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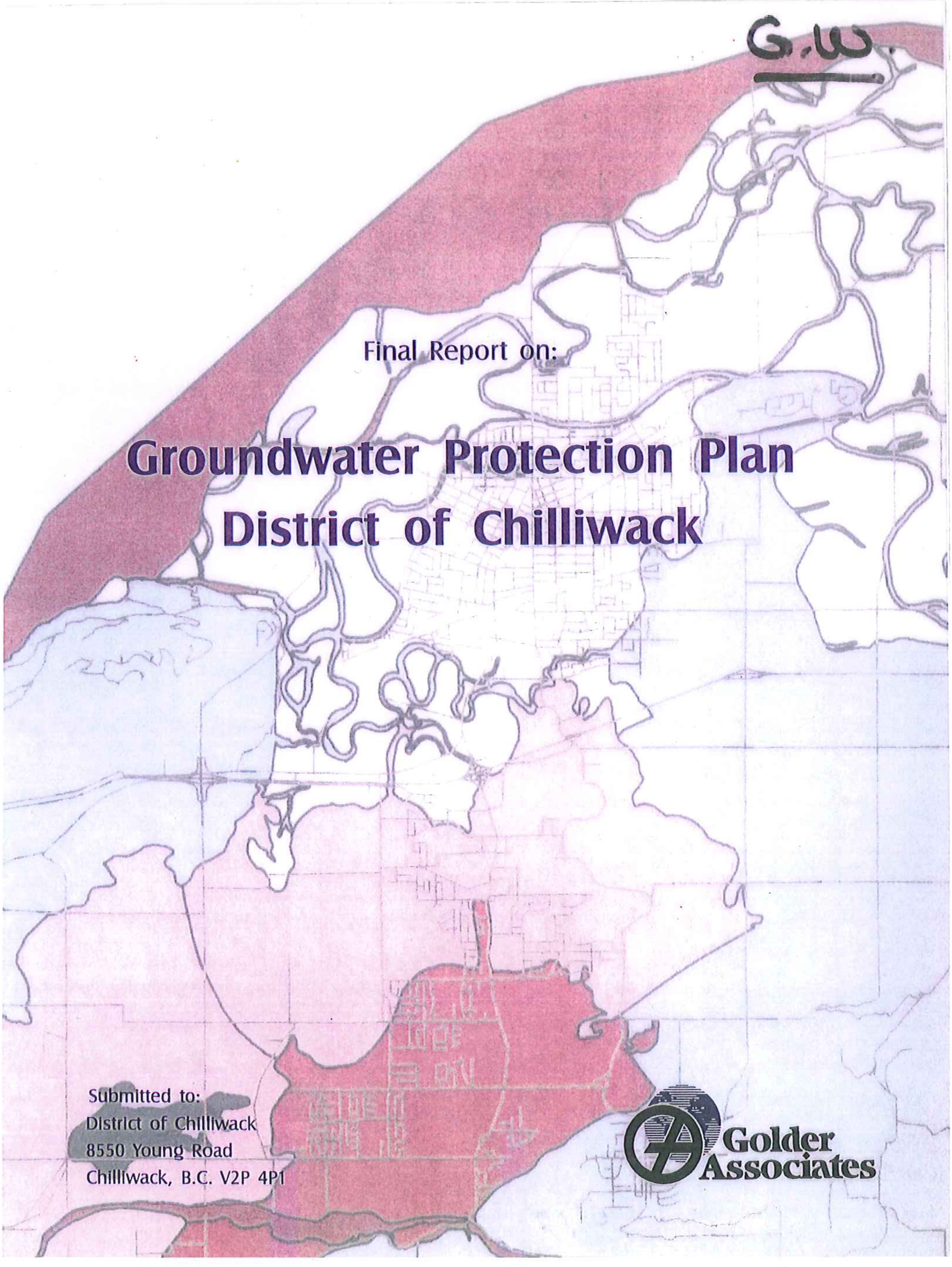

Final Report on:

Groundwater Protection Plan
District of Chilliwack

Submitted to:
District of Chilliwack
8550 Young Road
Chilliwack, B.C. V2P 4P1

Golder Associates

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1.0 INTRODUCTION

Golder Associates Ltd. is pleased to present this Groundwater Protection Plan to the District of Chilliwack. The project was carried out in accordance with the Terms of Reference outlined in your letter dated January 20, 1997 and our proposal dated February 11, 1997 (our file number P97-1038).

The District of Chilliwack currently obtains most of its water supply from groundwater sources and a lessor component (approximately 42 percent) from surface water sources. With increasing concerns over the quality of surface water supplies due to siltation, giardia and cryptosporidium, the District intends to phase out the use of surface water and rely solely on groundwater to meet the future water supply needs of the District. In recent years, groundwater supplies in the Fraser Valley, including the District of Chilliwack, have come under increasing threat of contamination from a variety of sources, including agricultural activities, land application of wastes, septic systems, municipal landfills, leaking underground storage tanks and industrial activities. Once contaminated, groundwater is exceedingly difficult, and sometimes impossible, to restore and the costs of developing alternative supplies are high.

Given the dependence of the District of Chilliwack on groundwater as a source of water supply, the intrinsic vulnerability of the local aquifers, and the risk of groundwater contamination from pressures related to increased development, the District is ideally suited for the implementation of a Groundwater Protection Plan. Implementation of groundwater protection measures will not only help to protect public health, but will protect ecosystems associated with wetlands, streams and lakes that rely on groundwater as a source of recharge.

In order to achieve the greatest degree of groundwater protection, this Groundwater Protection Plan was developed by combining the strategies of both *wellhead protection* and *aquifer protection*. Wellhead protection involves the delineation of capture zones of community wells and the use of protection measures to manage activities within those zones, while aquifer protection consists of the delineation of entire aquifers and the implementation of protection measures in more vulnerable areas of those aquifers. While wellhead protection is considered essential for protection of existing District groundwater supplies, aquifer-wide protection provides consideration for other areas that are currently supplied by private wells and areas where the District may wish to develop additional groundwater supplies in the future.

The development of this Groundwater Protection Plan included delineation of capture zones of existing and potential District water supply wells at both current and projected pumping rates, and groundwater vulnerability mapping to identify sensitive areas outside of the capture zones. Once the areas requiring protection were delineated, a contaminant inventory was conducted to identify existing and potential threats to groundwater quality. Based on the results of these tasks, a number of recommendations were developed for both wellhead protection of District water supply wells and for regional-level land use strategies and groundwater protection measures for vulnerable areas located outside of the capture zones. Groundwater Monitoring and Contingency Plans were also developed as part of this Groundwater Protection Plan. The purpose of the Groundwater Monitoring Plan is to provide early warning of impending water quality problems, while the Contingency Plan identifies measures that should be implemented to protect groundwater in the event of a spill or an accident.

In accordance with the Terms of Reference, the scope of this Groundwater Protection Plan is limited to groundwater quality concerns. Issues related to the ability of the local aquifers to sustain the current and future water supply requirements of the District were not addressed in this study. Similarly, the potential for well interference between existing or potential production wells and neighbouring wells was not addressed.

2.0 HYDROGEOLOGY

Most groundwater supplies within the District of Chilliwack are derived from two major aquifers: the Chilliwack-Rosedale Aquifer and the Sardis-Vedder Aquifer. A description of these aquifers is presented below.

2.1 Chilliwack-Rosedale Aquifer

The Chilliwack-Rosedale Aquifer underlies most of the Fraser River flood plain across the District of Chilliwack (Figure 1). The aquifer is comprised of sand and gravel deposited by the Fraser River, ranging in thickness from 30 m in the east to 10 m in the west. The gravel content of the aquifer diminishes towards the west, so that west of Chilliwack Mountain the sediments are characterized primarily by sand. Most of the aquifer is overlain by a thin, protective layer of floodplain silts. In the region between Chilliwack Mountain and the east boundary of the District, north of the Trans Canada Highway, these silts range in thickness from 1 m to 3 m. South of the highway, the aquifer is overlain by 2 m to 4 m of silt and peat. In a 2 km by 5 km area located east of the Chilliwack urban center, from Vedder Mountain to McGuire Road, surface fines up to 20 m thick have been identified within a large paleochannel. In the area west of Chilliwack Mountain, the surficial silt unit is on the order of 2 to 3 m thick at the Trans Canada Highway. The silts thicken to up to 10 m in localized, abandoned channel-fill deposits in the vicinity of the Lickman interchange, while to the south, silts and clays up 5 m to 13 m thick have been identified.

The water table within the Chilliwack-Rosedale Aquifer generally lies within 4 m of ground surface and is often found less than 2 m below ground surface. The aquifer is recharged by precipitation that falls on the valley floor, runoff from the uplands to the south and leakage from several small streams along the southern boundary of the valley. Groundwater flow is directed primarily towards the west, with groundwater discharging into the Fraser River and small streams and sloughs in the central and northern part of the aquifer. Hydraulic gradients are relatively low, and in some parts of the aquifer groundwater flows at velocities on the order of a few meters per year.

2.2 Sardis-Vedder Aquifer

The Sardis-Vedder Aquifer is located in the areas of Vedder Crossing and Sardis at the south edge of the District. The aquifer is comprised of a large alluvial fan formed by the Chilliwack River where the river exits the Cascade Mountains. The proximal portion of the fan is comprised of gravels more than 60 m thick, overlain by a thin cap of sand and silty sand. The fan thins towards its margins, where it has prograded over Fraser River floodplain deposits to the north and lacustrine deposits to the west. The distal portions of the fan are up to 30 m thick and predominantly characterized by gravel, sand and minor silt.

In the proximal portion of the fan, the water table ranges from approximately 14 m below ground surface at the fan apex to approximately 5 m around the edge, with the exception of the area south of the Vedder River, where water-levels of 1.5 m to 2.5 m below ground surface have been observed. Other unidentified areas may exist around the edge of the proximal fan where the water table is shallow. In the distal portions of the fan, the water table ranges from approximately 5 m below ground surface to less than 2 m around the edges. The Sardis-Vedder Aquifer is likely recharged by the Vedder River, runoff from the upland areas located to the south, and local precipitation. Groundwater flow within the aquifer is generally directed from the apex of the fan at the Vedder Bridge outwards in a radial direction towards the distal portions of the fan. Hydraulic gradients within the aquifer are relatively high, and groundwater velocities are on the order of tens to hundreds of meters per year.

2.3 Other Aquifers

In addition to the two major aquifers described above, groundwater supplies are also derived from bedrock and glaciofluvial sediments in the uplands along the southeast part of the District and from small alluvial fans located along the edge of the Cascade Mountains in the eastern part of the District (Figure 1). South of the District boundary, additional groundwater supplies are derived from the Chilliwack River Aquifer comprised of sands and gravels deposited by the Chilliwack River.

3.0 GROUNDWATER USE

3.1 District of Chilliwack

3.1.1 Current Water Supply

The total population of the District of Chilliwack was estimated to be 62,431 (in 1995) in a report prepared by UMA Environmental entitled "*District of Chilliwack Water Distribution System Upgrade Analysis*" (dated 1996). Most of this population is currently serviced by the District water supply system, the extent of which is shown in Figure 2. Most of the District's water supply is derived from groundwater sources and a lesser component (approximately 42 percent) is derived from surface water sources. The surface water supplies are derived from intakes at Elk, Dunvill and Nevin Creeks at the southeast edge of the District (Figure 2). A description of the groundwater supply wells is presented below.

Wells 1, 2 and 3 (Sardis-Vedder Aquifer)

Over half of the water supply for the District of Chilliwack is currently obtained from three production wells (Wells 1, 2 and 3) located in the Sardis-Vedder Aquifer. Wells 1 and 2 are located adjacent to each other at the southwest corner of Watson and Tyson Roads, while Well 3 is located at the west edge of the CFB Chilliwack property approximately 150 m north of Keith Wilson Road (Figure 2).

Well 1, drilled in 1973, is eight inches (203 mm) in diameter and screened over a depth interval of 60 ft to 81 ft (18.2 m to 24.7 m). Well 2, drilled in 1977, is 16 inches (406 mm) in diameter and screened over a depth interval of 60 ft to 98 ft (18.2 m to 29.9 m). According to Mr. Eric Dyck, Well 1 has a maximum pumping rate of 50 L/s while Well 2 has a maximum pump rate of 200 L/s. Collectively, the maximum pumping rate for Wells 1 and 2 is about 210 L/s. Based on a review of volumes removed from Wells 1 and 2 over the period of 1991 through 1996 (Appendix I), Wells 1 and 2 were pumped at a rate equivalent to a continuous pumping rate of 79 L/s over that period (Table 1).

Well 3, drilled in 1964, is 16 inches (406 mm) in diameter, 112 ft (34.1 m) deep and screened over an unknown depth interval. The well was initially used as a water supply source by CFB Chilliwack and was turned over to the District in the mid 1980s. According to Mr. Dyck, up until this year the maximum pumping rate of the well was limited to 50 L/s to 60 L/s due to constraints with the pump and distribution system. However, we understand that Well 3 has been recently upgraded and is currently capable of producing about 220 L/s. Based on a review of volumes removed from Well 3 over the period of 1991 through 1996 (Appendix I), Well 3 was pumped at a rate equivalent to a continuous pumping rate of 41 L/s over that period (Table 1).

Well logs for Wells 1, 2 and 3, obtained from B.C. Environment's water well records database, are provided in Appendix II.

Wells 4 and 5 (Chilliwack-Rosedale Aquifer)

In 1995, a test well drilling program was carried out in the east Chilliwack area under the supervision of Klohn-Crippen Consultants Ltd. (Klohn). Based on the results of this program, the District proceeded with the completion of two production wells (Wells 4 and 5) in the Chilliwack-Rosedale Aquifer in 1996. Well 4 ("Rosedale Well") is located south of Yale Road just west of Rosedale, while Well 5 ("Annis Road Well") is located west of Annis road and south of the Trans Canada Highway (Figure 2).

Well 4 is 20 inches (500 mm) in diameter and Well 5 is 12 inches (300 mm) in diameter. Both wells are screened over an interval from 60 ft to 80 ft (18.3 m to 24.4 m). Klohn estimated the "safe yield" of the wells to be on the order of 140 L/s for Well 4 and 102 L/s for Well 5. According to Mr. Dyck, the maximum pumping rates of both wells are currently limited to 75 L/s due to the existing pumps. Based on a review of the volumes removed from the wells over a two month period in 1996 (Appendix I), Wells 4 and 5 were pumped at rates equivalent to continuous pumping rates of 37 L/s and 20 L/s, respectively over that period (Table 1).

Well logs for Wells 4 and 5, obtained from the Klohn report, are provided in Appendix II.

3.1.2 Future Water Supply Requirements

We understand that based on projected population growth, the water supply requirements for the District of Chilliwack are expected to increase significantly over the next 30 years, rising to a maximum daily demand on the order of 192 ML/day (or an equivalent average pumping rate of 2220 L/s) by the year 2027 (personal communication, Phil Blaker, April 18, 1997). In order to meet these demands and phase out its reliance on surface water supplies (due to concerns with siltation, giardia and cryptosporidium), the District intends to develop additional groundwater supplies. We understand that the District's current strategy is to develop additional water supply wells in the Sardis-Vedder Aquifer. Further development of the Sardis-Vedder Aquifer is preferred over the Chilliwack-Rosedale Aquifer because groundwater of Sardis-Vedder Aquifer is of good quality (groundwater sampling results provided in Appendix III) and not characterized by elevated iron and manganese concentrations.

Sardis-Vedder Aquifer

According to Mr. Shand, of Stanley Associates Engineering Ltd., (Stanley) the District is considering meeting the water supply requirements of the next 10 years by drawing from approximately five wells (the three existing wells plus two additional wells) located in the Sardis-Vedder Aquifer, each with a maximum pumping rate on the order of 100 to 200 L/s.

Existing Water Supply Wells - Wells 1, 2 and 3

Although we understand that Well 2 may be capable of a maximum pumping rate of about 200 L/s with upgrading, Mr. Shand indicated that in future, Wells 1 and 2 will not likely be pumped at rates in excess of the current rate of 200 L/s to 210 L/s. However, we understand that in the future, the District may upgrade Well 3 to achieve a maximum pumping rate of approximately 220 L/s.

Proposed Water Supply Wells - CFB Chilliwack Well and TW95-1

In addition to Wells 1, 2 and 3, there are two other water wells located within the Sardis-Vedder Aquifer that are under consideration for future use by the District: the CFB Chilliwack Well and Test Well TW95-1.

The CFB Chilliwack well is located at the southeast corner of the Base in Building Number 1038 (Figure 2). The well, owned by the Department of National Defence, has historically serviced the water supply requirements of the Base. The well, drilled in 1975, is 16 inches (406 mm) in diameter and screened over a depth interval of 220 ft to 230 ft (67 m to 70 m). According to Mr. Ed Lemee, of the Department of National Defence, the maximum pumping rate for the well is 65 L/s. Mr. Lemee estimated that with the reduced population currently present on the Base, the well is currently pumped for about 5 hours per day. Based on this estimate, the current pumping rate for the CFB well is estimated to be equivalent to a continuous pumping rate of 13 L/s (Table 1). Historically, when the Base was fully occupied, Mr. Lemee estimated that the well pumped for 12 to 13 hours per day, which is equivalent to a continuous pumping rate of about 30 L/s.

As part of the 1995 test well drilling program, a 12 inch (300 mm) diameter test well (TW95-1) was completed at the east edge of the CFB Chilliwack Base northwest of the intersection of Vedder Road with Keith Wilson Rd. (Figure 2). The well was screened over the interval of 120 ft to 150 ft (36.6 m to 45.7 m). Klohn estimated the "safe yield" of the well to be on the order of 133 L/s.

Well logs for the CFB Chilliwack well and TW95-1 are provided in Appendix II.

Proposed Test Well Locations

Due to concerns over Native land claims on the CFB Chilliwack property, the District is considering other potential test well locations in the Sardis-Vedder Aquifer to meet future water supply demands. We understand that two proposed test well locations are currently under consideration. One proposed test well location is 44720 Keith Wilson Road, east of Peach Road, and the second location is 5290 Vedder Road, just north of the Vedder River (Figure 2).

Chilliwack-Rosedale Aquifer

Wells 4 and 5

We understand that plans for future use of Wells 4 and 5 are uncertain at this time due to the presence of elevated levels of iron and manganese in groundwater at those locations (laboratory reports provided in Appendix III). Treatment would likely be required to allow continued use of Wells 4 and 5. According to Mr. Shand, should Wells 4 and 5 continue to be used in the future, pumping rates similar to those estimated by Klohn could be achieved by upgrading of the pumps.

3.2 Other Groundwater Users

A comprehensive inventory of private water wells other than those owned by the District was beyond the scope of this study. However, Golder Associates assembled some information concerning regional groundwater use to assist with the development of the protection plan.

Within the District of Chilliwack, groundwater is used by several other purveyors besides the District itself. A search of water well records identified some 500 private water wells across the District. Some of these wells supply water to property owners located outside the area serviced by the municipal water supply system (Figure 2), while other wells are located in areas now supplied by the municipal system and have likely been abandoned. Presumably, some older wells located in rural areas now serviced by municipal supplies may be maintained by property owners for watering of gardens. A search of large capacity wells (wells yielding in excess of 200 Imperial gallons per minute, or 13 L/s) identified 39 large capacity wells across the District (Figure 3 and Appendix IV). Most of these are presumed to be used for irrigation; a select number may be used by other facilities.

According to Mr. George Rice of the Ministry of Health, in addition to the District water supply system, there are on the order of 10 other smaller waterworks facilities within the District that service local communities such as trailer parks. Several of these facilities use groundwater as a water supply source. A request for information concerning the location, nature and quality of groundwater used by community waterworks was made to the Ministry of Health; however, the information was not received prior to issuing of this report.

4.0 VULNERABILITY MAPPING

4.1 Methodology

Groundwater vulnerability mapping consists of determining the intrinsic sensitivity of a groundwater resource to contamination through consideration of a number of hydrogeological variables. Following compilation and review of available hydrogeological information, a number of existing vulnerability mapping schemes were evaluated to select the most effective mapping technique for the District of Chilliwack. The mapping schemes were evaluated for suitability with respect to the following criteria:

- local hydrogeology;
- available data;
- ability of the scheme to discern five categories of relative groundwater vulnerability in accordance with the guidelines for vulnerability mapping established by the International Association of Hydrogeologists (IAH); and
- ability to employ mapping technique under the existing project budget.

During the review, particular consideration was given to the AVI (Aquifer Vulnerability Index) vulnerability mapping scheme, a technique favoured by B.C. Environment following its pilot vulnerability mapping study in the Abbotsford/Aldergrove area (report entitled *"Evaluating Methods of Aquifer Vulnerability Mapping for the Prevention of Groundwater Contamination in British Columbia"*, by K. Ronneseth, M. Wei and M. Gallo of B.C. Environment, December, 1995). However, the AVI scheme was not considered sensitive enough for use in the District of Chilliwack because under the AVI scheme, the entire District falls into one vulnerability category (highly vulnerable). An alternative mapping scheme that is widely employed in the United States, known as DRASTIC, was also considered, but was dismissed because the scheme requires a number of input parameters that were not readily available. In addition, the DRASTIC mapping scheme could not be employed within the existing project budget.

Following the review of various vulnerability mapping techniques, a method known as "GOD" (Groundwater occurrence/Overall aquifer class/Depth to Groundwater), developed by Foster of the British Geological Survey, was selected for use in the

District of Chilliwack. The "GOD" system is simple to employ, well-suited to the local hydrogeology and allows some flexibility. "GOD" is a parametric rating system, whereby a numerical score is assigned to each hydrogeological parameter within a given area. A total rating for each area is then obtained by multiplying the scores of the hydrogeological parameters. The final rating is divided into segments (from minimum to maximum) expressing a relative vulnerability degree. An overview of the GOD scheme is shown in Figure 4. As shown, the method uses a total of three hydrogeological input parameters consisting of groundwater occurrence (G), overall aquifer class (O), and depth to water (D).

The vulnerability mapping was carried out by assigning a score to each of the three hydrogeological input parameters within each of the near-surface facies units identified in the *"Near Surface Facies Map"* (Draft, November 28, 1995) developed by Monahan, P.A. and V. M. Levson of the British Columbia Geological Survey as part of the Chilliwack Seismic Microzonation Project. Appropriate scores for each hydrogeological parameter were selected on the basis of the facies definitions provided by Monahan and Levson, a review of information contained within water well and geotechnical borehole logs from across the District, and geological cross-sections compiled by Monahan.

For the purpose of this study, the following assumptions were used to categorize groundwater occurrence (G):

- unconfined - areas where no protective silt, clay or till overburden is present above the aquifer;
- semi-unconfined - areas where less than 2 m of silt, clay or till overburden is present above the aquifer;
- semi-confined - areas where 2 to 5 m of silt, clay or till overburden is present above the aquifer;
- confined - areas where greater than 5 m of silt, clay or till overburden is present above the aquifer; and

- artesian confined - areas where greater than 5 m of silt, clay or till overburden is present and where water wells completed in the underlying aquifer exhibit flowing artesian conditions.

In cases where low permeability silts and/or clays are interbedded with aquifer materials, the groundwater occurrence score was reduced to account for some degree of protection offered by the lower permeability sediments.

For overall aquifer class (O), sediments contained within the Chilliwack-Rosedale Aquifer and distal portions of the Vedder River Fan were assigned a score of 0.7 in accordance with the "GOD" scheme. Sediments contained within proximal portions of the Vedder River fan and alluvial fans located at the southeast edge of the District were assigned a score of 0.8 to reflect the coarser nature of the sediments in those areas.

After scores were assigned to each of the hydrogeological input parameters, a final rating for each near-surface facies was determined by multiplying the three scores. Based on the total rating, each near surface facies was assigned a groundwater vulnerability rating of negligible, low, moderate, high or extreme. For near-surface facies characterized by variable hydrogeological parameters, the facies were assigned a range of appropriate groundwater vulnerabilities. In order to produce the groundwater vulnerability map, Golder Associates obtained a copy of the near-surface facies map produced by Monahan and Levson in digital format and assigned an appropriate colour to each facies based on its vulnerability rating. A final version of the vulnerability map was produced following review and comment on a draft version of the map by Mr. Patrick Monahan.

4.2 Results

The results of the vulnerability mapping are presented in Figure 5. In general, the vulnerability of groundwater to contamination from surface sources increases with increasing aquifer permeability, absence of a protective confining layer above the aquifer, and shallower water tables.

Based on the results, the Sardis-Vedder Aquifer is classified as the most vulnerable area of the District. As discussed in Section 2.0, the proximal portion of the Vedder Fan is comprised of gravel and coarse sand. While these sediments are overlain by a thin layer of sand and silty sand, the aquifer is considered to be unconfined due to the absence of a low permeability layer above the aquifer. Across most of the proximal fan, where the water table lies at a depth of between 5 m and 14 m below ground surface, the aquifer is classified as "highly vulnerable". However, around the edges of the proximal fan and in the area south of the Vedder River, where water-levels of less than 5 m have been observed, the aquifer is classified as "extremely vulnerable". At present there is insufficient data to delineate the boundary between high and extreme areas of groundwater vulnerability in the proximal fan. Therefore, the entire proximal fan has been classified as "highly to extremely vulnerable" to reflect the variation in hydrogeological parameters.

The distal portion of the Vedder Fan is characterized by slightly less permeable sediments consisting of gravel, sand and minor silt. Similar to the proximal fan, the aquifer is unconfined in this area. The water table across the distal fan is generally shallower than in the proximal fan, ranging from approximately 5 m to less than 2 m. Based on these hydrogeological parameters, the distal portions of the fan are classified as "highly vulnerable", with the exception of two areas.

The two portions of the distal fan with differing vulnerability classifications include an area at the east edge of the distal fan in the vicinity of Bailey Road and a small area within the western portion of the fan north of Keith Wilson Road between Hopedale and Lickman Roads. In these areas, the distal fan is overlain by 5 to 18 m of silt, fine sand and peat. The presence of these confining sediments in these areas results in a lower vulnerability rating. The area at the east edge of the fan is classified under a vulnerability rating of "low", while the small area within the western portion of the fan is classified under a vulnerability rating of "negligible" based on evidence of flowing artesian conditions at one location in that facies unit.

The Chilliwack-Rosedale Aquifer is characterized by sand and gravel sediments and a water table that generally lies within 4 m of ground surface. The aquifer falls into two vulnerability categories largely as the result of the variability of the silt layer above the aquifer. While no confining layer can be considered "impermeable", the presence of a low-permeability silt layer above much of the Chilliwack-Rosedale Aquifer provides a degree of protection from surface contamination sources. Across most of the aquifer, from Chilliwack Mountain to the east boundary of the District in the area north of the

Trans Canada Highway, the aquifer is overlain by approximately 1 m to 3 m of silt. Since areas with less than 2 m of confining silt are classified as "moderately vulnerable" and areas with greater than 2 m of silt are considered to be less vulnerable, the north portion of the Chilliwack-Rosedale Aquifer has been assigned a rating of "low to moderate vulnerability" to reflect the variation in hydrogeological parameters. The west and southern parts of the aquifer have been assigned a rating of "low vulnerability" based on the presence of greater than 2 m of confining silt in these areas. Broad generalizations were required in order to assign a score to hydrogeological parameters such as the thickness of the confining silt layer. In actual fact, the nature of the confining silt layer is considerably variable. There may be areas across both north and south portions of the Chilliwack-Rosedale Aquifer where the confining silts are completely absent and the underlying aquifer is highly vulnerable. In other areas, such as in the vicinity of the paleochannel described in Section 2.1 and the Lickman interchange, where silts of up to 20 m and 10 m thick (respectively) have been found, the aquifer is considerably less vulnerable.

A number of small alluvial fans are located along the edge of the Cascade Mountains in the eastern part of the District (Figure 1). While these fans have not been formally classified as aquifers, they may serve as sources of groundwater supply. The proximal portions of these fans are characterized by unconfined silty gravel and diamicton. Limited water-level information indicates that the water table lies approximately 5 m below ground surface in the proximal portions of the fans. Based on these hydrogeological parameters, the proximal portions of the fan are classified as "moderately vulnerable". Distal portions of the fan, characterized by finer sediments, are classified under the category of "low vulnerability".

Most of the remainder of the District is classified under the category of low vulnerability. Regions of low groundwater vulnerability include the area at the west edge of the District characterized by fine-grained lacustrine sediments; the area at the east edge of the District characterized by colluvium and Cheam slide debris; and bedrock, pleistocene deposits and eolian silts associated with the uplands along the southeastern portion of the District.

Active river channels, including the Fraser and Vedder Rivers, have been assigned a ranking of "extreme vulnerability" based on the relatively permeable nature of the sediments within these channels and the presence of the water table at ground surface. In contrast, semi-active and abandoned river channels and sloughs, most of which are located across the north half of the Chilliwack-Rosedale Aquifer, were assigned a ranking of "low vulnerability" because the channels are generally characterized at the surface by significant thicknesses (2 m to 6 m) of low permeability silt, clay and peat.

4.3 Limitations Associated with Groundwater Vulnerability Mapping

Vulnerability mapping provides an excellent tool to assist planners and regulators make informed, environmentally sound decisions regarding land use and protection of groundwater quality. They can also be used as a means of raising public awareness about groundwater protection. However, it is important that the limitations associated with vulnerability mapping be fully understood.

Firstly, the groundwater vulnerability map was prepared by generalizing a number of hydrogeological parameters for each facies unit. In reality, hydrogeological parameters within a facies unit are subject to considerable variability which has a significant affect on the groundwater vulnerability. For example, as discussed in Section 4.2, the vulnerability classification of the Chilliwack-Rosedale is considered to be generalized because of the variable nature of the silt layer above the aquifer.

Secondly, vulnerability mapping provides a measure of the *intrinsic* vulnerability of groundwater to contamination based on the natural aquifer characteristics. It does not account for areas where existing groundwater contamination is present, or the risk of contaminant release (the risk of contaminant release is addressed by the contaminant inventory). In addition, there is no guarantee that areas classified under the "low vulnerability" category cannot become contaminated. While the risk of groundwater contamination may be reduced with an increased thickness of surface fines, a deeper water table and a lower permeability aquifer, contamination is, nevertheless, still possible under these conditions.

Similarly, the vulnerability map does not account for the characteristics of individual contaminants that may be released. No distinction is made between contamination resulting from conservative contaminants, such as nitrate, which will migrate with groundwater flow, versus non-conservative contaminants, such as metals, that typically sorb onto soil particles.

Perhaps the most significant limitation concerning vulnerability mapping is that it only accounts for the release of contaminants at ground surface; it does not account for the subsurface release of contaminants. This has significant implications for contamination resulting from subsurface sources such as improperly abandoned wells, USTs, unlined lagoons, pipelines and landfill sites. While these sources may be located in an area classified by low groundwater vulnerability, if releases from these sources occur at some depth below the protective confining layer, groundwater contamination will likely result.

5.0 CAPTURE ZONE ANALYSIS

5.1 General

During the pumping of a water production well, groundwater is removed from a finite volume of the aquifer. In the initial phases of pumping, the drawdown cone created by the well expands and groundwater is removed from storage within the aquifer (due to pore drainage, aquifer matrix compression, and water compressibility). In later stages, once the drawdown cone attains sufficient dimensions and/or intersects a water body, groundwater flows radially towards the production well and the aquifer is replenished by recharge due to precipitation and/or leakage form streams, rivers, and geologic units bounding the aquifer.

To efficiently manage and protect a groundwater supply, an understanding of the well "capture zone" and the "time of travel" zones is required. A "capture zone" is the area of an aquifer from which all groundwater will eventually arrive at the production well, even after a considerable amount of time. A "time of travel" zone is the area of an aquifer from which groundwater will be pumped out in a predefined amount of time. For example, a the contaminant is released within the 1-year time of travel zone, it can be expected to arrive at the production well in approximately 1 year. Once the capture zone and time of travel zones are estimated, protective measures can be implemented within the zones to ensure the safety of the water supply.

Golder Associates carried out an analysis of the capture zones for the water supply wells operated by the District of Chilliwack. The capture zones were estimated for the existing water supply Wells 1, 2, 3, 4, 5, and the CFB Well under current pumping rates, and for all the existing wells and the proposed water supply well TW95-1 under projected pumping rates. The analysis used a regional groundwater flow model developed for the District by Emerson Groundwater Consultants Inc. (EGC), and two sub-models developed by Golder Associates. The following sections outline the methodology used in the capture zone modelling, the results of the analysis, and the limitations of the modelling study.

5.2 Modelling Methodology

Several methods of capture zone analysis exist including: 1) type curves and analytical expressions for the capture zone extent (e.g. Javandel and Tsang, 1986), 2) analytical groundwater flow models (e.g. Bonn and Rounds, 1990), and 3) numerical flow and transport models. The methods vary in their accuracy and applicability, with methods 1 and 2 being restricted to a relatively simple groundwater regimes, and method 3 being capable of addressing scenarios with more complicated hydrostratigraphy, hydrogeologic boundaries, and variable pumping scenarios. Because the hydrogeology within the District is relatively complex, and because a regional groundwater flow model for the District had already been developed, the latter approach was selected.

Two computer codes developed by the United States Geological Survey were used to estimate the extent of the capture zones near the pumping wells. MODFLOW (McDonald and Harbaugh, 1988), which is a 3-D finite-difference transient flow code, was used to simulate groundwater flow throughout the District. MODPATH (Pollock, 1989), a 3-D particle tracking code supplementing MODFLOW, was employed to simulate groundwater transport due to advection in the vicinity of the pumping wells.

The regional groundwater flow model developed by EGC provided an overview of the hydrogeological regime in the Chilliwack-Rosedale Aquifer and Sardis-Vedder Aquifer. The regional model was subdivided into two smaller scale sub-models and particle tracking was used to delineate the capture zones and time of travel zones corresponding to each pumping well. A description of the regional model and two sub-models is presented below.

5.2.1 Regional Groundwater Flow Model

The regional groundwater flow model for the District of Chilliwack was developed by Mr. Dan Emerson of EGC. The model, which comprises both the Sardis-Vedder Aquifer and the Chilliwack-Rosdale Aquifer, was developed to serve as a tool for managing the groundwater supply for the District. A description of the modelling methodology used to develop the regional model, including model design, calibration and sensitivity analysis, was provided to the District by EGC in a separate document.

5.2.2 Local Groundwater Flow and Particle Tracking Models

The regional groundwater flow model described in the preceding section is capable of simulating groundwater flow on a relatively coarse scale, which is dictated by the 150 m spacing of the computer grid. A much finer scale was needed for the delineation of the capture zones, particularly for wells located within the Chilliwack-Rosdale Aquifer, where the hydraulic gradients are comparatively high. Consequently, two sub-models were created within the regional model by Golder Associates to provide sufficient resolution for the capture zone analysis.

The location of the two sub-models is shown on Figure 6. The sub-model for the Sardis-Vedder Aquifer was designed to encompass the part of the aquifer in the vicinity of production Wells 1, 2, 3, the CFB Well, and test well TW95-1. The model extends from 571,900 E to 578,050 E, and from 5,437,000 N to 5,443,000 N. The sub-model for the Chilliwack-Rosdale Aquifer was constructed to comprise a section of the aquifer near production Wells 4 and 5, from 583,600 E to 592,899 E, and 5,442,975 N to 5,451,375 N. When constructing the sub-models, care was taken to ensure that the cone of depression created by the pumping wells would not intersect the sub-model boundaries.

A variable gridblock size was used in the sub-models. A coarse, 150 m x 150 m grid spacing was used away from the pumping wells, whereas a 50 m x 50 m grid spacing was utilized in the vicinity of the wells. This mesh refinement near the pumping wells provided sufficient resolution for the delineation of the capture zones. All boundary conditions and hydrogeological parameters used in the regional groundwater model were preserved in the sub-models. Constant head boundary conditions were used along the edges of the sub-models, where the sub-model edges did not conform to the regional model boundaries. Constant heads along these boundaries were set to the heads computed by the regional model for the corresponding gridblocks. The hydraulic heads and volumetric budgets computed by the sub-models were compared with the hydraulic heads and budgets calculated by the regional model for the corresponding sections of the aquifer, to ensure model consistency.

The sub-models were used to calculate hydraulic heads for both current and future pumping conditions as discussed in the following section. The hydraulic heads computed by the sub-models were then used for particle tracking. Between 40 to 50 particles were placed around each pumping well and the pathlines were computed in the backward tracking mode, in the direction opposite to the direction of groundwater flow. This approach allowed the delineation of the capture zone without the prior knowledge of the potential location of the contaminant source. In addition, time-dependent backward tracking was performed to estimate time of travel zones for each well. The time-dependent particle tracking was performed under the assumption that the effective porosity of the aquifer material is 0.3 (Maidement, 1992). Travel time zones were computed for:

- 2 months – approximated time required by biological pathogens moving in groundwater to degrade (Matthes, et al., 1985);
- 1 year – intermediate time selected based on the hydrogeological conditions prevailing in the District;
- 5 years – the average time considered necessary to implement groundwater remedial measures in response to a contamination event according to the U.S. Environmental Protection Agency; and
- 50 years – minimum travel time between a contaminant source and the receiving environment, as required by B.C. Environment.

5.3 Results of Capture Zone Analysis

The capture zones and time of travel zones for the District's production wells were estimated for both current and future pumping conditions. In general, the capture zones and time of travel zones are more circular and cover larger areas in the Chilliwack-Rosdale Aquifer, where the hydraulic gradients are relatively weak. The zones are more elongated and smaller in the Vedder-Sardis Aquifer, where the hydraulic gradients are stronger.

The following section presents the rationale for the selection of pumping rates used in the modelling study, and describes the extent of the zones for each production well.

5.3.1 Current Pumping Conditions

The pumping rates used for the evaluation of the capture zones and time of travel zones for current pumping conditions are summarized in Table 1. The pumping rates were calculated based on the yearly groundwater abstraction volumes recorded between 1991 and 1996. The groundwater abstraction records were provided by the District and are included in Appendix I.

The calculated pumping rates for each production well are somewhat lower then the corresponding instantaneous pumping rates. This is because the pumping rates calculated from the yearly abstraction volumes account for seasonal variation in water supply demand and for mechanical downtime.

Wells #1 and #2 – Vedder-Sardis Aquifer

Wells #1 and #2 are located in close proximity; therefore, for the purposes of the analysis, they were considered to act a single well. Thus, only one capture zone and one set of time of travel zones were estimated for both wells, as shown on Figure 13.

The model-predicted capture zone for the Wells #1 and #2 is elongated, with the long axis oriented in the north-south direction. It extends approximately 110 m to the north and 1.5 km to the south of the wells to the Vedder River. The capture zone embraces the smaller capture zone calculated for Well #3. The shape of the capture zone indicates that most of the groundwater extracted from these wells originates at the Vedder River.

The model estimates that all groundwater from within the capture zone for Wells #1 and #2 will arrive at the wells in a time equivalent to 3.5 years or less. Consequently, only 1-year and 60-day time of travel zones were computed for these wells. The 1-year time of travel zone extends approximately 110 m north and 800 m south of the wells, whereas 60-day time of travel zone stretches out 90 m north and 250 south of the wells.

Well #3 – Vedder-Sardis Aquifer

The capture zone calculated for Well #3 for current pumping conditions is elongated in a north-south direction, as shown on Figure 13. The zone extends across an area from approximately 70 m north of the well to 900 m south of the well. The model predicts that all groundwater from within the capture zone will travel to the production well in 2 years or less. Because of relatively short travel time, only 1-year and 60-day time of travel zones were estimated. The 1-year time of travel zone extends from approximately 70 m north to 700 m south of Well #3. The 60-day time of travel zone extends from approximately 70 m north to 160 m south of the production well.

CFB Well – Vedder-Sardis Aquifer

The capture zone computed for the CFB Well for current pumping conditions is relatively small when compared with the capture zone calculated for Wells #1, #2, and #3 (Figure 13). This is because the assumed pumping rate at the CFB Well is lower than pumping rates assumed for Well #1, #2, and #3, and because the CFB Well is located in close proximity of Vedder River. The capture zone for the CFB Well is elongated in a north-south direction and extends from approximately 30 m north to 130 m south of the well. The capture zone corresponds to a 60-day time of travel zone.

Well #4 – Chilliwack-Rosdale Aquifer

The capture zone estimated for Well #4 for current pumping conditions covers a much larger area than the capture zones estimated for wells completed in Vedder-Sardis Aquifer (Figure 17). The zone is more circular, with a long axis oriented a southwest-northeast direction. It extends from approximately 650 m southwest to 2.4 km northeast of Well #4, and corresponds to a 50 year travel time zone.

Because groundwater flows at lower velocities in the Chilliwack-Rosdale Aquifer, all three time of travel zones were calculated for Well #4. The approximate extent of the time of travel zones upgradient and down-gradient from Well #4 is provided below:

- 5 year – from 350 m southwest to 550 m northeast;
- 1 year – from 250 m southwest to 250 m northeast; and
- 60 day – from 100 m southwest to 100 m northeast.

Well #5 – Chilliwack-Rosdale Aquifer

The shape of the capture zone calculated for Well #5 is distinctly different from the shape of the capture zones estimated for the other production wells because of the proximity of Well #5 to the bedrock outcrop along the south edge of the valley (Figure 19). The long axis of the capture zone lies parallel to the valley edge and is oriented in a southwest-northeast direction. The capture zone extends from approximately 1 km southwest to 2.1 km northeast from Well #5. The zone corresponds to a 20-year time of travel zone.

The approximate dimensions measured for 5-year, 1-year, and 60-day time of travel zones, as measured along their long axis, are outlined below:

- 5 year – from 600 m southwest to 500 m northeast;
- 1 year – from 300 m southwest to 250 m northeast; and
- 60 day – from 100 m southwest to 100 m northeast.

5.3.2 Future Pumping Conditions

Pumping rates used to estimate the capture zone and time of travel zones for the District's water supply wells under future pumping conditions are summarized in Table 1. The pumping rates were selected based on our understanding of the following: 1) the projected increase in water demand, 2) an anticipated improvement in well capacity due to proposed upgrades to the pumps and distribution system, 3) current estimates of well yields for individual production wells, and 4) historical groundwater abstraction records. Because pumping rates are expected to be higher in the future, the capture zones and time of travel zones estimated for future pumping conditions are larger than those estimated for current pumping conditions.

Wells #1 and #2 – Vedder-Sardis Aquifer

The capture zone calculated for Wells #1 and #2 for future pumping conditions is shown in Figure 14. The capture zone is wider and extends further north (approximately 300 m) of the production wells than the capture zone estimated for current pumping conditions. The model predicts that all groundwater from within the capture zones will arrive at Wells #1 and #2 in less then 5 years. The 1-year time of travel zone stretches from approximately 300 m north to 900 m south of the wells, whereas the 60-day time of travel zone extends from approximately 150 m north to 300 south of the wells.

Well #3 – Vedder-Sardis Aquifer

Similar to the current pumping conditions, the model-predicted capture zone for Well #3 for future pumping conditions is encompassed within the capture zones calculated for Well #1 and #2. The zone is wider than the zone estimated for current pumping conditions, and extends 100 m north of the well (Figure 14). The capture zone for Well #3 corresponds to the 2.5-year time of travel zone. The 1-year time of travel zone extends from approximately 100 m north to 800 m south of the well, and the 60-day time of travel zone extends from 100 m north to 200 m south of the well.

CFB Well – Vedder-Sardis Aquifer

The capture zone simulated for the CFB Well for future pumping conditions (Figure 14) is only slightly larger than the zone estimated for current conditions, despite an increase in pumping rate. This is because the CFB Well is strongly influenced by the proximity of the Vedder River and by pumping from proposed well TW95-1. The CFB Well capture zone calculated for future pumping conditions is nearly equal to the 60-day time of travel zone.

TW95-1 – Vedder-Sardis Aquifer

The capture zone was estimated for the proposed well TW95-1, as shown on Figure 14. The zone is similar to the zone calculated for Well #3, and extends from approximately 150 north to 800 m south of the well. The southern extent of the capture zone is bounded by Vedder River. The capture zone simulated for TW95-1 corresponds to the 1.5-year time of travel zone. The 1-year time of travel zone extends from approximately 100 m north to 750 m south, and the 60-day time of travel zone extends from 100 m north to 200 m south of the proposed well.

Well #4 – Chilliwack-Rosdale Aquifer

The capture zone simulated for Well #4 for future pumping conditions is shown on Figure 18. The zone extends from approximately 1.1 km southwest to 3.4 m northeast of the well northeast of the well, the capture zone encompasses several smaller capture zones created by private water supply wells. The model predicts that all groundwater from the capture zone will arrive at Well #4 in 50 years or less.

The approximate dimensions of the travel time zones estimated for Well #4 for future pumping conditions are outlined below:

- 5 year – 600 m southwest to 700 m northeast;
- 1 year – 300 m southwest to 300 m northeast; and
- 60 day – 150 m southwest to 100 m northeast.

Well #5 – Chilliwack-Rosdale Aquifer

The capture zone calculated for Well #5 for future pumping conditions is shown on Figure 20. Because of the proximity of the well to the edge of the valley and to several private water wells, the capture zone is highly irregular. The zone extends from approximately 1.1 km southwest to 2.5 m northeast from Well #5, and corresponds to a 35-year time of travel zone. The approximate dimensions of time of travel zones of shorter duration were estimated as:

- 5 year – 900 m southwest to 1,100 m northeast;
- 1 year – 400 m southwest to 450 m northeast; and
- 60 day – 150 m southwest to 150 m northeast.

5.4 Model Limitations

State of the art methods were used to estimate capture zones for the water production wells operated by the District of Chilliwack. These methods are superior to the analytical approaches described in Section 5.2, and provide the best representation of the capture zones given the available hydrogeological data for the District. However, even with the considerable amount of data available, the capture zones and travel time zones estimated for the District are subject to the following limitations:

- The analysis of the capture zones for the production wells does not account for seasonal fluctuations in precipitation, stage in the Fraser and Vedder Rivers, and recharge from small streams and creeks. Such fluctuations are expected to influence the hydraulic gradients throughout the District, with gradients being generally higher in winter and lower during summer. Thus, the production wells will influence larger sections of the aquifer during the summer and the influence will decrease in winter. The groundwater flow and particle tracking models developed for the District represent average yearly conditions, and therefore the estimated capture zones reflect these average conditions only.

- The estimates of time of travel zones neglect the groundwater flow through the near- surface silts and clays overlying most of the Chilliwack-Rosdale Aquifer, and pertain exclusively to the movement of groundwater within the aquifer. In both aquifers, the groundwater flow is expected to be essentially horizontal, whereas the groundwater flow in the silts and clays is expected to be nearly vertical. The models developed for the aquifers simulate the groundwater flow using one layer for the silts and clays, and one layer for the underlying aquifer. Such models simulate the horizontal flow reasonably well but are incapable of accurately simulating vertical hydraulic gradients. It will take longer for potential contaminants to travel from the ground surface to the production wells than predicted by the model. More field data from the vicinity of the production wells and more detailed groundwater models would be needed to provide better estimates of the time of travel zones.

- The models used for the capture zone analysis do not account for dispersion of contaminants in groundwater. Dispersion is a transport process that causes a plume of contaminants to arrive at the receptor earlier than the water particle moving by advection only, and causes the plume to spread at right angles to the direction of groundwater flow. Thus, it is possible that contaminants originating from a source located within the capture zone will arrive at the production well earlier than predicted by the model (but at reduced concentration). It is also likely that some contaminants from sources located outside (and nearby) the capture zone boundaries could cross the boundary and migrate towards the pumping well.

- The models developed for the capture zone analysis do not take under consideration retardation and degradation of contaminants in groundwater. Retardation is a process that slows down the spreading of contaminants in groundwater, whereas degradation causes a reduction of the mass that originally entered the subsurface. Both processes counteract the effects of dispersion described in the preceding bullet.

- The models used for the analysis of the capture zones assume constant pumping rates at the production wells owned by the District and at other private water wells. In reality, pumping rates vary on a daily and seasonal basis based on water supply demand and downtime due to maintenance. The constant pumping rates used in the models represent average pumping rates that were calculated from the yearly groundwater withdrawal data, as outlined in Section 5.3. If the existing groundwater flow model was revised to incorporate seasonal variations in groundwater recharge, capture zones could be delineated for both low and high pumping conditions based on daily groundwater withdrawal data.

- The capture zone estimated for the production wells do not incorporate the influence of private wells with capacities smaller than 1,000 m^3/day (200 Igpm). Although the influence of such wells is expected to be generally small, they might influence the capture zones created by the District's production wells if located in close vicinity to the production wells in areas where the hydraulic gradients are relatively weak. A comprehensive inventory of local water wells would be required.

6.0 CONTAMINANT INVENTORY

6.1 Methodology

A contaminant inventory was carried out to identify existing and potential sources of groundwater contamination within the District of Chilliwack. The inventory was comprised of two components:

1. A regional inventory to identify general environmental concerns across the District, with particular emphasis on areas of moderate to extreme groundwater vulnerability; and

2. Comprehensive inventories of each capture zone identified in Section 5.0.

A summary of information sources used to complete the regional and capture zone contaminant inventories is presented below.

1. A search of databases maintained by B.C. Environment to identify 1) sites contained within the Contaminated Sites Registry, 2) sites contained within the WASTE database (used to manage information related to permits and approvals) and 3) sites contained within the database for spills reported to the Ministry.

2. A meeting with Ms. Beverley Locken, Agricultural Impact Officer with B.C. Environment, to discuss potential groundwater contamination related to agricultural activities.

3. Enquiries with Mr. George Rice, Deputy Chief, Ministry of Health regarding water quality concerns and groundwater use.

4. A visit to CFB Chilliwack to review the draft report on *"Environmental Site Investigation and Comprehensive Study, CFB Chilliwack, Vedder Crossing"*, by Dillon Consulting Ltd., March, 1997; and review of other environmental reports (listed in Section 6.2.7) provided by the Department of National Defence.

5. Interview with Mr. Wayne Green, Fire Chief concerning the status of underground storage tanks and fire response plans.

6. Enquiry with Mr. Mark Rowlands, Assistant Manager, Environmental Services, Fraser Valley Regional District regarding environmental concerns.

7. Enquiries with the Ministries of Aboriginal Affairs, Public Works and Health Canada and with the Sto:lo Nation concerning environmental concerns, groundwater use and groundwater quality on local Indian Reserves.

8. Discussions with District of Chilliwack staff Kirsti Domay (Environmental Services Technician), Leonard Stein (Utilities Superintendent) and Phil Blaker (Utilities Engineer) regarding potential environmental concerns.

9. Search of business licenses database maintained by the District of Chilliwack.

10. Review of historical fire insurance maps for Chilliwack (1953), Yarrow (1946), Rosedale (1942) and Sardis (1945).

11. Review of 1:20,000 TRIM maps, 1:50,000 topographic maps and 1:20,000 community map.

12. Review of orthophotos.

13. Review of District maps showing the extent of sanitary sewers, drainage and water distribution systems.

14. Review of the District of Chilliwack Official Community Plan (1990 - 2001), Zoning Bylaw 1993 No. 1841, Highway and Traffic Bylaw 1996, No. 2344, and zoning map.

15. Review of environmental reports (listed in Section 6.2.6) concerning the Bailey Landfill.

16. Review of groundwater quality data from the following sources:

    - Groundwater monitoring of Wells 1, 2, 3, 4 and 5 by the District;
    - Groundwater monitoring of monitoring well MW3 by the District;
    - Groundwater monitoring of CFB Well by the Department of National Defence;
    - Groundwater monitoring of B.C. Environment observation well #255 (Yarrow) by B.C. Environment;
    - Results of the *"Fraser Valley Groundwater Monitoring Program, Final Report"* (October, 1995), by the Ministry of Health, Ministry of Environment and Ministry of Agriculture, Fisheries and Food; and

- Results of the "*Fraser Valley Groundwater Monitoring Program, Phase I Report*" (April, 1993) and "*Drinking Water Study*" (March, 1992), by Gartner Lee Ltd.

17. Site reconnaissance of capture zones.

6.2 Results of Regional Contaminant Inventory

The results of the regional contaminant inventory are presented below.

6.2.1 Search of B.C. Environment Databases

In response to a request from Golder Associates, B.C. Environment conducted a search of its databases to identify sites located within the District of Chilliwack. A total of three databases maintained by B.C. Environment were searched; the Contaminated Sites Registry, the WASTE database and the Spills database.

Contaminated Sites Registry

The Contaminated Sites Registry identifies those sites for which the Ministry holds environmental information. These records are limited to information obtained since approximately 1989. The existence of a site within the Contaminated Sites Registry does not necessarily imply that the site is contaminated because under the existing Contaminated Sites Regulation, the site registration process can be triggered by a number of mechanisms including property transactions and facility upgrades. Similarly, there may be a number of contaminated sites within the District that have not been identified by the site registry. A summary of sites contained within the registry and the status of those sites is provided in Table 2 and site locations are illustrated in Figure 4. Of the 38 sites identified, the majority are located in the Chilliwack urban center. Only one site (the CFB Chilliwack property) is located within an identified capture zone (a detailed description of the CFB Chilliwack property is presented in Appendix V). Three sites (Site Registry Numbers 15, 24 and 37) were identified within high groundwater vulnerability areas.

WASTE Database

The WASTE database is used by the Ministry to manage information related to permits and approvals for effluent discharge, refuse or storage of special waste, and pollution abatement and pollution prevention orders. A total of 29 sites were identified from the WASTE database as shown in Table 28. The locations of these sites are shown in Figure 9. The majority of property owners identified by the WASTE database hold permits for the discharge of effluent. Two property owners, Cattermole Timber and the District of Chilliwack (Bailey Landfill), hold permits for the disposal of refuse material (a discussion of the Bailey Landfill is presented in Section 6.2.6). Three property owners hold permits for the storage of special waste materials. At the time of the database search, pollution abatement/prevention orders had been filed against three property owners at Waste Database Numbers 9, 15 and 16. All of these sites are located within high groundwater vulnerability areas. Since the search was conducted we understand that an order has been filed against the DeGroot farm, as discussed in Section 6.6.2.

Spills Database

A limited database has been maintained by B.C. Environment since 1995 for spills reported to the Ministry's Lower Mainland Region. Minor spills have been reported at 40 locations across the District over the past two and a half years. Materials spilled included hydrocarbons, solvents, pesticides and manures. Presumably, many other spills may have occurred that were not reported to B.C. Environment. The sites are listed in Table 2C and illustrated in Figure 9. No spills were reported within the capture zones; however, six spills were reported in high groundwater vulnerability areas (Spills Database Numbers 13, 20, 24, 27, 39 and 40). Environmental emergency response officers with B.C. Environment did not recall the occurrence of any major spills in the District of Chilliwack over the past few years.

6.2.2 Agricultural Issues

Environmental Concerns Related to the Agriculture Industry

As part of the contaminant inventory, Golder Associates met with Beverly Locken, Agricultural Impact Officer with B.C. Environment's Environmental Impact Section in

Surrey, B.C. Ms. Locken is responsible for environmental issues related to the agricultural industry across the Lower Mainland, including the District of Chilliwack.

Environmental issues related to agriculture are regulated according to the *Code of Agricultural Practice* ("the Code") by the recently established *Agricultural Waste Control Regulations* under the *Waste Management Act*. Other regulations applicable to the agricultural industry include the *Pesticide Control Act,* which regulates the use of pesticides, and the *Farm Practices Protection (Right to Farm) Act,* which regulates issues related to noise, odour and dust. A number of environmental guidelines have also been issued, including the *Manure Management Guidelines for the Lower Fraser Valley* and guidelines for individual commodity groups such as the *Environmental Guidelines for Dairy Producers in British Columbia.*

The intent of the Code is that farmers who comply with the Code do not require a permit for livestock waste disposal. However, operations involved in activities that fall outside of normal farming practices, such as processing facilities, require permits. There are two such operations requiring permits within the District of Chilliwack. Of these, one operation (Fraser Valley Duck and Goose Ltd., located south of Yarrow) is currently under a pollution prevention abatement order for inappropriate discharge of effluent to the ground (Agricultural Property Number 2, Figure 9).

We understand that in the Chilliwack area, agriculture is dominated by the dairy industry, with an increasing trend towards larger, industrial-style farm operations. When asked about environmental concerns related to the farming industry within the District of Chilliwack, Ms. Locken estimated that about 80 percent of the farming operations are out of compliance with the Code. Specific agricultural properties where B.C. Environment has identified potential environmental concerns are summarized in Figure 9. The primary environmental concerns related to agriculture are listed below in order of decreasing priority:

1. poor manure spreading practices;
2. uncovered manure stockpiles;
3. unlined lagoons used for storage of liquid manure; and
4. milk parlour discharge.

The greatest environmental concerns in the District of Chilliwack appear to be related to the storage and use of animal wastes. Problems are caused by poor management practices and the fact that for many farms, the available land base is not adequate to accommodate the wastes generated by the current livestock and poultry densities. The following presents a brief description of each of the issues listed above:

Poor Manure Spreading Practices

Poor manure spreading practices observed in the District of Chilliwack include both over-application of manures and spreading of manures during the winter months. Manure spread during the rainy, winter season is carried by run-off into surface water bodies and leached into groundwater. The spreading of manure during the winter months is in violation of the Code, since the Code requires that manure be applied to land only as a fertilizer or soil conditioner.

Uncovered Manure Stockpiles

Uncovered manure stockpiles represent another key environmental concern within the District. Precipitation falling on uncovered manure stockpiles carries runoff from the wastes into surface water bodies and groundwater. The Code requires that manure stockpiles be covered over the period of October 1 to April 1.

Unlined Lagoons Used for Storage of Liquid Manure

The discharge of liquid manures into unlined, earthen lagoons represents a significant risk to groundwater, particularly in areas where the protective silt layer overlying the Chilliwack-Rosedale Aquifer is thin or absent, or where the lagoons have been excavated through the silt into the permeable aquifer below. In such cases, the lagoons provide a direct conduit for the transmission of contaminants to groundwater. According to Ms. Locken, the highest densities of earthen lagoons are observed along Prairie Central Road.

An unlined pit that has reportedly been receiving discharge of liquid manures for the past seven years has been identified on the property located immediately north of the District water supply Wells #1 and #2 (Agricultural Property Number 1, Figure 9). A pollution prevention order has been issued to the current land owner, Mr. DeGroot.

B.C. Environment has conducted groundwater sampling for total metals, bacteriological parameters and nitrates/nitrites on the property of concern and water wells on three adjacent properties. Total metals were within the acceptable levels and no bacteriological parameters were identified. Nitrates/nitrites were found at concentrations ranging from 1.7 mg/L to 2.5 mg/L, which are below the drinking water guideline of 10 mg/L but above background levels (ambient nitrate/nitrite concentrations are estimated to be below 0.5 mg/L), indicating groundwater in this area has been influenced by anthropogenic activities.

Milk Parlour Discharge

Discharges from milk parlours represent another environmental concern. Equipment in milk parlours is reportedly washed down using acids. The resultant discharge cannot be released to septic tile fields because the acids and fats contained within the discharge cause the fields to fail, and there is a reluctance to discharge to lagoons due to limited storage capacities. As a result, milk parlour discharges are occasionally discharged to ditches, representing a potential source of surface water and groundwater contamination.

Impact of Agricultural Activities on Groundwater Quality

Contamination of groundwater by animal wastes results in elevated levels of nitrates, fecal coliform and biological pathogens. Agricultural activities have been implicated as the primary cause of elevated nitrate concentrations in Lower Fraser Valley groundwater sources. The presence of nitrates in groundwater poses a health risk to infants, particularly those under six months of age. When infants consume too much nitrate they develop a blood disorder called methaemoglobinaemia, also known as "blue-baby syndrome". For this reason, the Canadian drinking water guideline for nitrates has been established at 10 mg/L nitrate (expressed as nitrogen). In addition to nitrates, bacteria and biological pathogens, in discharges of animal waste to surface water can lead to eutrophication (introduction of excess nutrients resulting in excessive algae growth) and depletion of dissolved oxygen, thereby posing a risk to aquatic organisms.

To date, little information is available concerning the groundwater quality across the District of Chilliwack. The most recent data is available from the "*Fraser Valley Groundwater Monitoring Program*" carried out by the Ministry of Health, Ministry of

Environment, Lands and Parks and Ministry of Agriculture, Fisheries and Food (final report issued October, 1995). The study involved groundwater sampling of 192 community wells and 75 private wells across the Fraser Valley between 1992 and 1993. A total of 14 wells within the District of Chilliwack were sampled as part of this program, including District Wells 1, 2 and 3. Groundwater from the 14 wells met the drinking water criteria for nitrates. Nitrate concentrations were below 1 mg/L at all locations except a shallow, dug well near Promotory Heights, where an elevated nitrate concentration of 3 mg/L was identified (the source of nitrate at this location was not likely related to agricultural activity).

The Fraser Valley Groundwater Monitoring Program also involved a review of historical groundwater chemistry data collected over the period of 1981 to 1988 under the Water Quality Check Program (WQCP) managed by B.C. Environment. Based on the review (which was outlined in a report prepared by Gartner Lee Ltd. entitled *"Fraser Valley Groundwater Drinking Water Study"*), 22 water wells were identified in the Chilliwack area with nitrate concentrations above 1 mg/L. Concentrations of nitrates in those wells ranged from 1 to 8.5 mg/L, which are below the drinking water guideline of 10 mg/L, but at levels that reflect contamination from anthropogenic sources.

Based on this limited data, a significant regional deterioration of groundwater quality related to animal wastes is not apparent in the District of Chilliwack. However, localized areas, such as the groundwater in the vicinity of the waste pit near Wells 1 and 2, and the 22 wells contained within the WQCP database, have been identified where groundwater degradation has occurred. Given the trend of increasing nitrate concentrations in groundwater observed in other parts of the Fraser Valley such as Abbotsford, (report on *"Nitrates and Pesticides in the Abbotsford Aquifer"*, by Environment Canada, July 1992), continued degradation of groundwater is likely unless measures are implemented to protect groundwater.

In addition to animal manures, application of chemical fertilizers and pesticides by the agricultural industry can represent a significant threat to groundwater quality. In discussions with Ms. Joanne Edwards, Pesticide Management Officer with B.C. Environment, Ms. Edwards indicated that insufficient information is available to assess the magnitude of problems, if any, related to the use of chemical fertilizers and pesticides in the District of Chilliwack. Sampling for pesticides was not carried out at the 14 wells as part of the Fraser Valley Groundwater Monitoring Program.

6.2.3 Septic Systems

According to Mr. George Rice, Deputy Chief, Ministry of Health, there are on the order of 10,000 permits for septic system disposal within the District of Chilliwack. Private septic systems are located in areas not serviced by the District sanitary system, the extent of which is shown in Figure 10.

Septic systems are common sources of groundwater contamination, contributing bacteria, viruses, nitrates, detergents, oils and chemicals to groundwater. A discussion regarding the implications of nitrate contamination is presented in Section 6.2.2. Groundwater contamination from septic systems results in cases where systems are poorly sited, designed or constructed, where systems are poorly maintained, or where septic system densities are too high to allow sufficient renovation. A request was made of the Ministry of Health to provide documentation on areas within the District where groundwater contamination related to septic systems have been observed. However, this information was not received prior to preparation of this report. Some of the elevated nitrates concentrations identified in groundwater across the District (discussed in Section 6.2.2) may be partly related to septic system disposal.

6.2.4 Soak-Away-Pits/Exfiltration Wells

We understand that the District uses soak-away-pits/exfiltration wells in many areas for discharge of storm water. Specifically, we understand that in the area west of Tyson Road (located within a high groundwater vulnerability area), storm water is discharged to exfiltration wells constructed in the Sardis-Vedder Aquifer. While we understand that the exfiltration wells are constructed with provisions for sediment entrapment, storm water runoff commonly contains contaminants such as oils, antifreeze and biological constituents which could potentially be transmitted directly to the aquifer by the exfiltration wells.

6.2.5 Existing and Abandoned Water Supply Wells

As discussed in Section 3.2, there are likely many properties with abandoned water wells that were once supplied by wells and are now connected to the municipal water system. Improperly abandoned wells provide direct conduits for the migration of surface contaminants to the underlying aquifer. In some cases, abandoned wells are used for the disposal of wastes such as motor oil. Because improperly abandoned wells provide direct pathways to underlying aquifers, their presence represents a threat to groundwater regardless of the vulnerability classification of the area.

In addition to abandoned wells, groundwater contamination can result from active drinking water supply wells that are poorly constructed or poorly sited. Similar to improperly abandoned wells, active wells with corroded casings or improper surface seals can provide conduits for the migration of surface runoff or septic effluent to the aquifer. Mr. Rice sited cases in the District where water wells have inadvertently been drilled through the middle of septic tile fields.

Mr. Rice also raised concerns over the potential for active wells to contaminate the District water distribution system. Mr. Rice indicated that in some areas now serviced by the municipal system, such as Rosedale, property owners continue to use old sand points that are cross-connected with the main water distribution line for watering of gardens. The quality of groundwater from these shallow sand points is somewhat suspect due to the impact of septic systems and other near-surface sources of contamination. Under low pressure conditions there is the danger of backflow from the sand points into the main water distribution line. While backflow regulators are required at property boundaries, Mr. Rice stated that these do not exist in all areas.

6.2.6 Landfilling and Dumping

Bailey Landfill

The District disposes of its solid waste at the permitted Bailey Landfill site, located east of Matheson Road (Waste Database Number 5, Figure 9). The landfill site is located on the valley floor at the edge of the uplands, just east of the Sardis-Vedder Aquifer. According to a report entitled "*Closed Landfill Water Quality Survey, Lower Mainland Region*", by B.C. Environment, dated June 1993, the landfill has received residential, commercial, industrial and some garden waste since 1974. According to an "*Operations and Closure Plan for the Bailey Landfill*" prepared by UMA Engineering Ltd. and Gartner Lee Ltd. in September, 1993, a toe drain collection system was installed around the north and west sides of the landfill in 1986 which conveys leachate to municipal sewer lines. A dilute leachate plume extending northward from the landfill has been identified. Ongoing groundwater monitoring at five locations by the District indicates that the plume is characterized by elevated levels of iron and ammonia ("*Bailey Road Sanitary Landfill Review of Leachate Monitoring Data*", dated November 17, 1995 by Thurber Environmental Consultants Ltd.). The on-going groundwater monitoring program does not appear to include sampling for volatile organic compounds (VOCs), which are commonly associated with landfill leachate.

Wolfe Road Dump

The Wolfe Road Dump is located south of Wolfe Road in a wetland area west of the Chilliwack urban center (Dumping Site Number 1, Figure 9). According to Ms. Kirsti Domay, Environmental Services Technician with the District of Chilliwack, the site was used as an uncontrolled dump from about 1964 to 1979. From 1979 until 1986, when it was closed, the site was permitted for solid waste disposal by the District.

Tzeachten Indian Reserve

According to District staff, there are anectodal reports of dumping on the Tzeachten Indian Reserve in an area west of Vedder Road (Dump Site Number 2, Figure 9). A pit was reportedly excavated to a depth below the water table and filled with 50 truckloads of material including gypsum wallboard, tar paper and household waste. While this area is outside of the capture zones for the District wells, it is located in the vulnerable Sardis Aquifer and may be within the capture zone of another large capacity private water well identified in Figure 3.

Grigg Road Dump

According to District staff, a small, uncontrolled dump is located at the end of Grigg Road north of the Hope Slough (Dump Site Number 3, Figure 9).

Wotypka and Unger Properties

During our review of information regarding the CFB Chilliwack site, Golder Associates was provided with a copy of Phase I and II investigations of six land parcels located west of CFB Chilliwack that were once considered for acquisition by the Department of National Defence (DND). One of these land parcels (the English property) is currently under consideration as a proposed test well location by the District. The reports are listed below:

- *"Phase 1 Investigation of Six Land Parcels Adjacent to CFB Chilliwack"* Prepared for Base Environmental Officer by Environmental Services, Public Works Canada, November 10, 1994; and
- *"Phase 2 Investigation of Six Land Parcels Adjacent to CFB Chilliwack"* Prepared for Base Environmental Officer by Environmental Services, Public Works Canada, March 26, 1995.

The reports identified two properties located southwest of the proposed test well location at 44720 Keith Wilson Road, where former gravel pits were used for the disposal of municipal and DND wastes or surplus material (Dump Sites Numbers 4 and 5, Figure 9). These properties included the Webster property located at 5396 Webster Rd. and the Unger property located at 44554 Keith Wilson Rd. A subsequent field investigation identified metallic contamination at depth in soils in the vicinity of the buried waste. Groundwater sampling at 10 monitoring well locations identified elevated levels of metals in groundwater. No hydrocarbon or volatile organic compounds were found. The Webster and Unger properties may or may not lie within the capture zone of the proposed test well.

Former Landfill at CFB Chilliwack

A former landfill was identified at the south edge of the CFB Chilliwack property. A description of the landfill is provided in Appendix V.

6.2.7 CFB Chilliwack

Background

CFB Chilliwack is located in Vedder Crossing north of the Vedder River and west of Vedder Road. Established in 1942, the Base has served as a training center for officer cadets and military trades, a support and administrative center for militia units located in the lower mainland and interior of B.C. and home to the 1 Combat Engineer Regiment. CFB Chilliwack consists of a 62-hectare residential site located north of Keith Wilson Road with recreational facilities and married quarters and a 132-hectare commercial industrial site located primarily south of Keith Wilson Road with military schools, single quarters, heavy equipment maintenance facilities and training facilities. We understand that the Base is currently being decommissioned in preparation for its closure in 1998 and that plans for the re-development of the site are uncertain at this time.

Summary of Previous Studies

A number of environmental investigations have been carried out at CFB Chilliwack on behalf of the Department of National Defence (DND) over the past six years. Currently, an environmental site investigation (ESI) is being conducted by Dillon Consulting Ltd. (Dillon) to identify environmental issues that should be addressed as part of the site decommissioning. The preliminary results of the ESI are presented in the following report:

- Draft Report on *"Environmental Site Investigation and Comprehensive Study, CFB Chilliwack, Vedder Crossing"* by Dillon Consulting Ltd., March 1997.

Because the above report has not been finalized or reviewed by regulatory authorities, DND would not release a copy of the report to Golder Associates. However, in support of the District of Chilliwack's groundwater protection plan, Golder Associates was permitted to visit CFB Chilliwack to carry out a review of the report in-house. The ESI carried out by Dillon consisted of a historical review (Phase I); geophysical surveys, limited subsurface investigation and an archeological overview (Phase II); additional subsurface investigation of selected areas (Phase III), and analysis and reporting (Phase IV). In addition, a "Comprehensive Study" was carried out to identify environmental impacts related to site decommissioning. During their Phase I and II investigations, Dillon identified 34 areas of potential environmental concern for investigation (Figure 11). Two additional areas of potential concern (the "Electrical Switching Station" and the "Former Medical Depot") were identified during the Phase III investigation (Figure 11).

In addition to the Dillon ESI, an investigation of the former Canex Service Station (referred to as Area 29 in the Dillon report) was carried out by O'Connor Associates Environmental Inc. (O'Connor) in 1996, and an investigation of the former landfill site (referred to as Area 23 in the Dillon report) and soakage pits (referred to as Area 3 in the Dillon report) was carried out by Stanley Associates Engineering (Stanley) in 1990. Golder Associates was provided with copies of each of these reports for review:

- *"Subsurface Environmental Investigation, Former Canex Service Station, CFB Chilliwack, British Columbia, Location No. C00090"* Submitted to Shell Canada Products Ltd., Prepared by O'Connor Associates Environmental Inc., February 1997; and
- *"CFB Chilliwack Environmental Assessment"* by Stanley Associates Engineering Ltd., May 1991.

We understand that an environmental investigation of the Base was also carried out by Soilcon Laboratories Ltd. (Soilcon) in 1993. Golder Associates did not receive a copy of that report. During our review of available information, Golder Associates also identified references to previous studies conducted by Laidlaw Environmental Services and Morrow and Associates Engineering Inc. Golder Associates did not obtain a copy of these reports.

In addition to the environmental investigations outlined above, an investigation into waste management practices employed while the Base was in operation was conducted by Moneco Consultants Ltd. (Moneco) over the period of 1990 to 1991. The results of the study were presented in the following report, which was provided to Golder Associates for review:

- *"Environmental Baseline Study CFB Chilliwack"* (Volume I - Executive Summary; Volume II - Environmental Setting, Land-Use and Legislation; Volume III - Site Characteristics and Activities, and Volume IV - Conclusions and Recommendations) by Monenco Consultants Ltd., February, 1992.

Environmental Concerns

As outlined above, Dillon identified 36 areas of potential environmental concern across the Base. The location of these areas is shown in Figure 11 and an index to the sites is provided in Table 3. As part of Dillon's ESI, limited soil sampling was carried out at 16 of these locations and groundwater sampling was carried out at nine locations. A detailed description of the environmental concerns identified at the CFB site based on a review of the investigations carried out by Dillon and others is presented in Appendix V. A summary and discussion of the results of is presented below.

Summary and Discussion

The results of the environmental investigations carried out at the Base indicate that in most areas where groundwater sampling was carried out, groundwater was characterized by levels of some metals (aluminum, arsenic, chromium, iron, lead and manganese) in excess of drinking water standards. In addition, groundwater from the vicinity of the soakage pits in "Area 3" contained oil and grease and levels of methyl ethyl keytone (MEK) at a concentration below the limit for chronic exposure established by the U.S. EPA. Groundwater associated with the underground storage tank (UST) removed from the petroleum, oil and lubricant (POL) Training Facility in "Area 20" contained detectable levels of extractable hydrocarbons, and groundwater associated with UST's removed from the former Canex Service Station (Area 29) contained detectable levels of ethyl benzene above the drinking water standard, xylenes just below the drinking water standard, 2,4-dimethylphenol (for which no drinking water standards are available) and petroleum hydrocarbons. Groundwater downgradient of the former landfill site (Area 23) contained detectable levels of oil and grease and pentachlorophenol below drinking water standards.

To date, the level of groundwater contamination identified at the Base is relatively low. However, while a level of groundwater contamination may be permissible for industrial and commercial land use, strictly speaking, even low levels of groundwater contamination may not be acceptable for municipal water supply wells. In addition, there are a number of areas of potential environmental concern at the Base for which limited or no groundwater quality information is available. These areas include the four existing UST's that are known or suspected to be leaking, the former bunker C above ground storage tanks (AGT's) located in "Area 16" where groundwater sampling for polycyclic aromatic hydrocarbons (PAHs) has not been carried out, the POL storage areas, the areas of historical waste disposal, particularly the former medical depot, and the storm water retention pond (Area 21). These areas may contribute additional sources of metals, hydrocarbons, PAHs or volatile organic compounds (VOCs) to local groundwater.

6.2.8 Proposed Land Use

Sections 6.2.1 through 6.2.7 provide a description of groundwater contamination sources identified during the regional contaminant inventory. While several areas posing an *existing threat* to groundwater have been identified, it should be recognized that any land use activities involving the storage, use or handling of hazardous materials represent a *potential threat* to groundwater quality. To address this issue, Golder Associates has provided a rating of the relative risk that the proposed land use categories outlined in the Official Community Plan (1990-2001) pose to groundwater (Table 4). In Figure 12 the proposed land use for the area above the Sardis-Vedder Aquifer has been coloured to reflect the relative risk to groundwater.

In general, lands occupied by commercial and industrial properties pose the greatest threat to groundwater. Typical sources of groundwater contamination resulting from commercial facilities include gasoline and diesel from gas stations, solvents from drycleaning facilities, oils and solvents from auto repair shops and scrap yards, and countless others. Typical sources of groundwater contamination from industrial facilities include metals and solvents from machine and metal working shops, wood waste and solvents from sawmills, and various other chemicals from manufacturing facilities. Generally, agricultural land use poses a moderate threat to groundwater, except in the cases of inappropriate waste disposal described in Section 6.2.2, where agriculture represents a greater threat. Generally, residential land use poses a relatively low risk to groundwater; however, groundwater contamination can result from septic systems (nitrates), lawn chemicals (fertilizers and pesticides) and inappropriate handling of hazardous household products.

6.3 Results of Contaminant Inventories for Capture Zones

Contaminant inventories of the capture zones were conducted by means of field reconnaissance and supplemented by data from other information sources outlined in Section 6.1. The inventory did not include interviews with private property owners or site-specific inspections. Other than the information contained within historical fire insurance maps and available reports outlined in Section 6.1, the inventory did not include a review of historical site activities.

6.3.1 Wells 1 and 2

Capture zones delineated for Wells 1 and 2 under current and projected pumping conditions are illustrated in Figures 13 and 14, respectively. These same capture zones are illustrated relative to the CFB Chilliwack site plan in Figures 15 and 16. A description of the land use activities within the 60-day and one-year time of travel zones and the total capture zones is presented below.

60 - Day Time of Travel Zone

Wellhead

Wells 1 and 2 are located in separate pump houses and surrounded by a fence to restrict public access. At the time of the site visit, two cars, and a tractor with a trailer possibly containing lawn chemicals, were parked on the grass immediately outside the fence. Spills resulting from these vehicles could represent a potential risk to groundwater.

Tyson Road

We understand that the District does not have a designated route for the transportation of dangerous goods. However, a number of highways have been designated as municipal truck routes, including Tyson Road from Keith Wilson Road to Evans Road. Spills or accidents resulting in the release of hazardous materials in the vicinity of the wellhead could represent a serious threat to groundwater.

Neighbourhood Commercial Centre

A neighbourhood commercial center is located adjacent to the wells on the east side of Tyson Road (5960 Tyson Rd.). Businesses located within this center consist of Esquires Coffee, Sardis Dental Center, All Star Pizza, Watson Medical Clinic, Thumbs Up Video, and Flemings Corner Store. Small quantities of medical wastes are likely generated by the dental and medical clinics. At the time of the site visit, two dumpsters were located in a paved laneway at the south end of the center. In general, the property appeared to be well-kept and activities conducted at the site do not appear to represent a significant threat to groundwater.

Mount Slesse Middle School

Mount Slesse Middle School is located south of Wells 1 and 2 at 5871 Tyson Rd. The school building is located at the south end of the property and a large playing field is located at the north end adjacent to the wells. In general, the school does not likely represent a significant risk to the water supply wells; however, potential contaminants associated with the school property may include the use of lawn care chemicals on the playing fields, chemicals associated with building maintenance (such as waste oils and solvents) and general building wastes.

Residential Properties

The remainder of the area within the 60-day time of travel is characterized by one and two family residential land use. Sources of groundwater contamination potentially associated with these properties include lawn care chemicals, common household products, and wastes related to property maintenance and automotive repair. These properties are serviced by the municipal sewer (Figure 10).

One-Year Time of Travel Zone

Stormwater Exfiltration Area

The stormwater exfiltration area located north of Keith Wilson Road is considered to represent one of the most significant threats to the groundwater quality at Wells 1 and 2. Storm water runoff is commonly characterized by contaminants such as oils, antifreeze, gasoline, other petroleum products and biological constituents. Groundwater monitoring carried out by the District at monitoring well MW3, located at the northeast edge of the stormwater exfiltration area in May, 1996 indicated that at that time, no detectable levels of VOCs, pesticides, herbicides or mineral oil and grease were present in groundwater at that location and dissolved metals were within drinking water guidelines. To a lesser degree, lawn care chemicals used on the playing fields above the stormwater exfiltration area may also pose a potential threat to groundwater.

DeGroot Farm

The DeGroot farm is located immediately north of Wells 1 and 2 at 6167 Tyson Road. As discussed in Section 6.2.2, an unlined pit that has reportedly been receiving discharge of liquid manures is located on this property. Under current pumping conditions, it does not appear that the pit area lies within the existing capture zone of the wells (Figure 13); however, in future when continuous pumping rates are higher, the capture zone may be expanded to encompass the pit area (Figure 14). The potential impact of animal wastes on groundwater quality was discussed in Section 6.2.2.

Twin Rinks Arena

The Twin Rinks arena is located south of Wells 1 and 2 at 5745 Tyson Rd. The building is surrounded by a large, paved parking lot. Maintenance materials appear to be stored at the south end of the building. Potential contaminants associated with the facility include de-icing chemicals, chemicals associated with building maintenance (such as solvents, waste oils and machinery servicing wastes) and general building wastes. A recycling depot operated by the District, where solid waste materials are dropped off, is located at the east edge of the parking lot.

Watson Glen Park

Watson Glen Park is located between Twin Rinks arena and Mount Slesse Middle School. The park consists of a grassed playing area. Other than the potential for use of lawn care chemicals, the park does not likely represent a threat to groundwater.

Total Capture Zone

The total capture zone for Wells 1 and 2 is equivalent to a 3.5-year travel time under current pumping conditions and 5-year travel time under future pumping conditions.

CFB Chilliwack

Under current pumping conditions, the capture zone for Wells 1 and 2 encompasses most areas of environmental concern identified on the CFB Chilliwack property (Figure 15), including "Areas" 9, 10, 11, 12, 19, 20, 21, 22, 23, 27 and 30 and seven of the eight existing underground storage tanks. Under future pumping conditions, the capture zone would likely be expanded to encompass "Areas" 1, 3, 5, 13, 14, 15, 16, 28 and 29 (Figure 16). A detailed description of these areas, and the potential risk they pose to groundwater, is outlined in Appendix V.

Vedder River

Under both current and future pumping conditions, the Vedder River acts a source of recharge to groundwater supplying Wells 1 and 2. Therefore, surface water degradation or contamination of the Vedder River poses a risk to the groundwater quality at Wells 1 and 2. Gravel mining activities conducted along the river bed represent one of many potential sources of contamination in the Vedder River. Urban runoff and effluent discharges may also impact surface water quality.

Rural Properties

Under future pumping conditions, the capture zone for Wells 1 and 2 would be expanded to include the rural properties located west of CFB Chilliwack. Since these properties are not serviced by municipal water or sewer, septic systems and/or poorly constructed wells associated with these properties could represent potential sources of groundwater contamination (as described in Sections 6.2.3 and 6.2.5 of the regional contaminant inventory, respectively); however, the risk of groundwater contamination from these sources is considered to be low in this area due to the relatively low population density.

Information concerning six of the rural properties within the expanded capture zone was obtained from a Phase I and II environmental site investigation provided to Golder

Associates by DND. The results of investigations of buried refuse material at 5396 Webster Rd. and 44554 Keith Wilson Rd. were discussed in Section 6.2.6 of the regional contaminant inventory. In addition to buried refuse, isolated surface contamination by metals was identified on the Besler property at 5373 Peach Rd.

Agricultural Land Use

Under future pumping conditions, the capture zone of Wells 1 and 2 would be expanded to include the agricultural properties located west of Peach Road. The potential for groundwater contamination resulting from agricultural land use is described in the regional contaminant inventory in Section 6.2.2.

6.3.2 Well 3

The capture zones delineated for Well 3 under current and projected pumping conditions are illustrated in Figures 13 and 14, respectively. These same capture zones are illustrated relative to the CFB Chilliwack site plan in Figures 15 and 16. A description of land use within the 60-day and one-year time of travel zones and the total capture zones is presented below.

60 - Day Time of Travel Zone

CFB Chilliwack

Well 3 is located in a pump house on the CFB Chilliwack Base adjacent to a laneway. There are two small buildings located east of the pump house: Building number 1012A is used for storage of unknown materials and Building 147 is reportedly used for storage of petroleum hydrocarbons, oils and lubricants. Release of these materials by means of a spill or fire could pose a serious threat to groundwater at Well 3.

The former medical depot (Building 1012) is located south of Well 3 within the 60-day time of travel. Dillon's environmental site investigation indicated that medical wastes may have been buried north of the building, immediately south of the wellhead. Medical wastes were not found in three test pits excavated in that area; however, some debris (wood and steel pipe) was encountered. No soil or groundwater sampling was conducted.

Under future pumping conditions, the 60-day time of travel zone for Well 3 would be expanded to encompass Building 1056 to the east and the Electrical Switch Station to the southwest. No information is available concerning the nature of activities carried out at Building 1056 (the CFB Chilliwack site plan refers to the building as 3 PPCLI Headquarters, BCPO, BGSO, Mountaineer). The electrical switching station was identified as an area of concern in Dillon's environmental site investigation. Two test pits were excavated in the area to investigate reports of buried electrical material. Some debris (paint cans and porcelain) was identified in the test pits; however, no soil or groundwater sampling was conducted.

Residential Properties

The west half of the area within the 60-day time of travel is characterized by one and two family residential land use. Sources of groundwater contamination potentially associated with these properties include lawn care chemicals, common household products, and wastes related to property maintenance and automotive repair. These properties are serviced by the municipal sewer (Figure 10).

Keith Wilson Road

Keith Wilson Road has been designated as a municipal truck route from Boundary to Vedder Roads. Spills or accidents resulting in the release of hazardous materials in the vicinity of the wellhead could represent a serious threat to groundwater.

One-Year Time of Travel Zone

CFB Chilliwack

Under current pumping conditions, the one-year time of travel zone for Well 3 encompasses one area of environmental concern (Area 6) identified by Dillon, while under future pumping conditions, it encompasses several areas of concern (Areas 6, 9, 10, 17, 19, 20, 21, 22 and 25 and six UST's). A detailed description of these areas, and the potential risk they pose to groundwater, is outlined in Appendix V.

Total Capture Zone

The total capture zone for Well 3 is equivalent to a 2-year travel time under current pumping conditions and a 2.5-year travel time under future conditions.

CFB Chilliwack

Under current pumping conditions, the total capture zone for Well 3 encompasses two additional areas of environmental concern identified by Dillon (Areas 17 and 18). Under future pumping conditions, the total capture zone also encompasses the former landfill site at "Area" 23. A detailed description of these areas, and the potential risk they pose to groundwater, is outlined in Appendix V.

Vedder River

Under both current and future pumping conditions, the Vedder River acts a source of recharge to groundwater supplying Well 3. Therefore, as described for Wells 1 and 2, surface water degradation or contamination of the Vedder River poses a risk to the groundwater quality at Well 3.

6.3.3 CFB Chilliwack Well

The capture zones delineated for the CFB Chilliwack Well under current and projected pumping conditions are illustrated in Figures 13 and 14, respectively. These same capture zones are illustrated relative to the CFB Chilliwack site plan in Figures 15 and 16. For the CFB Well, the total capture zone is equivalent to a 60-day travel time under both current and future pumping conditions. A description of land use within that zone is presented below.

Total Capture Zone (60-Day Time of Travel)

CFB Chilliwack

Because the CFB Chilliwack Well is located close to the Vedder River, which acts as a source of groundwater recharge, the total capture zone for the well is relatively small under both current and future pumping conditions. Under current pumping conditions, the capture zone does not encompass any of the areas of environmental concern identified by Dillon. Under future pumping conditions, the capture zone encompasses one UST, located east of Building Number 1008, which was installed in 1994 as part of the wastewater system. The UST is reportedly constructed of fibreglass and contains a membrane liner and therefore does not likely represent a significant threat to groundwater.

Vedder River

Degradation of surface water quality in the Vedder River poses a greater risk to the CFB Chilliwack Well than Wells 1, 2 and 3 (described above) because the time of travel from the Vedder River to the CFB Well is only 60 days.

6.3.4 TW95-1

The capture zone for test well TW95-1 under projected pumping conditions is illustrated relative to the District address map in Figure 14 and relative to the CFB Chilliwack site plan in Figure 16. A description of land use within the 60-day and one-year time of travel zones and the total capture zone is presented below.

60 - Day time of Travel Zone

Commercial District

In general, the risk of groundwater contamination at TW95-1 is considered to be high due to the proximity of the well to the commercial district along Vedder Road. Many of the businesses along this strip appear to have been in operation for a long period of time and a number of potential contaminants may be associated with them. Of particular concern are two properties located within the 60-day time of travel zone: a gas station and motor vehicle repair shop located north of the well and a laundromat located south of the well (Figure 14).

The major concern associated the gas station is the potential for leakage from underground storage tanks containing gasoline and diesel. Due to the immiscible nature of these products, the release of even small quantities of these chemicals could have serious consequences. Additional contaminants potentially associated with both the gas station and the auto repair shop include waste oils, solvents, acids, paints, automotive wastes and cutting oils.

The concern associated with the laundromat is the chemicals that may be employed in the drycleaning operation. Drycleaning operations employ solvents such as perchloroethylene, petroleum solvents and Freon, and spotting chemicals such as trichloroethane, ammonia, peroxides, hydrochloric acid, rust removers and amyl acetate. Of these, perchloroethylene (PCE), Freon and trichloroethane represent particular concerns because they are dense, non-aqueous phase liquids (DNAPLs). Because DNAPLs are denser than water, when product is released to the environment it sinks to the base of the aquifer and slowly dissolves into the groundwater. PCE and trichloroethane degrade sequentially through a series of transformation products, ultimately degrading to vinyl chloride, a known carcinogen.

CFB Chilliwack

TW95-1 is located in a grass field on the east edge of the CFB Chilliwack property east of the Base dental clinic (Building 1064). The dental clinic was not identified as an area of potential concern by Dillon; some medical wastes may be generated at that facility.

Vedder Road

Vedder Road has been designated as a municipal truck route from the Vedder River to Highway 1. Spills or accidents resulting in the release of hazardous materials in the vicinity of the wellhead could represent a serious threat to groundwater.

Total capture Zone (One -Year Time of Travel)

The total capture zone for TW95-1 corresponds to a travel time of just over one year. Hence, the aerial extent of the one-year time of travel zone and the total capture zone are similar and are discussed under the same section.

Commercial District

Several additional commercial properties are encompassed within the total capture zone for TW95-1, including a gas station located south of TW95-1 along Vedder Road just north of Morton Road (Figure 14). The concerns related to this facility are the same as those described for the gas station within the 60-day time of travel zone.

CFB Chilliwack

Two areas of concern (Areas 7 and 8) were identified by Dillon within the capture zone of TW95-1. A detailed description of these areas, and the potential risk they pose to groundwater, is outlined in Appendix V.

Vedder River

The Vedder River would serve as a source of recharge to groundwater supplying TW95-1. Therefore, as described for Wells 1, 2, 3 and the CFB Well, surface water degradation or contamination of the Vedder River poses a risk to the groundwater quality at TW95-1.

Area Outside of Total Capture Zone

Commercial District

There are two other properties located just north of the capture zone of TW95-1 that warrant mention. A large gas station is located at the corner of Vedder and Thomas Road and a drycleaning facility is located in the Vedder Village Mall. Although these facilities are located outside the projected capture zone, due to their close proximities to TW95-1, substances released at these facilities could still conceivably reach the wellhead through the mechanism of lateral dispersion.

The potential impact of substances associated with gas stations and drycleaners has already been described above. According to the District Fire Chief, Mr. Wayne Green, the oil company that operates the large gas station is the only major oil company in the District of Chilliwack that does not employ double-walled USTs in accordance with the *"Environmental Code of Practice for Underground Storage tank Systems Containing Petroleum Products and Allied Petroleum Products"*. No enquiries were made regarding the status of USTs at this particular facility.

In addition to vehicle fueling, the gas station property contains a car wash, drop-off depot for waste oil recycling and an AGT containing propane. Soaps, detergents and oils resulting from the car wash facility are presumably discharged to the municipal storm drains.

6.3.5 Well 4

The capture zones delineated for Well 4 under current and projected pumping conditions are illustrated in Figures 17 and 18, respectively. Land use activities within the 60-day, one-year and five-year time of travel zones and the total capture zones are described below in the context of current pumping conditions.

60 - Day Time of Travel Zone

Rosedale Middle School

Well 4 is located in a pump house at the northeast corner of the grounds of Rosedale Middle School on Yale Road. The school building is located southwest of the well, while sports fields associated with the school are located at the south end of the property. Potential contaminants of concern associated with the school property are the same as those outlined for Mount Slesse Middle School in Section 6.3.1. In addition, we understand from Mr. Rice that an old septic disposal field is located within 30 m of the wellhead. Potential contaminants associated with septic disposal were outlined in Section 6.2.3. of the regional contaminant inventory.

Residential Properties

There are a number of residential properties located within the 60-day time of travel zone east of Well 4. Potential contaminants associated with residential properties were outlined in Section 6.3.1. The residential properties are serviced by private septic systems, which represent a concern given the close proximity of the properties to the wellhead (the closest residential property is approximately 3 m away). In addition, during the site reconnaissance, burn piles consisting of garden and building debris were observed in the backyards of the two residences located immediately adjacent to the well. The use of accelerants such as gasoline or diesel by property owners to ignite the burn piles would represent a significant threat to groundwater. Finally, although the local residences are serviced by the municipal water system, there may or may not be abandoned wells located on those properties that may serve as conduits for the subsurface migration of contaminants.

Hope Slough

The Hope Slough is located north of Well 4 on the north side of Yale Road. Since water transmitted by the slough may serve as a source of recharge to groundwater in the vicinity of Well 4, degradation of this surface water body could have an adverse impact on Well 4. No information is available concerning the water quality in the Hope Slough.

Yale Road

Yale Road has been designated as a municipal truck route from Highway 1 to the east boundary of the District. Spills or accidents resulting in the release of hazardous materials in the vicinity of the wellhead could represent a serious threat to groundwater.

One - Year Time of Travel Zone

Agricultural Land Use

The one-year time of travel zone encompasses the agricultural properties located north of Yale Road. The potential for groundwater contamination resulting from agricultural land use is described in the regional contaminant inventory in Section 6.2.2.

CN Rail Line

The CN Rail line is located southeast of Well 4 within the one - year time of travel zone. Potential contaminants associated with the railway include diesel, herbicides applied to the right- of-way, creosote used to preserve the railway ties, and release of materials transported by rail.

Five - Year Time of Travel Zone

The five-year time of travel zone encompasses additional residential and agricultural properties as shown in Figure 17.

Total Capture Zone

The total capture zone for Well 4 corresponds to a 50-year time of travel under both existing and future pumping conditions.

The total capture zone of Well 4 encompasses a large area characterized mainly by agricultural land use. In addition, the capture zone includes commercial and industrial properties located in Rosedale. Contaminants released in this area would require on the order of 10 years or more to reach the wellhead.

Commercial Properties

The total capture zone encompasses the commercial district of Rosedale. A number of potential contaminants may be associated with the businesses in this area. Properties of particular concern include a gas station and two auto maintenance garages (Figure 17) located on Yale Road. Based on a review of historical fire insurance maps, service stations have been associated with these properties since at least the early 1950s. Another property of concern is a maintenance yard located on Ford Road. Two fuel pumps were observed on this property, indicating the presence of UST's. A discussion of potential contaminant sources resulting from gas stations and auto maintenance facilities was presented in Section 6.3.1.

Industrial Properties

The total capture zone also encompasses an area of Rosedale that has been zoned for industrial land use. It appears that all of the industrial land is currently occupied by one manufacturing company. We understand that the company manufactures agricultural implements and equipment related to the transport industry. Potential contaminants associated with this facility include paints, metals and solvents.

Oil and Gas Pipelines

Oil and gas pipelines are located at some distance to the south and north of Well 4, respectively, within the total capture zone.

6.3.6 Well 5

The capture zones delineated for Well 5 under current and projected pumping conditions are illustrated in Figures 19 and 20, respectively. Land use activities within the 60-day, one-year and five-year time of travel zones and the total capture zones are described below in the context of current pumping conditions.

60 - Day Time of Travel Zone

Wellhead

Well 5 is located in a pump house and surrounded by a fence to restrict public access. A gravel parking lot and corn market is located north of the well, while agricultural fields are located to the south and west. Potential contamination resulting from incidental spills from parked vehicles and is considered to be low.

One - Year Time of Travel Zone

Maintenance Area - The Falls Golf Course

A maintenance area for the Falls Golf Course is located northeast of Well 5 east of Annis Road. General housekeeping practices at the property appear to be poor, and as a result, the maintenance area may pose a significant risk to groundwater at Well 5. At the time of the site visit, two AGT's were observed in the yard, one containing diesel and the other gasoline. The area beneath the tanks was not paved, and there was obvious soil staining where drips and leakage had occurred. Several 45 gallon drums and 20 gallon pails (possibly containing substances such as waste oils) were observed outside one of the two sheds on the property, and the ground beneath the drums was visibly stained. In addition, a small pit, approximately 1 m in diameter and 0.5 m deep, was observed on the property where liquids (possibly fertilizer) had obviously been discharged.

Agricultural and Rural Properties

The remainder of the properties within the one-year time of travel zone are characterized by agricultural and rural land use. The potential for groundwater contamination resulting from agricultural activities was described in the regional contaminant inventory in Section 6.2.2. Although both rural and agricultural properties in this area are serviced by private septic systems, given the low population density the contamination resulting from septage effluent is expected to be relatively low.

Five Year Time of Travel Zone

The five-year time of travel zone encompasses additional rural and agricultural properties as shown in Figure 19.

Total Capture Zone

The total capture zone for Well 5 corresponds to a 20-year time of travel under current pumping conditions and a 35-year time of travel under future pumping conditions.

The Falls Golf Course

The total capture zone for Well 5 encompasses much of the Falls Golf Course, located east of Annis Road. In addition to the maintenance yard already described, there is the potential for groundwater contamination related to the use of fertilizers and pesticides.

Properties along Hack Brown Road

Three other properties are located east of Well 5 along Hack Brown Road, just south of the Trans Canada Highway. Contaminants released at these properties would require on the order of 10 years or more to reach the wellhead. Johnston and Milne Contracting own the property located at 50700 Hack Brown Road. The property was largely vacant other than some heavy equipment (a backhoe, tractor and some trailers) and a small pile of demolition material. The Chilliwack Campsite and RV site is located at 50850 Hack Brown Road. Possible contaminants associated with this site include septage, gasoline and household hazardous wastes from recreational vehicles. A construction yard is located at 50950 Hack Brown Road. It appears that activities carried out at the site include gravel sorting. Piles of sand and gravel, demolition fill (possibly including old railway ties), old tires and trucks and trailers were observed on site.

6.3.7 Proposed Test Well Locations

A contaminant inventory of the two proposed test well locations was beyond the scope of this study. However, based on available information, we offer the following comments concerning land use activities in the vicinity of the proposed test well locations.

Similar to the other wells completed in the Sardis-Vedder Aquifer, the ultimate source of recharge for the two test wells would be the Vedder River. Therefore, degradation of water quality in the Vedder River would pose a risk to groundwater quality at both test well locations.

For the test well proposed at the corner of Peach and Keith Wilson Roads, a Phase I environmental site investigation of that property was conducted on behalf of DND (referenced in Section 6.2.6). The report identified a small mounded area at the northeast corner of the property that may contain waste material. An investigation of the mound was not carried out. As discussed in Section 6.2.6, Phase I and II investigations of properties to the southwest of the proposed test well location identified areas where municipal and DND wastes or surplus material was dumped. These properties may or may not lie within the capture zone of the test well. In addition, the reports identified the presence of isolated surface contamination by metals on the Besler property located southwest of the test well at 5373 Peach Road. Much of the capture zone for the proposed test well location is expected to encompass the CFB Chilliwack Base to the south. Potential concerns associated with the Base were outlined in Appendix V.

7.0 RECOMMENDATIONS FOR GROUNDWATER PROTECTION

While the development and implementation of groundwater protection measures will require some effort and expense on behalf of the District, these costs are considered relatively minor in comparison with costs associated with the loss of District water supplies as the result of contamination. In the next section (Section 7.1), a number of specific recommendations are presented for *wellhead protection* within the capture zones of the District production wells. A proposed strategy to achieve some degree of groundwater protection at the CFB Chilliwack property is presented in Section 7.2. Section 7.3 presents recommendations for *aquifer protection* by means of regional land use planning and general protection measures.

7.1 Recommendations for Protection of Capture Zones

7.1.1 General Approach

In our opinion, the best means of achieving groundwater protection within both capture zones and vulnerable parts of the aquifers is through public education. Public education involves informing the public about the location of capture zones and other areas of high groundwater vulnerability, raising awareness of the threats various activities pose to groundwater in those areas, and educating the public about what steps they can take to protect the resource. Consideration should be given to a public education campaign to achieve these objectives.

The contaminant inventory identified properties within the capture zones that may represent some level of risk to groundwater (Section 6.3). In the next sections, a number of protection measures for these properties are presented for consideration. It should be noted that the contaminant inventory did not include interviews with the property owners, inspections of the properties, or quantification of the types and amounts of materials handled at these sites. Consideration should be given to assembling this site-specific information and evaluating the data in the context of the local hydrogeological conditions. Based on the results of this analysis, the District may then wish to proceed with the implementation of some of the protection measures outlined below using an incremental approach.

7.1.2 Recommendations for Groundwater Protection at all Well Locations

- Consideration should be given to launching a public education campaign on groundwater protection using the media (newspaper articles, television and radio). The campaign would identify the capture zones, threats to groundwater supplies in those zones, and the measures individuals can take to protect the resource. Consideration could be given to using the local Chamber of Commerce to help disseminate information. In our experience, the use of a maps to show areas requiring protection is highly effective.

- Signage could be placed at regular intervals around the total capture zones for Wells 1, 2 and 3 and around the five-year time of travel zone for Wells 4 and 5. The signs would inform the public that they are entering a "Groundwater Protection Zone" and would provide a phone number to call to report spills or dumping. The use of signage was found to be successful in Amherst, New Brunswick, where signs were placed at 50 m intervals around their groundwater protection zone.

- Flyers could be distributed to households and businesses located within the capture zones (and other vulnerable parts of the aquifer) providing information concerning measures property owners can take to protect groundwater. The flyers could include information concerning proper handling and disposal of hazardous household waste, proper use of lawn chemicals, and ways of restricting impacts related to automotive and household repair. Some examples of information brochures developed for other communities are provided in Appendix VI.

- Consideration should be given to arranging for a hazardous waste collection day once or several times each year or establishing drop-off stations outside of the high groundwater vulnerability area for generators of small quantities of hazardous waste. These measures would provide property owners with a convenient way of disposing of hazardous materials.

- For residences located in capture zones that are serviced by private septic systems (Wells 4 and 5), flyers providing information on septic system maintenance could be distributed. The flyers should include recommendations such as pumping of septic tanks every two to three years. The Township of Langley has developed a brochure on septic system maintenance that could be adapted for use in the District of Chilliwack (Appendix VI). In addition, Environment Canada has produced an information brochure (Appendix VI) and video on septic system maintenance that have been well received.

- Consideration should be given to conducting an inventory of private water wells located in the capture zones. Once these wells are identified, an analysis should be conducted to determine the potential for interference between those wells and the pumping wells. Consideration should be given to distributing information brochures concerning wellhead protection to private well owners. An example of an information brochure prepared by the Newfoundland Department of Environment is presented in Appendix VI. Inactive wells identified by the survey should be properly decommissioned.

- The presence of three schools (Mount Slesse Middle School, Watson Elementary School and Rosedale Middle School) within capture zones of the wells presents an ideal opportunity to educate school children about groundwater protection. A number of educational tools are available to raise awareness for groundwater protection, including Project "WET" (Water Education for Teachers) in Idaho (an interdisciplinary water education program for Idaho educators and young people) and Project WILD, developed by the Canadian Federation of Wildlife.
- In addition to the general public, District employees should be educated about requirements for groundwater protection. Handling of lawn care and other chemicals in the vicinity of the wellheads should not be permitted. Vehicle parking on unpaved areas adjacent to the wellheads should be prohibited. The use of lawn care chemicals in the areas of Watson Glen Park and the playing fields above the stormwater exfiltration area should be restricted.
- The use of road-side herbicides within capture zones should be prohibited.
- As outlined in Section 6.3, since the Vedder River acts as a source of recharge for groundwater in the Sardis-Vedder Aquifer, including Wells 1, 2, 3, the CFB Chilliwack Well and TW95-1, provisions should be made for protection of the river. Gravel extraction activities along the river bed should be carried out in accordance with best management practices. Stormwater and effluent discharge to the river should be minimized. A spill response plan should be adopted to address contamination events.
- In the capture zones of Wells 4 and 5 where the protective layer of surface silt is relatively thin (1 to 4 m), consideration could be given to restricting the depths of excavations in these areas. Such excavations should not be permitted to remain open for extended periods of time.
- A number of recommendations to protect groundwater from activities related to the agricultural industry are presented in Section 7.3.2.

7.1.3 Recommendations for Groundwater Protection at Wells 1 and 2

- Tyson Road - consideration should be given to restricting municipal truck transportation along Tyson Road from Keith Wilson to Watson Road. Alternatively, a spill response plan should be adapted to address contamination events along the roadway.

- Neighbourhood Commercial Center - education flyers such as those discussed in Section 7.1.2 should be distributed to businesses located at 5960 Tyson Road. If, in future, existing businesses move from this area and new businesses are developed, high risk businesses such as drycleaners or gas stations should be prohibited in this area.

- Mount Slesse Middle School - the District should consider assisting Mount Slesse School with the development of a best management plan that addresses hazardous materials handled by the school. The plan should include restrictions on the use of lawn care chemicals on the school playing fields and provide provisions for the proper storage, handling and disposal of building maintenance chemicals.

- Stormwater Exfiltration Area - the District should continue ongoing monitoring of groundwater quality at monitoring well MW3 to ensure that stormwater discharged to the exfiltration area does not impact local groundwater. Because the travel time from the exfiltration area to the wellheads is estimated to be on the order of 4 to 6 months, groundwater sampling should be carried out at MW3 every three months for physical parameters, dissolved anions and metals, VOCs, total extractable hydrocarbons (TEH) and biological constituents. Analysis for pesticides and herbicides should be carried out at MW3 every six months.

- DeGroot Farm - we understand that the Ministry of Environment has imposed a pollution prevention order on the DeGroot property to cease the discharge of liquid manures into the unlined pit. It is recommended that the District continue to work with the Ministry to resolve this issue.

- Twin Rinks Arena - consideration should be given to making enquiries regarding the de-icing chemicals used by the arena and assessing their suitability for use in the groundwater protection area. The District may also wish to assist the Twin Rinks Arena with the development of a best management plan to addresses hazardous materials handled by the facility, including de-icing chemicals and building maintenance chemicals.

- CFB Chilliwack - at one time, a monitoring well (MW2) was located north of the CFB Chilliwack Base just south of Keith Wilson Road (Figure 13). Groundwater monitoring should be carried out at MW2 on an annual basis for physical parameters, dissolved anions and metals, VOCs, TEH and PAHs to monitor groundwater quality downgradient from the Base. Should MW2 no longer exist, a new monitoring well should be installed in that same area. Other strategies for groundwater protection at the CFB Chilliwack Base are presented in Section 7.2.

7.1.4 Recommendations for Groundwater Protection at Well 3

- CFB Chilliwack - consideration should be given to requesting that DND remove any hazardous materials currently stored in Buildings 1012A and 147. Consideration should also be given to conducting additional field investigations to investigate the possibility of buried bio-medical wastes adjacent to the wellhead. At a minimum, groundwater from Well 3 should be tested for VOCs and biological pathogens. To monitor groundwater quality downgradient from the remainder of the Base, consideration should be given to installation of a monitoring well (MW4) near Keith Wilson Road (Figure 13). The monitoring well should be sampled for physical parameters, dissolved metals and anions and TEH every three months and for VOCs and PAHs every six months. Other strategies for groundwater protection at the CFB Chilliwack Base are presented in Section 7.2.

- Keith Wilson Road - consideration should be given to restricting municipal truck transportation along Keith Wilson Road from Tyson to Vedder Road. Alternatively, a spill response plan should be adopted to address contamination events along the roadway.

7.1.5 Recommendations for Groundwater Protection at CFB Chilliwack Well

- Wellhead - because the CFB Chilliwack Well is located on DND property, a site reconnaissance of the wellhead was not carried out. Should the CFB Well be adopted for use by the District, public access to the wellhead should restricted.

- CFB Chilliwack - periodic pressure testing of the UST located east of Building Number 1008 should be conducted to ensure the tank remains in good working order. Other general strategies for groundwater protection at the CFB Chilliwack Base are presented in Section 7.2.

7.1.6 Recommendations for Groundwater Protection at TW95-1

- Due to the close proximity of TW95-1 to the commercial district along Vedder Road, the location of TW95-1 does not afford a great degree of groundwater protection. Consideration could be given to not proceeding with the development of this water supply source. Should the District wish to proceed with the development of TW95-1, considerable efforts will be required to achieve a level of groundwater protection. At a minimum, information flyers such as those described in Section 7.1.2 should be distributed to the businesses located in this area. Additional provisions for groundwater protection are outlined below.

- Dry Cleaning Establishments - due to the serious health implications related to drycleaning chemicals and the presence of a drycleaning establishment within the 60-day time of travel zone, consideration should be given to requiring the laundromat located within the 60-day time of travel zone discontinue drycleaning operations at that site. Because the other drycleaning facility is located just beyond the capture zone, that facility could be permitted to remain; however, to ensure that drycleaning chemicals are being handled in an appropriate manner, the District may wish to assist the facility with the development of a best management plan. The best management plan should include provisions for appropriate handling, storage and disposal of drycleaning and spotting chemicals. In addition, at least one monitoring well (MW5; Figure 14) should be installed at the north edge of the capture zone south of the drycleaners and monitored on a semi-annual basis for VOCs.

- Gas Stations and Auto Repair Shop - at the present there are no regulations governing USTs; however, a number of guidelines (such as requirements for secondary containment) for USTs are outlined in the *"Environmental Code of Practice for Underground Storage Tank Systems Containing Petroleum Products and Allied Petroleum Products"* issued by the Canadian Council of Ministers of the Environment, 1993. It is recommended that the District engage in dialogue with the owners of the nearby gas stations and auto repair shop to inform the property owners that they are located in a groundwater protection area and educate them about the potential risks (and liabilities) their properties pose to groundwater. The District should consider requesting that these facilities implement the measures outlined in the Code of Practice. At a minimum, the District should consider requesting that USTs located on these properties be subjected to pressure testing to determine whether the existing tanks are leaking. In addition, the District should consider assisting the property owners, particularly those located within the 60-day time of travel zone, to develop best management plans. The best management plans should include provisions for appropriate handling, storage and disposal of waste oils, solvents, acids, paints, and automotive wastes. Finally, at least three monitoring wells (MW6, MW7 and MW8) should be installed to monitor for potential contaminant migration from these sites (Figure 14). Monitoring wells MW6 and MW7 would be located within the 60-day time of travel zone between TW95-1 and gas station to the north, while MW8 would be located at the edge of the 60-day time of travel zone between TW95-1 and the gas station to the south. Monitoring wells MW6 and MW7 should be sampled monthly for total extractable hydrocarbons and BTEX (benzene, toluene, ethylbenzene and xylene) and every three months for VOCs and dissolved metals. Monitoring well MW8 should be sampled every three months for total extractable hydrocarbons and BTEX and every six months for VOCs and dissolved metals.

- Zoning Modifications - to ensure a level groundwater protection is maintained with future development, consideration should be given to making zoning modifications within the one-year time of travel zone to prohibit gas stations, auto repair shops, drycleaning establishments, and any other businesses that handle significant quantities of hazardous materials. The existing businesses identified in the above bullet would be grandfathered in place provided they meet the requirements outlined above.

- Vedder Road - consideration should be given to restricting municipal truck transportation along Vedder Road from the Vedder River to Thomas Road. Alternatively, a spill response plan should be adopted to address contamination events along the roadway.

- CFB Chilliwack - General strategies for groundwater protection at the CFB Chilliwack Base are presented in Section 7.2.

7.1.7 Recommendations for Groundwater Protection at Well 4

- Rosedale Middle School - the District should consider assisting Rosedale Middle School with the development of a best management plan that addresses hazardous materials handled by the school. The plan should include restrictions on the use of lawn care chemicals on the school playing fields and provide provisions for the proper storage, handling and disposal of building maintenance chemicals. In addition, the District should seek assurances that the septic tile field servicing the school is being properly maintained. It is recommended that groundwater monitoring for physical parameters, dissolved anions and biological constituents be carried out every three months at some location between the septic tile field and the wellhead. Monitoring for VOCs and dissolved metals should be carried out at this location an annual basis. If the existing observation well (OW95-2) is appropriately situated, the monitoring could be carried out at that location.

- Residential properties - the District should consider approaching the individual property owners of residences located within the 60-day time of travel to advise them about proper handling of household waste, the use of lawn care chemicals, automotive and household repair, and maintenance of septic systems. In particular, homeowners should be prohibited from burning garden and other household wastes.

- Hope Slough - efforts should be made to protect the water quality of the Hope Slough by prohibiting the stormwater and other discharges.

- Yale Road and CN Rail Line - a spill response plan should be adopted to address contamination events along these right-of-ways.

- Commercial and Industrial Properties - owners of the maintenance yard, gas station, two auto repair shops and the manufacturing company located in Rosedale should be informed about their positions within the capture zone and encouraged to develop best management plans with assistance from the District. In particular, these businesses should be encouraged to implement the *"Environmental Code of Practice for Underground Storage Tank Systems Containing Petroleum Products and Allied Petroleum Products*". In addition, at least one monitoring well (MW9) should be installed between the commercial/industrial area of Rosedale and Well 4 at the outer boundary of the five-year time of travel zone. The well should be monitored on an annual basis for VOCs, total extractable hydrocarbons and dissolved metals;

7.1.8 Recommendations for Groundwater Protection at Well 5

- Wellhead - consideration should be given to paving the gravel parking lot immediately north of the wellhead to provide protection from contaminants that may be associated with spills from parked vehicles.

- The Falls Golf Course - the District should assist the Falls Golf course with the development of a best management plan. Specifically, the plan should include provisions for the proper handling, use and disposal of fertilizers, pesticides and herbicides and substances associated with vehicle and property maintenance such as gasoline, diesel, waste oils, paint and solvents. The District should consider requesting that the Falls Golf course move their maintenance facility to another part of their property away from the 60-day time of travel zone. Alternatively, AGTs containing diesel and gasoline should be subject to secondary containment in accordance with the *"Environmental Code of Practice for Aboveground Storage Tank Systems Containing Petroleum Products"* , developed by the Canadian Council of Ministers, August, 1994. Other hazardous materials such as those outlined above should be limited to small quantities and should be stored on a concrete pads. The discharge of fertilizers or other hazardous materials to the ground via pits or ditches should be prohibited. Stained soils should be removed from the site and disposed of at an appropriate facility. In addition, observation well OW95-3 should be monitored every three months for physical parameters, dissolved anions, total extractable hydrocarbons, dissolved metals and VOCs and on an annual basis for herbicides and pesticides.

- Properties along Hack Brown Road - the properties located along Hack Brown Road should be informed about their positions within the capture zones and encouraged to adopt best management practices.

7.2 Recommendations for Groundwater Protection - CFB Chilliwack

As discussed in Section 2.0, groundwater flow in the Sardis-Vedder Aquifer is generally directed in a radial pattern from the apex of the fan towards the distal portions of the aquifer (Figure 6). The CFB Chilliwack property is located near the apex of the fan and is therefore situated near the source of recharge for the production wells and much of the aquifer (which has been classified as highly vulnerable). Because the Base lies within the capture zones of existing production Wells 1, 2, 3 and the Chilliwack well, the proposed production well (TW95-1), and the test well proposed for the corner of Peach and Keith Wilson Roads, proper management of historical contamination and future land use activities at the site is critical to the success of the groundwater protection plan.

With regards to the historical contamination, the District should seek assurances from DND that adequate steps have been taken to characterize and remediate contaminated soils and groundwater associated with the Base during site decommissioning. DND should be provided with the results of the capture zone analysis, and should contaminated soils and groundwater be permitted to remain on the Base following decommissioning, the District may wish to request that an environmental risk assessment be commissioned by DND to assess the potential impact of this contamination on District water supplies. In addition, the District should consider monitoring of groundwater quality downgradient of the Base at the two locations (MW2 and MW4) as described in Sections 7.1.2 and 7.1.3.

Because of the critical position of the Base relative to groundwater flow and the high vulnerability of the area to groundwater contamination, it is recommended that future land uses within the CFB Chilliwack property be restricted to those that pose a low risk to groundwater in accordance with the rating scheme illustrated in Table 4. Land uses considered appropriate for this area include recreation, civic use, low-density residential, rural, rural residential, and suburban residential. Should moderate to very high risk land uses be considered for this area, a significant number of controls would be required to provide some degree of groundwater protection. Some examples of such controls are presented in Section 7.3.1. At a minimum, gas stations, dry cleaning establishments, and other facilities that use hazardous substances should be prohibited from the CFB Chilliwack property within areas corresponding to the one-year time of travel for the production wells.

7.3 Recommendations for Aquifer Protection

7.3.1 Regional Land Use Strategies

Table 4 provides a rating of the relative risk various land use activities pose to groundwater. The District may wish to consider these ratings relative to the results of the vulnerability mapping (Figure 5) when developing proposed land use for the Future Plan. Land uses that pose a low to moderate risk to groundwater (Table 4) are most appropriate for high vulnerability areas such as the Sardis-Vedder Aquifer. As shown in Figure 12, based on the Official Community Plan (1990-2001) (OCP), a considerable proportion of the proposed land use over the Sardis-Vedder Aquifer is considered of high risk to groundwater. High risk land uses such as commercial and industrial development are more suited to areas characterized by low groundwater vulnerability.

Given the intention of the District to develop additional drinking water supplies within the Sardis-Vedder Aquifer and the high vulnerability of the aquifer to contamination, further industrial development in the area of the Sardis-Vedder Aquifer is not advised. Golder Associates concurs with the strategy of the OCP which called for promotion of future industrial development in the Village West area. Based on our vulnerability mapping, groundwater in the vicinity of Village West is considered to be relatively well-protected from contamination due to the presence of relatively thick surface fines above the Chilliwack-Rosedale Aquifer in that area. Further industrial development in the Yarrow and Rosedale areas; however, as discussed in the OCP, should be subject to strict controls due to the high and moderate groundwater vulnerability ratings (respectively) of these areas. Provisions for the protection of existing, private community water wells in the Yarrow area should also be considered when evaluating future industrial development in that area. Should industrial development be considered for areas of high groundwater vulnerability such as the Sardis Vedder Aquifer, the District may wish to conduct an assessment to identify types of industry that pose a lower risk to groundwater. Permitted industry should then be subject to design and operational controls (such as provisions for closed systems) that reduce the potential for contaminant release to the environment.

Further commercial development in the Sardis and Vedder areas should also be subject to controls. For example, gas stations, drycleaning establishments and other facilities that use hazardous substances should be required to develop best management plans with provisions for secondary containment, monitoring and reporting.

Regardless of the controls that may be placed on industry and commercial facilities, the presence of these operations in areas of high groundwater vulnerability would represent some degree of risk. As an alternative, consideration could be given to relocating the well field to another area (for example, closer to the Vedder River) where the capture zones would not encompass areas of high-risk land use. The District may wish to conduct a cost-benefit analysis to evaluate these two options.

Golder Associates concurs with the strategy of the OCP to encourage growth in the uplands areas of the District rather than on the valley floor. As shown in Figure 5, the uplands are characterized by relatively low groundwater vulnerability.

We understand that the District is expanding its sewer lines as additional resources become available. The results of the vulnerability mapping should be considered when identifying new areas for expansion.

7.3.2 Agricultural Issues

The regional contaminant inventory identified a number of potential environmental concerns related to agricultural activities (Section 6.2.2). In the next section, several protection measures are presented for consideration, most of which are aimed at limiting the level of nitrate loading to the aquifers. It should be noted that to date, no information is available concerning current levels of nutrient loading in the District of Chilliwack, or the levels of nutrient loading that can be safely sustained without impacting groundwater. The District may wish to conduct an assessment of nutrient loading to assist with the development of groundwater protection strategies for agricultural land use.

Enforcement of the Code of Agricultural Practice

It appears that agricultural activities that pose the greatest risk to groundwater are those that contravene the Code of Agricultural Practice. A significant degree of groundwater protection could be achieved by more effective enforcement of the Agriculture Waste Control Regulation. The Code is currently enforced through a "peer inspection system". Due to staffing limitations, B.C. Environment does not carry out ongoing field inspections but simply relies upon complaints from neighbouring farmers to enforce the Code. The District of Chilliwack may wish to consider becoming involved in field inspection at a reconnaissance level to identify agricultural properties of potential concern, with particular emphasis on properties located within capture zones and vulnerable areas. The District could then work with peer advisory groups such as the Agricultural Peer Advisory Service, the Horticultural Coalition, or Envirolert (operated by the B.C. Cattleman's Association) to resolve the concerns. If the concerns cannot be resolved by these agencies, the properties of concern could be reported to B.C. Environment for enforcement of the Code in support of the Groundwater Protection Plan.

Aerial Surveys

In the Abbotsford area, B.C. Environment has conducted aerial surveys during the winter months to identify uncovered manure stockpiles. We understand that no further flights are scheduled due to government cut backs. The District may wish to consider financing an aerial survey, perhaps on an annual basis, to identify sites of concern.

Control of Livestock Densities/Removal of Wastes

In addition to working with peer advisory groups and B.C. Environment to assist with enforcement of the Code, there are a number of other protection measures related to agricultural land use the District may wish to implement. Consideration could be given to controlling livestock densities on new and expanding farms to ensure that the available land base is adequate to accommodate the resultant wastes. In cases where the existing land base is insufficient to accommodate the wastes, consideration should be given to trucking excess wastes off-site, particularly from capture zones and vulnerable areas of the aquifer. We understand that in the Abbotsford area, where significant groundwater contamination due to nitrates been identified, approximately 10 % of animal wastes are trucked off the aquifer and used to supplement nutrient-deficient soils in Delta.

Waste Lagoons and Pits

Consideration should also be given to the prohibition of earthen lagoons and pits. A building permit should be required for construction of waste lagoons, with requirements that the lagoons be properly engineered, lined, and have a storage capacity of at least six months.

Waste Management Plans

Consideration could also be given to requiring all new and expanding farms to prepare a Waste Management Plan. Farmers on existing farms should also be encouraged to develop such a plan. According to a report on the "*Management of Agricultural Wastes in the Lower Fraser Valley*" issued by the Management of Agricultural Wastes in the Lower Fraser Valley Program Steering Committee in March, 1997, a Waste Management Plan should consist of the following elements:

- nutrient handling nutrient handling and utilization;
- manure storage;
- off-farm movement of manure if required;
- reduction of manure nutrients on the farm;
- riparian area management; and
- conservation farming techniques.

Education and Awareness

One of the most important means of groundwater protection related to the agricultural industry is education and awareness. Farmers should be made aware of the risk that improper farm practices pose to groundwater quality, the relative vulnerability of the aquifer beneath their properties, best management practices and alternative technologies.

Prior to implementation of the protection measures outlined above, the District may wish to engage in dialogue with the appropriate regulatory authorities (FVRD, B.C. Environment, the B.C. Ministry of Agriculture), the Agricultural Peer Advisory Council, the Horticultural Coalition, Envirolert (managed by the Cattleman's Association) and stakeholder groups such as the East Chilliwack Dairy Association, and the Poultry and Hog Associations.

7.3.3 Public Education/Septic System Maintenance/Hazardous Waste Collection

Several of the recommendations presented for wellhead protection in Section 7.1 could be implemented in areas of high vulnerability or across the entire District to achieve some level of aquifer protection. Specifically, the recommendations regarding public education, septic system maintenance and hazardous waste collection could be implemented across the entire District.

7.3.4 Soak-Away-Pits/Exfiltration Wells

Concerns over the use of soak-away-pits/exfiltration wells in the Sardis-Vedder aquifer were raised in Section 6.2.4. Consideration could be given to the incorporation of passive treatment systems (wetlands/swales) for metal and oil removal prior to discharge.

7.3.5 Private Water Wells

Consideration should be given to conducting a comprehensive water well inventory of the District to identify active and inactive wells. In particular, the inventory should identify community water wells (servicing private waterworks facilities and Indian Reserves) and large capacity wells that may require protection. Consideration should be given to distributing information brochures concerning wellhead protection to private well owners as discussed in Section 7.1.2. Based on the results of the inventory, improperly abandoned water wells should be grouted to prevent them from serving as conduits for the subsurface migration of contaminants.

7.3.6 Landfilling and Dumping

Continued groundwater monitoring and assessment should be carried out at the Bailey Landfill to monitor the effectiveness of the leachate collection system. The District may wish to consider engaging in dialogue with the Tzeachten Indian Reserve to inform them that their reserve is located in an area of high vulnerability and to seek assurances that no further dumping in this area will occur.

7.4 Implementation

The District may wish to consider forming a groundwater protection committee to assist with the development and implement of the Groundwater Protection Plan. The committee may consist of District staff, provincial and federal government representatives and stakeholder groups such as private water purveyors. Because groundwater protection involves a range of issues such as USTs, septic systems, agriculture and contaminated sites, cooperation and commitment amongst the various regulatory authorities is essential to the success of the plan.

Requests for information concerning groundwater use by community waterworks facilities located outside of the area serviced by the District were made to the Ministry of Health; however, this information was not received prior to issuing of this report. Once these water purveyors are identified, consideration should be given to inviting them to participate in the development of the Groundwater Protection Plan.

Because the development of groundwater supplies by the District will be ongoing over the next few years, the Groundwater Protection Plan must be adapted to address changing conditions. Specifically, capture zones for production wells should be re-evaluated once future pumping rates are confirmed and additional production wells are developed. Consideration should be given in the future to revising the groundwater flow model to incorporate seasonal variations in recharge, precipitation and stage of the Fraser River and Vedder River. Based on this revised groundwater flow model, capture zones could be delineated for both high and low seasonal pumping conditions. Similarly, a re-inventory should be conducted every two years to identify new contaminant sources.

As part of the Groundwater Protection Plan, provisions should be also made for groundwater monitoring and contingency planning. Groundwater monitoring (Section 8.0) provides early warning of impending water quality problems and a means of assessing the success of the plan. A contingency plan (Section 9.0) identifies measures that should be implemented to protect groundwater in the event of a spill or an accident and identifies alternative water supplies in the event of a short-term or long-term interruption in the supply.

8.0 GROUNDWATER MONITORING PLAN

8.1 Introduction

Groundwater monitoring represents an essential part of groundwater protection. It provides early warning of impending water quality problems and a means of assessing the success of the Groundwater Protection Plan. We understand that groundwater monitoring currently conducted by the District consists of sampling of Wells 1, 2, 3, 4 and 5 on a regular basis for physical parameters, dissolved anions, selected total and dissolved metals and bacteriological parameters. Sampling for volatile organic compounds (VOCs), total extractable hydrocarbons (TEH), herbicides, pesticides and a comprehensive suite of metals is conducted on an occasional basis at the water supply wells and one monitoring well (MW3).

8.2 Groundwater Monitoring at Existing and Proposed Monitoring Wells

Based on the results of the contaminant inventory, a number of recommendations were made for groundwater monitoring in the vicinity of the District wells (Section 7.1). Where possible, existing groundwater monitoring wells were recommended for use. However, in some areas, the installation of additional groundwater monitoring wells was recommended. Locations of proposed and existing groundwater monitoring wells are shown for each capture zone in Figures 13, 17 and 19 and summarized for the District in Figure 21. A summary of the proposed sampling program for the monitoring wells is provided below:

District Water Well	Monitoring Well	Analysis	Sampling Frequency
Wells 1 & 2	MW2 (existing)	physical parameters dissolved anions dissolved metals VOCs TEH PAHs	annual
Wells 1 & 2	MW3 (existing)	physical parameters dissolved anions dissolved metals VOCs TEH biological constituents	3 months
		pesticides & herbicides	6 months
Well 3	MW4 (proposed)	physical parameters dissolved anions dissolved metals TEH	3 months
		VOCs PAHs	6 months
TW95-1	MW5 (proposed)	VOCs	6 months
TW95-1	MW6, MW7 (proposed)	TEH BTEX	monthly
		dissolved metals VOCs	3 months
TW95-1	MW8 (proposed)	TEH BTEX	3 months
		dissolved metals VOCs	6 months
Well 4	OW95-2 (existing)	physical parameters dissolved anions biological constituents	3 months
		dissolved metals VOCs	annual

District Water Well	Monitoring Well	Analysis	Sampling Frequency
Well 4	MW9 (proposed)	dissolved metals VOCs TEH	annual
Well 5	OW95-3 (existing)	physical parameters dissolved anions dissolved metals VOCs TEH	3 months
		pesticides & herbicides	annual

Note: VOCs = volatile organic compounds
TEH = total extractable hydrocarbons
PAH = polycyclic aromatic hydrocarbons

A list of chemical constituents for each type of analysis is presented in Table 5.

8.3 Groundwater Monitoring at District Water Supply Wells

In addition to sampling at the monitoring well locations, a proposed groundwater monitoring program for the District water supply Wells 1, 2, 3, 4, 5 along with the CFB well and TW95-1 has been developed. In summary, the following groundwater monitoring program is proposed:

1. Quarterly monitoring for the following constituents:
   - physical parameters
   - dissolved anions
   - total and dissolved metals
   - biological constituents
2. Annual monitoring the following parameters:
   - TEH
   - VOCs
   - pesticides and herbicides

In addition, as discussed in Section 7.1, consideration should be given to sampling of Well 3 for a comprehensive suite of biological pathogens to assess the potential impact of buried bio-medical waste (if present) near the wellhead.

8.4 Recommended Sampling Procedures

8.4.1 Groundwater Monitoring Wells

Well Purging

Groundwater monitoring wells should be purged prior to sampling to remove stagnant water and ensure the collection of a representative groundwater sample. At each monitoring well location, both purging and sampling should be carried out using dedicated Waterra™ foot valves and dedicated lengths of polyethylene tubing.

At least three well volumes should be removed prior to sampling. A well volume is defined as the total amount of water within the monitoring well pipe from the static water level to the bottom of the well pipe. One well volume can thus be calculated based on the following formula:

$$\pi \times r^2 \times (B-W) \times 1000 = \text{volume of water in well (litres)}$$

Where B = depth to bottom of casing (m), W = depth to water in casing (m), and r = the internal radius of the well (m). The well volume should be calculated prior to each sampling event by measuring the depth of the water level in the well using an electronic water level probe. Care must be taken to clean the water level probe between monitoring wells to ensure cross-contamination does not occur. Cleaning consists of washing the probe and tape with soapy water, rinsing with warm water and a final rinsing with distilled water.

Field measurements of pH, specific conductivity and temperature should be taken periodically during the purging process to monitor the groundwater chemistry. Purging should be continued until the field indicator parameters appear to stabilize or until a total of 10 well volumes have been removed (which ever comes first).

Care must be taken to ensure the Waterra™ foot valves and polyethylene tubing do not come into contact with the ground surface or other potential sources of contamination during purging and sampling. Latex gloves must be worn at all times when handling the tubing and replaced between sampling locations. Should the tubing be temporarily removed from the well, a clean ground sheet should be used to ensure the tubing does not contact the ground surface. Water samples should not be exposed to tobacco smoke or vehicle exhaust.

Groundwater Sampling

Groundwater samples should be collected in clean containers provided by the analytical laboratory. The type and number of sampling containers and preservatives (if required) for each set of analysis will be specified by the laboratory.

For monitoring wells where VOC sampling is required, VOC samples should be collected in duplicate prior to other the constituents. VOC samples are collected in glass vials fitted with Teflon-coated rubber septas. The vials should be filled until the water mounds on top of the rim and then the cap should be placed on gently. After collection, vials should be carefully examined for the presence of trapped air bubbles. Any samples found to contain trapped air should be re-collected.

Water samples for dissolved metals analysis should be passed through a disposable, in-line 0.45 um filter and pumped directly into laboratory-supplied plastic bottles containing nitric acid preservative. A new filter should be used for each sampling location.

In order to assess and validate the quality of the laboratory analysis, one duplicate sample should be collected for every ten samples and submitted to the laboratory as a blind duplicate. In addition, a travel blank consisting of deionized water (prepared by the laboratory) should be submitted for quality assurance for VOC analyses.

Sample Storage and Shipping

Groundwater samples should be labelled clearly with an indelible marker. Labels should include sample identification, date and time collected, sampler, project descriptor, parameter to be analyzed and preservative (if added). Immediately following collection, sample bottles should be transferred to a cooler containing freezer gel packs and maintained at 4 degrees Celsius. Samples should be shipped to the laboratory under chain of custody (forms provided by the laboratory upon request) within 24 hours collection. The analytical laboratory should be advised of the sample delivery in advance to ensure analysis within the allowed holding time.

8.4.2 District Water Supply Wells

Groundwater samples should be collected from the District water supply wells using the same protocols outlined above. To assess the water quality of the individual wells, the groundwater samples should be taken at the well heads rather than at some location down the distribution line. The samples should be taken after a period of sustained pumping to ensure collection of representative samples.

9.0 CONTINGENCY PLAN

9.1 Introduction

The goal of wellhead protection is to prevent the contamination of underground drinking water supplies. Even under the best prevention plans, contamination may occur. When this happens, a contingency plan directing a coordinated and timely response is an effective tool for assuring a continued supply of potable water.

Periodic emergencies or disruptions may occur due to natural disasters, chemical contamination, and physical disruption. These threaten the supply and distribution of public drinking water supplies to some degree; ranging from a few hours of disruption to contamination of an entire water supply source. The objective of this contingency plan is to minimize the impact of disruption, primarily related to chemical contamination of groundwater, on the public, and restore the water supply service to the District through improved response capabilities and enhanced public education.

The objectives of the Contingency Plan include:

- Document existing well capacities;
- Consider potential conditions resulting in loss of the water supply;
- Describe prevention and emergency procedures for response to aquifer contamination in the capture zone; and
- Identify potential alternate water sources to meet Chilliwack's needs if one or more wells are contaminated or otherwise removed from service.

9.1.1 Existing Emergency Plans

The Chilliwack Emergency Plan, last revised in March 1997, has a stated purpose to assign responsibilities for the preparation for, response to, and recovery from emergencies and disasters. The Emergency Plan does not address specific utilities concerns such as loss of water supply. The Emergency Plan sets up a general Incident Command Structure with assigned responsibilities but does not consider incident scenarios.

The District of Chilliwack has a Waterworks Emergency Response Plan (the "Waterworks ERP"), prepared March 1995 and last revised August 1995, both by Stanley Associates Engineering Ltd. The Waterworks ERP primarily considers the downstream portion of the water supply system, that portion which follows pumping or collection: disinfection with chlorine gas for surface water; contamination of the distribution system; loss of a source; watermain breaks; major fire flow conditions; and terrorist threat. The Waterworks ERP also provides a brief consideration of the potential for chemical contamination of the groundwater near one or more of the wells or of the surface water in one of the lake sources.

9.1.2 Existing Well Conditions

The existing well conditions and water supply rates are described in Section 3 of this report. In summary, the capacity of each water source is:

Well or Surface Water Source	Present Average Capacity (L/s)	Ultimate Capacity (L/s)	Depth to Water Table (m)
Wells #1 & #2	79	150	8
Well #3	41	100	11
Well #4	37	70	less than 4
Well #5	20	70	less than 4
Dunville-Nevin Intakes	70	70	Surface
Elk Creek Intake	40	40	Surface
Total	287 L/s	500 L/s	

9.2 Potential Conditions Resulting in Loss of Water Supply

There are a number of conditions that potentially could lead to the loss or contamination of the water supply. Some of the most likely conditions include:

- Earthquake - power loss, distribution line breaks (especially at crossings), well house building damage, reservoir damage, etc.;

- Power outage – loss of regional power or local power supply disruption;

- Flooding – Fraser River or Vedder River inundation of well house and loss of power or contamination of water supply;
- Fire – at well house;
- Chlorine leak - for surface water sources only;
- Contaminated source (chemical) – spills, leaks from underground or aboveground storage tanks, leaks from processes, infiltration of nitrates from agricultural fertilization practices;
- Contaminated source (biological) – contamination of surface water by persons or animals, contamination of groundwater from septic fields, agricultural manure spreading operations;
- Water main break – due to corrosion, impact, earthquake;
- Vandalism; and
- Explosion/bomb – terrorist activity, build-up of methane from natural sources, accident.

Where the condition is physical (e.g., water main break) the corrective action is both straightforward and part of the normal activities of the Public Works crews. Where other conditions are present, such as contamination due to a leaking underground storage tank at a gas station, a greater variety of approaches is possible with some being significantly more costly and risky than others. In those cases a planned approach is required and may require involvement from contaminant hydrogeologists.

A further consideration with respect to events such as earthquakes is that a number of incidents may occur simultaneously. The responsibility of the Emergency Operations personnel is to rank the incidents in terms of priority. For the purposes of this plan, when contamination of soil or groundwater is being ranked, the Capture Zones should be the first priority.

Contaminated Groundwater Response (Unknown Source)

Contamination may be detected in the groundwater without knowledge of a spill or source. In the event that contamination is detected in the groundwater, the initial response will be to shut down all wells until the water supply that is the source of the contaminants is isolated. At that time, the contaminated well can be shut down and the other wells can be reactivated to flush the water system. The response, once the source well is known, is to investigate the cause and make the necessary remedial actions as discussed below.

9.3 Preventing Contamination - First Response

9.3.1 Spill Responsibility

The Chilliwack Fire Department has the lead role for response to a spill involving an accident, associated with a fire, or similar incidents. Where material is spilled in the course of business, the commercial or industrial party responsible for care and control of the material prior to the spill has responsibility for reporting and remedying the spill under the B.C. Waste Management Act, Spill Reporting Regulation[1]. However, the Chilliwack Fire Department would likely be called to the site of a large spill at a business. Responsibility for remediation of historical releases of contaminants is described in the Contaminated Sites Regulation[2] and generally falls to the person who caused the release.

9.3.2 Recognition of Spill in Capture Zone

The Capture Zone for each groundwater well is indicated in Figure 7. There are four Capture Zone lines on the map, indicating the 60-day, one year, five year and total capture zone. The zones represent the time it takes water to get to the well under average hydraulic and pumping conditions. All parties potentially involved in a spill clean-up within a Capture Zone, must recognize that a spill in the Capture Zone may not only represent an immediate danger to persons in the area, but also an immediate danger to persons consuming water. The Capture Zones for each water source should be noted on the Fire Department reference maps and the Chilliwack Emergency Plan. For spills in the Capture Zones of the wells, response personnel must consider that there is a unseen receptor beneath the ground surface that must also be protected. *Without specific education on the need to protect the groundwater resource, it is unlikely that response personnel will take the necessary steps to protect it adequately.*

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[1] Spill Reporting Regulation, B.C. Reg. 263/90 pursuant to the Waste Management Act.

[2] Contaminated Sites Regulation, B.C. Reg. 375/96, pursuant to the Waste Management Act.

At Wells #1, #2, and #3, the surficial geology from the ground surface to the top of the groundwater consists primarily of sands and gravels. There is little impediment to a spill reaching the groundwater within a relatively short time and a spill, once in the soil, would be difficult to contain. Wells #4 and #5 have some protection due to the presence of silty soils above the groundwater level, but this only provides a slightly longer time allowance for remediation, not contaminant protection. In addition, the hydraulic conditions near Wells #4 and #5 result in a much larger capture zone.

9.3.3 Spill Response Inside Capture Zones

Spill response within a Capture Zone requires recognition that use of material that is mobile or increases the mobility of the spilled material in the ground (e.g., water), will increase the risk of groundwater contamination. Where possible, every effort should be made to contain and collect a spill, not disperse it. Spill response depends on a number of factors relating to site-specific conditions, the material spilled, weather, available resources, etc. For groundwater protection, the most significant difference is between liquid and solid materials and these are discussed separately below.

Liquids

If a liquid spill of a Dangerous Good[3] in quantities greater than about 5,000 litres occurs within a 60-day Capture Zone, the associated groundwater well(s) should be shut down immediately, pending further assessment of the conditions and the adequacy of the spill response. A spill of a Dangerous Good within 10 metres of the wellhead with a volume greater than about 100 litres should also result in a shut down of the well.

If the product spilled is either flammable or immediately dangerous to life or health, it is preferable to use foam to decrease the immediate risk, if appropriate. The foam can reduce the fire risk and the mixture of spilled product and foam can then be vacuumed up with a suction truck. Certain fire fighting foams contain toxic chemicals that may contaminate the groundwater supply if allowed to disperse in the ground. The Fire Department should evaluate their foam used and consider non-toxic alternatives if toxic foams are used. When foam is used within a Capture Zone it should be vacuumed up to limit the risk of groundwater impact.

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[3] A Dangerous Good is defined in the Canadian Transport of Dangerous Goods Act and Regulation.

If the product spilled is non-flammable, not immediately dangerous to life and health, and provided an exclusion zone can be maintained around the area, then other recovery methods should be considered. Because of the nature of the soils in the well areas, action to contain the material is likely required within hours if the groundwater supply is to be preserved.

Some of the methods for recovery of liquids spilled to the ground include the following. Other methods are available and the Fire Department personnel in charge of Hazardous Materials response should have a copy of a HazMat response manual to aid with selection of a response method.

<u>Berming and pumping</u> – berms of soil, absorbent, or other material are placed around the spill to limit its lateral spread on the ground surface. The liquid is pumped from the containment area into tankage as soon as possible.

Requires berm material, pump with screen, and drums or other containers.

<u>Interception trenches</u> – a trench dug through and around the spill area to below the liquid level in the soil. A pump or pumper truck is used to pump the recovered liquid into a suitable storage vessel.

Requires an excavator, sump pump with screen, and tankage. Note, in the area near Wells #4 and #5, a silt layer overlies the aquifer, a trench should not be dug through this layer without first consulting a Contaminant Hydrogeologist.

<u>Product recovery wells</u> – well points advanced into and around the spill zone to capture the liquid contaminant and pump it to suitable containers. Beneficial when the product has reached depths not readily accessible by an excavator.

Requires a groundwater drill rig, groundwater well supplies, pump, and tankage. Note, in the area near Wells #4 and #5, a silt layer overlies the aquifer, a well should not be drilled through this layer without first consulting a Contaminant Hydrogeologist.

Mass excavation – the entire spill area is excavated using characteristics of the contaminant (e.g., odour, colour, pH) to guide the extent of the excavation. Appropriate when the spill volume is not very large and the excavation can proceed faster than the infiltration of the liquid.

Requires an excavator, liner material for placement of excavated soil, dump trucks for soil removal, location to take the soil, sorbents and other liquid collection equipment for liquid draining from soil.

When the majority of the spilled liquid has been recovered, the soil that is contaminated with the liquid will require treatment. The type of treatment will depend on a number of factors. If there is no significant contaminant mobilization condition likely to occur in the near future (e.g., heavy rainfall, fire suppression water intrusion), the treatment of contaminated soil does not need to proceed immediately and should await expert advice.

The Chilliwack Emergency Plan requires an update to include the names of equipment operators for spill response. In addition, the names of companies specializing in hazardous materials handling should be included. The equipment types should include, as a minimum, excavators, drillers, pump/vacuum trucks, dump trucks, potable water tankers, well suppliers, absorbent suppliers, portable water treatment plants, etc.

All spill response must be conducted by appropriately trained and equipped personnel or contractors. Knowledge of the appropriate level of person protective equipment is essential. Hazards associated with Dangerous Goods are compiled in the North American Emergency Response Guidebook.

Solids or Sludges

Spilled solids do not normally pose an immediate risk to the groundwater supply, provided there is no mobilization condition present (e.g., heavy rainfall, fire suppression water intrusion). Spilled solids or sludges should be removed as soon as possible, before a mobilizing condition is present. In the interim, the material should be covered with a waterproof cover to limit rainwater infiltration. If the material is fine grained, wet or very hazardous, the upper layer of soil beneath the spill area should also be removed. The extent of removal of such soils can be assessed in consultation with environmental professionals.

Requires an excavator or loader, containers or dump trucks, and a disposal location.

Contaminated Groundwater Response (Unknown Source)

Contamination may be detected in the groundwater without knowledge of a spill or source. In the event that contamination is detected in the groundwater, the initial response will be to shut down all wells until the water supply that is the source of the contaminants is isolated. At that time, the contaminated well can be shut down and the other wells can be reactivated to flush the water system. The response, once the source well is known, is to investigate the cause and make the necessary remedial actions as discussed below.

9.3.4 Spill Response Outside of Capture Zones

Normal spill clean-up can be used when spills occur outside of a Capture Zone and remediation can be planned for a longer term than for spills within a Capture Zone. Because of the cost of remediating contaminated soil, all efforts should be made at recovery as soon as possible after the spill. However, due to biological and physical attenuation of hydrocarbons (e.g., gasoline, diesel) dispersion methods of fire control of highly flammable substances are less likely to result in contamination of existing wells if it is introduced beyond the capture zone. The impacts of any spill and the response to it should be assessed in the follow-up phase.

9.4 Preventing Contamination - follow-up phase

Once a spill has occurred and initial clean-up completed or a historical spill has been determined, an evaluation of the safety of the water supply needs to be initiated. If the water supply is potentially jeopardized, additional mitigation measures may be required.

9.4.1 Ongoing Incident Assessment

After initial response procedures have begun, evaluation of the situation for short-term and long-term impacts must commence. Those questions requiring answers may be:

- What is the current status of the water supply?
- What is the current status of the response effort?
- How long and what will it take to return the system to normal operations?
- Do the response efforts need to be changed or should new activities be initiated?

The District should be considering these questions and including the Chief Medical Health Officer in assessing the status of the water supply. The answers may change throughout the response effort; therefore, these questions should be asked periodically. Depending on the answer, the District may wish to develop alternative response strategies, such as:

- Is there a need to implement water restrictions? To advance to the next stage of restrictions?
- Do the residents need to boil water before drinking? Should the existing boil water requirements be lifted?

9.4.2 Assessment of Time-To-Impact

Where a spill has occurred within a Total Capture Zone, monitoring of the spill and its effect on the well should be commenced. A minimum of three groundwater monitoring wells should also be installed and monitored: two (to be installed after the spill) at the spill site between the wellhead and the spill; and one at the 60 day Capture Zone line between the spill site and the wellhead. The monitoring frequency should be assessed in consultation with a contaminant hydrogeologist. The wells are recommended at the 60-day line, as analyses for most parameters require a minimum of one week and certain parameters may require four weeks. Typically, a confirmatory sample would be desirable prior to discontinuing use of the well; hence the need for 8 weeks for analyses, plus decision time.

9.4.3 Mitigation Measures

If contaminants are detected in the groundwater within a Total Capture Zone, some mitigation measures are possible, as described below. The selection of a mitigation measure will depend on the specific contaminant and the nature and extent of the release.

To ensure the most appropriate measure is selected, a contaminant hydrogeologist and/or a remediation engineer should be consulted.

Stop pumping from the well head - this will change the hydraulic gradient and, therefore, the groundwater velocity. Both the speed of groundwater movement and the direction will change if the pump is stopped. This will provide additional time for treatment or removal of the contaminants before they reach the well head.

Install groundwater pump and treat wells between the source and the well head – these wells would extract the water in their vicinity, upgradient of the well head. The water pumped from the recovery wells would be run through an appropriate treatment train to remove the contaminants and, likely, reinjected into the ground. Groundwater pump and treat systems typically have very long terms of operation and it may be more cost effective to drill a new well.

In situ treatment of contaminated soil and groundwater – depending on the contaminant, it may be possible to install an in situ treatment technology that removes the contaminants from the water without having to pump water. For example, for a gasoline spill, air sparging into the groundwater and soil vapour extraction of the overlying soils is a proven method of removing the hydrocarbons.

Well head treatment – may be used as a polishing step or as the treatment method if significant assurance of treatment can be provided. A typical polishing step would be to pass the groundwater through a series of activated carbon filters to remove traces of hydrocarbons. Significant safeguards are required in such a system as a failure in the system could lead to contamination of all the water in the reservoirs and the distribution network.

9.4.4 Procedures for Non-Contamination Events

Natural causes, ranging from lightning and storms to floods, volcanic eruptions, and earthquakes, may result in telephone or power outages, structural failure of facilities, or pipeline breaks. These events are likely to affect supply for individual wells but the solutions to the issues relating to an individual well are relatively straightforward. For example, if power is lost to the wellhead due to an earthquake (the well itself is likely to survive but the power to the well or the building at surface may be damaged), resumption of power can be readily facilitated by bringing a generator to the site. Well #3 is already equipped with a stand-by generator but provisions for fuelling of the generator following a seismic event should be considered.

An earthquake could also damage distribution lines and water trucks would be required to haul water from the well head to the users, provided roads were useable. The District may consider methods of installing temporary water supply lines for emergency water supply around damaged areas.

Following a seismic event, there may be multiple breaks in water lines. To respond to this type of event, the District must have the facilities and plan in place to allow isolation of critical water lines for their expeditious repair. Less critical lines will require inspection and repair and should be isolated from the main lines until this can be completed. Leaking lines are potential sources of bacteriological contamination, especially if the pressure through the system is not at optimum due to numerous leaks. The District, as part of Emergency Planning must develop a ranking of critical water distribution lines to assess the repair priority.

In the event of an earthquake or similar event that disrupts distribution lines, the surface water sources may become more important. It is easier to establish portable, self-powered equipment at a lake for surface water removal than it is to fix a distribution line. If Chilliwack removes the surface water intakes from use, the facilities should be mothballed, not decommissioned, to allow faster reactivation during an emergency.

Acts of terrorism or vandalism could affect any part of the system. While physical damage to a system will likely be detectable, an act of terrorism involving contamination of the water supply may be difficult to detect – either the presence in the water or the location of the contaminant source. In such cases, upon detection, immediate discontinuance of pumping and provision of an alternative water supply may be required.

Flooding may affect a well by introduction of flood water contaminants into the well casing. Flood protection should be provided for each well house and provisions for groundwater chlorination should be available. At present, groundwater is not chlorinated in the District.

9.4.5 Spill Recording

Because Chilliwack's water supply requirements are expected to increase over time, additional wells will likely be required. Therefore, a record of all spills to the ground should be maintained, preferably in a GIS format with the information on the spill included in the GIS database. When a new well is considered, the surrounding area can be evaluated for potential contaminant sources including the spill history provided in the GIS database and the BC Environment Site Registry[4].

9.4.6 Resources

Emergency Response Plan

The District of Chilliwack Emergency Plan should include a map showing the capture zone for each drinking water well. Because of the long-term risk of damage, special procedures should be included for incident response in the Capture Zones. The activation of the Emergency Plan will likely include requirements on the water system.

Logistical Support Resources

Key to the contingency planning process is assuring that proper personnel, equipment, and technical resources are available in case of a water supply disruption. The call-out roster in the Waterworks Emergency Plan needs to explicitly identify personnel who can facilitate securing of required equipment in a timely fashion, co-ordination, financial approvals, etc.

Personnel and Technical Resources

The Waterworks Plan should contain an *Emergency Call Roster*, *Personnel List* and *Employee Experience Table*. These need to be updated quarterly and distributed to

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[4] The Site Registry is a database maintained by BC Environment for the purposes of listing sites that have been assessed with respect to contamination status. Access to the Site Registry is available through BC Online.

Emergency Dispatch, Police, Fire and Parks Departments, and all divisions of Chilliwack Public Works.

Equipment and Materials Resources

In the event of an emergency, the District has a Mutual Aid agreement with the City of Abbotsford for emergency assistance. Available water treatment equipment by location, rolling stock and rental equipment at nearby suppliers should be kept on a database at the District. Name and phone number of qualified operators of the respective equipment should be placed in an *Employee Experience Table*.

Other Resources

The District maintains a complete spare parts inventory for the ongoing maintenance and operation of the water system. In the event of a disruption the District has no water wagons in their fleet and external contractors would be required. For hazardous conditions and spill response, the Fire Department will be called upon to respond. Due to the agricultural and light industrial nature of the District, there are nearby machine shops, pump repair and electrical repair facilities within the District and in the adjoining communities.

Financial Resources

Procuring alternative water supplies, especially on an emergency basis, can be costly. The level of funding necessary to meet these needs must be reviewed not only for response to specific incidents, but also with the costs attributed to maintaining and updating the District's *Contingency Plan.*

Public Communications/Community Relations

It is important for the District to maintain effective communication with the public before and after a supply disruption incident. This will minimize confusion and frustration and potentially lead to the public's cooperation in response implementation. An individual or position needs to be identified as the Public Communications Officer.

For day-to-day incidents the Administration Office will contact the media. For emergency or accidents, the Director of Public Works may delegate incident response to the appropriate division heads. The persons to be contacted are listed in the Waterworks Plan.

9.5 Water Supply loss impact and Replacement Alternatives

The two major issues with respect to loss of a supply source are alternate supplies – both short and long-term – and delivery method. In tandem with these supply alternatives, imposed conservation measures are the most common method of reducing demand. The following sections provide alternatives and considerations for short and long-term supply, alternate water delivery systems, and conservation.

9.5.1 Short Term Supply

In general, the categories of short term alternative water supplies are:

- Supply from within the system;
- Supply from outside the system; and
- Water supply treatment.

More than one of these options may be employed depending on the nature of the disruption and the specific characteristics of the water supply system. Not all options work for each situation. It is also important to point out that the option may also be dependent upon the season in which the disruption occurs. For example, tank trucks may not be viable in the winter due to freezing conditions. These options are discussed in more detail below.

Supply From Within The System

There are a variety of methods of obtaining additional supply from the system should one or more wells need to be removed from service.

Additional wellhead capacity – as indicated in the Introduction to the Contingency Plan, each of the wells can produce more water than at present by increasing the pumping frequency. While a significant increase in short term capacity is known to be available, the duration that higher flow rates can be sustained requires additional investigation. It is important to consider that if a well is contaminated and, therefore shut down but other wells in the vicinity are drawn down at a faster rate, this will affect the hydraulic gradients and the capture zones. This is especially important to consider in the Sardis area.

Additional surface water and treatment plant capacity – at the surface water intakes, there may be additional water available (possibly depending on the season) and treatment capacity to increase the flow from these sources. Consideration must be given to the maximum amount of water that may be drawn from these sources under the terms of the Water License.

Excess capacity – the present system is designed to maintain a certain residual volume of water in the reservoirs for fire water. In extreme circumstances, this supply could be drawn down.

Supply From Outside The System

Alternate Groundwater Sources - within the District are a number of established wells that are not part of the existing water supply system. These wells could be connected to the system to provide additional capacity. The CFB Chilliwack production well is already tied into the water distribution system and can provide additional supply on demand. There are a number of concerns that need to be addressed prior to connecting a different well to the system and may include:

- Presence of nitrates and/or faecal coliforms in many areas, primarily associated with intensive agriculture;
- High levels of iron in wells near the Fraser River (e.g., Wells #4 and #5) may impart either objectionable levels of iron to the water or may require treatment for iron removal; and
- Potential presence of hydrocarbons and other contaminants in wells at and adjacent to CFB Chilliwack.

Interties with other Districts or Municipalities – in the course of extending the water distribution network, connections with other water supply districts should be considered. These connections can be used to increase the water supply in the District.

Bottled Water – may be used to deliver clean drinking water to a wide variety of locations. Recent bacteriological outbreaks in community water systems have led to increased use (and therefore availability) of commercially bottled water. Where the entire water supply system is contaminated, bottled water may be the only viable method of distributing clean drinking water.

Treated Wastewater – may be made available for outside irrigation of parks, schools, golf courses and other land application uses of water. Contamination of an aquifer may not only affect the District's water supply, but also agricultural users who draw water from the same aquifer. Provision of treated water, delivered by tanker truck may provide the necessary water supply to ensure a crop is not lost. Application of wastewater to food crops should only be conducted in consultation with the Chief Medical Health Officer.

Water Supply Treatment

Where a water supply source has been contaminated, a short-term method of restoring the supply may be to add a package water treatment unit at the wellhead, reservoir, or point of use. For certain contaminants this is a reasonable alternative but there may be significant delays in establishing a reliable water treatment system at the wellhead or reservoir, given the volume of water to be treated. The only point-of-use treatment normally considered is boiling of water.

9.5.2 Long-Term Replacement Alternatives

Long-term water replacement is different from emergency and short-term options in two ways: 1) the amount of time to evaluate is longer allowing for more analysis and future needs evaluation prior to a decision being made; and 2) the viable alternative range is larger. Once the District has implemented an interim source, they may evaluate replacement options that are more capital intensive and take longer to implement.

The following actions would be required in implementation of a long-term solution.

- Intensive investigation to determine the type, extent and source of the contamination. The expected duration of the contamination event should be estimated.

- Develop remediation alternatives for type, extent and expected duration of the contamination. Remediation alternatives may include: additional treatment in-system for removal of the contamination; or complete abandonment of the wells and commissioning of wells in new areas or expansion of surface water uses.

- Investigate interconnections with the surrounding communities as interim solutions to providing additional domestic water supply.

- Identify sources of financial funds to be used in implementation of the selected remediation alternative.

- Minimize the period required for construction of the selected remediation alternative through consideration of the following:

  - design/build selection of consultant/contractor;

  - pre-purchase equipment;

  - time and material contractor selection; and/or

  - initiate construction prior to consultant completing design.

9.5.3 Water Distribution

In addition to the supply sources, the delivery method may need consideration if either the source is remote to the system or the distribution system is damaged in an area. Alternative delivery methods include the following:

- Tanker trucks;

- Bottled water; and

- Temporary pipelines.

Tanker Trucks

Although tanker trucks may be units specifically designed for hauling water, a larger supply of appropriate tankers may be available in the area through use of milk tankers.

These units would require cleaning prior to use but would provide a food grade container for hauling relatively large volumes of water. During the course of use for potable water supply, the tankers should not be used for any other purpose unless they can be demonstrated, to the satisfaction of the Chief Medical Health Officer, to be free of contaminants.

Tanker trucks may be particularly well suited to:

- Provide delivery of domestic water at sites of industrial or commercial consumption which have been limited in allowable consumption.
- Provide delivery of domestic water to potable water stations where residents can obtain drinking water. To maximize the use of the mobile tanker, stationary tanks should be used at such stations into which the tanker discharges.
- Provide delivery of treated wastewater for irrigation use.

Bottled Water

Bottled water is likely the most effective manner to deliver, in a controlled manner, a set amount of drinking water to residential users. The water can be delivered from remote sources to individual addresses or to a central staging area.

Temporary Pipelines

Temporary pipelines can be used to bypass a failed section of pipe or to deliver water from a source not normally used. The District should maintain a stock of fittings to allow rapid retrofits of failed pipeline sections. For some water supply requirements, agricultural irrigation pipe may be one of the most versatile temporary pipelines for long distance water transport. Because of the nature of agricultural irrigation pipe, no specific skills are required to connect pipes and sections can be largely completed independent of other sections.

9.5.4 Conservation Activities

The most effective method of meeting the supply requirements is to implement conservation measures. While some water use restrictions would be enacted by bylaw or emergency order, the District can take steps at present to reduce the overall water demand and thereby increase or maintain the excess capacity in the system.

Water Use Restrictions

During water supply shortages, it is normal and generally expected that water use restrictions will be imposed. If a curtailment in water supply is required, the following facilities should be considered priority water users and should be provided with an uninterrupted water supply:

- Hospital;
- Emergency facilities;
- Fire fighting systems; and
- Public drinking water supplies.

A variety of stages of water use restriction may be considered and imposed. However, the success of the restrictions in a District the size of Chilliwack will more likely be due to education than enforcement.

Educating the Community

Community confidence in the water system is fundamental to a successful response to a water supply disruption incident. Without the community's help in whatever the circumstance, even the most prepared system may fail. By continuing to educate the public ahead of time about their role in conservation, the District greatly improves the community's ability to actively cooperate with the District during an emergency. It is also essential that the District's message be clear and defensible, people who have cause to disbelieve the urgency of a conservation measure are less likely to follow the District's request.

Building community confidence is a continuous action requiring periodic reminders as to the role of the customers for ensuring their water supply. The District can achieve this confidence through continued outreach to the community through their various programs – sewer pretreatment, business outreach, moderate risk waste program, household hazardous waste management, wellhead protection, etc. Building plan approval, bylaws, and sewer use restrictions can lead to the increased use of such measures as low water flow devices (e.g. lavatory fixtures), use of water recycle equipment (e.g., in car washes), installation of optimum landscape irrigation equipment, etc. Chilliwack can decrease the water supply requirement (or maintain the requirement during growth) by proactively planning for conservation.

9.6 Reviewing and Updating the Plan

Contingency planning is not a one-step process. It is the District's Response Plan for incidents that may disrupt the community's water supply. Any changes to this plan – response agency telephone numbers, shifts in land use, turnover in personnel – all may affect the plan's timeliness. It is essential that the District establish a regular review period, every six months or annually. For critical components, such as emergency notification phone numbers, lists should be updated on a more frequent basis.

The District should test the plan using tabletop scenarios annually, followed by a debriefing session to identify deficiencies in the plan. Also, after significant modifications or improvements to the system, the District may wish to review the plan to ensure conformity with the modifications or to update the plan in response to deficiencies.

9.7 Recommendations

The Waterworks Emergency Response Plan, last revised August 1995, should be amended into the District's Emergency Response Plan. Certain aspects of the Waterworks Plan can be stand-alone, such as the failure of a watermain, but many of the aspects discussed in the Waterworks Plan may require a co-ordinated effort by emergency response personnel and, as such, should be in the overall ERP. The ERP should consider that a threat to the water supply, if not responded to correctly, could be as devastating as many other disasters.

The Emergency Response Plan needs to be reviewed, upgraded, and updated to include scenario management. In addition, a list of suppliers of typical construction equipment and hazardous materials response equipment needs to be included in the Plan.

In the event of an earthquake or similar event that disrupts distribution lines, the surface water sources may become more important. It is easier to establish portable, self-powered equipment at a lake for surface water removal than it is to fix a distribution line. If Chilliwack removes the surface water intakes from use, the facilities should be mothballed, not decommissioned, to allow faster reactivation during an emergency.

10.0 LIMITATIONS AND USE OF REPORT

This report was prepared for the exclusive use of the District of Chilliwack. In evaluating the requirements for groundwater protection, Golder Associates Ltd. has relied in good faith on information provided by sources noted in this report. We accept no responsibility for any deficiency, misstatements or inaccuracy contained in this report as a result of omissions, misstatements or fraudulent acts of others.

Any use which a third party makes of this report, or any reliance on or decisions to be made based on it, are the responsibility of such third parties. Golder Associates Ltd. accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this report.

11.0 CLOSURE

We trust that this report meets your current requirements. Should you have any questions or comments please do not hesitate to call.

Yours very truly,

GOLDER ASSOCIATES LTD.

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TABLE 1

Groundwater Extraction Volumes (m^3)

	Well #1 and #2	Well #3	Well #4*	Well #5**
1991	1,387,370	1,684,153	-	-
1992	1,893,421	1,201,234	-	-
1993	1,229,826	2,216,129	-	-
1994	2,620,082	1,772,873	-	-
1995	3,699,406	839,373	-	-
1996	4,081,067	89,894	193,302	206,880
Yearly Average	2,485,195	1,300,609	193,302	206,880
Average Yearly Pumping Rate (l/s)	79	41	37	20

* records for Jul and Aug of 96 only

** records for Sep to Dec of 96 only

Current and Future Pumping Rates

	Current Conditions		Future Conditions	
Well Number	Instantaneous Pumping Rate (l/s)	Average Pumping Rate (l/s)	Instantaneous Pumping Rate* (l/s)	Average Pumping Rate** (l/s)
Well #1 and #2	210	79	210	150
Well #3	160	41	200	100
Well #4	75	37	140	70
Well #5	75	20	100	70
CFB Well	63.5	13	200	100
TW95-1	currently not in use		130	100

* as estimated by the District

** estimated based on the future water supply demand and historical pumping records

Table 2A
Sites Contained Within BC Environments' Contaminated Sites Registry

GOLDER ID	SITE ID	COMMON NAME	ADDRESS	CITY	STATUS	NOTES
1	79	ESSO SERVICE STATION (FORMERLY TEXACO)	45996 YALE ROAD	CHILLIWACK	ACTIVE - UNDER REMEDIATION	
2	91	45682-45696 YALE ROAD WEST	45696 YALE ROAD WEST	CHILLIWACK	ACTIVE - ASSESSMENT COMPLETE	
3	176	EAST CHILLIWACK CONSUMERS' COOP	46255 CHILLIWACK CENTRAL ROAD	CHILLIWACK	ACTIVE - UNDER REMEDIATION	
4	203	FORMER SHELL BULK PLANT	8890 SCHOOL STREET	CHILLIWACK	ACTIVE - UNDER REMEDIATION	
5	253	46017 YALE ROAD	46017 YALE ROAD	CHILLIWACK	ACTIVE - UNDER REMEDIATION	
6	254	TURBO SERVICE STATION # 8517	45740 YALE ROAD WEST	CHILLIWACK	ACTIVE - UNDER REMEDIATION	
7	299	CHEVRON STATION-45864 OLD YALE RD.	45864 YALE ROAD	CHILLIWACK	ACTIVE - ASSESSMENT COMPLETE	
8	371	FORMER PETRO CANADA BULK PLANT	44580 OLD YALE ROAD	CHILLIWACK	ACTIVE - UNDER REMEDIATION	
9	430	CHEVRON CANADA - 45456 YALE ROAD	45456 YALE ROAD WEST	CHILLIWACK	INACTIVE - NO FURTHER ACTION	
10	514	SHELL CANADA 46299 YALE ROAD EAST	46299 YALE ROAD EAST	CHILLIWACK	ACTIVE - UNDER ASSESSMENT	
11	1064	CHEVRON CHILLIWACK BULK PLANT	YALE ROAD	CHILLIWACK	ACTIVE - UNDER REMEDIATION	
12	1243	YARROW METER STATION NO 14	5260 BOUNDARY ROAD	CHILLIWACK	ACTIVE - ASSESSMENT COMPLETE	
13	1265	BROADWAY MOTORS - CHILLIWACK	46605 1ST AVENUE	CHILLIWACK	ACTIVE - UNDER ASSESSMENT	
14	1268	PETRO-CANADA SERVICE STATION #02602	46372 YALE ROAD	CHILLIWACK	ACTIVE - REMEDIATION COMPLETE	
15	1339	YARROW ESSO	42170 YARROW CENTRAL ROAD	CHILLIWACK	INACTIVE - NO FURTHER ACTION	
16	1357	FORD MOUNTAIN CORRECTIONAL INSTITUTE	57657 CHILLIWACK ROAD	CHILLIWACK	ACTIVE - UNDER ASSESSMENT	1
17	1380	BC TEL - CHILLIWACK PLANT CENTRE	46167 5TH AVENUE	CHILLIWACK	ACTIVE - UNDER REMEDIATION	
18	1414	MOUNT THURSTON CORRECTIONS FACILITY	53033 CHILLIWACK LAKE ROAD	CHILLIWACK	ACTIVE - UNDER ASSESSMENT	1
19	1422	INDEPENDENT SUPER SAVE - CHILLIWACK	46909 YALE ROAD	CHILLIWACK	ACTIVE - UNDER ASSESSMENT	
20	1462	CHERRY FORD SALES - YALE ROAD	45681 YALE ROAD	CHILLIWACK	INACTIVE - NO FURTHER ACTION	
21	1538	FORMER THRIFTY GAS - YALE ROAD WEST	45922 YALE ROAD WEST	CHILLIWACK	INACTIVE - REMEDIATION COMPLETE	
22	2318	FORMER TOOL BOX SITE	45589 YALE ROAD WEST	CHILLIWACK	ACTIVE - UNDER ASSESSMENT	
23	2656	SHELL CARD LOCK - CHILLIWACK	7970 LICKMAN ROAD	CHILLIWACK	ACTIVE - UNDER REMEDIATION	
24	3166	PETRO-CANADA STATION	7591 VEDDER	CHILLIWACK	ACTIVE - UNDER ASSESSMENT	
25	3327	MAPLE GENERAL STORE	48920 YALE ROAD EAST	CHILLIWACK	ACTIVE - UNDER ASSESSMENT	
26	3404	45680 YALE ROAD WEST	45680 YALE ROAD WEST	CHILLIWACK	ACTIVE - UNDER ASSESSMENT	
27	3405	45674 & 45678 YALE ROAD WEST	45674 & 45678 YALE ROAD WEST	CHILLIWACK	ACTIVE - UNDER ASSESSMENT	
28	3590	CHEVRON SERVICE STATION - LICKMAN ROAD	LICKMAN ROAD AND HIGHWAY 1	CHILLIWACK	INACTIVE - NO FURTHER ACTION	
29	3771	CHEAM GOLF CENTRE	44610 LUCKAKUCK WAY	CHILLIWACK	UNKNOWN STATUS	
30	3866	CFB CHILLIWACK	KEITH WILSON ROAD	CHILLIWACK	ACTIVE - UNDER ASSESSMENT	
31	3933	43615 YALE ROAD WEST, CHILLIWACK	43615 YALE ROAD WEST	CHILLIWACK	SITE PROFILE RECEIVED	
32	3996	PETRO-CANADA - 45632 YALE ROAD WEST	45632 YALE ROAD WEST	CHILLIWACK	ACTIVE - UNDER REMEDIATION	
33	3997	PETRO-CANADA - 8850 SCHOOL STREET	8850 SCHOOL STREET	CHILLIWACK	UNKNOWN STATUS	
34	289	PETRO CANADA STATION BRIDAL FALLS TRAVEL	53560 BRIDAL FALLS ROAD	ROSEDALE	ACTIVE - UNDER REMEDIATION	1
35	1254	49473 YALE ROAD	49473 YALE ROAD	ROSEDALE	ACTIVE - UNDER ASSESSMENT	
36	1187	FORMER DAIRYLAND SITE	45450 SPRUCE DRIVE	SARDIS	INACTIVE - NO FURTHER ACTION	
37	3298	7163 VEDDER ROAD	7163 VEDDER ROAD	SARDIS	ACTIVE - UNDER ASSESSMENT	
38	3828	7062 SUMAS PRAIRIE ROAD, SARDIS	7062 SUMAS PRAIRIE ROAD	SARDIS	SITE PROFILE RECEIVED	
Notes		1. Outside district boundaries				
		2. Location of site unknown; site not shown on figure				
		3. Site locations shown on Figure 9				

August 15/97

Table 2B
Sites Contained Within BC Environments' Waste Data Base

972-1846

GOLDER ID	CLIENT NAME	GENERAL_LOCATION	CITY	FILE_TYPE	TYPE	FILE NO.	STATUS	SECTION	NOTES
1	BCG, ENVIRONMENT AND PARKS	CHILLIWACK, CULTUS LAKE	CHIL	Permit	Effluent	7507	Active	MUNICIPAL	1
2	CATTERMOLE TIMBER	CHILLIWACK, 10 KM WEST	CHIL	Permit	Refuse	2530	Active	INDUSTRIAL	
3	CHEAM VIEW TROUT FARMS	CHILLIWACK, UPPER PRAIRIE ROAD	CHIL	Permit	Effluent	7886	Suspended	INDUSTRIAL	2
4	CHILLIWACK GOLF & COUNTRY CLUB	SARDIS, 41894 YALE ROAD WEST	CHIL	Permit	Effluent	12010	Active	MUNICIPAL	
5	CHILLIWACK, DISTRICT OF	CHILLIWACK-MATHESON ROAD	CHIL	Permit	Refuse	1822	Active	MUNICIPAL	
6	CULTUS LAKE PARKS BOARD	CULTUS LAKE	CHIL	Permit	Effluent	4782	Active	MUNICIPAL	1
7	DARGATZ MINK RANCH LTD.	CHILLIWACK, 10282 REEVES ROAD	CHIL	Permit	Effluent	5899	Active	INDUSTRIAL	
8	ELK CREEK FEED COMPANY LTD.	CHILLIWACK, 49760 CHILLIWACK CENTRAL ROAD	CHIL	Permit	Effluent	14524	Active	INDUSTRIAL	
9	FRASER VALLEY DUCK & GOOSE LTD.	CHILLIWACK, 4540 AND 4535 SIMMONS ROAD	CHIL	Order	Effluent	14448	Active	ENVIRONMENTAL ASSESSMENT	
10	FRASER VALLEY DUCK AND GOOSE LTD.	CHILLIWACK, 42915 VEDDER MOUNTAIN ROAD	CHIL	Approval	Effluent	14612	Active	INDUSTRIAL	
11	FRASER VALLEY DUCK AND GOOSE LTD.	YARROW, SIMMONS ROAD	CHIL	Permit	Effluent	6428	Amend in Progress	INDUSTRIAL	
12	GORDANIA ESTATES LIMITED	ROSEDALE, 52324 YALE ROAD EAST	CHIL	Permit	Effluent	2400	Active	MUNICIPAL	1
13	GRACE-MAR DAIRY INC.	CHILLIWACK, 47582 YALE ROAD	CHIL	Permit	Effluent	10503	Active	INDUSTRIAL	
14	KILCO INDUSTRIES LTD.	ROSEDALE, 53560 BRIDAL FALLS ROAD, VOX 1XO	CHIL	Permit	Effluent	13426	Active	MUNICIPAL	1
15	KIM, YONG WAN & HYE SOOK	CHILLIWACK, 7163 VEDDER ROAD	CHIL	Order	Effluent	14871	Active	SPECIAL WASTE	
16	KLOOT, ALFRED J. AND RITA H.	CHILLIWACK, 6786 PREST ROAD	CHIL	Order	Effluent	14894	Active	ENVIRONMENTAL ASSESSMENT	
17	MAWJI, MADATALI E.	ROSEDALE, 49473 YALE ROAD	CHIL	Approval	Storage	14320	Active	SPECIAL WASTE	
18	MAZATEC SERVICES LTD.	CHILLIWACK, 44335 YALE ROAD WEST	CHIL	Restrictive	Storage	13342	Active	SPECIAL WASTE	
19	MUXLOW, HARVEY LEN	SARDIS, 43386 ADAMS ROAD	CHIL	Permit	Effluent	12246	Active	MUNICIPAL	
20	OK JO, BUNG	YARROW, 41844 NO. 3 ROAD	CHIL	Permit	Effluent	12025	Active	MUNICIPAL	
21	PILLSBURY CANADA LIMITED	SARDIS	CHIL	Permit	Effluent	1684	Active	INDUSTRIAL	2
22	PROUSE, NORMAN DANIEL	CHILLIWACK, 8280 PREST ROAD	CHIL	Permit	Effluent	13077	Active	MUNICIPAL	
23	REMPEL BROS. CONCRETE LTD.	CHILLIWACK-TOWER ROAD	CHIL	Permit	Effluent	4849	Active	INDUSTRIAL	
24	REMPEL BROS. CONCRETE LTD.	CHILLIWACK-TOWER ROAD	CHIL	Permit	Effluent	1982	Active	INDUSTRIAL	
25	SCHOOL DISTRICT NO. 33 (CHILLIWACK)	CHILLIWACK, 46361 YALE ROAD	CHIL	Permit	Storage	13598	Active	SPECIAL WASTE	
26	SCOTT PAPER LIMITED	CHILLIWACK, NORTH EAST	CHIL	Permit	Effluent	12733	Active	MUNICIPAL	2
27	THE OWNERS STRATA PLAN NW-540	SARDIS, CHILLIWACK LAKE ROAD	CHIL	Permit	Effluent	4219	Active	MUNICIPAL	2
28	VALLEY RITE MIX LTD.	CHILLIWACK, BRINX ROAD	CHIL	Permit	Effluent	5516	Active	INDUSTRIAL	
29	WESTCOAST ENERGY INC.	ROSEDALE, 52138 DYKE ROAD	CHIL	Permit	Effluent	2234	Active	INDUSTRIAL	2
Notes	1. Outside district boundaries								
	2. Location of site unknown; site not shown on figure								
	3. Site locations shown on Figure								

Table 2C
Spills Reported to BC Environment

GOLDER ID	EEIR	DATE	LOCATION	AREA	MATERIAL	AMOUNT	UNITS	NOTES
1	80845	97/06/20	Off Hwy # 1 across from Bridal Falls	Bridal Falls	burning of garbage	unknown		1
2	80102	97/04/10	44025 Old Yale Rd	Chilliwack	diesel fuel	about 200	litres	
3	80074	97/04/07	Cana Rd Off Old Yale Rd	Chilliwack	liquid manure	unknown		2
4	80074	97/04/07	Cana Rd Chilliwack off Old Yale Rd	Chilliwack	liquid manure	unknown		2
5	73836	97/03/28	175 Forest Cr	Chilliwack	falling trees	unknown		2
6	73847	97/03/28	9200 Block Pres Rd	Chilliwack	diesel & motor oil	20 litres & 10 litres		
7	73781	97/03/23	44610 Luckakuck Way	Sardis	gasoline	80 gals		
8	73728	97/03/19	Property W of Bell Crk N of Chilliwack Lake Rd	Chilliwack	petroleum products	unknown		2
9	73728	97/03/19	(49091 Chilliwack Lake Rd)	Chilliwack	petroleum products	unknown		1
10	73660	97/03/13	Shell Chilliwack Card Lock Lickman Rd	Chilliwack	diesel	10	litres	
11	73493	97/02/23	Cross Airport Rd/Creek Cres behind 8435 PiperCres	Chilliwack	oil slick	unknown		
12	73427	97/02/15		Chilliwack	oil	unknown		2
13	72843	96/12/27	6336 Vedder Rd & Tzaachte	Sardis	gas/diesel	40	litres	
14	72804	96/12/19		Chilliwack	Phenol			2
15	72804	96/12/19	Hwy #1 and #9	Chilliwack	phenol un 2312	no spill		1
16	72620	96/11/29	45970 First Ave	Chilliwack	gas	20-30	litres	
17	72480	96/11/16	Yale Rd /Chapman Rd/Junior School	Chilliwack	slick	unknown		
18	72470	96/11/15	Matheson Road	Chilliwack	landfill leachate	70 - 80 ft		
19	72359	96/10/27	Tank farm	Chilliwack	gas (potential spill)	unknown		2
20	71839	96/09/19	4950 Bergman Rd, Yarrow	Chilliwack	diesel	20-30	litres	
21	71640	96/08/27	45340 Creekside Drive	Chilliwack	pesticide (insecticide?)	unknown		
22	71489	96/08/14	Rosedale Hwys	Rosedale	diesel	20-30	litres	2
23	71120	96/07/12	7970 Lickman Rd	Chilliwack	diesel	10-20	litres	
24	71130	96/07/12	45610 Lukakuk Way	Chilliwack	gasoline (regular)	<20	litres	
25	71149	96/07/12	Shell Stn 7970 Lickman Rd Cardlock	Chilliwack	diesel	7-10	litres	
26	70989	96/06/30	Cultas Lake off Columbia Valley Hwy near lakeside	Chilliwack	gasoline	unknown		1
27	70813	96/06/16	Trailer #53 Ungsworth Rd	Sardis	furnace oil	unknown		
28	70797	96/06/14	Owner of Riverside 45530 Vedder Mount Rd	Chilliwack	diesel	50-100	gal	
29	70989	96/06/03	Cultas Lake off of Columbia Val Hwy	Chilliwack	gas/oil	unknown		1
30	70472	96/05/10		Chilliwack	oil	unknown		2
31	70069	96/04/09	49051 Sheldon Rd	Chilliwack	horse manure	unknown		2
32	63641	96/03/29	Tool Booth Hwy 5	Chilliwack	diesel	unknown		1
33	63461	96/03/10	Annacis Rd & Hack Brown Rd	Chilliwack	gasoline	?		2
34	63126	96/02/28	8992 Nowell Street	Chilliwack	solvents	various		
35	63164	96/02/11	Chilliwack Lake Road	Chilliwack	silt and sand	completely filled		1
36	63043	96/02/01	off Lickman Rd on Industrial Way	Chilliwack	used oil	5	litres	
37	63023	96/01/30	Bridal Falls	Rosedale	diesel	?		1
38	62274	95/11/13		Chilliwack	sheen	?		2
39		95/11/07	Chilliwack @ Vedder River Crossing	Chilliwack	crude oil	?		
40		95/11/01		Chilliwack	hydrolic oil	90	l	2
Notes	1. Outside district boundaries							
	2. Location of site unknown; site not shown on figure							
	3. Site locations shown on Figure 9							

Table 3

Index to Areas of Potential Environmental Concern at CFB Chilliwack as shown on Figure 11.

Area	Description	Nature of Potential Environmental Concern
1	Building 122 – Former Base Transport Storage Area	• former UST • vehicle maintenance
2	Building 1054 – RC Chapel	• former UST
3	3 PPCLI Compound	• soakage pits
4	Building 37 – Former Hospital and Dental Clinic	• discharge to sanitary
5	CFOCS – Former Base Maintenance Area	• former UST • vehicle maintenance
6	CFOCS Training Building 1118 Industrial Site	• vehicle storage • POL storage
7	Building 41A – Old Carpentry Shop	• waste disposal
8	Building 4 – Base Photo	• discharge to sanitary • former UST
9	CE Compound	• PCBs • POL storage • former UST
10	POL Area	• former USTs
11	Former Hazardous Storage Area	• hazardous materials storage
12	Site of Transformer Spill	• PCBs
13	Training Area	• use of hydrocarbons
14	Historical Maintenance	• vehicle maintenance
15	Training Area	• hazardous materials storage
16	Building 1016 – Steam Plant	• former AGTs
17	Building 1031 – Outdoor Range	• metals
18	Fire Fighter Training Area	• use of hydrocarbons
19	Sandblasting Area	• metals • soakage pit
20	Sewage Drying Beds and POL Training Facility	• former USTs • sanitary waste
21	Stormwater Retention Pond	• stormwater
22	Historical POL Facility	• former USTs
23	Former Landfill Site	• waste disposal
24	Base Vehicle Washracks (7)	• stormwater
25	Soakage Pits (44)	• soakage pits
26	POL Storage Areas (27)	• POL storage
27	Acid Bath Dilution Chambers (13)	• discharge to soakage pits and sanitary
28	Old Burn Site	• waste disposal
29	Shell / Canex Station	• former USTs
30	Base Training Areas (18)	• metals • PCBs

Table 3 (cont'd)

Area	Description	Nature of Potential Environmental Concern
31	Oil Water Separators (12)	• discharge to sanitary
32	POL Storage Tanks (50)	• AGTs • USTs
33	Heating Oil UST Removal Program for PMQs and other Buildings (185)	• USTs
34	Vandell Property	• vehicle storage
-	Former Medical Depot	• waste disposal
-	Electrical Switching Station	• waste disposal

Notes:

Areas of potential concern identified by Dillon Consulting Ltd. in their Draft Report on "Environmental Site Investigation and Comprehensive Study, CFB Chilliwack, Vedder Crossing", March 1997.

UST = underground storage tank
AGT = above ground storage tank
POL = petroleum, oil and lubricants

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Table 4
Relative Risk of Proposed Land Use to Groundwater

Proposed Land Use Categories		Relative Risk to Groundwater
AGR	Agricultural	Moderate
AP	Airport	Very High
CPR	Community Park and Recreation	Range from Low to High
CSROAD	Comprehensive Suburban Residential Outdoor Recreational Development	Moderate
DD	Downtown Development	Range from High to Very High
ER	Environmental Reserve	Very Low
GC	General Commercial	Range from High to Very High
GCMDR	General Commercial Medium Density Residential	Range from High to Very High
GI	General Industrial	Very High
HSI	Heavy and Special Industrial	Very High
ICU	Institutional and Civic Use	Range from Low to High
IR	Indian Reserve	Range from Low to Very High
LDR	Low Density Residential	Low
MDR	Medium Density Residential	Moderate
HDR	High Density Residential	High
OR	Outdoor Recreation	Moderate
R	Rural	Low
RSC	Regional Shopping Center	Range from High to Very High
RM	Resource Management (Forestry)	Moderate
RR	Rural Residential	Low
SR	Suburban Residential	Low
TC	Thoroughfare Commercial	Range from High to Very High
TCGI	Thoroughfare Commercial Low Density Residential	Range from High to Very High
VRMA	Vedder River Management Area	Range from High to Very High

Notes:

1. Proposed land use categories are defined in District of Chilliwack Official Community Plan, 1990-2001.
2. Relative risk assigned based on ratings provided in U.S. EPA Seminar Publication entitled "Wellhead Protection: A Guide for Small Communities, February, 1993.

TABLE 5

Groundwater Monitoring Plan – List of Chemical Constituents

Physical Tests

Colour
Conductivity
Dissolved Solids
Total Hardness
pH
Turbidity

Dissolved Anions (mg/L)

Alkalinity
Chloride
Fluoride
Sulfate
Nitrate Nitrogen
Nitrite Nitrogen
Nitrate & Nitrite

Metals (mg/L)

Aluminum
Arsenic
Barium
Boron
Cadmium
Calcium
Chromium
Copper
Iron
Lead
Magnesium
Manganese
Mercury
Potassium
Selenium
Sodium
Zinc

Biological Constituents

Fecal & Total Coliform

VOCs

Benzene
Ethylbenzene
Styrene
Toluene
o-Xylene
m,p-Xylene
Bromodichloromethane
Bromoform
Carbon Tetrachloride
Chlorobenzene
Chloroethane
Chloroform
Chloromethane
Dibromochloromethane
1,2-Dichlorobenzene
1,3-Dichlorobenzene
1,4-Dichlorobenzene
1,1-Dichloroethane
1,2-Dichloroethane
1,1-Dichloroethylene
cis-1,2-Dichloropropylene
trans-1,2-Dichloroethylene
Dichloromethane
1,2-Dichloropropane
cis-1,3-Dichloropropylene
trans-1,3-Dichloropropylene
1,1,1,2-Tetrachloroethane
1,1,2,2-Tetrachloroethane
Tetrachloroethylene
1,1,1-Trichloroethane
1,1,2-Trichloroethane
Trichloroethylene
Trichlorofluoromethane
Vinyl Chloride

PAH

Acenaphthylene
Acenaphthene
Acridine
Anthracene
Benzo(a)pyrene
Benzo(a)anthracene
Benzo(b)fluoranthene
Benzo(ghi)perylene
Benzo(k)fluoranthene
Chrysene
Dibenzo(a,h)anthracene
Dibenzo(ah)pyrene
Fluoranthene
Fluorene
Indeno(1,2,3-cd)pyrene
Naphthalene
Phenanthrene
Pyrene

TEH

total extractable hydrocarbons C10-C30

Pesticides and Herbicides

A routine analysis should be conducted for each of the following types of pesticides and herbicides (the list of constituents covered under the routine analysis may vary slightly between laboratories).

Organochloride Pesticides (OCP)
Organophosphate Pesticides (OPP)
Carbonate Pesticides
Sterilants
Acid – Extractable Herbicides

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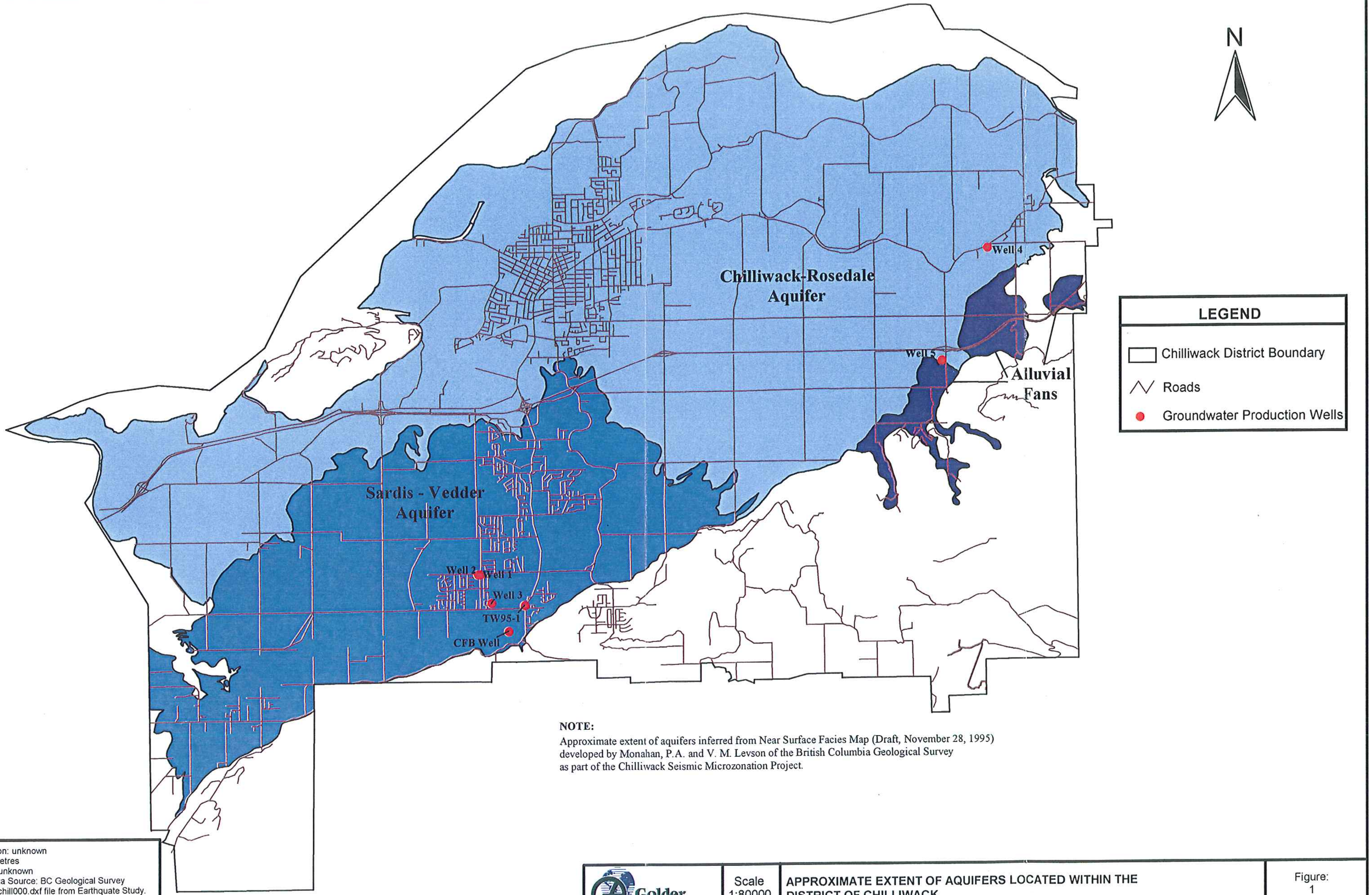


NOTE:
Approximate extent of aquifers inferred from Near Surface Facies Map (Draft, November 28, 1995) developed by Monahan, P.A. and V. M. Levson of the British Columbia Geological Survey as part of the Chilliwack Seismic Microzonation Project.

Project Number: 972-1846 Date: 21 August 1997 Technician: DKM Layout: "Aquifer Layout"

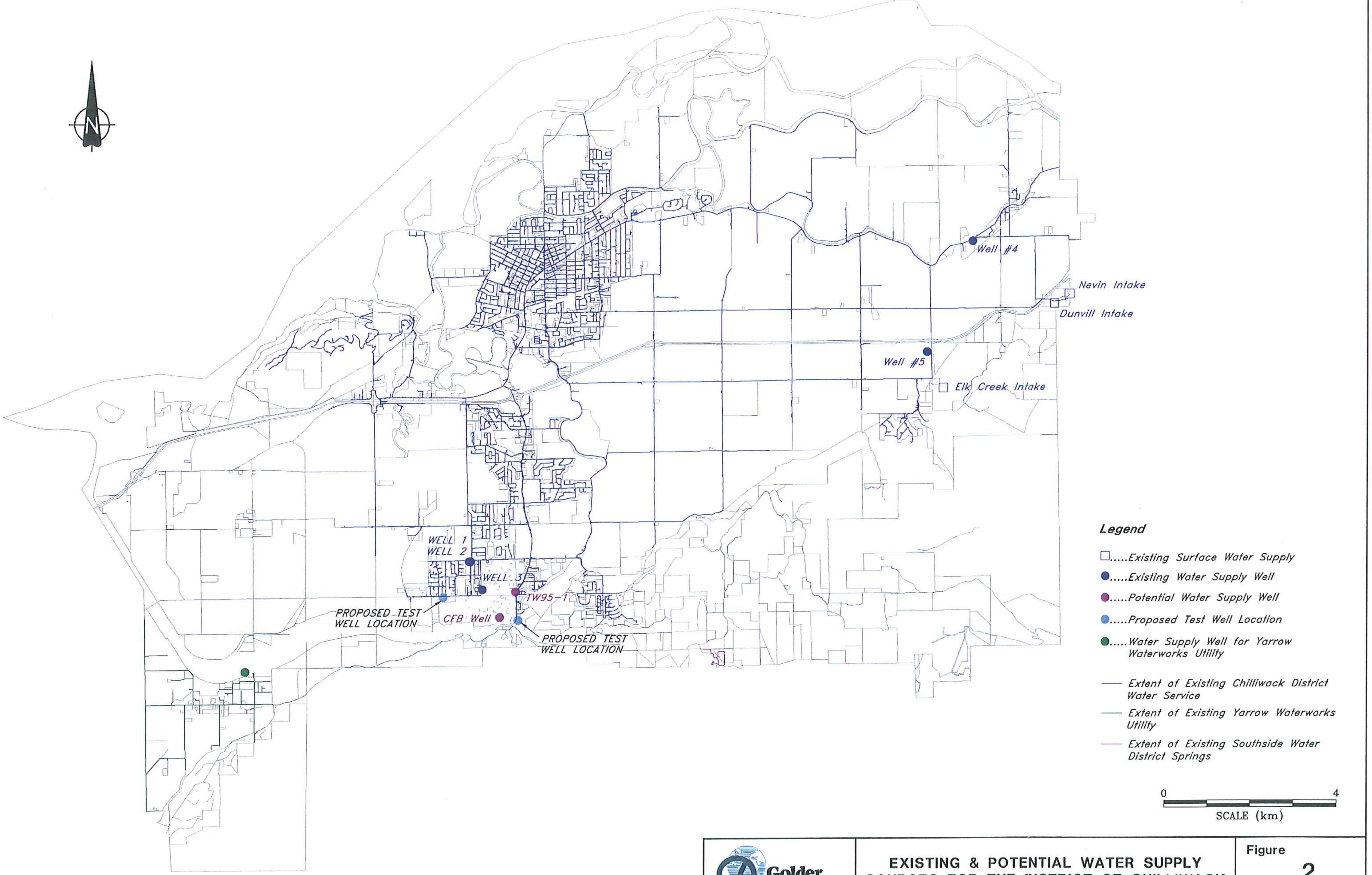
Projection: unknown
Units: metres
Datum: unknown
Map Data Source: BC Geological Survey
Branch chill000.dxf file from Earthquate Study.
Modified by Jill Sacre (Golder Ass. Ltd.).
BCGS Contact: Vic Levson (250) 952-0391

Golder Associates

Scale
1:80,000

APPROXIMATE EXTENT OF AQUIFERS LOCATED WITHIN THE DISTRICT OF CHILLIWACK

Figure:
1



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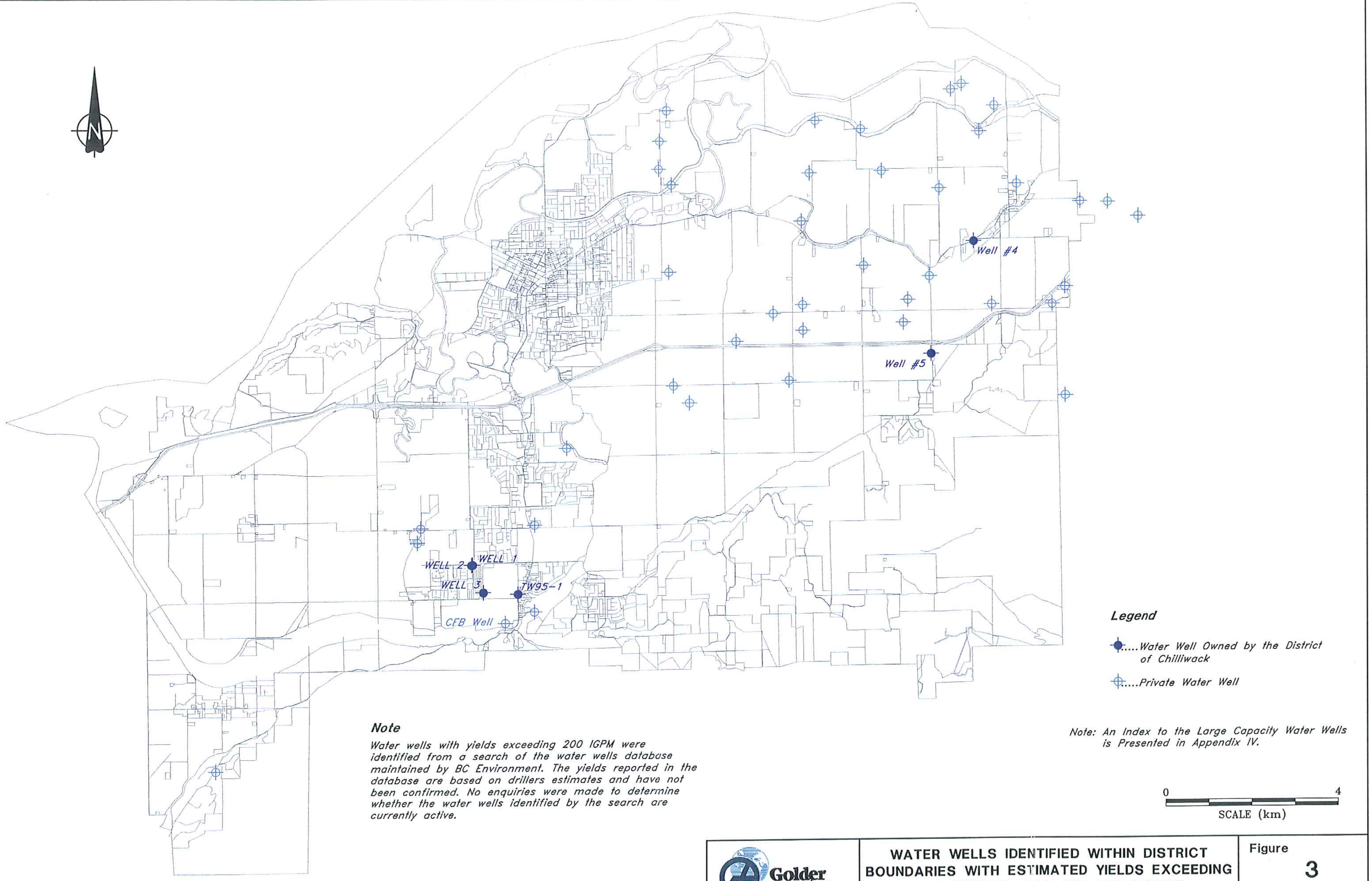
EXISTING & POTENTIAL WATER SUPPLY SOURCES FOR THE DISTRICT OF CHILLIWACK

Figure 2

Project: 972-1846 Drawn: s.s.s Reviewed: J.S. Rev.: 21-AUG-97 J:\972-1846\P1846-3.DWG



Legend

⊕....Water Well Owned by the District of Chilliwack

⊕....Private Water Well

Note: An Index to the Large Capacity Water Wells is Presented in Appendix IV.

Note

Water wells with yields exceeding 200 IGPM were identified from a search of the water wells database maintained by BC Environment. The yields reported in the database are based on drillers estimates and have not been confirmed. No enquiries were made to determine whether the water wells identified by the search are currently active.

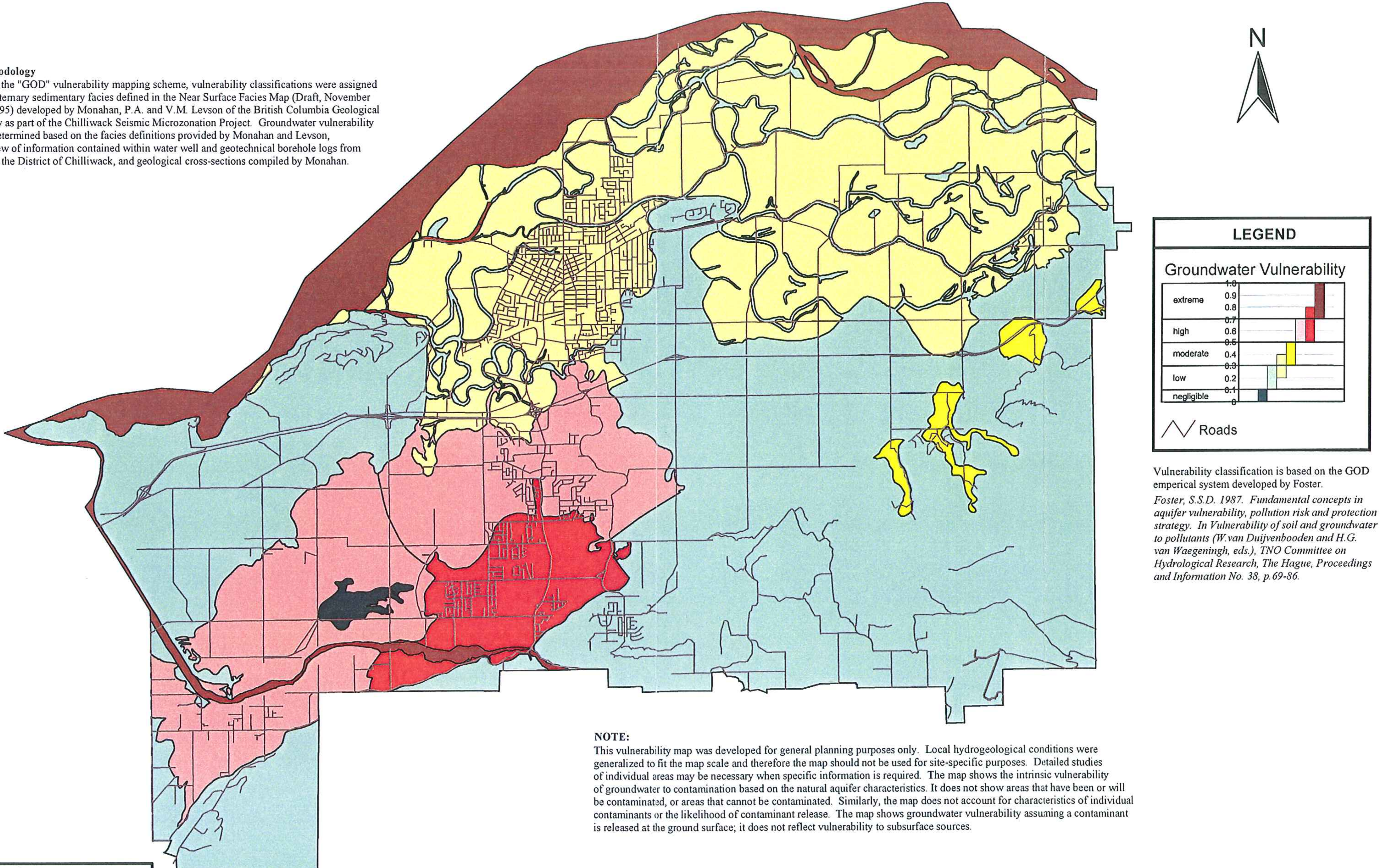
Golder Associates

WATER WELLS IDENTIFIED WITHIN DISTRICT BOUNDARIES WITH ESTIMATED YIELDS EXCEEDING 200 IMPERIAL GALLONS PER MINUTE

Figure 3

Methodology

Using the "GOD" vulnerability mapping scheme, vulnerability classifications were assigned to quaternary sedimentary facies defined in the Near Surface Facies Map (Draft, November 28, 1995) developed by Monahan, P.A. and V.M. Levson of the British Columbia Geological Survey as part of the Chilliwack Seismic Microzonation Project. Groundwater vulnerability was determined based on the facies definitions provided by Monahan and Levson, a review of information contained within water well and geotechnical borehole logs from across the District of Chilliwack, and geological cross-sections compiled by Monahan.



Vulnerability classification is based on the GOD emperical system developed by Foster.

Foster, S.S.D. 1987. Fundamental concepts in aquifer vulnerability, pollution risk and protection strategy. In Vulnerability of soil and groundwater to pollutants (W.van Duijvenbooden and H.G. van Waegeningh, eds.), TNO Committee on Hydrological Research, The Hague, Proceedings and Information No. 38, p.69-86.

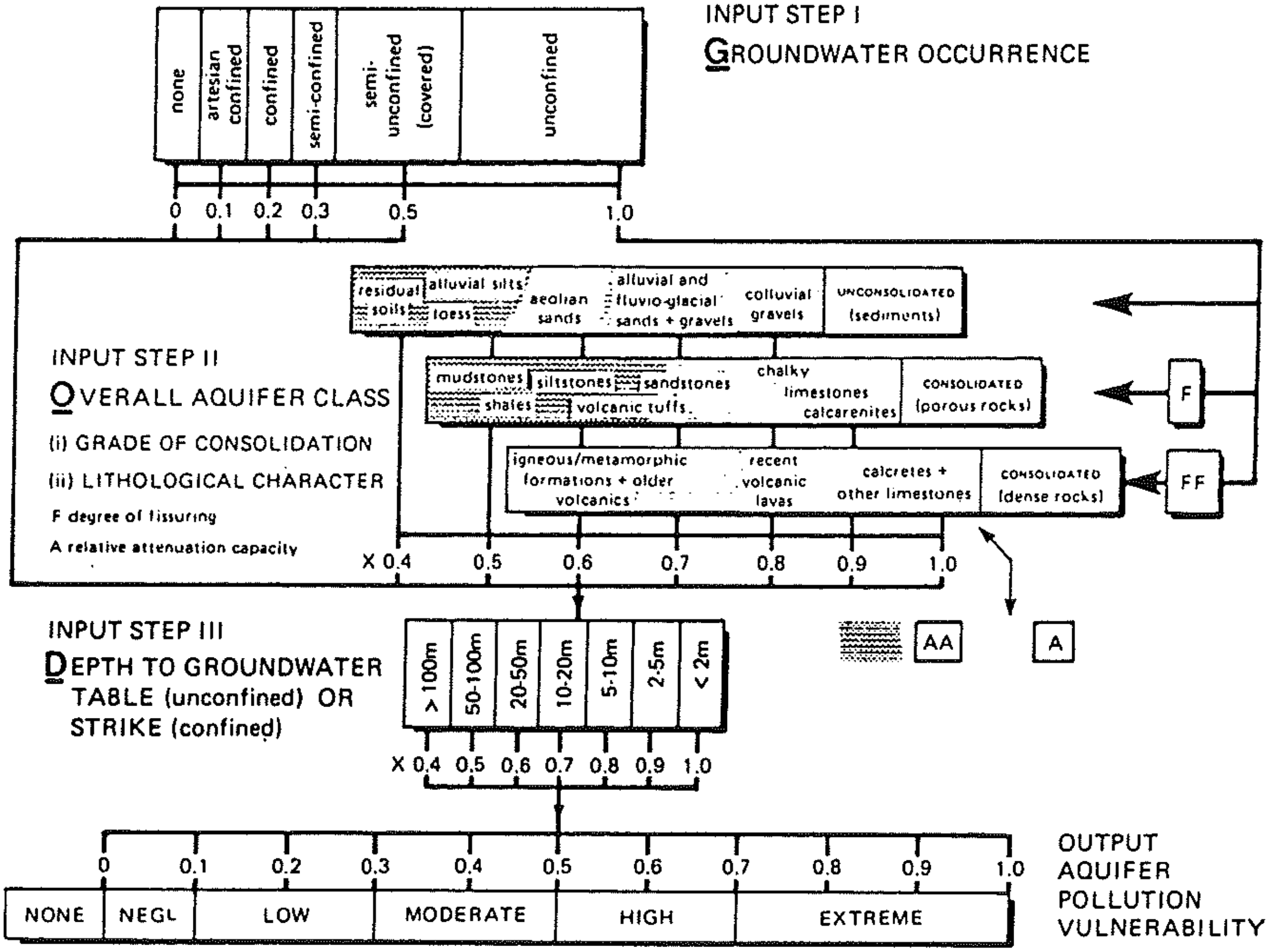
NOTE:

This vulnerability map was developed for general planning purposes only. Local hydrogeological conditions were generalized to fit the map scale and therefore the map should not be used for site-specific purposes. Detailed studies of individual areas may be necessary when specific information is required. The map shows the intrinsic vulnerability of groundwater to contamination based on the natural aquifer characteristics. It does not show areas that have been or will be contaminated, or areas that cannot be contaminated. Similarly, the map does not account for characteristics of individual contaminants or the likelihood of contaminant release. The map shows groundwater vulnerability assuming a contaminant is released at the ground surface; it does not reflect vulnerability to subsurface sources.

Projection: unknown
Units: metres
Datum: unknown
Map Data Source: BC Geological Survey
Branch chill000.dxf file from Earthquate Study.
BCGS Contact: Vic Levson (250) 952-0391

Golder Associates	Scale 1:80,000	GROUNDWATER VULNERABILITY TO CONTAMINATION FROM SURFACE SOURCES DISTRICT OF CHILLIWACK	Figure: 5

Project Number: 972-1846 Date: 21 August 1997 Technician: DKM Layout: "Groundwater Layout"



REFERENCE:

Foster S.S.D. 1987. Fundamental concepts in aquifer vulnerability, pollution risk and protection strategy. <u>In</u> Vulnerability of soil and groundwater to pollutants (W. van Duijvenbooden and H.G. van Waegeningh, eds.), TNO Committee on Hydrological Research, The Hague, Proceedings and Information No. 38, p. 69-86.

Project No. 972-1846 Drawn ~ Reviewed J.S. Date Aug '97

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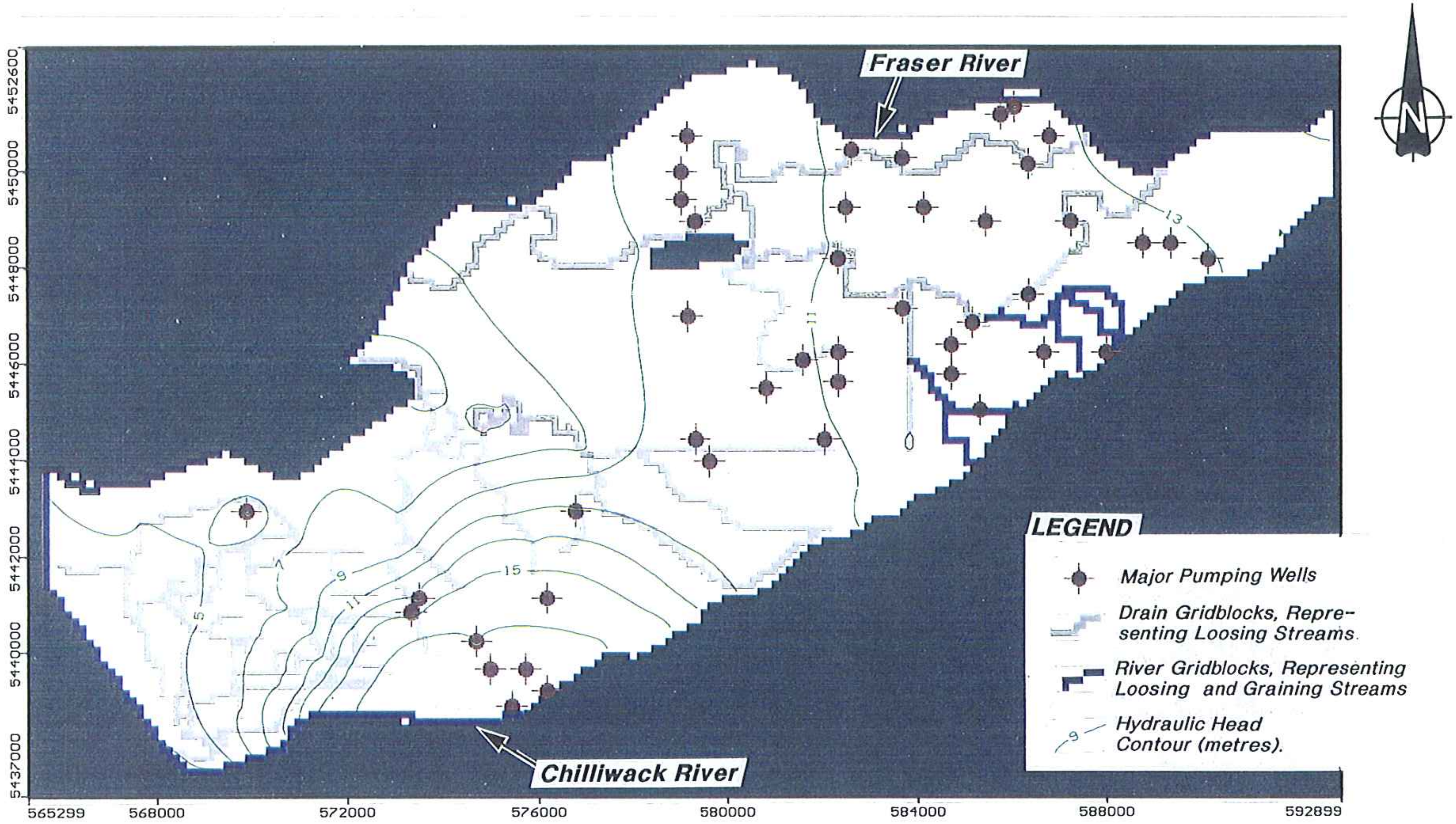
"GOD" VULNERABILITY MAPPING SCHEME

Figure

4



Project No. 972-1846
Drawn W. Z.
Reviewed J.S.
Date Aug '97

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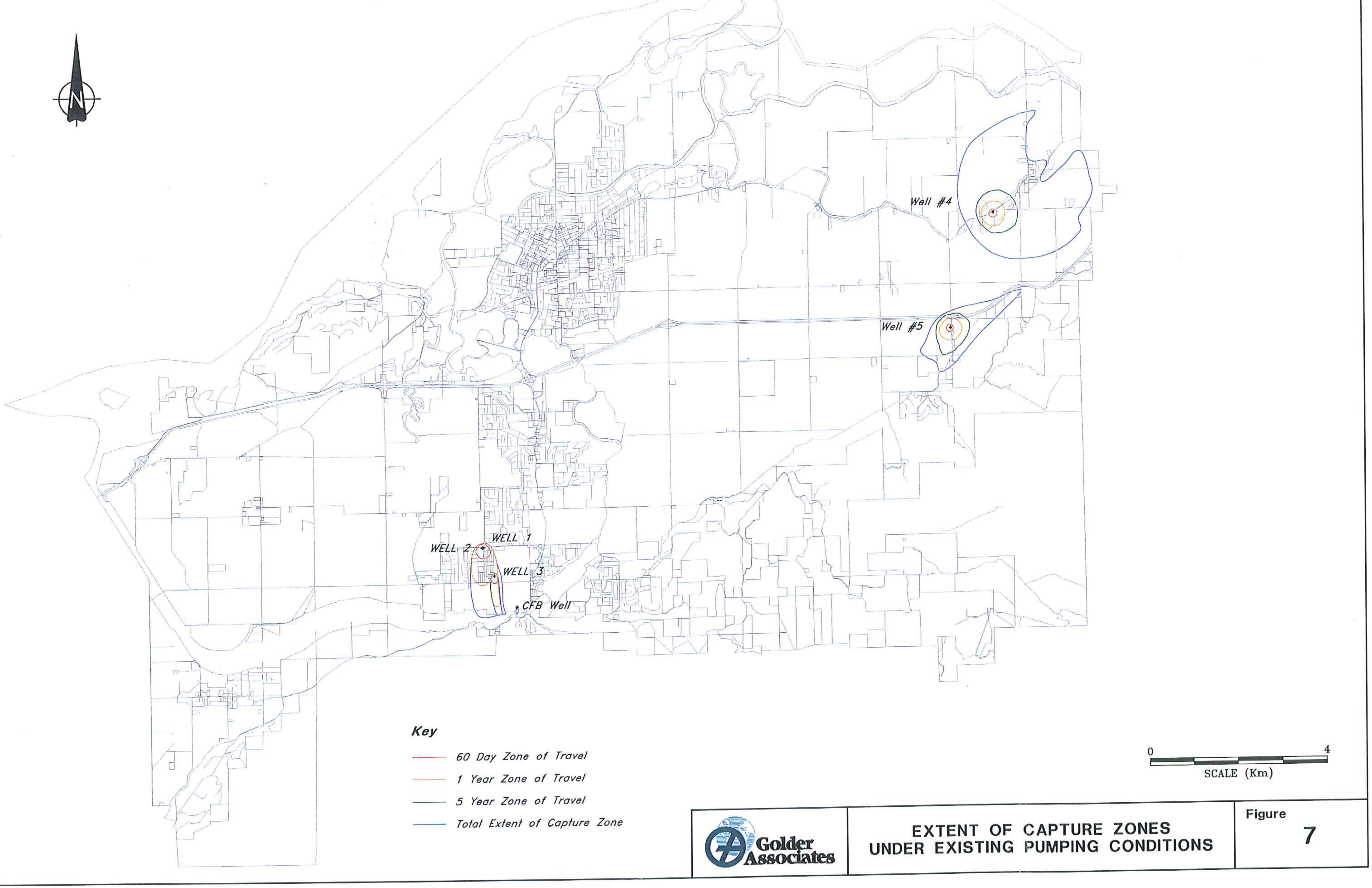
REGIONAL GROUNDWATER FLOW MODEL

Figure

6



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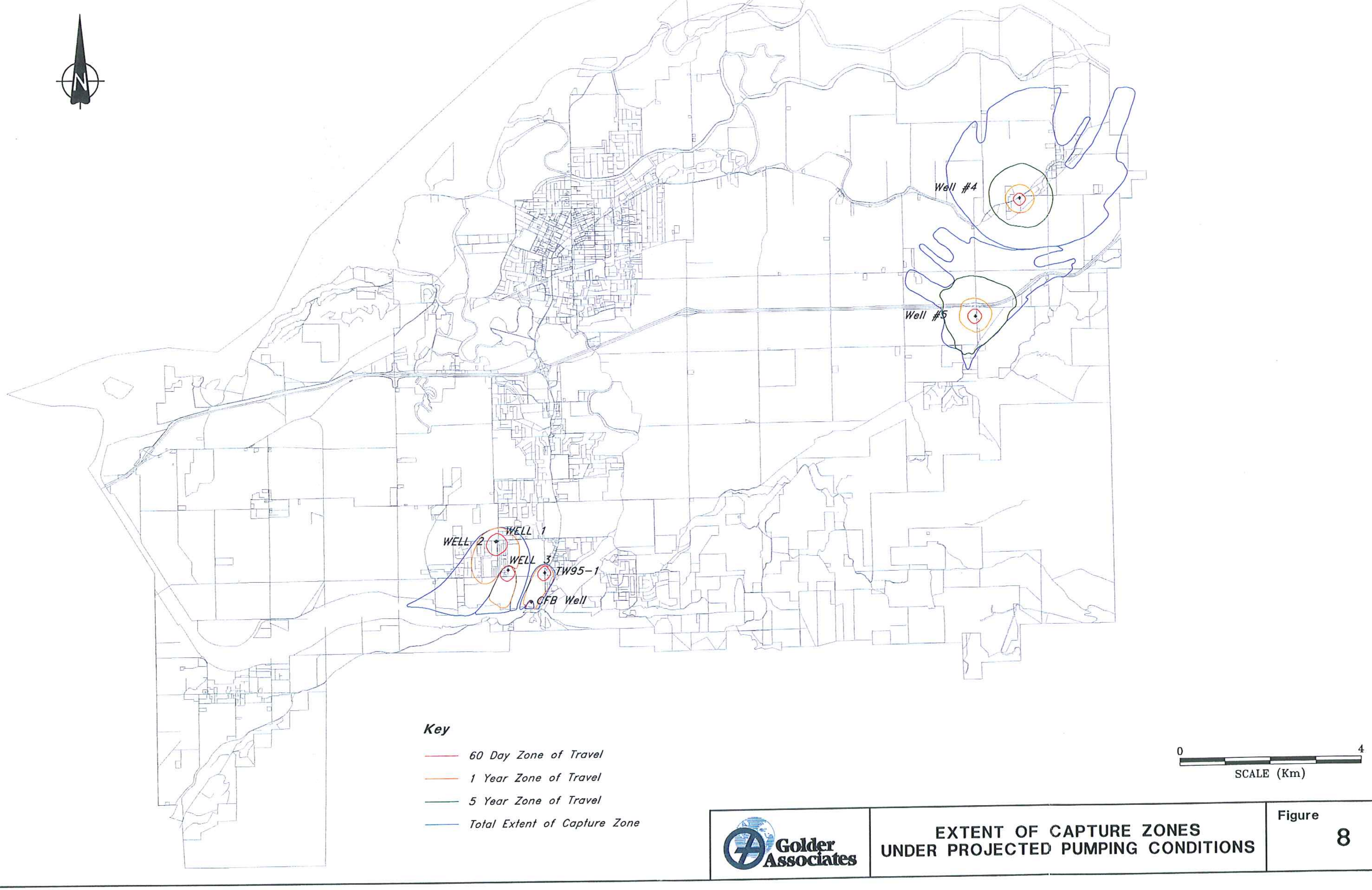
EXTENT OF CAPTURE ZONES UNDER EXISTING PUMPING CONDITIONS

Figure 7

Project: 972-1846 Drawn: s.s.s Reviewed: J.S. Rev.: 21-AUG-97 J:\972-1846\P1846-8.DWG



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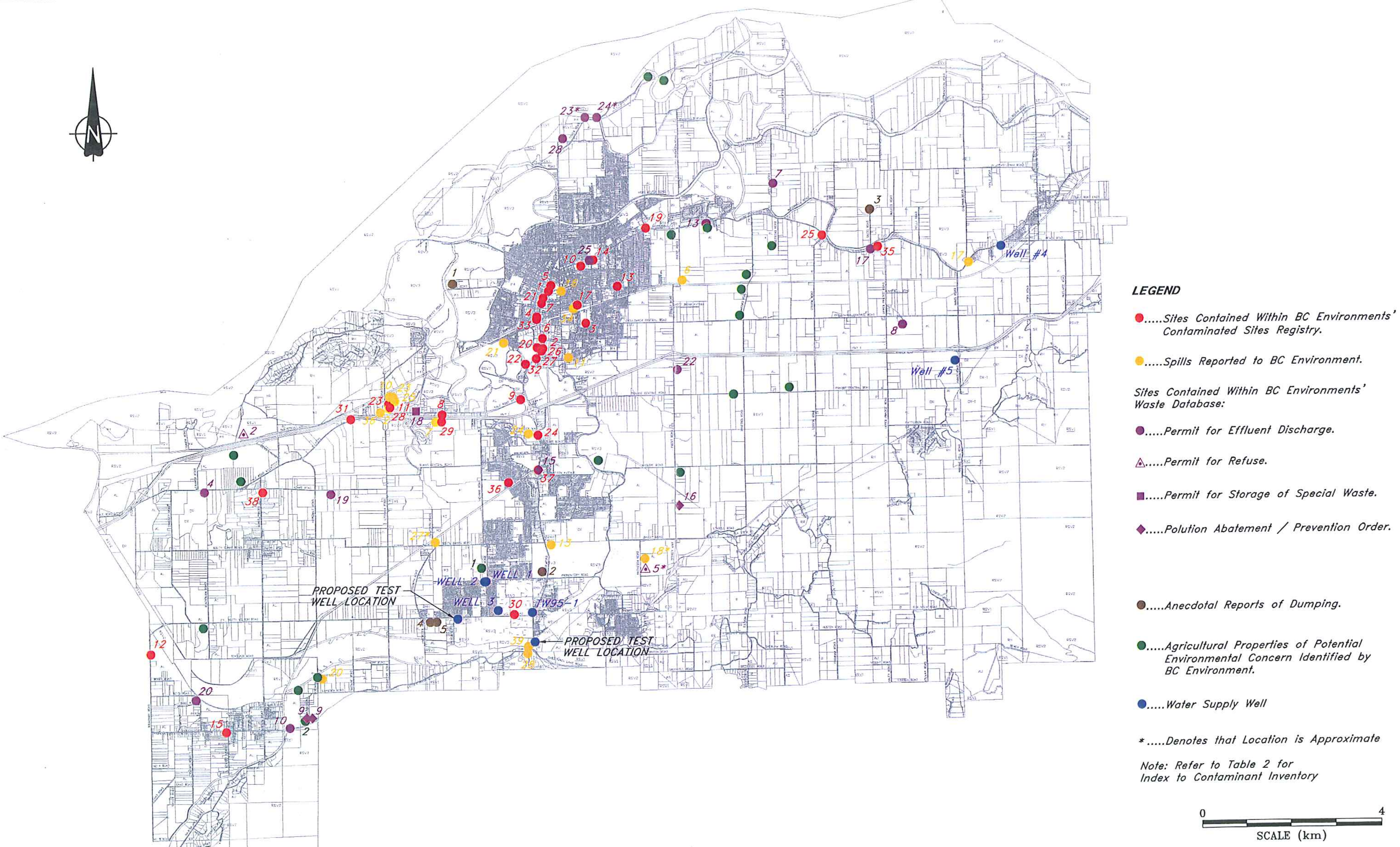
EXTENT OF CAPTURE ZONES UNDER PROJECTED PUMPING CONDITIONS

Figure

8

Project: 972-1846 Drawn: s.s.s Reviewed: J.S. Rev.: 21-AUG-97 J:\972-1846\P1846-9.DWG

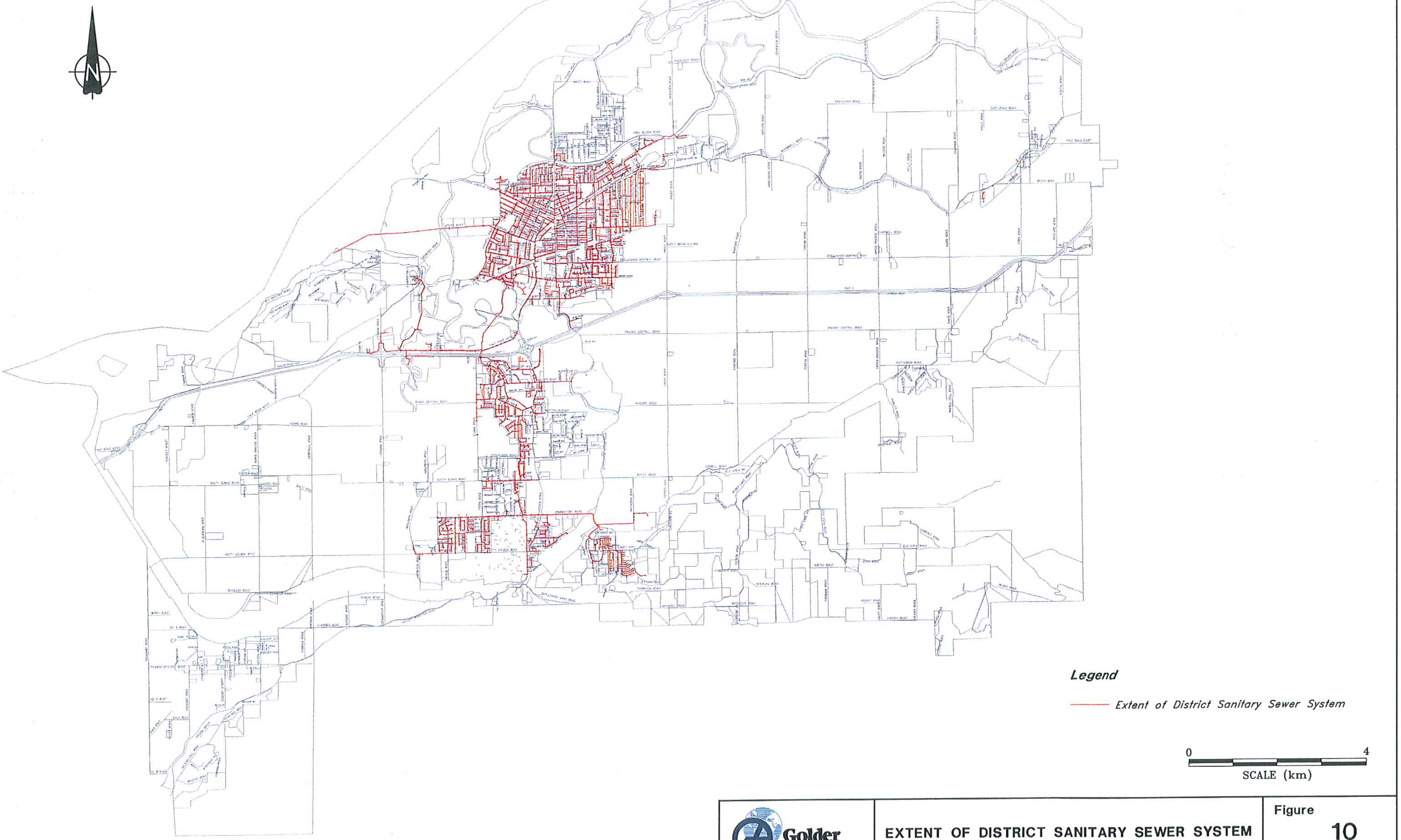
Project: 972-1846 Drawn: s.s.s Reviewed: J.S. Rev.: 21-AUG-97 J:\972-1846\P1846-2.DWG



Golder Associates

RESULTS OF REGIONAL CONTAMINANT INVENTORY

Figure 9



Golder Associates

EXTENT OF DISTRICT SANITARY SEWER SYSTEM

Figure
10

Project: 972–1846 Drawn: s.s.s Reviewed: J.S. Rev.: 21–AUG–97 J:\972–1846\P1846–5.DWG

LEGEND

●.....*Underground Storage Tank ("Area 32")*

●.....*Groundwater Monitoring Well*

●.....*Water Supply Well*

▨.....*Area of Potential Environmental Concern Identified During Environmental Site Investigation Conducted by Dillon Consulting Ltd. 1996–1997*

Notes

1. *Refer to Table 3 for Index to Areas of Concern.*
2. *Areas of Concern Nos. 26,27,30, 31,32,33, & 34 are Not Shown on the CFB Site Plan.*

0 400
SCALE (m)

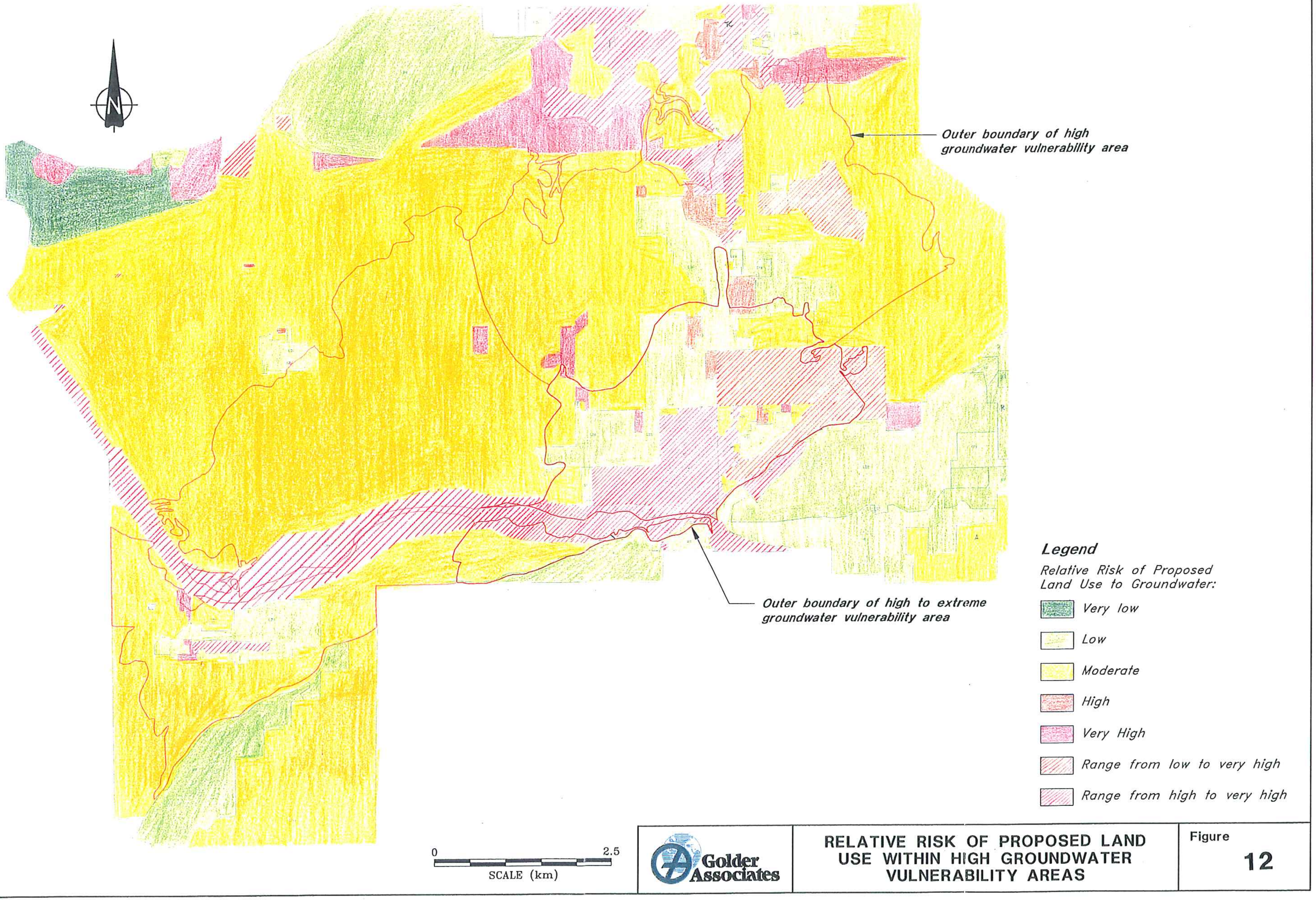
REFERENCE
Base Map of CFB Chilliwack provided by Department of National Defence, Base Construction Engineering Department.

Golder Associates

CFB CHILLIWACK
AREAS OF POTENTIAL ENVIRONMENTAL CONCERN

Figure
11

Project: 972-1846 Drawn: s.s.s Reviewed: J.S. Rev.: 21-AUG-97 J:\972-1846\P1846-1.DWG



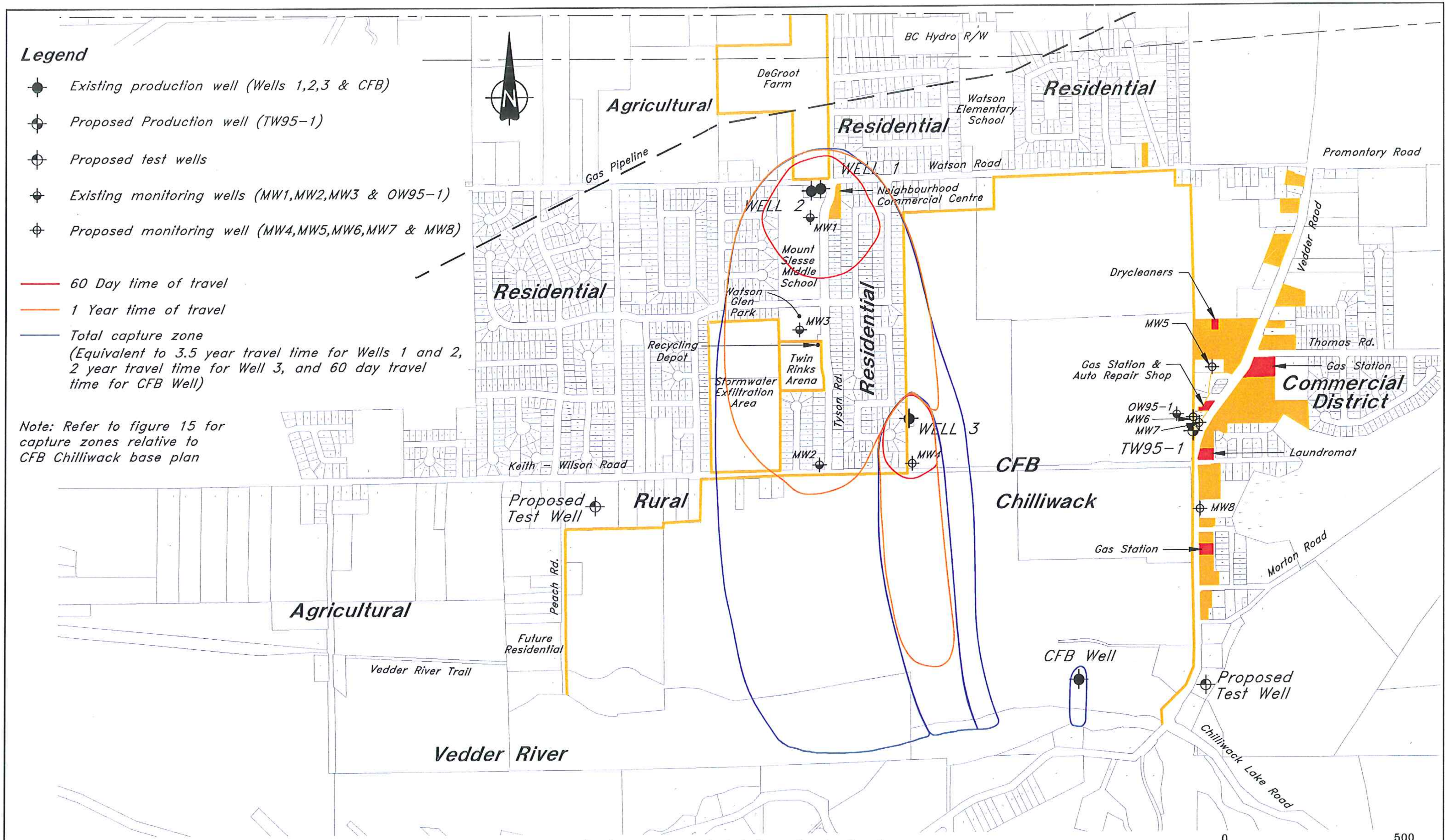
Golder Associates

RELATIVE RISK OF PROPOSED LAND USE WITHIN HIGH GROUNDWATER VULNERABILITY AREAS

Figure

12

Project: 972-1846 Drawn: s.s.s Reviewed: J.S. Rev.: 20-AUG-97 J:\972-1846-P1846-6.DWG



Capture zones calculated on the basis of the following average pumping rates:

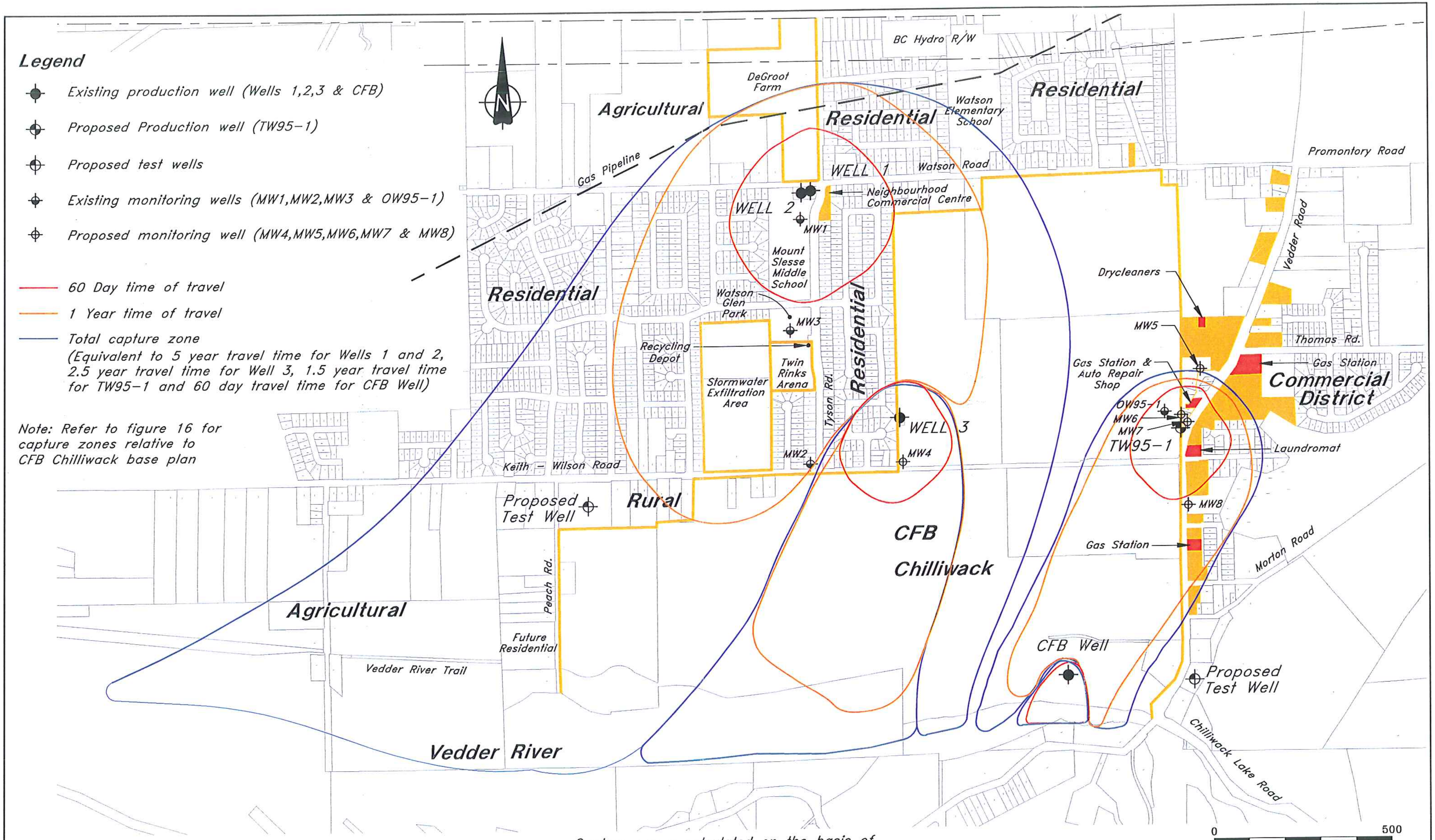
Wells 1 and 2: 79L/s
Well 3: 41L/s
CFB Well: 13L/s

Golder Associates

CAPTURE ZONES FOR WELLS 1, 2, 3 AND THE CFB WELL, UNDER CURRENT PUMPING CONDITIONS

Figure 13

Project: 972-1846 Drawn: s.s.s Reviewed: J.S. Rev.: 21-AUG-97 J:\972-1846\P1846-11.DWG



Capture zones calculated on the basis of the following average pumping rates:

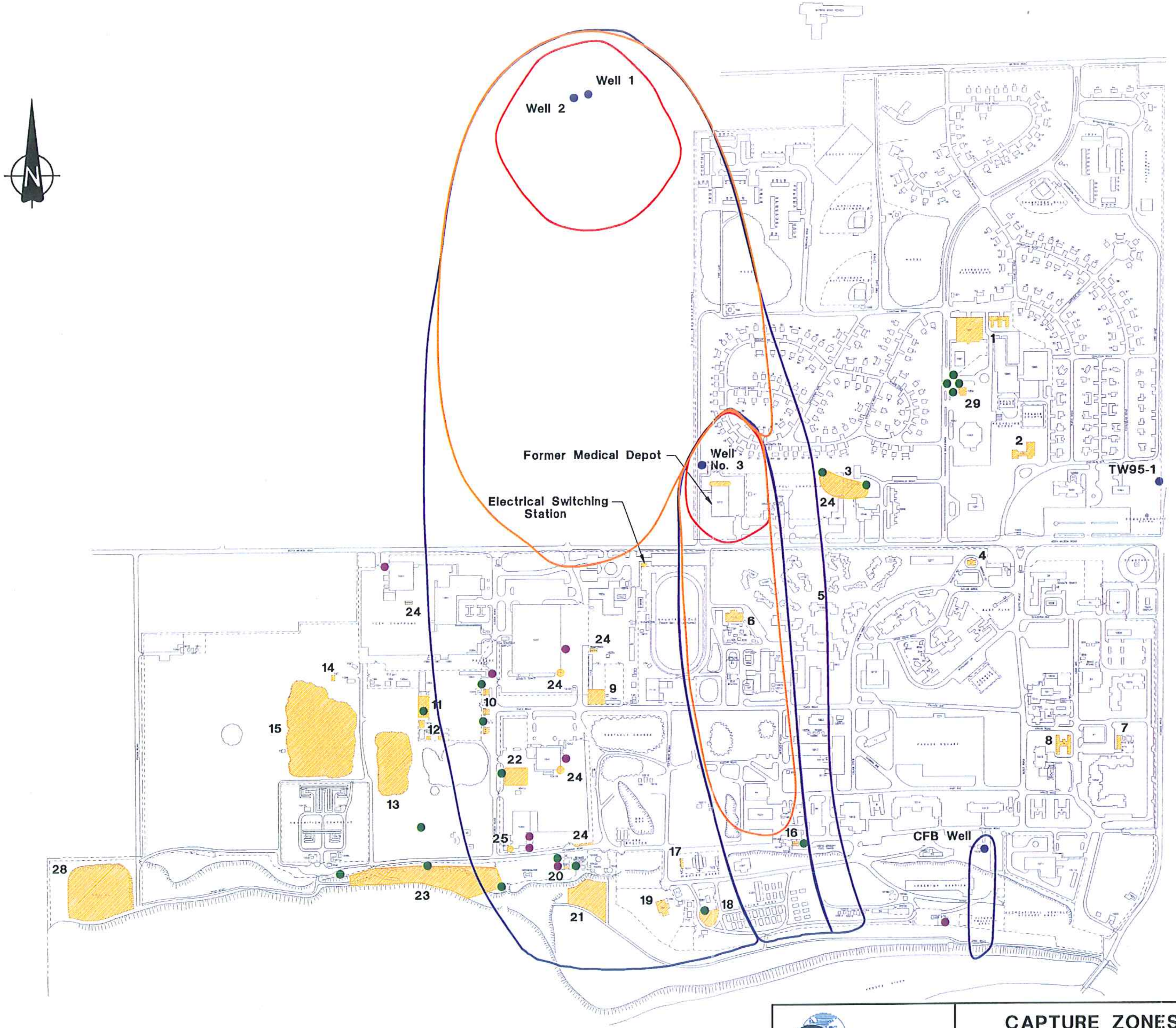
Wells 1 and 2: 150L/s
Well 3: 100L/s
CFB Well: 100L/s
TW95-1: 100L/s

Golder Associates

CAPTURE ZONES FOR WELLS 1, 2 & 3, THE CFB WELL AND TW95-1 UNDER PROJECTED PUMPING CONDITIONS

Figure
14

Project: 972-1846 Drawn: s.s.s Reviewed: J.S. Rev.: 21-AUG-97 J:\972-1846\P1846-10.DWG



LEGEND

●.....*Underground Storage Tank ("Area 32")*

●.....*Groundwater Monitoring Well*

●.....*Water Supply Well*

▨.....*Area of Potential Environmental Concern Identified During Environmental Site Investigation Conducted by Dillon Consulting Ltd. 1996–1997*

— *60 Day Zone of Travel*

— *1 Year Zone of Travel*

— *Total Extent of Capture Zone*

Notes

1. *Refer to Table 3 for Index to Areas of Concern.*
2. *Areas of Concern Nos. 26,27,30, 31,32,33, & 34 are Not Shown on the CFB Site Plan.*

0 400
SCALE (m)

REFERENCE
Base Map of CFB Chilliwack provided by Department of National Defence, Base Construction Engineering Department.

Golder Associates

CAPTURE ZONES UNDER CURRENT PUMPING CONDITIONS RELATIVE TO CFB CHILLIWACK BASE

Figure
15

Project: 972–1846 Drawn: s.s.s Reviewed: J.S. Rev.: 21–AUG–97 J:\972–1846\P1846–16.DWG

Project: 972-1846 Drawn: s.s.s Reviewed: J.S. Rev.: 21-AUG-97 J:\972-1846\P1846-17.DWG

LEGEND

● .....Underground Storage Tank ("Area 32")

● .....Groundwater Monitoring Well

● .....Water Supply Well

▨ .....Area of Potential Environmental Concern Identified During Environmental Site Investigation Conducted by Dillon Consulting Ltd. 1996-1997

— 60 Day Zone of Travel

— 1 Year Zone of Travel

— Total Extent of Capture Zone

Notes

1. Refer to Table 3 for Index to Areas of Concern.
2. Areas of Concern Nos. 26,27,30, 31,32,33, & 34 are Not Shown on the CFB Site Plan.

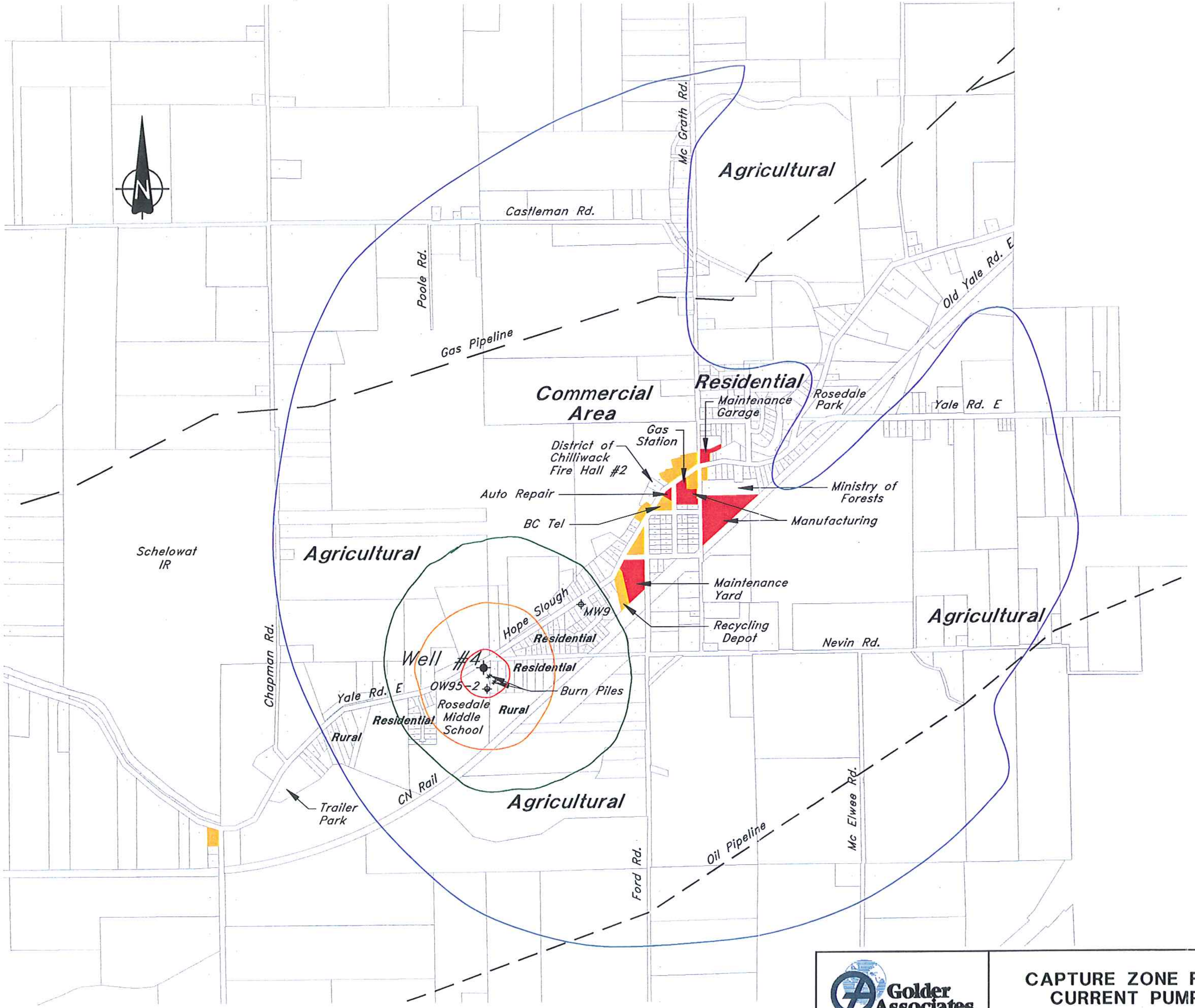
0 400
SCALE (m)

REFERENCE
Base Map of CFB Chilliwack provided by Department of National Defence,
Base Construction Engineering Department.

Golder Associates

CAPTURE ZONES UNDER PROJECTED PUMPING CONDITIONS RELATIVE TO CFB CHILLIWACK BASE

Figure
16



Legend

● Existing production well (Well 4)

⊕ Existing monitoring wells (OW95-2)

⊕ Proposed monitoring well (MW9)

60 Day time of travel

1 Year time of travel

5 Year time of travel

Total capture zone
(Equivalent to 50 year travel time)

Capture zone calculated on the basis of an average pumping rate of 37L/s

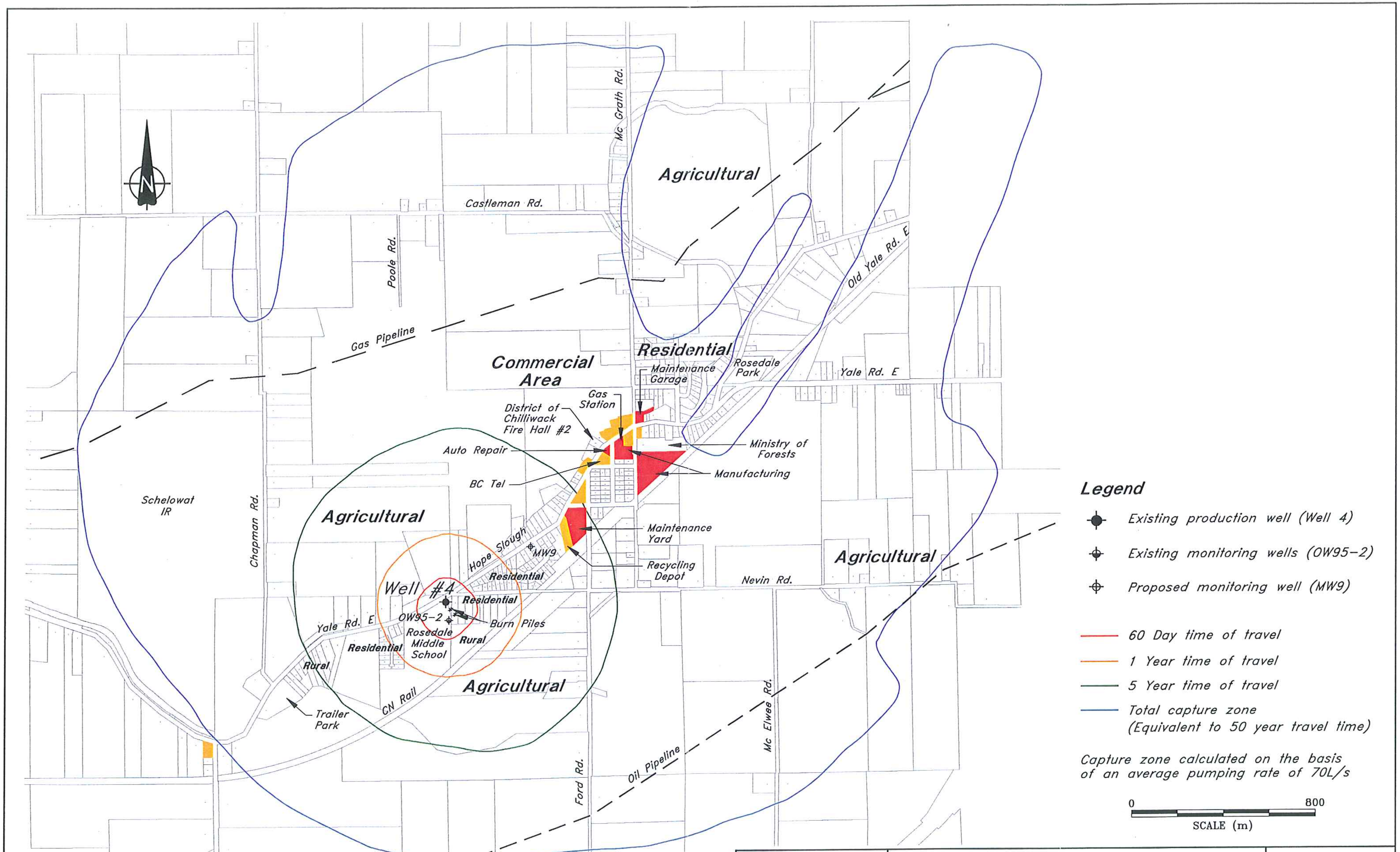
0 800
SCALE (m)

Golder Associates

CAPTURE ZONE FOR WELL 4 UNDER CURRENT PUMPING CONDITIONS

Figure
17

Project: 972-1846 Drawn: s.s.s Reviewed: J.S. Rev.: 21-AUG-97 J:\972-1846\P1846-14.DWG

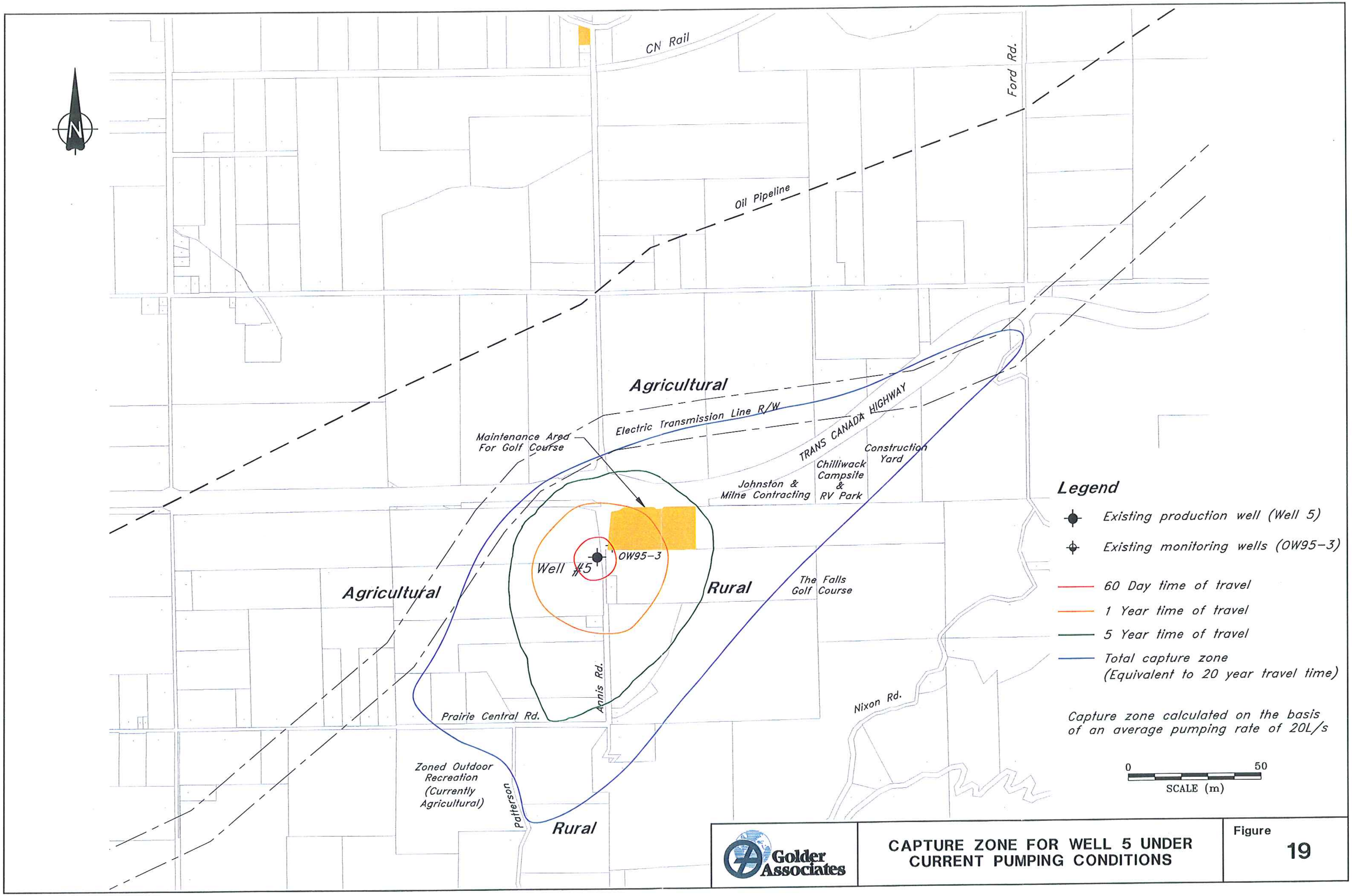


Golder Associates

CAPTURE ZONE FOR WELL 4 UNDER PROJECTED PUMPING CONDITIONS

Figure 18

Project: 972-1846 Drawn: s.s.s Reviewed: J.S. Rev.: 21-AUG-97 J:\972-1846\P1846-12.DWG



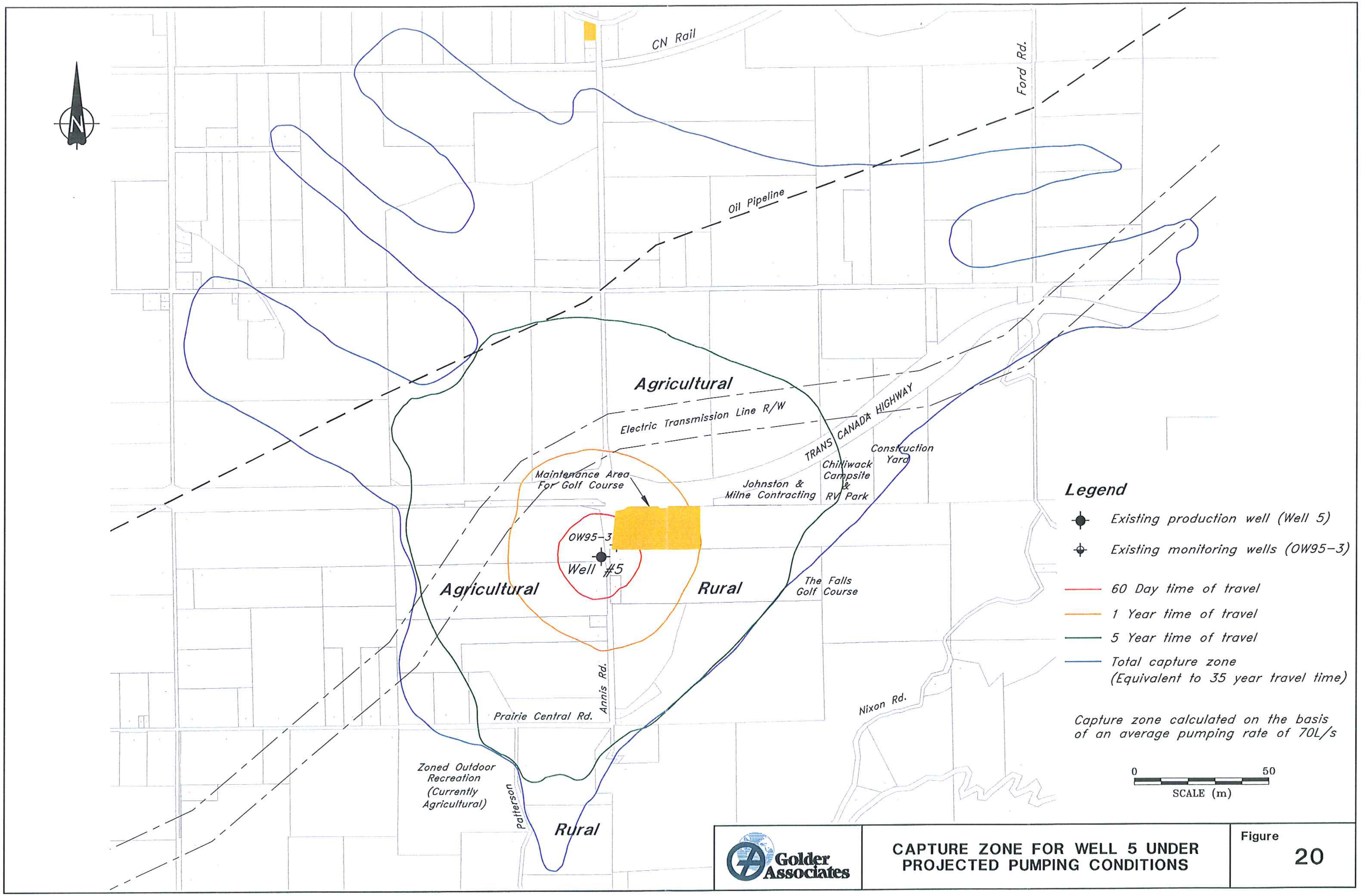
Capture zone calculated on the basis of an average pumping rate of 20L/s

Golder Associates

CAPTURE ZONE FOR WELL 5 UNDER CURRENT PUMPING CONDITIONS

Figure 19

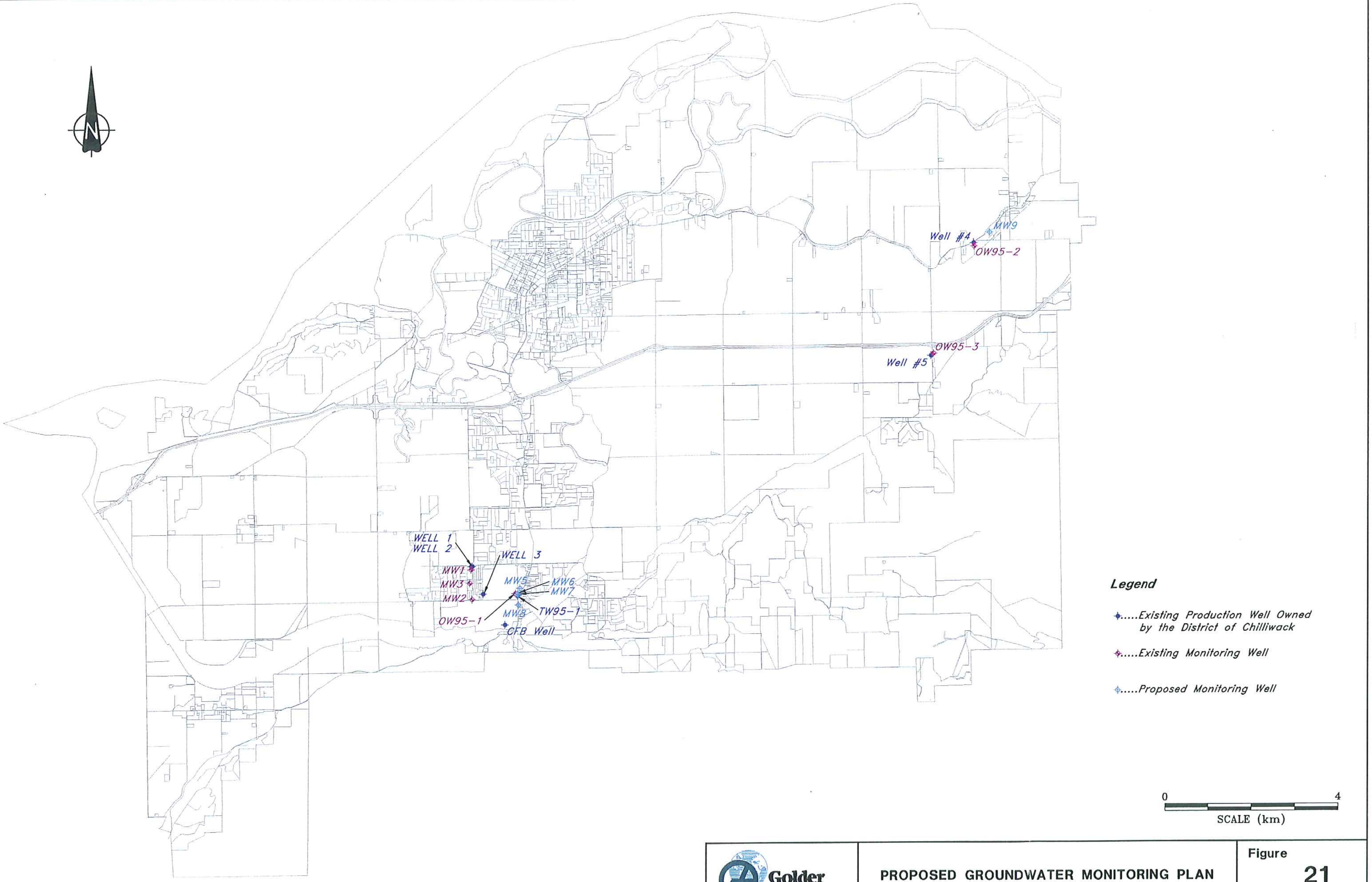
Project: 972-1846 Drawn: s.s.s Reviewed: J.S. Rev.: 21-AUG-97 J:\972-1846\P1846-15.DWG



CAPTURE ZONE FOR WELL 5 UNDER PROJECTED PUMPING CONDITIONS

Figure 20

Project: 972-1846 Drawn: s.s.s Reviewed: J.S. Rev.: 21-AUG-97 J:\972-1846\P1846-13.DWG



Golder Associates

PROPOSED GROUNDWATER MONITORING PLAN

Figure

21

Project: 972-1846 Drawn: s.s.s Reviewed: J.S. Rev.: 21-AUG-97 J:\972-1846\P1846-18.DWG

APPENDIX I

SUMMARY OF WATER PRODUCTION FOR THE DISTRICT OF CHILLIWACK, 1991-1996

Water Production by Source (m3) 1991-1995

1991

Location	Elk Creek	Dunvill/Nevin	Reservoir	Well # 1 & 2	Well # 3	Well # 4	Well # 5	TOTAL
Jan	5,460	252,787	-14,436	88,562	198,024			530,396
Feb	421	205,431	-2,843	84,881	151,508			439,399
Mar	395	257,570	-5,894	62,569	184,118			498,757
Apr	66,807	218,887	-587	87,479	138,584			511,170
May	104,955	245,601	-3,946	96,567	94,879			538,055
Jun	105,840	233,832	-2,205	188,098	1,587			527,152
Jul	156,386	246,512	-3,413	181,645	82,847			663,977
Aug	40,920	237,878	-4,860	151,845	232,307			658,090
Sep	20,174	216,352	1,584	139,546	178,701			556,353
Oct	0	218,369	2,226	132,029	190,420			543,044
Nov	85,432	141,806	-3,864	76,537	186,019			485,929
Dec	170,680	191,529	1,078	97,614	45,161			506,062
1991 TOTAL	**757,472**	**2,666,553**	**-37,161**	**1,387,370**	**1,684,153**			**6,458,385**

1992

DATE	Elk Creek	Dunvill/Nevin	Reservoir	Well # 1 & 2	Well # 3	Well # 4	Well # 5	TOTAL
Jan	77,218	174,129	-1,823	165,390	86,073			500,988
Feb	219,402	0	-15,171	220,147	71,635			496,012
Mar	245,177	75,486	959	202,024	20,563			544,209
Apr	183,982	177,026	-640	139,060	22,173			521,602
May	208,433	229,494	-370	224,511	0			662,067
Jun	146,063	206,700	1,250	174,654	181,811			710,477
Jul	180,462	190,957	1,869	111,280	152,291			636,858
Aug	96,474	196,190	-396	140,201	247,585			680,053
Sep	77,534	152,209	1,204	98,651	227,601			557,199
Oct	164,566	138,309	-3,393	73,540	171,443			544,464
Nov	182,789	162,112	1,484	167,615	14,883			528,883
Dec	175,541	204,354	186	176,349	5,177			561,607
1992 TOTAL	**1,957,640**	**1,906,966**	**-14,842**	**1,893,421**	**1,201,234**			**6,944,419**

1993

DATE	Elk Creek	Dunvill/Nevin	Reservoir	Well # 1 & 2	Well # 3	Well # 4	Well # 5	TOTAL
Jan	111,657	217,091	-1,043	216,351	58,547			602,602
Feb	175,322	182,205	-1,024	158,276	30,722			545,501
Mar	164,811	177,134	-319	167,343	58,147			567,116
Apr	169,151	191,853	1,530	173,281	31,903			567,717
May	114,750	243,848	-3,468	17,520	236,856			609,505
Jun	169,689	198,125	3,699	0	212,547			584,059
Jul	207,753	196,384	-5,242	0	236,309			635,203
Aug	197,068	215,190	1,406	51,743	200,074			665,482
Sep	0	198,287	1,835	117,965	326,753			644,840
Oct	0	151,631	2,510	119,263	309,199			582,603
Nov	0	148,377	970	121,106	270,080			540,533
Dec	0	224,178	818	86,978	244,994			556,968
1993 TOTAL	**1,310,200**	**2,344,304**	**1,670**	**1,229,826**	**2,216,129**			**7,102,129**

1994

DATE	Elk Creek	Dunvill/Nevin	Reservoir	Well # 1 & 2	Well # 3	Well # 4	Well # 5	TOTAL
Jan	0	246,115	-1,985	59,903	242,243			546,276
Feb	2,485	200,588	-1,369	75,434	214,754			491,892
Mar	123,728	143,344	-3,862	125,095	170,238			558,544
Apr	159,141	180,681	-1,702	115,391	118,329			571,839
May	188,623	195,213	-2,377	123,286	191,712			696,457
Jun	158,195	182,098	4,198	121,871	165,968			632,330
Jul	79,880	244,453	-3,848	347,450	157,211			825,146
Aug	0	226,053	-4,102	327,336	231,525			780,812
Sep	0	159,438	-1,208	340,847	127,521			626,598
Oct	0	157,764	-439	338,562	101,383			597,271
Nov	64,185	183,435	-1,983	324,492	4,466			574,595
Dec	112,552	116,384	1,725	320,416	47,523			598,600
1994 TOTAL	**888,790**	**2,235,567**	**-16,951**	**2,620,082**	**1,772,873**			**7,500,359**

1995

DATE	Elk Creek	Dunvill/Nevin	Reservoir	Well # 1 & 2	Well # 3	Well # 4	Well # 5	TOTAL
Jan	200,818	167,492	-4,893	198,657	13,572			575,645
Feb	20,362	143,517	-3,076	351,743	0			512,546
Mar	130,721	209,215	-849	249,618	0			588,705
Apr	209,856	197,149	-634	214,942	0			621,314
May	210,591	229,857	-1,338	350,997	19,972			810,079
Jun	208,939	212,978	1,611	315,914	24,068			763,510
Jul	12,224	253,172	-4,639	518,395	64,521			843,672
Aug	75,140	186,697	-9,903	341,630	107,901			701,465
Sep	0	152,399	-3,535	444,793	107,181			700,838
Oct	85,863	155,533	-6,076	345,050	150			580,520
Nov	40,674	131,771	960	377,292	1,299			551,996
Dec	19631	45426	4832	-9625	500710			560974
1995 TOTAL	**1,214,818**	**2,085,206**	**-27,540**	**3,699,406**	**839,373**			**7,811,263**

1996

DATE	Elk Creek	Dunvill/Nevin	Reservoir	Well # 1 & 2	Well # 3	Well # 4	Well # 5	TOTAL
Jan	94,824	121,602	-9,004	353,511	9			560,943
Feb	120,032	193,463	-5,188	259,328	0			567,635
Mar	169,810	212,456	5,835	222,314	0			610,416
Apr	123,684	202,255	-4,156	287,931	0			609,714
May	143,057	223,195	-355	268,279	0			634,176
Jun	184,020	214,222	3,256	288,661	5,064			695,223
Jul	156,484	241,788	180	435,753	44,819	29,373		908,396
Aug	8,692	190,611	18,931	478,376	30,469	163,930	0	891,008
Sep	0	133,213	9,825	462,705	9,534	0	12,309	627,586
Oct	0	153,702	6,811	363,626	0	0	86,666	610,805
Nov	0	184,291	1,381	316,453	0	0	66,880	569,004
Dec	0	221,671	1,542	344,129	0	0	41,025	608,368
1996 TOTAL	**1,000,604**	**2,292,468**	**29,058**	**4,081,067**	**89,894**	**193,302**	**206,880**	**7,893,273**

APPENDIX II

WATER WELL LOGS FOR WELLS 1, 2, 3, 4, 5, CFB CHILLIWACK WELL AND TW 9-1

Ministry of Environment, Lands and Parks Groundwater Database System
Water Well data by Well Tag Number

92-H-011

Information Disclaimer

Well #1

Well Tag Number 000000027459
Street WATSON & TYSON
Site Area Island
Location Accuracy UTM Code UTM Zone UTM East UTM North
BCGS Number (NAD 27) 092H011111 **Well** 13
Comments
Comments
Construction Method Unknown Constru **Diameter** 8 inches
Construction Date 19730101 **Driller** PACIFIC WATER WELLS **License Number**
Water Utility
Land District NEW WESTMINSTER **District Lot Plan** 26537 **Lot**
Township 23 **Section** 12 **Range**
Indian Reserve
Meridian Block Quarter
Elevation 0 **Well Depth** 100 feet **Water Depth** 27 feet **Bedrock Depth** UNK feet
Well Yield 305 USGM **Artesian Flow** 0
Watershed Well Use Unknown Well Use **Certificate**
Screen from 60 **to** 81 feet
Slot Size 1 0 **Slot Size 2** 0 **Slot Size 3** 0 **Slot Size 4** 0
X 0 **Y** 0 **Z** 0
Old Sequence Number 12 **Old Mapsheet** 6
Lithology Info Flag Y **Pump Test Info Flag**
Groundwater Section File Info Flag
Sieve Info Flag Screen Info Flag
Water Chemistry Info Flag Y **Field Chemistry Info Flag**
Site Info (SEAM) E218086 **Observation Well Number** 0
Other Info Flag Date entered to WELL
From 0 To 28 Ft. Gravel with some silt and sand compact # 946
From 28 To 81 Ft. Looser gravel and sand # 947
From 81 To 90 Ft. Silty gravel and sand # 948
From 90 To 100 Ft. Mostly silt and sand drilled # 949
From 0 To 0 Ft. Open hole # 950

121 53 32
49 6 30

Ministry of Environment, Lands and Parks Groundwater Database System
Water Well data by Well Tag Number

Information Disclaimer
The Province disclaims all responsibility for the accuracy of information provided. Information provided should not be used as a basis for making financial or any other commitments.

Well #2

Well Tag Number 000000036299
Street WATSON & TYSON
Site Area **Island**
Location Accuracy **UTM Code** **UTM Zone** **UTM East** **UTM North**
BCGS Number (NAD 27) 092H011111 **Well** 14
Comments
Comments
Construction Method Unknown Constru **Diameter** 16 inches
Construction Date 19770101 **Driller** PACIFIC WATER WELLS **License Number**
Water Utility
Land District NEW WESTMINSTER **District Lot** **Plan** **Lot**
Township 23 **Section** 12 **Range**
Indian Reserve
Meridian **Block** **Quarter**
Elevation 0 **Well Depth** 98 feet **Water Depth** 27 feet **Bedrock Depth** UNK feet
Well Yield 2000 USGM **Artesian Flow** 0
Watershed **Well Use** Unknown Well Use **Certificate**
Screen from 60 **to** 98 feet
Slot Size 1 0 **Slot Size 2** 0 **Slot Size 3** 0 **Slot Size 4** 0
X 0 **Y** 0 **Z** 0
Old Sequence Number 13 **Old Mapsheet** 6
Lithology Info Flag Y **Pump Test Info Flag** Y
Groundwater Section File Info Flag Y
Sieve Info Flag Y **Screen Info Flag**
Water Chemistry Info Flag Y **Field Chemistry Info Flag**
Site Info (SEAM) E218088 **Observation Well Number** 0
Other Info Flag **Date entered to WELL**
From 0 To 22 Ft. Sand and gravel, compact # 951
From 22 To 33 Ft. Loose sand and gravel # 952
From 33 To 98 Ft. Coarse gravel and sand with a layer of # 953
From 0 To 0 Ft. sand @ 62', a layer of clay at 82', # 954
From 0 To 0 Ft. pieces of wood @ 82' # 955

121 57 [illegible]
[illegible]

Ministry of Environment, Lands and Parks Groundwater Database System
Water Well data by Well Tag Number

Information Disclaimer
The Province disclaims all responsibility for the accuracy of information provided. Information provided should not be used as a basis for making financial or any other commitments.

Well # 3

Well Tag Number 000000018598
Street 45215 KEITH WILSON RD.
Site Area SARDIS Island
Location Accuracy UTM Code UTM Zone UTM East UTM North
BCGS Number (NAD 27) 092H011111 **Well** 16
Comments
Comments
Construction Method Drilled **Diameter** 16 inches
Construction Date 19640101 **Driller** PACIFIC WATER WELLS **License Number**
Water Utility
Land District NEW WESTMINSTER **District Lot Plan** 84566 **Lot**
Township 23 **Section** 12 **Range**
Indian Reserve
Meridian Block Quarter
Elevation 0 **Well Depth** 112 feet **Water Depth** 37 feet **Bedrock Depth** feet
Well Yield 0 **Artesian Flow** 0
Watershed Well Use Community Water Supply **Certificate**
Screen from 0 **to** 0 feet
Slot Size 1 0 **Slot Size 2** 0 **Slot Size 3** 0 **Slot Size 4** 0
X 0 **Y** 0 **Z** 0
Old Sequence Number 0 **Old Mapsheet** 0
Lithology Info Flag Pump Test Info Flag
Groundwater Section File Info Flag
Sieve Info Flag Screen Info Flag
Water Chemistry Info Flag Y **Field Chemistry Info Flag**
Site Info (SEAM) E218088 **Observation Well Number** 0
Other Info Flag Date entered to WELL
From 0 To 45 Ft. FN/CRS silty sand # 1
From 45 To 112 Ft. FN/CRS sand and gravel,cobbles, boulders # 2
From 112 To 114 Ft. FN/CRS sand and gravel, and silt # 3

JH(m)	SPT BLOWS PER 0.15m	OTHER TESTS	SAMPLE TYPE AND NUMBER	SYMBOL	

STARTED: 95/07/07 **FINISHED:**

DRILLING METHODcable tool 20-in

GROUND ELEV(m):

COORDINATES(m):

DESCRIPTION OF MATERIALS

PIEZOMETER DETAILS

VANE FIELD LAB
PEAK ◆ ■
REMOLD ◇ □
▲UC/2
△P.PEN/2
● SPT N

W_P% W% W_L%
× - - - - - ○ - - - - - ×
10 30 50 70 90

SILTY SAND
- brown silty fine sand

2.5m

5.3

SANDY GRAVEL
- medium to coarse, subangular to rounded gravel
- with brown silty sand

6.9

SANDY GRAVEL AND COBBLES
- fine to coarse, subangular to rounded gravel
- with lots of subround to rounded cobbles to 75mm diameter
- and brown/grey silty fine to medium sand becoming less silty with depth
- sand less prevalent and coarser by 11.5 m
- subangular cobbles to 200 mm diameter by 11.5 m
- boulder at 12.8 m
- a little more, slightly finer sand and fewer cobbles by 13 m
- cobbles subangular to rounded 75 mm - 200 mm diameter

14.5

SANDY GRAVEL
- medium to coarse, subrounded to rounded gravel
- with grey fine to coarse sand and no cobbles
- finer gravel (fine to coarse) and less sand by 17.5 m
- with moderate number of cobbles 50 mm - 100 mm diameter
- more cobbles and less sand by 19 m
- fewer cobbles and more sand by 20.5 m (similar to 17.5 m)
- coarser sand (medium) and more cobbles (to 200 mm diameter) by 22 m

25.2

SAND
- fine grey sand
- with a few bits of medium to coarse, subrounded to rounded gravel
- and a couple of 105 mm diameter cobbles
- gravel and cobbles becoming less prevalent with depth

30.5

END OF TEST HOLE
NOTE: Hole logged from bailed samples

FORM: SI01 93/04/12

PROJECT NO.: PW67140103

PROJECT: Dist. of Chilliwack Groundwater Res. Dev.

LOCATION: Chilliwack, B. C.

LOGGED BY: K. Jardine **CHECKED BY:**

SHEET 1 **OF** 1 **HOLE NO.:**TW95-2 (Well 14)

TEST HOLE LOG

SPT BLOWS PER 0.15m | OTHER TESTS | SAMPLE TYPE AND NUMBER | SYMBOL

STARTED: 95/07/04 **FINISHED:**

DRILLING METHOD cable tool, 12-in

GROUND ELEV(m):

COORDINATES(m):

DESCRIPTION OF MATERIALS

PIEZOMETER DETAILS

20 60 100 140 180

VANE FIELD LAB
PEAK ◆ ■
REMOLD ◇ □
▲ UC/2
△ P.PEN/2
● SPT N

W_P% W% W_L%
× - - - - ○ - - - - ×
10 30 50 70 90

SILT
-dark grey-brown silt
- some angular to subangular fine gravel

- gravel slightly coarser and some subrounded cobbles to 50 mm diameter by 4 m

5.3
SAND
- brownish grey fine to medium sand

8.4
SANDY GRAVEL AND COBBLES
- fine to coarse, subangular to rounded gravel and cobbles to 75 mm diameter
- some grey medium sand
- cobbles less prevalent from 10 m to 13 m

14.4
SANDY GRAVEL
- fine to coarse, subangular to subround gravel
- with brown, medium to coarse sand

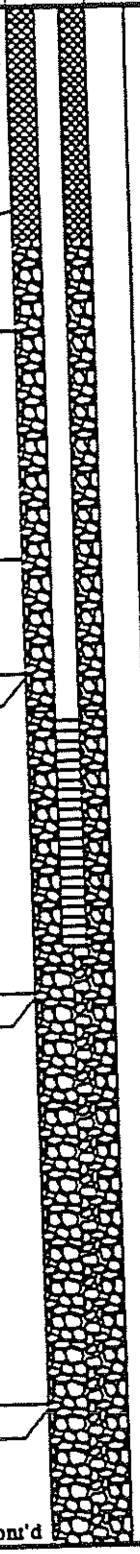
17.3
17.4 SILTY CLAY - light brown silty clay seam
SANDY GRAVEL
- fine to coarse, subangular to rounded gravel
- with some small cobbles becoming slightly larger with depth
- some brown medium to coarse sand

25.6
25.7 SILTY CLAY - light brown silty clay seam
SAND
- brown medium sand, fining downwards
- little bit of subangular to rounded fine to coarse gravel

- gravel disappears by 32 m

36.3
36.4 SILTY CLAY -- grey silty clay seam
SAND
- grey fine sand

...Cont'd



PROJECT NO.: PW67140103

PROJECT: Dist. of Chilliwack Groundwater Res. Dev.

LOCATION: Chilliwack, B. C.

LOGGED BY: K. Jardine **CHECKED BY:**

SHEET 1 **OF** 2 **HOLE NO.:** TW95-3 (Well 5)

FORM: S101 93/04/12

TEST HOLE LOG

STARTED: 95/07/04 **FINISHED:**

DRILLING METHOD: cable tool, 12-in

GROUND ELEV(m):

COORDINATES(m):

H(m)	SPT BLOWS PER 0.15m	OTHER TESTS	SAMPLE TYPE AND NUMBER	SYMBOL	DESCRIPTION OF MATERIALS	PIEZOMETER DETAILS
				▨	41.4	
					END OF TEST HOLE NOTE: hole logged from bailed samples	

20 60 100 140 180

VANE FIELD LAB
PEAK ◆ ■
REMOLD ◇ □
● SPT N
▲UC/2
△P.PEN/2

Wp% W% WL%
× - - - - - ○ - - - - - ×
10 30 50 70 90

FORM: SI01 93/04/12

PROJECT NO.: PW67140103

PROJECT: Dist. of Chilliwack Groundwater Res. Dev.

LOCATION: Chilliwack, B. C.

LOGGED BY: K. Jardine **CHECKED BY:**

SHEET 2 **OF** 2 **HOLE NO.:** TW95-3 (Well 5)

Ministry of Environment, Lands and Parks Groundwater Database System
Water Well data by Well Tag Number

Information Disclaimer
The Province disclaims all responsibility for the accuracy of information provided. Information provided should not be used as a basis for making financial or any other commitments.

CFB
well

Well Tag Number 000000031805
Street CFB CHILLIWACK
Site Area CHILLIWACK **Island**
Location Accuracy UTM Code UTM Zone UTM East UTM North
BCGS Number (NAD 27) 092H011112 **Well** 22
Comments
Comments
Construction Method Drilled **Diameter** 16 inches
Construction Date 19750101 **Driller** Unknown **License Number**
Water Utility
Land District NEW WESTMINSTER **District Lot Plan Lot**
Township 23 **Section** 1 **Range**
Indian Reserve
Meridian Block Quarter
Elevation 0 **Well Depth** 148 feet **Water Depth** 52 feet **Bedrock Depth** UNK feet
Well Yield 900 IGM **Artesian Flow**
Watershed Well Use Unknown **Well Use Certificate**
Screen from 0 **to** 0 feet
Slot Size 1 Slot Size 2 Slot Size 3 Slot Size 4
X 0 **Y** 0 **Z** 0
Old Sequence Number 10 **Old Mapsheet** 6
Lithology Info Flag Y **Pump Test Info Flag** Y
Groundwater Section File Info Flag Y
Sieve Info Flag Screen Info Flag
Water Chemistry Info Flag Y **Field Chemistry Info Flag**
Site Info (SEAM) Observation Well Number 0
Other Info Flag Date entered to WELL
From 0 To 0 Ft. No information # 67

TEST HOLE LOG

H(m)	SPT BLOWS PER 0.15m	OTHER TESTS	SAMPLE TYPE AND NUMBER	SYMBOL		PIEZOMETER	DETAILS

STARTED: 95/06/26 FINISHED:

DRILLING METHOD: cable tool - 12-in

GROUND ELEV(m):

COORDINATES(m):

20 60 100 140 180

VANE	FIELD	LAB	
PEAK	◆	■	▲UC/2
REMOLD	◇	□	△P.PEN/2

● SPT N

W_P% W% W_L%

×------○------×

10 30 50 70 90

DESCRIPTION OF MATERIALS

SAND AND GRAVEL
- grey medium sand to coarse, subangular to angular gravel with subangular to subround cobbles to 90 mm diameter

3.3 - some grey-brown silt

3.6 COBBLES
- layer of subround to rounded cobbles to 150 mm diameter

6.1 SAND

6.4 - medium to coarse sand with some medium gravel
- becoming silty with depth

8.3 - some cobbles to 75 mm diameter from 4.25 m to 5 m

COBBLES

9.5 SILTY GRAVEL
- compacted silty gravel (till)

11.3 COBBLES

SILTY GRAVEL

12.5 - compacted silty gravel

COBBLES

SILTY, SANDY GRAVEL
- fine to medium angular gravel
- with brownish grey silt and sand

18.6

SILTY SAND

19.5 - brownish grey silty fine to medium sand

20.5 - with few bits of medium to coarse gravel

21.0 SILTY GRAVEL AND COBBLES
- fine to coarse subangular to rounded gravel
- subround cobbles to 200 mm diameter

COBBLES

23.8

SILTY, SANDY GRAVEL
- silty fine to coarse subangular to rounded gravel
- with brownish grey silty medium to coarse sand
- few cobbles to 50 mm diameter becoming more prevalent and larger with depth

26.7

SAND AND GRAVEL
- grey fine to medium sand
- and coarse subangular to rounded gravel
- little silt

SANDY GRAVEL AND COBBLES

31.1 - coarse angular to rounded gravel and cobbles to 250 mm diameter
- with grey medium sand

CONSOLIDATED SAND AND GRAVEL
- grey silty fine to coarse sand and fine gravel
- some subrounded to rounded coarse gravel becoming more prevalent with depth

36.0 - virtually no cobbles but cobbles around 50 mm diameter become more prevalent with depth

SANDY GRAVEL
- grey sandy subangular fine to rounded coarse gravel
- cobbles to 60 mm diameter
- sand becoming less prevalent with depth
- gravel coarsening with depth

...Cont'd

FORM: S101 93/04/12

PROJECT NO.: PW67140103

PROJECT: Dist. of Chilliwack Groundwater Res. Dev.

LOCATION: Chilliwack, B. C.

LOGGED BY: K. Jardine CHECKED BY:

SHEET 1 OF 2 HOLE NO.: TW95-1

TEST HOLE LOG

(m)
SPT BLOWS PER 0.15m
OTHER TESTS
SAMPLE TYPE AND NUMBER
SYMBOL

STARTED: 95/06/26 **FINISHED:**

DRILLING METHOD cable tool - 12-in

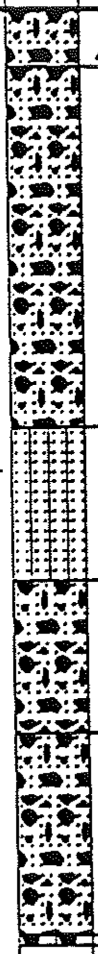
GROUND ELEV(m):

COORDINATES(m):

DESCRIPTION OF MATERIALS

PIEZOMETER DETAILS

20 60 100 140 180
VANE PEAK REMOLD
FIELD ◆ ◇
LAB ■ □
▲UC/2
△P.PEN/2
● SPT N
W_P% W% W_L%
× - - - - - ○ - - - - - ×
10 30 50 70 90



- cobbles to 175 mm diameter at 37.5 m

41.5

GRAVELLY SAND
- grey medium to coarse sand
- with fine to coarse subangular to subround gravel
- few subround cobbles to 50 mm diameter, becoming less prevalent with depth to 47 m

- some subrounded cobbles around 40 mm diameter and 175 mm diameter by 48 m

50.9

SILTY SAND
- grey silty fine sand
- with little coarse sand and fine gravel
- suspect about 40% silt

54.9

SANDY GRAVEL
- fine to coarse subangular to subround gravel
- with grey fine to coarse sand
- subround cobbles to 50 mm diameter increasing to 125 mm by 56 m

58.8

GRAVELLY SAND
- grey medium to coarse sand
- with fine to coarse subround to rounded gravel
- and cobbles to 75 mm diameter increasing in prevalence and size (to 125 mm) with depth

64.0

64.3 CEMENTED SILTY GRAVEL

END OF TEST HOLE
NOTE: hole logged from bailed samples

FORM: S101 93/04/12

PROJECT NO.: PW67140103

PROJECT: Dist. of Chilliwack Groundwater Res. Dev.

LOCATION: Chilliwack, B. C.

LOGGED BY: K. Jardine **CHECKED BY:**

SHEET 2 OF 2 **HOLE NO.:** TW95-1

APPENDIX III

GROUNDWATER QUALITY DATA

received from
Phil Blaker
Apr 21/97

WELL # 1 CANADIAN DRINKING GUIDE AESTHETIC OBJECTIVE IN WATER

	Aesthetic Objective	Units			Feb 27 1996	May 2 1995	Feb 15 1994	Sept 30 1992 *	Jan II 1991	June 14 1990 *
Physical Tests										
pH	6.5-8.5	pH units			7.16	7.67		6.51		8.04
True Color	15	CU			<5	<5		<5		<5
Turbidity	5	NTU			0.22	0.11		0.20		0.22
Total Dissolved Solids	500	mg/L			95	95		95.2		89
Dissolved Anions										
Chloride	250	mg/L			1.2	1.6		1.01		1.00
Sulphate	500	mg/L			8.5	7.7		7.85		7.79
Total Metals										
Iron	0.3	mg/L			<0.03	<0.03		<0.03		<0.03
Manganese	0.05	mg/L			<0.003	<0.003		<0.003		<0.003
Dissolved Metals										
Iron	0.3	mg/L			<0.03	<0.03		<0.03		<0.03
Manganese	0.05	mg/L			<0.003	<0.003		<0.003		<0.003
Sodium	200	mg/L			1.5	1.5		0.90		1.32

WELL # 1 POTABILITY CRITERIA IN WATER

	GCDWQ MAC	UNITS			Feb 27 1996	May 2 1995	Feb 15 1994	Sept 30 1992 *	Jan II 1991	June 14 1990 *
Physical Tests										
Conductivity	-	uS/cm			112	117		112		112
Turbidity	1	NTU			0.22	0.11		0.20		0.22
Hardness	-	mg/L			48	49		34.5		48.5
Dissolved Anions										
Bicarbonate Alkalinity	-	mg/L			59.2	56.4		57.7		51.5
Carbonate Alkalinity	-	mg/L			<0.5	<0.5		0		0
Hydroxide Alkalinity	-	mg/L			<0.5	<0.5		0		0
Fluoride	-	mg/L			<0.05	<0.05		<0.05		<0.05
Nitrate and Nitrite	10	mg/L			0.46	0.5		0.17		0.23
Nitrate	10	mg/L			0.46	0.5		~		~
Nitrite	1	mg/L			<0.002	<0.002		~		~
Sulphate	-	mg/L			8.5	7.7		7.85		7.79
Total Metals										
Magnesium	-	mg/L			1.43	1.49		1.36		1.84
Dissolved Metals										
Calcium	-	mg/L			17.1	17.1		~		16.6
Magnesium	-	mg/L			1.36	1.4		1.03		1.58
Potassium	-	mg/L			0.67	0.57		0.81		0.54
Silicon	-	mg/L			7	7.6		8.09		8.12
Sodium	200	mg/L			1.5	1.5		0.90		1.32

described as Watson Wells*

WELL # 2

CANADIAN DRINKING GUIDE AESTHETIC OBJECTIVE IN WATER

	Aesthetic Objective	Units			Feb 27 1996	May 2 1995	Feb 15 1994	Sept 30 1992 *	Jan II 1991	June 14 1990 *
Physical Tests										
pH	6.5-8.5	pH units			7.25	7.2	7.12	6.51	8.08	8.04
True Color	15	CU			<5	<5	<5	<5	<5	<5
Turbidity	5	NTU			0.12	0.10	0.10	0.20.	0.17	0.22
Total Dissolved Solids	500	mg/L			96	98	95	95.2	96	89
Dissolved Anions										
Chloride	250	mg/L			1.70	1.90	1.40	1.01	0.91	1.00
Sulphate	500	mg/L			8.70	8.00	7.40	7.85	7.89	7.79
Total Metals										
Iron	0.3	mg/L			<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Manganese	0.05	mg/L			<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
Dissolved Metals										
Iron	0.3	mg/L			<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Manganese	0.05	mg/L			<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
Sodium	200	mg/L			1.60	1.70	1.60	0.90	1.06	1.32

WELL # 2

POTABILITY CRITERIA IN WATER

	GCDWQ MAC	UNITS			Feb 27 1996	May 2 1995	Feb 15 1994	Sept 30 1992 *	Jan II 1991	June 14 1990 *
Physical Tests										
Conductivity	-	uS/cm			113	121	112	112	113	112
Turbidity	1	NTU			0.12	0.10	0.10	0.20	0.17	0.22
Hardness	-	mg/L			49	50	48.5	34.5	50.5	48.5
Dissolved Anions										
Bicarbonate Alkalinity	-	mg/L			56.8	57.6	58.2	57.7	64.4	51.5
Carbonate Alkalinity	-	mg/L			<0.5	<0.5	<0.5	0	0	0
Hydroxide Alkalinity	-	mg/L			<0.5	<0.5	<0.5	0	0	0
Fluoride	-	mg/L			<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Nitrate and Nitrite	10	mg/L			0.63	0.6	0.25	0.17	0.29	0.23
Nitrate	10	mg/L			0.63	0.6	0.25	~	~	~
Nitrite	1	mg/L			<0.002	<0.002	<0.002	~	~	~
Sulphate	-	mg/L			8.7	8.0	7.4	7.85	7.89	7.79
Total Metals										
Magnesium	-	mg/L			1.48	1.62	1.59	1.36	1.65	1.84
Dissolved Metals										
Calcium	-	mg/L			17.2	17.6	17.1	~	17.6	16.6
Magnesium	-	mg/L			1.41	1.47	1.4	1.03	1.59	1.58
Potassium	-	mg/L			0.72	0.61	0.71	0.81	0.53	0.54
Silicon	-	mg/L			7.80	7.80	8.15	8.09	7.69	8.12
Sodium	200	mg/L			1.60	1.70	1.60	0.90	1.06	1.32

described as Watson Wells*

WELL # 3 CANADIAN DRINKING GUIDE AESTHETIC OBJECTIVE IN WATER

	Aesthetic Objective	Units			Feb 27 1996	May 2 1995	Feb 15 1994	Sept 30 1992	Jan 11 1991	June 14 1990
Physical Tests										
pH	6.5-8.5	pH units			7.33	7.4	7.24	6.7	7.79	7.83
True Color	15	CU			<5	<5	<5	<5	<5	<5
Turbidity	5	NTU			0.12	0.31	0.25	1.5	0.16	0.22
Total Dissolved Solids	500	mg/L			95	93	98	91.8	96	90
Dissolved Anions										
Chloride	250	mg/L			0.80	1.00	0.98	0.92	1.38	1.00
Sulphate	500	mg/L			7.7	7.6	7.7	7.94	7.31	7.77
Total Metals										
Iron	0.3	mg/L			<0.03	<0.03	<0.03	0.058	<0.03	<0.03
Manganese	0.05	mg/L			<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
Dissolved Metals										
Iron	0.3	mg/L			<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Manganese	0.05	mg/L			<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
Sodium	200	mg/L			1.5	1.4	1.7	1.08	0.91	1.42

WELL # 3 POTABILITY CRITERIA IN WATER

	GCDWQ MAC	UNITS			Feb 27 1996	May 2 1995	Feb 15 1994	Sept 30 1992	Jan 11 1991	June 14 1990
Physical Tests										
Conductivity	-	uS/cm			108	116	110	108	113	112
Turbidity	1	NTU			0.12	0.31	0.25	1.5	0.16	0.22
Hardness	-	mg/L			49	45	50.2	39.7	50.5	49.5
Dissolved Anions										
Bicarbonate Alkalinity	-	mg/L			60.4	57.6	59.2	57.7	59.0	52.5
Carbonate Alkalinity	-	mg/L			<0.5	<0.5	<0.5	0	0	0
Hydroxide Alkalinity	-	mg/L			<0.5	<0.5	<0.5	0	0	0
Fluoride	-	mg/L			<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Nitrate and Nitrite	10	mg/L			0.22	0.29	0.31	0.17	0.27	0.17
Nitrate	10	mg/L			0.22	0.29	0.31	~	~	~
Nitrite	1	mg/L			<0.002	<0.002	<0.002	~	~	~
Sulphate	-	mg/L			7.7	7.6	7.7	7.94	7.31	7.77
Total Metals										
Magnesium	-	mg/L			1.37	1.5	1.5	1.34	1.56	1.76
Dissolved Metals										
Calcium	-	mg/L			17.4	15.8	17.8	~	17.7	17.0
Magnesium	-	mg/L			1.34	1.27	1.38	1.15	1.51	1.59
Potassium	-	mg/L			0.66	0.6	0.69	0.77	0.49	0.53
Silicon	-	mg/L			6.6	6.5	7.4	7.61	6.79	7.69
Sodium	200	mg/L			1.5	1.4	1.7	1.08	0.91	1.42

WELL # 4

CANADIAN DRINKING GUIDE AESTHETIC OBJECTIVE IN WATER

	Aesthetic Objective	Units			Aug 22 1996	July 11 1996	Nov 06 1995	Oct 03 1995	Aug 10 1995	Aug 03 1995	May 31 1995
					CanTest	*CanTest*	*Morwest*	*CanTest*	*ASL*	*CanTest*	*CanTest*
Physical Tests											
pH	6.5-8.5	pH units			7.93	7.72			7.84	8.01	7.9
True Color	15	CU			5	5			<5		
Turbidity	5	NTU			1.6	1.9			2.22	1.3	32
Total Dissolved Solids	500	mg/L			290	300			201	280	265
Dissolved Anions											
Chloride	250	mg/L			1.1	0.8			1.2	0.5	1.0
Sulphate	500	mg/L			35	28			34.2	31	33
Total Metals											
Iron	0.3	mg/L			0.11	0.26	0.23	0.67	0.353	0.06	
Manganese	0.05	mg/L			0.077	0.079	0.08	0.082	0.09	0.091	
Dissolved Metals											
Iron	0.3	mg/L			<0.03	<0.03	0.19	<0.03		<0.03	0.05
Manganese	0.05	mg/L			0.073	0.071	0.08	0.071		0.083	0.039
Sodium	200	mg/L			3.99	3.8		3.84		5.1	5.1

WELL # 4

POTABILITY CRITERIA IN WATER

	GCDWQ MAC	UNITS			Aug 22 1996	July 11 1996	Nov 06 1995	Oct 03 1995	Aug 10 1995	Aug 03 1995	May 31 1995
Physical Tests											
Conductivity	-	uS/cm			349	356			346	333	326
Turbidity	1	NTU			1.6	1.9			2.22	1.3	32
Hardness	-	mg/L			153	158			179	159	176
Dissolved Anions											
Bicarbonate Alkalinity	-	mg/L			248	187			149(t)		
Carbonate Alkalinity	-	mg/L			<0.5	<0.5				<0.5	<0.5
Hydroxide Alkalinity	-	mg/L			<0.5	<0.5					
Fluoride	-	mg/L			0.24	<0.05			0.12	0.13	0.09
Nitrate and Nitrite	10	mg/L			<0.05	<0.05					
Nitrate	10	mg/L			<0.05	<0.05			0.042	<0.05	<0.05
Nitrite	1	mg/L			<0.002	<0.002			0.001	0.006	<0.002
Sulphate	-	mg/L			35	28			34.2	31	33
Microbiological Analysis											
Total Coliform (confirmed)	not det.	Col/100ml			<1	<1		<1			
Fecal Coliform	not det.	Col/100ml			<1	<1		<1			
Total Metals											
Magnesium	-	mg/L			6.16	6.17			6.87		
Dissolved Metals											
Calcium	-	mg/L			51.9	53.8		53.1	60.3(t)	53.6	60
Magnesium	-	mg/L			5.6	5.74		5.8	6.87(t)	5.97	6.32
Potassium	-	mg/L			0.87	0.81		0.82	1.37(t)	1.03	1.35
Silicon	-	mg/L			13.9	13.8		14.1	17.7*	15.4	10.5
Sodium	200	mg/L			3.99	3.8		3.84	6.19(t)	5.1	5.1

* see results for explanation

(t) denotes total metals

WELL # 5 CANADIAN DRINKING GUIDE AESTHETIC OBJECTIVE IN WATER

	Aesthetic Objective	Units		Nov/9/96	Sept 17 1996	Aug 29 1996	Nov 06 1995	Oct 24 1995	Oct 03 1996	July 27 1995	May 31 1995
Physical Tests					*ConTest*	*ConTest*	*Morwest*	*ConTest*	*ConTest*	*ASL*	*ConTest*
pH	6.5-8.5	pH units				7.68				7.55	7.96
True Color	15	CU				<5				8.6	
Turbidity	5	NTU				0.16				0.3	0.81
Total Dissolved Solids	500	mg/L				260				195	270
Dissolved Anions											
Chloride	250	mg/L				1.7				2.4	1.3
Sulphate	500	mg/L				39				43	50
Total Metals											
Iron	0.3	mg/L		.20	0.07	<0.03	1.6	<0.03	29	0.035	
Manganese	0.05	mg/L		.027	0.024	<0.003	0.01	<0.003	0.21	0.005	
Dissolved Metals											
Iron	0.3	mg/L			<0.03	<0.03	0.18	<0.03	<0.03	<0.03	<0.03
Manganese	0.05	mg/L			0.024	<0.003	0.01	<0.003	0.022	0.022	<0.003
Sodium	200	mg/L				3.66		3.7	7.91	7.91	4.9

WELL # 5 POTABILITY CRITERIA IN WATER

	GCDWQ MAC	UNITS			Sept 17 1996	Aug 29 1996	Nov 06 1995	Oct 24 1995	Oct 03 1996	July 27 1995	May 31 1995
Physical Tests											
Conductivity	-	uS/cm				324				340	334
Turbidity	1	NTU				0.16				0.3	0.81
Hardness	-	mg/L				144				168	176
Dissolved Anions											
Bicarbonate Alkalinity	-	mg/L				152				138(t)	
Carbonate Alkalinity	-	mg/L				<0.5					<0.5
Hydroxide Alkalinity	-	mg/L				<0.5					
Fluoride	-	mg/L				<0.05				0.07	0.07
Nitrate and Nitrite	10	mg/L				0.48					
Nitrate	10	mg/L				0.48				0.401	0.5
Nitrite	1	mg/L				<0.002				0.002	<0.002
Sulphate	-	mg/L				39				43	50
Microbiological Analysis											
Total Coliform (confirmed)	not det.	Col/100ml				<1		<1			
Fecal Coliform	not det.	Col/100ml				<1		<1			
Total Metals											
Magnesium	-	mg/L				3.31				4.25	
Dissolved Metals											
Calcium	-	mg/L				52.3		52.6	51.9	60.3(t)	62.6
Magnesium	-	mg/L				3.31		3.36	3.2	4.25(t)	4.81
Potassium	-	mg/L				0.58		0.38	0.54	0.75(t)	0.59
Silicon	-	mg/L				9.4		8.7	8.63	11.5*	10.5
Sodium	200	mg/L				3.66		3.7	7.91	4.68(t)	4.9

* see results for explanation

(t) denotes total metals

quanta trace laboratories inc.

401 - 3700 Gilmore Way, Burnaby, British Columbia, Canada V5G 4M1
Telephone: (604) 438-5226 Fax: (604) 436-0565

To: PHH ENVIRONMENTAL LTD.
100-10551 Shellbridge Way
Richmond, B.C.
V6X 2W9

Workorder: 29417
Received : 13-Aug-96
Completed: 22-Aug-96

Attn: Janeen Griffith

CFB Chilliwack Well

Re: CFB Chilliwack

ANALYSIS
OF
WATER SAMPLES

METHODOLOGY

The numbers next to the parameter names refer to limits from the Canadian Drinking Water 1989 Maximum Guidelines. All units are in milligrams per litre (mg/L=ppm) unless otherwise stated. The symbol "<" means less than the value shown, and ">" means greater than the value shown. Limits in () including pH indicate Aesthetic Objectives. Hardness >500 usually considered unacceptable. Analytical methodology is in accordance with procedures described in publications of the American Public Health Association, B.C. Ministry of the Environment and Environment Canada - Conservation and Protection.

ACCREDITATION

Quanta Trace is accredited by the Canadian Association of Environmental Analytical Laboratories (CAEAL), by the Standards Council of Canada (SCC). and by Washington State Department of Ecology for specific tests. Quanta Trace is also registered in the B.C. Ministry of Environment Laboratory Registration Program.

To: PHH ENVIRONMENTAL LTD.

W/O: 29417 Page 1

Sample type identification	water Chilcotin Well	water CFB Chilliwack Well	water CFB Chilliwack Rafting Area	water CFB Chilliwack Rafting Area	water CFB Chill wack OPSE
Lab Reference #	29417-001	29417-002	29417-003A	29417-003B	29417-004
CALC. TOTAL DISSOLVED SOLIDS					
calculated (500)	986.	83.5	114.	118.	273.
PHYSICAL PARAMETERS					
conduct. uS/cm	1500	135.	175.	175.	400.
turbid NTU 1/(5)	< 1.	< 1.	9.0	9.0	8.0
colour TCU (15)	5.	< 5.	< 5.	< 5.	5.
pH (6.5-8.5)	8.5	7.8	7.0	7.0	8.7
CHEMICAL PARAMETERS - ANIONS					
total alk. CaCO3	688	55	77	79	220
fluoride 1.5	< 1.	< 1.	< 1.	< 1.	< 1.
chloride (250)	37	1.3	4.7	5.1	1.2
nitrite N 1	< 1.	< 0.5	< 0.5	< 0.5	< 0.5
nitrate N 10	2	0.2	0.1	< 0.1	< 0.1
sulfate (500)	130	8	7	8	3
TOTAL HARDNESS					
as CaCO3 [500]	330.	63.9	79.6	82.8	24.3

To: PHH ENVIRONMENTAL LTD.

W/O: 29417 Page 2

Sample type		water	water	water	water	water
Identification		Chilcotin Well	CFB Chilliwack Well	CFB Chilliwack Rafting Area	CFB Chilliwack Rafting Area	CFB Chilliwack OPSEE
Lab Reference #		29417-001	29417-002	29417-003A	29417-003B	29417-004
CHEMICAL PARAMETERS - CATIONS						
calcium	Ca	17.6	22.5	22.1	23.0	6.55
magnesium	Mg	69.4	1.87	4.99	5.18	0.63
Sodium	(200)	242.	3.23	6.83	6.81	109.
potassium	K	44.	0.8	0.3	0.1	0.4
CHEMICAL PARAMETERS - METALS						
aluminum	0.2	< 0.01	< 0.01	< 0.01	< 0.01	0.80
arsenic	0.025	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
barium	1	0.0444	0.0116	0.0151	0.0156	0.149
boron	5	0.02	< 0.01	0.01	0.01	1.22
~~cadmium~~	~~0.005~~	~~< 0.0005~~	~~< 0.0005~~	~~< 0.0005~~	~~< 0.0005~~	~~< 0.0005~~
chromium	0.05	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
copper	(1)	0.021	0.046	0.010	0.010	0.062
iron	(0.3)	0.115	0.022	2.11	2.21	0.469
lead	0.01	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
manganese	(0.05)	0.0537	0.0014	0.0721	0.0758	0.0121
mercury	0.001	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002
selenium	0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
uranium	0.1	< 0.06	< 0.06	< 0.06	< 0.06	< 0.06
zinc	(5)	0.004	0.004	2.00	2.09	0.035
antimony	Sb	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
beryllium	Be	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002
bismuth	Bi	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
cobalt	Co	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
lithium	Li	0.003	< 0.002	< 0.002	< 0.002	0.052
molybdenum	Mo	0.007	< 0.005	< 0.005	< 0.005	< 0.005
nickel	Ni	0.003	< 0.002	< 0.002	< 0.002	< 0.002
phosphorus	P	0.20	< 0.06	0.13	< 0.06	< 0.06
silicon	Si	11.1	4.67	7.93	8.25	7.28
silver	Ag	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
strontium	Sr	0.267	0.084	0.278	0.287	0.253
sulfur	S	40.1	2.5	2.5	2.5	1.3
thorium	Th	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
tin	Sn	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
titanium	Ti	< 0.001	< 0.001	< 0.001	< 0.001	0.016
vanadium	V	0.017	0.004	0.003	0.004	0.004
zirconium	Zr	0.001	< 0.001	< 0.001	< 0.001	0.001

t results are for internal use only. Quanta Trace liability is limited to the testing fee paid. Approved:

APPENDIX IV

WATER WELLS WITH YIELDS ABOVE 200 IGPM

Apendix IV
Water Wells with Yields above 200 GPM
District of Chilliwack

Description	Easting	Northing	Capacity	Estimate Rate (cms)	L/s	Source or Criteria
Well 1	574674	5440285	50 L/s	0.079	79	1991-96 averages
Well 2	574648	5440279	160L/s	combined with #1	combined with #1	1991-96 averages
Well 3	574923	5439647	160L/s	0.041	41	1991-96 averages
Well 4	586268	5447649	75 L/s	0.037	37	1996 averages
Well 5	585283	5445076	75 L/s	0.02	20	1996 averages
TW95-1	575720	5439580	130 L/s	0	0	estimated by Klohn
CFB Chilliwack	575430	5438940	63.5 L/s	0.013	13	estimated by District
plant (BCE well 187)	573400	5440800	500 GPM ?	0.0157725	15.7725	50%
plant	573475	5441130	505 GPM	0.015930225	15.930225	50%
east of Sardis pond	576835	5442967	300 GPM	0.0018927	1.8927	10%
irrigation ?	579678	5443995	500 GPM	0.0031545	3.1545	10%
irrigation ?	579307	5444391	400 GPM	0.0025236	2.5236	10%
irrigation ?	581980	5444492	300 GPM	0.0018927	1.8927	10%
irrigation ?	581613	5446031	600 GPM	0.0037854	3.7854	10%
irrigation ?	580751	5445401	300 GPM	0.0018927	1.8927	10%
irrigation ?	582307	5445640	250 GPM	0.00157725	1.57725	10%
irrigation ?	582299	5446226	700 USGM	0.0044163	4.4163	10%
irrigation ?	583723	5447113	300 GPM	0.0018927	1.8927	10%
irrigation ?	584640	5445800	700 GPM	0.0044163	4.4163	10%
irrigation ?	584748	5446325	700 GPM	0.0044163	4.4163	10%
irrigation ?	585246	5446858	250 GPM	0.00157725	1.57725	10%
irrigation ?	582270	5448141	500 GPM	0.0031545	3.1545	10%
domestic ?	585478	5448869	1000 GPM	0.006309	6.309	10%
school N of Rosedale ?	587258	5448959	500 GPM	0.00788625	7.88625	20%
irrigation ?	579200	5447000	200 GPM	0.0012618	1.2618	10%
irrigation ?	578980	5450000	200 GPM	0.0012618	1.2618	10%
irrigation ?	579260	5449000	200 GPM	0.0012618	1.2618	10%
irrigation ?	578960	5449360	500 GPM	0.0031545	3.1545	10%
irrigation ?	586680	5446200	500 GPM	0.0031545	3.1545	10%
irrigation ?	582460	5449240	200 GPM	0.0012618	1.2618	10%
irrigation ?	582600	5450440	800 GPM	0.0050472	5.0472	10%
irrigation ?	583660	5450240	200 GPM	0.0012618	1.2618	10%
irrigation ?	584140	5449280	300 GPM	0.0018927	1.8927	10%
irrigation ?	586400	5450160	250 GPM	0.00157725	1.57725	10%
camp ?	588400	5444100	200 GPM	0.0012618	1.2618	10%
camp ?	588400	5446600	200 GPM	0.0012618	1.2618	10%
camp ?	588100	5446200	200 GPM	0.0012618	1.2618	10%
trailer park ?(BCE 165)	588740	5448550	300 GPM	0.0018927	1.8927	10%
domestic	590100	5448200	200 GPM	0.0012618	1.2618	10%
domestic	569840	4442860	500 GPM	0.0031545	3.1545	10%
tree nursery/domestic	579150	5450700	200 GPM	0.0012618	1.2618	10%
industry by Fraser	586000	5451250	1000 GPM	0.031545	31.545	50%
industry by Fraser	586750	5450750	450 GPM	0.01419525	14.19525	50%
industry by Fraser	585750	5451125	250 GPM	0.00788625	7.88625	50%
domestic	568750	5435550	360 GPM	0.00227124	2.27124	10%

NOTE: table was partially based on data supplied by Emerson Groundwater Consultants

APPENDIX V

SUMMARY OF POTENTIAL ENVIRONMENTAL CONCERNS AT CFB CHILLIWACK

Refer to Final Report on "Environmental Site Investigation and Comprehensive Study, CFB Chilliwack, Vedder Crossing", currently under preparation by Dillon Consulting Ltd.

APPENDIX VI

SAMPLES OF INFORMATION MATERIAL ON GROUNDWATER PROTECTION

Public Information Brochure Published by the City of Renton, Washington

Potential contaminants include the following:

- Poisons
- Pesticides, herbicides
- Paints, solvents
- Gasoline, fuel oils
- Lubricating oils, grease
- Antifreeze
- Household cleaners
- Detergents
- Acids, salts
- Sewage, manure
- Other hazardous wastes

Good ecological housekeeping dictates proper disposal of these and other contaminants regardless of where you live. However, if you are in the sensitive areas indicated on the map, it is particularly important to the City of Renton's water supply that you:

DO NOT

- Dump or spill these materials on the ground or into sumps.
- Dump or spill these materials into gutters, storm sewers, open drainage courses, or ponds.
- Dispose of these materials in your septic tank or garbage can.
- Allow fuel or heating oil tanks to leak onto or into the ground.

DO

- Dispose of these materials only at approved collection points.
- Call King County Health Dept. (228-2620 or 587-2722) for information about collection points.
- Call City of Renton (235-2631) to report spills of these materials or to request additional information.
- Check your home heating oil or fuel tanks and pipelines for leaks.
- Check your septic tank and drainfield for proper operation.

PROTECT YOUR WATER SUPPLY

City of Renton
Water Department

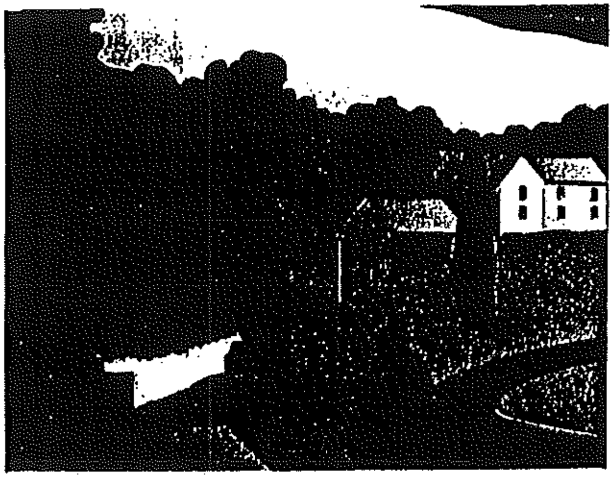
What You Can Do In Your Community

By working together, the people in a community can plan and create effective systems for managing hazardous wastes. Many communities have begun to sponsor Household Hazardous Waste collection days. These efforts have helped reduce the amount of hazardous waste in many areas while heightening public awareness of the problem.

Successful collection efforts in many cities have helped officials protect their community's wastewater treatment plants and groundwater from hazardous waste contamination. Many communities were able to collect large quantities of hazardous materials on the strength of a one or two day effort. If your community has a program for disposal of hazardous wastes, please support it.

We also encourage you to:

- ☐ Learn as much as you can about your wastewater treatment plant and share that information with your family and friends. Clean water is for everyone.
- ☐ Learn about your community's landfill system and special programs for the disposal of hazardous wastes.
- ☐ Contact you area's hazardous waste agency. They can provide information on companies which are licensed to handle hazardous wastes along with possible funding sources for such efforts.



What The Future Holds

Billions of dollars have been spent to clean up our lakes and streams. Many millions more have been spent to build and maintain adequate sanitary landfills.

Modern wastewater treatment plants have led us all to expect clean water and a safe environment as a part of our everyday lives. We now realize that we can not just discharge our wastes into a stream or bury hazardous waste without thinking about their impact on the environment.

For that reason and others, household hazardous waste collection has really caught on. Communities throughout the world have begun to develop programs to deal with household wastes. These efforts need to be expanded to include as many areas as possible.

For details on what you can do, contact your local wastewater treatment facility, Department of Public Works or Sanitation District. Or, for further information you can contact:

Water Environment Federation
601 Wythe Street
Alexandria, VA 22314-1994

Phone: U.S.A. 1 (703) 684-2400

Direct inquires to the Public Affairs department.

HOUSEHOLD HAZARDOUS WASTE

2

[illegible]

Are You Poisoning Your Water?

If someone were to drop a poisonous substance into your community's water supply, the act would be considered a serious crime and a state of public emergency would be declared.

But when you dump a can of paint thinner down the drain or throw out an old car battery with the trash, no alarms are sounded, no news flashes are issued. Yet, the impact on your water resources could be just as disastrous.

That is not a far-fetched statement. The average household contains between three and ten gallons or ten to forty liters of materials that are hazardous to human health or to the natural environment. Collectively, these materials can poison our water if they are not stored carefully and disposed of properly.

What Is A Hazardous Material?

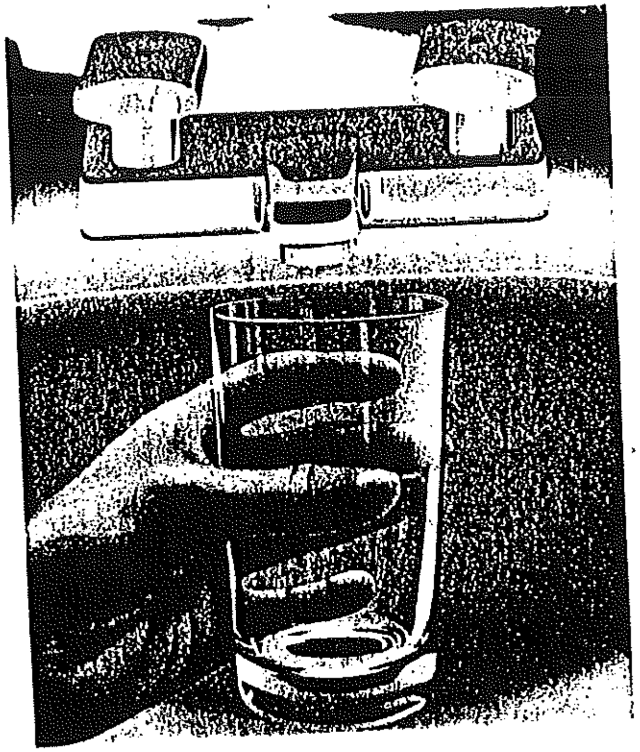
Many government environmental agencies consider a substance hazardous if it can catch fire, if it can react or explode when mixed with other substances, if it is corrosive, or if it is toxic.

This definition includes many things that you probably are storing right now in your garage, basement, bathroom, or kitchen. Some, like paint thinner or car batteries, are pretty obvious, but there are many that you might not ordinarily think of such as polishes, insecticides and glues.

Dangers Of Hazardous Waste

The improper disposal of household wastes can cause problems for the entire community. Wastes can be explosive or highly flammable. Sewers have exploded and garbage trucks have burned because people have carelessly discarded flammable or reactive wastes.

Hazardous wastes can also be corrosive. The acid from discarded auto batteries can eat away many substances. Some wastes are poisonous to humans or wildlife, while others can cause cancer, birth defects or other serious medical problems.



Where Do We Put Them?

One of the worst ways to dispose of many hazardous materials is to "just dump them down the drain." Wastewater treatment plants are not designed to handle certain types of hazardous wastes.

Unfortunately, disposing of wastes in a landfill has not proven an effective solution either. Without special design, the modern sanitary landfill is not equipped to accept hazardous wastes. Hazardous wastes improperly disposed of in a landfill can pollute the environment through the groundwater, surface water and air.

If the public cannot dispose of most hazardous wastes in the sewer system or a landfill, what can be done? This brochure describes some preventive measures you can take in your home to reduce the quantity of waste you must dispose. The **Household Hazardous Waste Chart** indicates the best way of dealing with most hazardous materials found in the home.

F: Re e T mo

You do not need a Ph.D. in chemistry to reduce the use of hazardous wastes in your home. The following suggestions can help:

- ☐ Before you buy a product, read the label and make sure that it will do what you want. Once you buy something you are responsible for disposing of it properly.
- ☐ Do not buy more than you need. That way, you will not need to dispose of the surplus.
- ☐ Read and follow directions on how to use a product and dispose of the container. (There is a good reason why the labels say "do not incinerate" or "do not mix with bleach.")
- ☐ Use safer substitutes when they are available.

Second: Take Care Of The Wastes

Even if you reduce the wastes that must be dealt with as outlined above there is still the question of what to do with what is left over.

Recycling is an excellent way of handling some hazardous wastes. Used motor oil, paint thinners and some other solvents can be refined and reused just as aluminum cans are. Local civic groups can help you identify recycling programs.

Municipal or commercial incineration is another effective means of dealing with some hazardous wastes. However, a specially designed incinerator is needed to destroy hazardous materials. "Incinerators" in your home, such as your fireplace or woodstove, can not get hot enough to destroy hazardous wastes and should **never** be used to destroy wastes.

Take your household hazardous wastes to a licensed contractor or recycling agency which may be located through the yellow pages. If such a group does not exist, your local wastewater treatment operator may be able to give you more information on the disposal of liquid waste. Your local sanitation department may be able to give you more information on the disposal of solid wastes.

The **Household Hazardous Waste Chart** will guide you in disposing of potentially hazardous material around your home. You should display this chart in a convenient location.

Remember to never dump hazardous wastes on the ground, and always check the chart before pouring them down the drain.

HOUSEHOLD HAZARDOUS WASTE CHART

The following chart prepared by the Water Environment Federation will help you establish the most effective means of disposing of typical hazardous wastes used around your home or garden.

Blue dots (●) indicate products which can be poured down the drain with plenty of water. If you have a septic tank, additional caution should be exercised when dumping these items down the drain. In fact, there are certain chemical substances that cannot be used with a septic tank. Read the labels to determine if a product could damage the septic tank.

Yellow diamonds (◆) indicate materials which cannot be poured down the drain, but can be safely disposed of in a sanitary landfill. Be certain the material is properly contained before it is put out for collection or carried to the landfill.

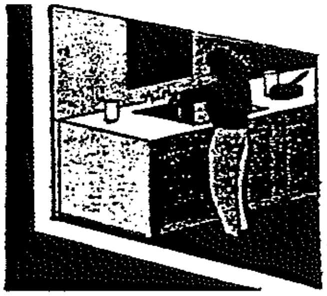
The red boxed squares (▣) indicate hazardous wastes which should be saved for a community wide collection day or given to a licensed hazardous wastes contractor. (Even the empty containers should be taken to a licensed contractor if one is available.)

Green packages (❖) in the fourth column indicate recyclable material. If there is a recycling program in your area, take the materials there. If not, encourage local officials to start such a program.

For more information on the safest way to dispose of these and other products contact your area's solid and hazardous waste department or federal environmental agency. We suggest that you note here these important phone numbers in your local area:

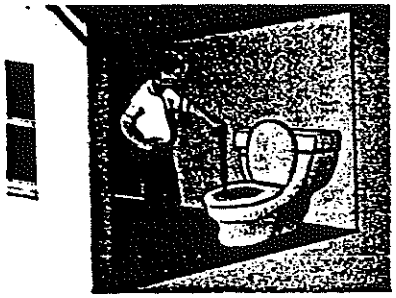
Hazardous Waste Management Agency ☎ ____________

Poison Control Center ☎ __________________________



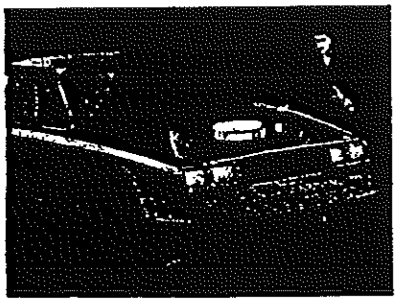
KITCHEN

TYPE OF WASTE	●	◆	▣	❖
Aerosol cans (empty)		◆		
Aluminum cleaners	●			
Ammonia based cleaners	●			
Bug sprays			▣	
Drain cleaners	●			
Floor care products			▣	
Furniture polish			▣	
Metal polish with solvent			▣	
Window cleaner	●			
Oven cleaner (lye base)		◆		



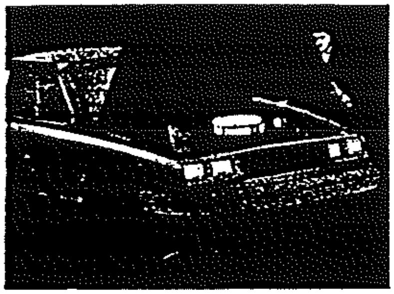
BATHROOM

TYPE OF WASTE	●	◆	▣	❖
Alcohol based lotions (aftershaves, perfumes, etc.)	●			
Bathroom cleaners	●			
Depilatories	●			
Disinfectants	●			
Permanent Lotions	●			
Hair relaxers	●			
Medicine (expired)	●			
Nail polish (solidified)		◆		
Toilet bowl cleaner	●			
Tub and tile cleaners	●			



GARAGE

TYPE OF WASTE	●	◆	▣	❖
Antifreeze				❖
Automatic transmission fluid			▣	❖
Auto body repair products		◆		
Battery acid (or battery)			▣	❖
Brake fluid			▣	
Car wax with solvent			▣	
Diesel fuel			▣	❖
Fuel oil			▣	❖
Gasoline			▣	❖
Kerosene			▣	❖

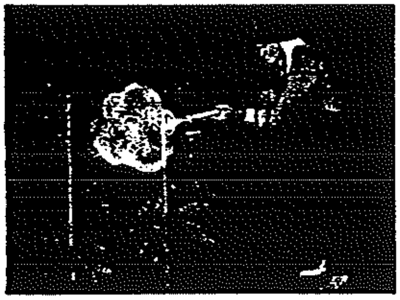


G A R A G E

Antifreeze				❖
Automatic transmission fluid			▣	❖
Auto body repair products		◆		
Battery acid (or battery)			▣	❖
Brake fluid			▣	
Car wax with solvent			▣	
Diesel fuel			▣	❖
Fuel oil			▣	❖
Gasoline			▣	❖
Kerosene			▣	❖
Metal polish with solvent			▣	
Motor oil			▣	❖
Other oils			▣	
Windshield washer solution	●			

WORKSHOP

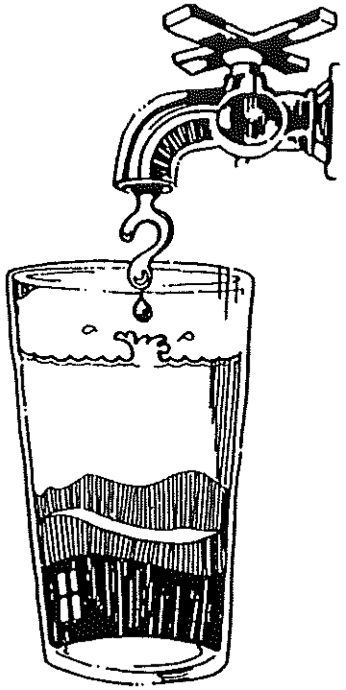
Paint brush cleaner with solvent			▣	❖
Paint brush cleaner with TSP	●			
Aerosol cans (empty)		◆		
Cutting oil			▣	
Glue (solvent based)			▣	
Glue (water based)	●			
Paint — latex		◆		
Paint — oil based			▣	
Paint — auto			▣	
Paint — model			▣	
Paint thinner			▣	❖
Paint stripper			▣	
Paint stripper (lye base)	●			
Primer			▣	
Rust remover (with phosphoric acid)	●			
Turpentine			▣	❖
Varnish			▣	
Wood preservative			▣	



G A R D E N

Fertilizer		◆		
Fungicide			▣	
Herbicide			▣	
Insecticide			▣	
Rat poison			▣	
Weed killer			▣	

How long will your water be safe to drink?



information about your groundwater supply

provided by the

Grimshaw Aquifer Management Advisory Committee

Canada-Alberta
Environmentally
Sustainable
Agriculture
Agreement
CAESA

Groundwater is a hidden and often forgotten resource. To ensure long-term, high quality groundwater supplies, safe for human use, an aquifer management plan is an important step in protecting this valuable resource.

Grimshaw Aquifer Management Advisory Committee

The Grimshaw Aquifer Management Advisory Committee was recently formed to develop a management plan that stresses the maintenance of water quality and quantity within the Grimshaw Aquifer for current and future users.

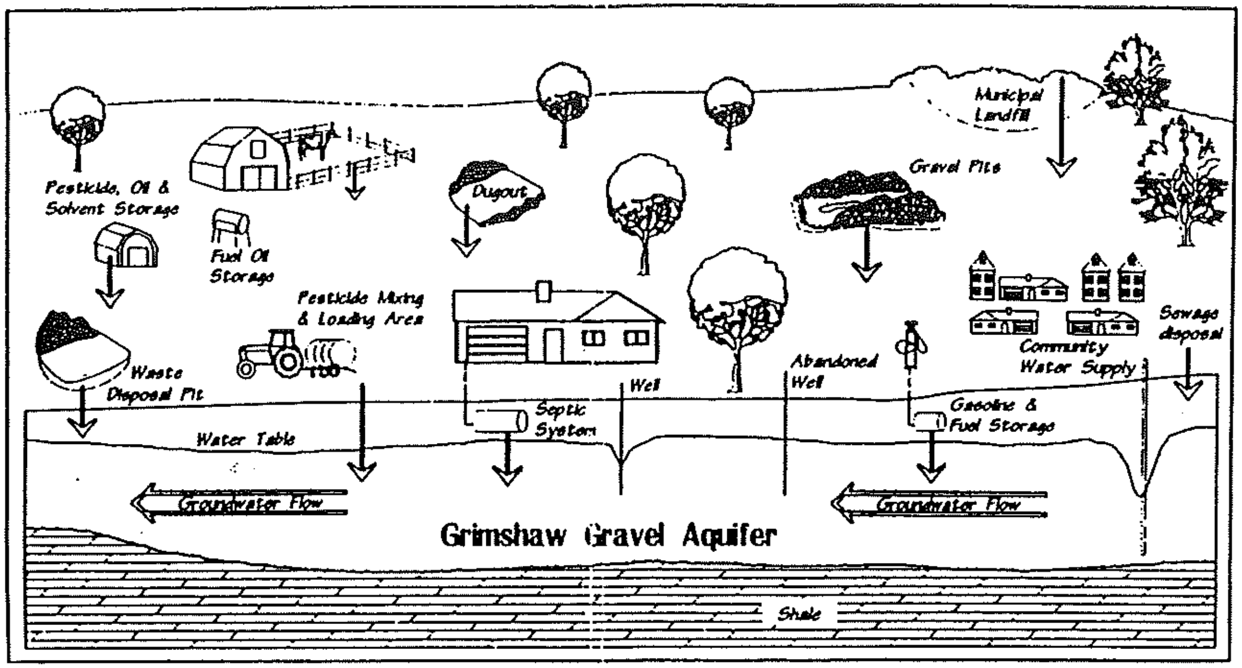
The Committee consists of elected officials and water co-operative representatives. Alberta Environmental Protection, Alberta Agriculture Food and Rural Development, Prairie Farm Rehabilitation Administration (PFRA) and the Mackenzie Regional Planning Commission provide technical advice and recommendations to the Committee. The Committee is an advisory body that will make recommendations for managing the groundwater resource. Implementation of the plan will be a cooperative effort between the local authorities and government departments.

Why do we need a plan?

It is difficult to manage a resource until you understand how it functions. How much water is available in the aquifer? Are we contaminating the aquifer? Answers to these questions will help us to determine what steps we should take if we hope to continue using this water supply. The Grimshaw Aquifer Management Advisory Committee believes that we need to know if we are polluting or depleting our water supply. Preparing an aquifer management plan will help enable us to understand: how the aquifer functions; how we as residents impact the aquifer; and what can be done to protect this resource. Information about the aquifer is currently being compiled and evaluated. This work is being funded by the Canada-Alberta Environmentally Sustainable Agriculture Agreement (CAESA).

We need to hear what you think ...

The Grimshaw Aquifer is an important resource to you and the region. This aquifer is your water supply source. We would appreciate hearing your thoughts and feelings on an aquifer management plan. What can we do today to protect this water resource for future generations without compromising the existing users?



This diagram illustrates how land above the aquifer can contribute to groundwater contamination. Contaminants such as toxins, nitrate and micro-organisms, can come from various land uses and practices.

Many toxic chemicals used in farming operations represent a potential risk to local groundwater contamination. Septic systems, barnyards, fertilizer storage areas, dugouts, disposal pits and land management practices all represent potential sources of groundwater contamination. One common contaminant often generated from these sources is nitrate. Wells, both active and abandoned, are also potential point sources of contamination. Factors such as an improper well seal, proximity to contaminants and improper well abandonment can increase the risk of direct contamination of groundwater supplies.

Industrial, commercial and residential land uses can also produce contaminants. Underground fuel storage, chemical storage, stormwater runoff, sewage disposal, and landfills are just some examples of land uses that need to be properly managed. Gravel pits also represent potential sources of contamination since they represent areas where a direct connection to the aquifer occurs. The way these potential sources of contamination are managed will effect the groundwater. A review and assessment of all potential contaminant sources is necessary to develop an approach to protecting our groundwater, a resource we cannot afford to lose.

Grimshaw Aquifer Management Advisory Committee

our goal

to develop a management plan that stresses the maintenance of water quality and quantity within the Grimshaw Aquifer for current and future users.

The Grimshaw Aquifer Management Advisory Committee would appreciate hearing from everyone who uses and depends on this water supply. It is important that you have a voice in the management of your water supply. Please contact the Mackenzie Regional Planning Commission at **338-3028** if you have any comments, questions or would like more information. If you have written comments, please send them to the **Grimshaw Aquifer Management Advisory Committee, c/o Mackenzie Regional Planning Commission, Box 450, Berwyn, Alberta, T0H 0E0.** Thank you for taking the time to think about this important resource.

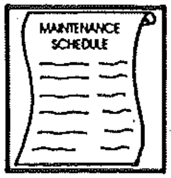
As part of the management plan, information about the aquifer is currently being gathered. Initial work on a hydrogeology study for the Grimshaw Aquifer is being undertaken by a private consultant. The study is being funded by

Canada-Alberta
Environmentally Sustainable
Agriculture Agreement
(CAESA)

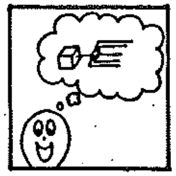
Canada Alberta

Agriculture Building a Healthy Environment

DO's



DO:
Keep a record of Pumping, Inspections and other Maintenance.

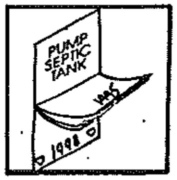


DO:
Learn the location of your septic system and drainfield.

DO:
Take leftover hazardous household chemicals to your approved hazardous waste collection center for disposal.

DO:
Practice water conservation.

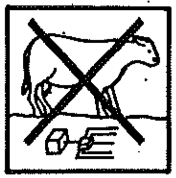
DO:
Have your tank pumped out and system inspected every 2-3 years.



DO:
Divert roof drains, surface water from driveways and hillsides away from the septic system.

DONT's

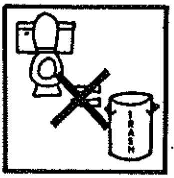
DON'T:
Make or allow repairs to your septic system without obtaining the required Health Department permit.



DON'T:
Allow livestock on drain field.

DON'T:
Allow anyone to drive or park over any part of the septic system.

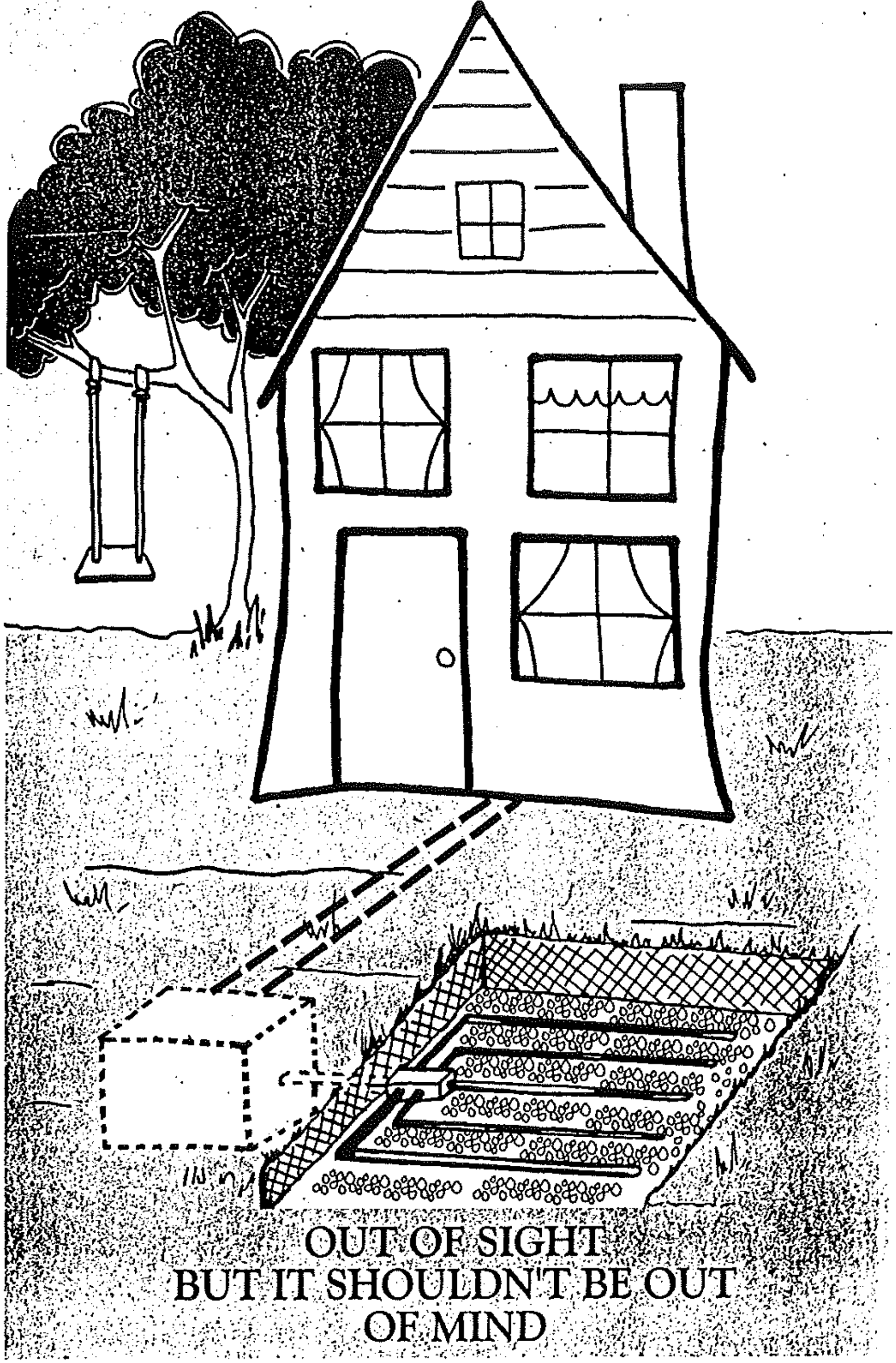
DON'T:
Use your toilet or drains as trash cans by dumping nondegradables down.



For more information contact:

Brochure prepared and funded by:
The Engineering Dept. of the Township of Langley,
The Salmon River Watershed Management Partnership and
The Dept. of Fisheries and Oceans in cooperation with
The Ministry of Health - Boundary Health Unit.

YOUR SEPTIC SYSTEM



OUT OF SIGHT
BUT IT SHOULDN'T BE OUT
OF MIND

Thousands of us living in rural settings get our water from the ground and deposit our sewage back into the same ground by way of SEPTIC SYSTEMS.

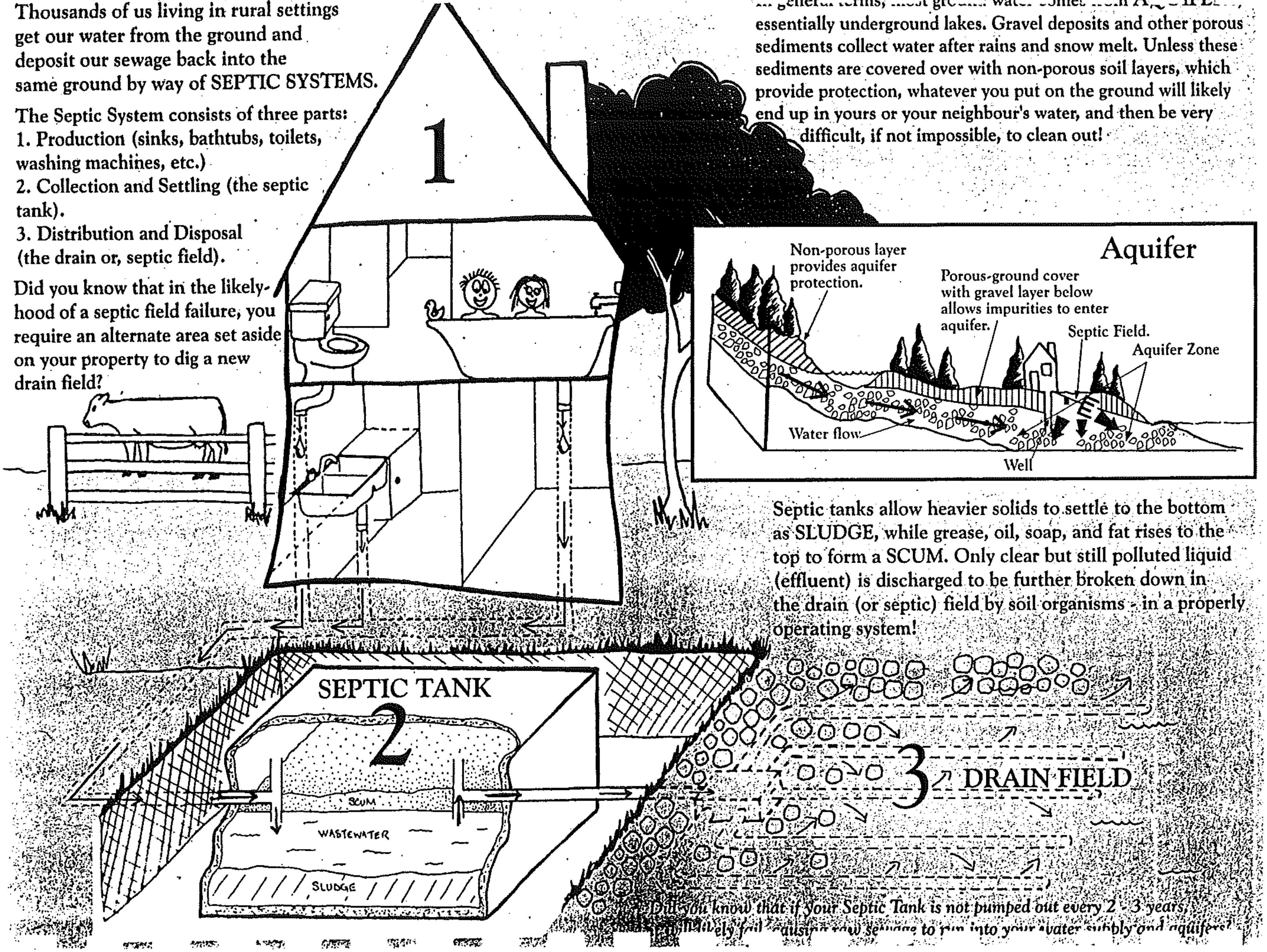
The Septic System consists of three parts:

1. Production (sinks, bathtubs, toilets, washing machines, etc.)
2. Collection and Settling (the septic tank).
3. Distribution and Disposal (the drain or, septic field).

Did you know that in the likelyhood of a septic field failure, you require an alternate area set aside on your property to dig a new drain field?

In general terms, most ground water comes from AQUIFERS, essentially underground lakes. Gravel deposits and other porous sediments collect water after rains and snow melt. Unless these sediments are covered over with non-porous soil layers, which provide protection, whatever you put on the ground will likely end up in yours or your neighbour's water, and then be very difficult, if not impossible, to clean out!

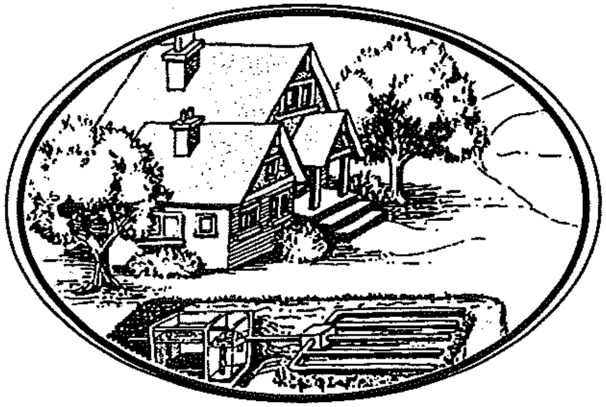
Septic tanks allow heavier solids to settle to the bottom as SLUDGE, while grease, oil, soap, and fat rises to the top to form a SCUM. Only clear but still polluted liquid (effluent) is discharged to be further broken down in the drain (or septic) field by soil organisms - in a properly operating system!



Did you know that if your Septic Tank is not pumped out every 2 - 3 years, it will likely fail causing raw sewage to run into your water supply and aquifers?

SEPTIC SYSTEM MAINTENANCE

Pure & Simple



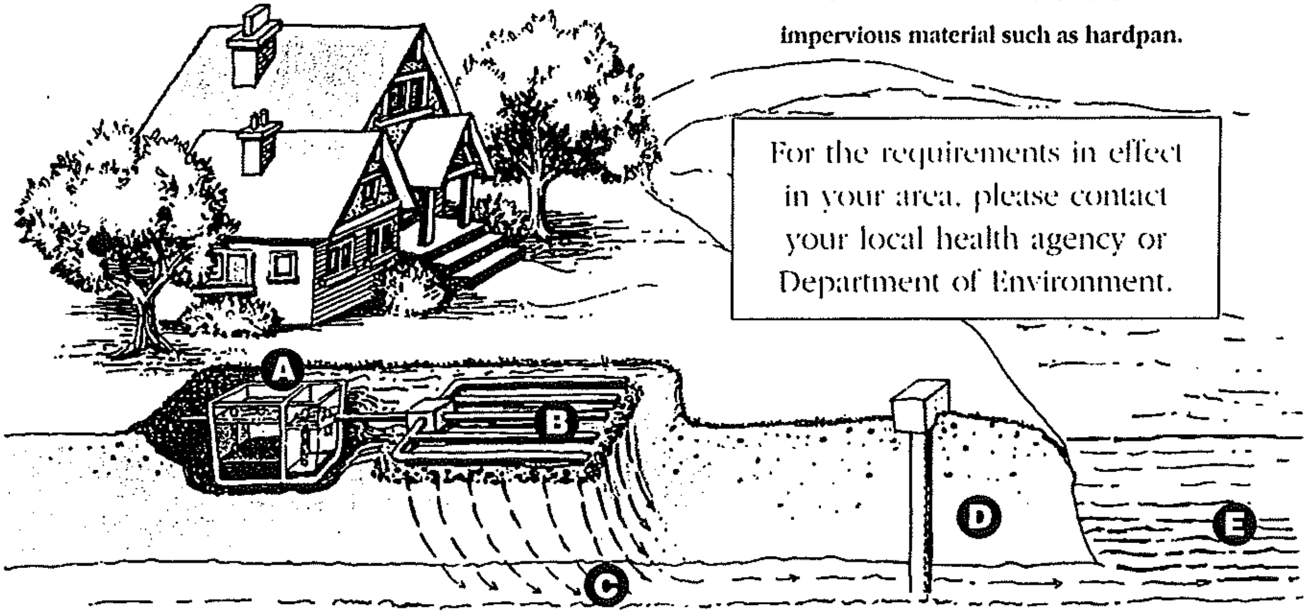
A Guide for Homeowners

Your simple step-by step guide
to septic systems maintenance and
trouble-shooting.

A Conventional Gravity Flow Sewage Disposal System

Size and Dimensions:

The average septic tank requires a space about 10 ft. x 10 ft. The disposal (or drain) field should be 30 ft. x 50 ft. or larger, with an additional area of similar size held in reserve in case of drainfield failure. The drainfield should have 4 ft. of good native soil from the surface to the water table or hardpan and a minimum of 2 ft. vertical separation from the trench bottom to the water table or impervious material such as hardpan.



For the requirements in effect in your area, please contact your local health agency or Department of Environment.

There are many types of septic systems used across Canada. Depending on location and soil condition, homeowners may use treatment plants, sand filters, pumps or siphons. The treatment principles are generally the same in all systems.

In conventional systems, waste water from sinks, tubs and toilets flush out of the house into a tank Ⓐ that separates and stores the solids. Bacteria help to break down some of the heavier sludge and floating scum, but the rest accumulates in the tank until it is pumped out.

The partially treated waste water (or effluent) flows from the tank into a distribution box that evenly divides the discharge into a network of pipes Ⓑ that lie buried in gravel-filled trenches in the drainfield. Small holes in each pipe allow waste water to seep through the gravel, then into the soil. As effluent trickles through the soil, any remaining particles are removed by natural filtration and bacterial action. When waste water finally reaches the water table Ⓒ, it has been treated and cleansed.

If waste water doesn't get the full treatment contaminants can leach into the ground water Ⓒ that supplies our wells Ⓓ, or drain directly into Ⓔ lakes, streams - or our own backyard!

ONGOING

Care & Maintenance

Pure water is important to the quality of life we enjoy in Canada. How we dispose of waste water once we've used it is crucial to the health of our families and our communities.

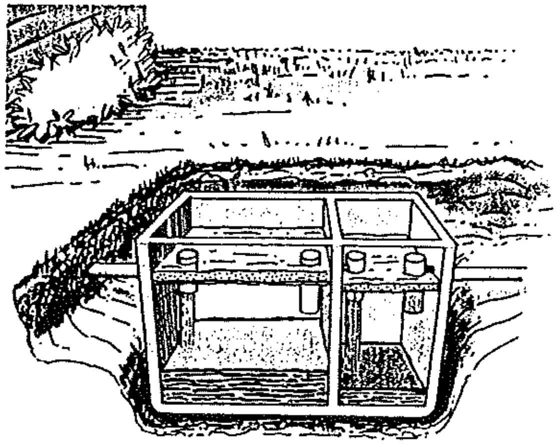
In rural areas, individual sewage disposal (or septic) systems use natural treatment and filtration to clean waste water before it is dispersed underground.

When septic systems work properly, they are efficient, inexpensive to maintain and environmentally friendly; when they fail, they cause odours, water pollution and major expense.

By properly maintaining sewage disposal systems, homeowners play a significant role in protecting our health and natural resources.

WARNING SIGNS

- **slow or backed up drains**
- **patches of lush growth over the drainfield**
- **unpleasant odours around the yard**
- **sewage surfacing on lawns or in ditches**



TYPICAL SEPTIC TANK INSTALLATION

The key to a healthy septic system is to ***protect the tank and drainfield from becoming clogged*** with solids. This means having the tank pumped regularly, conserving water and keeping harmful material out of the system.

A plugged tank or disposal field can cause sewage to back up into the house or seep into the environment. This can present a health hazard and be very expensive to repair or replace. It is important to watch for signs that your system may be failing.

Preventative Measures

- Don't put non-degradables down sinks or toilets. No cigarettes, diapers, hair, grease, cat litter, coffee grounds, etc.
- Don't use commercial septic tank additives; they are unnecessary, expensive and may cause pollution.
- Don't use excessive amounts of bleach or kitchen solvents.

Don'ts

- Don't pour harmful chemicals down your drains: no paint, kerosene, solvents, antifreeze, gas, oil, herbicides or pesticides. These can leach into groundwater and poison the environment.
- Don't stress the system with multiple laundry loads on one day.
- Don't discharge water softening devices into the system.
- Don't park or drive on your drainfield. Outbuildings, patios or pools can compact the soil, crush pipes and reduce aerobic action in the drainfield.
- Don't saturate your drainfield with automatic sprinkling.

Caring for Your System

- **HAVE YOUR TANK PUMPED EVERY 3 TO 5 YEARS.** Septic system professionals should inspect the entire system - field, distribution box and pump chambers.
- Know where your system is. Keep a photo or map and maintenance records.
- Be safety conscious when checking your system. Watch for heavy tank covers, sewer gases and raw sewage.
- Practice water conservation by using **low flush toilets, water saving faucets and shower heads, dishwashers only when full** – your system will last longer.

Do's

- Take hazardous wastes to approved disposal centres.
- Plant grass on your drainfield rather than trees or shrubs. **Water sparingly.**
- Divert roof, patio and driveway runoff away from the drainfield. Keep sump pumps, hillside runoff and foundation drains away from the system as well.
- Protect the reserve drainfield area.
- Ensure that your system is large enough for your needs. Garburetors put extra pressure on the system. So do additional bedrooms or suites.
- Contact your local public health agency for permits for repairs, improvements, installations and further information.

Public Information Brochure Published by the Department of Environment, Newfoundland

Where does groundwater come from?

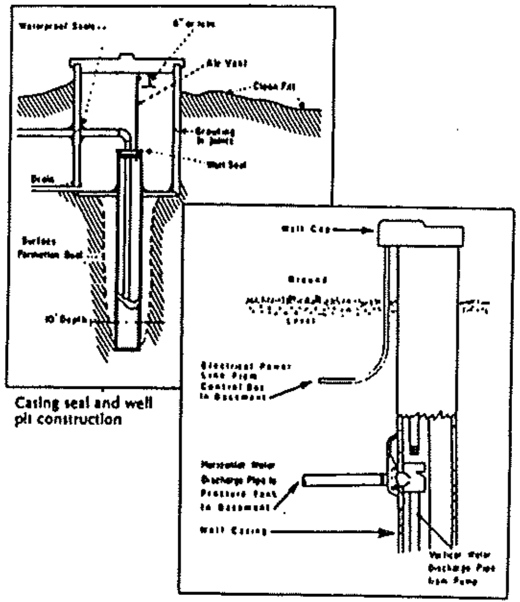
The groundwater that enters your well may have begun its journey many years ago. In most cases it is derived directly from precipitation; in others it first enters a pond or river. From either source groundwater must seep down vertically through the soil layers until it reaches the water table. Water beneath this level is always moving in a direction determined by the elevation of the water table at that point. Normally the movement is from high ground to low ground but this can be altered by the resistance to flow that is exerted by the soils and rock formations through which it seeps. Depending on the size of the openings in these materials, many years may elapse before the water that began as rain or snow reaches your well.

How does groundwater get contaminated?

As groundwater seeps through the soil and rock formations in which your well is constructed, its quality is altered. This is usually to your advantage. Most surface waters are turbid and contain undesirable organisims. The filtering effect of soils gives us the crystal clear, clean water that is characteristic of groundwater. It can be well appreciated that if the soil itself is contaminated with substances such as oil, gasoline, animal wastes, or any soluable material, then the waters percolating through such soil will become contaiminated too. The other major cause of poor quality well water is the entrance of contaminated surface water directly into the well through defective casing seals or improper pump installations.

How do I protect my well from pollution?

Once a well has been drilled in a safe location, the most obvious way to protect it is to be sure that the ground around it slopes away from it. This will prevent surface water from ponding near the casing. The next step is to provide the proper hookup to the pressure system. Only the pitless adapter or the drained well pit are recommended for this purpose (these are depicted below). Burial of the well is not recommended. Remember! Your well should be accessible for inspection and investigation in case any problem should arise in the future. An undrained well pit is also to be avoided. Such a pit tends to fill up with water and promote leakage into the well casing.



Casing seal and well pit construction

Pitless adapter

The following common sense precautions need to be taken when finishing the well:

- Don't locate oil tanks near the well.
- Don't park old vehicles near the well.
- Don't store soluable materials near the well.
- And finally, check the well occasionally to make sure that all is in order.

What if I decide to abandon my well?

If you ever decide to abandon your well remember, groundwater belongs to everybody. In addition to providing you with access to the resource for your requirements, your well will be a ready conduit for surface waters when the casing corrodes away. Unwittingly, you may contaminate your neighbour's well. To prevent this from happening, it is a requirement of the Well Drilling Act that an abandoned well must be back filled with cement grout or bentonite clay.

What if I have any specific questions or problems?

If your questions have not been answered here, please contact us at the following address:

Department of Environment,
Water Resources Division,
Groundwater Branch,
P.O. Box 4750,
St. John's, Newfoundland.
A1C 5T7

or phone 576-2539 or 576-2563