' Dark gray to olive green, fine to medium SAND (water bearing)			631.0				
		634.0'-644.0' Olive gray SILT and CLAY, little gravel Olive gray SILT alternating with dark gray SILT			634.0	127 128			
640						129		12" Casing	
		644.0'-706.0' Olive gray silty, fine to medium SAND (little to no water)			644.0	130			
650						131			
						132		8" Riser	
660						133		Filter Pack of CSSI 6/9 sand and washed Lonestar fine gravel (4/8)	
670						134			
680									
690									
								697.0' Pressure Relief Screen	
700									



DRILL RIG: Cable Tool
DRILLING CONTRACTOR: Charon Drilling
DRILLER: T. Michaelson

LOGGED: M. Kisch/M. Birch
CHECKED:
DATE:

Golder Associates

PROJECT: Blaine/Well 1
Replacement/WA

PROJECT NUMBER: 953 1144.106

WATER WELL LOG Well 1

WELL LOCATION: Blaine Watershed

SHEET 8 OF 8

DATUM: MSL

BORING DATE:

DEPTH FEET	BORING METHOD	SOIL PROFILE DESCRIPTION	USCS	GRAPHIC LOG	ELEV. DEPTH	SAMPLES NUMBER	SAMPLES TYPE	WELL CONSTRUCTION DESCRIPTION	DIAGRAM
700	Cable Tool						Grab	Filter Pack of CSSI 6/9 sand and washed Lonestar fine gravel (4/8) 8" Riser 12" Perforated Casing 8" Stainless Steel 70 slot screen 726.0' Bottom of screen 727.0' Casing cut Casing Shoe at 731'	
710 720		706.0'-728.0' Dark gray (5Y 4/1), coarse to fine SAND and coarse to fine GRAVEL, trace silt (Water Bearing)			706.0				
730		728.0'-733.0' No Samples			728.0				
740 750 760 770 780 790 800		733.0' End of Hole			733.0				

DRILL RIG: Cable Tool

DRILLING CONTRACTOR: Charon Drilling

DRILLER: T. Michaelson

LOGGED: M. Kirsch/M. Birch

CHECKED:

DATE:

Golder Associates

well #2

1

835

STATE OF WASHINGTOn

DEPARTMENT OF CONSERVATION
AND DEVELOPMENT Appli. #6562

Location E

WELL LOG

No. Permit #6158

Date May 21, 19 65

Record by Driller

Source Driller's Record

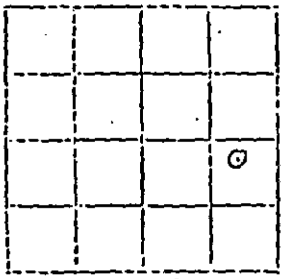


Diagram of Section

Location: State of WASHINGTON

County Whatcom

Area 700' W. & 400'S of E¼ cor.

Map

NE ¼ SE ¼ sec. 4 T. 40 N., R. 1 E. E./W.

40/1E-4I
File number

Drilling Co. G. A. Benzona

Address Rt. 3, Box 107, Ferndale, Washington

Method of Drilling Cable Date April 11, 19 63

Owner City of Blaine

Address City Hall, Blaine, Washington

Land surface, datum ft. above/below

21

well #2?

CORRELATION	MATERIAL	THICKNESS (feet)	DEPTH (feet)
	(Transcribe driller's terminology literally but paraphrase as necessary, in parentheses. If material water-bearing, so state and record static level if reported. Give depths in feet below land-surface datum unless otherwise indicated. Correlate with stratigraphic column, if feasible. Following log of materials, list all casings, perforations, screens, etc.)		
	Municipal well - 10-8-6" x 642'		
	Blue clay	0	72
	Coarse gravel sand, water	72	82
	Gravel and clay	82	151
	Coarse gravel and sand	151	159
	Coarse gravel, hard packed	159	178
	Gravel and sand, loose	178	182
	Hard packed gr., P stoped at		189
	Reduced to 8" drill	189	456
	8" stopped, reduced to 6"	456	
	Stickey clay	456	538
	Sandy clay	538	634
	Fine sand and water, clean	634	644
	Fine quicksand & clay, mix	644	690
	Fine silty quicksand	690	700
	Pulled 6" back to 642, set 6" screen.		TD 642'

Turn over Sheet of sheets

836

well #3

STATE OF WASHINGTON
DEPARTMENT OF CONSERVATION
AND DEVELOPMENT

WELL LOG

No. Appli. 5086
Cert. 3912-A

Date 6-21, 1961

Record by well driller

Source driller's record

Location: State of WASHINGTON

County Whatcom

Area

Map

NW¼ SW¼ sec. 3 T. 40 N., R. 1 E.

Diagram of Section

40/1E 3M

File number

#3

Drilling Co. G. A. Bezona & Son

Address Ferndale, Wash.

Method of Drilling Date , 19

Owner City of Blaine, Wash.

Address

Land surface, datum ft. above below

Well #3

(Transcribe driller's terminology literally but paraphrase as necessary, in parentheses. If material water-bearing, so state and record static level if reported. Give depths in feet below land-surface datum unless otherwise indicated. Correlate with stratigraphic column, if feasible. Following log of materials, list all casings, perforations, screens, etc.)

Corre-lation	Material	Thickness (feet)	Depth (feet)
	Sand & gravel (water @ 20')	28	28
	Coarse gravel, water	1	29
	Fine sand, water	9	38
	Loose, coarse gravel, water	18	56
	Hard packed gravel & boulders	3	59
	Coarse, loose gravel, water	12	71
	Hand packed sand	4	75
	(Pulled back to 71 ft.)		
	Dim. 75'x8"		
	DD: 50 ft.		
	Yield: 404 g.p.m.		
	10' perforated casing		
	¼" slot 8" in length from 65 to 75 ft.		

Turn up

Sheet of sheets

WATER WELL REPORT
STATE OF WASHINGTON

#4

File Original and First Copy with the Division of Water Resources
Second Copy — Owner's Copy
Third Copy — Driller's Copy

Application No. 1625
Permit No.

OWNER:
City of Blaine
P. O. Box H
Blaine, Washington

(2) LOCATION OF WELL:
County Whatcom Owner's number, if any— G
¼ ¼ Section T. R. W.M.
Bearing and distance from section or subdivision corner

(3) TYPE OF WORK (check):
New Well ☒ Deepening ☐ Reconditioning ☐ Abandon ☐
If abandonment, describe material and procedure in Item 11.

(4) PROPOSED USE (check):
Domestic ☐ Industrial ☐ Municipal ☒
Irrigation ☐ Test Well ☐ Other ☐

(5) TYPE OF WELL:
Rotary ☐ Driven ☒
Cable ☐ Jetted ☐
Dug ☐ Bored ☐

(6) CASING INSTALLED: Threaded ☐ Welded ☒
8" Diam. from 0 ft. to 84 ft. Gage Sch.40
" Diam. from ft. to ft. Gage
" Diam. from ft. to ft. Gage

PERFORATIONS: Perforated? ☐ Yes ☒ No
perforator used none
SIZE of perforations in. by in.
perforations from ft. to ft.
perforations from ft. to ft.
perforations from ft. to ft.
perforations from ft. to ft.
perforations from ft. to ft.

(8) SCREENS: Well screen installed ☒ Yes ☐ No
Manufacturer's Name Johnson
Type Model No.
Diam. 6" Slot size #100 Set from 62' ft. to 97' ft.
Diam. 6" Slot size #70 Set from 82' ft. to 97' ft.

(9) CONSTRUCTION:
Was well gravel packed? ☐ Yes ☒ No Size of gravel:
Gravel placed from ft. to ft.
Was a surface seal provided? ☐ Yes ☒ No To what depth? ft.
Material used in seal—
Did any strata contain unusable water? ☐ Yes ☒ No
Type of water? Depth of strata
Method of sealing strata off

(10) WATER LEVELS:
Static level ft. below land surface Date 6/29/65
Artesian pressure lbs. per square inch Date
controlled by
(Cap, valve, etc.)

(11) WELL TESTS: Drawdown is amount water level is lowered below static level
Was a pump test made? ☒ Yes ☐ No If yes, by whom? Pump and Motor Ser
Yield: 600 gal./min. with 5 ft. drawdown after hrs.

Recovery data (time taken as zero when pump turned off) (water level measured from well top to water level)

Time	Water Level	Time	Water Level

Date of test
Bailer test gal./min. with ft. drawdown after hrs.
Artesian flow no g.p.m. Date
Temperature of water 50° Was a chemical analysis made? ☐ Yes ☐ No

(12) WELL LOG: Diameter of well 8 inches
Depth drilled 98 ft. Depth of completed well 97 ft.

Formation: *Describe by color, character, size of material and structure, and show thickness of aquifers and the kind and nature of the material in each stratum penetrated, with at least one entry for each change of formation.*

MATERIAL	FROM	TO
Gravely top soil	0'	11'
Gravely clay	11'	19'
Sandy clay	19'	25'
Sandy H. P.	25'	33'
Gravely clay	33'	41'
Cleaner gravel	41'	48'
Gravely clay	48'	59'
Dirty sand	59'	75'
Cleaner sand (water)	75'	98'
Gravely clay	98'	
15' screen #100 #70 #75		
S. T. 24' 6" T.O.C.		
98' Deep		
84' C.H.		
Well produces 500 G. P. M.		

Work started 19 Completed 19

(13) PUMP:
Manufacturer's Name Peerless Pump Co.
Type: Line shaft turbine H.P. 20

Well Driller's Statement:
This well was drilled under my jurisdiction and this report is true to the best of my knowledge and belief.

NAME Pump and Motor Service
(Person, firm, or corporation) (Type or print)
Address Rt. 2 BOX 192 Oak Harbor, Wash.

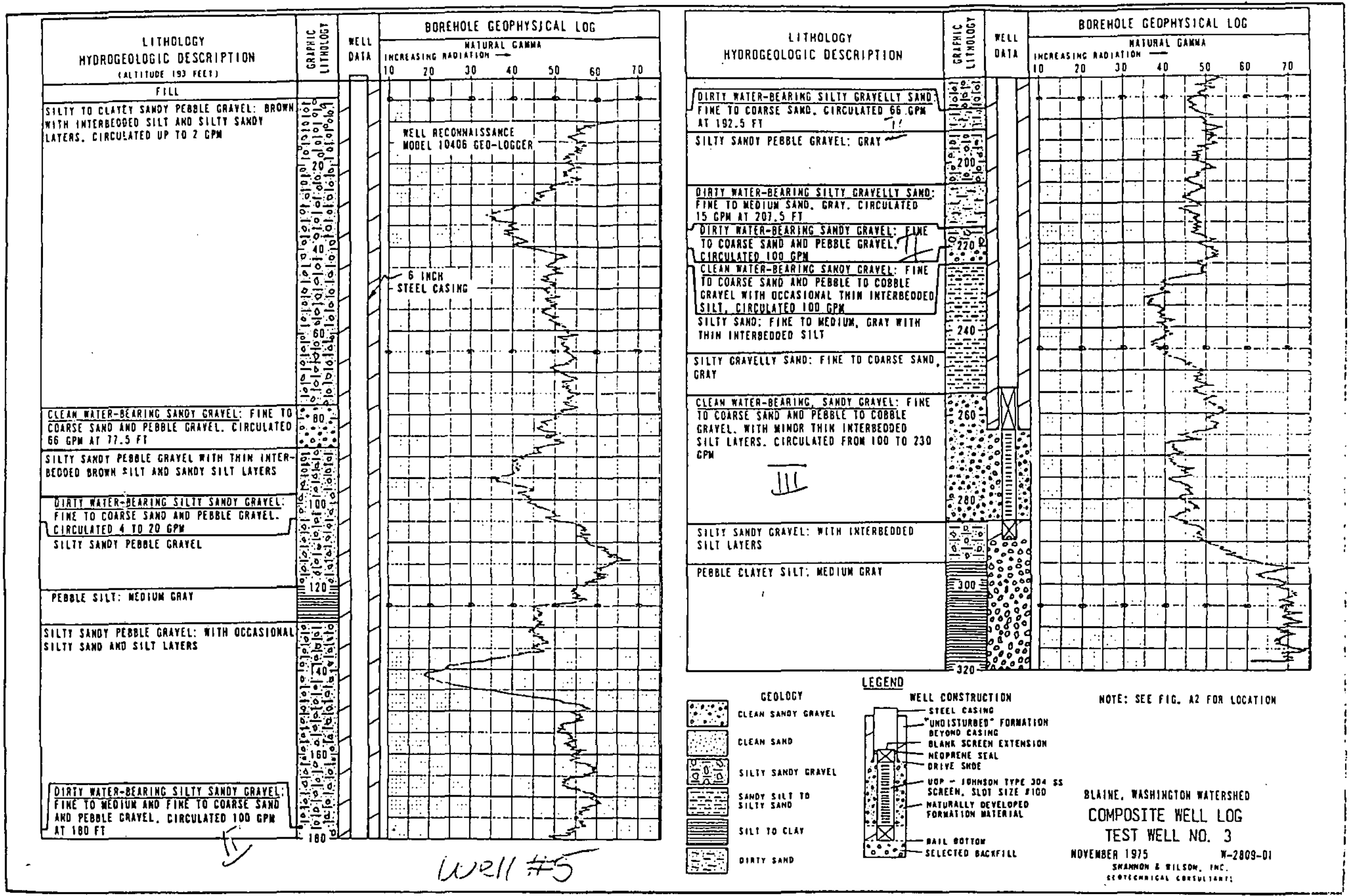
[Signed]
(Well Driller)

License No. Date OCT 6 1965

(USE ADDITIONAL SHEETS IF NECESSARY)

F. No. 7356—(Rev. 9-62)—8-62—5M. 75168.

#4



FILL

SILTY TO CLAYEY SANDY PEBBLE GRAVEL: BROWN WITH INTERBEDDED SILT AND SILTY SANDY LAYERS. CIRCULATED UP TO 2 GPM

CLEAN WATER-BEARING SANDY GRAVEL: FINE TO COARSE SAND AND PEBBLE GRAVEL. CIRCULATED 66 GPM AT 77.5 FT

SILTY SANDY PEBBLE GRAVEL WITH THIN INTERBEDDED BROWN SILT AND SANDY SILT LAYERS

DIRTY WATER-BEARING SILTY SANDY GRAVEL: FINE TO COARSE SAND AND PEBBLE GRAVEL. CIRCULATED 4 TO 20 GPM

SILTY SANDY PEBBLE GRAVEL

PEBBLE SILT: MEDIUM GRAY

SILTY SANDY PEBBLE GRAVEL: WITH OCCASIONAL SILTY SAND AND SILT LAYERS

DIRTY WATER-BEARING SILTY SANDY GRAVEL: FINE TO MEDIUM AND FINE TO COARSE SAND AND PEBBLE GRAVEL. CIRCULATED 100 GPM AT 180 FT

I

Well #5

DIRTY WATER-BEARING SILTY GRAVELLY SAND: FINE TO COARSE SAND. CIRCULATED 66 GPM AT 192.5 FT

I

SILTY SANDY PEBBLE GRAVEL: GRAY

DIRTY WATER-BEARING SILTY GRAVELLY SAND: FINE TO MEDIUM SAND. GRAY. CIRCULATED 15 GPM AT 207.5 FT

DIRTY WATER-BEARING SANDY GRAVEL: FINE TO COARSE SAND AND PEBBLE GRAVEL. CIRCULATED 100 GPM

II

CLEAN WATER-BEARING SANDY GRAVEL: FINE TO COARSE SAND AND PEBBLE TO COBBLE GRAVEL WITH OCCASIONAL THIN INTERBEDDED SILT. CIRCULATED 100 GPM

SILTY SAND: FINE TO MEDIUM, GRAY WITH THIN INTERBEDDED SILT

SILTY GRAVELLY SAND: FINE TO COARSE SAND, GRAY

CLEAN WATER-BEARING, SANDY GRAVEL: FINE TO COARSE SAND AND PEBBLE TO COBBLE GRAVEL. WITH MINOR THIN INTERBEDDED SILT LAYERS. CIRCULATED FROM 100 TO 230 GPM

III

SILTY SANDY GRAVEL: WITH INTERBEDDED SILT LAYERS

PEBBLE CLAYEY SILT: MEDIUM GRAY

NOTE: SEE FIG. A2 FOR LOCATION

BLAINE, WASHINGTON WATERSHED

COMPOSITE WELL LOG
TEST WELL NO. 3

NOVEMBER 1975 W-2809-01

SHANNON & WILSON, INC.
GEOTECHNICAL CONSULTANTS

FIG. A5

#5

well # 6

LOG & AS-BUILT DIAGRAM

FIGURE 2

GEOLOGIC LOG

DRILLER: ARMSTRONG-CHARON DRILLING
COMPLETION DATE: NOVEMBER 7, 1985
ALTITUDE: APPROX. 150 FEET

GROUND SURFACE

Very fine to fine gravelly, sandy, clayey SILT; brown. Fill in upper 1 foot.

Fine to medium sandy SILT; gray, with fine gravelly layers.

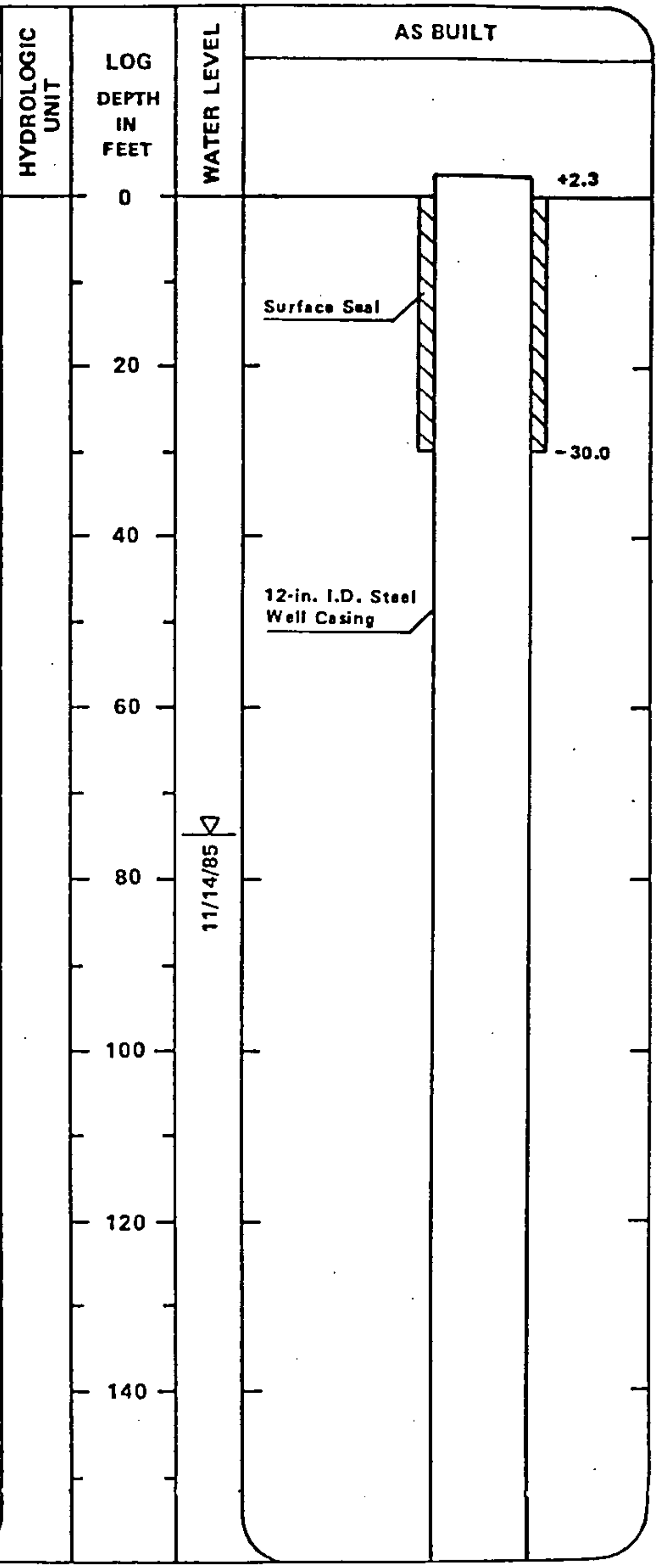
Silty, clayey, fine to coarse gravelly, medium to very coarse SAND; gray.

Silty, clayey, fine to coarse sandy, very fine to medium GRAVEL; gray, with scattered coarse gravel.

Silty, fine to coarse sandy, very fine to medium GRAVEL; gray, with scattered coarse gravel

Very fine to medium gravelly, fine to very coarse SAND; gray, locally slightly silty.

Water bearing, medium to coarse sandy, very fine to coarse GRAVEL; gray, with thin silty clay layers



SHANNON & WILSON, INC.
GROUNDWATER SECTION
SEATTLE, WASHINGTON
(206) 632-8020

BLAINE WATERSHED
BLAINE, WASHINGTON

WELL NO. 19

W-4473-01
APRIL 1986

FIG. 2
Sheet 1 of 2

Well #6

LOG & AS-BUILT DIAGRAM

FIGURE 2

GEOLOGIC LOG

Silty, very clayey, fine to medium SAND; gray, with scattered gravel.

Water bearing, medium SAND; gray, with scattered fine to coarse gravel.

Medium to coarse, gravelly, fine sandy CLAY; gray.

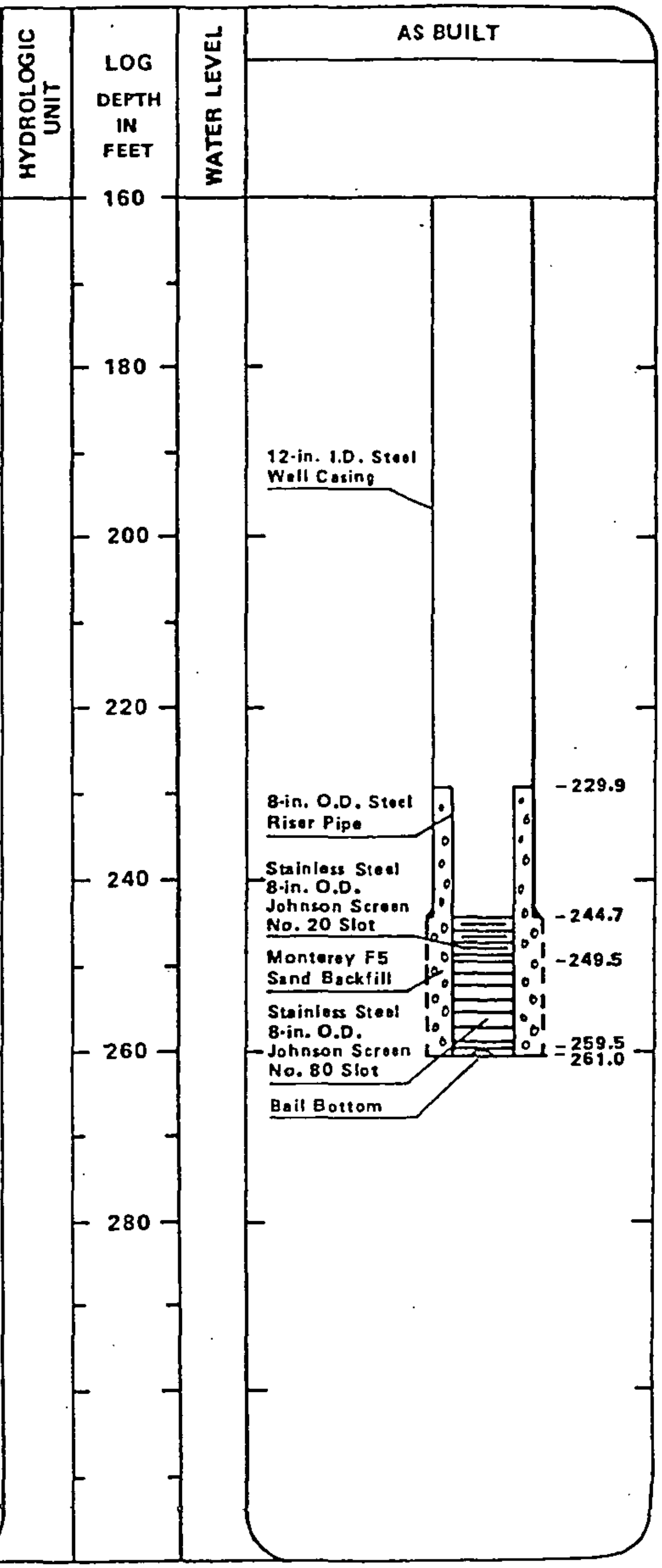
Clayey, silty fine SAND; gray, becoming cleaner with increasing depth.

Medium to coarse gravelly, medium to coarse SAND; gray, with scattered cobbles, and layers of silty clay and gravel.

Water bearing, slightly gravelly to gravelly, fine to coarse SAND; gray.

Water bearing, cobbly, fine to coarse gravelly, fine to coarse SAND; gray, with thin silty clay layers.

TOTAL DEPTH: 261 FEET



SHANNON & WILSON, INC.

GROUNDWATER SECTION
SEATTLE, WASHINGTON
(206) 632-8020

BLAINE WATERSHED
BLAINE, WASHINGTON

WELL NO. 19

W-4473-01
APRIL 1986

FIG. 2
Sheet 2 of 2

505-S31-T41-R2 41/2-31F1

On H St. rd. abt .5 mi. E. of Delta Line rd. SE¼,SW¼, elev abt 200
ke 1939 Eberly

	Th	Dp
Soil	3	3
Hardpan	20	23
Blue clay	137	160
Fine sand	7	167
Blue clay	64	231
Fine sand	3	234

- - - - - - - - - - - - - - - - - - -

606-S33-T41-R2 41/2-33N1

On H st. rd. abt 1 mi. W. of int. w/ Markworth rd. SW¼,SW¼ elev abt 240
Radke 1946 Burk

	Th	Dp
Soil	3	3
Hardpan	18	21
Blue sticky clay	233	254
Fine sand	4	258
Blue clay	44	302

- - - - - - - - - - - - - - - - - - -

820-S31-T40-R1 41/1-31Q1 Well #7

City of Blaine, abt. 25' W. and 50" S. of int. of G and 12th St extended. SW¼, SE¼, elev. abt. 55
Jannsen 1929 City of Blaine

	Th	Dp
Yellow clay	14	14
Blue clay	145	159 159
Gravel and clay	9	168
Gravel, cmented	2	170
Sand and gravel	30	200
Sand	11	211
Clay	1	212
Sand	16	228
Sand w/ shale streaks	12	240
Sand, clay, and shale	7	247 75.28

12th St. Well

– 9

41/1 31Q

Well diameter = 12 in (from the City)

Well #8

App. #10178
Per. #9714
Cer. #6916

STATE OF WASHINGTON
DEPARTMENT OF CONSERVATION
DIVISION OF WATER RESOURCES

①

848

48

Lincoln Park
1 of 2

WELL LOG

Record by Driller
Source Driller's record

Location: State of WASHINGTON
County Whatcom
400' S & 125' W from S1/16
corner between Sec. 31 & 32
SE.¼ SE.¼ sec. 31 T. 41N., R. 1 E. W.

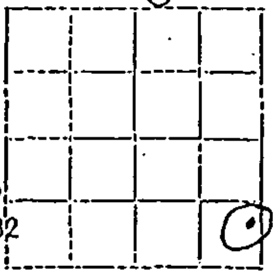


Diagram of Section

File number 41/1E-31R

Drilling Co. Richardson Well Drilling Co, Inc.
Address P.O. Box 2266, Tacoma, WA 98444
Method of Drilling Cable Date Oct. 21, 19 69
Owner City of Blaine
Address City of Blaine, P.O. Box H, Blaine 98230
Land surface, datum 196 ft. above below
SWL: 93'6" Date October 14, 19 69 Dims.: 12" (from the city)

(Transcribe driller's terminology literally but paraphrase as necessary, in parentheses. If material water-bearing, so state and record static level if reported. Give depths in feet below land-surface datum unless otherwise indicated. Correlate with stratigraphic column, if feasible. Following log of materials, list all casings, perforations, screens, etc.)

Correlation	Material	From (feet)	To (feet)	
	Top soil	0	3	
	Clay & gravel	3	13	
	Clay, blue & boulder	13	18	
	Clay, blue & boulder	18	28	
	Clay, blue	28	72	
	Clay, sandy blue & gravel	72	80	
	Clay, sandy & gravel	80	91	
	Sand, dirty & gravel - water	91	108	17
	Clay, coated gravel	108	111	
	Clay, gray	111	136	
	Clay, sandy	136	163	
	Sand, fine & gravel	163	167	4
	Sand, fine, sticky & clay	167	170	
	Sand, fine & clay	170	174	
	Sand, coarse & fine & gravel	174	190	16

Turn up

Sheet ____ of ____ sheets

Well #8

48 (cont

WELL LOG.—Continued No. ..../.........

CORRELATION	MATERIAL	From (feet)	To (feet)
	Depth forward	——	
	Sand, fine hard packed & clay & gravel, coated	190	191
	Sand, coarse & fine & Cravel, clay coated	191	197
	Gravel, clay coated	197	200
	Casing: 12" from 0' to 176' - welded		
	Screens: UOP Johnson, stainless		
	12 slot size 20 from 174' to 185'		
	12 slot size 25 from 185' to 200'		
	Pump test: 200 g.p.m. with 53' after 2 hrs.		
	250 g.p.m. with 70' after 3 hrs.		
	Surface Seal: to 11'-concrete		
	Recovery data: 5 min. 105 - 10 min. 100		
	20 min. 99 - 30 min. 98		
	45 min. 98 - 50 min. 98		
	Date: Oct. 21, 1969		
	Pump: Gould, Vertical turbine, 30 H.P.		

3.7 gpm/ft

Lincoln Park

2 of 2

S. F. No. 7449—OS—12-65.

Well #9

WATER WELL REPORT
STATE OF WASHINGTON

Start Card No. 075957
Water Right Permit No.

(1) OWNER: Name CITY OF BLAINE -GOLDER Address BLAINE BLAINE, WA 98230-

(2) LOCATION OF WELL: County WHATCOM - NE 1/4 NE 1/4 Sec 5 T 40 N., R 1E WM
(2a) STREET ADDRESS OF WELL (or nearest address) BLAINE

(3) PROPOSED USE: TEST WELL

(4) TYPE OF WORK: Owner's Number of well (If more than one) 6
NEW WELL Method: ROTARY

(5) DIMENSIONS: Diameter of well 8 inches
Drilled 300 ft. Depth of completed well 163 ft.

(6) CONSTRUCTION DETAILS:
Casing installed: 8 " Dia. from +3 ft. to 151 ft.
WELDED " Dia. from ft. to ft.
" Dia. from ft. to ft.

Perforations: NO
Type of perforator used
SIZE of perforations in. by in.
perforations from ft. to ft.
perforations from ft. to ft.
perforations from ft. to ft.

Screens: YES
Manufacturer's Name JOHNSON
Type STAINLESS STEEL Model No. KO
Diam. 8 slot size 60 from 150 ft. to 160 ft.
Diam. slot size from ft. to ft.

Gravel packed: NO Size of gravel
Gravel placed from ft. to ft.

Surface seal: YES To what depth? 19 ft.
Material used in seal BENTONITE GROUT
Did any strata contain unusable water? NO
Type of water? Depth of strata ft.
Method of sealing strata off

(7) PUMP: Manufacturer's Name
Type H.P.

(8) WATER LEVELS: Land-surface elevation above mean sea level ... ft.
Static level 85.3 ft. below top of well Date 09/13/90
Artesian Pressure lbs. per square inch Date
Artesian water controlled by

(9) WELL TESTS: Drawdown is amount water level is lowered below static level.
Was a pump test made? NO If yes, by whom?
Yield: gal./min with ft. drawdown after hrs.

Recovery data
Time Water Level Time Water Level Time Water Level

Date of test / /
Bailer test gal/min. ft. drawdown after hrs.
Air test 200+ gal/min. w/ stem set at 145 ft. for 1 hrs.
Artesian flow g.p.m. Date
Temperature of water Was a chemical analysis made? NO

(10) WELL LOG

Formation: Describe by color, character, size of material and structure, and show thickness of aquifers and the kind and nature of the material in each stratum penetrated, with at least one entry for each change in formation.

MATERIAL	FROM	TO
TOPSOIL	0	2
BROWN CLAY & GRAVEL	2	9
BROWN GRAVEL & CLAY	9	10
BROWN CLAY & GRAVEL	10	23
GRAY GRAVEL & CLAY	23	35
BROWN GRAVEL & SAND	35	44
BROWN SAND & GRAVEL	44	52.5
GRAY GRAVEL & CLAY	52.5	60
GRAY GRAVEL CLAY & SAND	60	100
BROWN GRAVEL SAND & WATER	100	135
GRAY GRAVEL SAND & WATER	135	136
BROWN GRAVEL SAND & WATER	136	140
BROWN GRAVEL SAND & WATER	140	162
BROWN GRAVEL SAND & WATER	162	182
GRAY SAND GRAVEL & WATER	182	196
BROWN SAND CLAY & WATER	196	220
GRAY SAND & CLAY	220	235
GRAY CLAY SAND - SEEPAGE	235	247
GRAY CLAY & GRAVEL	247	253
GRAY CLAY	253	255
GRAY SAND	255	295
GRAY SAND GRAVEL & CLAY	295	

Work started 09/11/90 Completed 09/14/90

WELL CONSTRUCTOR CERTIFICATION:
I constructed and/or accept responsibility for construction of this well, and its compliance with all Washington well construction standards. Materials used and the information reported above are true to my best knowledge and belief.

NAME HAYES DRILLING, INC.
(Person, firm, or corporation) (Type or print)

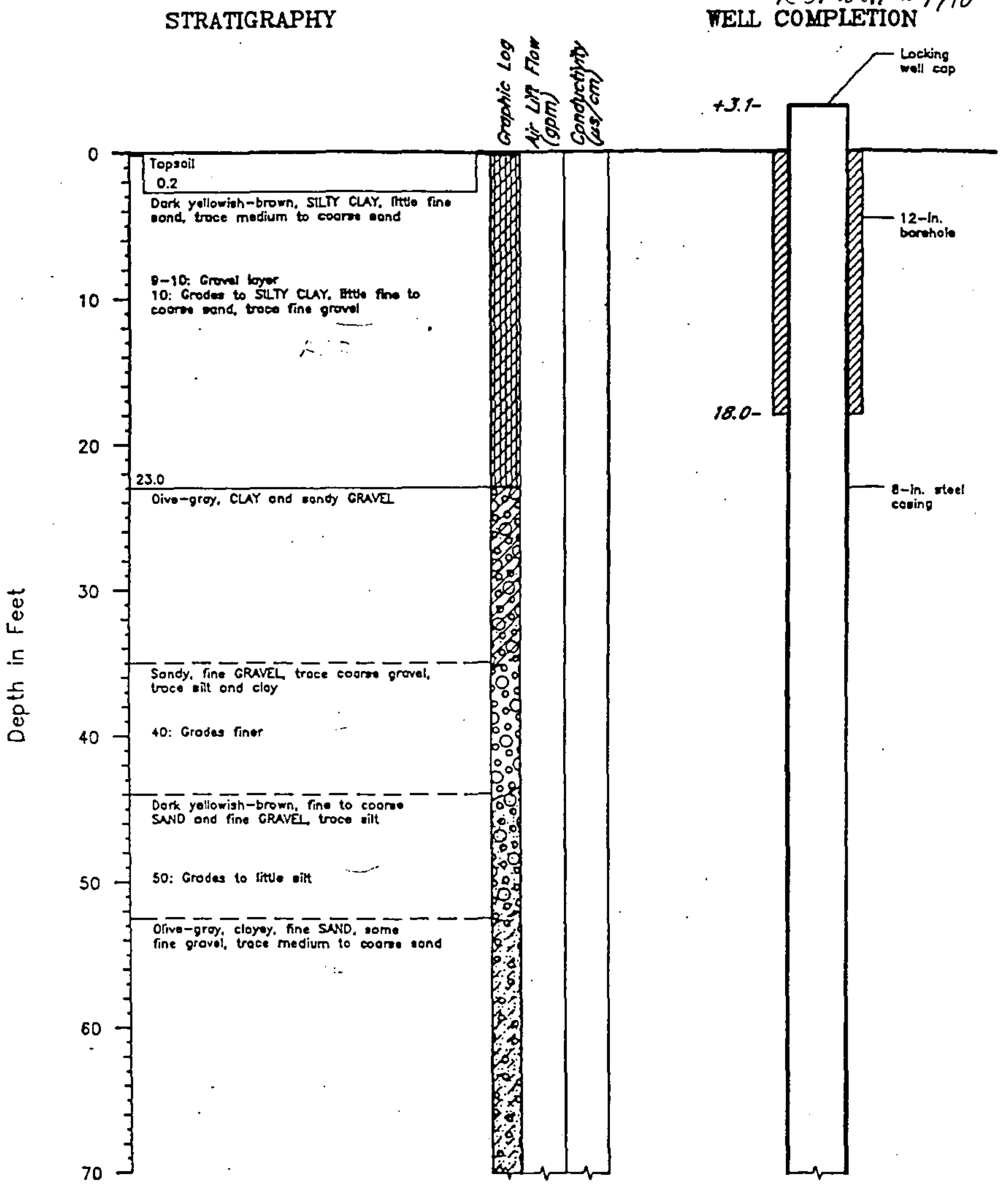
ADDRESS 556 ERSHIG RD. BOW, WA

[SIGNED] Steve License No. 762

Contractor's Registration No. HAYESDI106J5 Date 04/02/91

1351

Test Well #9/10



Topsoil

Dark yellowish-brown, SILTY CLAY, little fine sand, trace medium to coarse sand

9-10: Gravel layer
10: Grades to SILTY CLAY, little fine to coarse sand, trace fine gravel

Olive-gray, CLAY and sandy GRAVEL

Sandy, fine GRAVEL, trace coarse gravel, trace silt and clay

40: Grades finer

Dark yellowish-brown, fine to coarse SAND and fine GRAVEL, trace silt

50: Grades to little silt

Olive-gray, clayey, fine SAND, some fine gravel, trace medium to coarse sand

WELL COMPLETION LEGEND:

▨ Bentonite Grout	▯ 8" Steel Casing
▩ Bentonite Chips	▤ 8-in., telescopic stainless steel wellscreen
░ Pea Gravel	
▽ Water Level	NOT TO SCALE

Date: 9/10/90-9/14/90
Ground Elevation: –
T.O.C. Elevation: –
Drill Rig: Speed Star
Drill Method: Air rotary

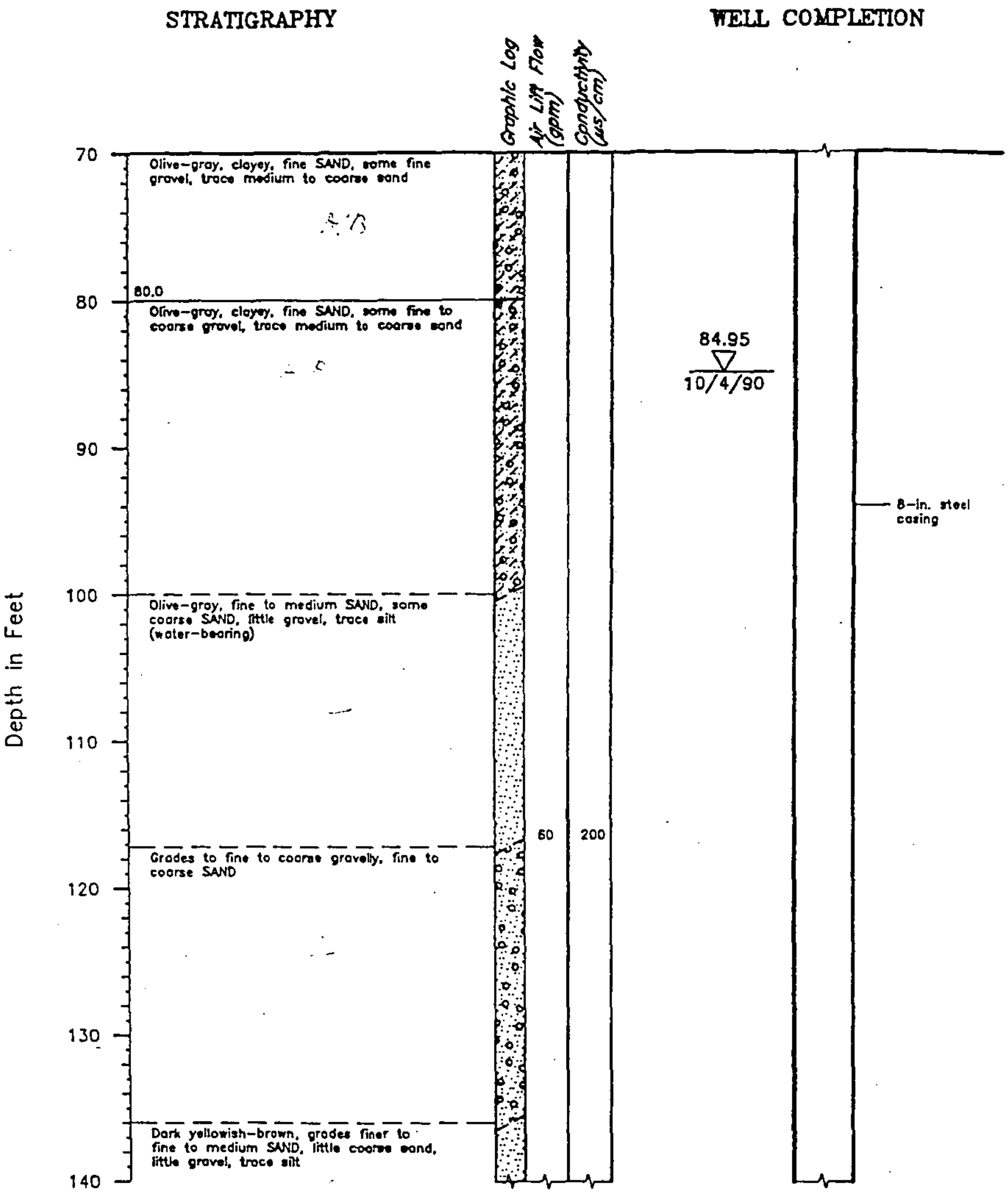
Test well for City well #9/10

FIGURE **A-3**
SHEET 1 OF 5

GWMP-3
RECORD OF BOREHOLE

BLAINE/GWMP/WA

PROJECT NO [illegible]3-1060.203 DWG NO 34338 DATE 11/1/90 DRAWN JSS APPROVED ___



Olive-gray, clayey, fine SAND, some fine gravel, trace medium to coarse sand

Olive-gray, clayey, fine SAND, some fine to coarse gravel, trace medium to coarse sand

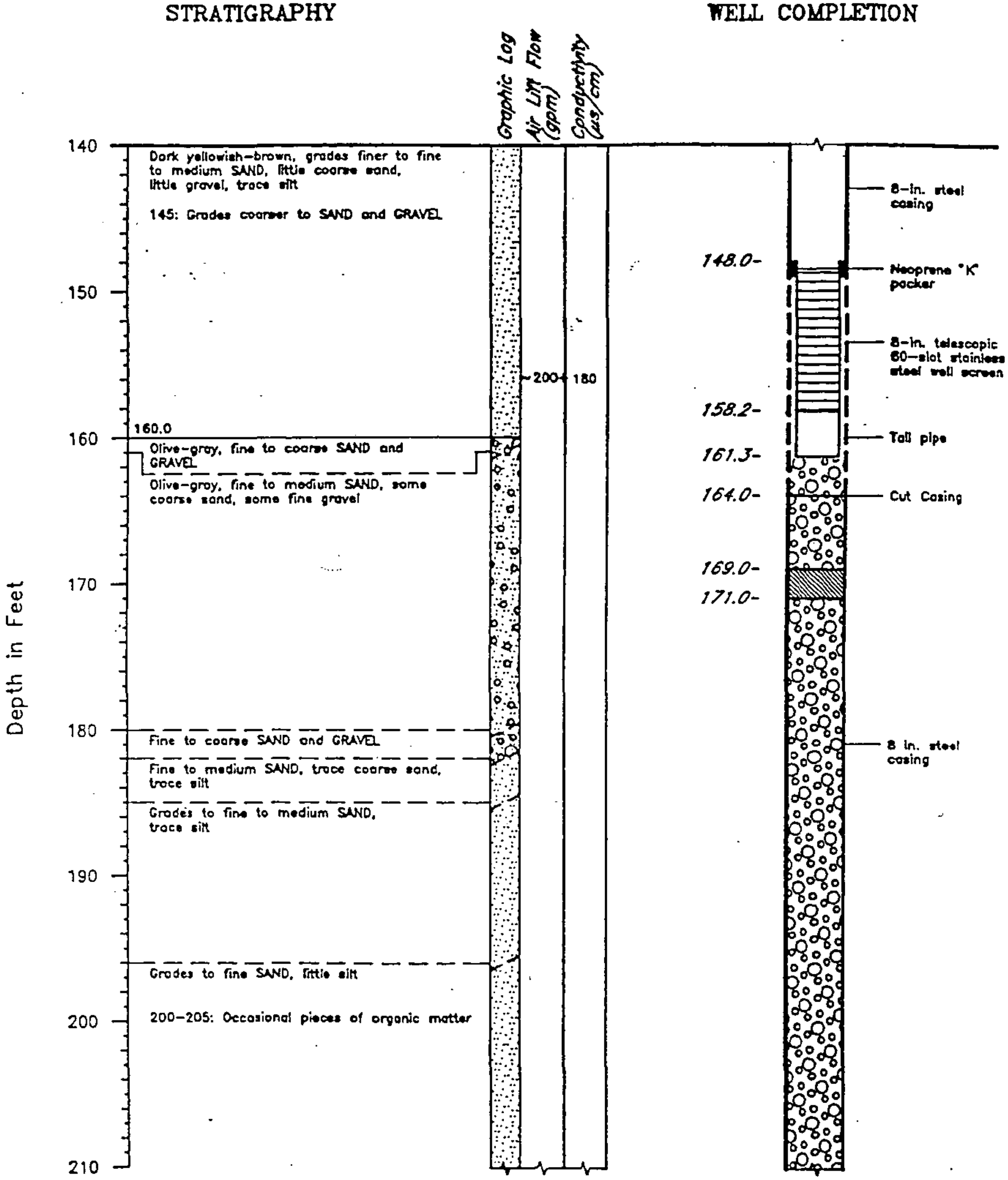
Olive-gray, fine to medium SAND, some coarse SAND, little gravel, trace silt (water-bearing)

Grades to fine to coarse gravelly, fine to coarse SAND

Dark yellowish-brown, grades finer to fine to medium SAND, little coarse sand, little gravel, trace silt

FIGURE **A-3**
SHEET 2 OF 5
GWMP-3
RECORD OF BOREHOLE
BLAINE/GWMP/WA

PROJECT NO 903-1060.303 DWG NO 34339 DATE 11/1/90 DRAWN JSS APPROVED ___



Dark yellowish-brown, grades finer to fine to medium SAND, little coarse sand, little gravel, trace silt

145: Grades coarser to SAND and GRAVEL

Olive-gray, fine to coarse SAND and GRAVEL

Olive-gray, fine to medium SAND, some coarse sand, some fine gravel

Fine to coarse SAND and GRAVEL

Fine to medium SAND, trace coarse sand, trace silt

Grades to fine to medium SAND, trace silt

Grades to fine SAND, little silt

200-205: Occasional pieces of organic matter

FIGURE **A-3**
SHEET 3 OF 5
GWMP-3
RECORD OF BOREHOLE
BLAINE/GWMP/WA

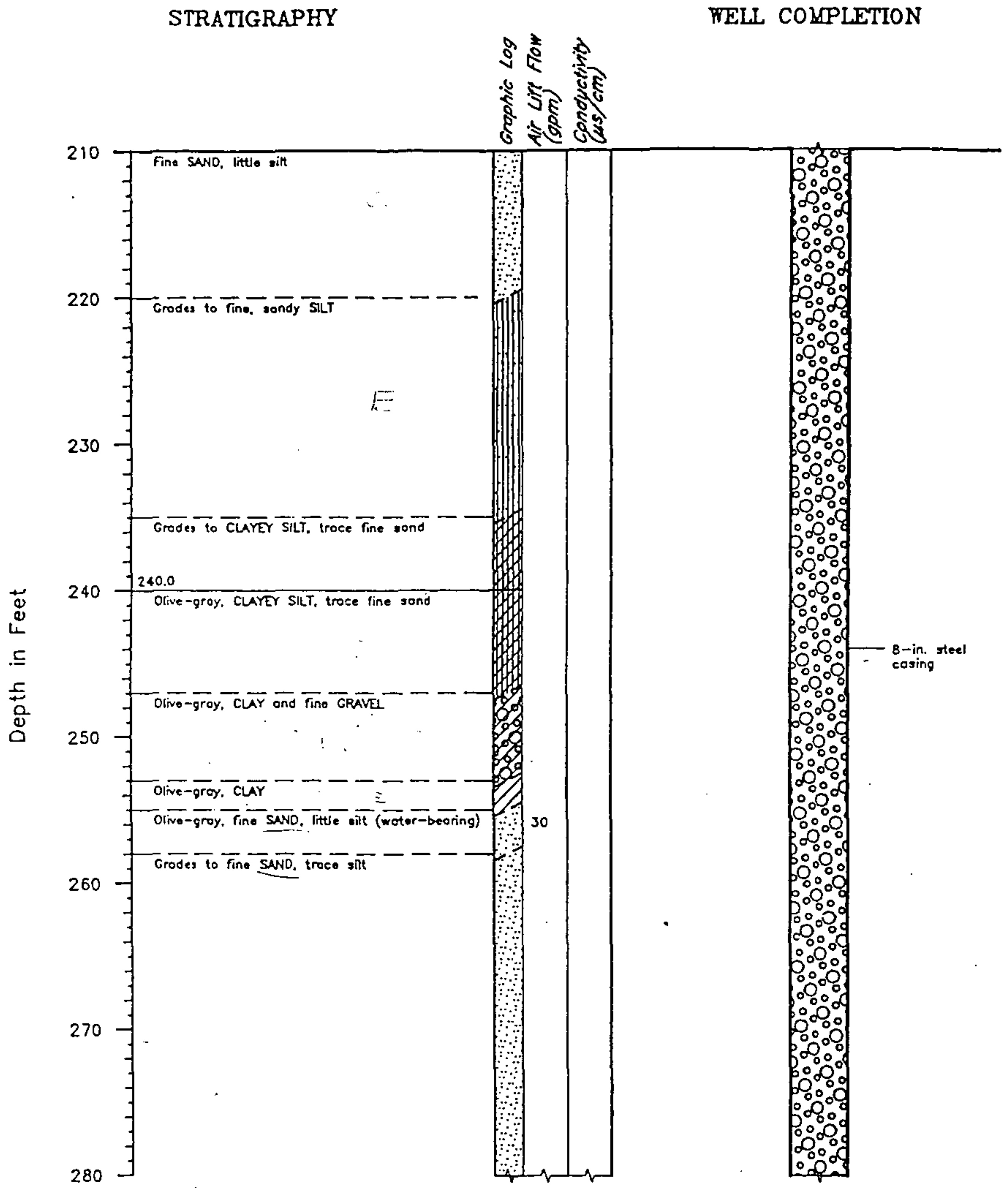


FIGURE **A-3**
SHEET 4 OF 5

GWMP-3

RECORD OF BOREHOLE

BLAINE/GWMP/WA

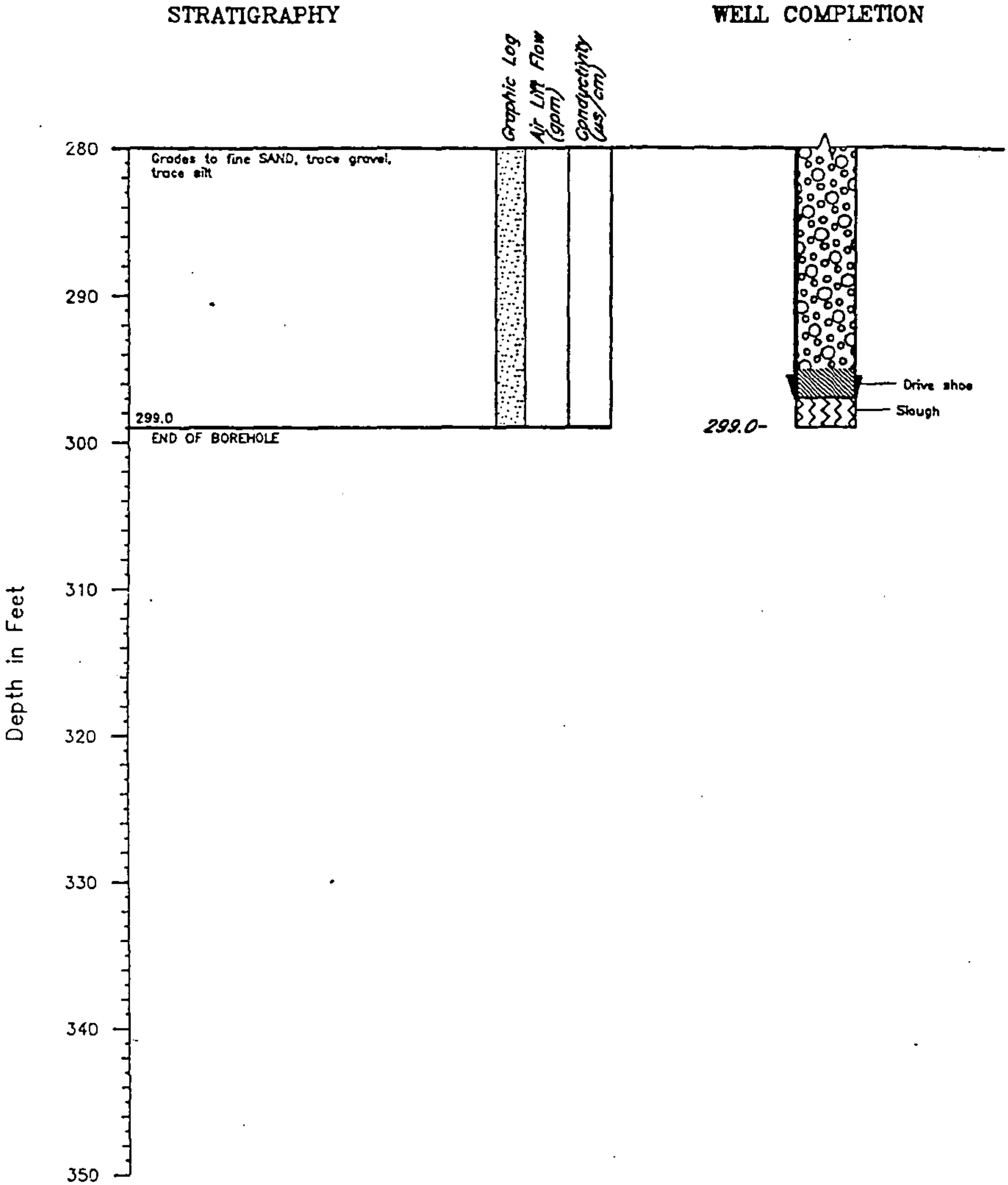


FIGURE **A-3**
SHEET 5 OF 5
GWMP-3
RECORD OF BOREHOLE
BLAINE/GWMP/WA

PROJECT NO 903-1060.303 DWG NO 34342 DATE 11/1/90 DRAWN JSS APPROVED ___

SELECTED WATER LEVEL AND WATER QUALITY MONITORING WELLS

40/01-3R

File Original and First Copy with
Department of Ecology
Second Copy — Owner's Copy
Third Copy — Driller's Copy

WATER WELL REPORT
STATE OF WASHINGTON

Application No. ....
Permit No. ....

(1) OWNER: Name Mr. John Nolte Address V[illegible] View Rd., Blaine

(2) LOCATION OF WELL: County Whatcom SE ¼ [illegible] ¼ Sec. 3 T. 40 N., R. 1E W.M.

Bearing and distance from section or subdivision corner

(3) PROPOSED USE: Domestic ☒ Industrial ☐ Municipal ☐ Irrigation ☐ Test Well ☐ Other ☐

(4) TYPE OF WORK: Owner's number of well (if more than one) ....
New well ☒ Method: Dug ☐ Bored ☐
Deepened ☐ Cable ☒ Driven ☐
Reconditioned ☐ Rotary ☐ Jetted ☐

(5) DIMENSIONS: Diameter of well 6 inches.
Drilled 180 ft. Depth of completed well 168 ft.

(6) CONSTRUCTION DETAILS:

Casing installed: 6 " Diam. from +2 ft. to 163 ft.
Threaded ☐ ...." Diam. from .... ft. to .... ft.
Welded ☒ ...." Diam. from .... ft. to .... ft.

Perforations: Yes ☐ No ☐
Type of perforator used ....
SIZE of perforations .... in. by .... in.
.... perforations from .... ft. to .... ft.
.... perforations from .... ft. to .... ft.
.... perforations from .... ft. to .... ft.

Screens: Yes ☒ No ☐
Manufacturer's Name Johnson
Type Stainless Model No. ....
Diam. 6 Slot size 40 from 163 ft. to 168 ft.
Diam. .... Slot size .... from .... ft. to .... ft.

Gravel packed: Yes ☐ No ☒ Size of gravel: ....
Gravel placed from .... ft. to .... ft.

Surface seal: Yes ☒ No ☐ To what depth? 20 ft.
Material used in seal Bentonite clay
Did any strata contain unusable water? Yes ☐ No ☒
Type of water? .... Depth of strata ....
Method of sealing strata off ....

(7) PUMP: Manufacturer's Name ....
Type: .... H.P. ....

(8) WATER LEVELS: Land-surface elevation above mean sea level .... ft.
Static level 146'-11" ft. below top of well Date sept. 4
Artesian pressure .... lbs. per square inch Date ....
Artesian water is controlled by .... (Cap, valve, etc.)

(9) WELL TESTS: Drawdown is amount water level is lowered below static level
Was a pump test made? Yes ☐ No ☒ If yes, by whom? ....
Yield: .... gal./min. with .... ft. drawdown after .... hrs.
" .... " .... " .... "
" .... " .... " .... "

Recovery data (time taken as zero when pump turned off) (water level measured from well top to water level)

Time	Water Level	Time	Water Level	Time	Water Level

Date of test ....
Bailer test 10 gal./min. with nil ft. drawdown after 2 hrs.
Artesian flow .... g.p.m. Date ....
Temperature of water .... Was a chemical analysis made? Yes ☐ No ☐

(10) WELL LOG:

Formation: *Describe by color, character, size of material and structure, and show thickness of aquifers and the kind and nature of the material in each stratum penetrated, with at least one entry for each change of formation.*

MATERIAL	FROM	TO
Sand & gravel	0	36
Boulder app 2'	5	7
Sand & gravel & littel clay (blue)	36	44
" & Fine gravel & littel clay (rrown)	44	75
" & gravel (dry)	75	114
" & " lieetel clay	114	119
" & " (dry)	119	148
" & littel clay (brown) & WATER	148	156
" & gravel & WATER	156	166
" & clay seams & water	166	180

Job No [illegible]
File No [illegible]
Date [illegible]
GOL[illegible]

[illegible] 198[illegible]

Work started Aug. 17 19 84 Completed Sept. 4 19..

WELL DRILLER'S STATEMENT:

This well was drilled under my jurisdiction and this report true to the best of my knowledge and belief.

NAME Livermore & Son, Inc. (Person, firm, or corporation) (Type or print)

Address 6053 Portalway , Ferndale

[Signed] D. E. Livermore (Well Driller)

License No. 272 Date Sept. 5, 19[illegible]

15

40/1E/3 C

WATER WELL REPORT

STATE OF WASHINGTON

Start Card No. 072720
Water Right Permit No.

(1) OWNER: Name BOURSAW, ALBERT Address 9259 STATVOTT RD BLAINE, WA 98230-

(2) LOCATION OF WELL: County WHATCOM - NE 1/4 NW 1/4 Sec 3 T 40 N., R 1E WM
(2a) STREET ADDRESS OF WELL (or nearest address) 9593 FLAMBEAU RD, BLAINE

(3) PROPOSED USE: DOMESTIC

(4) TYPE OF WORK: Owner's Number of well (If more than one) 1
NEW WELL Method: ROTARY

(5) DIMENSIONS: Diameter of well 6 inches
Drilled 189 ft. Depth of completed well 187 ft.

(6) CONSTRUCTION DETAILS:
Casing installed: 6 " Dia. from 0 ft. to 187 ft.
WELDED " Dia. from ft. to ft.
" Dia. from ft. to ft.

Perforations: NO
Type of perforator used
SIZE of perforations in. by in.
perforations from ft. to ft.
perforations from ft. to ft.
perforations from ft. to ft.

Screens: NO
Manufacturer's Name
Type Model No.
Diam. slot size from ft. to ft.
Diam. slot size from ft. to ft.

Gravel packed: NO Size of gravel
Gravel placed from ft. to ft.

Surface seal: YES To what depth? 18 ft.
Material used in seal BENTONITE
Did any strata contain unusable water? NO
Type of water? Depth of strata ft.
Method of sealing strata off

(7) PUMP: Manufacturer's Name Jacuzzi
7S41011P-S2 Type Submersible H.P. 3/4

(8) WATER LEVELS: Land-surface elevation above mean sea level ... ft.
Static level 160 ft. below top of well Date 06/07/91
Artesian Pressure lbs. per square inch Date
Artesian water controlled by

(10) WELL LOG

Formation: Describe by color, character, size of material and structure, and show thickness of aquifers and the kind and nature of the material in each stratum penetrated, with at least one entry for each change in formation.

MATERIAL	FROM	TO
BROWN CLAY GRAVEL	0	178
WATER CLAY GRAVEL	178	180
GRAVEL WATER	180	188
BROWN CLAY	188	189

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JUN 21 1991
DEPT. OF ECOLOGY

Work started 06/06/91 Completed 06/07/91

(9) WELL TESTS: Drawdown is amount water level is lowered below static level.
Was a pump test made? yes If yes, by whom? OPSWD
Yield: 10 gal./min with 3'8" ft. drawdown after 2 hrs.

Recovery data

Time	Water Level	Time	Water Level	Time	Water Level
30min	162'4"				

Date of test / /
Bailer test gal/min. 22 ft. drawdown after hrs.
Air test 10 gal/min. w/ stem set at 182 ft. for 1 hrs.
Artesian flow g.p.m. Date
Temperature of water Was a chemical analysis made? no

WELL CONSTRUCTOR CERTIFICATION:
I constructed and/or accept responsibility for construction of this well, and its compliance with all Washington well construction standards. Materials used and the information reported above are true to my best knowledge and belief.

NAME DAHLMAN PUMP & WELL DRILL
(Person, firm, or corporation) (Type or print)

ADDRESS PO BOX 422,BURLINGTON, WA

[SIGNED] License No, 0623

Contractor's
Registration No. DAHLMPW123LC Date 06/10/91

40/1/4a

WATER WELL REPORT
STATE OF WASHINGTON

Start Card No. [redacted]
Water Right Permit No.

(1) OWNER: Name FREEMAN, SCOTT Address P. O. BOX 721 BLAINE, WA 98230-

(2) LOCATION OF WELL: County WHATCOM - NE 1/4 NE 1/4 Sec 4 T 40 N., R 1 WM
(2a) STREET ADDRESS OF WELL (or nearest address) H STREET, BLAINE

(3) PROPOSED USE: DOMESTIC

(4) TYPE OF WORK: Owner's Number of well (If more than one)
NEW WELL Method: ROTARY

(5) DIMENSIONS: Diameter of well 6 inches
Drilled 254 ft. Depth of completed well 254 ft.

(6) CONSTRUCTION DETAILS:
Casing installed: 6 " Dia. from 0 ft. to 254 ft.
WELDED " Dia. from ft. to ft.
" Dia. from ft. to ft.

Perforations: NO
Type of perforator used
SIZE of perforations in. by in.
perforations from ft. to ft.
perforations from ft. to ft.
perforations from ft. to ft.

Screens: NO
Manufacturer's Name
Type Model No.
Diam. slot size from ft. to ft.
Diam. slot size from ft. to ft.

Gravel packed: NO Size of gravel
Gravel placed from ft. to ft.

Surface seal: YES To what depth? 18 ft.
Material used in seal BENTONITE
Did any strata contain unusable water? NO
Type of water? Depth of strata ft.
Method of sealing strata off

(7) PUMP: Manufacturer's Name
Type H.P.

(8) WATER LEVELS: Land-surface elevation above mean sea level ... ft.
Static level 190 ft. below top of well Date 06/26/92
Artesian Pressure lbs. per square inch Date
Artesian water controlled by

(9) WELL TESTS: Drawdown is amount water level is lowered below static level.
Was a pump test made? If yes, by whom?
Yield: gal./min with ft. drawdown after hrs.

Recovery data
Time Water Level Time Water Level Time Water Level

Date of test / /
Bailer test gal/min. 40 ft. drawdown after hrs.
Air test 18 gal/min. w/ stem set at ft. for . hrs.
Artesian flow g.p.m. Date
Temperature of water Was a chemical analysis made?

(10) WELL LOG

Formation: Describe by color, character, size of material and structure, and show thickness of aquifers and the kind and nature of the material in each stratum penetrated, with at least one entry for each change in formation.

MATERIAL	FROM	TO
BROWN CLAY & GRAVEL	0	194
WATER & SAND GRAVEL & CLAY	194	196
BLUE CLAY & GRAVEL	196	233
WATER & GRAVEL 3 GPM	233	245
WATER & GRAVEL 18 GPM	245	254

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JUL 02 1992
DEPT. OF ECOLOGY

Work started 06/26/92 Completed 06/26/92

WELL CONSTRUCTOR CERTIFICATION:
I constructed and/or accept responsibility for construction of this well, and its compliance with all Washington well construction standards. Materials used and the information reported above are true to my best knowledge and belief.

NAME DAHLMAN PUMP & WELL DRILL
(Person, firm, or corporation) (Type or print)

ADDRESS PO BOX 422, BURLINGTON, WA

[SIGNED] License No. 0623

Contractor's Registration No. DAHLMPW123LC Date 06/29/92

File Original and First Copy with
Department of Ecology
Second Copy—Owner's Copy
Third Copy—Driller's Copy

WATER WELL REPORT

STATE OF WASHINGTON

Start Card No.

41/1/3D

54

Water Right Permit No.

(1) OWNER: Name MARK WASLOHN Address FLAMBEAU RD. BLAINE

(2) LOCATION OF WELL: County WHATCOM NW ¼ NW ¼ Sec. 3 T. 41 N., R. 1E W.M.

(2a) STREET ADDDRESS OF WELL (or nearest address) 40?

(3) PROPOSED USE: ☒ Domestic ☐ Irrigation ☐ DeWater ☐ Industrial ☐ Test Well ☐ Municipal ☐ Other

(4) TYPE OF WORK: Owner's number of well (if more than one)

☐ Abandoned ☒ New well ☐ Deepened ☐ Reconditioned

Method: ☐ Dug ☒ Cable ☐ Rotary ☐ Bored ☐ Driven ☐ Jetted

(5) DIMENSIONS: Diameter of well 6 inches.

Drilled 212 feet. Depth of completed well 212 ft.

(6) CONSTRUCTION DETAILS:

Casing installed: 6" Diam. from 0 ft. to 212 ft.

☐ Welded " Diam. from ft. to ft.

☐ Liner installed

☐ Threaded " Diam. from ft. to ft.

Perforations: Yes ☐ No ☒ 214' TOTAL PIPE

Type of perforator used

SIZE of perforations in. by in.

perforations from ft. to ft.

perforations from ft. to ft.

perforations from ft. to ft.

Screens: Yes ☐ No ☒

Manufacturer's Name

Type Model No.

Diam. Slot size from ft. to ft.

Diam. Slot size from ft. to ft.

Gravel packed: Yes ☐ No ☒ Size of gravel

Gravel placed from ft. to ft.

Surface seal: Yes ☒ No ☐ To what depth? 20+ ft.

Material used in seal BENTONITE

Did any strata contain unusable water? Yes ☐ No ☐

Type of water? Depth of strata

Method of sealing strata off

(7) PUMP: Manufacturer's Name

Type: H.P.

(8) WATER LEVELS: Land-surface elevation above mean sea level ft.

Static level 194 ft. below top of well Date 7-11-92

Artesian pressure lbs. per square inch Date

Artesian water is controlled by (Cap, valve, etc.)

(9) WELL TESTS: Drawdown is amount water level is lowered below static level

Was a pump test made? Yes ☐ No ☐ If yes, by whom?

Yield: gal./min. with ft. drawdown after hrs.

Recovery data (time taken as zero when pump turned off) (water level measured from well top to water level)

Time	Water Level	Time	Water Level	Time	Water Level

Date of test

Bailer test 7 gal./min. with TOTAL ft. drawdown after 1 hrs.

Airtest gal./min. with stem set at ft. for hrs.

Artesian flow g.p.m. Date 7-11-92

Temperature of water Was a chemical analysis made? Yes ☐ No ☐

(10) WELL LOG or ABANDONMENT PROCEDURE DESCRIPTION

Formation: Describe by color, character, size of material and structure, and show thickness of aquifers and the kind and nature of the material in each stratum penetrated, with at least one entry for each change of information.

MATERIAL	FROM	TO
CLAY & GRAVEL	0	19
RED CLAY	19	30
GRAVEL W/CLAY	30	210
GRAVEL W/WATER	210	212

RECEIVED
AUG 04 1992
DEPT OF ECOLOGY

Work started 6-27-92 19. Completed 7-11-92 19

WELL CONSTRUCTOR CERTIFICATION:

I constructed and/or accept responsibility for construction of this well, and its compliance with all Washington well construction standards. Materials used and the information reported above are true to my best knowledge and belief.

NAME STAR DRILLING SERVICE (PERSON, FIRM, OR CORPORATION) (TYPE OR PRINT)

Address 3930 CLIFFSIDE DR. BLHM

(Signed) Herman Lehnert (WELL DRILLER) License No. 0266

Contractor's Registration No. STAR DS207DK Date 7-14-92 19

(USE ADDITIONAL SHEETS IF NECESSARY)

ECY 050-1-20 (10/87) 1329

e Original and First Copy with
partment of Ecology
nd Copy—Owner's Copy
Copy—Driller's Copy

WATER WELL REPORT

STATE OF WASHINGTON

40/01E/05-A
Start Card No. 022614

Water Right Permit No.

(1) OWNER: Name Joe Miller Address 9665 Harvey Rd.,Blaine

(2) LOCATION OF WELL: County Whatcom NE ¼ NE ¼ Sec. 5 T. 40 N., R. 1 W.M.

(2a) STREET ADDRESS OF WELL (or nearest address)

(3) PROPOSED USE: ☒ Domestic ☐ Irrigation ☐ DeWater Industrial ☐ Test Well ☐ Municipal ☐ Other ☐

(4) TYPE OF WORK: Owner's number of well (if more than one)
Abandoned ☐ New well ☒ Deepened ☐ Reconditioned ☐
Method: Dug ☐ Cable ☒ Rotary ☐ Bored ☐ Driven ☐ Jetted ☐

(5) DIMENSIONS: Diameter of well 6 inches.
Drilled 98 feet. Depth of completed well 98 ft.

(6) CONSTRUCTION DETAILS:
Casing installed: 6 " Diam. from +1 ft. to 93 ft.
Welded ☒ " Diam. from ft. to ft.
Liner installed ☐
Threaded ☐ " Diam. from ft. to ft.

Perforations: Yes ☐ No ☒
Type of perforator used
SIZE of perforations in. by in.
perforations from ft. to ft.
perforations from ft. to ft.
perforations from ft. to ft.

Screens: Yes ☒ No ☐
Manufacturer's Name Johnson
Type Stainless Steel Model No.
Diam. 6 Slot size 20 from 93 ft. to 98 ft.
Diam. Slot size from ft. to ft.

Gravel packed: Yes ☐ No ☒ Size of gravel
Gravel placed from ft. to ft.

Surface seal: Yes ☒ No ☐ To what depth? 25+ ft.
Material used in seal Puddled blue clay
Did any strata contain unusable water? Yes ☐ No ☒
Type of water? Depth of strata
Method of sealing strata off

(7) PUMP: Manufacturer's Name Fairbanks Morse
Type: Submergible H.P. 3/4

(8) WATER LEVELS: Land-surface elevation above mean sea level ft.
Static level 7'-1" ft. below top of well Date 1/17/90
Artesian pressure lbs. per square inch Date
Artesian water is controlled by (Cap, valve, etc.)

(9) WELL TESTS: Drawdown is amount water level is lowered below static level
Was a pump test made? Yes ☒ No ☐ If yes, by whom? [illegible]
Yield: 15 gal./min. with 5 ft. drawdown after 2 hrs.
" " " "
" " " "

Recovery data (time taken as zero when pump turned off) (water level measured from well top to water level)

Time	Water Level	Time	Water Level	Time	Water Level

Date of test
Bailer test gal./min. with ft. drawdown after hrs.
Airtest gal./min. with stem set at ft. for hrs.

(10) WELL LOG or ABANDONMENT PROCEDURE DESCRIPTION

Formation: Describe by color, character, size of material and structure, and show thickness of aquifers and the kind and nature of the material in each stratum penetrated, with at least one entry for each change of information.

MATERIAL	FROM	TO
Top soil	0	2
Sand,gravel & hardpan	2	8
Sand,gravel & blue clay (soft)	8	33
Sand,gravel & little clay (brown)	33	47
Sand,gravel (dry)	47	
Sand,gravel & WATER		98
Sand gravel & bleu clay	98	

RECEIVED
JAN 29 1990
DEPARTMENT OF ECOLOGY
NORTHWEST REGION

Work started 1/12/90, 19 . Completed 1/18/90, 19

WELL CONSTRUCTOR CERTIFICATION:

I constructed and/or accept responsibility for construction of this well, and its compliance with all Washington well construction standards. Materials used and the information reported above are true to my best knowledge and belief.

NAME Livermore & Son,Inc. (PERSON, FIRM, OR CORPORATION) (TYPE OR PRINT)
Address 6053 Portalway,Fermdale
(Signed) (WELL DRILLER) License No. 272
Contractor's Registration No. Livers*199 JG Date 1/18/90, 19

40/1E/2D

WATER WELL REPORT
STATE OF WASHINGTON

Start Card No. 078106
Water Right Permit No.

(1) OWNER: Name CONNELLY, DOUG Address 8092 COMOX RD BLAINE, WA 98230-

(2) LOCATION OF WELL: County WHATCOM - NW 1/4 NW 1/4 Sec 2 T 40 N., R 1E WM
(2a) STREET ADDRESS OF WELL (or nearest address) VALLEY VIEW RD

(3) PROPOSED USE: MUNICIPAL

(4) TYPE OF WORK: Owner's Number of well (If more than one)
NEW WELL Method: ROTARY

(5) DIMENSIONS: Diameter of well 8 inches
Drilled 151 ft. Depth of completed well 148.6 ft.

(6) CONSTRUCTION DETAILS:
Casing installed: 8 " Dia. from +3 ft. to 134 ft.
WELDED " Dia. from ft. to ft.
" Dia. from ft. to ft.

Perforations: NO
Type of perforator used
SIZE of perforations in. by in.
perforations from ft. to ft.
perforations from ft. to ft.
perforations from ft. to ft.

Screens: YES
Manufacturer's Name JOHNSON/H.SMITH
Type STAINLESS STEEL Model No. KO
Diam. 8 slot size 20 from 133.6 ft. to 143.6 ft.
Diam. 8 slot size 30 from 143.6 ft. to 148.6 ft.

Gravel packed: NO Size of gravel
Gravel placed from ft. to ft.

Surface seal: YES To what depth? 19 ft.
Material used in seal BENTONITE
Did any strata contain unusable water? NO
Type of water? Depth of strata ft.
Method of sealing strata off

(7) PUMP: Manufacturer's Name
Type H.P.

(8) WATER LEVELS: Land-surface elevation above mean sea level ... ft.
Static level 101.8 ft. below top of well Date 06/10/91
Artesian Pressure lbs. per square inch Date
Artesian water controlled by

(9) WELL TESTS: Drawdown is amount water level is lowered below static level.
Was a pump test made? NO If yes, by whom?
Yield: gal./min with ft. drawdown after hrs.

Recovery data
Time Water Level Time Water Level Time Water Level

Date of test / /
Bailer test gal/min. ft. drawdown after hrs.
Air test 100 gal/min. w/ stem set at 126 ft. for 1 hrs.
Artesian flow g.p.m. Date
Temperature of water Was a chemical analysis made? NO

(10) WELL LOG

Formation: Describe by color, character, size of material and structure, and show thickness of aquifers and the kind and nature of the material in each stratum penetrated, with at least one entry for each change in formation.

MATERIAL	FROM	TO
GRAVEL	0	2
TOPSOIL	2	3
BROWN GRAVEL & CLAY	3	6
TAN GRAVEL & CLAY	6	16
GRAY GRAVEL SAND & CLAY	16	20
BROWN GRAVEL SAND & CLAY	20	31
GRAY CLAY	31	34
GRAY GRAVEL SAND & SILT	34	37
TAN GRAVEL & SAND	37	39
BROWN SAND CLAY & GRAVEL	39	52
BROWN SAND GRAVEL & SILT	52	59
BROWN GRAVEL & SAND	59	63
BROWN GRAVEL SAND & SILT	63	117
BROWN GRAVEL SAND & WATER	117	124
BROWN GRAVEL SAND & CLAY	124	125.5
BROWN SAND & SILT	125.5	130
BROWN SAND & WATER	130	139
BROWN GRAVEL SAND & WATER	139	149
BROWN CLAY	149	

RECEIVED
JUL 05 1991
DEPT. OF ECOLOGY

Work started 06/06/91 Completed 06/10/91

WELL CONSTRUCTOR CERTIFICATION:
I constructed and/or accept responsibility for construction of this well, and its compliance with all Washington well construction standards. Materials used and the information reported above are true to my best knowledge and belief.

NAME HAYES DRILLING, INC.
(Person, firm, or corporation) (Type or print)

ADDRESS 556 ERSHIG RD. BOW, WA

[SIGNED] Steve License No. 762

Contractor's Registration No. HAYESDI106JS Date 06/12/91

1421

926 · 007 · 1 · 2 · 2 #13

WATER WELL RECORD

DEPT. OF ENVIRONMENT, WATER RESOURCES SERVICE, WATER INVESTIGATIONS BRANCH VICTORIA, BRITISH COLUMBIA

Z ☐☐☐ WELL NO. ☐☐☐

☐☐☐☐☐☐☐ E

☐☐☐☐☐☐☐ N

Z X Y NO.

NAT. TOPO. SHEET NO. ______

LEGAL DESCRIPTION: LOT Wh/E SEC. 4 TP. 7 R. ____ D.L. ____ LAND DISTRICT New West. PLAN 5409.

DESCRIPTIVE LOCATION 18609 - 0 AVE., SURREY. LICENCE NO. ____ DATE ____

OWNER'S NAME Ian Barrioch + Gloria Lawson ADDRESS 18609 - 0 Ave, Surrey.

DRILLER'S NAME Langley W.W. ADDRESS Langley. DATE COMPLETED 9·12·80

DEPTH 130' ELEVATION OF ____ OPI ☐ ESTIMATED ☐ SURVEYED CASING DIAM. ____ LENGTH ____

METHOD OF CONSTRUCTION drilled. CASING DIAM 6" LENGTH ____

SCREEN LOCATION ____ SCREEN ☑ SIZE 25 LENGTH ____ TYPE S.S.

SANITARY SEAL YES ☐ NO ☐ SCREEN ☐ SIZE ____ LENGTH ____ TYPE ____

PERFORATED CASING ☐ LENGTH ____ PERFORATIONS FROM ____ TO ____

GRAVEL PACK ☐ LENGTH ____ DIAM. ____ SIZE GRAVEL, ETC. ____

DISTANCE TO WATER 94' ☐ ESTIMATED WATER LEVEL

FROM ____ ☐ MEASURED ELEVATION ____ ARTESIAN PRESSURE ____

DATE OF WATER LEVEL MEASUREMENT ____ WATER USE domestic

PRODUCTION TEST SUMMARY

DATE ____

TEST BY ____

BAIL TEST ☑ PUMP TEST ☐ DURATION OF TEST 1 hr.

RATE 15 gpm. DRAWDOWN 15'

WATER LEVEL AT COMPLETION OF TEST 109'

AVAILABLE DRAWDOWN ____ SPECIFIC CAPACITY ____

PERMEABILITY ____ STORAGE COEFF. ____

TRANSMISSIVITY ____

RECOMMENDED PUMPING RATE ____

RECOMMENDED PUMP SETTING ____

CHEMISTRY

TEST BY ____ DATE ____

TOTAL DISSOLVED SOLIDS ____ mg/l TEMPERATURE ____ °C pH ____ SILICA (SiO_2) ____ mg/l

CONDUCTANCE ____ µmhos/cm AT 25°C TOTAL IRON (Fe) ____ mg/l TOTAL HARDNESS ($CaCO_3$) ____ mg/l

TOTAL ALKALINITY ($CaCO_3$) ____ mg/l PHEN. ALKALINITY ($CaCO_3$) ____ mg/l MANGANESE (Mn) ____ mg/l

COLOUR ____ ODOUR ____ TURBIDITY ____

ANIONS	mg/l	epm
CARBONATE (CO_3)		
BICARBONATE (HCO_3)		
SULPHATE (SO_4)		
CHLORIDE (Cl)		
$NO_2 + NO_3$ (NITROGEN)		
• TKN. (NITROGEN)		
PHOSPHORUS (P)		

CATIONS	mg/l	epm
CALCIUM (Ca)		
MAGNESIUM (Mg)		
SODIUM (Na)		
POTASSIUM (K)		
IRON (DISSOLVED)		

• TKN = TOTAL KJELDAHL NITROGEN

NO_2 = NITRITE NO_3 = NITRATE

CHEMISTRY SITE NO. ____

CHEMISTRY FIELD TESTS

TEST BY ____ DATE ____ EQUIPMENT USED ____

LITHOLOGY

FROM	TO	DESCRIPTION
0	12'	gravel
12'	27'	hard pan
27'	72'	crumbled gravel
72'	88'	silty sand + clay.
88'	94'	silty sand + clay.
94'	108'	silty sand, pressure from aquifer
108'	122'	Fine sand (silty)
122'	130'	coarse sand.

CONTENTS OF FOLDER

☑ DRILL LOG ☐ PUMP TEST DATA ☐ CHEMICAL ANALYSIS

☐ SIEVE ANALYSIS ☐ GEOPHYSICAL LOGS ☐ REPORT

OTHER ____

92 G · 007 · 2 · 1 · 1 .

\# 23

WATER WELL RECORD

DEPT. OF ENVIRONMENT, WATER RESOURCES SERVICE, WATER INVESTIGATIONS BRANCH VICTORIA, BRITISH COLUMBIA

Z ☐☐ WELL NO. ☐☐☐

☐☐☐☐☐☐ E

☐☐☐☐☐☐☐ N

Z X Y NO.

NAT. TOPO. SHEET NO.

LEGAL DESCRIPTION: LOT 7 SEC. SW 3 TP. 7 R. ___ D.L. 36 LAND DISTRICT NWD PLAN 47538

DESCRIPTIVE LOCATION 200-192 ST. SURREY B.C. LICENCE NO. ___ DATE ___

OWNER'S NAME GARRY STORSLEY ADDRESS 200-192 ST. SURREY

DRILLER'S NAME COLUMBIA W.W. ADDRESS LANGLEY DATE COMPLETED 83/05/13

DEPTH 108' ELEVATION OF (027) ☐ ESTIMATED ☐ SURVEYED CASING DIAM. 6" LENGTH 105

METHOD OF CONSTRUCTION CABLE TOOL CASING DIAM ___ LENGTH ___

SCREEN LOCATION 100'-105' SCREEN ☐ SIZE 10 SLOT. LENGTH 4'-10" TYPE JOHNSON S.S

SANITARY SEAL YES ☐ NO ☐ SCREEN ☐ SIZE ___ LENGTH ___ TYPE ___

PERFORATED CASING ☐ LENGTH ___ PERFORATIONS FROM ___ TO ___

GRAVEL PACK ☐ LENGTH ___ DIAM. ___ SIZE GRAVEL, ETC. ___

DISTANCE TO WATER 60' ☐ ESTIMATED WATER LEVEL

FROM GROUND LEVEL ☑ MEASURED ELEVATION ___ ARTESIAN PRESSURE ___

DATE OF WATER LEVEL MEASUREMENT 83/05/13 WATER USE DOMESTIC

PRODUCTION TEST SUMMARY

DATE 83/05/13

TEST BY COLUMBIA WATER WELLS

BAIL TEST ☑ PUMP TEST ☐ DURATION OF TEST 2 HRS.

RATE 15 USGPM. DRAWDOWN 20'

WATER LEVEL AT COMPLETION OF TEST 85

AVAILABLE DRAWDOWN ___ SPECIFIC CAPACITY ___

PERMEABILITY ___ STORAGE COEFF. ___

TRANSMISSIVITY ___

RECOMMENDED PUMPING RATE 15 GPM.

RECOMMENDED PUMP SETTING 95'

LITHOLOGY

FROM	TO	DESCRIPTION
0	1	TOP SOIL
1	19	BROWN SILTY CLAY WITH ROCKS
19	52	PACKED BROWN SILTY SAND WITH ROCK - SOME COBBLES
52	59	FINE SAND AND GRAVEL WITH PACKED SILT.
59	68	SANDY TILL - BROWN WASH
68	78	TILL - GRAY WASH
78	80	BROWN SILTY SAND MAKING SOME WATER. (6.5')
80	93	WATER BEARING VERY FINE SAND
93	105	WATER BEARING COARSE TO MEDIUM FINE SAND AND GRAVEL.
105	107	WATER BEARING SILTY SAND AND ROCKS.
107	108	GRAY STONEY CLAY
		CASING ABOVE GROUND 16"

CHEMISTRY

TEST BY ___ DATE ___

TOTAL DISSOLVED SOLIDS ___ mg/l TEMPERATURE ___ °C pH ___ SILICA (SiO_2) ___ mg/l

CONDUCTANCE ___ µmhos/cm AT 25°C TOTAL IRON (Fe) ___ mg/l TOTAL HARDNESS ($CaCO_3$) ___ mg/l

TOTAL ALKALINITY ($CaCO_3$) ___ mg/l PHEN. ALKALINITY ($CaCO_3$) ___ mg/l MANGANESE (Mn) ___ mg/l

COLOUR ___ ODOUR ___ TURBIDITY ___

ANIONS	mg/l	epm
CARBONATE (CO_3)		
BICARBONATE (HCO_3)		
SULPHATE (SO_4)		
CHLORIDE (Cl)		
$NO_2 + NO_3$ (NITROGEN)		
• TKN. (NITROGEN)		
PHOSPHORUS (P)		

CATIONS	mg/l	epm
CALCIUM (Ca)		
MAGNESIUM (Mg)		
SODIUM (Na)		
POTASSIUM (K)		
IRON (DISSOLVED)		

• TKN = TOTAL KJELDAHL NITROGEN CHEMIST ___ SITE ___

NO_2 = NITRITE NO_3 = NITRATE

CHEMISTRY FIELD TESTS

TEST BY ___ DATE ___ EQUIPMENT USED ___

CONTENTS OF FOLDER

☑ DRILL LOG ☐ PUMP TEST DATA ☐ CHEMICAL ANALYSIS

☐ SIEVE ANALYSIS ☐ GEOPHYSICAL LOGS ☐ REPORT

OTHER ___

SOURCES OF INFORMATION DRILLER

926·007·2·1·1

\# 28

WATER WELL RECORD

MINISTRY OF ENVIRONMENT, WATER MANAGEMENT BRANCH

VICTORIA, BRITISH COLUMBIA

Z ☐☐☐ WELL NO. ☐☐☐

☐☐☐☐☐☐☐ E

☐☐☐☐☐☐☐☐ N

Z X Y NO.

NAT. TOPO. SHEET NO.

LEGAL DESCRIPTION: LOT 16 SEC. SW 1/4 3 TP. 7 R. D.L. LAND DISTRICT 36 NWD PLAN 59338

DESCRIPTIVE LOCATION 19506 - 3A Ave. Surrey, B.C LICENCE NO. DATE

OWNER'S NAME R.J. HARVEY ADDRESS 1850 Southmere Cres., Surrey

DRILLER'S NAME Nor West ADDRESS 23191 Fraser Hwy, Langley DATE COMPLETED 2/11/85

DEPTH 150' ELEVATION OF (101) ☐ ESTIMATED ☐ SURVEYED CASING DIAM. 6" LENGTH 148'

METHOD OF CONSTRUCTION air rotary CASING DIAM LENGTH

SCREEN LOCATION 143'3"-150' SCREEN ☐ SIZE #15 LENGTH 6'9" TYPE S.S.

SANITARY SEAL YES ☐ NO ☐ SCREEN ☐ SIZE LENGTH TYPE

PERFORATED CASING ☐ LENGTH PERFORATIONS FROM TO

GRAVEL PACK ☐ LENGTH DIAM. SIZE GRAVEL, ETC.

DISTANCE TO WATER 110' ☐ ESTIMATED WATER LEVEL

FROM Surface ☐ MEASURED ELEVATION ARTESIAN PRESSURE

DATE OF WATER LEVEL MEASUREMENT WATER USE

PRODUCTION TEST SUMMARY

DATE

TEST BY

BAIL TEST ☐ PUMP TEST ☐ DURATION OF TEST

RATE DRAWDOWN

WATER LEVEL AT COMPLETION OF TEST

AVAILABLE DRAWDOWN SPECIFIC CAPACITY

PERMEABILITY STORAGE COEFF.

TRANSMISSIVITY

RECOMMENDED PUMPING RATE 20 gpm

RECOMMENDED PUMP SETTING 140'

LITHOLOGY

FROM	TO	DESCRIPTION
0	30	loose gravel + cobbles
30	48	silty gravel + cobbles
48	75	Stoney clay
75	83	till
83	90	Sand + gravel (dry)
90	105	silty sand
105	115	silty, stoney, clay
115	130	silty sand (wet)
130	135	silty fine water bearing sand
135	150	water bearing sand.

7032-15002-0

907·2·1

CHEMISTRY

TEST BY DATE

TOTAL DISSOLVED SOLIDS mg/l TEMPERATURE °C pH SILICA (SiO_2) mg/l

CONDUCTANCE µmhos/cm AT 25°C TOTAL IRON (Fe) mg/l TOTAL HARDNESS ($CaCO_3$) mg/l

TOTAL ALKALINITY ($CaCO_3$) mg/l PHEN. ALKALINITY ($CaCO_3$) mg/l MANGANESE (Mn) mg/l

COLOUR ODOUR TURBIDITY

ANIONS	mg/l	epm
CARBONATE (CO_3)		
BICARBONATE (HCO_3)		
SULPHATE (SO_4)		
CHLORIDE (Cl)		
$NO_2 + NO_3$ (NITROGEN)		
• TKN. (NITROGEN)		
PHOSPHORUS (P)		

CATIONS	mg/l	epm
CALCIUM (Ca)		
MAGNESIUM (Mg)		
SODIUM (Na)		
POTASSIUM (K)		
IRON (DISSOLVED)		

• TKN = TOTAL KJELDAHL NITROGEN

NO_2 = NITRITE NO_3 = NITRATE

CHEMISTRY FIELD TESTS

TEST BY DATE EQUIPMENT USED

CONTENTS OF FOLDER

☑ DRILL LOG ☐ PUMP TEST DATA ☐ CHEMICAL ANALYSIS

☐ SIEVE ANALYSIS ☐ GEOPHYSICAL LOGS ☐ REPORT

OTHER location sketch

SOURCE OF INFORMATION driller

926·007·2·1·1 #25

WATER WELL RECORD

DEPT. OF ENVIRONMENT, WATER RESOURCES SERVICE, WATER INVESTIGATIONS BRANCH VICTORIA, BRITISH COLUMBIA

☐ Z ☐☐ WELL NO. ☐

☐☐☐☐☐☐☐ E

☐☐☐☐☐☐☐ N

Z X Y NO.

NAT. TOPO. SHEET NO. -

LEGAL DESCRIPTION: LOT 21 SEC. SW3 TP. 7 R. ____ D.L. ____ LAND DISTRICT NWD PLAN 66312

DESCRIPTIVE LOCATION 19558 3A AVE LANGLEY LICENCE NO. ____ DATE ____

OWNER'S NAME MR DAVE LaPIERRE ADDRESS 19558 3A AVE LANGLEY

DRILLER'S NAME NOR-WEST W.W. ADDRESS LANGLEY DATE COMPLETED 84/01/05

DEPTH 460' ELEVATION OF (101) ☐ ESTIMATED ☐ SURVEYED CASING DIAM. 6" LENGTH 227'6"

METHOD OF CONSTRUCTION AIR ROTARY CASING DIAM ____ LENGTH ____

SCREEN LOCATION 222'3"-233' SCREEN ☑ SIZE 10 SLOT LENGTH 10'7" TYPE S.S.

SANITARY SEAL YES ☐ NO ☐ SCREEN ☐ SIZE ____ LENGTH ____ TYPE ____

PERFORATED CASING ☐ LENGTH ____ PERFORATIONS FROM ____ TO ____

GRAVEL PACK ☐ LENGTH ____ DIAM. ____ SIZE GRAVEL, ETC. ____

DISTANCE TO WATER 170' ☑ ESTIMATED WATER LEVEL

FROM GROUND LEVEL ☐ MEASURED ELEVATION ____ ARTESIAN PRESSURE ____

DATE OF WATER LEVEL MEASUREMENT 84/01/05 WATER USE DOMESTIC

PRODUCTION TEST SUMMARY

DATE 84/01/05

TEST BY NOR-WEST W.W

BAIL TEST ☐ PUMP TEST ☐ DURATION OF TEST ____

RATE ____ DRAWDOWN ____

WATER LEVEL AT COMPLETION OF TEST ____

AVAILABLE DRAWDOWN ____ SPECIFIC CAPACITY ____

PERMEABILITY ____ STORAGE COEFF. ____

TRANSMISSIVITY ____

RECOMMENDED PUMPING RATE 3 gpm

RECOMMENDED PUMP SETTING 220'

CHEMISTRY

TEST BY ____ DATE ____

TOTAL DISSOLVED SOLIDS ____ mg/l TEMPERATURE ____ °C pH ____ SILICA (SiO_2) ____ mg/l

CONDUCTANCE ____ µmhos/cm AT 25°C TOTAL IRON (Fe) ____ mg/l TOTAL HARDNESS ($CaCO_3$) ____ mg/l

TOTAL ALKALINITY ($CaCO_3$) ____ mg/l PHEN. ALKALINITY ($CaCO_3$) ____ mg/l MANGANESE (Mn) ____ mg/l

COLOUR ____ ODOUR ____ TURBIDITY ____

ANIONS	mg/l	epm
CARBONATE (CO_3)		
BICARBONATE (HCO_3)		
SULPHATE (SO_4)		
CHLORIDE (Cl)		
NO_2 + NO_3 (NITROGEN)		
• TKN. (NITROGEN)		
PHOSPHORUS (P)		

CATIONS	mg/l	epm
CALCIUM (Ca)		
MAGNESIUM (Mg)		
SODIUM (Na)		
POTASSIUM (K)		
IRON (DISSOLVED)		

• TKN = TOTAL KJELDAHL NITROGEN

NO_2 = NITRITE NO_3 = NITRATE

CHEMISTRY SITE ____

"The attached information has been supplied gratuitously to the Province of British Columbia and has not been independently confirmed. Those persons relying on it do so at their own risk, and all persons to whom it is supplied should be cautioned against its use in making financial and other commitments. Comments on the well records may be obtained on request by contacting the drillers concerned."

CHEMISTRY FIELD TESTS

TEST BY ____ DATE ____ EQUIPMENT USED ____

LITHOLOGY

FROM	TO	DESCRIPTION
0	12	SAND GRAVEL + BOULDERS
12	16	SANDY BLUE CLAY
16	21	SAND, GRAVEL, CLAY + BOULDERS
21	54	TILLY GRAVEL some BOULDERS
54	58	DIRTY SILTY W.B. SAND + GRAVEL
58	172	FAT TILL SOME BOULDERS
172	184	STONEY GRAY HARDPAN
184	222	SILTY SAND + GRAVEL
222	232	WET SAND + GRAVEL (SILTY)
232	256	V. SILTY DIRTY SAND + GRAVEL SLIGHTLY W.B.
256	285	WET TILL + GRAVEL
285	308	WET SILTY SAND + CLAY (GRAY)
308	332	SILTY GRAY CLAY w. seams of FINE W.B. SAND
332	340	HARD GUMMY GRAY CLAY
340	460	GUMMY GRAY CLAY S[illegible]s of Very fine W.B. SAN

CONTENTS OF FOLDER

☑ DRILL LOG ☐ PUMP TEST DATA ☐ CHEMICAL ANALYSIS

☐ SIEVE ANALYSIS ☐ GEOPHYSICAL LOGS ☐ REPORT

OTHER ____

92G·007·2·1·1

#3

WATER WELL RECORD

MINISTRY OF ENVIRONMENT, WATER MANAGEMENT BRANCH

VICTORIA, BRITISH COLUMBIA

Z ☐☐☐ WELL NO. ☐

Z X Y NO.

NAT. TOPO. SHEET NO. — —

LEGAL DESCRIPTION: LOT 1 SW¼ SEC. 3 TP. 7 R. __ D.L. __ LAND DISTRICT N. W. D. PLAN 57998

DESCRIPTIVE LOCATION 19653 - 0 Ave LICENCE NO. __ DATE __

OWNER'S NAME H LAPIERRE BORDER SAND & GRAVEL ADDRESS __

DRILLER'S NAME NORWEST ADDRESS LANGLEY DATE COMPLETED 79/08/23

DEPTH 300' ELEVATION OF (101) ☐ ESTIMATED ☐ SURVEYED CASING DIAM. __ LENGTH __

METHOD OF CONSTRUCTION __ CASING DIAM 6" LENGTH __

SCREEN LOCATION __ SCREEN ☐ SIZE __ LENGTH __ TYPE __

SANITARY SEAL YES ☐ NO ☐ SCREEN ☐ SIZE __ LENGTH __ TYPE __

PERFORATED CASING ☐ LENGTH __ PERFORATIONS FROM __ TO __

GRAVEL PACK ☐ LENGTH __ DIAM. __ SIZE GRAVEL, ETC. __

DISTANCE TO WATER __ ☐ ESTIMATED WATER LEVEL

FROM __ ☐ MEASURED ELEVATION __ ARTESIAN PRESSURE __

DATE OF WATER LEVEL MEASUREMENT __ WATER USE __

PRODUCTION TEST SUMMARY

DATE __

TEST BY __

BAIL TEST ☐ PUMP TEST ☐ DURATION OF TEST __

RATE not developed, welded cap on well DRAWDOWN __

WATER LEVEL AT COMPLETION OF TEST __

AVAILABLE DRAWDOWN __ SPECIFIC CAPACITY __

PERMEABILITY __ STORAGE COEFF. __

TRANSMISSIVITY __

RECOMMENDED PUMPING RATE __

RECOMMENDED PUMP SETTING __

LITHOLOGY

FROM	TO	DESCRIPTION
0	10	silty sand & gravel
10	15	silty stony brown clay
15	52	sandy till, gravel & boulders
52	68	hard silty clay till
68	174	very hard till & boulders
174	210	silty w.b. sand, till & boulders
210	237	silty sand gravel boulders
237	266	silty w.b. sand
266	295	fine w.b. sand lots of wood
295	300	hard silty till

CHEMISTRY

TEST BY __ DATE __

TOTAL DISSOLVED SOLIDS __ mg/l TEMPERATURE __ °C pH __ SILICA (SiO_2) __ mg/l

CONDUCTANCE __ µmhos/cm AT 25°C TOTAL IRON (Fe) __ mg/l TOTAL HARDNESS ($CaCO_3$) __ mg/l

TOTAL ALKALINITY ($CaCO_3$) __ mg/l PHEN. ALKALINITY ($CaCO_3$) __ mg/l MANGANESE (Mn) __ mg/l

COLOUR __ ODOUR __ TURBIDITY __

ANIONS	mg/l	epm
CARBONATE (CO_3)		
BICARBONATE (HCO_3)		
SULPHATE (SO_4)		
CHLORIDE (Cl)		
$NO_2 + NO_3$ (NITROGEN)		
* TKN. (NITROGEN)		
PHOSPHORUS (P)		

CATIONS	mg/l	epm
CALCIUM (Ca)		
MAGNESIUM (Mg)		
SODIUM (Na)		
POTASSIUM (K)		
IRON (DISSOLVED)		

* TKN = TOTAL KJELDAHL NITROGEN

NO_2 = NITRITE NO_3 = NITRATE

CHEMISTRY SITE NO. __

CHEMISTRY FIELD TESTS

TEST BY __ DATE __ EQUIPMENT __

CONTENTS OF FOLDER

☐ DRILL LOG ☐ PUMP TEST DATA ☐ CHEMICAL ANALYSIS

☐ SIEVE ANALYSIS ☐ GEOPHYSICAL LOGS ☐ REPORT

OTHER __

SOURCE OF INFORMATION FEDERAL RECORDS.

APPENDIX B

WATER QUALITY

TABLE B-1

GROUNDWATER QUALITY: CITY OF BLAINE WELLS

	Well ID				No. 1			New No. 1		No. 2
	Sampling Date	MCL	(1949)	(1959)	(1979)	(1990)	(1993)	11/3/95	(1979)	(1990)
Physical	pH	6.5-8.5								
Characteristics	Temperature (°F)	NA								
	Specific Conductance	700 us/cm	133		180	360		390	325	380
	TDS	500	99	93						
	Color	15 units			3	5		<5	12	5
Inoganics	Arsenic	0.05			<0.02	<0.01		<0.01	<0.02	<0.01
	Alkalinity as CaCO3	NA						150		
	Bicarbonate as CaCO3	NA	78	70						
	Hardness as CaCO3	NA	57	51	65	70		62	56	60
	Carbonate	NA								
	Chloride	NA	3.3	2.5	17	30		33	47	35
	Fluoride	2	0.2	0.1	0.1	<0.2		<0.50	0.2	<0.2
	Nitrate as N	10	0.1	0.1	0.2	<0.2	1	<0.5	0.2	0.3
	Sulfate	250	6.7	4.4				10		
	Barium	1			<0.5	<0.25		<0.10	<0.5	<0.25
	Cadmium	0.01			<0.001	<0.002		<0.0020	<0.001	<0.002
	Calcium	NA	12	12				12		
	Chromium	0.05			<0.02	<0.01		<0.01	<0.02	<0.01
	Iron	0.3	0.01	0	<0.1	<0.1		<0.05	<0.1	<0.1
	Lead	0.05			<0.01	<0.002		<0.002	<0.01	<0.002
	Magnesium (Tot)	NA	6.5	5.2				6.1		
	Manganese	0.05	0		0.03	0.035		0.024	0.01	0.018
	Mercury	0.002			<0.001	<0.0005		<0.0005	<0.001	<0.0005
	Potassium	NA	2					5.6		
	Selenium	0.01			<0.005	<0.005		<0.005	<0.005	<0.0005
	Silica	NA	24	25						
	Silver	0.05			<0.02	<0.01		<0.01	<0.02	<0.01
	Sodium	NA	5.8	5.1		50		66		60

< indicates that the analyte of interest was not detected, to the limit of detection indicated.
* indicates exceedance of MCL. Blanks indicate not sampled for. NA indicates not applicable. Unit of concentration is mg/L.

GROUNDWATER QUALITY: CITY OF BLAINE WELLS

	Well ID						No. 3			
	Sampling Date	**MCL**	**(1993)**	**(1959)**	**(1960)**	**(1962)**	**(1965)**	**(1968)**	**(1969)**	**(1979)**
Physical	pH	6.5-8.5		7.5	7.4	7.8	7.9	8.4	8.1	
Characteristics	Temperature (°F)	NA		48.2	46.4			42.8	53.6	
	Specific Conductance	700 us/cm		129	128	137	133	143	140	120
	TDS	500		93		98	93	104	99	
	Color	15 units		5		5	0	0	0	5
Inoganics	Arsenic	0.05								<0.02
	Alkalinity as CaCO3	NA			57	60	59	62	62	
	Bicarbonate as CaCO3	NA		70	70	73	72	72	75	
	Hardness as CaCO3	NA		51	61	57	54	60	58	53
	Carbonate	NA		0		0	0	2	0	
	Chloride	NA		2.5		2.5	2.8	3	2.4	6
	Fluoride	2		0.1		0.1	0.2	0.2	0.1	0.1
	Nitrate as N	10	<0.1	0.1		0.4	0.9	0.8	0.5	0.4
	Sulfate	250					5.6	6	6.3	
	Barium	1								<0.5
	Cadmium	0.01								<0.001
	Calcium	NA		12		14	14		15	
	Chromium	0.05								<0.02
	Iron	0.3		<0.1		0.01		<0.01	0.03	<0.1
	Lead	0.05								<0.01
	Magnesium (Tot)	NA		5.2		5.4	4.8	4.9	4.9	
	Manganese	0.05				<0.05	<0.05	0.01	<0.05	<0.01
	Mercury	0.002								<0.001
	Potassium	NA		1.3		1.3	1	1.2	1.2	
	Selenium	0.01								<0.005
	Silica	NA		25		25	21	25	24	
	Silver	0.05								<0.02
	Sodium	NA		5.1		5.5	5.4	5.5	5.3	

< indicates that the analyte of interest was not detected, to the limit of detection indicated.
* indicates exceedance of MCL. Blanks indicate not sampled for. NA indicates not applicable. Unit of concentration is mg/L.

GROUNDWATER QUALITY: CITY OF BLAINE WELLS

	Well ID			No. 4			No. 5			
	Sampling Date	**MCL**	**(1993)**	**(1979)**	**(1990)**	**(1993)**	**(1975)**	**(1979)**	**(1986)**	**(1993)**
Physical	pH	6.5-8.5					7.9			
Characteristics	Temperature (°F)	NA								
	Specific Conductance	700 us/cm		110	140		213	164	260	
	TDS	500					116			
	Color	15 units		3	5		4	3	5	
Inoganics	Arsenic	0.05		<0.02	<0.01			<0.02	0.012	
	Alkalinity as CaCO3	NA					89			
	Bicarbonate as CaCO3	NA					108.6			
	Hardness as CaCO3	NA		50			52	75	80	
	Carbonate	NA								
	Chloride	NA		4	5		2.5	4	15	
	Fluoride	2		0.1	<0.2		0.4	0.2	<0.2	
	Nitrate as N	10	0.6	0.3	1.1	1.2	0.5	0.2	<0.2	<0.1
	Sulfate	250					8.6			
	Barium	1		<0.5	<0.25			<0.5	<0.25	
	Cadmium	0.01		<0.001	<0.02			<0.001	<0.002	
	Calcium	NA					20.8			
	Chromium	0.05		<0.02	<0.01			0.04	<0.01	
	Iron	0.3		<0.1	<0.1		0.23	<0.1	0.48*	
	Lead	0.05		<0.01	<0.002			<0.01	<0.01	
	Magnesium (Tot)	NA					4.8			
	Manganese	0.05		<0.01	<0.01		0.04	0.04	0.078*	
	Mercury	0.002		<0.001	<0.0005			<0.001	<0.0005	
	Potassium	NA								
	Selenium	0.01		<0.005	<0.005			<0.005	<0.005	
	Silica	NA					20.3			
	Silver	0.05		<0.02	<0.01			<0.02	<0.01	
	Sodium	NA			5		4			

< indicates that the analyte of interest was not detected, to the limit of detection indicated.
* indicates exceedance of MCL. Blanks indicate not sampled for. NA indicates not applicable. Unit of concentration is mg/L.

TABLE B-1

GROUNDWATER QUALITY: CITY OF BLAINE WELLS

	Well ID		No. 7		Lincoln Park		12th St.
	Sampling Date	MCL	(1990)	(1973)	(1979)	(1983)	(1956)
Physical	pH	6.5-8.5					7.9
Characteristics	Temperature (°F)	NA					
	Specific Conductance	700 us/cm	200		180		
	TDS	500		130			
	Color	15 units	5	1	7	5	1
Inoganics	Arsenic	0.05	<0.01		<0.02	<0.01	
	Alkalinity as CaCO3	NA					
	Bicarbonate as CaCO3	NA					100.8
	Hardness as CaCO3	NA	80	80	86		60
	Carbonate	NA					
	Chloride	NA	<5	5	5	<5.0	5.5
	Fluoride	2	<0.2	0	0.3	<0.2	
	Nitrate as N	10	<0.2	0.16	0.2	<0.2	0.01
	Sulfate	250		8			
	Barium	1	<0.25		<0.5	<0.25	
	Cadmium	0.01	<0.002		<0.001	<0.002	
	Calcium	NA					12.3
	Chromium	0.05	<0.01		<0.02	<0.01	
	Iron	0.3	<0.01	0.05	<0.1	<0.05	0.05
	Lead	0.05	<0.002		0.01	<0.01	
	Magnesium (Tot)	NA					7.1
	Manganese	0.05	0.047	0.01	0.02	0.053*	0.01
	Mercury	0.002	<0.0005		<0.001	<0.0005	
	Potassium	NA					
	Selenium	0.01	<0.005		<0.005	<0.005	
	Silica	NA					29.6
	Silver	0.05	<0.01		<0.02	<0.01	
	Sodium	NA	10				18

< indicates that the analyte of interest was not detected, to the limit of detection indicated.
* indicates exceedance of MCL. Blanks indicate not sampled for. NA indicates not applicable. Unit of concentration is mg/L.

TABLE B-2

GROUNDWATER QUALITY DATA: GWMP MONITORING NETWORK

	Well ID				Aller					Berg	
	Sampling Date	MCL	11/20/90	3/20/91	4/15/91	7/18/91	10/9/91	11/20/90	3/20/91	4/15/91	7/18/91
Physical	pH	6.5-8.5		8.00		6.69	6.70		7.40		6.37*
Characteristics	Temperature (°C)	NA	11	10		16	12	11	9		11
	Specific Conductance	700 us/cm		100		118	140		160		173
	TDS	500	66					40			
	Color	15 units	<5					<5			
Inorganics	Total Alkalin	NA	46					63			
	Bicarbon Alkalin	NA	46					63			
	Carbon Alkalin	NA	<5					<5			
	Hydrox Alkalin	NA	<5					<5			
	Chloride	NA	<5					<5			
	Nitrate as N	10		0.57					<0.05		
	Nitrite as N	NA		<0.005			0.001		<0.005		
	Nitrate/Nitrite as N	NA	0.38			0.38	0.20	<0.05			<0.05
	Sulfate	250	<5					9			
	Calcium	NA	8					10			
	Iron	0.3	<0.05	0.09		0.04	<0.01	0.26	0.42*		0.31*
	Magnesium	NA	3					6			
	Manganese	0.05	<0.02	<0.01		<0.01	<0.01	0.11*	0.07*		0.12*
	Potassium	NA	1.4					1.5			
	Silica	NA	20.0					12.0			
	Sodium	NA	5.30					7.70			
Total Organic Halides		NA	<0.008					<0.008			
Turbidity (NTU)		1	0.20	<0.5		1.3*	<0.01	0.70	1.4*		2.5*
Total Coliform(CFU/100ml)		1/100ml			<2.5					<2.5	

< indicates not detected, to the limit of detection.
* indicates exceedance of MCL. Blanks indicate parameter not sampled for. NA indicates not applicable. Unit of concentration is mg/L.

TABLE B-2

GROUNDWATER QUALITY DATA: GWMP MONITORING NETWORK

	Well ID				Boettcher					Colacurcio	
	Sampling Date	MCL	10/9/91	11/19/90	3/19/91	7/18/91	10/9/91	11/19/90	3/20/91	4/15/91	7/18/91
Physical	pH	6.5-8.5	6.75		8.6*	7.60	6.70		6.4*		7.29
Characteristics	Temperature (°C)	NA	11	9	9	11	10	8	10		11.5
	Specific Conductance	700 us/cm	200	120	420	131.6	110	210	110		137.5
	TDS	500		68				72			
	Color	15 units		<5				<5			
Inorganics	Total Alkalin	NA		42				46			
	Bicarbon Alkalin	NA		42				46			
	Carbon Alkalin	NA		<5				<5			
	Hydrox Alkalin	NA		<5				<5			
	Chloride	NA		<5				<5			
	Nitrate as N	10			<0.05				0.24		
	Nitrite as N	NA	0.001		<0.005		<0.001		<0.005		
	Nitrate/Nitrite as N	NA	<0.01	1.70		1.60	1.70	1.70			1.60
	Sulfate	250		<5				<5			
	Calcium	NA		8				8			
	Iron	0.3	0.48*	1.7*	0.10	0.06	0.14	<0.05	0.09		0.03
	Magnesium	NA		4				4			
	Manganese	0.05	0.12*	0.18*	<0.01	<0.01	<0.01	<0.02	<0.01		<0.01
	Potassium	NA		1.1				1.2			
	Silica	NA		22.0				21.0			
	Sodium	NA		5.60				5.80			
Total Organic Halides		NA		0.018				<0.008			
Turbidity (NTU)		1	2.2*	4*	<0.5	1.6*	0.68	0.60	<0.5		1.5*
Total Coliform(CFU/100ml)		1/100ml			<2.5					<2.5	

< indicates not detected, to the limit of detection.

* indicates exceedance of MCL. Blanks indicate parameter not sampled for. NA indicates not applicable. Unit of concentration is mg/L.

TABLE B-2

GROUNDWATER QUALITY DATA: GWMP MONITORING NETWORK

	Well ID		
	Sampling Date	MCL	10/9/91
Physical	pH	6.5-8.5	
Characteristics	Temperature (°C)	NA	11
	Specific Conductance	700 us/cm	6.8
	TDS	500	160
	Color	15 units	
Inorganics	Total Alkalin	NA	
	Bicarbon Alkalin	NA	
	Carbon Alkalin	NA	
	Hydrox Alkalin	NA	
	Chloride	NA	
	Nitrate as N	10	
	Nitrite as N	NA	<0.001
	Nitrate/Nitrite as N	NA	1.70
	Sulfate	250	
	Calcium	NA	
	Iron	0.3	<0.01
	Magnesium	NA	
	Manganese	0.05	<0.01
	Potassium	NA	
	Silica	NA	
	Sodium	NA	
Total Organic Halides		NA	
Turbidity (NTU)		1	<0.01
Total Coliform(CFU/100ml)		1/100ml	

< indicates not detected, to the limit of detection.

* indicates exceedance of MCL. Blanks indicate parameter not sampled for. NA indicates not applicable. Unit of concentration is mg/L.

TABLE B-2

GROUNDWATER QUALITY DATA: GWMP MONITORING NETWORK

	Well ID			Leer					Wood		
	Sampling Date	**MCL**	11/19/90	3/19/91	7/18/91	10/9/91	11/20/90	3/20/91	4/15/91	7/22/91	10/9/91
Physical	pH	6.5-8.5		8.30	6.60	5.3*		6.90		6.79	7.25
Characteristics	Temperature (°C)	NA	9	9	14.5	13	11	10		15	13.5
	Specific Conductance	700 us/cm	170	10	85.3	70	220	120		99	160
	TDS	500	<20				52				
	Color	15 units	<5				<5				
Inorganics	Total Alkalin	NA	13				86				
	Bicarbon Alkalin	NA	13				86				
	Carbon Alkalin	NA	<5				<5				
	Hydrox Alkalin	NA	<5				<5				
	Chloride	NA	7.1				<5				
	Nitrate as N	10		<0.05				<0.05			
	Nitrite as N	NA		<0.005		<0.001		<0.005			0.001
	Nitrate/Nitrite as N	NA	1.90		1.80	1.40	<0.05			<0.05	<0.01
	Sulfate	250	<5				7				
	Calcium	NA	4				12				
	Iron	0.3	0.07	0.09	0.04	0.04	<0.05			0.43*	0.38*
	Magnesium	NA	2				5				
	Manganese	0.05	0.04	0.02	0.02	0.02	0.04			0.05*	0.05*
	Potassium	NA	0.6				3.1				
	Silica	NA	6.8				9.8				
	Sodium	NA	5.90				14.00				
Total Organic Halides		NA	<0.008				0.020				
Turbidity (NTU)		1	4*	<0.5	1.4*	0.25	0.30	<0.5		1.5*	1.4*
Total Coliform(CFU/100ml)		1/100ml		5*					<2.5		

< indicates not detected, to the limit of detection.
* indicates exceedance of MCL. Blanks indicate parameter not sampled for. NA indicates not applicable. Unit of concentration is mg/L.

TABLE B-2

GROUNDWATER QUALITY DATA: GWMP MONITORING NETWORK

	Well ID			GWMP-1				GWMP-2		
	Sampling Date	MCL	10/2/90	3/25/91	7/22/91	10/10/91	10/9/90	3/25/91	7/22/91	10/10/91
Physical	pH	6.5-8.5	8.40	8.30	7.07	7.00	7.65	7.90	7.16	7.20
Characteristics	Temperature (°C)	NA	12	10	13.5	11	10	10	13	11
	Specific Conductance	700 us/cm	210	110	204	270	180	120	186.4	250
	TDS	500	130				130			
	Color	15 units	<5				<5			
Inorganics	Total Alkalin	NA	52				80			
	Bicarbon Alkalin	NA	52				80			
	Carbon Alkalin	NA	<5				<5			
	Hydrox Alkalin	NA	<5				<5			
	Chloride	NA	<5				5			
	Nitrate as N	10		<0.05				<0.05		
	Nitrite as N	NA		<0.005		<0.001		<0.005		<0.001
	Nitrate/Nitrite as N	NA	<0.05		<0.05	<0.01	<0.05		<0.05	<0.01
	Sulfate	250	6				<5			
	Calcium	NA	16				13			
	Iron	0.3	0.48*	3.9*	0.42*	0.24	0.11	0.3*	0.13	0.13
	Magnesium	NA	7.6				5.3			
	Manganese	0.05	0.05*	0.09	0.3*	0.05*	0.10	0.12*	0.12*	0.12*
	Potassium	NA	3.3				2.2			
	Silica	NA	22.2				25.7			
	Sodium	NA	8.20				9.50			
Total Organic Halides		NA								
Turbidity (NTU)		1	18*	5*	1.8*	1.6*	<0.5	<0.5	0.40	0.11
Total Coliform(CFU/100ml)		1/100ml		<2.5				<2.5		

< indicates not detected, to the limit of detection.
* indicates exceedance of MCL. Blanks indicate parameter not sampled for. NA indicates not applicable. Unit of concentration is mg/L.

TABLE B-2

GROUNDWATER QUALITY DATA: GWMP MONITORING NETWORK

	Well ID			GWMP-3				City Well No. 4		
	Sampling Date	MCL	10/5/90	3/25/91	7/29/91	10/10/91	11/19/90	3/19/91	7/22/91	10/10/91
Physical	pH	6.5-8.5	7.86	8.10	7.12	7.30		8.00	7.05	6.85
Characteristics	Temperature (°C)	NA	11	10	12	11	9	9	11	9.5
	Specific Conductance	700 us/cm	210	110	196	240	110	170	154.1	200
	TDS	500	130				72			
	Color	15 units	<5				<5			
Inorganics	Total Alkalin	NA	84				80			
	Bicarbon Alkalin	NA	84				80			
	Carbon Alkalin	NA	<5				<5			
	Hydrox Alkalin	NA	<5				<5			
	Chloride	NA	6				<5			
	Nitrate as N	10		<0.05				<0.05		
	Nitrite as N	NA		<0.005		<0.001		<0.005		<0.001
	Nitrate/Nitrite as N	NA	<0.05		<0.05	<0.01	0.87		1.00	0.57
	Sulfate	250	<5				6			
	Calcium	NA	14				10			
	Iron	0.3	<0.03	0.94*	0.05	0.08	<0.05	<0.03	<0.01	<0.01
	Magnesium	NA	6.2				4			
	Manganese	0.05	0.05	0.11*	0.1*	0.1*	<0.02	<0.01	<0.01	<0.01
	Potassium	NA	3.0				1.4			
	Silica	NA	25.3				20.0			
	Sodium	NA	8.70				5.70			
Total Organic Halides		NA					<0.008			
Turbidity (NTU)		1	<0.5	3*	0.10	0.15	0.30	<0.5	0.30	<0.01
Total Coliform(CFU/100ml)		1/100ml		<2.5				<2.5		

< indicates not detected, to the limit of detection.
* indicates exceedance of MCL. Blanks indicate parameter not sampled for. NA indicates not applicable. Unit of concentration is mg/L.

TABLE B-2

GROUNDWATER QUALITY DATA: GWMP MONITORING NETWORK

	Well ID			City Well No. 6				12th St.		
	Sampling Date	MCL	11/19/90	3/19/91	7/22/91	10/10/91	11/19/90	3/19/91	7/22/91	10/10/91
Physical	pH	6.5-8.5			6.62	7.80	6.68	7.40	7.13	7.75
Characteristics	Temperature (°C)	NA	9		11	11	11	10	12	11
	Specific Conductance	700 us/cm	180		197	360	360	220	243	280
	TDS	500	130				110			
	Color	15 units	<5				<5			
Inorganics	Total Alkalin	NA	82				85			
	Bicarbon Alkalin	NA	82				85			
	Carbon Alkalin	NA	<5				<5			
	Hydrox Alkalin	NA	<5				<5			
	Chloride	NA	<5				5			
	Nitrate as N	10		<0.05				<0.05		
	Nitrite as N	NA		<0.005		0.001		<0.005		<0.001
	Nitrate/Nitrite as N	NA	<0.05		<0.05	<0.01	<0.05		<0.05	<0.01
	Sulfate	250	12				7			
	Calcium	NA	16				13			
	Iron	0.3	0.29	0.15	<0.01	<0.01	0.25	1*	0.01	<0.01
	Magnesium	NA	7				7			
	Manganese	0.05	0.03	0.03	0.04	0.04	0.06*	0.06*	0.04	0.04
	Potassium	NA	2.4				3.8			
	Silica	NA	14.0				26.0			
	Sodium	NA	9.10				12.00			
Total Organic Halides		NA	0.011				0.009			
Turbidity (NTU)		1	5.00	<0.5	0.20	<0.01	1*	5.8*	0.30	<0.01
Total Coliform(CFU/100ml)		1/100ml		<2.5				<2.5		

< indicates not detected, to the limit of detection.
* indicates exceedance of MCL. Blanks indicate parameter not sampled for. NA indicates not applicable. Unit of concentration is mg/L.

TABLE B-2

GROUNDWATER QUALITY DATA: GWMP MONITORING NETWORK

	Well ID			Lincoln			Boblett St.	
	Sampling Date	MCL	11/19/90	3/19/91	7/22/91	10/10/91	7/16/91	7/29/91
Physical	pH	6.5-8.5		8.40	7.23	7.70	8.07	7.84
Characteristics	Temperature (°C)	NA	11	13	11	10	12.5	13
	Specific Conductance	700 us/cm	150	80	216	240	23	209
	TDS	500	120					
	Color	15 units	5					
Inorganics	Total Alkalin	NA	94				100	105
	Bicarbon Alkalin	NA	94				100	105
	Carbon Alkalin	NA	<5				<5	<5
	Hydrox Alkalin	NA	<5				<5	<5
	Chloride	NA	5				<5	<5
	Nitrate as N	10		<0.05				
	Nitrite as N	NA		<0.005		0.001		
	Nitrate/Nitrite as N	NA	<0.05		<0.05	<0.01	<0.05	<0.05
	Sulfate	250	6				<10	<10
	Calcium	NA	16				16	14.4
	Iron	0.3	<0.05	0.05	0.02	<0.01	0.02	<0.01
	Magnesium	NA	6				7.6	7.3
	Manganese	0.05	0.04	0.04	0.05*	0.05*	0.04	0.04
	Potassium	NA	4.0				2.7	2.4
	Silica	NA	21.0					
	Sodium	NA	11.00				15.00	15.00
Total Organic Halides		NA	<0.008					
Turbidity (NTU)		1	0.80	<0.5	0.30	0.16	<0.5	<0.1
Total Coliform(CFU/100ml)		1/100ml		<2.5				<2

< indicates not detected, to the limit of detection.
* indicates exceedance of MCL. Blanks indicate parameter not sampled for. NA indicates not applicable. Unit of concentration is mg/L.

GROUNDWATER QUAILTY DATA: WHPP MONITORING NETWORK

	Sample Location		Harvey		Langley		Dillen		Freeman		Waslohn		Connelly		GWMP-1	GWMP-2	GWMP-3
	Well ID	MCL	#28		#3		#37		#30		#54		#6		GWMP-1	GWMP-2	GWMP-3
	Sampling Date		10/24/94	6/5/95	10/24/94	6/5/95	10/24/94	6/6/95	10/24/94	6/5/95	10/24/94	6/5/95	10/24/94	6/6/95	6/6/95	6/5/95	6/5/95
Physical	pH	6.5-8.5	6.68	7.7	6.91	7.5	7.02	5.8*	6.98	6.2*	6.71	6.6	7.09	7.2	7.8	7.8	8.1
Characteristics	Temperature (°C)	NA	15	9.8	12	10	12	11.5	14	10.5	18	10.8	12	10.2	11.0	10.4	10.5
	Specific Conductance	700	136	120	171	130	180	170	176	160	137	130	125	110	200	400	600
	TDS	500	97	100	79	100	101	140	97	120	85	110	78	90	140	120	130
Inorganics	Biocarbonate																
	Alkalinity as $CaCO_3$	NA	53	56	57	58	86	90	65	66	65	62	48	48	100	88	90
	Hardness as $CaCO_3$	NA	51	47	58	53	80	77	66	66	75	56	46	50	78	64	69
	Chloride	250	2.1	2	2.2	3	3.8	4	2.8	3	2.4	3	2.1	2	2	2	3
	Nitrate as N	10	0.6	0.7	0.7	0.8	0.4	0.5	<0.2	<0.2	1.7	1.4	0.5	0.7	0.2	<0.2	<0.2
	Sulfate as SO_4	250	3.9	4	5	5	4.7	5	11	11	3.6	4	4.1	4	8	2	4
	Calcium	NA	11.8	12	13.1	13	17.5	18	16.3	17	12.3	12	10.5	10	21	16	17
	Iron	0.3	0.079	<0.05	<0.02	<0.05	<0.02	<0.05	0.19	0.14	0.271	<0.05	0.02	<0.05	0.85*	0.1	<0.05
	Magnesium	NA	5.35	5.3	6.07	5.9	8.87	9.2	6.22	6.4	7.5	7.4	4.67	4.6	9.9	6.3	7.3
	Manganese	0.05	<0.005	<0.002	<0.005	<0.002	<0.005	<0.002	0.032	0.039	0.011	0.003	<0.005	<0.002	0.6*	0.12*	0.095*
	Potassium	NA	2.0U	1.2	2.1	1.4	2.0U	1.8	2.3	1.9	2.0U	1.4	2.0U	1.1	3.5	2.3	3
	Silica as SiO_2	NA	23.1	73	23.1	71	23.5	72	20	64	23.8	75	25	77	66	78	70
	Sodium	NA	5.8	6.3	6.44	6.4	8.56	8.2	6.62	6.5	8.06	7.7	6.14	5.8	10	12	10
Organic	TOC	NA	<0.5	<1.0	<0.5	<1.0	<0.5	<1.0	<0.5	1	<0.5	1.5	<0.5	<1.0	1.4	2.1	<1.0
Turbidity (NTU)		1		0.45		0.4		0.9		1.2		0.8		0.85	NA	0.17	0.18
E. Coli. Count (MPN/100ml)				<1		<1		<2		<1		<1		<2	<2	<1	<1
Total Califorms (CFU/100ml or MPN/100ml)		<1/100ml	1	38.4*	<1	<1	<1	<2	<1	<1	<1	<1	<1	<2	<2	<1	<1

Note: < indicates that the analyte of interest was not detected, to the limit of detection indicated.

Blanks indicate not sampled for.

The analysis were conducted by Columbia Analytical Laboratory for the samples on Oct. 24, 1994 and by Laucks for the samples on June 5-6, 1995.

Unit for total coliform is CFU/100ml used by Columbia Analytical Laboratory and MPN/100ml used by Laucks.

Unit of concentration is mg/L. Well#37 was owned previously by Mr. Miller and is currently owned by Mr.Dillen.

APPENDIX C

TWODAN MODELING RESULTS AND CAPTURE ZONE DELINEATION

<u>TABLE C-1</u>

SUMMARY OF MEASURED AND SIMULATED WATER TABLE ELEVATIONS

Well Owner/Name	Map Location ID	Measured Water Table Elevation (ft)	Simulated Water Table Elevation (ft)	Difference* Between Simulated and Measured (ft)
GMWP-1	GMWP-1	95.4	94.8	-0.6
GMWP-2	GMWP-2	83.9	94.6	10.7
GMWP-3	GMWP-3	81.9	107.5	25.6
MW-1	MW-1	280	280.0	0.0
John Notle	29	189.4	186.5	-2.9
Albert Boursaw	15	246	232.8	-13.2
Mark Waslohn	54	248.2	240.5	-7.7
Doug Connelly	6	264.3	254.5	-9.8

Uncertainty associated with model calibration includes the topographic elevations of ground surface at well locations (e.g., +- 20 ft margin for GWMP-2, +- 15 ft for GWMP-1), seasonal fluctuation of ground water elevations, and different aquifer units in which the wells were screened.

*Difference = Simulated - Measured Water Table Elevation.

TABLE C-2

SUMMARY OF TOT CAPTURE ZONES UNDER PRESENT PUMPING CONDITIONS

Method	Well ID	1-Year Area (Acres)	5-Year Area (Acres)	10-Year Area (Acres)	Relative Accuracy of Method	Remarks
Hydrogeologic Mapping(1)	All City Wells	NA	NA	2,500	Moderate	Long-term steady-state recharge areas.
Analytical Modeling	No. 3 No. 4 No. 5 No. 6	283	1,089	1,421	Good	Capture zone based on modeled ground water travel times
	No. 8	64	293	390		

(1) Cannot be used to determine time-based capture zones.

TABLE C-3

SUMMARY OF TOT CAPTURE ZONES UNDER FUTURE PUMPING CONDITIONS

Method	Well ID	1-Year Area (Acres)	5-Year Area (Acres)	10-Year Area (Acres)	Relative Accuracy of Method	Remarks
Hydrogeologic Mapping(1)	All City Wells	NA	NA	2,500	Moderate	Long-term steady-state recharge areas.
Analytical Modeling	No. 3 No. 4 No. 5 No. 6	282	1,085	1,428	Good	Capture zone based on modeled ground water travel times
	No. 8 (Lincoln Park)	65	286	629		
	No. 7 (12th St.)	21	114			
	No. 9 (Boblett)	43	172	183		

(1) Cannot be used to determine time-based capture zones.

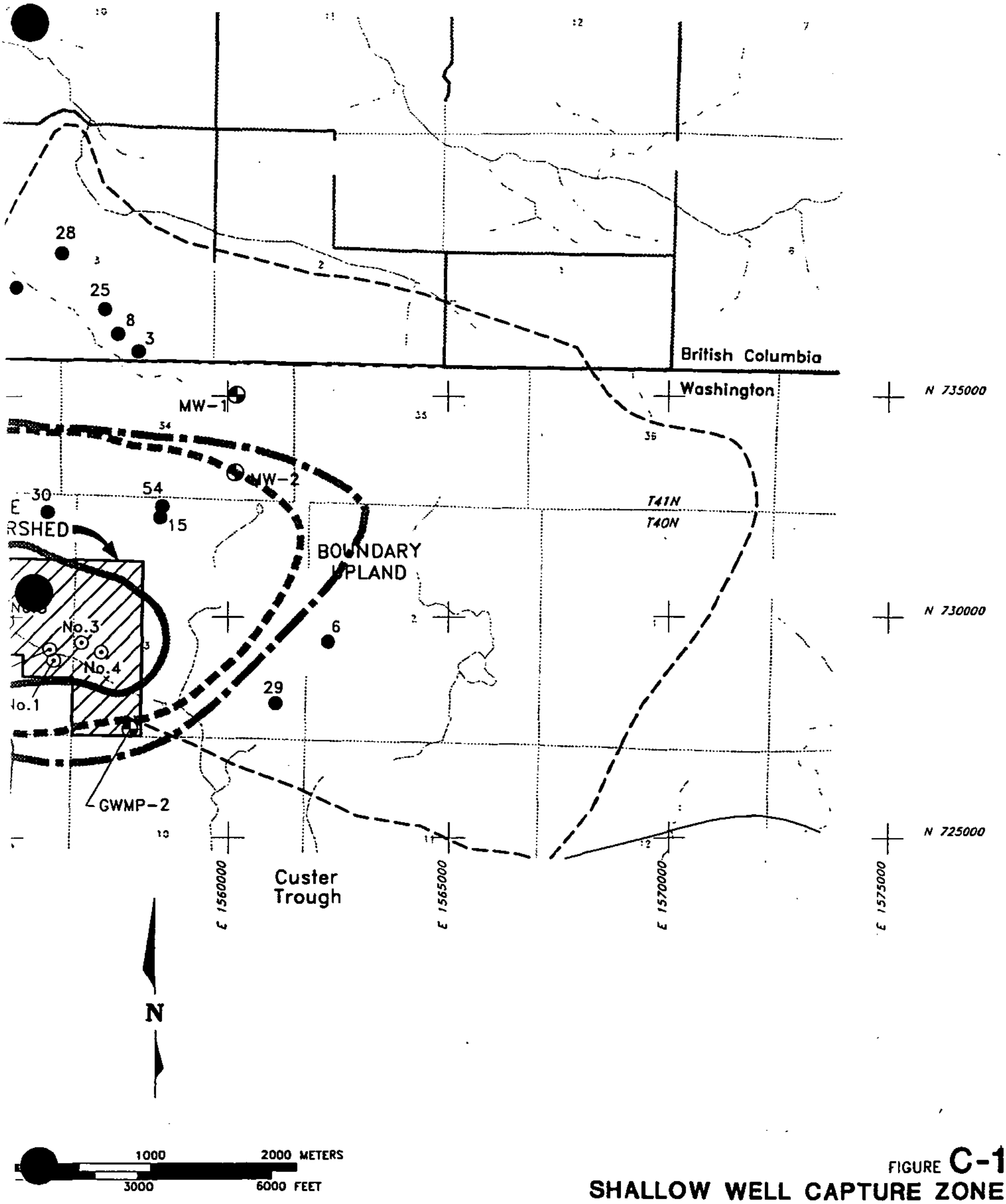
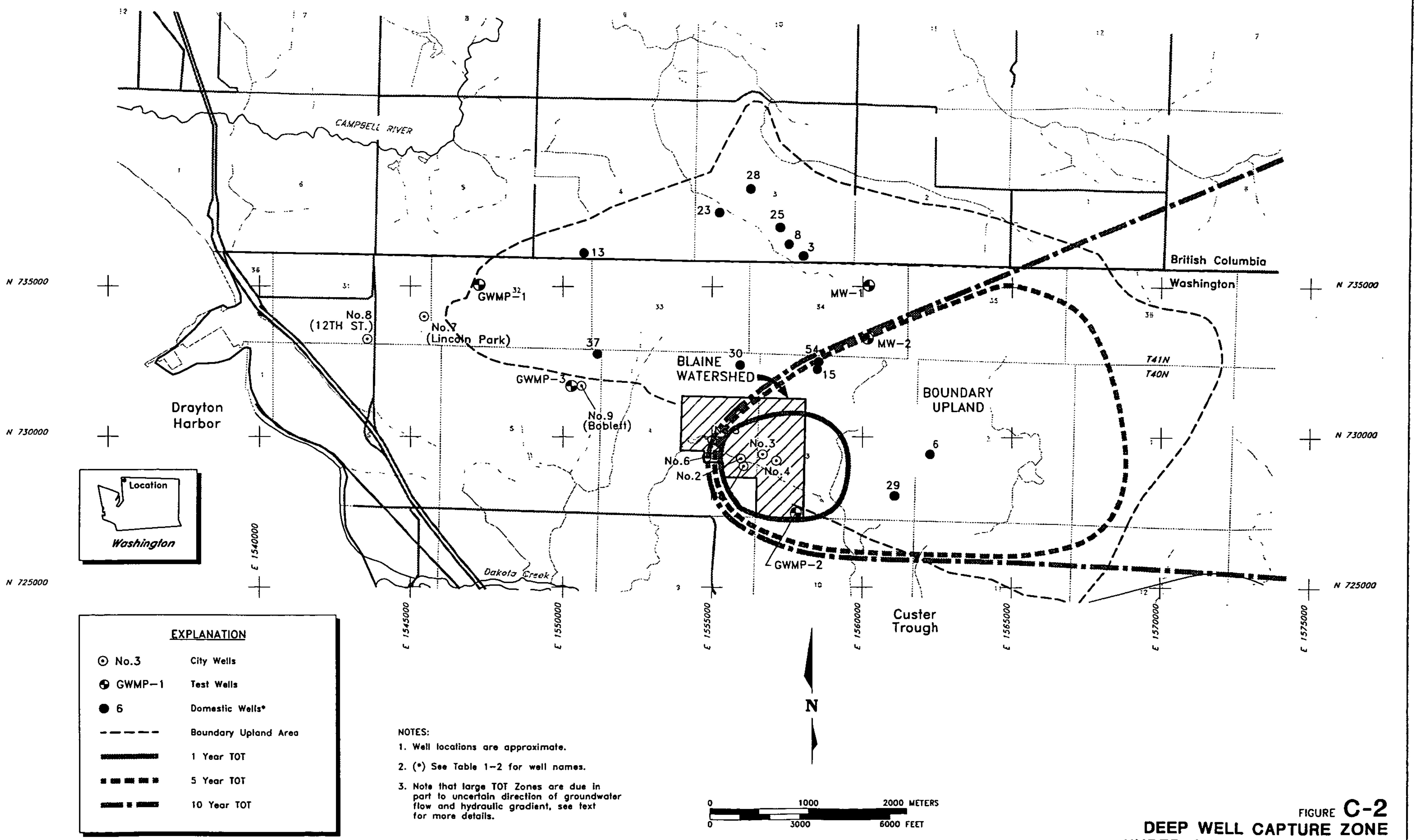


FIGURE **C-1**

SHALLOW WELL CAPTURE ZONE UNDER CURRENT CONDITIONS

CITY OF BLAINE/BLAINE WHPP/WA

Golder Associates



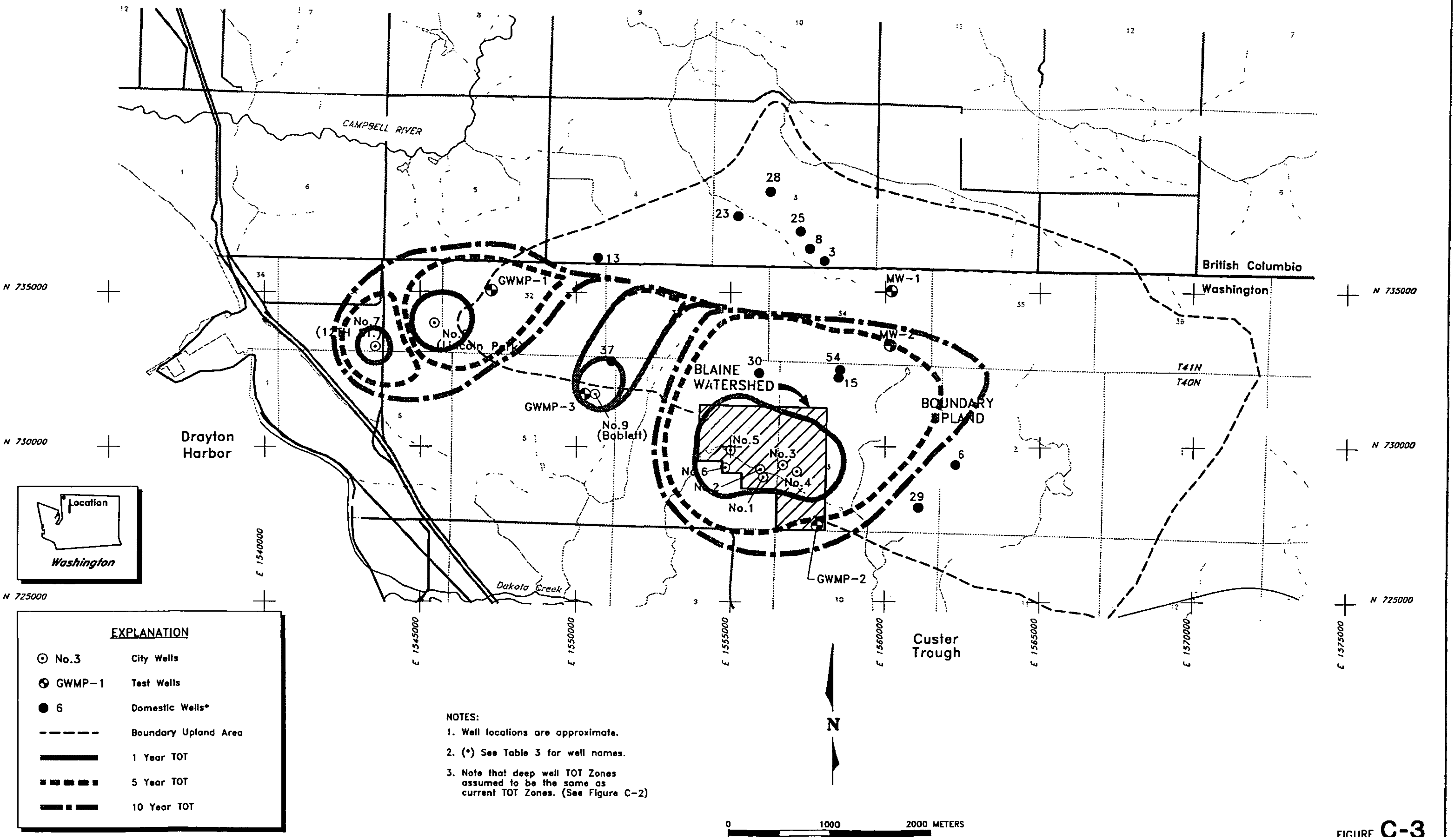
NOTES:

1. Well locations are approximate.
2. (*) See Table 1-2 for well names.
3. Note that large TOT Zones are due in part to uncertain direction of groundwater flow and hydraulic gradient, see text for more details.

FIGURE C-2

DEEP WELL CAPTURE ZONE UNDER CURRENT CONDITIONS

CITY OF BLAINE/BLAINE WHPP/WA



NOTES:

1. Well locations are approximate.
2. (*) See Table 3 for well names.
3. Note that deep well TOT Zones assumed to be the same as current TOT Zones. (See Figure C-2)

FIGURE C-3

SHALLOW WELL CAPTURE ZONE UNDER FUTURE CONDITIONS

CITY OF BLAINE/BLAINE WHPP/WA

C:\DPT\9431673\107\63736 2-22-96 14:27 xrf: NONE

Golder Associates

APPENDIX D

NITRATE LOAD ANALYSIS

TABLE D-1

Nitrate Loading Under Current Conditions

TOTAL NITRATE CONCENTRATION - ESTIMATION OF LOAD FROM BOUNDARY UPLAND

Scenario 0: Unsewered Housing under Current Conditions

Model Parameters:

Total Recharge from Boundary Upland: 3.7 cfs

Total Area: 2077.4 acres

Area of proposed Annexation 1200 acres

Action Level: 5 mg/L (half of MCL)

Critical Load: 45,254 gm/day

Source	Description	Total Area	# of	Fertilizer Area (acres) (1)				Nitrate Applic. (lbs/1,000 ft^2/yr)(2a)				Portion of Nitrate Leached to Watertable(2b)				Load
		(acres)	Units	Min	Max	Mean	Expected	Min	Max	Mean	Expected	Min	Max	Mean	Expected	(gm/day)
Fertilizer	5-Arce Housing	1200.0	200	23.0	27.5	25.3	26.2	2.0	3.0	2.5	2.4	10.0%	60.0%	35.0%	43.6%	1,499

Source	Description	Total Area	Flow (gal/day per person)(3)				# of	Persons/	Volume	Potential Nitrate Conc. (mg/L)(3)				Load
		(acres)	Min	Max	Mean	Expected	Units	Unit	(L/d)	Min	Max	Mean	Expected	(gm/day)
Septic	5-Acre Housing	1200	50	70	60	66	200	2.5	124,066	30	40	35	32	3,961

Predicted Contam. Load: 5,460

Method: Risk-based analysis - using EXCEL & CRYSTAL BALL

Assumption: Triangular distribution assumed for all parameters, including source concentrations. Statistics for variables (minumum, maximum, mean, and expected value) are shown on tables.

Total Pumping Rate:	2 cfs
Pumping Volume:	1.79E+09 L/yr
Boundary Upland Volume :	3.30E+09 L/yr
Load from Boundary Upland:	1,993 kg/yr
Predicted Total Future Load:	1,993 kg/yr
Predicted Fut. Well Con (4):	0.60 mg/L

*Assumed Present Well Conc: 0 mg/L (Background)

(1) Frimpter, H. et al, 1990. A Mass-Balance Nitrate Model for Predicting the Effects of Land Use on Groundwater Quality. U.S. Geological Survey OFR 88-493. Appendix A, Table 9A, Section 9.

(2) Frimpter, H. et al, 1990. A Mass-Balance Nitrate Model for Predicting the Effects of Land Use on Groundwater Quality. U.S. Geological Survey OFR 88-493

(2a) Appendix A, Table 7A and Section 8; (2b) Appendix A, Section 9.

(3) Frimpter, H. et al, 1990. A Mass-Balance Nitrate Model for Predicting the Effects of Land Use on Groundwater Quality. U.S. Geological Survey OFR 88-493. Appendix A, Table 1A, Section 1.

(4) Based on mixing of Boundary Upland infiltration and total groundwater production.

Statistical Analysis Results

Predicted Concentration at 10%	0.5 mg/L
Predicted Concentration at 50%	0.57 mg/L
Predicted Concentration at 90%	0.65 mg/L

TABLE D-2

Nitrate Loading From Development of One-Acre Parcels

TOTAL NITRATE CONCENTRATION - ESTIMATION OF LOAD FROM BOUNDARY UPLAND

Scenario 1: Unsewered Housing on One-Acre parcels

Model Parameters:

Total Recharge from Boundary Upland:	3.7	cfs	Action Level:	5	mg/L (half of MCL)
Total Area:	2077.4	acres	Critical Load:	45,254	gm/day
Area of proposed Annexation	1200	acres			
Zoning outside annex ed area= 1 unit/10 acres (70 units)		80% of total area to be developed			

Source	Description	Total Area (acres)	# of Units	Fertilizer Area (acres) (1)				Nitrate Applic. (lbs/1,000 ft²/yr)(2a)				Portion of Nitrate Leached to Watertable(2b)				Load (gm/day)
				Min	Max	Mean	Expected	Min	Max	Mean	Expected	Min	Max	Mean	Expected	
Fertilizer	1-Acre Housing	1200.0	1030	118.2	141.9	130.1	126.3	2.0	3.0	2.5	2.7	10.0%	60.0%	35.0%	39.0%	7,079

Source	Description	Total Area (acres)	Flow (gal/day per person)(3)				# of Units	Persons/ Unit	Volume (L/d)	Potential Nitrate Conc. (mg/L)(3)				Load (gm/day)
			Min	Max	Mean	Expected				Min	Max	Mean	Expected	
Septic	1-Acre Housing	1200	50	70	60	68	1030	2.5	657,927	30	40	35	38	25,106

Predicted Contam. Load: 32,185

Method: Risk-based analysis - using EXCEL & CRYSTAL BALL

Assumption: Triangular distribution assumed for all parameters, including source concentrations. Statistics for variables (minumum, maximum, mean, and expected value) are shown on tables.

Total Pumping Rate:	2 cfs
Pumping Volume:	1.79E+09 L/yr
Boundary Upland Volume:	3.30E+09 L/yr
Load from Boundary Upland:	11,748 kg/yr
Predicted Total Future Load:	15,052 kg/yr
Predicted Fut. Well Con (4):	4.56 mg/L

*Assumed Present Well Conc: 1 mg/L (Background)

(1) Frimpter, H. et al, 1990. A Mass-Balance Nitrate Model for Predicting the Effects of Land Use on Groundwater Quality. U.S. Geological Survey OFR 88-493. Appendix A, Table 9A, Section 9.

(2) Frimpter, H. et al, 1990. A Mass-Balance Nitrate Model for Predicting the Effects of Land Use on Groundwater Quality. U.S. Geological Survey OFR 88-493

(2a) Appendix A, Table 7A and Section 8; (2b) Appendix A, Section 9.

(3) Frimpter, H. et al, 1990. A Mass-Balance Nitrate Model for Predicting the Effects of Land Use on Groundwater Quality. U.S. Geological Survey OFR 88-493. Appendix A, Table 1A, Section 1.

(4) Based on mixing of Boundary Upland infiltration and total groundwater production.

Statistical Analysis Results

Predicted Concentration at 10%	3.71	mg/L
Predicted Concentration at 50%	4.11	mg/L
Predicted Concentration at 90%	4.5	mg/L

TABLE D-3

Nitrate Loading From Development of Five-Acre Parcels

TOTAL NITRATE CONCENTRATION - ESTIMATION OF LOAD FROM BOUNDARY UPLAND

Scenario 2: Unsewered Housing on Five-Acre parcels

Model Parameters:

Total Recharge from Boundary Upland:	3.7	cfs	Action Level:	5	mg/L (half of MCL)
Total Area:	2077.4	acres	Critical Load:	45,254	gm/day
Area of proposed Annexation	1200	acres			

Zoning outside annex ed area = 1 unit/10 acres (70 units) 80% of total area to be developed

Source	Description	Total Area (acres)	# of Units	Fertilizer Area (acres) (1)				Nitrate Applic. (lbs/1,000 ft^2/yr)(2a)				Portion of Nitrate Leached to Watertable(2b)				Load (gm/day)
				Min	Max	Mean	Expected	Min	Max	Mean	Expected	Min	Max	Mean	Expected	
Fertilizer	5-Acre Housing	1200.0	262	30.1	36.1	33.1	34.1	2.0	3.0	2.5	2.2	10.0%	60.0%	35.0%	32.9%	1,351

Source	Description	Total Area (acres)	Flow (gal/day per person)(3)				# of Units	Persons/ Unit	Volume (L/d)	Potential Nitrate Conc. (mg/L)(3)				Load (gm/day)
			Min	Max	Mean	Expected				Min	Max	Mean	Expected	
Septic	5-Acre Housing	1200	50	70	60	64	262	2.5	159,495	30	40	35	34	5,393

Predicted Contam. Load: 6,743

Method: Risk-based analysis - using EXCEL & CRYSTAL BALL

Assumption: Triangular distribution assumed for all parameters, including source concentrations. Statistics for variables (minumum, maximum, mean, and expected value) are shown on tables.

Total Pumping Rate:	2 cfs
Pumping Volume:	1.79E+09 L/yr
Boundary Upland Volume:	3.30E+09 L/yr
Load from Boundary Upland:	2,461 kg/yr
Predicted Total Future Load:	5,766 kg/yr
Predicted Fut. Well Con (4):	1.74 mg/L

*Assumed Present Well Conc: 1 mg/L (Background)

(1) Frimpter, H. et al, 1990. A Mass-Balance Nitrate Model for Predicting the Effects of Land Use on Groundwater Quality. U.S. Geological Survey OFR 88-493. Appendix A, Table 9A, Section 9.

(2) Frimpter, H. et al, 1990. A Mass-Balance Nitrate Model for Predicting the Effects of Land Use on Groundwater Quality. U.S. Geological Survey OFR 88-493

(2a) Appendix A, Table 7A and Section 8; (2b) Appendix A, Section 9.

(3) Frimpter, H. et al, 1990. A Mass-Balance Nitrate Model for Predicting the Effects of Land Use on Groundwater Quality. U.S. Geological Survey OFR 88-493. Appendix A, Table 1A, Section 1.

(4) Based on mixing of Boundary Upland infiltration and total groundwater production.

Statistical Analysis Results

Predicted Concentration at 10%	1.66 mg/L
Predicted Concentration at 50%	1.76 mg/L
Predicted Concentration at 90%	1.85 mg/L

TABLE D-4

Nitrate Loading From Development of One Quarter-Acre Parcel

TOTAL NITRATE CONCENTRATION - ESTIMATION OF LOAD FROM BOUNDARY UPLAND

Scenario 3: Sewered Housing on One Quarter-Acre Parcels and Unsewered Housing on 10-Acre Parcels

Model Parameters:

Total Recharge from Boundary Upland:	3.7	cfs	Action Level:	5	mg/L (half of MCL)
Total Area:	2077.4	acres	Critical Load:	45,254	gm/day
Area of proposed Annexation	1200	acres			

Zoning outside annex ed area = 1 unit/10 acres (70 units) 80% of total area to be developed

Source	Description	Total Area (acres)	# of Units	Fertilizer Area (acres) (1)				Nitrate Applic. (lbs/1,000 ft²/yr)(2a)				Portion of Nitrate Leached to Watertable(2b)				Load (gm/day)
				Min	Max	Mean	Expected	Min	Max	Mean	Expected	Min	Max	Mean	Expected	
Fertilizer	Mixed Zoning	1200.0	3910	448.8	538.6	493.7	520.0	2.0	3.0	2.5	2.2	10.0%	60.0%	35.0%	34.1%	20,984

Source	Description	Total Area (acres)	Flow (gal/day per person)(3)				# of Units	Persons/ Unit	Volume (L/d)	Potential Nitrate Conc. (mg/L)(3)				Load (gm/day)
			Min	Max	Mean	Expected				Min	Max	Mean	Expected	
Septic	Mixed Zoning	1200	50	70	60	55	70	2.5	36,215	30	40	35	39	1,395

Predicted Contam. Load: 22,379

Method: Risk-based analysis - using EXCEL & CRYSTAL BALL

Assumption: Triangular distribution assumed for all parameters, including source concentrations. Statistics for variables (minumum, maximum, mean, and expected value) are shown on tables.

Total Pumping Rate:	2	cfs
Pumping Volume:	1.79E+09	L/yr
Boundary Upland Volume:	3.30E+09	L/yr
Load from Boundary Upland:	8,168	kg/yr
Predicted Total Future Load:	11,473	kg/yr
Predicted Fut. Well Con (4):	3.47	mg/L

*Assumed Present Well Conc: 1 mg/L (Background)

(1) Frimpter, H. et al, 1990. A Mass-Balance Nitrate Model for Predicting the Effects of Land Use on Groundwater Quality. U.S. Geological Survey OFR 88-493. Appendix A, Table 9A, Section 9.

(2) Frimpter, H. et al, 1990. A Mass-Balance Nitrate Model for Predicting the Effects of Land Use on Groundwater Quality. U.S. Geological Survey OFR 88-493

(2a) Appendix A, Table 7A and Section 8; (2b) Appendix A, Section 9.

(3) Frimpter, H. et al, 1990. A Mass-Balance Nitrate Model for Predicting the Effects of Land Use on Groundwater Quality. U.S. Geological Survey OFR 88-493. Appendix A, Table 1A, Section 1.

(4) Based on mixing of Boundary Upland infiltration and total groundwater production.

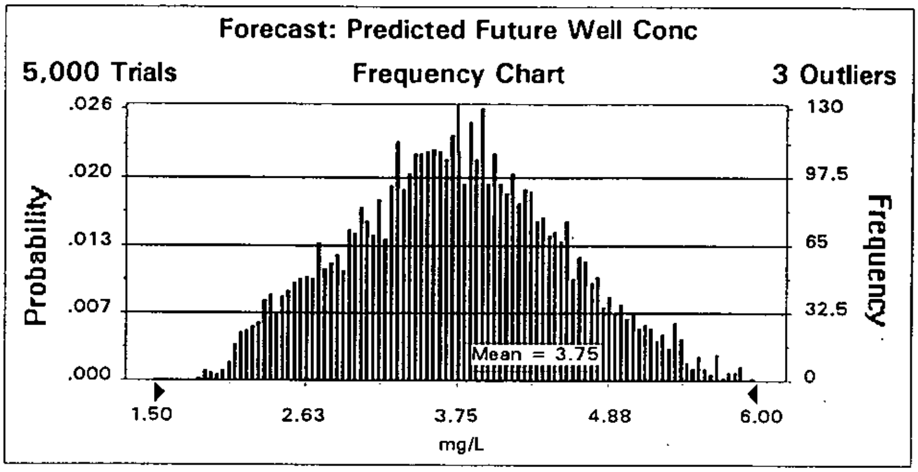
Statistical Analysis Results

Predicted Concentration at 10%	2.68	mg/L
Predicted Concentration at 50%	3.74	mg/L
Predicted Concentration at 90%	4.79	mg/L

NITRATE LOADING STATISTICS AND ASSUMPTIONS

Crystal Ball Report
Simulation started on 10/11/96 at 17:20:01
Simulation stopped on 10/11/96 at 17:21:41

Forecast: Predicted Future Well Conc **[APPDTAB.XLS]TableD-4 - Cell: C30**
One-Quarter Acre Lot Sewered Development



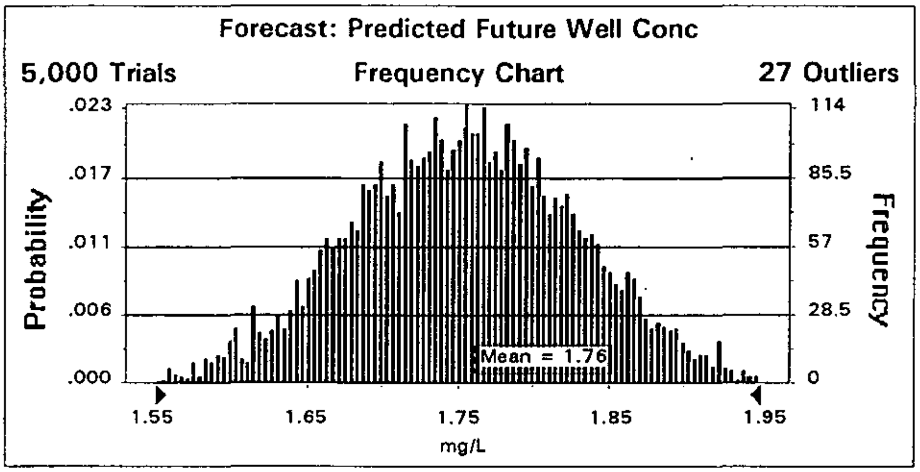
Percentiles:

Percentile	mg/L
0%	1.86
10%	2.68
20%	3.05
30%	3.32
40%	3.54
50%	3.74
60%	3.95
70%	4.17
80%	4.43
90%	4.79
100%	6.06

End of Forecast

NITRATE LOADING STATISTICS AND ASSUMPTIONS

Forecast: Predicted Future Well Conc **[APPDTAB.XLS]TableD-3 - Cell: C30**
Five-Acre Lot Unsewered Development



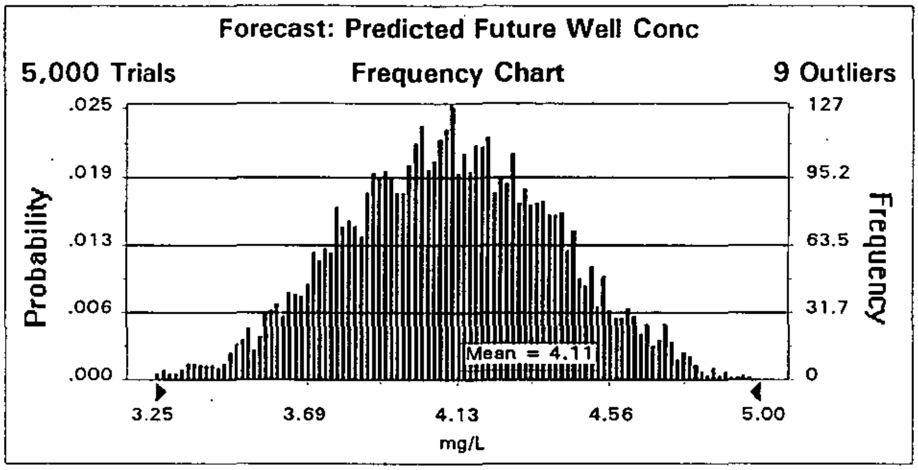
Percentiles:

Percentile	mg/L
0%	1.52
10%	1.66
20%	1.69
30%	1.71
40%	1.74
50%	1.76
60%	1.77
70%	1.80
80%	1.82
90%	1.85
100%	2.03

End of Forecast

NITRATE LOADING STATISTICS AND ASSUMPTIONS

Forecast: Predicted Future Well Conc **[APPDTAB.XLS]TableD-2 - Cell: C30**
One-Acre Lot Unsewered Development



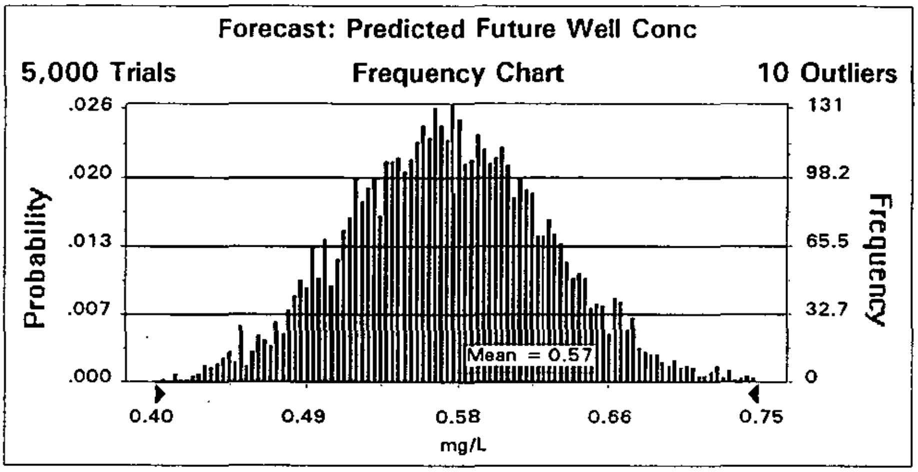
Percentiles:

Percentile	mg/L
0%	3.14
10%	3.71
20%	3.84
30%	3.94
40%	4.03
50%	4.11
60%	4.19
70%	4.28
80%	4.37
90%	4.50
100%	5.04

End of Forecast

NITRATE LOADING STATISTICS AND ASSUMPTIONS

Forecast: Predicted Future Well Conc **[APPDTAB.XLS]TableD-1 - Cell: C29**
Present Conditions



Percentiles:

Percentile	mg/L
0%	0.39
10%	0.50
20%	0.52
30%	0.54
40%	0.56
50%	0.57
60%	0.59
70%	0.60
80%	0.62
90%	0.65
100%	0.76

End of Forecast

NITRATE LOADING STATISTICS AND ASSUMPTIONS

Assumptions

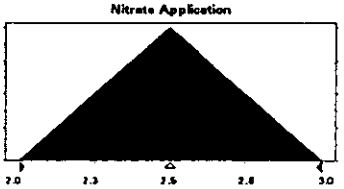
One-Quarter Acre Lot Sewered Development

Assumption: Nitrate Application **[APPDTAB.XLS]TableD-4 - Cell: L13**

Triangular distribution with parameters:

Minimum	2.0	(=I13)
Likeliest	2.5	(=K13)
Maximum	3.0	(=J13)

Selected range is from 2.0(=I13) to 3.0(=J13)
Mean value in simulation was 2.5

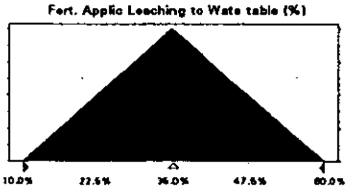


Assumption: Fert. Applic Leaching to Wate table (%) **[APPDTAB.XLS]TableD-4 - Cell: P13**

Triangular distribution with parameters:

Minimum	10.0%	(=M13)
Likeliest	35.0%	(=O13)
Maximum	60.0%	(=N13)

Selected range is from 10.0%(=M13) to 60.0%(=N13)
Mean value in simulation was 35.1%



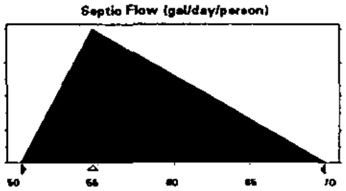
NITRATE LOADING STATISTICS AND ASSUMPTIONS

Assumption: Septic Flow (gal/day/person) **[APPDTAB.XLS]TableD-4 - Cell: G18**

Triangular distribution with parameters:

Minimum	50	(=D18)
Likeliest	55	(=G18)
Maximum	70	(=E18)

Selected range is from 50 to 70
Mean value in simulation was 58

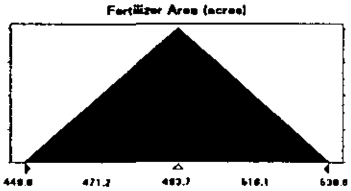


Assumption: Fertilizer Area (acres) **[APPDTAB.XLS]TableD-4 - Cell: H13**

Triangular distribution with parameters:

Minimum	448.8	(=E13)
Likeliest	493.7	(=G13)
Maximum	538.6	(=F13)

Selected range is from 448.8 to 538.6
Mean value in simulation was 493.7



Assumption: Potential Nitrate Concentration (mg/L) **[APPDTAB.XLS]TableD-4 - Cell: N18**

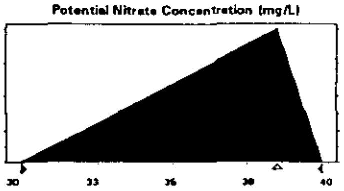
Triangular distribution with parameters:

Minimum	30	(=K18)
Likeliest	39	(=N18)
Maximum	40	(=L18)

Selected range is from 30 to 40
Mean value in simulation was 36

NITRATE LOADING STATISTICS AND ASSUMPTIONS

Assumption: Potential Nitrate Concentration (mg/L) (cont'd) [APPDTAB.XLS]TableD-4 - Cell: N18



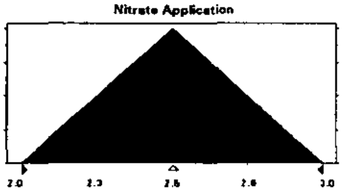
Five-Acre Lot Unsewered Development

Assumption: Nitrate Application [APPDTAB.XLS]TableD-3 - Cell: L13

Triangular distribution with parameters:

Minimum	2.0	(=I13)
Likeliest	2.5	(=K13)
Maximum	3.0	(=J13)

Selected range is from 2.0(=I13) to 3.0(=J13)
Mean value in simulation was 2.5

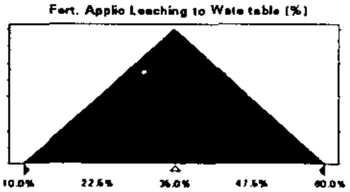


Assumption: Fert. Applic Leaching to Wate table (%) [APPDTAB.XLS]TableD-3 - Cell: P13

Triangular distribution with parameters:

Minimum	10.0%	(=M13)
Likeliest	35.0%	(=O13)
Maximum	60.0%	(=N13)

Selected range is from 10.0%(=M13) to 60.0%(=N13)
Mean value in simulation was 35.1%



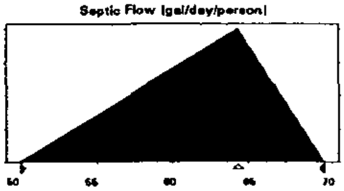
NITRATE LOADING STATISTICS AND ASSUMPTIONS

Assumption: Septic Flow (gal/day/person) **[APPDTAB.XLS]TableD-3 - Cell: G18**

Triangular distribution with parameters:

Minimum	50	(=D18)
Likeliest	64	(=G18)
Maximum	70	(=E18)

Selected range is from 50 to 70
Mean value in simulation was 61

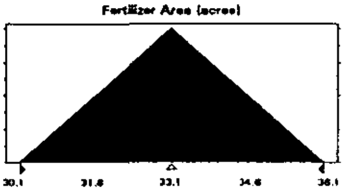


Assumption: Fertilizer Area (acres) **[APPDTAB.XLS]TableD-3 - Cell: H13**

Triangular distribution with parameters:

Minimum	30.1	(=E13)
Likeliest	33.1	(=G13)
Maximum	36.1	(=F13)

Selected range is from 30.1 to 36.1
Mean value in simulation was 33.1



Assumption: Potential Nitrate Concentration (mg/L) **[APPDTAB.XLS]TableD-3 - Cell: N18**

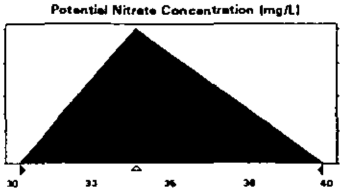
Triangular distribution with parameters:

Minimum	30	(=K18)
Likeliest	34	(=N18)
Maximum	40	(=L18)

Selected range is from 30 to 40
Mean value in simulation was 35

NITRATE LOADING STATISTICS AND ASSUMPTIONS

Assumption: Potential Nitrate Concentration (mg/L) (cont'd) **[APPDTAB.XLS]TableD-3 - Cell: N18**



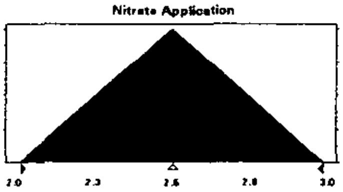
<u>One-Acre Lot Unsewered Development</u>

Assumption: Nitrate Application **[APPDTAB.XLS]TableD-2 - Cell: L13**

Triangular distribution with parameters:

Minimum	2.0	(=I13)
Likeliest	2.5	(=K13)
Maximum	3.0	(=J13)

Selected range is from 2.0(=I13) to 3.0(=J13)
Mean value in simulation was 2.5

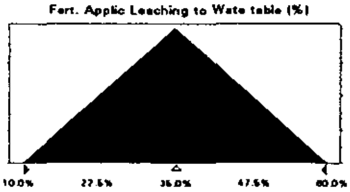


Assumption: Fert. Applic Leaching to Wate table (%) **[APPDTAB.XLS]TableD-2 - Cell: P13**

Triangular distribution with parameters:

Minimum	10.0%	(=M13)
Likeliest	35.0%	(=O13)
Maximum	60.0%	(=N13)

Selected range is from 10.0%(=M13) to 60.0%(=N13)
Mean value in simulation was 35.3%



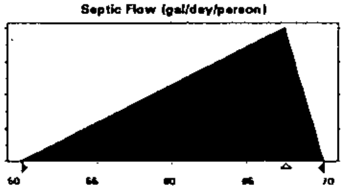
NITRATE LOADING STATISTICS AND ASSUMPTIONS

Assumption: Septic Flow (gal/day/person) **[APPDTAB.XLS]TableD-2 - Cell: G18**

Triangular distribution with parameters:

Minimum	50	(=D18)
Likeliest	68	(=G18)
Maximum	70	(=E18)

Selected range is from 50 to 70
Mean value in simulation was 62

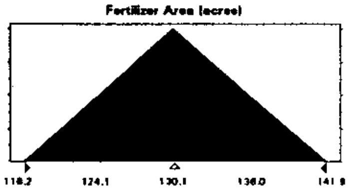


Assumption: Fertilizer Area (acres) **[APPDTAB.XLS]TableD-2 - Cell: H13**

Triangular distribution with parameters:

Minimum	118.2	(=E13)
Likeliest	130.1	(=G13)
Maximum	141.9	(=F13)

Selected range is from 118.2 to 141.9
Mean value in simulation was 130.0



Assumption: Potential Nitrate Concentration (mg/L) **[APPDTAB.XLS]TableD-2 - Cell: N18**

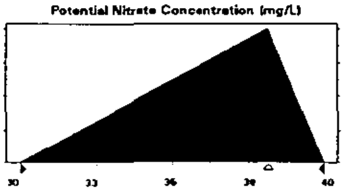
Triangular distribution with parameters:

Minimum	30	(=K18)
Likeliest	38	(=N18)
Maximum	40	(=L18)

Selected range is from 30 to 40
Mean value in simulation was 36

NITRATE LOADING STATISTICS AND ASSUMPTIONS

Assumption: Potential Nitrate Concentration (mg/L) (cont'd) **[APPDTAB.XLS]TableD-2 - Cell: N18**

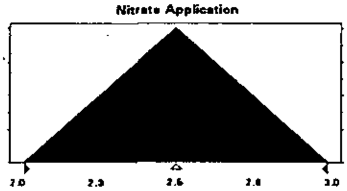


<u>Present Conditions</u>
Assumption: Nitrate Application **[APPDTAB.XLS]TableD-1 - Cell: L12**

Triangular distribution with parameters:

Minimum	2.0	(=I12)
Likeliest	2.5	(=K12)
Maximum	3.0	(=J12)

Selected range is from 2.0(=I12) to 3.0(=J12)
Mean value in simulation was 2.5

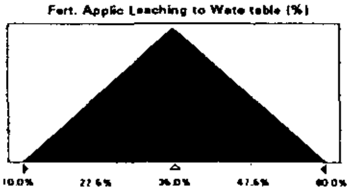


Assumption: Fert. Applic Leaching to Wate table (%) **[APPDTAB.XLS]TableD-1 - Cell: P12**

Triangular distribution with parameters:

Minimum	10.0%	(=M12)
Likeliest	35.0%	(=O12)
Maximum	60.0%	(=N12)

Selected range is from 10.0%(=M12) to 60.0%(=N12)
Mean value in simulation was 34.9%



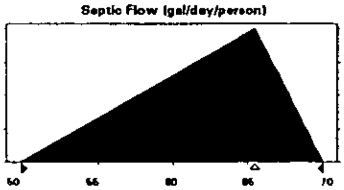
NITRATE LOADING STATISTICS AND ASSUMPTIONS

Assumption: Septic Flow (gal/day/person) **[APPDTAB.XLS]TableD-1 - Cell: G17**

Triangular distribution with parameters:

Minimum	50	(=D17)
Likeliest	66	(=G17)
Maximum	70	(=E17)

Selected range is from 50 to 70
Mean value in simulation was 62

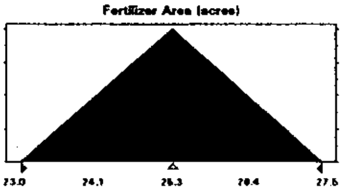


Assumption: Fertilizer Area (acres) **[APPDTAB.XLS]TableD-1 - Cell: H12**

Triangular distribution with parameters:

Minimum	23.0	(=E12)
Likeliest	25.3	(=G12)
Maximum	27.5	(=F12)

Selected range is from 23.0 to 27.5
Mean value in simulation was 25.3



Assumption: Potential Nitrate Concentration (mg/L) **[APPDTAB.XLS]TableD-1 - Cell: N17**

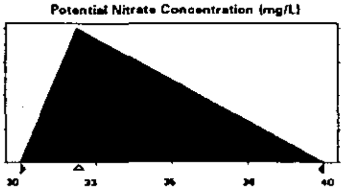
Triangular distribution with parameters:

Minimum	30	(=K17)
Likeliest	32	(=N17)
Maximum	40	(=L17)

Selected range is from 30 to 40
Mean value in simulation was 34

NITRATE LOADING STATISTICS AND ASSUMPTIONS

Assumption: Potential Nitrate Concentration (mg/L) (cont'd) **[APPDTAB.XLS]TableD-1 - Cell: N17**



End of Assumptions

APPENDIX E

EPA RISK RANKING ANALYSIS

TECHNICAL APPENDIX A: ASSUMPTIONS AND LIMITATIONS OF THE PRIORITY SETTING APPROACH

The Priority Setting Approach incorporates many assumptions. This appendix discusses the major assumptions regarding aquifer physical properties, zone of contribution, potential contamination sources, toxicity of contaminants or contaminant mixtures, and dense and light non-aqueous phase liquids. It also provides a summary of the effects on the risk scores if these assumptions vary from actual field settings.

Aquifer Physical Properties

The theoretical basis of this Approach's transport component includes two elements: (1) the Darcy flow law to describe the movement of contaminants from the source to the aquifer in the unsaturated zone and (2) an analytical two-dimensional transport model (developed by Wilson and Miller) to describe the movement of contaminants in the saturated zone from directly below the source to the wellhead.

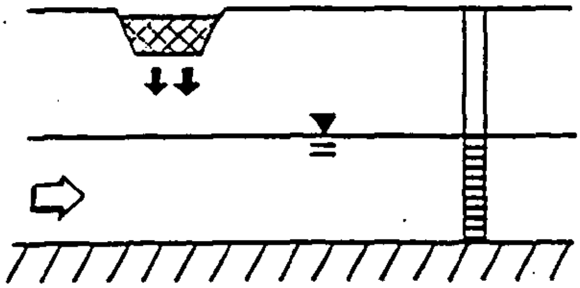
Several basic hydrogeologic settings can be reasonably evaluated using the Priority Setting Approach, as presented in Exhibit A-1. In Setting 1, contamination from the source is released into an unconfined (water table) aquifer and is intercepted by a well in the same aquifer. In Setting 2, contamination results from the failure in a confined aquifer of the casing of a Class I, II, or III injection well. This contamination is then intercepted by a well drawing water from the same confined aquifer. Setting 3 involves a contamination source in a recharge zone for a confined aquifer that is in direct hydraulic connection with the ground surface. This situation occurs if the confining layer is relatively thin or absent in the recharge zone. In Setting 4, the aquifer is overlain by a fine-grained clay that serves as a confining layer. In wells that penetrate the confining layer into the aquifer, the water level rises above the aquifer. This water level reflects the potentiometric surface of the aquifer. In this case, users should be careful to use the distance from the source to the top of the confined aquifer, and not to the potentiometric surface, as the depth to aquifer when completing the Wellhead Datasheet.

This Approach is designed to evaluate potential sources of contamination in a single aquifer-single well system. To evaluate a composite hydrogeologic setting using this Approach, each aquifer and its associated contamination sources must be considered separately.

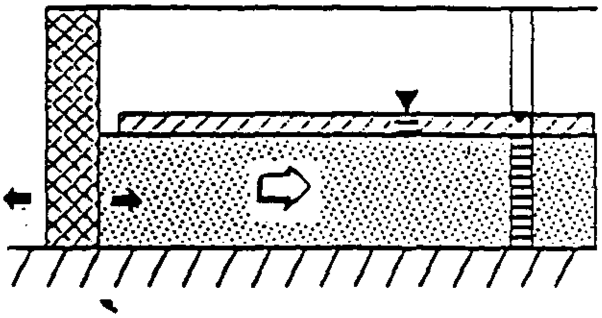
Exhibit A-1

Hydrogeologic Settings that Can Be Evaluated with the Priority Setting Approach

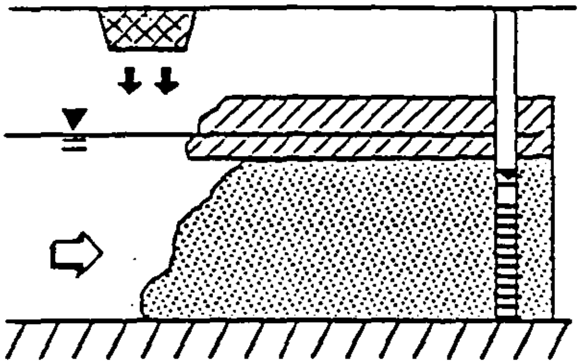
Setting 1. Surface Contamination Source-Unconfined (Water Table) Aquifer



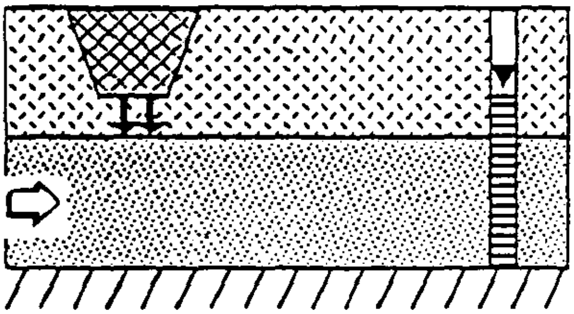
Setting 2. Deep Source-Confined Aquifer

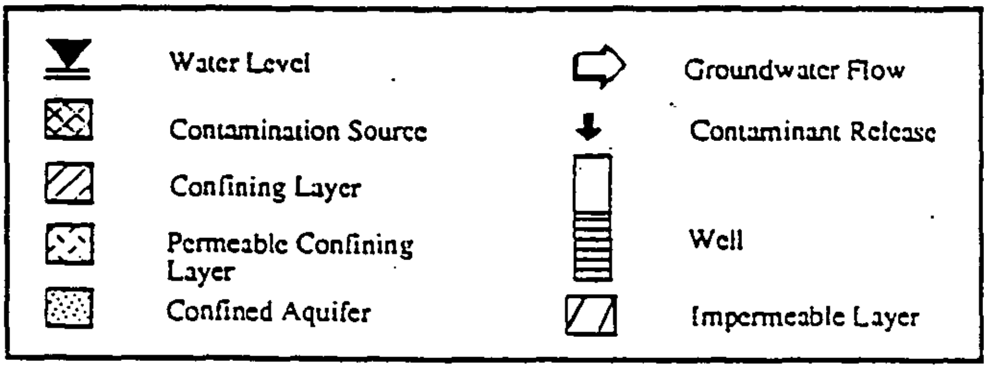


Setting 3. Surface Source in Recharge Area- Confined Aquifer



Setting 4. Surface Source-Confined Aquifer





This Approach assumes homogeneity and isotropy of the hydrogeologic system within the WHPA. In particular, it assumes that the hydrogeologic parameters are uniform throughout the WHPA,[1] that uniform and steady flow prevails, and that the aquifer is of infinite extent. This implies that the thickness and flow rate in the unsaturated and saturated zones are constant. Moreover, the flow velocity in the aquifer is assumed to reflect both the effects of the regional hydraulic gradient and pumping stresses, and is set to an average constant for the entire WHPA.

This Approach provides default hydraulic conductivity values as a function of the type of material (e.g., sand or clay); these defaults do not vary between the saturated and unsaturated zones. Default flow velocities are based upon a unit hydraulic gradient and an average porosity of 0.3. This requires that the effect of drawdown near the well in an unconfined aquifer be relatively small compared to the saturated thickness. Consequently, it is assumed that pumping rates are not so excessive so as to completely dewater even a fine-grained aquifer. If the user does not know the pumping rate in an aquifer consisting primarily of sand, then he or she should select the appropriate ground-water velocity score from Table W.4. Finally, it is assumed that wells fully penetrate the aquifer.

Zone of Contribution

WHPAs can be delineated using a variety of techniques ranging from simple, somewhat arbitrary graphical techniques to complicated methods based upon analytic or numerical modeling. In practice, the WHPA boundary may coincide with a ground-water divide, lithologic boundary, or even a jurisdictional border. This Approach assumes that the boundaries of a WHPA are contained within the zone of contribution, as described in the Office of Ground Water and Drinking Water's "Delineation of Wellhead Protection Areas." Depending on how the WHPA has been delineated, there may exist contamination sources in the zone of contribution that are not located inside the WHPA. If you know of such sources, you may want to evaluate them in addition to sources located inside the WHPA.

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[1] The Darcy flow law and Wilson and Miller model consider the following major parameters: vertical distance from the contamination source to the top of the aquifer, unsaturated hydraulic conductivity, longitudinal distance from the contamination source to the wellhead, aquifer flow velocity, porosity, and transverse dispersivity (a measure of how fast contamination spreads in the direction perpendicular to the prevailing ground-water direction).

Contamination Sources

The Priority Setting Approach also makes assumptions about the physical and chemical characteristics of the sources of potential contamination. For example, it is assumed that the contamination is in the form of an aqueous solution having the same density and viscosity as water. It is further assumed that constituent concentrations do not vary with time. The transport model considers each source as a point source and assumes that concentrations do not vary in the vertical dimension. Retardation coefficients and biodegradation rates are also assumed to be constants that are not affected by concentration or by mixture with other constituents. Leakage from a contamination source is assumed to influence neither the shape of the water table nor the prevailing ground-water velocity. Finally, this Approach assumes that the contamination at the wellhead is not diluted from capture of "clean water" during pumping.

Toxicity of the Contaminant

Toxicity of the contaminant indicates the potential health hazard posed by ingesting the contaminant. The Toxicity scores are based on established dose-response relationships obtained from EPA's Integrated Risk Information System (IRIS) or from the RASH database (only for a few contaminants). Using these dose-response relationships, a "critical dose" is defined for each contaminant, which represents the dose at which health risks become of concern.

Because carcinogens and non-carcinogens act differently on the body, the critical dose is defined differently for each of them (note that the Priority Setting Approach does not address microbiological contaminants). For non-carcinogens, the critical dose is defined as the EPA-defined oral reference dose (RfD), which is the threshold exposure level at which health effects begin to occur. For carcinogens, it is generally assumed that no threshold levels exist because any level can cause cancer. Therefore, for carcinogens, the critical dose is defined as the dose that increases the risk of cancer by 10^{-5} over background levels; i.e., an excess cancer risk of 1 in 100,000. This Approach converts these critical doses into critical concentrations (in milligrams per liter of drinking water) using standard Office of Ground Water and Drinking Water assumptions (i.e., two liters consumed per day over a 70-year lifetime exposure period).

Toxicity of the contaminant is defined as the decimal logarithm of the inverse of the critical concentration in mg/l. Thus, the Toxicity Score T has units of $\log_{10}(1/(\text{mg/l}))$. You read the Toxicity score T directly from a concentration scoring graph (end of Form S.1) or a table (Form S.2).

Because the health risks posed by carcinogens and non-carcinogens are very different, as are the methods used to define these risks, many users may prefer to track them separately. If you choose to produce only one screening and ranking of all sources, then you can consider both carcinogens and non-carcinogens together. In this case, the Priority Setting Approach has a built-in formula for comparing carcinogenic and non-carcinogenic risks. As discussed previously, this Approach implicitly equates a 10^{-5} lifetime cancer risk to a lifetime exposure to the reference dose (RfD) for non-carcinogens. You can alter this assumption to reflect different policy calls. For example, you can choose to equate a 10^{-6} lifetime cancer risk to a lifetime exposure to the reference dose (RfD) for non-carcinogens. In this case, you should add a 1 to all the risk scores for carcinogenic contaminants as computed in Task V, Step 1. If you choose to equate a 10^{-4} lifetime cancer risk to a lifetime exposure to the reference dose (RfD) for non-carcinogens, then you should subtract a 1 from all the risk scores for carcinogenic contaminants.

Dense and Light Non-Aqueous Phase Liquids (DNAPLs and LNAPLs)

Dense non-aqueous phase liquids (DNAPLs), also known as sinkers, and light non-aqueous phase liquids (LNAPLs), also known as floaters, are ground-water contaminants that are relatively insoluble in water and have densities greater than and less than water, respectively. Due to their density and limited solubility in water, DNAPLs and LNAPLs can pose special risks to ground-water quality. If released in large quantities, these liquids can migrate vertically under the influence of gravity (i.e., sink to the bottom of the saturated zone if a DNAPL or float on the water table if an LNAPL) and act as a highly concentrated, long-term source of contamination.

The Priority Setting Approach allows you to recognize DNAPLs and LNAPLs in two stages. First, contaminant Form S.1 notes those contaminants that are potential DNAPLs or LNAPLs (see Task II, Step 5). Second, this Approach provides a rule of thumb for determining whether a potential DNAPL or LNAPL will act as a true DNAPL or LNAPL based on the quantity of the contaminant released. Specifically, a potential DNAPL or LNAPL will act as a true DNAPL or LNAPL if the Quantity score for that contaminant is greater than or equal to 3; that is, if the contaminant is released at an annual rate of 1,000 kg per year or more (see Task III, Step 6).

The Transport Worksheet does not model the fate and transport phenomena specific to DNAPLs and LNAPLs. These liquids follow different transport patterns from other common contaminants because they are denser or lighter and more or less viscous than water. As a result, they tend to sink to the impervious base of the saturated zone (for DNAPLs) or float on top of the water table (for LNAPLs). For example, because DNAPLs tend to move along impervious layers of soils or rock, they will move away from a drinking water well if the impervious layer is tilted away from the well. In this case, the Priority Setting Approach will overestimate the risk posed by a DNAPL. Because of the complexity of the transport phenomena involved, however, this Approach does not provide guidance on whether the Risk scores will be over-estimated or under-estimated in the case of DNAPLs or LNAPLs.

Therefore, this Approach does not apply to potential DNAPLs or LNAPLs with a Quantity score of 3 or more.

NOTE: DNAPLS and LNAPLs can be a serious threat to wellheads and are extremely difficult to remove from the water supply once contamination occurs. If you believe a DNAPL or LNAPL is present in the water supply or threatens a wellhead, you should pay special consideration to this threat.

Validity of the Risk Estimates Under Field Conditions that Diverge from the Priority Setting Approach Assumptions

Exhibit A-2 presents a summary explanation of the effects on the accuracy of the Risk scores if you diverge from the assumptions summarized in this appendix. The first column lists field conditions that differ from the conditions assumed in this Approach. The second column notes the effects on the risk estimates as a result of diverging from the model conditions.

For example, this Approach assumes that contaminants flow in a straight line between a source and a well. If a source is not directly upgradient, the contaminant flow path will most likely not be a straight line. In this Approach, such sources are called "off-center" sources. The Priority Setting Approach over-estimates the risks posed by an off-center source because it underestimates the travel time of the contaminants from such sources. Note that in some instances, it is not possible to say whether the Priority Setting Approach will overestimate or underestimate risks. For example, for DNAPLs or LNAPLs, it may overestimate or underestimate risks depending on a number of factors not modeled in this Approach (see the discussion above on DNAPLs and LNAPLs).

Exhibit A-2

Validity of the Risk Estimates Under
Field Conditions that Diverge from the Priority Setting Approach's Assumptions

Field Condition	Effect of Field Condition Upon Accuracy of Risk Estimate
Non-uniform aquifer thickness	Overestimate/Underestimate - depends on downgradient trend
Spike release at source	Overestimate/Underestimate - depends on distance to source and flow velocity
Seasonal pumping cycle	Overestimate
Areal source	Overestimate/Underestimate - depends on relative proximity of source to wellhead
Dense non-aqueous phase liquids (DNAPLs)	Overestimate/Underestimate - depends on density, viscosity, quantity, and surface tension of contaminant
Light non-aqueous phase liquids (LNAPLs)	Overestimate/Underestimate - depends on density, viscosity, quantity, and surface tension of contaminant
Partial penetration of well	Overestimate
Contaminant dispersion in unsaturated zone	Overestimate
Dilution at wellhead	Overestimate
Off-center source	Overestimate
Anisotropy	Overestimate/Underestimate - depends on relative position of source and well

TECHNICAL APPENDIX B: CONCEPTUAL OVERVIEW OF THE PRIORITY SETTING APPROACH

The Priority Setting Approach is a simple tool that allows the manager of a WHPA to assess the risks posed by potential sources of wellhead contamination. This appendix presents a general overview of the Approach's framework, describes the two components of risk in this Approach, and reviews how risk is computed as a function of these two risk components.

Overview of the Priority Setting Approach's Framework

The Priority Setting Approach is applied through a set of step-by-step worksheets. The user is led through a series of simple computations to calculate the risk posed by each potential contamination source within a WHPA. This section describes how this Approach emulates a human health risk assessment using simple, yet meaningful additive risk scores.

The Priority Setting Approach Emulates a Conventional Human Health Risk Assessment

The Priority Setting Approach is based on a simplified version of a conventional human health risk assessment. A conventional human health risk assessment generally answers two basic questions: (1) what is the frequency/duration of the exposure to a substance? and (2) what is the degree of toxicity of the substance? For the purposes of this Approach, the exposure and toxicity coefficients equate to: (1) What is the probability that something will go wrong? and (2) What are the consequences in the event something does go wrong?

This Approach considers two components of risk. For a given contaminant or contaminant mixture present at a potential contamination source, the user estimates a Risk score as the sum of two risk components:

(1) Likelihood of well contamination; that is, the likelihood that the contaminant will be released from that source and will reach the well within a specified period of time.

(2) Severity of well contamination; that is, the potential health hazard from drinking water drawn from the well that has been polluted by that

contaminant, taking into account contaminant dilution and dispersion between the source and the wellhead.

The Overall Risk score for a given source of potential contamination is the highest of the Risk scores associated with each contaminant or contaminant mixture present at the source.

Scoring Is Based on Logarithmic Conversion of Natural Units

The algorithms used in this Approach reflect the "natural units" of each risk parameter. For example, contaminant releases are expressed as mass released per unit of time (kg/yr), while contaminant concentrations are measured as mass unit per unit volume of water (kg/m^3). In addition, the risk parameters are functionally related within this Approach in the same manner that they are in a conventional human health risk assessment. The reliance on natural units of measurement and natural functional relationships ensures that the scores are non-arbitrary. That is, each variable is assigned its natural "weight" in terms of its contribution to the final Risk score.

The functional products of a conventional risk assessment are generally derived by multiplying several individual parameters to determine risk assessments. To ensure relative ease of use of this Approach without compromising on the rigor of a conventional risk assessment, the Priority Setting Approach assumes a conversion of the basic product (derived risk values) using the decimal logarithmic function. As a result, individual parameters generally are summed rather than multiplied to obtain risk scores.

The implicit use of decimal logarithmic conversion is best illustrated by the following example. The quantity of contaminant released annually (in kg/yr) is equal to the product of the volume of "waste" released annually (in $m^3/yr = 1,000\ l/yr$) times the contaminant concentration in waste (in $kg/m^3 = 1,000\ ppm = 1,000\ mg/l$). Using the decimal logarithmic conversion, the Quantity score ($\log_{10}(kg/yr)$) is computed as the sum of the Volume score ($\log_{10}(m^3/yr)$) plus the Concentration score (in $\log_{10}(kg/m^3)$). That is, if 1 million liters of a solution containing benzene at a concentration of 1,000 ppm are released annually, then the Quantity score is equal to 3: i.e., 3 for the Volume score (i.e., $\log_{10}(1,000\ m^3/yr)$) plus 0 for the Concentration score (i.e., $\log_{10}(1 kg/m^3)$), which means that 1,000 kilograms of benzene are released annually).

Likelihood of Well Contamination

Likelihood of well contamination gives the probability that a source contaminant will reach the well within a user-specified time horizon, referred to as the Planning Period. As described in this section, for a given contaminant or contaminant mixture at a given source of potential contamination, Likelihood of well contamination is the sum of two partial risk scores: the Likelihood of release at the source and the Likelihood that the contaminant will reach the well.

Likelihood of Release at the Source (L_1)

Likelihood of release at the source (L_1) reflects the likelihood of an average-sized release of a contaminant from a source. L_1 is a function of the source type and is based on engineering failure analyses that account for the type of potential contamination source (e.g., landfills versus tanks). It is also a function of design characteristics (e.g., number and type of liners at a landfill) and operating status (e.g., age), as appropriate. For example, the L_1 values for tanks are a function of tank design (one of 12 designs in the Priority Setting Approach) and tank age, and are derived from the Hazardous Tank Failure Model (ref. 12).

To derive the L_1 score, refer to the tables in the Source Worksheets, which provide the L_1 score as a function of input parameters such as the age, design, and status of a specific source. Higher values of L_1 indicate a greater likelihood of release. For example, an L_1 score of 0 corresponds to a probability of 1 (i.e., 100 percent chance of release), while an L_1 score of -3.5 corresponds to a lower probability of 0.0032.

Likelihood that the Contaminant Released Will Reach the Well (L_2)

This partial risk score reflects the probability that the contaminant will reach the well within the Planning Period, assuming that the contaminant is released from the source starting from day one in the source's lifetime. The Transport Worksheet derives the Likelihood of reaching the well (L_2) by comparing (1) the time of travel of the contaminant from the source to the well, to (2) the sum of the source age plus the Planning Period.

For simplification, the L_2 score is approximated as the sum of two scores: L_U for the unsaturated zone and L_S for the saturated zone. The L_U score is based on the time of travel of the contaminant through the unsaturated zone in comparison to the Planning Period. Likewise, the L_S score is based on the time of travel through the saturated zone to the well in comparison to the Planning Period.

For a given contaminant, the time of travel through the unsaturated zone (TOT_U) is given by Darcy's law as a function of the depth to the aquifer, the hydraulic conductivity of the unsaturated zone, and the contaminant mobility. If all parameters could be estimated with precision, the question "will the released contaminant cross the unsaturated zone within the Planning Period?" could be answered simply "yes" or "no." That is, the probability that the contaminant will cross the unsaturated zone within the Planning Period is either zero (i.e., $L_U = -\infty$) if TOT_U is less than the Planning Period, or one (i.e., $L_U = 0$) if TOT_U is greater than or equal to the Planning Period. In this Approach, however, input parameters are estimated within ranges, and functional relationships are only approximations of the fate and transport phenomena taking place. Due to this uncertainty, this Approach computes a probability that is between zero and one, that is, a likelihood L_U that is between $-\infty$ and 0.

Likewise, for a given contaminant, the time of travel through the saturated zone (TOT_s) is a function of the distance from the source to the well, ground-water velocity, and the contaminant mobility. Because of the uncertainty and variability of these input parameters and, therefore, of the functional relationship to compute TOT_s, this Approach computes a probability between zero and one (i.e., likelihood L_s between $-\infty$ and 0) that the contaminant will cross the saturated zone to the well within the Planning Period.

You read the values of L_U and L_s from tables as a function of the above-mentioned input parameters. Then compute the Likelihood that the contaminant will reach the well (L_2) by summing L_U and L_s. Bypass the calculations of L_U and L_s and set the L_2 score equal to 0 if the source discharges directly to a conduit system (e.g., abandoned utility network) that provides a short-cut to the well for the released contaminant. L_2 values are less than or equal to 0, with higher values (approaching zero) indicating higher probabilities that the contaminant will reach the well if released.

Deriving the Likelihood of Well Contamination (L)

For a given contaminant present at a given source, the well will be contaminated within the Planning Period *if and only if* the contaminant is released from the source and reaches the well within the Planning Period. Thus, the probability of well contamination is equal to the probability of release from the source multiplied by the probability that the contaminant will reach the well within the Planning Period. Taking the decimal logarithm of these probabilities, the Likelihood of well contamination (L) is the sum of the Likelihood of release of the contaminant at the source (L_1) plus the Likelihood that the contaminant will reach the well within the planning period (L_2):

Likelihood of well contamination score (L)	=	Likelihood of release score (L_1)	+	Likelihood of reaching the well score (L_2)

The Likelihood of well contamination (L) is less than or equal to 0. The higher the value of L (i.e., the closer L is to 0), the higher the likelihood that the contaminant will be released and reach the well within the specified Planning Period.

Severity of Well Contamination

For a given contaminant or contaminant mixture at a potential source of contamination, Severity of well contamination (S) reflects the potential health hazard from drinking water from a well that has been polluted by that contaminant. As discussed in this section, Severity of well contamination (S) is the sum of three partial risk scores: the Quantity (Q) of contaminant released annually at the source, Attenuation (A) due to transport from the source to the well, and the Toxicity (T) of the contaminant.

Quantity Released at the Source (Q)

Quantity released at the source (Q) is the expected mass of contaminant or contaminant mixture released annually from a given source of potential contamination. The expected quantity of contaminant released annually (in kg/yr) is equal to the product of the annual expected volume of "waste" released (m^3/yr) times the contaminant concentration in the waste (in kg/m^3). Applying the logarithmic conversion, you compute the Quantity released score (Q) (in $\log_{10}$(kg/yr)) by adding the Volume score (represents the volume of "waste" released, in $\log_{10}(m^3/yr)$) and the Concentration score (represents the contaminant concentration in waste, in $\log_{10}(kg/m^3)$).[1]

The Source Worksheets provide tables for determining the Volume score as a function of input parameters such as facility type and size, as appropriate. You either determine the Concentration score from a graph provided in Contaminant Form S.1 as a function of the contaminant concentration (if known), or read the default, contaminant-specific Concentration score applicable to the source from Form S.2.[2] The resulting scores for Q generally range from -1 to 5, with the latter representing the largest theoretical contaminant mass release.

Attenuation Due to Transport (A)

Attenuation due to transport (A) reflects the dilution and decay of the contaminant released due to transport from the source to the well. Attenuation is defined as the contaminant concentration at the wellhead per unit of contaminant released annually at the source. Therefore, Attenuation due to transport has units of $\log_{10}((mg/l)/(kg/yr))$. Note that the Attenuation score actually reflects the lack of attenuation of the contaminant; i.e., the higher the Attenuation score, the lesser the dilution and decay of the contaminant.

The Transport Worksheet calculates the Attenuation score (A) as the sum of two Attenuation scores: one for the unsaturated zone, A_U, and one for the saturated zone, A_S. The unsaturated zone attenuation score (A_U) is a function of the unsaturated zone hydraulic conductivity, the contaminant persistence and mobility (as provided in the contaminant forms), and the depth to aquifer. It measures the ratio of the quantity of contaminant leaving the unsaturated zone to enter the saturated zone divided by the quantity of contaminant entering the unsaturated zone after being released from the source. Thus, the unsaturated zone attenuation score (A_U) has units of $\log_{10}((kg/yr)/(kg/yr))$; i.e., it is dimensionless.

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[1] This is true for all sources except agrichemical applications, where the "Volume" score is in $\log_{10}$ (hectares) and the "Concentration" score is in $\log_{10}$ (kg/hectare/yr).

[2] The Contaminant Concentration Scoring Graph in Form S.1 simply converts the contaminant concentration from kg/m^3 to a Concentration score in decimal logarithm.

The saturated zone Attenuation score (A_s) is a function of ground-water velocity, the contaminant persistence and mobility, the type of material in the saturated zone, and the distance from the source to the well. Using the Wilson and Miller equation to model the fate and transport of contaminants in the saturated zone, this Approach provides the saturated zone Attenuation score (A_s) in units of $\log_{10}((mg/l)/(kg/yr))$.

You derive the Attenuation score (A) by working through a series of tables that factor in the relevant parameters described above. The resulting Attenuation score is generally less than 0, with higher values of the Attenuation score indicating higher contaminant concentration at the well per unit of mass released at the source. The Attenuation score thus reflects the lack of attenuation from the source to wellhead.

Toxicity of the Contaminant (T)

Toxicity of the contaminant (T) indicates the potential health hazard posed by ingesting the contaminant. The Toxicity scores (T) are based on established dose-response relationships obtained from EPA's Integrated Risk Information System (IRIS) or from the RASH database (only for a few contaminants). Using these dose-response relationships, the Priority Setting Approach defines a "critical dose" for each contaminant. The critical dose is defined as the oral reference dose (RfD) for non-carcinogens and the dose corresponding to an excess lifetime risk of 10^{-5} (1 in 100,000) for carcinogens. This Approach converts these critical doses into critical concentrations (in mg/liter of drinking water) using standard Office of Ground Water and Drinking Water assumptions (i.e., two liters consumed per day over a 70-year lifetime exposure period).

Toxicity of the contaminant (T) is defined as the decimal logarithm of the inverse of the critical concentration. Thus, Toxicity (T) has units of $\log_{10}(1/(mg/l))$. You read the Toxicity score (T) directly from a simple table (in either Contaminant Form S.1 or in Form S.2). Toxicity scores (T) range from -2.4 to 3.8, with higher scores (e.g., 3.8) indicating more toxic contaminants.

Deriving the Severity of Well Contamination (S)

For a given contaminant or contaminant mixture at a given source of potential contamination, Severity of well contamination (S) is the sum of Quantity released at the source (Q), Attenuation due to transport (A), and Toxicity of the contaminant (T):

$$\text{Severity score (S)} = \text{Quantity score (Q)} + \text{Attenuation score (A)} + \text{Toxicity score (T)}$$

where

S is Severity of well contamination score, dimensionless

Q is Quantity released at the source, in $\log_{10}$(kg/yr)

A is Attenuation due to transport, in $\log_{10}$[(mg/l)/(kg/yr)]

T is Toxicity of the contaminant in $\log_{10}$[1/(mg/l)].

The term (Q+A) represents the contaminant concentration at the well. Adding the term T to the term (Q+A) is equivalent to dividing the contaminant concentration at the well by the contaminant's critical concentration in drinking water. Thus, the Severity of well contamination score (S) indicates the estimated number of times the contaminant concentration at the well will vary from the contaminant's critical concentration in drinking water. For example, a Severity of well contamination score (S) of 0 means that the contaminant concentration at the well is estimated to be equal to the critical concentration. If the Severity score (S) is equal to 1, the contaminant concentration at the well is one order of magnitude (i.e., ten times) higher than the critical concentration. Conversely, a Severity score (S) of -1 indicates a contaminant concentration at the well that is one order of magnitude less than the critical concentration. The Severity scores (S) derived from the calculations can be either negative or positive, with higher values indicating greater contamination severity.

Risk of Well Contamination

This section describes how the Likelihood score (L) and Severity score (S) of well contamination are combined to derive a Risk score (R) of well contamination for each contaminant or contaminant mixture present at a given source. It then describes how the contaminant-specific Risk scores are aggregated to derive an Overall Risk score for each potential source of contamination. The difference between the Risk score (R) and the Overall Risk score is that the Overall Risk score is source-specific, whereas the Risk score is contaminant-specific.

Risk of Well Contamination Posed by a Contaminant (R)

For a given source of potential contamination, the Risk of well contamination (R) posed by a given contaminant or contaminant mixture is equal to the sum of the Likelihood of well contamination (L) and the Severity of well contamination (S):

Risk score (R) = Likelihood score (L) + Severity score (S)

In natural units, the risk of well contamination posed by a given contaminant is the product of the probability of well contamination, times the severity of well contamination. For example, if a contaminant at a potential source has a Risk score of -1, then this contaminant is expected to contaminate the well at a concentration equal to one tenth its critical concentration in drinking water.

Risk of Well Contamination Posed by a Source

The Overall Risk of well contamination posed by a given source is equal to the highest of the Risk scores (R) of well contamination posed by individual contaminant mixtures present at the source. For example, if a source has two contaminants A and B with individual Risk scores equal to -2 and -0.5, then this source has an Overall Risk score of -0.5.

You can also determine the Risk Level (i.e., Low, Medium, or High) posed by a potential source of contamination as a function of its Overall Risk score. If the Overall Risk score is less than -4, then the source poses a Low level of risk. If the Overall Risk score is greater than 0, then the source poses a High risk level. If the source has an Overall Risk score between -4 and 0, then it poses a Medium risk of well contamination. In this case, the contaminant is expected to contaminate the well with a concentration of between 1/10,000[a] its critical concentration and its critical concentration.

Plotting Contaminants and Sources on the Risk Matrix

The Risk Matrix allows you to visualize the risks posed by either individual contaminants or contaminant mixtures at a source or the Overall Risks posed by individual sources within the WHPA. You will plot individual contaminants and the sources based on their Likelihood (L) and Severity (S) scores. Sources of contamination are plotted based on the Likelihood (L) and Severity (S) scores of the contaminant with the highest Risk score (R).

The Risk Matrix is divided into three regions corresponding to the three Risk Levels: Low, Medium, and High. The lines separating two adjacent regions in the matrix represent equal Risk scores (as the Likelihood score (L) goes down, the Severity score (S) goes up by an equal amount to maintain the Risk score (Risk = L + S)).

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The references cited below can provide useful information on the Source Datasheets, Source Worksheets, Wellhead Datasheet, and Contaminant Forms. The following table points you to references for these sheets.

Sheet	Reference Number
Source Datasheets and Source Worksheets	5, 8, 10-13, 16, 19-21, 25, 26, 35, 37, 39, 41, 54, 59, 63
Wellhead Datasheet	59
Contaminant Forms	1, 9, 12, 14, 15, 21-29, 31-33, 40, 42, 46, 48-54, 59-63, 70, 72

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ACRONYMS, SYMBOLS, AND DEFINITIONS

ACRONYMS

DNAPL	dense non-aqueous phase liquid
IRIS	Integrated Risk Information System (an EPA toxicity database)
LNAPL	light non-aqueous phase liquid
SWDA	Safe Water Drinking Act
TOT	time-of-travel (of a chemical released in the wellhead area)
WD	used in this manual to mean the Wellhead Datasheet
WHPA	Wellhead Protection Area

SYMBOLS

A	Attenuation of the contaminant due to transport
A_S	Attenuation of the contaminant in the saturated zone
A_U	Attenuation of the contaminant in the unsaturated zone
L	Likelihood of well contamination
L_1	Likelihood of contaminant release at the source
L_2	Likelihood of reaching the well if contaminant release occurs
L_S	Likelihood of transport through the saturated zone
L_U	Likelihood of transport through the unsaturated zone to the saturated zone
Q	Quantity of contaminant expected to be released at the source
S	Severity of potential well contamination
T	Toxicity of the contaminant

DEFINITIONS[1]

Anisotropy - the condition of having different properties when measured along axes in different directions. See its antonym - **Isotropy.**

Aquifer - a formation, group of formations, or part of a formation that contains sufficient saturated permeable material to yield significant quantities of water to wells and springs.

Attenuation - to reduce, weaken, dilute, or lessen in severity, value, or amount such as the attenuation of contaminants as they migrate from a particular source. In the context of the Priority Setting Approach, the Attenuation score actually reflects the lack of attenuation of the contaminant; i.e., the higher the Attenuation score, the lesser the dilution and decay of the contaminant.

Cone of Depression - A depression of the potentiometric surface in the shape of an inverted cone that develops around a well which is being pumped.

Confined aquifer - an aquifer bounded above and below by confining units of distinctly lower permeability than that of the aquifer itself.

Contaminant - an undesirable substance not normally present or an unusually high concentration of a naturally occurring substance in water or soil.

Contamination - the addition to water of contaminants, preventing the use or reducing the usability of the water. Sometimes considered synonymous with pollution.

Darcy's law - an empirical law that states that the velocity of flow through a porous medium is directly proportional to the hydraulic gradient under certain assumptions.

Drainage well - a well installed to drain surface water, storm water, or treated waste water into underground strata.

Flow, steady - a characteristics of a flow system where the magnitude and direction of specific discharge are constant in time at any point.

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[1] Terms and definitions from (1) U.S. Department of Interior, U.S. Geological Survey, *Federal Glossary of Selected Terms: Subsurface Water Flow and Solute Transport*, Reston, Virginia, 1989, (2) U.S. Environmental Protection Agency, Office of Emergency Response, *RCRA Ground-Water Monitoring Technical Enforcement Guidance Document*, Washington, D.C., 1986, (3) U.S. Environmental Protection Agency, *Guidance for Applicants for Wellhead Protection Program Assistance Funds under the Safe Water Drinking Act*, 1987, and (4) 40 CFR Section 144.6.

Flow, unsteady - a characteristics of a flow system where the magnitude and/or direction of specific discharge changes with time.

Ground water - that part of the subsurface water that is in the saturated zone.

Ground-water flow - the movement of water in the zone of saturation.

Ground-water recharge - the process of water addition to the unsaturated zone or the volume of water added by this process.

Ground-water velocity - see velocity, interstitial.

Heterogeneity - a characteristics of a medium in which material properties vary from point to point.

Homogeneity - a characteristic of a medium in which material properties are identical everywhere.

Hydraulic conductivity - the volume of water that will move through a medium in a unit of time under a unit hydraulic gradient through a unit area measured perpendicular to the direction of flow. See also unsaturated flow.

Hydraulic gradient - slope of the water table or potentiometric surface.

Hydrogeology - the science dealing with the occurrence of groundwater, its utilization, and its functions.

Hydrologic properties - those properties of a rock that govern the entrance of water and the capacity to hold, transmit, and deliver water, such as porosity, effective porosity, specific retention, permeability, and the directions of maximum and minimum permeabilities.

Impermeable - a characteristic of some geologic material that limits its ability to transmit significant quantities of water under the head differences ordinarily found in the subsurface.

Infiltration - the downward entry of water into the soil or rock. **Net infiltration** - the amount of rain, melting snow, or surface water, minus evaporation and plant transpiration, that enters into the soil or rock.

Injection well - a well into which fluids are being injected. The different kinds of injection wells are:

> Class I: Wells used to inject liquid hazardous wastes or dispose of industrial and municipal waste waters beneath the lower-most underground source of drinking water (USDW).
>
> Class II: Wells used to dispose of fluids associated with the production of oil and natural gas (hydrocarbons), to inject fluids for enhanced oil recovery, or for the storage of liquid hydrocarbons.
>
> Class III: Wells used to inject fluids for the extraction of minerals (i.e., solution mining).
>
> Class IV: Wells used to dispose of hazardous or radioactive wastes into or above a USDW. The USEPA has banned the use of these wells.
>
> Class V: Wells not included in the other classes and generally used to inject nonhazardous fluid into or above a USDW.

Isotropy - the condition in which the property or properties of interest are the same when measured along axes in any direction.

Non-point source - a source originating over broad areas, such as areas of fertilizer and pesticide application and leaking sewer systems, rather than from discrete points.

Permeability - the property of a porous medium to transmit fluids under an hydraulic gradient.

Point source - any discernable, confined, or discrete conveyance from which contaminants are or may be discharged, including, but not limited to, any pipe, ditch, channel, tunnel, conduit, well, container, rolling stock, or concentrated animal feeding operation.

Porosity, effective - the ratio, usually expressed as a percentage, of the total volume of voids available for fluid transmission to the total volume of the porous medium.

Potentiometric surface - an imaginary surface representing the static head of groundwater and defined by the level to which water will rise in a tightly cased well.

Pumping rate - the rate at which ground water is pumped from an aquifer.

Recharge area - an area in which water reaches the zone of saturation by surface infiltration.

Reference dose - for non-carcinogens, the exposure threshold above which health effects begin to occur.

Retardation factor - the ratio of the average linear velocity of ground water to the velocity of the retarded constituent.

Saturated zone - that part of the earth's crust beneath the regional water table in which all voids, large and small, are filled with water under pressure greater than atmospheric.

Solubility - the total amount of solute species that will remain indefinitely in a solution maintained at constant temperature and pressure in contact with the solid crystals from which the solutes were derived.

Transport - conveyance of solutes and particulates in the unsaturated or saturated zone.

Unconfined aquifer - an aquifer that has a water table.

Unconfined ground water - water in an aquifer that has a water table.

Unsaturated flow - the movement of water in a porous medium in which the pore spaces are not filled to capacity with water.

Unsaturated zone - the zone between the land surface and the regional water table. Generally, water in this zone is under less than atmospheric pressure, and some of the voids may contain air or other gases at atmospheric pressure.

Utility chase - a trench or channel used to house water, gas, electricity, or sewer lines, or other such underground utility lines.

Velocity, average interstitial - the average rate of ground-water flow in interstices expressed as the product of hydraulic conductivity and hydraulic gradient divided by the effective porosity.

Water table - upper surface of a zone of saturation, where the body of ground water is not confined by an overlying impermeable zone.

Well - a bored, drilled, or driven shaft, or a dug hole, whose depth is greater than the largest surface dimension.

Wellfield - one or more wells in the same general area containing a distribution system.

Wellhead - the portion of a well that extends above ground.

Wellhead Protection Area - the surface and subsurface area surrounding a water well or wellfield, supplying a public water system through which contaminants are likely to move toward and reach such well or wellfield.

Zone of contribution - all areas that recharge or contribute water to a well or well field.

APPENDIX F

WATERSHED OPERATIONS PLAN

This Appendix provides guidelines for the acquisition and recording of data in the Blaine Watershed. This includes water level monitoring, pumping rate monitoring, sampling, and equipment maintenance recording. This operations plan will provide the data necessary to document the operational efficiency and system performance of wells in the Watershed, and to detect operational or water quality problems at an early stage.

F.1 Site Access

Access to the Watershed and wells within the Watershed should be controlled at all times. Access should be limited to authorized personnel. The gate to the Watershed should be locked to prevent unauthorized vehicle access. Each well building or fenced enclosure, as well as electrical service panels and utility vaults, should be kept locked at all times unless work is actually being done on that well. Service personnel need to ensure that all wells are secure, and the watershed gate locked, before leaving the Watershed area.

F.2 Water Level Measurement

Water level data are required to assess well performance and for determining seasonal and long-term water level trends in the Watershed. Water levels should be measured in all wells on a weekly basis. The water levels should be measured with an electric water level sounder, such as a Solinst or Actat meter. Permanent measuring points should be established on each well so a consistent reference point is used for each measurement. Water levels should be measured to the nearest 0.1 foot. A note should be made as to the status of the well at the time of measurement (i.e., whether the pump is on or off). A sample form for the recording of water level and other data is included as Attachment A. These forms should be used in the field, and completed forms stored at the Public Works Office.

F.3 Flow Measurements

The discharge of all wells should be recorded on a weekly basis except during peak usage times when daily meter readings should be recorded. The total quantity of water pumped from for each well should be read and recorded with the water level data on a weekly basis and on a daily basis during peak usage times. The instantaneous reading on the flowmeter should also be recorded, if the pump is on. In conjunction with flow meter readings, the hour meters on all pump motors should be read and the readings recorded.

F.4 Water Quality Sampling

Water quality samples must be taken from each well as specified by WDOH to detect any deterioration in water quality. The samples should be analyzed for organic compounds as well as inorganic constituents, as specified by WDOH.

F.4.1 Sampling Protocol

Water quality samples must be taken properly to ensure representative samples are taken. The following procedures should be observed:

- The well to be sampled should have been on for at least 15 minutes prior to sampling to ensure that all water in the casing has been purged from the well;
- Motor vehicles should not be left parked and running in the vicinity of the well while the sample is taken;
- Samples are to be taken in laboratory-supplied containers which are filled slowly and completely;
- A label with the date, time, well name, and sample ID should be neatly completed and applied to each bottle immediately after the sample is taken;
- Sampling instructions supplied by the laboratory should be carefully followed;
- The samples should be placed in a cooler with ice immediately, and kept cool at all times;
- The samples should be shipped to the laboratory in coolers, as soon as possible to ensure sample holding times are not violated; and
- Chain - of - custody should be maintained and documented, and all sampling information should be recorded immediately after taking each sample.

F.5 Equipment Monitoring

In addition to water level and discharge monitoring and water quality sampling, the condition of the equipment and any maintenance, servicing, or changes in the condition of the pump and well equipment and performance should be documented in a pump and equipment maintenance record. This information should include the following:

- Record of pump and equipment servicing;
- Any changes in pumps, piping, or other fixtures;
- Record of when and why wells are taken out of service; and
- Observations of pump and equipment conditions, such as motor noise and heat, oil consumption, vibrations, changes in electrical amperage or voltage load, and caviation noise.

These observations can be recorded on a form, such as that included in Attachment B, or in a dedicated log book for each well.

ATTACHMENT A

WELL PERFORMANCE DATA SHEET

WELL ID:

Date	Time	Sampler ID	Water Level (feet below measuring point)	Pump On? (Y/N)	Totalizer Flow Meter	Instantaneous Flow Meter	Flow Units	Hour Meter (hours)	Sample Taken? (Y/N)	Sample ID	Comments

ATTACHMENT B

WELL MAINTENANCE AND OPERATIONS DATA SHEET

WELL ID:

Date	Time	Service Person	Maintenance Comments	Other Comments (oil use, heat/noise, electrical use, vibration, other)

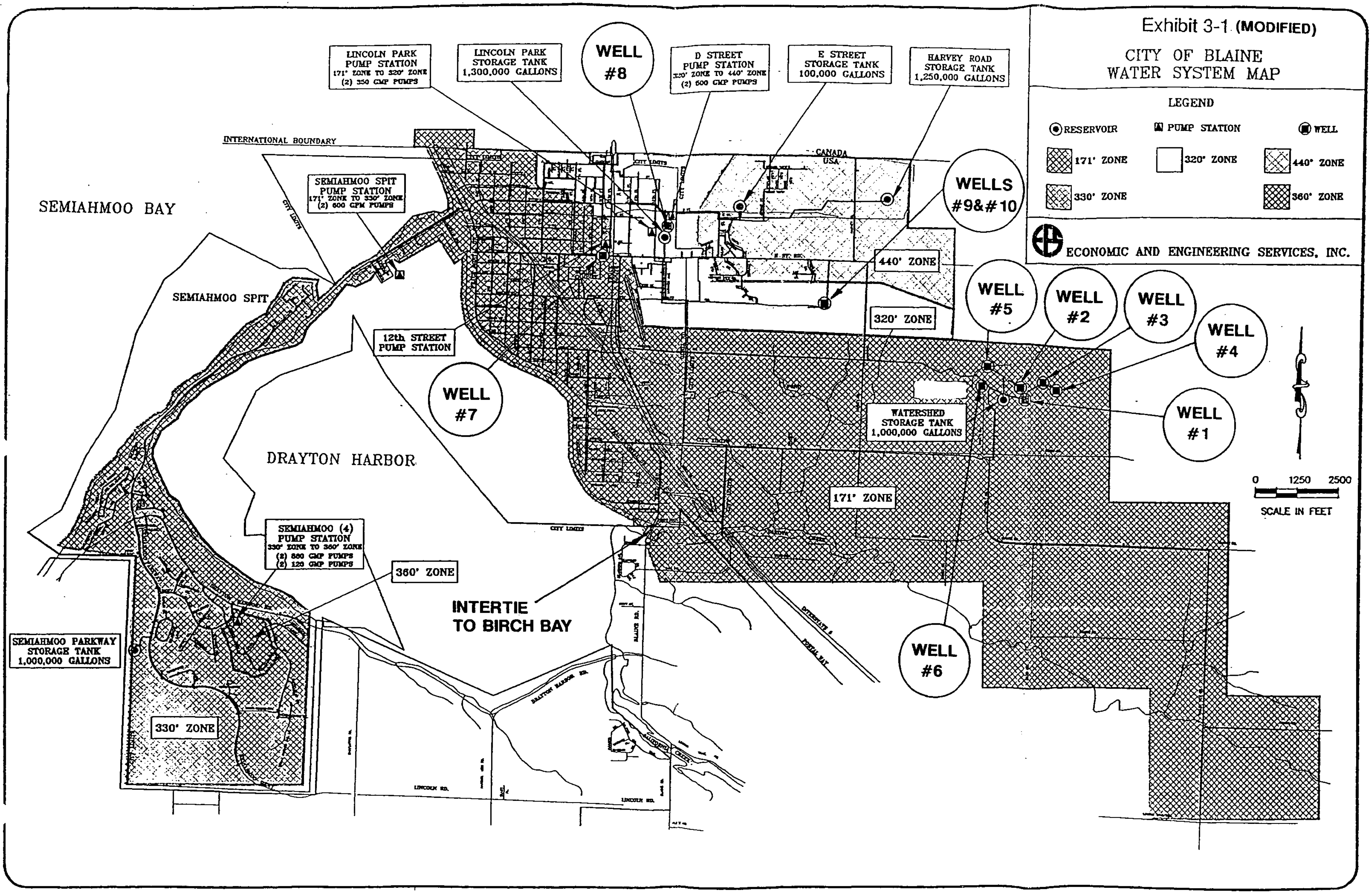
Exhibit 3-1 **(MODIFIED)**

CITY OF BLAINE
WATER SYSTEM MAP

M: \BLAINE\P43340\EXHIBITS\WATER\BLA4-1EX.DWG

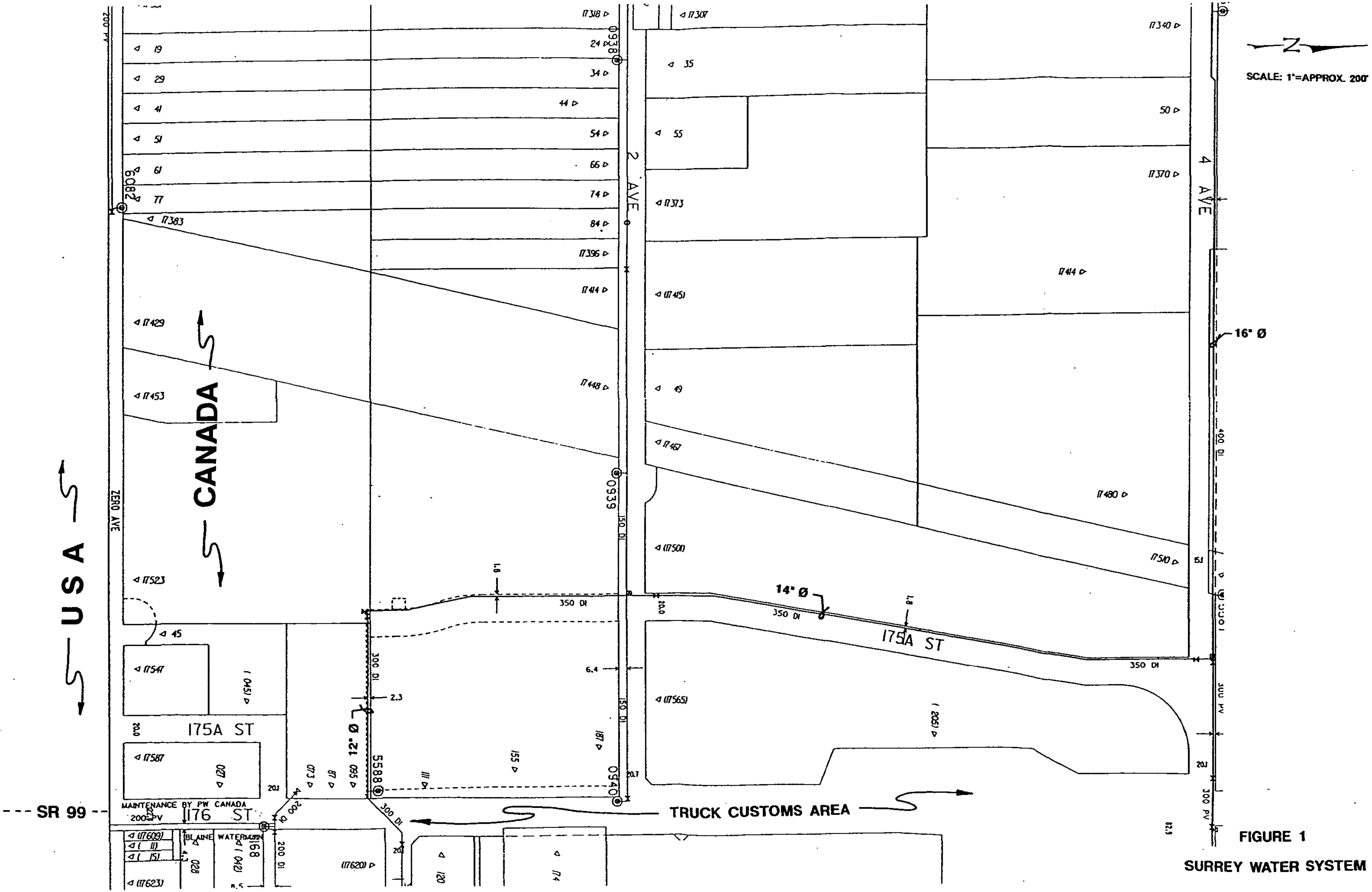

FIGURE 1

SURREY WATER SYSTEM

APPENDIX B

CITY OF BLAINE
WATER SUPPLY EMERGENCY RESPONSE ACTION PLAN

The City of Blaine Emergency Water Supply Plan is a multistaged plan designed to be implemented as progressively more serious conditions develop with respect to meeting system demands including domestic supply, equalizing storage, fire storage and irrigation requirements.

Included within each stage are:

» **Water Supply Emergency Response Action Plan (WSERAP).** Includes information on actions which can be taken and are controllable by the City of Blaine.

» **Description of water supply conditions and expected savings at that stage.**

» **Customer Conservation Actions.** Includes conservation actions that will be requested or required of Water Utility customers in order to meet needed reductions in consumption.

» **Public Information Element.** A summary of the various means used to inform the public of the current water supply situation at each stage and what actions they will be requested to take.

» **Enforcement Actions.** Includes information about what enforcement actions the Department will taken in stages requiring mandatory water use restrictions.

A. SUMMER SHORTAGE RESPONSE PLAN

Since this type of shortage is realized during the summer months, the focus of the shortage response would be to reduce outdoor water uses.

Following is a description of the five stages of conservation actions included in the Plan.

1. Stage I - Minor Shortage Potential

Stage I of the WSERAP is implemented when the system storage remains below 70% of the total storage capacity over a 24-hour period.

Savings at this stage would be generated by water system management actions. All conservation actions combined would produce about 0.10 MGD of savings.

a. Water Supply Emergency Response Action Plan. The City of Blaine Water Utility would eliminate all non-essential operating system water uses to include pipeline flushing, reservoir overflow, and other uses.

b. Customer Conservation. In Stage I, no specific conservation actions are requested of customers.

c. Public Information Element. At Stage I of the WSERAP, the impact on the public due to supply problems would be limited. Because the impact of these actions is not really discernable, and since they may need to be in effect for a relatively short period of time, there would be no need to prematurely draw attention to a situation that may never require public actions. The existing conservation program should be used primarily to stimulate public awareness of conservation without a specific message of a potential water shortage.

2. Stage II - Moderate Shortage Potential

Stage II is implemented when:

- Total system storage remains below 50% of the total storage capacity over a 24-hour period.
- Weather forecasts predict a continuing trend of warmer, drier than normal conditions.

a. Water Supply Emergency Response Action Plan.

b. Customer Conservation Actions. In addition to system management conservation actions, the City of Blaine Water Utility would ask for voluntary reductions in outdoor water use by all customers. This would be a public appeal to voluntarily limit law sprinkling, car washing and other outdoor uses. At this point, all customer actions are voluntary. No surcharges or other economic incentives would be used.

c. Public Information Element. The success of implementing the WSERAP at Stage II largely depends on the cooperation of the general public in voluntarily reducing their outdoor water consumption. Public information efforts would need to be increasingly active in order to generate the necessary cooperation. The public would need to be motivated to save, and it would be important to acquaint the public with the nature of the water supply problem. In directly addressing the potential emergency situation, however, the public information effort shall be tempered in the event that weather conditions change, and the status of the water supply improves.

In addition to informing the public of the developing emergency situation, public information efforts at Stage II should attempt to create public attitudes that are receptive to conservation measures and inform water users of the most effective ways to reduce outdoor water use. To accomplish these objectives, public information efforts would utilize the mass media and specially developed materials, as well as the existing conservation program to promote conservation.

3. Stage III - Serious Shortage

Stage III is implemented when:

- Total system storage remains below 35% of the total storage capacity over a 24-hour period.
- System inflows continue to be low.
- Weather forecasts predict a continuing trend of warmer and drier than normal conditions.

a. Water Supply Emergency Response Action Plan.

b. Customer Conservation Actions. Because of the need for substantial reductions in water demand, the City of Blaine Water Utility would require outdoor water use restrictions for all customers. Non-commercial irrigation would be limited, and customers would also be asked to eliminate all other outdoor uses of water.

c. Public Information Element. By the time it would be necessary to move to Stage III of the Water Supply Emergency Response Action Plan, the general public should have a basic understanding of the nature of the emergency, and would have been informed of ways to reduce their outdoor water consumption.

With the imposition of outdoor water use restrictions, it would be necessary to adequately inform the public of those restrictions and any related enforcement efforts in order to gain maximum compliance.

To improve compliance with the imposed restrictions, public information requires repetition of the conservation message using multiple communication mediums. As public information intensifies, all projects of the existing conservation program would focus primarily on the shortage and direct more time to special public information efforts for the Water Supply Emergency Response Action Plan.

d. Enforcement Actions. The present billing system makes penalties such as surcharges or other economic incentives prohibitively difficult to implement. As part of its ongoing work on the WSERAP, staff would investigate enforcement methods used elsewhere and develop an approach for use here. Realistically, however, enforcement of the water use restrictions would very likely employ peer group pressure and observations by the City of Blaine Water Utility field employees during their regular work schedule.

A new billing system is expected to be developed during the next few years and the issue of surcharges is expected to be addressed. If the capability for penalty assessment/surcharge is developed for utilization of water over a given amount, it will be included in the next revision of the WSERAP.

4. Stage IV - Severe Shortage

Stage IV is implemented when conditions as described in Stage III occur in conjunction with equipment failure affecting the City's inability to supply water to traditional levels or if total system storage drops below 20% of the total storage capacity over a 24-hour period. At this time, the amount of savings available from lawn watering reductions begin to decline sharply, making it necessary to generate savings in other ways.

a. Water System Management Actions. Water system management actions are the same as in Stage III.

b. Customer Conservation Actions. In addition to continuing the outdoor water use reductions from Stage III, residential customers would be asked to voluntarily cut back on indoor water uses. Commercial/industrial customers would also be asked to reduce water consumption.

   Since a drought condition and implementation of a Stage IV response is an abnormal situation, the estimate of how much water can be saved by reducing lawn watering is very difficult to project.

c. Public Information Element. With a new request for residential customers to reduce water consumption indoors as well as outdoors, a new thrust must be introduced in public information efforts at Stage IV. Information on ways to conserve water indoors must be presented. Focusing on the community effort to reduce water consumption lends positive reinforcement for everyone to cooperate with the requested reductions. This requires more community involvement, as well as activities and materials specifically directed at promoting community spirit.

d. Enforcement Actions. Enforcement measures would be developed as part of the ongoing development work on the WSERAP (see comments under Stage III enforcement).

5. Stage V - Critical Emergency

Stage V is implemented when customer demands and system pressure requirements cannot be met and major reductions in water use are required. It is extremely unlikely that a shortage would ever become this severe. Nonetheless, it is necessary to plan for such an event.

a. Water System Management Actions. Water system management actions would be the same as in Stage III. In addition, system pressure may be reduced due to a lower availability of water in regulating basins and storage reservoirs. Local fire departments would be advised of any changes in system pressure which could impact fire flows.

b. Customer Conservation Actions. Stage V would require water rationing. When rationing is put into effect, user categories would be established and maximum water allocations would be set for each category. Customers would be required to reduce water use to the minimum amount possible. The goal for water rationing would be a 40% reduction in overall water use.

c. Public Information Element. If the shortage condition warrants implementation of Stage V of the WSERAP, people would have to be totally and constantly aware of conserving water. Public information would play a key role at this point in maintaining people's incentive to reduce water consumption. The seriousness of the situation should be reflected in all public information efforts.

Once rationing is in place, public information would be used to inform customers of enforcement measures and effective means of reducing water consumption while still maintaining personal health and safety.

d. Enforcement Actions. Enforcement measures would be developed as part of the ongoing work on the WSERAP (see comments under Stage III enforcement).

CITY OF BLAINE PUBLIC WORKS DEPARTMENT
WATER CURTAILMENT PLAN

Action Stage	I	II	III	IV
	Total Storage Less Than:			
Storage:	70%	50%	35%	20%
Equipment:	Minor Loss of Capacity	Loss of 25% of Well Capacity	Loss of 50% of Well Capacity	Major catastrophe
Demand reduction actions:	Voluntary conservation. Initiate public awareness through media efforts. Suggest watering of lawns every 3rd day. Car wash from buckets with shutoff.	Eliminate non-essential outdoor use. *Mandatory:* Water lawns every 3rd day. Advise wholesale customers to impose restrictions.	Eliminate outdoor use. No lawn watering. No car washing. Gardens only when necessary. Advise wholesale customers to impose restrictions.	Curtail commercial/industrial use except for essential services. Advise wholesale customers to impose restrictions.
City of Blaine actions:	General media notice re conservation. Bi-weekly watering letter.	Reduce system use. Main flushing, reservoir cleaning, temporary hydrant use curtailed.	Continue with reduced system use.	Intermittent supply to parts of City. Reduced system pressure. Use of water trucks.

F:\WP51\WATER\WSERAP.STO

APPENDIX H

CONTAMINANT SOURCE CONTROL BUSINESS AND AGENCY SAMPLE NOTIFICATION LETTERS

Pursuant to Washington Department of Health requirements (Chapter 246-290 WAC), notification letters will be sent to the businesses located within the City of Blaine's Wellhead Protection Area (WHPA) that may have a potential to adversely affect the City's drinking water supply. Agencies with jurisdiction over management of a portion of the potential contaminant sources identified in the WHPA will also be notified so that the agency can take the City's ground water vulnerability into consideration when making future management decisions.

Copies of the sample business and agency notification letters follow, along with addresses for jurisdictional agencies and business identified within the WHPA.

CONTAMINANT SOURCE CONTROL BUSINESS NOTIFICATION LETTER

Date

Business
Address
City, State   Zip Code

Dear Owner/Operator:

In order to protect the drinking water supply of the City of Blaine, the City is developing a Wellhead Protection Program in accordance with Washington Department of Health requirements (WAC 246-290-135). As part of our Wellhead Protection Program, the City mapped the area overlying the short-term recharge zone of our drinking water supply wells. This is called our Wellhead Protection Area.

Following the mapping of the Wellhead Protection Area, the City conducted an inventory of **potential** sources of ground water contamination within the area. The nature of your business (or facility), and its location within our Wellhead Protection Area, indicate that your activities may have the potential to affect the City's drinking water supply.

We hope that informing you of your location in our Wellhead Protection Area will result in an increase in precautions to ensure that above ground and/or underground storage of hazardous materials will not impact our drinking water quality. For further information, please call __________ at the City of Blaine, (306) 332-8820.

Sincerely,

____
City of Blaine

LAINE SCHOOL BUS
ARAGE
2 FIR AVENUE
INE, WA 98230

SGSA PACIFIC HWY
ORDER STA
ACIFIC HWY BORDER
TATION
LAINE, WA 98230

ORTHWEST PODIATRIC
AB INC
091 FIR AVENUE
LAINE, WA 98230-9702

LAINE SCHOOL DIST.
AMPUS
055 H STREET
LAINE, WA 98230

TARVIN SAMS #12
350 H STREET
LAINE, WA 98230-9671

USDOJ DEA BORDER
CROSSING BLAINE
PACIFIC HWY BORDER
CROSSING
BLAINE, WA 98230

PAYLESS 2882
1733 H STREET
BLAINE, WA 98230

TEXACO SS 63232553
1503 H STREET
BLAINE, WA 98230

CITY OF BLAINE
MUNICIPAL AIRPORT
1373 BOBLETT STREET
BLAINE, WA 98230-0490

TEXACO #63-076-1553
1503 H STREET
BLAINE, WA 98230

USGSA BLAINE BORDER
PATROL HDQ
1590 H STREET
BLAINE, WA 98230

A S RADIATOR WHSE
1635 BOBLETT STREET
BLAINE, WA 98230-3174

BLAINE SCHOOL DIST.
#503
1112 FIR AVENUE
BLAINE, WA 98230

GENERAL SERVICES
ADMINISTRATION
1590 H STREET
BLAINE, WA 98230-9670

YORKYS GROCERY #7
1307 BOBLETT
BLAINE, WA 98230-9748

CONTAMINANT SOURCE CONTROL
AGENCY NOTIFICATION LETTER

Date

Contact Person
Agency Name
Address
City, WA, Zip Code

Subject: City of Blaine Wellhead Protection Program, Contaminant Source Inventory

In accordance with Washington Department of Health requirements (WAC 246-290-135), the City of Blaine has developed a public water system Wellhead Protection Program for its municipal wells. As part of that program, the city delineated the boundaries of its Wellhead Protection Area and conducted inventories of potential sources of contamination within that area.

As jurisdictional agency for management of a portion of the contaminant sources identified through the inventory, the City of Blaine, pursuant to Department of Health requirements, is hereby notifying your agency of the inventory findings. Enclosed is a map demonstrating the ten-year time of travel boundary for the city's Wellhead Protection Area and a corresponding list of potential contaminant sources identified within those boundaries.

The City of Blaine requests that your agency consider the vulnerability of the city's Wellhead Protection Area when making decisions concerning the management of any of the identified contaminant sources that lie within your jurisdictional authority.

If you have questions or require additional information, please contact _________ at the City of Blaine Public Works Department at (360) 332-8820. Thank you for your support in protecting the City of Blaine's water supply.

Sincerely,

City of Blaine

CITY OF BLAINE
WELLHEAD PROTECTION PROGRAM
AGENCY NOTIFICATION LIST

Washington Department of Agriculture (Dept. of Ag.)

Pesticide Applicators
Silviculture Application Areas

CONTACT: ATTN: Lee Faulconer
Pesticide Management
WA Department of Agriculture
P.O. Box 42589
Olympia, WA 98504-2589

Washington State Department of Ecology (Ecology)

Airport - if RCRA regulated
Service stations
Underground storage tanks

CONTACT: ATTN: Kirk Cook
Water Quality Program
WA Department of Ecology
P.O. Box 47600
Olympia, WA 98504-7600

Washington State Department of Natural Resources (DNR)

Mines/gravel pits - mines with working face of more than 3 acres

CONTACT: ATTN: Wendy Gerstel
Geological and Earth Resources
P.O. Box 47007
Olympia, WA 98504-7007

Washington State Department of Transportation (DOT)

Highway transportation corridors (Pest. spraying) - state highways and interstate highways

CONTACT: ATTN: Marie Mills
WA Department of Transportation
P.O. Box 47331
Olympia, WA 98504-7331

Whatcom County Cooperative Extension (WCCE)

Agricultural, crops
Agricultural (open pasture), livestock**
Agricultural (confined), livestock**
Animal waste spreading**

CONTACT: ATTN: Supervisor
Whatcom County Cooperative Extension
1000 North Forest Street
Bellingham, WA 98225

Whatcom County Public Works and Utilities Department

Highway transportation corridors - county roads only

CONTACT: ATTN: Supervisor
Whatcom County Public Works and Utilities
Right of Way
901 West Smith Road
Ferndale, WA 98248

Whatcom County Health Department (WCHD)

Abandoned wells
Airport - if cond. exempt SQHWG
Auto repair, auto salvage - if cond. exempt SQHWG
On-site sewage systems***
Water well

CONTACT: ATTN: Environmental Health Specialist
Whatcom County Health Department
509 Girard Street
Bellingham, WA 98227

Sources with no responsible jurisdictional authority

Cemetery
Golf Courses
Parks and recreation
Railroad Right-of-Ways

Ecology will consider enforcement of water quality violations if voluntary compliance efforts undertaken by WCCE prove unsuccessful.

Depending on capacity as determined by daily common point flow, on-site sewage systems may be governed by WCHD, the Washington Department of Health, or Ecology; however, WCHD will act as a notification clearinghouse for on-site sewage systems.

APPENDIX I

RESPONSE TO COMMENTS ON DRAFT WELLHEAD PROTECTION PLAN

This appendix addresses the comments received on the City of Blaine's Draft Wellhead Protection Plan, dated March 13, 1996. Comment letters are included in Attachment 1 of this appendix. Comments were received from the Washington State Department of Health (WDOH), the Washington State Department of Ecology (Ecology), and Whatcom County Planning Department (Whatcom County). We appreciate the effort put fourth by the reviewers, and their constructive comments which have been incorporated to improve the WHPP.

Comments by each agency are addressed below.

Response to John Thielemann (Department of Health):

Comment 1: Currently, data collect and analysis efforts are ongoing to better characterize the hydraulic properties of the deep aquifer, and to better determine its potential long-term yield. These efforts, and the specific criteria that will be determined from the data collection effects will be summarized in the report.

Comment 2: City Wells No. 7 and 8 were not included in the survey, because they are in substantially better condition than the other wells in the Watershed. A note to this effect will be included in the report to document their condition. Verification of proper screen sizes will be included in the report to the extent possible based on available records.

Comment 3: Issues raised in this comment will be covered in the City's Water System Plan (WSP).

Comment 4: The City has already corrected a number of the deficiencies discussed in the Draft WHPP. The final WHPP will note those corrections that have already been made. Improvements to be made through the City's capital improvement program will be addressed in the WSP.

Comment 5: Possible blended water quality will be addressed in the WHPP. Also, an updated discussion of how sodium may be regulated in the future is included. Fixtures required for blending and blending procedures will be addressed in the WSP, as appropriate.

Comment 6: The strategies have been prioritized to the extent possible within the context of the risk assessment that was completed for the project. Beyond that, prioritization would be largely a subjective undertaking. Agencies responsible for implementation are identified in the program; however, it would inappropriate to single out specific personnel in this type of document, because changes in personnel could hamper the use of the WHPP. A matrix of recommended management program actions, including responsible agencies, will be included in the final WHPP.

Comment 7: A discussion will be added to the document regarding the use of the proposed pipeline from Ferndale to Birch Bay as an emergency or alternative supply.

design management strategies that are consistent with each agencies goals and resource limitations. However, Whatcom County agencies take policy direction from the Whatcom County Council; the city has no direct input. Thus, the city can request that Whatcom County agencies undertake certain actions, but must rely upon the good will and mutual interests in ground water protection on the part of those agencies in seeing those actions implemented.

It is worth noting that in the development of the earlier Blaine Ground Water Management Program, released in June 1994, the city sought support of county agencies for a number of protection strategies. Response, either affirmative or negative, from the county is still pending.

Under the Department of Health's Wellhead Protection Program, the responsibilities of city of Blaine are limited to the following:

- A completed susceptibility assessment form for all wells;
- Delineated Wellhead Protection Areas for all wells including the 1-year, five-year, and 10 year time of travel zones;
- Documentation of the methodologies used for delineation;
- A list of agencies notified of the Wellhead Protection Area Boundaries (can be combined with source control agency notification described below);
- An inventory of all actual and potential contaminant sources located within the Wellhead Protection Areas;
- A list of contaminant source owners/operators notified of their presence within the Wellhead Protection Programs;
- A list of contaminant source control agencies notified of the location actual and potential sources of ground water contamination identified within the Wellhead Protection Area;
- A contingency plan for providing a potable source of water in the event that existing supplies are lost due to contamination; and
- Documentation of notification and coordination with appropriate emergency response agencies (*Wellhead Protection Program Guidance Document*, Department of Health, 1995).

STATE OF WASHINGTON
DEPARTMENT OF HEALTH
1511 Third Ave., Suite 719 • Seattle, Washington 98101-1632

RECEIVED
JUL 10 1996
CITY OF BLAINE
PUBLIC WORKS

July 9, 1996

William Duffy
City of Blaine Water Utilities
1200 Yew Avenue
Blaine, Washington 98230

Subject: Whatcom County
City of Blaine Water System, PWS ID #07300U
Draft Wellhead Protection Plan
Submittal #96-0402

Dear Mr. Duffy:

We have reviewed the draft Wellhead Protection Plan/Program (WHPP) for the City of Blaine (Blaine) which was prepared by Golder Associates and received in this office on April 2, 1996. We have the following comments:

1. The WHPP recommends that future source capacity be developed from the deep aquifer. However, the recharge area, direction of flow, and other characteristics of the deep aquifer are not well defined at this time although it appears to be associated with a deep regional ground water flow from outside of the study area (see page 22). Please describe the specific criteria that must be determined to sufficiently define the deep aquifer and indicate how and when this criteria will be determined.

2. A survey was conducted of wells 1 through 6 which resulted in the various deficiencies noted in sections 7.1.1 to 7.1.7 and the recommended upgrades noted in section 9.1. The current condition and recommended upgrades for wells 7 and 8 should also be discussed. In addition, please verify that each well casing is fitted with a screened vent that is properly sized.

3. The reliability of the current power supply serving the well field and individual wells 7 and 8 should be characterized in terms of the reliability criteria listed under item 6 on page 9 of the WDOH Sizing Guidelines. The current condition of the associated electrical equipment and controls should also be noted. Consideration should be given to consolidating electrical equipment and adding a permanent standby generator at the well field if warranted. It is recommended that manual transfer switches and suitable connectors be installed at a minimum to allow each well to be powered by a portable engine driven generator.

4. Please discuss the City's plans and schedule for correcting the various deficiencies noted for each well source. Indicate which improvements will be accomplished under the City's capital improvement program and which will be corrected using city staff and normal maintenance funds.

5. A review of water quality information indicates that the two wells pulling from the deep aquifer have elevated levels of sodium, that elevated nitrate concentrations will continue to increase in the shallow aquifer as development occurs in the upper boundary area, and that it may be necessary to blend water from the various well sources. Describe the proposed blending process, the procedures for controlling it, and estimate the contaminant concentrations that could be obtained in the blended water. A detailed piping and control schematic of the well field should be included which indicates the capacity and concentration of the contaminants in each well source in the well field. The blending procedures should also be included or referenced in the water facilities operations manual.

6. The recommended management strategies discussed in section 9.2 are a key component of Blaine's WHPP and involve coordination with and subsequent action by many different state, county, and local entities such as the County Health Department, County Planning Department, County Department of Emergency Management, and the Washington Department of Ecology as summarized in the management responsibility matrix, Table 9-1. The various strategies should be prioritized and the key agencies and personnel responsible for implementing Blaine's well head protection program should be identified.

7. The long-term strategies for increasing Blaine's water supply and meeting it's current and projected peak day demands are discussed in Section 10.4. The possibility of using the proposed pipeline from Ferndale to Birch Bay as an emergency or alternative source of supply for Blaine should also be discussed.

8. Describe any additional studies that are necessary to determine the best means for increasing Blaine's water supply as well as the time frame for completing them.

9. Section 10.4.1 indicates that wells 9 and 10 have already been drilled in the shallow aquifer and that additional replacement or new wells are anticipated in the deep aquifer. The requirement for obtaining source approval from WDOH in accordance with WAC-246-290-130 before any new wells can be put into service should also be discussed.

10. The watershed operations plan in Appendix F indicates that water meter readings are to be recorded on a weekly basis for each well source. It is recommended that you record daily meter readings during the weeks of peak water usage in addition to the weekly meter readings.

11. Documentation must be included that all owners/operators of ground water contamination sources, regulatory agencies, and local emergency spill responders have been notified of Blaine's WHPP in accordance with WAC-246-290-135(4)(iv, v, & vii).

12. The WHPP is part of Blaine's water system plan (WSP) and must be referenced therein in accordance with WAC-246-290-135(4)(b). It is recommended that the key components of the WHPP be summarized and/or duplicated in the WSP. Key components may include the overall risk ranking of potential contaminant sources summarized in section 8.3, the responsibility matrix summarized in Table 9-1, and Figures 5-1 and 7-3 which show Blaine's wells, the location of potential contaminant sources, the estimated times of travel (TOT), and the recommended wellhead protection area.

Regulations establishing a schedule of fees for review of planning, engineering and construction documents have been adopted (WAC 246-290-990). An itemized invoice for $625.00 is enclosed. Please note that this fee covers our initial review and one more submittal on this wellhead protection plan. If additional submittal and review letters are required, an invoice for additional fees will be sent with the final approval letter. Please remit your complete payment in the form of a check or money order within thirty days of the date of this letter to: **WDOH, Revenue Section, P.O. Box 1099, Olympia, WA 98507-1099.**

If you have any questions regarding the above, please contact me at (206) 464-7071.

Yours truly,

John P. Thielemann

John P. Thielemann, P.E.
Regional Engineer
Northwest Drinking Water Operations

Enclosure

cc: Anne Atkeson, Whatcom County Health Department
Richard Rodriguez, WDOH-NWDW Operations

943-1673.137
[illegible]

1889

STATE OF WASHINGTON
DEPARTMENT OF ECOLOGY
P.O. Box 47600 • Olympia, Washington 98504-7600 • (206) 407-6000 • TDD Only (Hearing Impaired) (206) 407-6006

May 28, 1996

William M. Duffy
Department of Public Works
City of Blaine
1200 Yew Ave.
Blaine, WA 98230

943-1673
.06
III 021
6/25/96

RE: Blaine's Wellhead Protection Plan, G9300304

Dear Mr. Duffy:

Sorry for the delay in commenting on Blaine's Wellhead Protection Plan. The plan is thorough and fulfills most of the requirements outlined in the grant contract Scope of Work. Golder Associates performed their services to the City admirably. I have three comments that I would like to have incorporated into the final plan:

1. Please show the Ecology logo on the cover page, and in the introduction state that funding comes from Washington State's Department of Ecology Centennial Clean Water Fund.

2. The list of recommendations would be easier to read if they were placed in a matrix of some sort, with the associated implementing entity. Every study and task performed under this grant is for the purpose of developing a set of recommendations for solving Blaine's Wellhead Protection Plan. For both affected parties and implementing entities, ease of access to recommended actions is important.

3. Related to the above is the requirement to have letters of concurrence from implementing entities. Are they going to be part of the plan contents, or were you planning on posting them later. There are a lot of oughts and shoulds listed under the recommendations that need concurrence.

Thanks for a job well done. The next report should be your final. Once I receive that I can issue an agency approval letter for your plan.

Sincerely,

William A. Hashim

William A. Hashim
Project Manager
Water Quality

cc: John Glynn, Ecology
Golder Associates

RECEIVED
MAY 30 1996
Golder Associates

943-1673.107

City of Blaine

Department of Public Works

1200 Yew Avenue • Blaine, WA 98230
Bus: (360) 332-8820 Fax: (360) 332-7124

"The Peace Arch City"

May 9, 1996

943-1673
.06
I/022
6/25/96

Mark Birch
Golder Associates, Inc.
4104 148th Avenue NE
Redmond, WA 98052

Dear Mark:

Attached is a copy of the review comments received from Whatcom County as a result of their review of the City of Blaine's Wellhead Protection Plan.

I spoke with Derek Sandison from Adolphson Inc. about these issues and it was suggested that we meet with the County (Sue Blake) about our management strategies for the area.

In addition, once we receive comments from other agencies, we need to prepare a response letter and incorporate changes into the final document.

Should you have any questions, please give me a call.

Sincerely,

William Duffy

William M. Duffy
Water/Wastewater Operations Manager

Attachment

WHATCOM COUNTY

PLANNING AND DEVELOPMENT SERVICES

Michael T. Knapp, Director

5280 Northwest Drive
Bellingham, WA 98226

Scan: 769-6756 Fax: 738-2493
206/676-6756 206/380-8101

RECEIVED
APR 2 6 1996
CITY OF BLAINE
PUBLIC WORKS DEPT

April 25, 1996

Mr. William M. Duffy
Department of Public Works
1200 Yew Avenue
Blaine, WA 98230

Dear Mr. Duffy:

Thank you for the opportunity to review the draft Well Head Protection Program for the City of Blaine. As you are aware, the County has a particular interest in the Program because it affects the County position related to Blaine's urban growth area. Specifically, the County agreed to include much of the wellhead area as a Conditional UGA with the understanding that Blaine wanted to have control over its watershed for protection purposes, and not as a means to resolve urban growth needs. It is clear in reviewing the Program that Blaine has done a great deal of work to understand and manage it's water supply. I asked Sue Blake, Water Resource Planner, to review the plan and as a result, I have the following questions, comments, and concerns about the protection measures identified.

1) Many of the management recommendations target other agencies such as the County. While this seems reasonable if the area were to remain under County jurisdiction, it is my understanding that most of the area will be residential and under City jurisdiction. This will eventually occur through annexation but in the short term, interlocal agreement discussions are leaning toward City standards being applied in UGAs even prior to annexation. It would be useful to see an analysis of City regulations and programs that relate to watershed protection.

2) The Wellhead Program includes an analysis of future land use and concludes that sewered development on one quarter acre parcels would result in significant nitrate contamination of ground waters within the zone of contribution to the City's wells. The program further concludes that the nitrate source would be primarily from lawn fertilizers associated with residential and commercial development. Two possible management strategies are recommended to address the problem (voluntary BMP's and *consideration* of a landscape ordinance). In reviewing the details of both proposals, I do not feel assured that they will mitigate water quality impacts.

/3) Will the area be residential or will it also include commercial? If it does include commercial, what types of activities could this include and will special provisions be made to mitigate potential impacts to water quality?

4) The latest population projections developed for Blaine indicate that in 2015, Blaine will have a population of 7,800. This number was arrived at through joint discussions with Blaine and County Planning staff and may be useful to you in your planning efforts.

5) The draft County GMA Comprehensive Plan includes the following recommendation related to sand and gravel mining in wellhead protection areas:

> "MRL (mineral resource land) designations must not occur within the 15 year zone of contribution for designated wellhead protection areas."

If you feel this language adequately addresses your concerns as reflected in recommendations 9.2.2.1 you may want to express your support to the County Council.

6) In regards to recommendation 9.2.2.4, the County adopted a new stormwater ordinance and associated standards effective July 1, 1995. A copy of the standards is attached.

Thank you again for the opportunity to review this document. By continuing to work together on these issues we will be able to adequately plan for future growth in Whatcom County. Please contact myself or Sue Blake if you have questions or need further information.

Sincerely,

Vickie Hardin Woods

Vickie Hardin Woods
Planning Division Manager

cc: Michael Knapp
Pete Kremen
County Council Members