MUNICIPALITY of the COUNTY of KINGS

GREENWOOD SOURCE WATER PROTECTION COMMITTEE

Thursday May 8, 2025, at 10:00 a.m.
Greenwood Village Commission Office
904 Central Ave, Greenwood

1. Roll Call, Welcome

2. Approval of Agenda

3. Disclosure of Conflict-of-Interest Issues

4. New Business
   a. Review of 2019 Draft Management Plan

5. Adjournment

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GREENWOOD WATER UTILITY

SOURCE WATER PROTECTION PLAN

THE MUNICIPALITY OF THE COUNTY OF KINGS

Greenwood Source Water Protection Plan, Rev. 1

Created by:	Reviewed by:	Approved by:
Greenwood Source Water Protection Committee	Manager Engineering and Public Works	CAO
	Date	Date

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1. INTRODUCTION

In October 2002, the province released the policy document *A Drinking Water Strategy for Nova Scotia*, which provides the framework for managing drinking water supplies across the province. The Operating Permit for the Greenwood Water System requires the Municipality, as System owner, to implement elements of this policy document to ensure the long term integrity of the groundwater source.

The policy describes a multi-barrier approach to clean, safe drinking water. The three lines of defense of the multi-barrier approach are:

- Keeping clean water clean – an effective source water protection plan.
- Making it safe – treatment of water supply.
- Proving it is safe – monitoring and verification.

This document was developed to address the first barrier of this approach- keeping clean water clean. The most economical and effective method of achieving this is through a comprehensive and inclusive Plan to ensure the protection of the Greenwood Water Supply.

2. DESCRIPTION OF THE WATER SUPPLY

2.1 Well(s) Location and Ownership

The Municipality of Kings owns two production wells (GW8 and GW13) to supply the Greenwood water distribution system. The wells are located at 893 and 907 Meadowvale Road (respectively) in the Community of Tremont. Well GW 8 was drilled to a depth of 23.8 meters below grade and GW 13 was drilled to a depth of 27.1 meters below grade. Through testing conducted it has been determined that the aquifer that feeds the two production wells is *Groundwater Under Direct Influence of Surface Water (GUDI).* GUDI means there is groundwater and surface water interaction that occurs at less than 90 days travel time.

2.2 Description of Utility:

The current water supply and distribution system consists of standard pipe networks of various sizes, serving residential and commercial customers. The supply is delivered by pumping production wells GW8 and GW13. Well GW8 and GW13 are housed in vaults and control buildings. They pump water directly from the wellhead to GW12B, the water disinfection building. From there it is sent to two 360,000 US gallon (1.6 million litres) water storage towers. Water is fed from the towers to the return distribution main via gravity on demand.

The Greenwood water supply system is treated to provide system disinfection and to maintain biostability and safe potable water. Primary disinfection is conducted by two redundant UV systems that are used alternately for each well pump. Secondary disinfection is provided by sodium hypochlorite injection with metering pumps after the UV system. The reservoirs provide sufficient chlorine contact time.

2.3 Wellhead Protection Area Delineation:

The wellhead protection area is the area surrounding a well or wellfield that supplies a municipal drinking water supply. In Nova Scotia a minimum of 3 zones are recommended, based on the time of travel of certain contaminates or the amount of time it would take contaminates to enter the Greenwood source water.

In March of 2008, CBCL Limited in partnership with Terry W. Hennigar Water Consulting provided to the Municipality of Kings the report entitled: *Greenwood Capture Zone Modeling: Technical Report, Appendix A.* The purpose of this report was to provide the Municipality with a groundwater flow model for the Greenwood Water Utility's production wells.

Based on the information provided in the Technical Report, the zones were based on the consideration that the wells were GUDI and included the Annapolis Valley watershed. The study indicated that groundwater flow patterns flow from "the south mountain toward the Annapolis River, with components of the southwest in the outwash valley aquifer".

The zones are defined as the following:
Zone A – Well site control zone, encompassing a 25 meter radius around each well.
Zone B – the area within the 2 year capture zone.
Zone C – the area within the 5 year capture zone.
Zone D – the area within the 25 year capture zone.

A map of the delineated area can be found in Appendix B.

2.5 Current Land Uses in the Greenwood Source Water Protection Area - Appendix C

The report found in Appendix C entitled Land Use Planning Recommendations for the Greenwood Wellfield Protection Plan, CBCL Limited, illustrates the Risk Analysis conducted within the well field area. Page 13 of the report, table 5.2, contains an inventory of possible contamination issues per zone. As a note, in the original report Zone A was set at 250 ft surrounding each well, based on the fact the report indicates that the hydraulic conductivity of the sand units were increased by a factor of 10 beyond expected conditions, the committee felt it was acceptable to have Zone A protected area set at 25 meter "which is the absolute minimum size for this zone (CBCL, 2009, p. 10). With the surrounding area set at this, it has identified that Zone A was under the complete ownership of the Municipality.

The map as Appendix B, illustrating the delineation area has the Well Site Control Zone set at 25 meters and it also identifies areas of non-conforming uses. Non-conforming uses as per the Nova Scotia Municipal Government Act "means a use of land that is not permitted in the zone". For the purpose of this report these are uses of the land that do not meet the requirements for the Land-use By-law's developed for these areas, but for reasons of grandfathering are permitted to continue operating in their current form and may be considered for expansion or redevelopment only by Development Agreement as per by-law #56 Section 2.12.9.5 as Appendix D. It would be ensured through the Development Agreement that there would be no increase in potential for contamination of the groundwater.

3. GOALS AND OBJECTIVES:

3.1 Context

The Municipality of Kings owns and operates the water utility that provides the potable drinking water to the Village of Greenwood and surrounding area. The Drinking Water Strategy issued by Province of Nova Scotia requires that utilities that use ground water for drinking water undertake well head protection measures.

3.2 Goal

The function of the Greenwood Source Water Protection Committee is to advise Municipal Council and staff on the development and maintenance of a mutually beneficial, locally developed and administered Source Water Protection Program that protects the water source(s) of the Greenwood Water Utility. The goal of the plan is to protect the source water of the Greenwood Water Utility.

3.3 Stakeholders

- Policy: EPW-04-009, MUNICIPALITY OF THE COUNTY OF KINGS; Greenwood Water Utility Source Water Protection Committee Policy - Section 4 (Appendix G)

3.4 Responsibilities

- Policy: EPW-04-009, MUNICIPALITY OF THE COUNTY OF KINGS; Greenwood Water Utility Source Water Protection Committee Policy - Section 6 (Appendix G)

3.5 Deliverables

- A comprehensive and inclusive Plan to ensure the protection of the Greenwood Water Supply.

4. MANAGEMENT RECOMMENDATIONS:

4.1 Source Water Protection Management Options:

Acquisition of Land (A) – Land acquisition gives direct ownership and control of the source water protection area to the utility or municipality. This is a preferred option because of its obvious benefits. The purchase of land may include all lands within the source water protection area, or may be confined only to land areas that play a critical role in protecting the water source.

By-laws (B) – Land-use planning through the use of municipal planning strategies and zoning is a very powerful tool to ensure that potential contaminant threats or activities are sited away from the water source. Developing by-laws is subject to mandatory public consultation requirements.

Best Management Practices (B) – Once individuals and industries understand they may be part of the problem, they also understand they can be part of the solution. BMPs are a good way to introduce a change in the way businesses, industry and individuals treat the environment.

Contingency Planning (C) – An emergency response plan provides a blueprint for action in the event of a dangerous contamination occurrence within the source water protection area. All utilities or municipalities must have a contingency plan in place for their source water protection areas.

Designation (D) – Formal designation as a Protected Water Area under section 106 of the Nova Scotia Environment Act is a mechanism for utilities or municipalities to develop regulations for activities that have the potential to impair source water quality. Regulations will apply to the source water protection area defined by the utility or municipality and advisory committee.

Education and Stewardship (E) – Educating the people who live and work within source water protection areas creates a sense of ownership and shared responsibility for the protection of the water resource.

4.2 Potential Contaminants:

Potential Contaminants – Point sources	*Description*	*Well Control Site Zone A*	*Zone B 0-2 year*	*Zone C 2-5 year*	*Zone D 5–25 year*
Aggregate Related Industry	Petroleum hydrocarbons		X	X	X
Livestock Operation	Bacteria, nutrients, dissolved organic carbon		X		
Small Engine Repair Shop	Petroleum hydrocarbons, solvents		X		
NSPI Substation	PCB's, Petroleum hydrocarbons		X		
Heavy Machinery Maintenance and Storage	Petroleum hydrocarbons, solvents		X		
Private Wells	Point of entry for contaminants into groundwater		X	X	X
Liquid chlorine	Chemical contamination		X		
Greenwood Sewage Treatment Plant	Bacteria, nutrients, pharmaceuticals, dissolved organic carbon, chloride		X	X	
Cemetery	Bacteria, nutrients, dissolved organic carbon, chemicals			X	
Abattoir	Bacteria, nutrients, dissolved organic carbon, heavy metals (if contained in pest controls)				X
Salvage Yard	Petroleum hydrocarbons, solvents, metals, PAHs, battery acid				X
Home Heating Oil Tanks	Petroleum hydrocarbons		X	X	X
Residential Septic Systems	Bacteria, nutrients, pharmaceuticals, dissolved organic carbon, chloride		X	X	X
Residential herbicide and pesticide use	Chemicals		X	X	X

4.3 Risk Assessment Worksheet – Appendix E

As per CBCL Limited Table 5.2: Summary of Risk Analysis

4.4 Management Plan

Acquisition of Land (A)

The Municipality of Kings owns much of the land in zone A of the Source Water Protection Area. If the opportunity arises and the monies are available for further acquisition, this will be explored at this time. Currently, there is no active plan for Land Acquisition within the wellfield.

By-laws (B)

Land Use Planning / Municipal Planning Strategy

By-law 56, the Municipal Planning Strategy and Bylaw 75 were amended on January 12, 2012, to include land use policies and regulations aimed at protecting the Greenwood wellfields, as referenced in Appendix D. These amendments were developed by the Greenwood Wellfield Committee based on recommendations as delivered by CBCL Limited in the report "Land Use Recommendations for Greenwood Wellfield Protection Plan" found in Appendix C.

Best Management Practices (B)

Best Management practices will be recommended to residents, businesses and the Department of Transportation and Infrastructure Renewal, specifically for non-conforming uses.

7 Monitoring wells were installed at the Greenwood Sewage Treatment Plant to conduct ground water monitoring, **Appendix F**. The sampling was designed in line with "NSE Guidelines for the Handling, Treatment and Disposal of Septage" The intent of this sampling is to be able to identify changes in groundwater quality that may be indicative of a leak.

Monitoring plans will be established by the Municipality of Kings to ensure the water quality of the source water meets the *Guidelines for Canadian Drinking Water Quality* and as per *Guidelines for Monitoring Public Drinking Water Supplies.*

Contingency Planning (C)

Contingency Planning will be established and reviewed annually for Emergency conditions within the Source Water Protection Area; as per the **Municipality of Kings Water Utility Contingency and Emergency Notification Plan** on file at the Municipality of Kings Office.

Emergency Responders for Greenwood and surrounding area will be notified that this area is a Wellfield area, along with Emergency Contacts to use in the instance that an emergency contamination risk is introduced to this area.

Designation (D)

The Municipality of Kings does not wish to consider this, at this time.

Education and Stewardship (E)

This management option will be implemented using media outlets, the Municipal website and various other tools as agreed upon by the committee to educate residents of the source water protection area and other stakeholders.

5. IMPLEMENTATION AND EVALUATION:

5.1 Implementation

Acquisition of Land (A) - N/A

By-laws (B)

- By-law #56 and the Municipal Planning Strategy were updated to include the Greenwood Source Water Protection Area.

Date or implementation: January 12, 2012

Best Management Practices (B)

- Contact non-conforming uses within the well zones and recommend Best Management Practices as per the following guides:
  - A Guide to Recommended Agricultural Practices within Municipal Drinking Water Supply Areas in Nova Scotia
  - Best Management Practices/Forest Planning in Municipal Drinking Water Supply Areas in Nova Scotia
  - Mineral Exploration and Development in Municipal Water Supply Areas

Copies of these publications can be obtained from Nova Scotia Environment at http://www.gov.ns.ca/nse/surface.water/surfacewater.protection.asp

Date of implementation: March 24, 2015

- 7 Monitoring wells were installed at the Greenwood Sewage Treatment Plant to conduct ground water monitoring, **Appendix F**. The sampling was designed in line with "NSE Guidelines for the Handling, Treatment and Disposal of Septage" The intent of this sampling is to be able to identify changes in groundwater quality that may be indicative of a leak. The sampling schedule is as follows:

Field Measurements	**Frequency**	**Duplicate**
Water Level	Weekly	NA
Field Parameters (pH, conductivity, temperature, and dissolved oxygen)	Weekly	NA
Laboratory Analysis		
Total and Fecal Coliform, E. coli (MPN)	Quarterly	Semi-annual
Biochemical Oxygen Demand (BOD_5)	Quarterly	Semi-annual
Ammonia and Total Kjeldahl Nitrogen (TKN)	Semi-annual	Annual
General Chemistry (incl. nitrate, nitrite, phosphorus, chloride, boron)	Semi-annual	Annual
Dissolved Organic Carbon (DOC)	Annual	Annual
Dissolved Metals (filtered)	Annual	Annual
Bacteria, Ammonia, TKN, General Chemistry, DOC, metals	Special #1	Special #1
Volatile Organic Compounds (VOCs)	Special #2	NA
TPH/BTEX (Atlantic PIRI)	Special #2	NA

Special #1 – Sampled immediately if there are any indications of a spill or changes in groundwater quality.

Special #2 – Sampled if there is evidence that chemical contaminants could have entered the groundwater environment surrounding the STP.

Target Date for implementation: Began March 2011 and ongoing

- pH monitoring of the raw water will be conducted weekly, this will be used for trending purposes to indicate any spikes that could indicate a change in the water quality.

Target Date for implementation: Currently and ongoing

- Raw water total and E. coli coliform tests (present/absent) will be completed weekly to monitor changes in the groundwater bacterial quality.

Target Date for implementation: Currently and ongoing

- Annually, testing will be conducted on the parameters as per the Guidelines for Monitoring Public Drinking Water Supplies. The following parameters at a minimum will be tested:

Alkalinity	Colour	Potassium
Aluminum	Conductivity	Selenium
Ammonia	Copper	Sodium
Antimony	Fluoride	Sulphate
Arsenic	Hardness	Total Dissolved Solids
Barium	Iron	Total Organic Carbon
Boron	Lead	Turbidity
Cadmium	Magnesium	Uranium
Calcium	Manganese	Zinc
Chloride	Nitrate	
Chromium	pH	

Target Date for implementation: Currently and ongoing

- Every 5 years the raw water is monitored for parameters according to the Guidelines for Canadian Drinking Water Quality, latest edition, having maximum acceptable or interim maximum acceptable concentrations. They are as follows:

Aldicarb	Aldrin+dieldrin	Antimony
Arsenic	Altrazine+metabolites	Azinphos-methyl
Barium	Bendiocarb	Benzene
Benzo(a)pyrene	Boron	Bromate
Bromodichloromethane (BDCM)	Bromoxynil	Cadmium
Carbaryl	Carbofuran	Carbon tetrachloride
Chloramines	Chlorate	Chlorite
Chlorpyrifos	Chromium	Cyanazine
Cyanobacterial toxins – Microcystin-LR	Diazinon	Dicamba
1,2-Dichlorobenzene	1,4-Dichlorobenzene	1,2-Dichloroethane
1,1-Dichloroethylene	Dichloromethane	2,4-Dichlorophenol
2,4-Dichlorophenoxyacetic acid	Diclofop-methyl	Dimethoate
Dinoseb	Diquat	Diuron
Fluoride	Glyphosate	Haloacetic Acids – Total (HAAs)
Lead	Malathion	Mercury
Methoxychlor	Methyl tertiaty-butyl ether (MTBE)	Metolachlor
Metrabuzin	Monochlorobenzene	Nitrate
Nitrilotriacetic acid (NTA)	Paraquat (as dichloride)	Parathion
Pentachlorophenol	Phorate	Picloram
Selenium	Simazine	Terbufos

Tetrachloroethylene	2,3,4,6-Tetrachlorophenol	Trichloroethylene
2,4,6-Trichlorophenol	Trifluralin	Trihalomethanes-total
Uranium	Vinyl chloride	

Target Date for implementation: Currently and ongoing

- As part of the water utilitiy operators scheduled checks, the wellheads and surrounding area will be monitored for signs of damage or security concerns.

Target Date for implementation: Currently and ongoing

Contingency Planning (C)

- The contingency plans as established by the Municipality of Kings Department of Engineering and Public Works will be reviewed by the committee to determine if recommendations are needed to meet the needs of the Source Water Protection management Plan.

Target Date for implementation: March 24, 2015

Designation (D) - N/A

Education and Stewardship (E)

- The County website and other media outlets (as determined by the committee at the twice annual meeting) will be utilized to deliver a reminder to the residents, of the Source Water Protection Plan, as well as an education and communication component.

Target Date for implementation: Currently and ongoing

5.2 Evaluation

Twice annually the Committee will meet to review the Management Plan and the Land uses in the area to determine if any updates are required. If there have been identified issues within the year that may impact the Groundwater or the Management Plan, the committee will meet as required.

At the twice annual meeting, or sooner if required, the committee will review the monitoring results collected that year to determine if any results indicate that an update to the Management/ Monitoring

Plan is required. The committee, at this time, will determine if any expenditures are required that would need to be included in the budget process.

All monitoring results, identified issues and updates to the plan will be reported to Nova Scotia Environment as part of the Greenwood Water Utility Annual Report due April 1st.

6. REFERENCES

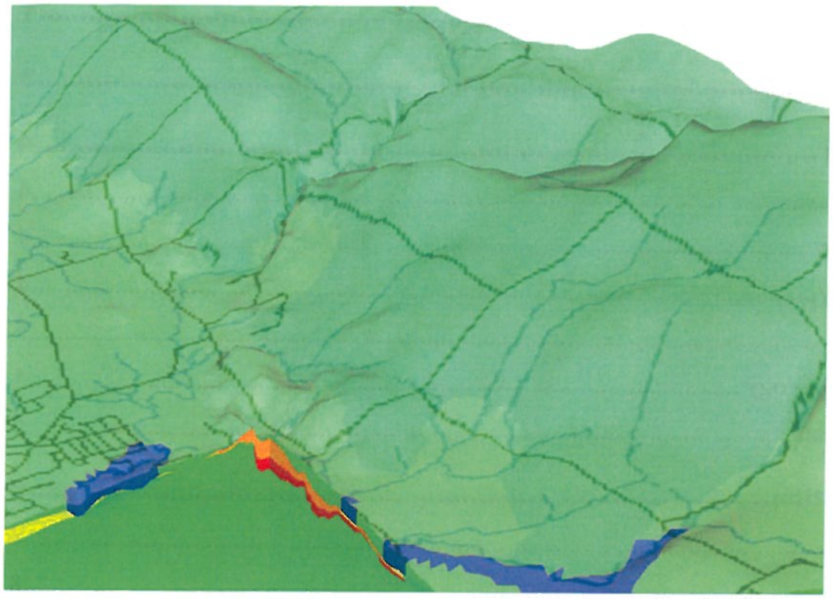
1. Nova Scotia Environment, Developing a Source Water Protection Management Plan: A Guide for Water Utilities and Municipalities, Steps 1-5
2. CBCL Limited and Water and Aquifer Technical Environmental Resources, Greenwood Capture Zone Modeling: Technical Report; March 2008
3. CBCL Limited, Land Use Planning Recommendations for the Greenwood Wellfield Protection Plan; January, 2009
4. CBCL Limited, Operation and Maintenance Manual, Greenwood Sewage Treatment Plant; September 2010

<u>Appendix A</u>

Greenwood Capture Zone Modelling; Technical Report

CBCL Limited, Water and Aquife*r* Technical Environmental Resources

Report No. 071032



Prepared for:
Village of Greenwood,
Nova Scotia

Greenwood Capture Zone Modelling: Technical Report

Final Report

March, 2008

CBCL

CBCL LIMITED

Consulting Engineers

WATER

WATER & AQUIFER TECHNICAL ENVIRONMENTAL RESOURCES TERRY W. HENNIGAR WATER CONSULTING

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Executive Summary

CBCL Limited was contracted in partnership with Terry W. Hennigar WATER Consulting to develop a groundwater flow model for the Village of Greenwood, Nova Scotia. The groundwater model allowed for delineation of a Well Head Protection Area (WHPA) around the Village of Greenwood well field. The results of the groundwater model form an integral part of the village's Well Head Protection Plan (WHPP) which is in development, and will be presented under a separate cover. Development of the groundwater flow model and subsequent results are described herein.

Information on the area geology, precipitation, soil types, groundwater flow, and pumping well capability was used to create a computer model of the Annapolis Valley flow system in a 102 km^2 area around Greenwood. The model software, FEFLOW 5.2, was used to produce and test groundwater flow patterns, and served as a tool to delineate the WHPA. When travel times of two years, five years, and 25 years were entered into the model, a roughly circular zone (or capture zone) corresponding to each travel time was produced. The modelled capture zones correspond to the zones of the WHPA:

- Zone A is the Well Site Control Zone, encompassing a 250 ft. radius around each well;
- Zone B is the area within the 2-year capture zone;
- Zone C is the area within the 5-year capture zone, and
- Zone D is the area within the 25-year capture zone.

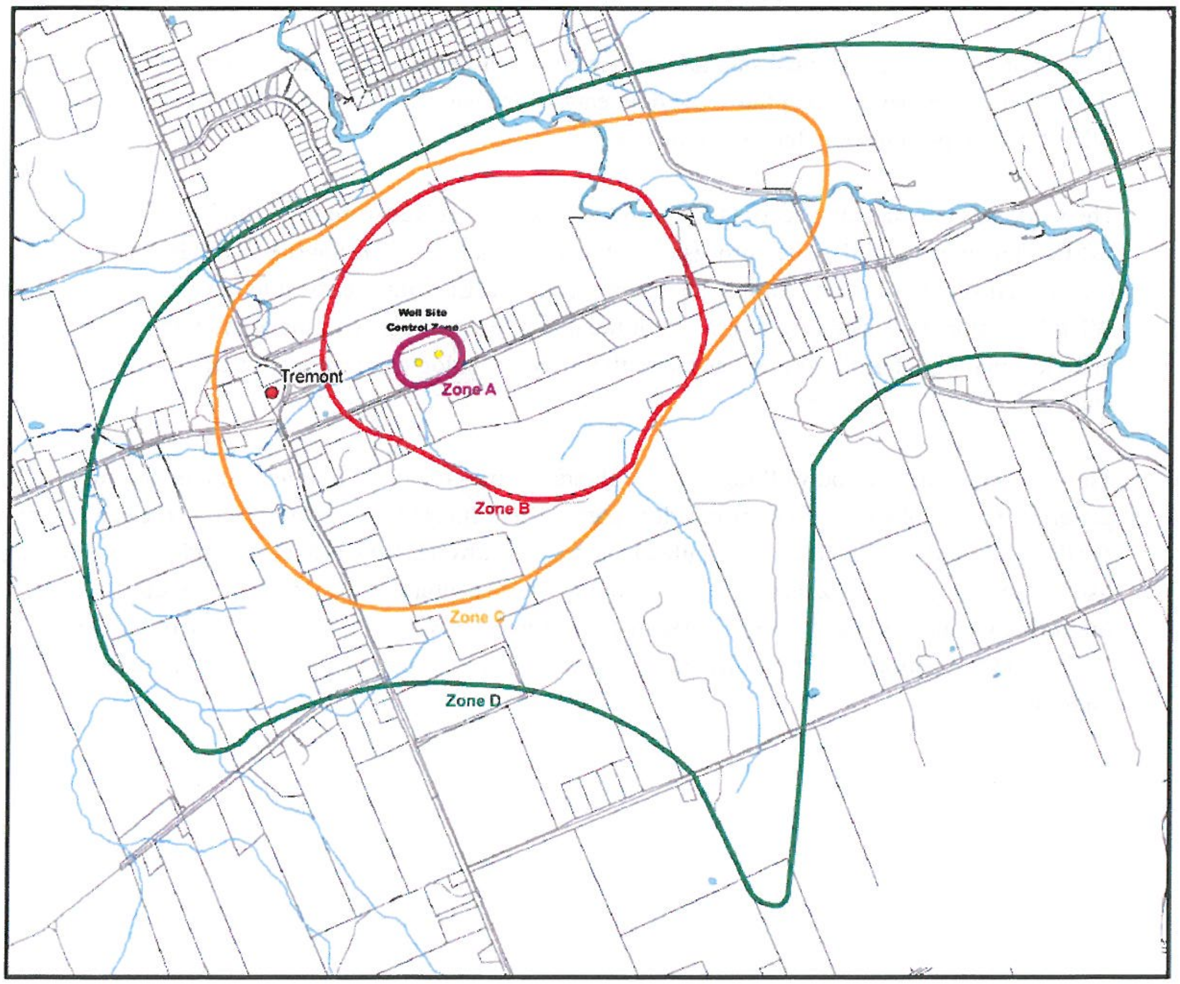
The groundwater flow model was calibrated to conform to expected patterns of groundwater flow and output from a regional model of groundwater flow in the Annapolis Valley. Water budget and infiltration data from the regional model were used as preliminary input for the current model, which was refined according to site specific conditions. Groundwater showed a strong component of flow from the South Mountain toward the Annapolis River, which formed the northern boundary of the model area.

The outwash valley aquifer which supplies the Greenwood well field showed components of flow along the valley axis toward the wells. Additional flow was drawn from the outwash plain to the north, kame complexes to the east and south, and from the underlying bedrock. Under non-pumping conditions, water entered the outwash valley primarily from kame deposits to the south and west of the aquifer, but flow patterns suggest some connection to the underlying Wolfville Formation sandstones. Backward particle tracking suggested that there may be a connection between the outwash valley and the Fales River less than 500 metres to the southeast.

The model was tested under varying conditions to determine the potential for each variable to affect the model output. Groundwater flow patterns were affected most directly by changes in the hydraulic conductivity of the outwash and kame sand units. Changing these properties by a factor of ten produced significantly altered flow patterns and hydraulic head values. The size of the capture zones also responded most strongly when the hydraulic conductivity of the sand units was increased, and when the hydraulic conductivity of all geologic units was increased. Higher hydraulic conductivities resulted in significantly larger capture zones.

The recommended WHP zones were delineated using capture zones generated under conservative conditions identified during the sensitivity analysis. The hydraulic conductivities of the sand units were increased by a factor of 10 beyond expected conditions. The resulting capture zones were two to three times larger than those produced under (expected) base conditions, introducing a factor of safety in WHPA delineation. WHP zones B and C are situated in an area bounded by the Fales River to the north and east, and Tremont Mountain Road to the west. WHP zone D extends toward Greenwood to the north, toward Greenwood Road to the east, just beyond Harmony Road to the south, and beyond Tremont Mountain Road to the west.

Well Head Protection Zones



Chapter 1 **Introduction**

CBCL Limited was contracted in partnership with Terry W. Hennigar WATER Consulting to develop a numerical groundwater flow model for the Village of Greenwood well field to determine the capture zones of the two municipal production wells currently supplying Greenwood. The identified capture zones were used as the technical basis for the delineation of a wellhead protection area (WHPA). The WHPA is divided into zones; each zone is defined according the amount of time it takes for groundwater to travel from the edge of the zone to the pumping well. The groundwater model defines these zones using backward particle tracking, a simulation of a conservative tracer moving through the groundwater away from the well along the groundwater flow path to the recharge area for the well.

This report provides a technical summary of groundwater model construction, development, testing, groundwater flow patterns, capture zone delineation, and sensitivity testing. A land use inventory and WHPP will be presented under a separate cover.

The work was conducted in accordance with the Nova Scotia Department of Environment and Labour's (NSEL) recommended five-step process for Developing a Municipal Source Water Protection Plan. The use of WHPA zones is the recommended approach by NSEL, and is critical to developing an appropriate WHPP. Factors to consider as indicators of the threat to the integrity of the aquifer and water quality include a number of attributes associated with the hydrogeology and characteristics of the wells as well as land use activities in the area.

The Village of Greenwood well field was evaluated in the context of regional and local groundwater flow patterns. By establishing groundwater flow patterns and fluxes throughout the area, the catchment area for the well field was determined. Finite elements groundwater flow modelling and particle tracking were used to delineate capture zones for the well field. These capture zones were used together with preliminary land use observations to establish a preliminary WHPA. The WHPA will be used to initiate Well Head Protection Planning activities to ensure long term security for the drinking water supply in Greenwood.

Chapter 2 **Physical Setting**

2.1 Physiography

The study area is centred on the Greenwood well field, extending 9 km to the west and 13 km to the east of the well field, meeting the Annapolis River to the north and extending several kilometres to the south onto the South Mountain (Figure 2.1). The study area limits and model boundaries were defined according to assumed shallow groundwater flow divides as indicated by watershed mapping. The west, east, and south boundaries coincide with sub-watershed boundaries, and the north boundary is defined by the Annapolis River. Portions of the western and southern boundaries traverse watershed boundaries to avoid including an unnecessarily large study area to the west and south.

The South Mountain dips from 200 metres above mean sea level (m ASL) at South Tremont to the valley floor at 15 m ASL. Kame complexes lining the foot of the south mountain generate a rolling, hummocky ground surface which gives way to level ground on the outwash plain of the Annapolis River. The Greenwood Well Field is located at the foot of the South Mountain at approximately 30 m ASL. Water courses originate as incised valleys traversing the South Mountain before reaching the valley plain and turning to the west along the valley axis, eventually discharging to the Annapolis River. The Annapolis River forms the central drainage course through this part of the Valley, exhibiting frequent meander loops as it passes to the north of Greenwood, receiving inflow from Zeke Brook in the east part of the study area, the Fales River near the CFB Greenwood Airport, and the Black River further downstream. Site features are shown in an aerial photo of the site on Figure 2.2.

2.2 Regional Geology

2.2.1 Surficial Geology

Surface soils in the study area are defined primarily by quaternary deposits of the Chignecto Ice Phase of the most recent glacial advance and subsequent retreat. The thickness of glacial deposits in the central part of the valley is typically 15 to 20 m, reaching up to 35 m near the river and thinning to less than five metres on the slope of the South Mountain. The surficial geology of the Greenwood area was described after Trescott (1968), and Cann and MacDougal (1965). Surface soils in the centre of the study area, including Greenwood, Kingston Village, and stretches along the Annapolis River from Greenwood Square to South Farmington, consist of outwash sand, in some areas overlying limited deposits of till. The outwash plane in the Greenwood area exhibits significant thicknesses of sand and gravel consistent with glaciofluvial deposition.

The margin of the South Mountain is mapped as kames and kame complexes. The amount of flowing water in environments where kame deposits occur varies, and effects the degree of sorting of material deposited. The hydraulic conductivity of kame deposits can vary from low in the case of poorly sorted silt and sand, to moderate or high in the case of well sorted stratified sand and gravel. Examples of well sorted stratified sand and gravel kame deposits are numerous in the study area. Several aggregate operations have been established in the study area to exploit these deposits.

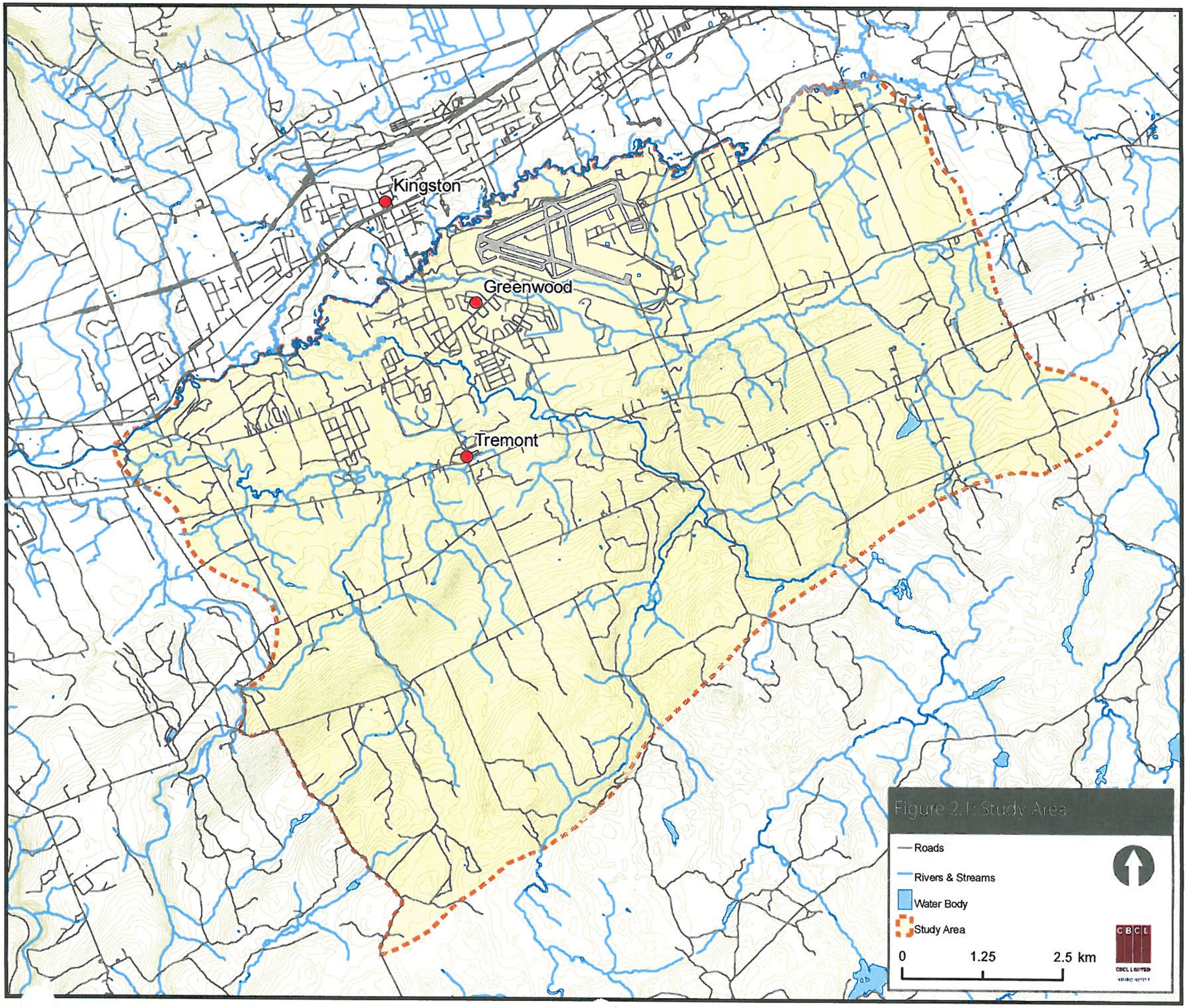

Kingston
Greenwood
Tremont
Figure 2.1: Study Area
Roads
Rivers & Streams
Water Body
Study Area
0
1.25
2.5 km
CBCL
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Figure 2.2: Wellfield & Vicinity
Wellfield
Tremont
Roads
Production Wells
Rivers & Streams
Water Body
Property Boundaries
0
0.15
0.3 km
CBCL
CBCL LIMITED

There are two outwash valleys within the study area which were mapped as part of the model domain. These features were formed as glaciers moved through existing linear depressions on the bedrock floor of the valley and then receded, carving out local valley features. Subsequent melt water filled these valleys with stratified, well sorted sand and gravel. A well stratified sand unit overlies a gravel unit in the outwash valley in the southwest part of the study area. This southwest outwash valley forms the aquifer which is the focus of this study.

Minor features in the study area include an exposed sandstone knob extending along the valley axis from South Greenwood to Millville, and smaller kame deposits between this feature and the Annapolis River. The northern part of the study area is covered predominantly by glacial till. The Annapolis River and associated modern floodplain occupy a 100 to 400 m band through the centre of the valley. The floodplain substrate consists of modern stream alluvium and outwash sands.

2.2.2 Bedrock Geology

The bedrock geology of the study area is described after Smitheringale (1959) and MacDonald and Ham (1994). Contacts between each formation occur from southwest to northeast along the valley axis. The Wolfville Formation comprises the base rock of the valley floor. Beds of sandstone, conglomerate, and siltstone occur as discontinuous, lenticular bodies throughout this geologic sequence. The thickness of the Wolfville Formation increases from 100 m at the well field and reaches up to 500 metres under the Annapolis River. The Wolfville Formation dips to the northwest at an angle of three to seven degrees, increasing in thickness from southeast to northwest.

Shale, siltstone, and quartzite of the lower paleozoic are present as part of the South Mountain in the study area. The Wolfville Formation overlies Halifax Formation slates and siltstones on the valley plane and in the well field area. The South Mountain is formed primarily by quartz monzonite and granodiorite of the South Mountain Batholith.

2.3 Regional Hydrogeology

Groundwater flow in the valley is discussed below in terms of four major hydrostratigraphic units (HU), corresponding to the major geologic units of the study area. The HUs is defined as:

1) The Quaternary HU (all unconsolidated glacial deposits and Holocene soils)
2) The Wolfville HU – higher producing interbedded sandstone, shales, and conglomerates
3) The Meguma HU – primarily slates of the Halifax Formation
4) The South Mountain HU – granite of the South Mountain Batholith

Groundwater flow in the valley is dominated by the regional topography, directing drainage down the valley slopes and into the valley plain where groundwater discharges to the Annapolis River or flows to the southwest as regional flow. Surface soil thicknesses tend to be lesser on the valley sides, providing varying degrees of confinement according to the proportion of fine material in the deposits. The valley floor typically exhibits thicknesses of over 15 m of Quaternary materials, often comprised of sand mixed with silt and clay or sandy till. Un-confined to semi-confined conditions thus predominate in the study area. Outwash, kame and esker gravel features comprise both unconfined to semi-confined aquifers in isolated parts of the study area, providing water of good quantity and quality (private wells obtain water from sand and gravel deposits throughout the valley plain). In many parts of the Annapolis Valley, Quaternary deposits have proven to be very good aquifers supplying groundwater of excellent quality to municipal water systems, industry, and agricultural users. The mean hydraulic conductivity of wells in unconsolidated deposits is 3 x 10^{-4} m/s (Rivard *et al.*, 2006). Unconfined aquifers exhibit the greatest vulnerability to potential contaminants. The degree of infiltration and thereby recharge to regional groundwater flow depends to a great extent on the distribution of surface soils in the study area.

The Wolfville HU is the most significant and widely exploited aquifer in the valley, supplying water of generally good quality in large quantities to domestic, municipal, industrial and agricultural users along the valley floor. The Wolfville HU occurs as beds of sedimentary rock, deposited in upward fining cycles as alluvial fans, fluvial floodplains, and shallow lacustrine dunes or playa environments (Rivard *et al.*, 2006). These beds range in thickness from two to ten metres and can extend laterally from 15 to 90 metres (Klein, 1962). Northeast trending faults have been suggested by Greenough (1995). Alternating beds of lower and higher hydraulic conductivity introduce an element of aquifer-aquitard interaction, producing artesian conditions in many of the lower conglomerate units of the Wolfville HU. The high siltstone and shale contents in the upper sequences of the Wolfville HU have been reported to produce semi-confining conditions in the lower Wolfville sandstone and conglomerate. Owing to the variable thickness and lateral extent of major water bearing strata, yields vary significantly across the valley floor, and wells need to be installed to site specific depths to obtain optimal yields. The mean hydraulic conductivity of the Wolfville HU was 6.6 x 10^{-6} m/s, ranging from 10^{-9} to 10^{-3} m/s (Rivard *et al.*, 2006). Borehole geophysics showed a layered structure suggestive of significantly anisotropic conditions with $K_{horiz} >> K_{vert}$ (Rivard *et al.*, 2006).

The South Mountain HU and Meguma HU comprise the bedrock in the southern part of the study area, and the basement rock underlying the Wolfville Formation. Low porosities and poorly connected fracture networks are cited in explaining the low observed hydraulic conductivities of these units. In general, drilled wells completed in the South Mountain HU presently have satisfactory yields for single family dwellings, although the potential for small central and institutional groundwater supplies located in the bedrock HU is limited. The mean hydraulic conductivity is in the 10^{-6} to 10^{-7} m/s range (Rivard *et al.*, 2006).

2.4 Pumping Well Data

Pumping wells GW8 and GW13 were drilled to 23.8 metres below grade (mbg) and 27.1 mbg respectively. A five metre thick sequence of sandy silt forms a semi-confining layer over the sand and gravel aquifer. The upper part of the aquifer is described primarily as sand, extending to a depth of 15 to 20 mbg. The gravel content increased significantly at 20 mbg, indicating the presence of a deeper high permeability zone. Well screens were placed over the most productive interval of gravel, near the base of each borehole.

Pumping test transmissivities were in the range 492 to 775 m^2/day (NSEL, 2006). Drawdown curves were reported to exhibit semi-confined to unconfined behaviour, showing early Theis response followed by steady state conditions. Using the screened interval to represent the aquifer thickness, the approximate hydraulic conductivity measured at GW13 is 3.0×10^{-3} m/s. Well performance data are shown in Table 1.1.

Table 1.1
Well Performance Data, Greenwood Well Field

Well ID	Well Diameter (mm)	Screen Interval (mbg)	Casing Depth (mbg)	Storativity	Transmissivity (m^2/d)	Safe Yield Pumping Rate (L/min)
GW8	254	15.2-23.5	18.6	10^{-1} to 10^{-3}	492	532
GW13	254	22.9-25.9	24.4	10^{-1} to 10^{-3}	775	591

The average demand for water in Greenwood varied from an average of 420 L/min in 2005 to 560 L/min from January 2006 to July 2007, with peak demands reaching up to 1,378 L/min during the summer months. The combined capacity of the well field was estimated to be 1,545 L/min (2,225 m^3/day) at peak demand, and 1,123 L/min (1617 m^3/day) under long-term sustainable use. The Production well characteristics are summarized in Table 1.2.

Table 1.2
Production Well Characteristics, Greenwood Well Field

Well ID	Northing	Easting	PID	TOC Elevation (m ASL)	Borehole Depth (m)	Max Capacity (m^3/day)	Date Drilled	Driller
GW8	4979744	348091	5182951	35.1	23.8	818	30-Apr-90	W&R
GW13	4978709	337670	5180187	34.0	27.1	1407	10-Jun-04	Valley Well

A study by AMEC (2007) concluded that the Greenwood well field draws Groundwater Under the Direct Influence (GUDI) of surface water. The capture of near-surface water by the Greenwood well field implies an immediate vulnerability to contaminants released at the ground surface, emphasizing the need for adequate protection of the well heads and surrounding capture zones.

Chapter 3 **Model Construction**

Groundwater flow patterns in the study area were investigated through development of a comprehensive three dimensional numerical model. Model development, calibration, and sensitivity testing were completed in order to generate the recommended WHP zones.

The model incorporates sources of input, flow boundaries, and aquifer/aquitard properties to generate a distribution of hydraulic head throughout the study area. Groundwater fluxes to and from surface water, and in and out of the model domain were calibrated to satisfy an overall water balance for the study area. The model output was used to test the sensitivity of key input parameters such as hydraulic conductivity and porosity. The effects of pumping on groundwater flow patterns were simulated within the model, using backward particle tracking to generate capture zones.

3.1 Model Software

The software selected for the current investigation was FEFLOW 5.2, a three-dimensional finite element package for simulating subsurface flow and transport. Finite elements calculations allow for efficient handling of large data sets (current model contains over 135 000 mesh elements), and for simulation of variably saturated conditions. This is particularly helpful in obtaining model convergence with a freely moving water table. FEFLOW was used previously to generate a regional model of the Annapolis Valley (Rivard *et al.,* 2006); continued use of this software for the site-specific model allowed for incorporation of existing regional model data, greatly reducing the time needed for collection of additional data.

3.2 Regional Model

A regional study of the Annapolis-Cornwallis Valley aquifers (ACVAS) was completed by the Geological Survey of Canada. The study included development of a regional groundwater flow model using FEFLOW. The model was calibrated to regional groundwater flow patterns and helped to establish a water budget for the valley as a whole. Input for the model was drawn from many sources, including the provincial water well database, the provincial pumping test database, borehole records, and new boreholes. A thorough assessment of infiltration rates was made, testing and comparing several methods in the process. The model geology was drawn from provincial mapping and borehole records, assigning hydraulic properties according to pumping test data. The model achieved calibration to regional groundwater flow patterns and produced a reliable water budget for the Annapolis Valley. Calibrated infiltration rates served as a key starting point for the site-specific model.

3.3 Site Specific Model

A boundary for the study area was defined according to sub-watershed divides to the west, east and south of the Greenwood well field, and along the Annapolis River to the north (the southern boundary intersects the Black River Watershed at one location; see Figure 2.1). The study area boundary was used as the model domain for the site-specific model of groundwater flow. Where possible and appropriate, data from the regional model was used as input data, helping to define the boundary conditions of the site-specific model. A significant portion of the model input was assigned using site-specific data and information drawn from sources describing the Greenwood area. The level of detail in model features increased from the regional model to the site-specific model, improving the resolution of model output for the definition of key features such as the outwash valley aquifer and associated capture zones.

3.3.1 Conceptual Model

The model domain is a 102 km^2 area centred on the Greenwood well field. The ground surface descends in terraces along the South Mountain, toward the broad outwash plain of the Annapolis River, forming one half of the U-shaped Annapolis Valley. The model was constructed by creating a frame of "superelements" around the model boundary and along the major water courses. The Meshbuilder module of FEFLOW was then used to construct a finite element mesh across the model area. The mesh serves to subdivide the model domain into individual triangular elements. Each element was assigned information on the flow properties, boundary conditions, and upon completion of the simulation, hydraulic head and flow data. The mesh was refined where significant features such as rivers, creeks, wells, and other boundary conditions were encountered. This mesh forms the basis for all data control points within the model domain. The elements were automatically extended into three dimensions as each geologic layer was built, expanding each triangular element into a six-node prism. Figure 3.1 shows the 3D finite element mesh, including the model layers as shown on cross-section A-A'.

The model contains six layers descending from the ground surface to the model basement:

1) Surface Soils Layer
2) Sand Layer
3) Gravel Layer
4) Wolfville Formation Sandstone and Conglomerate
5) Meguma Formation Slates
6) South Mountain Granite

The Wolfville Formation is not continuous across the model domain. In areas where the Wolfville Formations is absent, the layer thickness was set to 0.1 m, and the layer was assigned the hydraulic conductivity of the adjacent layer. The sequence of bedrock units was defined according to provincial mapping for the Greenwood area and using a strike angle of 7° (Hamblin, 2004; Smitheringale, 1959). Figure 3.2 shows the model area and sequence of geologic formations.

Layers 1 to 3 represent quaternary deposits that were further subdivided according to provincial mapping:

1) Surface Soils
    a. Sandy Silt
    b. Alluvium
    c. Till
2) Sand
    a. Kame Sand
    b. Outwash Sand
    c. Till
3) Gravel Layer
    a. Gravel
    b. Till

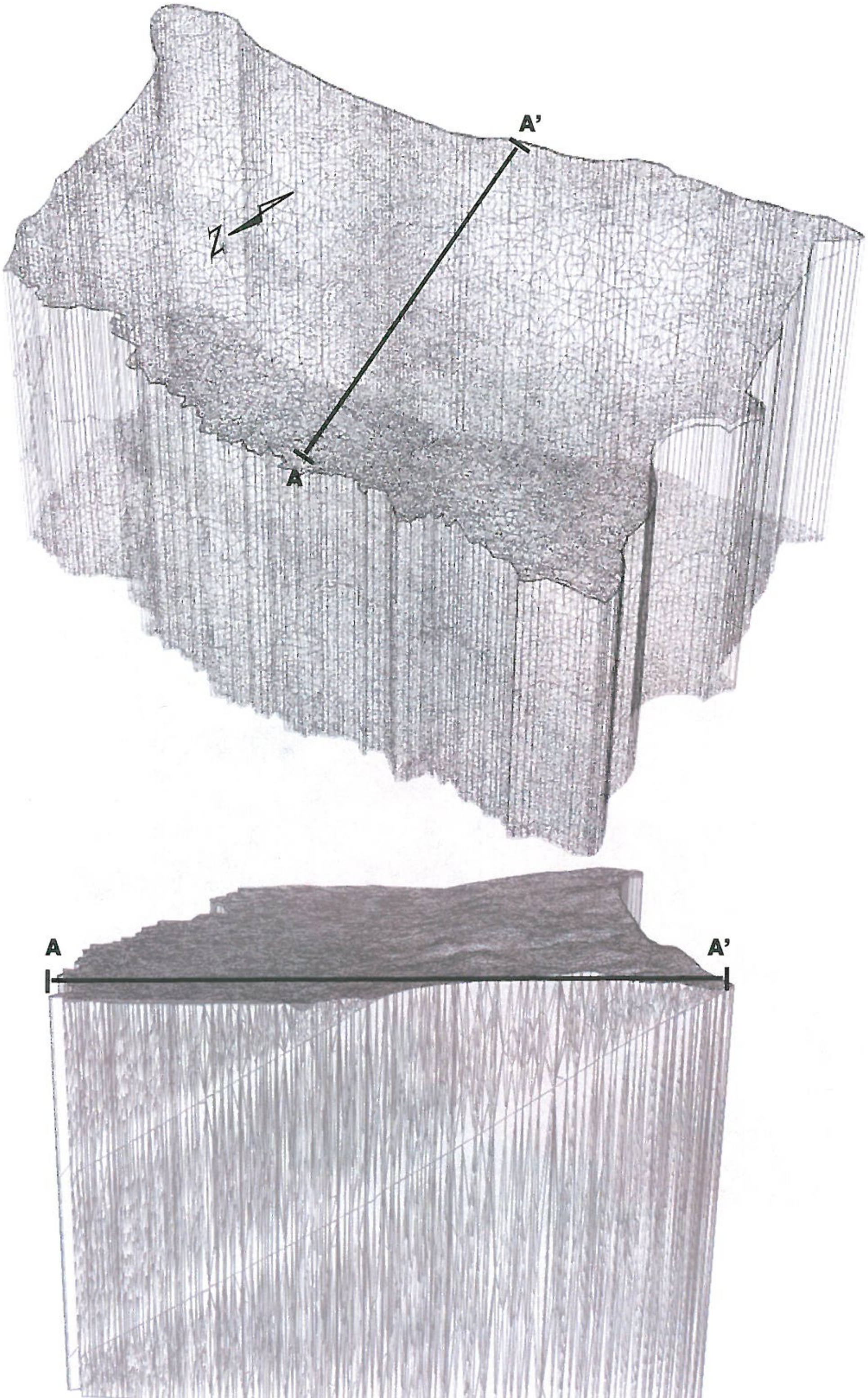

FIGURE 3.1	Finite Element Mesh	12/07/07	Greenwood Capture Zone Modelling	CBCL LIMITED Consulting Engineers

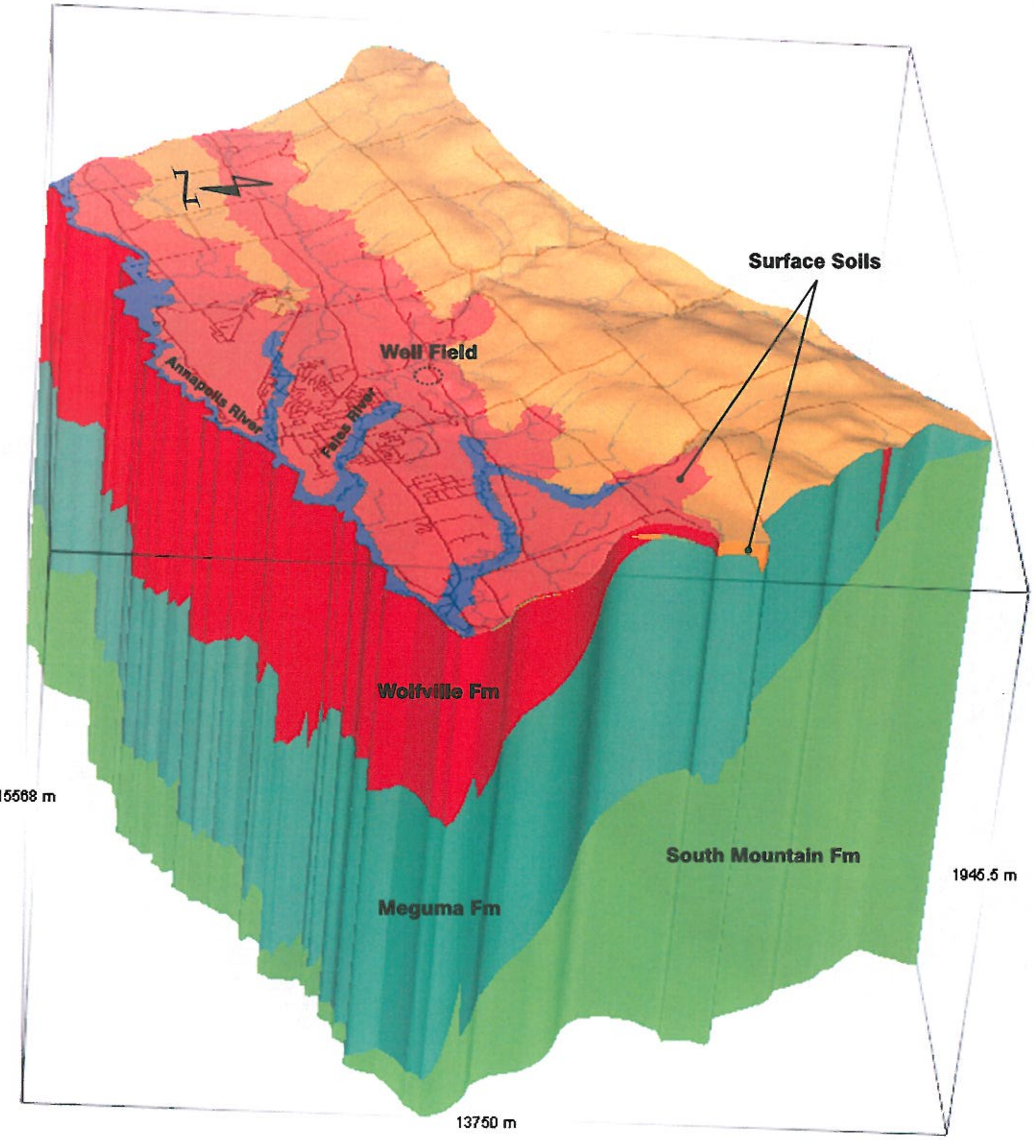

FIGURE 3.2	**Conceptual Model**	**12/07/07**	**Greenwood Capture Zone Modelling**

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The extent of each sub-class of soils was defined according to existing mapping. The thickness of each quaternary unit was determined according to borehole data from the provincial well logs database. Isopach mapping of saturated sand and gravel units was used to further refine the extent of outwash valleys (Trescott, 1968).

3.3.2 Model Input

Infiltration

The surface soil thickness and permeability vary throughout the model domain. Infiltration rates were assigned according to four predominant soil classes across the model domain: Outwash Sand, Kame Sand, Till, and Stream Alluvium. Infiltration data were generated based on the results of the regional model, data from Trescott (1968), and soils mapping (Cann and MacDougal, 1965). For the regional model, upper and lower limits for recharge values were calculated using the corrected water balance method (Rivard *et al.*, 2006). To satisfy the regional water balance of the model, the lower limits of recharge values were generally required. Table 3.1 summarizes the input infiltration values for each soil type.

Table 3.1
Infiltration Rates Defined by Water Balance Method and Surface Soil Mapping

Soil Type	Mean Potential Recharge	
	mm/year	m/day x 10^{-4}
Alluvium	50	1.37
Till	100	2.74
Kame Sand	200	5.48
Outwash Sand	300	8.22

Material Properties

The hydraulic conductivity of each formation was assigned based on data collated from the provincial pumping test database, and pumping tests of the Greenwood Well Field, summarized in Table 3.2. Anisotropy of the Wolfville Formation was inferred from existing data sources and borehole geophysics data showing predominant fracture orientation and bedding plane characteristics (Rivard *et al.*, 2006). Modelled anisotropy values are shown on Table 3.2.

Table 3.2
Measured and Modelled Hydraulic Conductivity Values

Layer	Formation		Kxy mean[1] (m/s)	Kxy modelled (m/s)	Anisotropy modelled
1	Surface Soils	Silt	1.0×10^{-6} to 6.9×10^{-5}	5×10^{-6}	Kz = Kxy
		Alluvium	5.6×10^{-7}	10^{-7}	Kz = Kxy
		Till	2.8×10^{-6} to 6.0×10^{-6}	2.5×10^{-6}	Kz = Kxy
2	Sand	Outwash Sand	2.1×10^{-5} to 3.4×10^{-4}	2×10^{-5}	Kz = Kxy/3
		Kame Sand	1.0×10^{-6} to 6.9×10^{-5}	7×10^{-5}	Kz = Kxy
		Till	2.8×10^{-6} to 6.0×10^{-6}	2.5×10^{-6}	Kz = Kxy
3	Gravel	Outwash Gravel	3.8×10^{-4}	4×10^{-4}	Kz = Kxy
		Till	2.8×10^{-6} to 6.0×10^{-6}	2.5×10^{-6}	
4	Wolfville		3.5×10^{-6} to 5.7×10^{-6}	5×10^{-4}	Kz = Kxy /100
5	Meguma		6.8×10^{-7}	2×10^{-7}	Kz = Kxy
6	South Mountain		1.5×10^{-6}	5×10^{-7}	Kz = Kxy

[1] Field measured values from permeameter testing, grain-size analysis, and pumping tests

Figure 3.3 illustrates the distribution of hydraulic conductivity across the model domain. Fence diagrams from the model interior show the Wolfville Formation (shown in lighter green) underlying quaternary deposits and overlying the Meguma (blue) and South Mountain Formations (darker green). The contact of the Wolfville Formation and underlying Meguma Formation occurs near the margin of the South Mountain. The thickness of the Wolfville increases to the north, reaching a modelled thickness of approximately 500 m in the location of the Annapolis River (thickness shown is based primarily on geological mapping). Quaternary deposits appear as a veneer over the bedrock on Figure 3.3. Fence-sections drawn through the two linear outwash valleys in the model domain show sequences of sand and gravel.

Figure 3.4 shows a detailed fence diagram of the Quaternary deposits in the Greenwood well field area. The buried outwash valley comprises a sequence of silt, sand, and gravel. Sand in the buried outwash valley was assigned the same properties as the surrounding kame complexes. The outwash valley becomes shallower to the west, terminating as it merges with a local, shallow surface water drainage basin which in turn feeds into the Black River to the west. The sequence of material in this local surface water basin consists of modern stream alluvium overlying outwash plain sands and a limited sequence of gravel.

The storativity of each geologic unit was estimated based on available pumping test data as summarized by Trescott (1968), Rivard *et al.* (2006), and data available in the NSEL pumping test database (2006). Measured and modelled storativity data are listed in Table 3.3. The range of observed storativity values was large, introducing a significant feasible range for the model input. Storativity was not a sensitive parameter, as discussed in Chapter 4. The porosity of the sand and gravel aquifer was set to 0.35 for capture zone delineation.

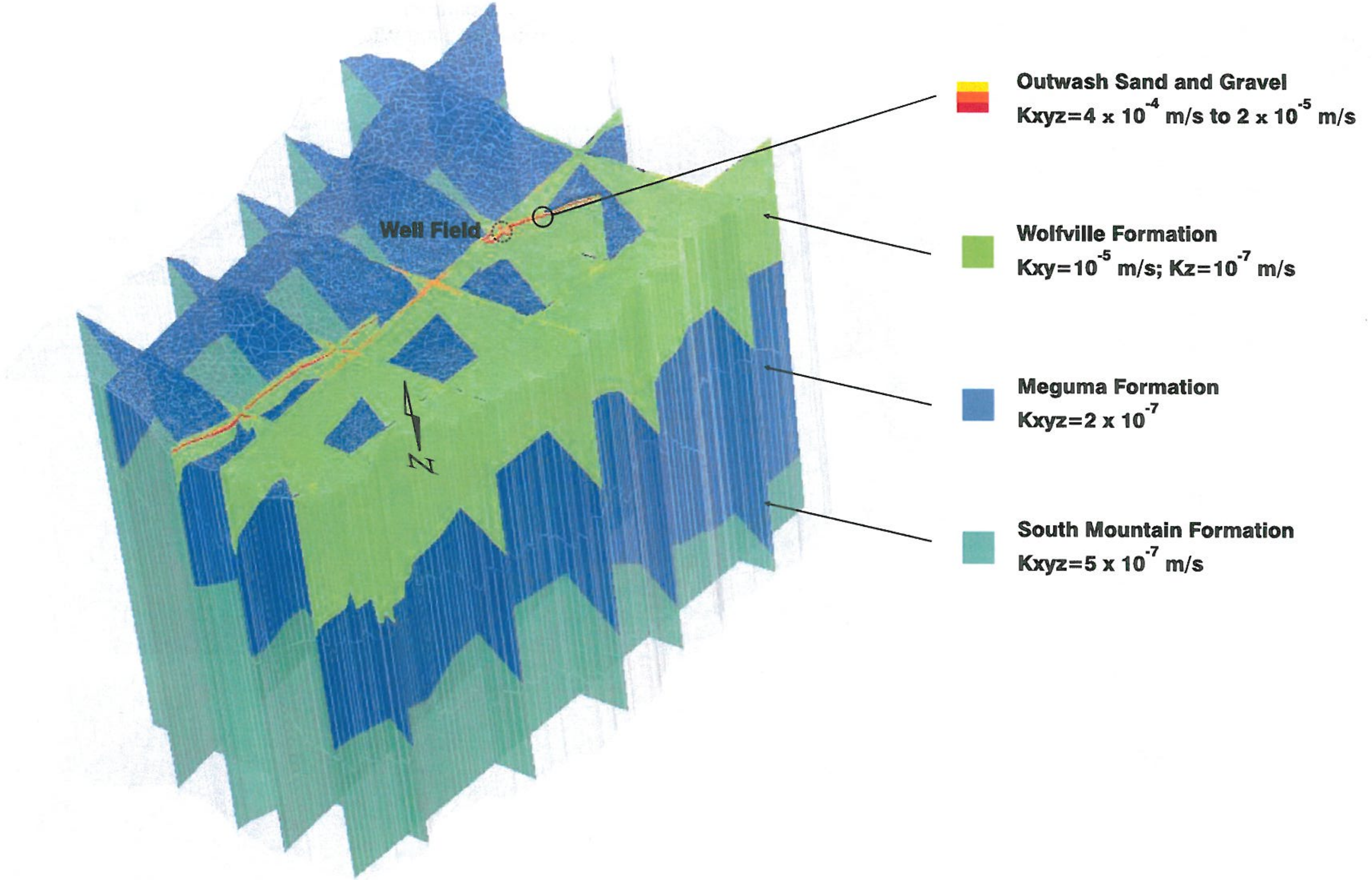

FIGURE 3.3	**Hydraulic Conductivity Distribution: Model Interior**	**12/07/07**	**Greenwood Capture Zone Modelling**

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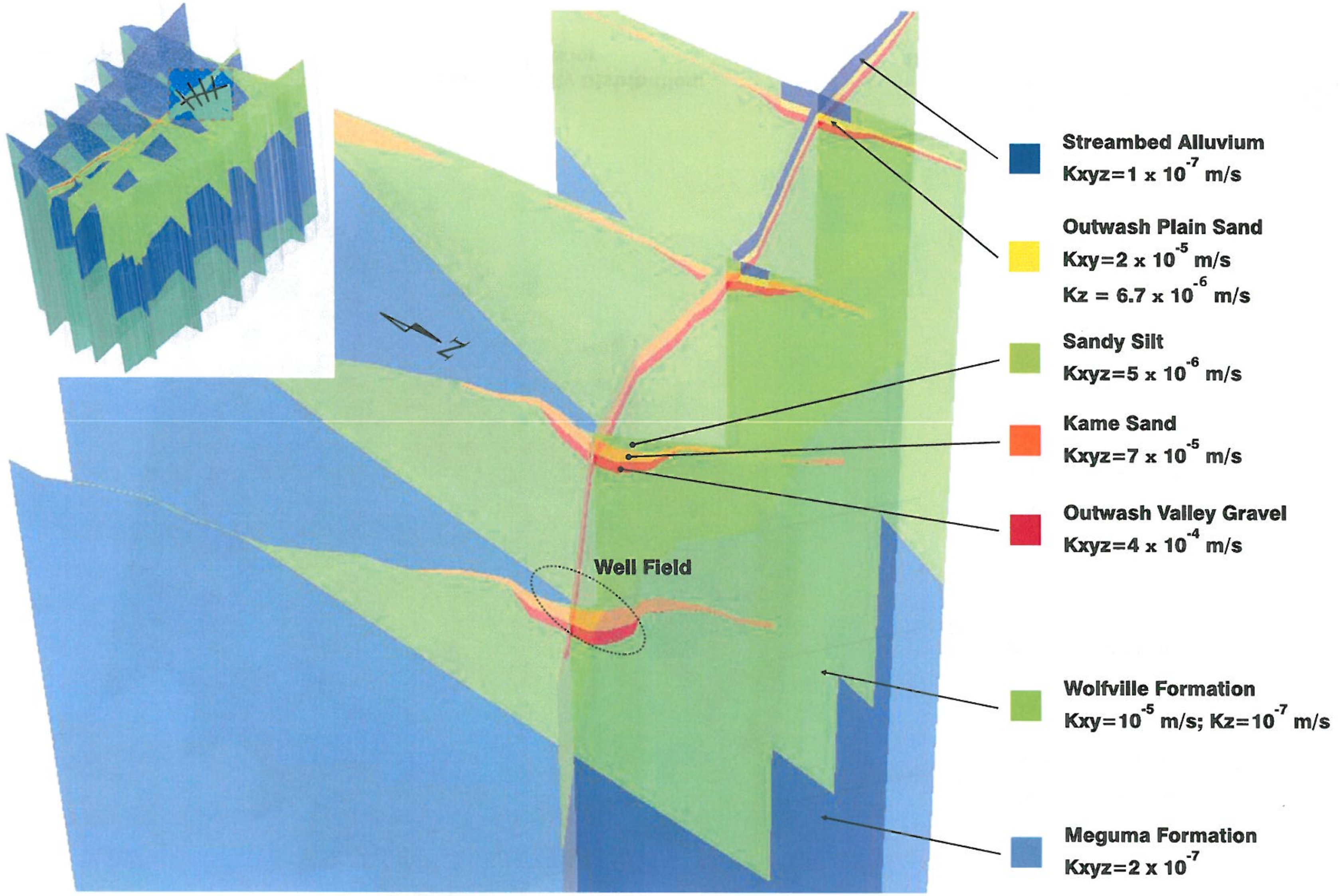

FIGURE 3.4

Hydraulic Conductivity Distribution: Outwash Valley Aquifer

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Table 3.3
Measured and Modelled Storativity Values

Layer	Formation	S observed	S modelled
1	Alluvium	-	0.00001
1	Silt	-	0.0001
1-3	Till	-	0.0001
2	Outwash Sand	0.0003 to 0.036[1]	0.003
2	Kame Sand	0.1 to 0.001[2]	0.001
3	Gravel	0.1 to 0.001[2]	0.003
4	Wolfville	0.0002[3]	0.0002
5	Meguma	0.0001[3]	0.0001
6	South Mountain	0.0001[3]	0.0001

[1] Field measured values (Trescott, 1968)
[2] Field measured values (AMEC, 2003)
[3] Compiled values (Rivard *et al.*, 2006)

Boundary Conditions
A schematic of the boundary condition locations is depicted in Figure 3.5. The flux boundary conditions (2nd type, Neumann) were present over the full thickness of the model but varied in magnitude as discussed below. Transfer boundary conditions (3rd type, Cauchy) were assigned over an appropriate thickness of material according to the size of the water coarse and associated depth of surface-water groundwater interaction. The extraction wells (4th type) are also depicted on Figure 3.4, but were assigned over the thickness of Layers 2 and 3 only (the sand and gravel layers).

A simplifying assumption was made that shallow groundwater flow divides (all flow within unconsolidated deposits) correspond to surface water flow divides in the model domain. No-flow boundary conditions were assigned to the south, west, and east boundaries of the study area over Layers 1 to 3. Data from the regional model suggested that flow from the south through the Meguma and South Mountain Formations was nominal. The Wolfville Formation is absent at the south boundary of the model. As such, the south boundary was assigned as a no-flow boundary over all layers of the model.

Where appropriate, fluxes in and out of the 2nd type model boundaries were assigned to the east and west boundaries of the model. Initial fluxes were assigned based on data from the regional model, and refined through mass balance calculations in the site specific model. Flux boundaries comprised a small percentage of flux for the overall water budget of the site specific model. The fluxes for each unit are summarized in Table 3.4.

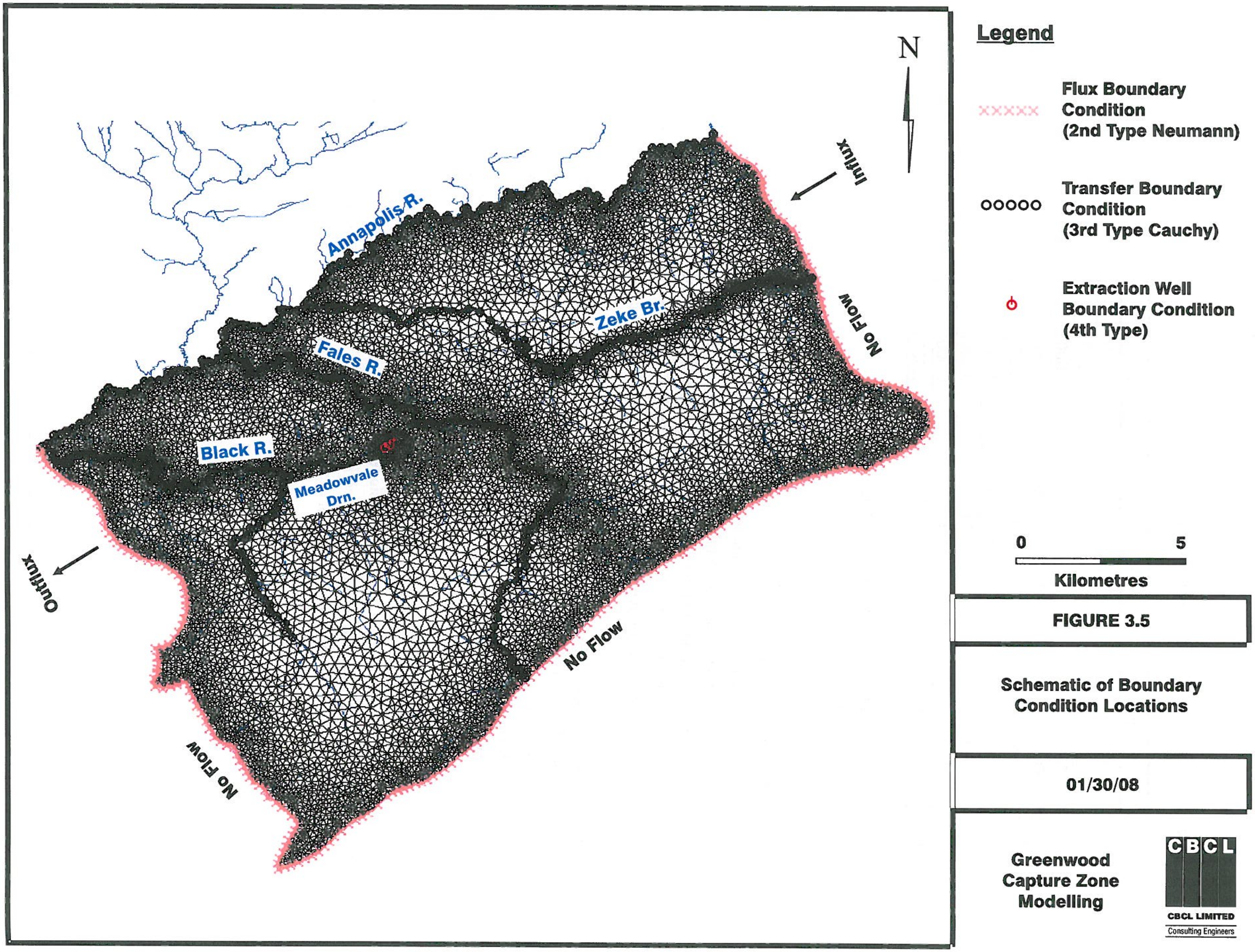

FIGURE 3.5

Schematic of Boundary Condition Locations

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Table 3.4
Modelled Type 2 (Flux) Boundary Conditions

Layer	Formation	East Boundary, north of outwash valleys (m/day)	East Boundary, south of outwash valleys. (m/day)	West Boundary, north of outwash valleys (m/day)	West Boundary, south of outwash valleys (m/day)
1	Surface Soils	0	0	0	0
2	Sand/Till	0	0	0	0
3	Gravel/Till	0	0	0	0
4	Wolfville	0.0001 (out)	0	0	0
5	Meguma	0.0011 (out)	0	0.001 (in)	0
6	South Mountain	0	0	0	0

Transfer boundary conditions were assigned to all rivers and creeks within the model domain. The Annapolis River was the only major river assigned to the model, defined as interacting with the top four layers, including some interaction with the Wolfville Formation sandstone. To improve model stability, the Annapolis River transfer boundary condition was also extended across the full thickness of the Meguma and South Mountain Formations. Discharge from these units to the Annapolis River was prevented by setting the transfer rate to zero (see Table 3.5).

The Black River and Fales River were limited to direct interaction with unconsolidated material only (Layers 1 to 3). Zeke Brook was limited to interaction with the upper two layers of the model, and the Meadowvale Drain was allowed to interact with Layer 1 only. This approach is based roughly on the approach of the ACVAS study, however, further work on surface water – groundwater interaction in the Annapolis Valley would allow for this aspect of the model to be refined. A field survey of surface water flow in the study area was used to define the reaches of smaller water courses to be included in the model. Rivers and brooks were also tested as constant head boundary conditions (1st type, Dirichlet) in calibration runs.

Transfer boundary conditions included a rate of transfer property, defined as the hydraulic conductivity of the colmation layer. The colmation layer is a streambed of nominal thickness which impedes flow between the water course and underlying formation. The rate of transfer for rivers was varied according to the size and influence of each river, listed in Table 3.5. The Annapolis River was assigned the highest rate of transfer, having the greatest interaction with the surrounding formations. The rate of transfer had a significant influence on the model water budget during calibration runs. The rate of transfer was adjusted to satisfy the model water budget, and to incorporate fluxes into and out of the model domain as measured in the regional model.

Table 3.5
Modelled Transfer Rates at Type 3 (Transfer) Boundary Conditions

Watercourse	Transfer Rate (1/day)
Annapolis River[1]	0.0014
Fales River, Black River	0.0007
Zeke Brook, Meadowvale Drain	0.0002

[1]Transfer Rate = 0 for Layers 5 and 6

The Greenwood well field was defined using 4th kind boundary conditions for each of the pumping wells. Pumping wells were assigned across the full thickness of the sand and gravel. Well boundaries are assigned to a single node in FEFLOW, with an assumed nominal borehole radius. Pumping rates were assigned according to the maximum rates sustainable for short-term (30 day) pumping in periods of drought. This maximum use scenario is used to provide conservative capture zones which are viable under any projected water use. The modelled pumping rates were 1407 m^3/day at GW13, and 818 m^3/day at GW8.

Initial head values were based on output from the regional flow model. Groundwater flow patterns in the site specific model were expected to correspond approximately to patterns observed in the regional model. Flow is generally from the South Mountain, discharging to the Annapolis River or joining regional flow through the centre of the valley to the southwest. Local shallow flow lines were expected to interact with the smaller water courses on a limited scale. Outwash valley features were expected to channelize flow to the southwest.

3.3.3 Problem Summary

The completed model contained a total of over 135,000 elements (connected by 80,000 nodes). Model simulations were run at steady state, necessitating only one time step. This condition was intended to simulate long-term, steady pumping conditions. The model was fully saturated, and allowed for a freely moving water table, the final elevation of which was determined by the distribution of hydraulic head in the model at the end of the simulation.

Chapter 4 **Results**

4.1 Calibrations

The numerical model was run in steady-state mode to simulate long-term flow conditions. Because transport processes were not modelled as part of the simulation, transient simulations were not considered relevant to the current investigation. Calibration of the site specific model was a semi-quantitative, iterative process, beginning with base case flow parameters derived from the regional model. Infiltration rates were selected to satisfy the regional water balance, and the remaining parameters adjusted to produce a satisfactory water budget for the site-specific model. Hydraulic head patterns and magnitudes were compared to the regional model, and were examined qualitatively to ensure an adequate fit to local hydrogeological conditions. Increasingly complex conditions were introduced as the model was refined, until the water courses were represented by transfer boundaries, and flux into and out of the model corresponded to flow conditions in the regional model. Colmation layer properties and fluxes into and out of the model were adjusted until the following conditions were satisfied:

- magnitude of hydraulic head in all parts of model were within the expected range, and were in approximate agreement with the regional model;
- patterns of hydraulic head were consistent with hydrogeological conditions, and were in approximate agreement with the regional model;
- fluxes into and out of the model were set to those measured in the regional model;
- the balance of flow exited or entered the model via the transfer boundaries; and
- error in the model water budget was less than 0.1%.

The water budget for the base case is reported in Table A1, Appendix A.

4.2 Model Output

The distribution of hydraulic head in the model output reflected existing knowledge of groundwater flow patterns in the Annapolis Valley. Modelled groundwater flow patterns are shown in the hydraulic head diagrams depicted on Figures 4.1 through 4.5. Figure 4.1 shows (a) head patterns at the ground surface and on the model exterior, with (b) a cut-away view of hydraulic head contour lines centred on the Greenwood well field. The model layers are shown on Figure 4.1(b) coloured according to the hydraulic conductivity of each layer. Head contours in the Wolfville Formation (shown in red on Figure 4.1(b)) show significant components of flow toward the Annapolis River, reflecting the model boundary conditions. Flow patterns throughout the model domain show a southeast to northwest trend.

Figure 4.2 shows hydraulic head patterns in the outwash valley aquifer in the absence of pumping. Figure 4.2(a) shows flow patterns along the axis of the outwash valley and Figure 4.2(b) shows flow patterns as a series of cross-sections through the outwash valley aquifer. Under pre-pumping conditions, groundwater flowed northward from kame complexes at the foot of the South Mountain and intersected the outwash valley aquifer. Some flow entering the deeper intervals of the outwash valley originated in the Wolfville Formation. The high permeability material in the outwash valley captured flow intersecting the valley, redirecting it to the southwest along the valley axis. Much of this flow appeared to discharge to the Black River transfer boundary, and to contribute flow to the west and north in the outwash plain. Discharge into

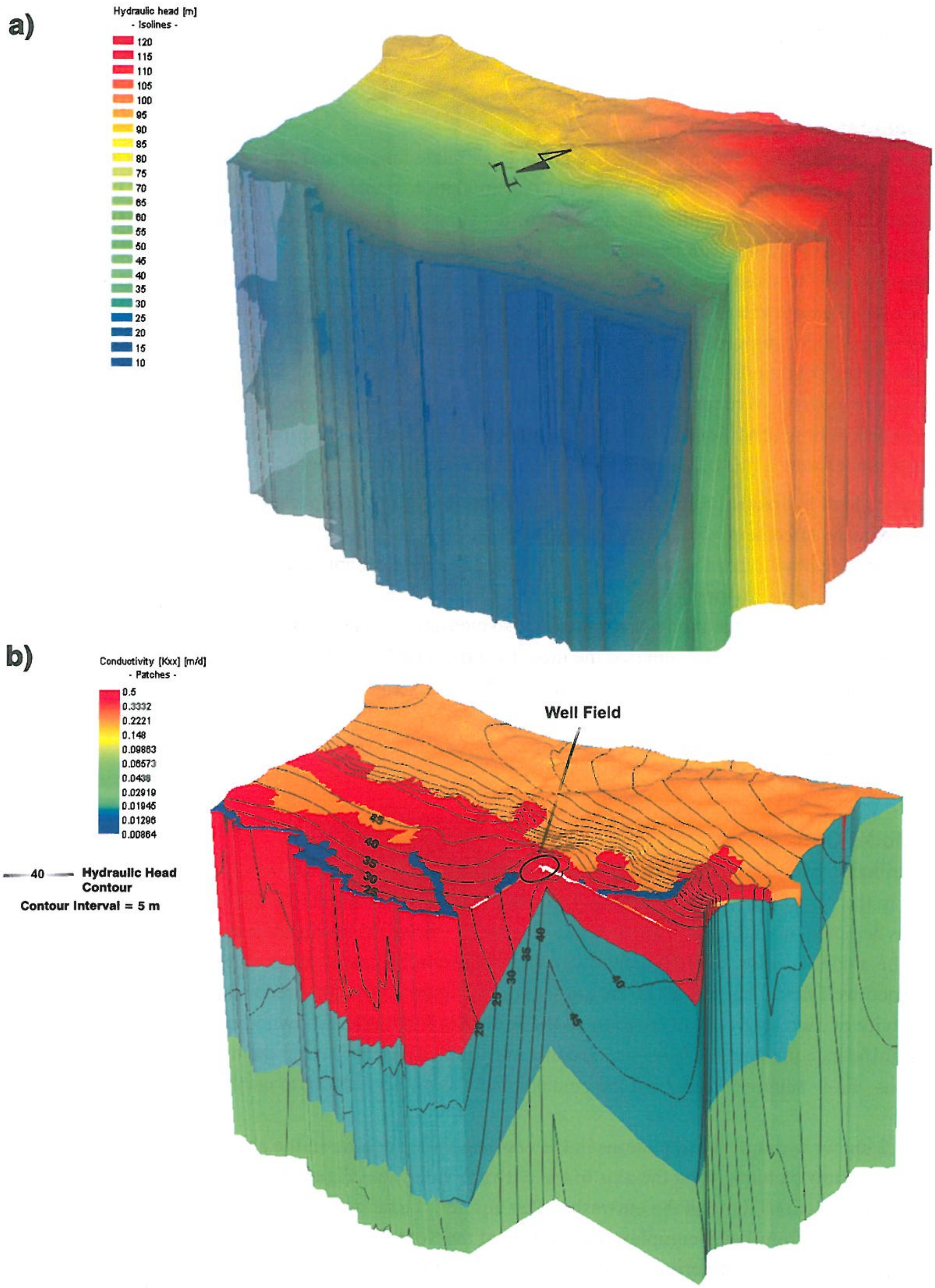

FIGURE 4.1	Hydraulic Head Distribution	12/07/07	Greenwood Capture Zone Modelling	CBCL LIMITED Consulting Engineers

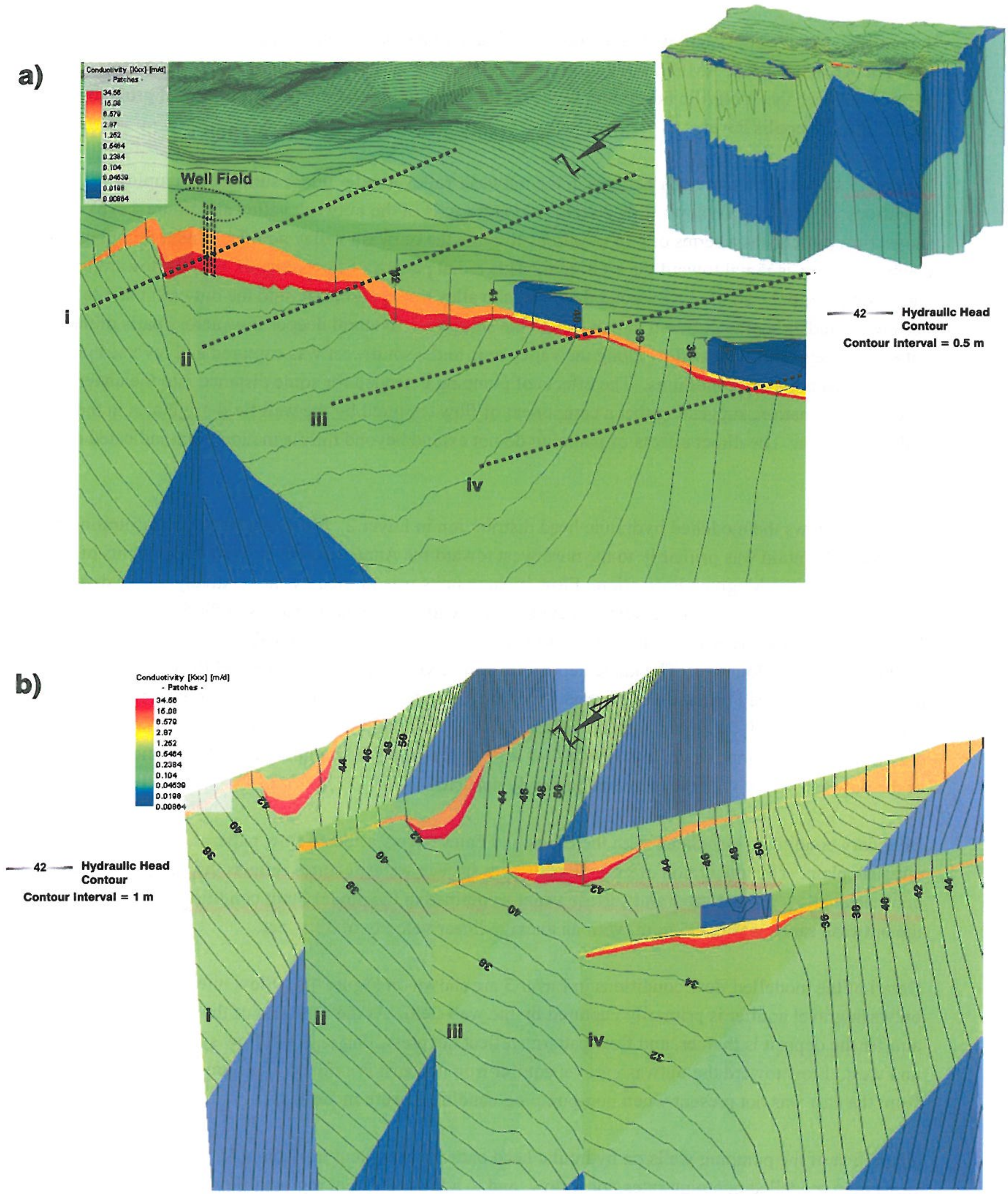

FIGURE 4.2

Hydraulic Head Distribution: Aquifer Detail, Non-Pumping Conditions

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the outwash plain is consistent with Trescott's prediction of a broader outwash deposit associated with this area (Trescott, 1968; AMEC, 2007). Deeper components of flow from the outwash valley also passed back into the Wolfville Formation to the north, contributing to the prevailing flow of groundwater toward the Annapolis River.

Figure 4.3 shows hydraulic head patterns in the outwash valley aquifer under simulated pumping conditions. Figure 4.3(a) shows flow patterns along the axis of the outwash valley and figure 4.3(b) shows flow patterns as a series of cross-sections through the outwash valley aquifer. Under pumping conditions, flow is radial toward the well field. This radial pattern of flow extends outward toward the kame complex to the southeast, beyond the outwash valley to the northeast, into the outwash plain to the northwest, and along the outwash valley axis to the southwest. Natural deeper flow across parts of the outwash valley, and shallow flow along the valley axis to the southwest was captured and reversed under the modelled pumping conditions. The effects of pumping extended for some distance into the underlying Wolfville Formation, suggesting that a component of flow captured by the well field originates in the bedrock aquifer. The direct effects of pumping do not extend beyond the stagnation point indicated on Figure 4.3(a).

Figure 4.4 shows the modelled hydraulic head distribution in Layer 2. Flow originating as infiltration on the South Mountain was primarily to the northwest toward the Annapolis River, with components of flow downward into the Meguma Formation. Flow in these units was limited by the relatively low hydraulic conductivity values. A steeper gradient is evident on the lower, steepest reaches of the South Mountain. This build up in hydraulic head is relieved as flow passes into the more permeable kame deposits at the base of the South Mountain. The kame deposits also receive components of upward flow from the underlying Wolfville Formation. The gradient in the kame deposits varied locally, showing a horizontal gradient of 0.002 to 0.008 m/m, and an average linear velocity of 5 to 18 m/year. Radial flow within the outwash valley (outlined in yellow, Figure 4.4) reflects the modelled pumping conditions, and connection of the outwash valley with the surrounding sandy deposits.

Boundary conditions associated with the Black and Fales Rivers affected flow patterns, particularly on the outwash plain. The interaction of groundwater with surface water features reflects the direct connection between shallow groundwater and surface water as defined in the model input conditions. The gradient in the outwash sands was 0.005 m/m, with an average linear velocity of 3 m/year.

Detail of the modelled flow conditions in Layer 3 are shown on Figure 4.5. Flow intersecting the outwash gravel aquifer is primarily captured by the well field. At the west end of the outwash gravel aquifer the deposit is thinner, and flow patterns reflect the prevailing regional flow system to the north and west. Flow toward the outwash gravel aquifer from the east is evident. This gradient toward the well from the east was not present when non-pumping conditions were modelled.

The effect of the pumping wells on hydraulic head patterns is evident in Figures 4.1 through 4.5. At the maximum modelled pumping rates, local flow, and to a limited extent regional flow from the bedrock, is drawn toward the Greenwood Well Field, creating a local depression in the equipotential surface. The effects of pumping on Layers 2 and 3 indicate that incoming precipitation or other releases at the ground

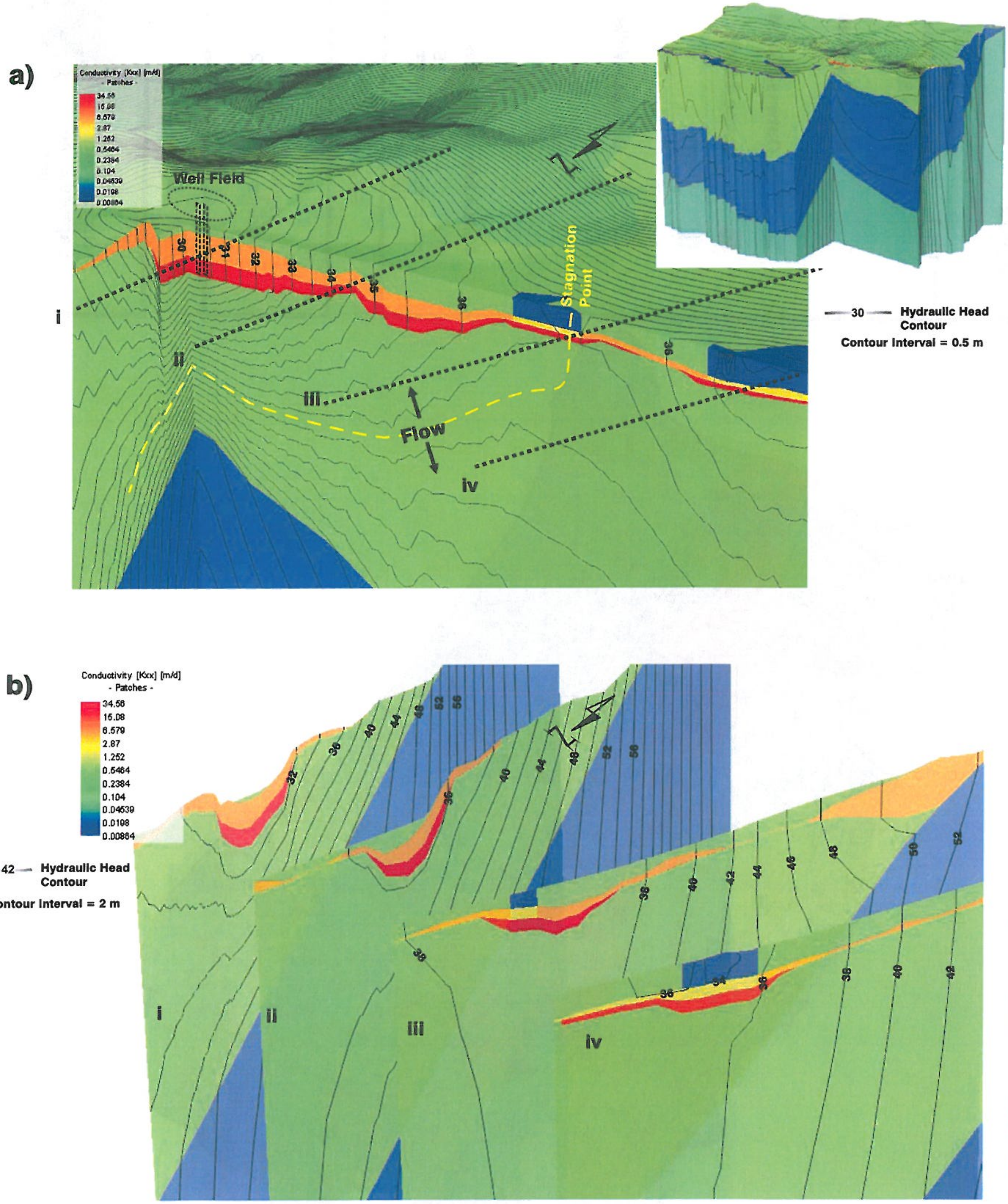
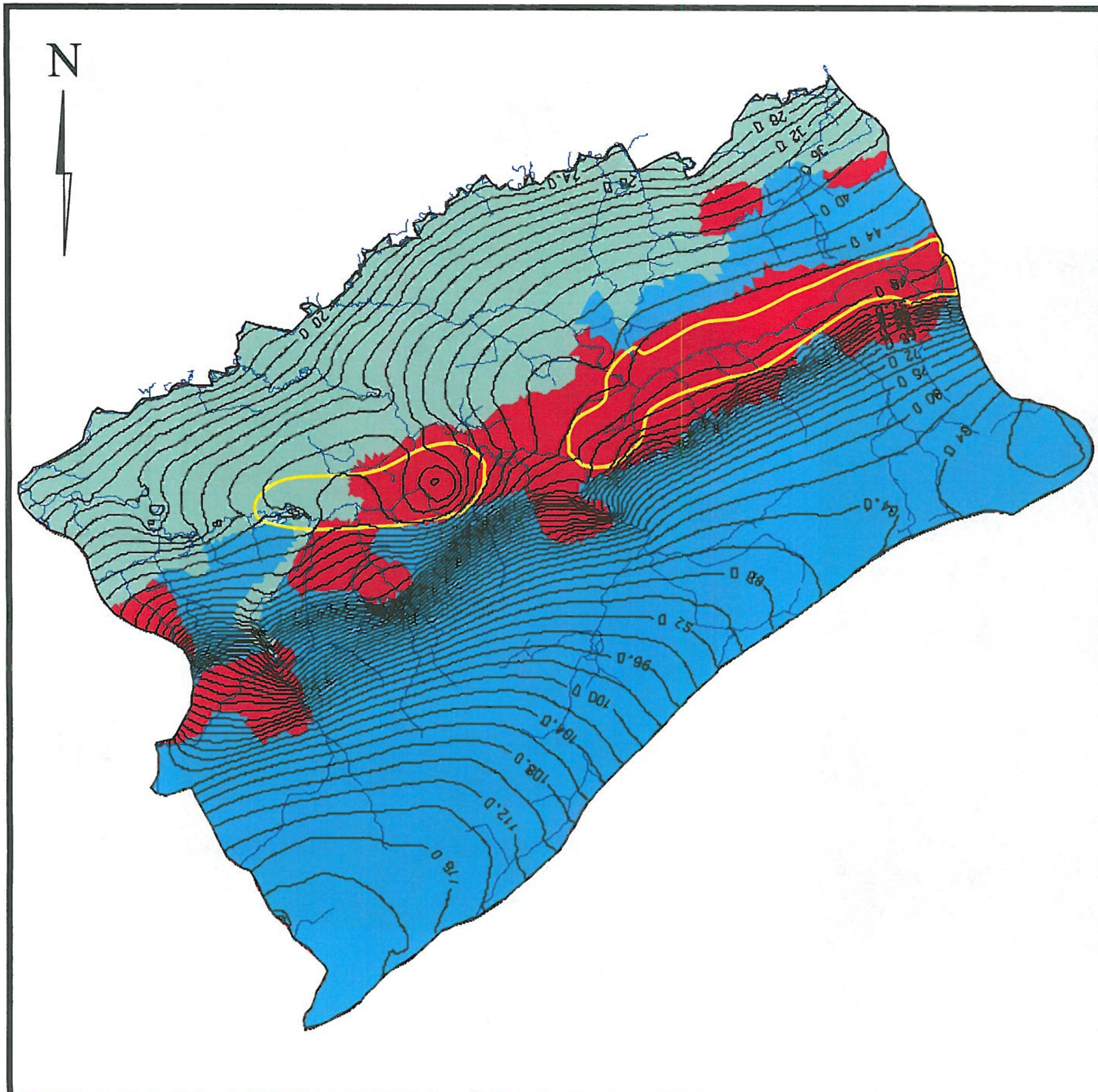


FIGURE 4.3	Hydraulic Head Distribution: Aquifer Detail, Pumping Conditions	12/07/07	Greenwood Capture Zone Modelling — CBCL LIMITED Consulting Engineers



Legend

— 108.0 — Hydraulic Head Contour (m AMSL)

Water Courses

Outwash Sand

Kame Sand

Till

Outwash Valley

Contour Interval = 2 metres

0 5

Kilometres

FIGURE 4.4

Hydraulic Head Contours in Layer 2

01/30/08

Greenwood Capture Zone Modelling

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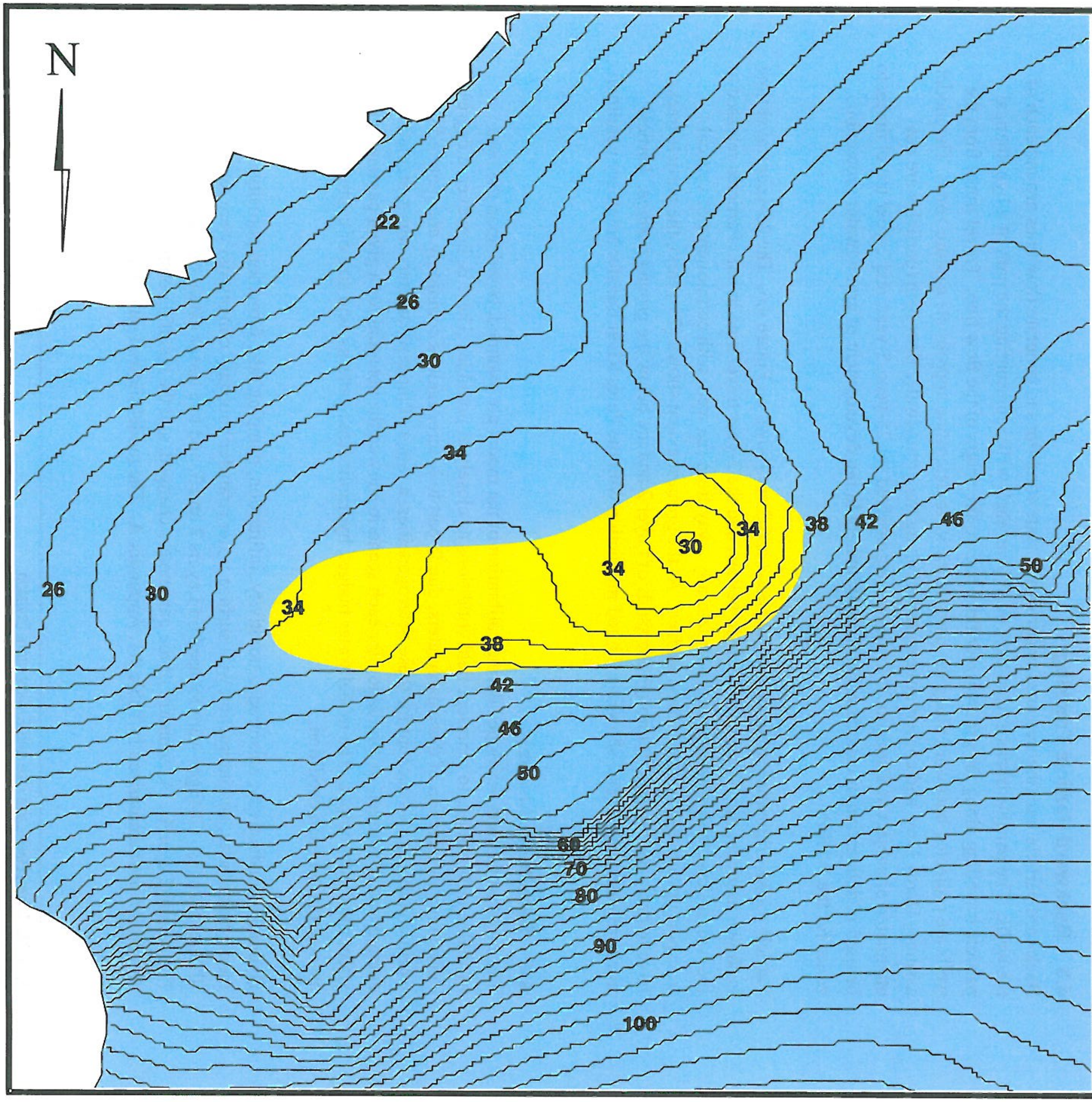

Legend

— 100.0 — Hydraulic Head Contour (m AMSL)

Water Courses

Outwash Gravel

Till

Contour Interval = 2 metres

0 5

Kilometres

FIGURE 4.5

Hydraulic Head Contours in Layer 3: Detail of Outwash Gravel

01/30/08

Greenwood Capture Zone Modelling

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surface close to the Greenwood well field could be drawn downward and captured by the pumping wells. Potential contaminant releases in this zone is a concern, illustrating the need for a WHPA.

The total assigned infiltration across the study area was 44,065 m^3, which accounted for the majority of water inputs to the model. Under pumping conditions, 5% of total infiltration exited the model through wells, and 95% through river boundary conditions. This simulation uses maximum pumping rates at all wells, and is not representative of daily pumping conditions in the study area. The actual amount of water withdrawn is considerably lower, but for the purposes of delineating conservative capture zones, a peak rate of groundwater extraction was used.

4.3 Backward Particle Tracking

Backward particle tracking was used under steady state conditions to generate flow lines around each of the wells. The particle tracks extend backward from each well, representing the path of a hypothetical particle travelling along the groundwater flow path to the origin of the flow line. Travel times from the wells are projected backward along the particle tracks to determine appropriate capture zones. The model assumes Darcy Flow and conservative transport along the groundwater flow path (particles are not attenuated or subject to dispersion). Zones were generated for 25-year, 5-year, and 2-year travel times, to be used in delineation of capture zones, and ultimately in the development of groundwater protection zones for the WHPP.

Particle tracks originating at the base of Layers 2 and 3 are shown on Figure 4.6. The 25-year travel time is shown in green, the 5-year travel time in yellow, and the 2-year travel time in red. Particles released at the well follow a three dimensional path laterally away from the well, with components of vertical transport upward toward the ground surface. At the greatest extent shown (25 years), the particle tracks have traced a path primarily through the sands of Layer 2 and are below the ground surface. Particle tracks released on Layer 2 showed a limited interaction with the Fales River transfer boundary condition.

4.4 Sensitivity Analysis

The input parameters developed during calibration of the model are assumed, based upon the best available information, to represent field conditions as closely as possible. There is, however, a degree of uncertainty in selection of these parameters, due in part to heterogeneities commonly encountered in real world conditions. To account for these heterogeneities, a range of input parameters was systematically entered into the model. A simulation for each scenario showed the potential for a given parameter to affect the model output. The model water budget, hydraulic head patterns, and size of capture zones were assessed under each condition.

Hydraulic conductivity, anisotropy, storativity, infiltration, pumping rate, formation porosity, fluxes at the model boundaries, and interaction with surface water (transfer boundary conditions) were tested at different ranges. Changes were focused on Layers 2 and 3, and to a lesser extent on the Wolfville Formation (Layer 4). A summary of the parameters changed, and the resulting output from the model simulation are summarized in Table A1, Appendix A. The model showed only minor responses to

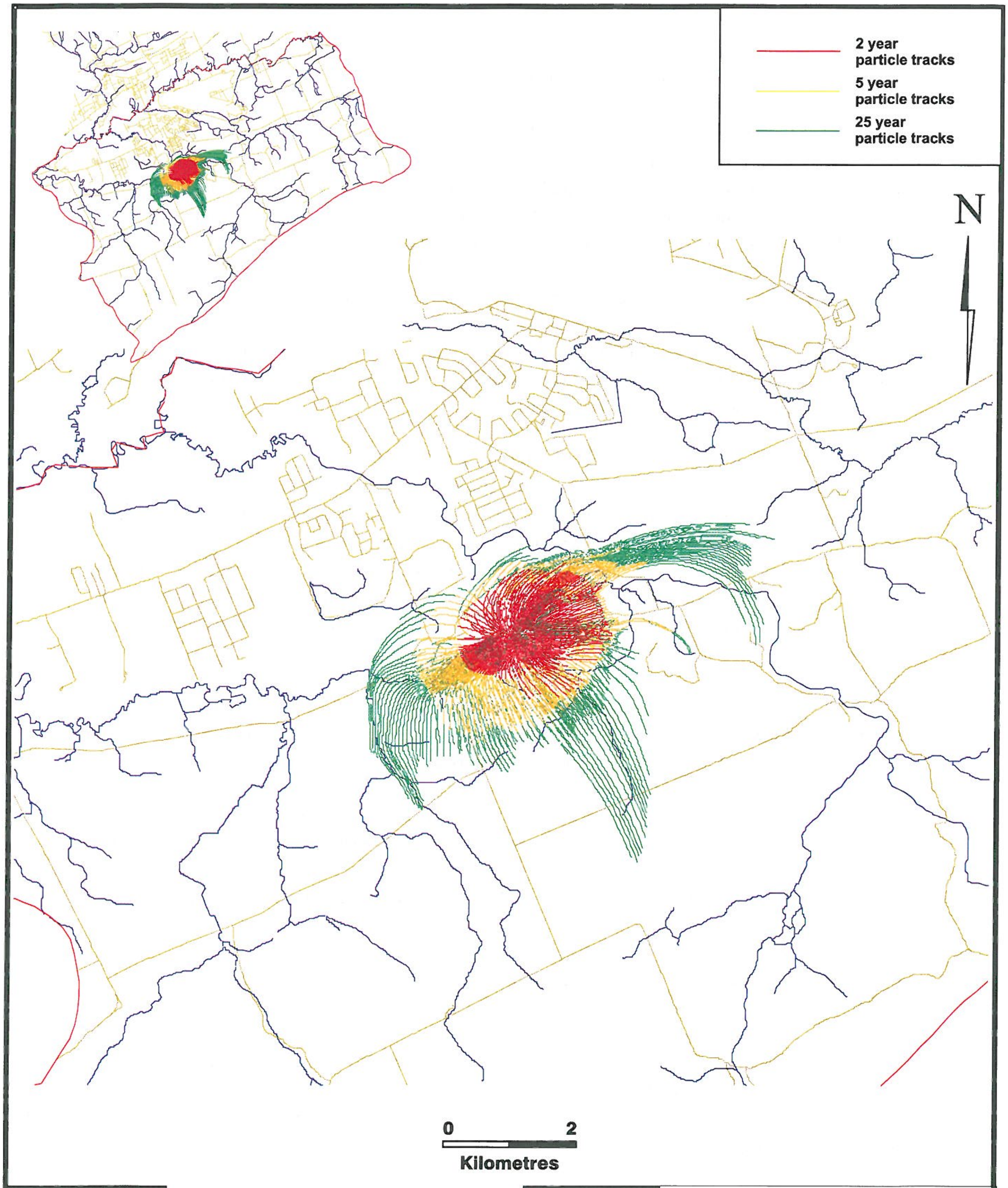

FIGURE 4.6	Particle Tracks Showing Capture Zones	12/06/07	Greenwood Capture Zone Modelling

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changes in storativity, anisotropy, and transfer rates at 3rd type boundary conditions. Hydraulic head patterns were not affected by porosity in the model calculations.

Hydraulic head patterns were affected directly by changes in hydraulic conductivity, infiltration rates, and flux boundary conditions. An increase in the hydraulic conductivity of the sands in Layer 3 caused a decrease in hydraulic head and hydraulic gradients, including the area captured by the cone of depression. An increase in the hydraulic conductivity of all units caused a greater increase in hydraulic head, and reduced the effects of river boundary conditions. A decrease in the hydraulic conductivity of the Wolfville Formation (Layer 4) caused an increase in hydraulic head and hydraulic gradients, increasing the influence of the river boundary conditions on Layers 1 to 3. The magnitude of hydraulic head responded most strongly to increases and decreases in the infiltration rate. This condition is expected, as infiltration accounts for most of the input to the model. Higher influxes at the outer boundaries of the model also caused increases in hydraulic head, hydraulic gradient, and a greater easterly component of flow. Discharge to the Black River was accentuated.

The size of the capture zones responded most directly to hydraulic conductivity. An increase in the hydraulic conductivity of the sand units in Layer 2 caused a direct response in particles released at the top of this layer, extending to the east in particular. The length of the flow path of particles reaching the 25 year travel time was greater when the hydraulic conductivity of the outwash sands was increased by a factor of 10. When the hydraulic conductivity of the Wolfville Formation was reduced, particle tracks in Layers 2 and 3 extended further to the west and south of the well field. An increase in the hydraulic conductivity of all units caused extension of particle tracks to the east in Layers 2 and 3, and to the south in Layer 3.

Figure 4.6 shows particle tracks originating at the base of Layers 2 and 3 under conservative conditions. The model parameters were adjusted to allow for the largest plausible capture zones under conditions promoting contaminant transport. This approach was used to account for potential local variability in model parameters such as hydraulic conductivity, recharge rate, and river boundary properties. The particle tracks shown represent a combined set of particle tracks for three different model simulations. Each simulation affected the shape and direction of particle tracks in a different part of the modelled area. The combined approach creates a worst-case scenario to account for very high local hydraulic conductivities. The capture zones in Figure 4.6 include particle tracks generated under the following conditions:

- the base case
- hydraulic conductivity of kame and outwash sands in Layer 2 increased by a factor of 10
- hydraulic conductivity of all units increased by a factor of 10

The edge of this composite 25-year capture zone extends beyond the outwash valley aquifer, intersecting the adjacent outwash plain, kame complex, and in the vertical plain the underlying bedrock aquifer. Particle tracks to the east extend underneath the Fales River, but do not show significant interaction with the modelled surface water feature.

4.5 Model Limitations

The groundwater flow model was calibrated semi-quantitatively based on the water balance developed for the regional model, and qualitatively against expected and known groundwater flow patterns in the Annapolis Valley. Observation well data were not available for a fully quantitative calibration. The model was developed in its current context as the best available tool for delineation of capture zones, however, without quantitative calibrations, a degree of uncertainty remains. It is assumed that the water balance achieved in the AVCAS model runs is accurate, and that the regional model provides an adequate input data set for the refined site-specific model. This incorporates the assumption that the water balance calculations used by Rivard *et al.* (2006) provide the best approximation field conditions of infiltration and contribution to regional flow. The sensitivity analysis was used as a tool to assess the potential implications of uncertainty in the model, and to build a safety factor into delineation of the WHP zones.

The conceptual model assumes a degree of homogeneity in the surface soils and bedrock geology mapping, and does not account for detail that could be provided with a more extensive borehole record. The current degree of accuracy is considered sufficient for the model scale. Other model assumptions include the following:

- steady state conditions reflect long term field conditions;
- there are no other major water takings in the model domain;
- the rate of infiltration is constant over time;
- there will be no major reductions in surface infiltration in the future;
- distributions of hydraulic conductivities are uniform throughout the study area;
- there is no fracture heterogeneity; and
- there are no major influences up gradient of model domain (i.e., major water takings, barriers to infiltration, unexpected increases in regional flow along the valley floor.)

Extraction well facilities were observed on CFB Greenwood during a windshield survey of the study area. Base personnel were unable to release borehole, pumping test, and usage records for these wells. AMEC (2007) reported that the Greenwood water supply system is connected to that of CFB Greenwood. In cases of emergencies, a valve would be opened, connecting the two systems. The CFB Greenwood wells could represent a second major water taking within the model domain. Without testing the potential effects of these water takings on the model, the results of this study are subject to a degree of uncertainty. The shape and size of the modelled capture zones could be affected by the wells on CFB Greenwood.

Current model calibrations have relied on knowledge of regional groundwater flow patterns, and the ACVAS model output for the Greenwood area. There are currently no monitoring wells in the study areas suited to field calibration of the model. Water level records from the Greenwood well field generally reflect intermittent pumping conditions, and are not considered reliable for steady-state calibration. It may be possible with additional work to use the provincial well database to generate a data set sufficient for minimal calibration of hydraulic head in the shallower units of the model domain.

Chapter 5 **Well Head Protection Zones**

Capture zones delineated as part of the site-specific groundwater model were used to define WHP zones, which are shown on Figure 5.1. The WHP zones were based on capture zone modelling produced under the conservative scenario illustrated in Figure 4.6.

The 25-year WHP zone (Zone D) intersects a new development to the north, and a largely rural area surrounding the well field, including a section of the Fales River (Figure 5.1). The 5-year capture zone (Zone C) extends up to 1500 m from the well field, also intersecting a part of the Fales River. The 2-year capture zone (Zone B) covers an area around the well field with a diameter of 400 to 800 m. A Well Site Control Zone (Zone A) delineates a minimum exclusion zone of 250 ft around each well.

The WHP zones will be used to specify permitted land uses, and to administer any land use restrictions necessary for the protection of Greenwood's groundwater supply. The level of risk posed by a contaminant is dependent on its residence time in the aquifer, and therefore groundwater travel time is an important consideration in the development of well field protection measures. The greatest protective measures are required within the Well Site Control Zone and 2-year zone because they are closest to the wells, with the recommended degree of protection decreasing with distance from the well.

In zones closest to the well field a broad spectrum of contaminants pose a potential threat to the security of the water supply. This group includes materials which are a threat even when released at low levels, or materials with poor mobility in groundwater. With increasing distance from the well field, the list of contaminants of concern becomes narrower, focusing on those materials which readily dissolve and are transported over long distances, or which form recalcitrant, long-lived source zones in aquifers. The key components of the WHPP will include an inventory of the land uses within the groundwater protection zones, a summary of the land use/activities of concern with respect to source water protection, and recommendations to reduce the risk to the water supply.

5.1 Zone A

The zone of critical importance is the area immediately around each of the wells. This zone was delineated using a 250 ft radius around each of the wells, accounting for greater than 15 days of travel time to the well heads. Activities in this zone would typically be strictly limited to operation of the well field. No storage, industrial or commercial activities, or use of on-site wastewater disposal systems should be permitted in this zone. Vehicle access should be strictly limited to maintenance personnel.

5.2 Zone B

Zone B is defined by the 2-year capture zone, and represents contaminants of low mobility but posing a significant health risk to water users. The contaminants of greatest concern within this zone are bacteria (primarily E. Coli) and viruses found in municipal sewage and animal waste. Application of manure or sewer sludge, livestock operations, salting of roads, chemical or fuel storage of any kind, and pesticide use should be prohibited. Nearby livestock and waste handling practices should be strictly monitored and

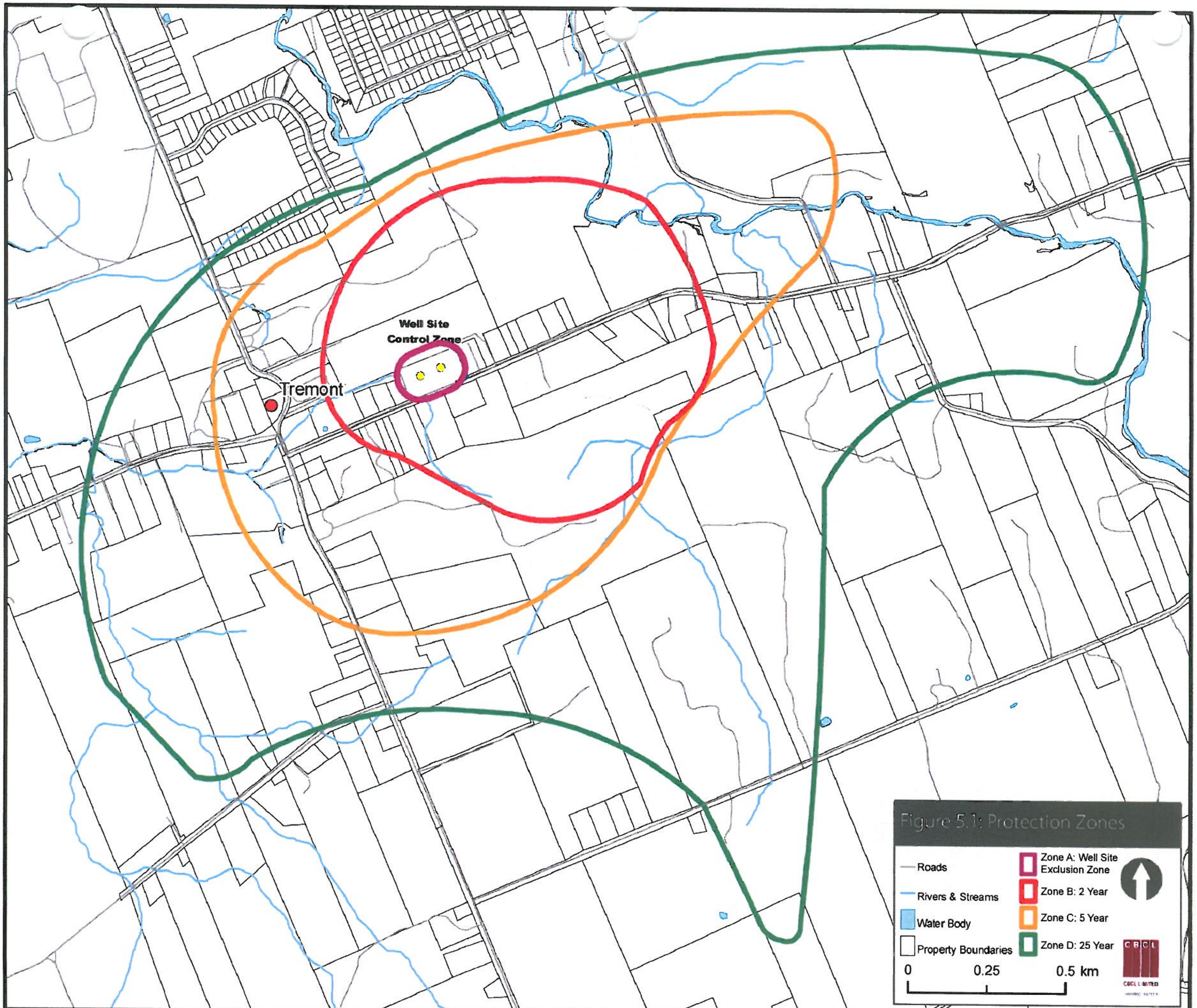
Figure 5.1: Protection Zones
Well Site
Control Zone
Tremont
Roads
Rivers & Streams
Water Body
Property Boundaries
Zone A: Well Site Exclusion Zone
Zone B: 2 Year
Zone C: 5 Year
Zone D: 25 Year
0
0.25
0.5 km
CBCL

reviewed. All activities excluded in Zones C and D must also be prohibited in Zone B. There is an aggregate extraction within Zone B, to the immediate north of the well field. New aggregate extractions would typically be prohibited within Zone B, and existing activities should be closely regulated.

5.3 Zone C

Zone C is defined by the 5-year capture zone, an area requiring restrictions on contaminants with moderate mobility and stability in the subsurface environment. Contaminants excluded from Zone 2 pose a health risk at moderate to low concentrations, and are subject to processes of adsorption and biodegradation. These materials generally require travel times of more than five years to be attenuated in subsurface environments. Petroleum hydrocarbon users, including service stations, automotive painting and repair shops, fuel storage and transfer of any kind, and auto salvage operations should be prohibited in this zone. Any kind of industrial process with the potential to release large volumes of liquid waste to the subsurface environment would be restricted within this zone. All activities excluded in Zone D must also be prohibited in Zone C.

5.4 Zone D

Zone D is defined by the 25-year capture zone, created to manage contaminants which pose a health risk at low concentrations, and which are readily transported over large distances and longer time frames. Zone D also represents the outer boundary of the WHPA as a whole. Dense non-aqueous phase liquids (DNAPLs) such as trichloroethylene and perchloroethylene (TCE and PCE: dry cleaning chemicals and degreasers) fall into this category, in part due to the recalcitrant nature of DNAPL source zones, and the tendency for DNAPLs to penetrate into deep aquifers. Species which are readily transported conservatively are more likely to arrive at the well head in high concentrations. Chloride, nitrate, and some metals exhibit this behaviour. Land use activities associated with these contaminants include landfills, dry cleaning facilities, metal shops, sewage disposal facilities, bulk salt storage, and bulk pesticide storage. Land uses and practices prohibited in Zones B and C should be monitored within Zone D. In addition to the suggested land use exclusions, a complete inventory of all agricultural, commercial and industrial practices within Zone D is recommended.

Chapter 6 **Summary and Recommendations**

6.1 Summary

The investigation to date has included a complete review of background material, including village water use requirements and the well field sustainable yield as previously defined (AMEC, 2007). Development of a finite elements model of groundwater flow allowed for delineation of capture zones. Capture zones were used to define Well Head Protection zones in preparation of a long-term Well Head Protection Plan for the Village of Greenwood. The following summarizes the primary elements of the study:

- The study area encompasses the lands surrounding the Village of Greenwood, defined according to watershed mapping;
- Existing peak water demand for the Village of Greenwood is 1,378 L/min;
- The well field is capable of supplying up to 1,545 L/min at peak demand, and 1123 L/min under long-term sustainable use;
- Groundwater flow patterns are characterized by flow from the South Mountain toward the Annapolis River, with components of local flow to the southwest in the outwash valley aquifer;
- The outwash valley aquifer serves the water needs of the Village of Greenwood;
- A regional model of groundwater flow in the Annapolis-Cornwallis Valley Aquifers was developed by the Geological Survey of Canada using the finite elements software package FEFLOW 5.2;
- The regional model was used as a basis for development of a refined model of groundwater flow for the study area;
- Input data for the model was taken from available sources, including the provincial water well database, pumping test database, and output from the regional model;
- The model consisted of six layers, mapped according to geologic formations present in the study area;
- No-flow, flux, and transfer boundary conditions were assigned around the perimeter of the model domain;
- Surface water courses were assigned as transfer boundary conditions;
- The Village of Greenwood well field was represented as extraction well boundary conditions within Layers 2 and 3 (outwash sand and gravel) of the model;
- Extraction rates were input as the maximum sustainable rate for pumping at all wells over a 100-day period;
- The model was calibrated semi-quantitatively against the water balance developed in the regional model, and qualitatively using known regional groundwater flow patterns;
- Capture zones were delineated using backward particle tracking from each well;
- A sensitivity analysis showed responses in hydraulic head patterns to hydraulic conductivity, infiltration rates, and fluxes at the model boundaries;
- The sensitivity analysis showed the strongest responses in capture zone size to the hydraulic conductivity of the outwash and kame sands, and to the overall hydraulic conductivity of all units;
- Capture zones were delineated for 2-year, 5-year, and 25-year times of travel;
- Conservative capture zones were developed as part of the sensitivity analysis;
- The conservative capture zones were used to define Well Head Protection (WHP) zones.

Recommendations

Several tasks remain to be completed in order to finalize the WHPP. The WHP zones described in this investigation are based on groundwater modelling only, and need to be refined and developed using property and zoning mapping. The following items will be completed as part of the WHPP:

- Additional field reconnaissance of well head protection areas;
- Comprehensive inventory of land uses and ownership within Greenwood, and documentation of land uses of concern;
- Establishment of an inventory and monitoring of agricultural practices on lands owned by Greenwood, and on adjacent commercial agricultural lands; and
- Risk analysis of potential groundwater protection concerns.

In addition the following activities are to be undertaken by the Municipality of the County of Kings:

- Develop land use controls, by-laws, voluntary agreements, and management strategies to effectively address risks; and
- Incorporation of Well Head Protection Plan into the Municipal Planning Strategy.

Upon completion of the risk analysis of potential groundwater protection concerns, a Report will be developed in conjunction with formation of the advisory committee and incorporation of the WHPP into the Municipal Planning Strategy.

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Appendix A

Sensitivity Analysis

Table A1. Summary of Output from Sensitivity Analyses

Model Name	S0	S1	S2	S3	S4	S5	S6
Parameter Altered	**Baseline**	**L1: Ksilt/10**	**L1: Ksilt*10**	**L2: Ksand/10**	**L2: Ksand*10**	**L4 (Wolfville Formation): K/10**	**L4 (Wolfville Formation): K*10**
Water Balance (m^3/d)							
In	3484	3480	3842	3473	3528	3381	4608
Out	-45325	-45330	-45683	-45312	-45372	-45192	-46449
Wells	-2225	-2225	-2225	-2225	-2225	-2225	-2225
Infiltration	44065	44065	44065	44065	44065	44065	44065
Imbalance	-1.1	-10.5	-0.5	2.1	-3.6	29.1	-0.2
Flux through Boundary Type (m^3/d)							
2nd	1944	1943	1944	1944	1944	1943	1944
3rd	-43785	-43794	-43785	-43782	-43788	-43755	-43785
4th	-2225	-2225	-2225	-2225	-2225	-2225	-2225
Sand Units (Layer 2)							
Qualitative Change Pontentiometric Surfaces		2 m higher	2-4 m lower	6 m higher; more even distribution across Kame field, exaggerated cone of dd	8 m lower; backed up at base of Mtn, low grad across Kame field, cone of dd not apparent	30 m higher; v. strong influence of rivers, high gradients at rivers; revsal of flow in well field	12 m lower; flat gradient below mtn, little river influence
South Mountain (S-N)							
Head south (m geodetic)	85	86	84	88	88	104	66
Head north (m geodetic)	22	28	24	24	24	26	22
Gradient (m/m)	0.009	0.008	0.008	0.009	0.009	0.011	0.006
Well Field East (S-N)							
Head south (m geodetic)	38	38	36	40	28	90	22
Head north (m geodetic)	36	34	34	34	26	90	21
Gradient (m/m)	0.002	0.004	0.002	0.006	0.002	0.000	0.001
Well Field West (S-N)							
Head east (m geodetic)	36	37	35	38	27	88	21
Head west (m geodetic)	35	34	34	34	26	78	21
Gradient (m/m)	0.0007	0.0020	0.0007	0.0027	0.0007	0.0067	0
L3 Area of 25 Year Capture Zone[1]:							
Area (m^2)	1826357	1639409	1878516	1072996	2501045	2516237	964864
% change	n/a	-10.2	2.9	-41.2	36.9	37.8	-47.2
L4 Area of 25 Year Capture Zone[2]:							
Area (m^2)	2586919	2596275	2564406	2142491	2637434	2766537	2060235
% change	n/a	0.4	-0.9	-17.2	2.0	6.9	-20.4

[1]Backward particle tracks released at base of sand unit

[2]Backward particle tracks released at base of gravel unit

Table A1. Summary of Output from Sensitivity Analyses

Model Name	**S7**	**S8**	**S9**	**S10**	**S11**	**S12**	**S13**	**S14**	**S15**
Parameter Altered	**All Units: K/10**	**All Units: K*10**	**L4: Kz=Kxy**	**S/10**	**S*10**	**n=0.25**	**n=0.4**	**Reduced Infiltration[3]**	**Increased Infiltration[4]**
Water Balance (m^3/d)									
In	No Convergence	4702	3464	3483	3483	3484	3484	3817	3411
Out		-46528	-45302	-45323	-45323	-45325	-45325	-32151	-77876
Wells		-2225	-2225	-2225	-2225	-2225	-2225	-2225	-2225
Infiltration		44065	44065	44065	44065	44065	44065	30560	76730
Imbalance		14.2	2.6	0.5	0.5	-1.1	-1.1	0.8	39.9
Flux through Boundary Type (m^3/d)									
2nd		1958	1944	1944	1944	1944	1944	1944	1944
3rd		-43784	-43781	-43784	-43784	-43785	-43785	-30278	-76408
4th		-2225	-2225	-2225	-2225	-2225	-2225	-2225	-2225
Sand Units (Layer 2)									
Qualitative Change Pontentiometric Surfaces		30 m lower; flat gradient below mtn, little river influence	Less influence by rivers and wells	no change	no change	no change	no change	40 m lower; lower gradients	66 m higher; higher gradients and influence by rivers
South Mountain (S-N)									
Head south (m geodetic)		62	86	85	85	85	85	58	132
Head north (m geodetic)		22	22	22	22	22	22	22	26
Gradient (m/m)		0.006	0.009	0.009	0.009	0.009	0.009	0.005	0.015
Well Field East (S-N)									
Head south (m geodetic)		22	42	38	38	38	38	32	52
Head north (m geodetic)		21	38	36	36	36	36	30	48
Gradient (m/m)		0.001	0.004	0.002	0.002	0.002	0.002	0.002	0.004
Well Field West (S-N)									
Head east (m geodetic)		21	42	36	36	36	36	30	50
Head west (m geodetic)		21	38	35	35	35	35	30	40
Gradient (m/m)		0	0.0027	0.0007	0.0007	0.0007	0.0007	0.0003	0.0067
L3 Area of 25 Year Capture Zone[1]:									
Area (m^2)		1670301	1380216	1581084	1597161	1628263	1573940	2043414	1105207
% change		-8.5	-24.4	-13.4	-12.5	-10.8	-13.8	11.9	-39.5
L4 Area of 25 Year Capture Zone[2]:									
Area (m^2)		3113511	1617227	2582468	2597732	2688024	2404308	2812734	2003107
% change		20.4	-37.5	-0.2	0.4	3.9	-7.1	8.7	-22.6

[1]Backward particle tracks released at base of sand unit

[2]Backward particle tracks released at base of gravel unit

[3]Alluvium = 25 mm/yr
Kame Sand = 150 mm/yr
Outwash Sand = 250 mm/yr
Coarse Till = 50 mm/yr

[4]Alluvium = 100 mm/yr
Kame Sand = 350 mm/yr
Outwash Sand = 450 mm/yr
Coarse Till = 200 mm/yr

Table A1. Summary of Output from Sensitivity Analyses

Model Name	**S16**	**S17**	**S18**	**S19**	**S20**	**S21**
Parameter Altered	**Pumping Rate = Long Term Sustainable Max[5]**	**Pumping Rate = Long Term Average[6]**	**No Influx at type 2 boundaries**	**Influx at type 2 boundaries *10**	**Flux at type 3 boundaries /10**	**Flux at type 3 boundaries *10**
Water Balance (m^3/d)						
In	3484	3476	333	37128	3337	10219
Out	-45922	-46995	-42179	-79012	-45177	-52066
Wells	-1617	-555	-2225	-2225	-2225	-2225
Infiltration	44065	44065	44065	44065	44065	44065
Imbalance	10.0	-8.7	-5.6	-44.3	0.5	-6.2
Flux through Boundary Type (m^3/d)						
2nd	1943	1944	0	19444	1944	1944
3rd	-44382	-45463	-41846	-61328	-43784	-43791
4th	-1617	-555	-2225	-2225	-2225	-2225
Sand Units (Layer 2)						
Qualitative Change Pontentiometric Surfaces	0.2 m higher	1 m higher; reduced cone of influence, increased river boundaries	6 m lower; more northerly flow along west boundary	36 m higher; much stronger easterly component of flow, discharge to Black R.	18 m higher across model area; reduced influence of river boundaries	4 m lower; stronger influence by rivers
South Mountain (S-N)						
Head south (m geodetic)	85	84	86	80	102	80
Head north (m geodetic)	22	22	24	24	42	22
Gradient (m/m)	0.009	0.009	0.009	0.008	0.008	0.008
Well Field East (S-N)						
Head south (m geodetic)	38	32	26	44	58	30
Head north (m geodetic)	36	30	24	40	56	28
Gradient (m/m)	0.002	0.002	0.002	0.004	0.002	0.002
Well Field West (S-N)						
Head east (m geodetic)	36	31	26	44	56	29
Head west (m geodetic)	35	24	22	38	56	24
Gradient (m/m)	0.0007	0.0047	0.0027	0.0040	0	0.003
L3 Area of 25 Year Capture Zone[1]:						
Area (m^2)	1154487	452911	1637341	1532381	2396932	1494229
% change	-36.8	-75.2	-10.3	-16.1	31.2	-18.2
L4 Area of 25 Year Capture Zone[2]:						
Area (m^2)	2121599	814287	2598901	2530387	2597252	2529342
% change	-18.0	-68.5	0.5	-2.2	0.4	-2.2

[1]Backward particle tracks released at base of sand unit

[2]Backward particle tracks released at base of gravel unit

[5]GW8 = 766 m^3/day GW13 = 851 m^3/day

[6]GW8 = 320 m^3/day GW13 = 235 m^3/day

<u>Appendix B</u>

Greenwood Wellfield Delineation Map

CBCL Limited, Water and Aquife*r* Technical Environmental Resources

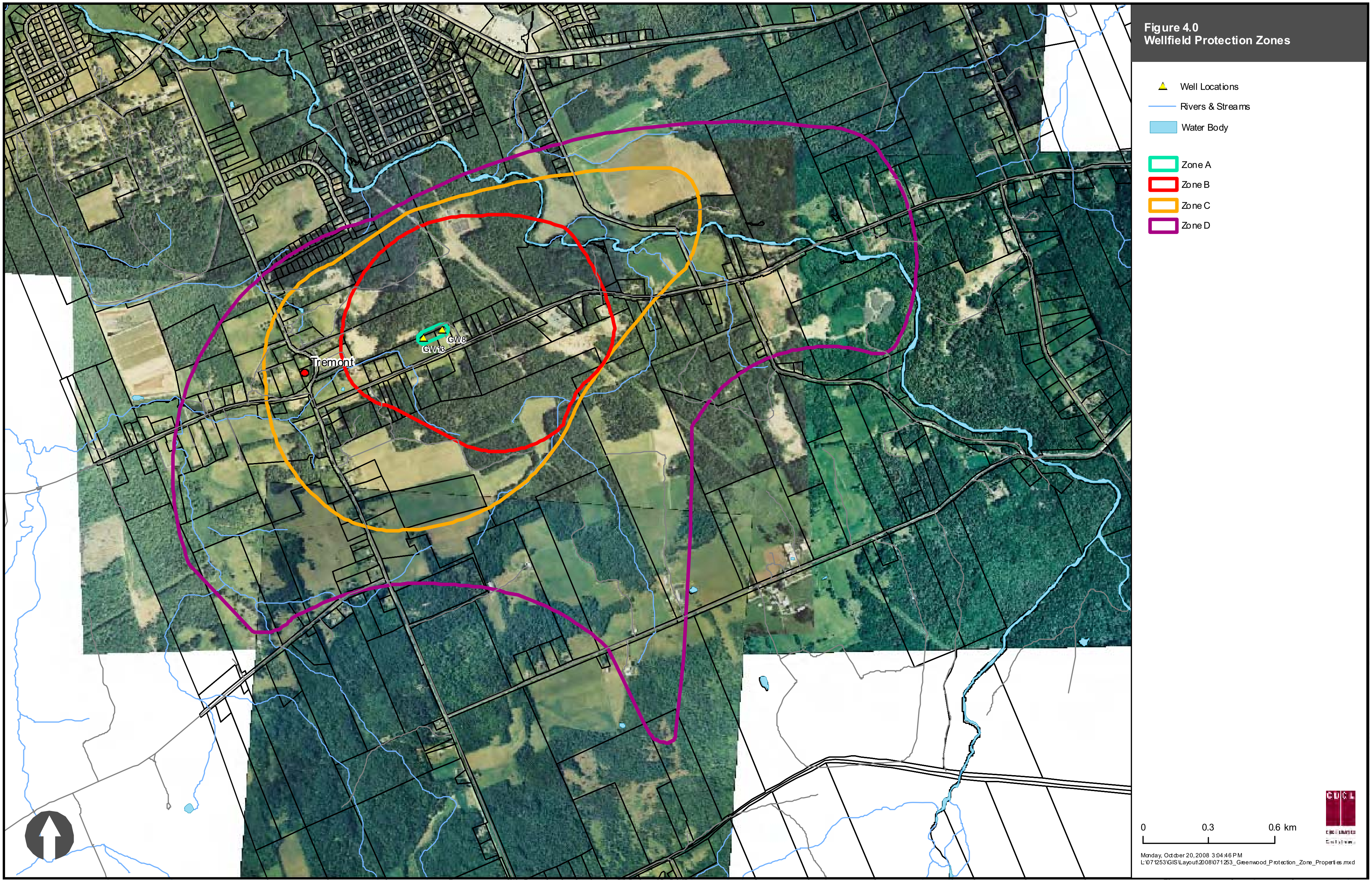
Figure 4.0
Wellfield Protection Zones
Well Locations
Rivers & Streams
Water Body
Zone A
Zone B
Zone C
Zone D
Tremont
GW8
GW13
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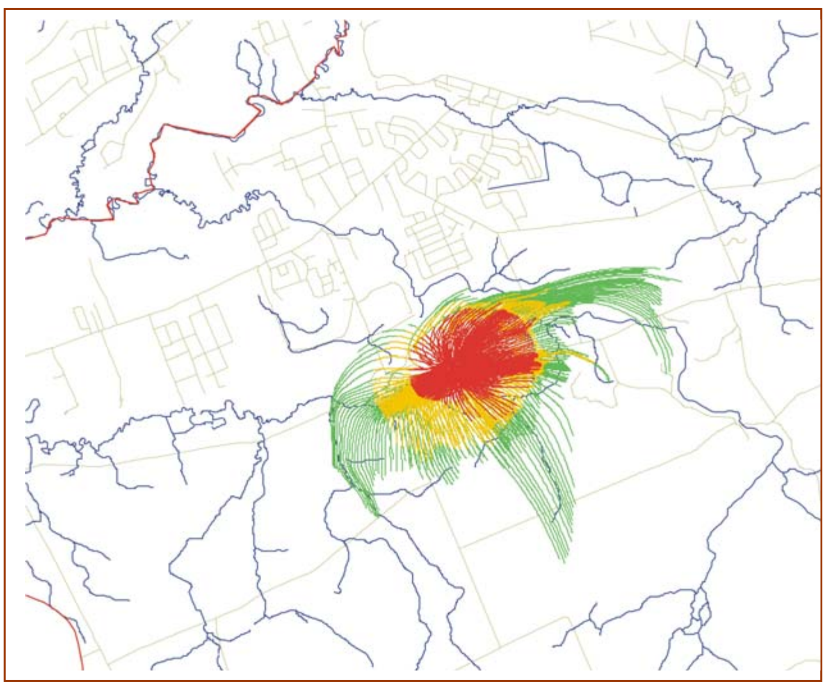
Appendix C

Land Use Planning Recommendations for Greenwood Wellfield Protection Plan

CBCL Limited

Project No. 071253



Prepared for:

Greenwood Water Utility Wellhead Protection Committee

Land Use Planning Recommendations for the Greenwood Wellfield Protection Plan

FINAL DRAFT

Report

January, 2009

CBCL

CBCL LIMITED

Consulting Engineers

ISO 9001

Registered Company

Land Use Planning Recommendations for the Greenwood Wellfield Protection Plan

Final Draft – January, 2009

Contents

1 Groundwater Protection in Greenwood

The Village of Greenwood, situated within the County of Kings, receives its drinking water from groundwater. In order to protect public health, it is vital to ensure the protection of the groundwater. Once a groundwater source is contaminated it can be impossible, or extremely costly to clean up. Groundwater contamination is very serious and in other parts of Canada has led to illness and death. Preventing contamination is the most effective way to ensure safe drinking water.

This report provides the Greenwood Water Utility Wellhead Protection Committee with land use planning recommendations that will form part of an overall Greenwood Wellfield Protection Plan. The purpose of the additional zoning outlined in this report is to protect the health and safety of *all* users who draw groundwater from the Greenwood aquifer, including residents in the area with private wells.

1.1 Village of Greenwood Wellfield Protection Area

This document builds on groundwater flow analysis summarized in the Greenwood Capture Zone Modelling: Technical Report by CBCL in March, 2008. The technical report established the Wellfield Protection Area based on the groundwater capture zones for Greenwood's two production wells. Figure 1.1 shows the location of the wellheads and the Wellfield Protection Area.

This document lays out the regulatory and policy contexts within which planning for the protection of the Greenwood Wellfield takes place. Land use planning tools available to the County of Kings are highlighted. Provided is a detailed discussion and analysis of zoning designations, ownership and current land use in the Wellfield Protection Area. This is followed by an analysis of potential sources of risk to the groundwater supply. Specific strategies for managing risk, using land use planning tools are recommended. A recommended implementation plan is provided.

2 Regulatory Framework

Planning to protect the groundwater supply for Greenwood, takes place within the broader context of federal, provincial and municipal planning regulations and policies. The following sections highlight areas of provincial and federal jurisdiction and relevant legislation and guidelines related to land use practices which pose potential risk to groundwater quantity and quality. The regulatory framework sets out the range of policies protecting source water. Section 3, will narrow in on the focus of this report, which is at the municipal level and how land use planning can be used as a tool for groundwater protection.

2.1 Drinking Water in Nova Scotia

Nova Scotia Environment (NSE) is the lead agency for providing access to safe, adequate and reliable public water supplies. The *Environment Act, 1994-95* and the *Water Resources Protection Act, 2000* provide the legislative framework for protecting water resources. The

Figure 1.1
Wellhead Location

Environmental Goals and Sustainable Prosperity Act, 2007 is also relevant to water protection as it establishes two of the Province's long-term environmental and economic objectives as having municipal drinking water supplies meeting Provincial standards by 2008 and developing a comprehensive water-resource management strategy by 2010.

Section 106 of the *Environment Act* permits the designation of protected water areas surrounding any water supply source. The designation may include regulations intended to prevent impairment of water quality, such as watercourse setbacks, sediment and erosion controls and animal pasture restrictions. More than twenty areas in Nova Scotia have this designation and each has slightly different restrictions depending on the needs of the community and water supply objectives. Within the County of Kings, the McGee Lake Watershed Protected Water Area Designation, was established in 2005 and protects there area surrounding McGee Lake and Mill Brook.

In 2002, the Province released A Drinking Water Strategy for Nova Scotia. The strategy is a comprehensive approach based in multi-barrier management. Multi-barrier management focuses on source protection, water treatment, and monitoring and reporting on a broad, watershed basis. Wellfield protection planning and Protected Water Area designations are key components of source water protection, and the provincial strategy recommends that municipalities develop a source water protection plan to prevent drinking water problems from occurring. In 2004 NSE provided municipalities with a guide for developing a source water protection plan. The guide includes five steps, which are being used to create the Wellfield Protection Plan for Greenwood:

- Form a source water protection advisory committee
- Delineate a source water protection area boundary
- Identify potential contaminants and assess risk
- Develop a source water protection management plan
- Develop a monitoring program to evaluate the effectiveness of protection

2.2 Regulations for Public Drinking Water & Wastewater

The requirements for water and wastewater treatment facilities and monitoring are set forth in the Water and Wastewater Facilities and Public Drinking Water Supplies Regulations made under the *Environment Act.* These regulations require facilities be operated by certified operators and classified according to size, population served and unit processes. Water and wastewater treatment facilities are classified from one through five, based on a point system outlined in the Facility Classification Standards.

Water quality monitoring and reporting is required for all public water supply systems in Nova Scotia. Regular testing must be conducted in accordance with the parameters set forth in the Guidelines for Monitoring Public Drinking Water Supplies. The microbiological, physical and chemical characteristics of a public drinking water supply cannot exceed the acceptable standards of the Guidelines for Canadian Drinking Water Quality. These guidelines are published by Health Canada on behalf of an intergovernmental committee, based on research related to health effects, aesthetic effects and operational considerations of water quality and treatment.

2.3 On-site Sewage Disposal

The On-site Sewage Disposal System Regulations made under the *Environment Act* are to ensure the safe and clean operation of sewage systems not managed centrally by a municipality, generally for single unit residential systems. Approval from the province is required for the installation of a sewage disposal system, which must meet regulations for design, installation and distance from wells, watercourses and other features. Certification is required for both the system designer and installer. The owner of a system is responsible for its proper functioning, and must make repairs to any malfunction. The On-site Sewage Disposal Systems Technical Guidelines are in accordance with the regulations and are intended to facilitate proper planning, design, selection, installation, operation and maintenance of on-site systems.

2.4 Well Construction

The Well Construction Regulations made under the *Environment Act* provide guidelines for the proper construction of groundwater wells. Improperly constructed or abandoned wells can result in contaminated surface and shallow groundwater entering the well and impacting well water or aquifer water quality. A well may not be constructed closer than the minimum distances from potential sources of contamination, particularly sewage disposal systems. A well may not be constructed in manner or location that could allow surface water to enter the well or aquifer.

A well casing at least 6.1m long is required, as well as a well liner and well screen. A minimum annular space of 25 mm outside the well casing is required. Any remaining volume of the outer borehole annulus is filled in with grout, drill cuttings or impermeable soil to the ground surface and prevents surface water from entering the annular space.

The Well Construction Regulations require the proper abandonment of wells no longer in use. The well must be immediately decommissioned by sealing it to prevent the vertical movement of water in accordance with criteria set forth in the Water Well Decommissioning Guidelines.

2.5 Petroleum Storage

The *Petroleum Management Regulations* made under the *Environment Act* include guidelines pertaining to any structure designed for the underground or aboveground storage of liquid petroleum of any kind, including gasoline, diesel and lubricants. The regulations include installation, monitoring and removal standards, and require certification of petroleum storage tank installers. In the event of a spill, the person responsible for the petroleum storage must follow the reporting procedures outlined in the *Emergency Spill Regulations* and take the necessary steps to stop the spill, clean up the affected area and rehabilitate the environment.

Domestic heating oil tanks hold approximately 1000 litres. NSE recommends the use of aboveground oil tanks that meet the national construction standards (National Standard of Canada's CAN/ULC-S602, *Aboveground Steel Tanks for the Storage of Combustible Liquids Intended to Be Used as Heating and/or Generator Fuels* & Laboratories of Canada's ULC/ORD C80, *Aboveground Non-metallic Tanks for Fuel Oil*). Insurance companies will sometimes recognize tanks constructed for longer lifespan or include containment features such as double-walled tanks. Domestic oil tanks must be installed according to national standards (Canadian Standards Association's CSA B-139, *Installation Code for Oil-Burning Equipment* (latest recognized edition and the *National Fire Code of Canada* (latest edition). NSE recommends that domestic oil tanks be installed by trained installers and be inspected regularly by a heating service professional. NSE recommends that tanks be installed indoors rather than outdoors to avoid corrosion and weathering that may damage the tank and potentially lead to a spill and environmental contamination.

2.6 Agricultural Practices

Agricultural practices which affect water quality include the use or management of fertilizer, livestock, manure and other wastes. These practices are regulated federally, provincially and municipally under various legislative statutes, regulations, and bylaws. The Environmental Regulations Handbook for Nova Scotia Agriculture, published by the Department of Agriculture, summarizes the role of each regulatory body affecting agricultural operations from an environmental standpoint.

Fertilizer storage and application, except in very large quantities, is not regulated. However, fertilizer contaminating surface or groundwater could trigger charges under four separate pieces of legislation, the *Canadian Environmental Protection Act*, the *Fisheries Act*, the *Health Act* or the *Environment Act*.

The bacteria and nutrients from the feces and urine of livestock may cause a significant adverse effect to water quality. Although there is no legislation that specifically states livestock and manure are not permitted in streams, there are two laws which in effect say this. The *Fisheries Act* states that no person shall alter fish habitat without approval and "no person shall deposit or permit the deposit of a deleterious substance of any type in water frequented by fish" or where the substance may enter water frequented by fish. The provincial *Environment Act* also says that no one can release (knowingly or not) into the environment a substance that causes or may cause a significant adverse effect. These laws are significant because the wastes of livestock qualify as deleterious substances. Additionally, the uncontrolled trampling of cattle on the banks of streams and on stream bottoms can disturb soil and stream sediments leading to siltation. Silt is also deemed a deleterious substance under the *Fisheries Act*.

Manure Management Guidelines in Nova Scotia were developed by the Department of Agriculture in 2006. The guidelines outline manure management systems and practices that help to reduce the risk of pollution and minimize odours. Recommended actions include proper manure storage facility siting, system design options, safety practices, ventilation and transportation methods. The National Farm Building Code specifies construction requirements for manure storage, and a permit is required.

The Environmental Farm Plan (EFP) Program was initiated in 1997 to help farmers identify and assess environmental risk by examining their farm operation from an environmental management perspective. It allows farmers to incorporate environmental considerations into business decisions, rather than addressing environmental issues as they arise. An EFP involves an environmental farm review which considers many factors, including effects to water quality. The program is led by the Nova Scotia Federation of Agriculture and NSAF, and is voluntary at this time, although it is recommended that all farmers participate.

2.7 Pesticides

The federal and provincial governments share the responsibility of pesticide regulation. Health Canada is responsible for the evaluation, registration and re-evaluation of pesticides used in Canada through the *Pest Control Products Act*. The enforcement and compliance of the import / export of pesticides or violations of label requirements are also under federal jurisdiction.

Through the Pesticide Regulations and the Activities Designation Regulations made under the *Environment Act*, NSE regulates the sale, use, storage and disposal of pesticides. The regulations also require certification of applicators and vendors of restricted or commercial class pesticides. In some cases, an approval permit is required from NSE to apply pesticides. A permit is also required for pesticide storage.

2.8 Forestry Practices

Forest harvesting on any woodland in Nova Scotia must take place according to the *Forests Act* and Wildlife Habitat and Watercourses Protection Regulations. Requirements pertaining to water protection include leaving buffer strips (special management zones) along water-courses. Under the *Environment Act*, NSE approval is required for the alteration of a water course by activities related to wood lot management.

2.9 Mineral Extraction

Mineral extraction in Nova Scotia falls under Provincial jurisdiction and must comply with all applicable legislation, regulations and guidelines. The *Mineral Resources Act* prohibits detailed ground exploration in municipal water supply watershed lands without first obtaining all necessary approvals from the NSE.

3 Municipal Planning and Groundwater Protection

Municipalities have an important role to play in drinking water protection. Municipal land use planning is identified by NSE as an excellent tool in developing source water protection plans. The Nova Scotia *Municipal Government Act* (MGA) gives municipal councils authority to govern at the municipal level and sets out municipal legislation. Within the MGA are several Statements of Provincial Interest that are intended to guide Provincial departments and municipalities in making land use decisions that respect the finite nature of Nova Scotia's land and water resources and lead towards sustainable development. Part VIII of the MGA focuses on planning and development and outlines legislation related to land use, ensuring consistency with Provincial interests and regulations.

3.1 Statement of Provincial Interest Regarding Drinking Water

The Statement of Provincial Interest Regarding Drinking Water in the MGA is intended to set the direction and provide guidance for how municipalities can ensure the protection of drinking water. The goal of this Statement of Provincial Interest is "To protect the quality of drinking water within municipal water supply watersheds". The Statement continues to emphasize that a "safe supply of drinking water is a basic requirement for all Nova Scotians" and that "inappropriate development in municipal water supply watersheds may threaten the quality of drinking water" (*Municipal Government Act*, 1998, Schedule B, Statements of Provincial Interest).

Decisions that Provincial departments and municipalities make about land use must be consistent with the Province's commitment to protecting drinking water. The Statement requires that planning documents identify all municipal water supply watersheds within the planning area and address the protection of drinking water. It identifies land use and development restrictions as well as watershed management strategies as important protection measures.

3.2 County of Kings Land Use Policies Related to Groundwater

The County of Kings Municipal Planning Strategy (MPS), Section 2.12 outlines the goals, objectives and policies related to the protection and management of county groundwater. The county emphasizes the importance of an adequate water supply as a basis for all other development objectives. Land use policies are intended to guide sound decision making regarding any expansion of the growth centres or changes in zoning that could threaten the water supply or increase risk of contamination or over-consumption.

Land use bylaws that protect water sources contribute to the county's goals for managing groundwater supplies. While public education and other programs are important aspects of the county's multifaceted approach to water protection, two of the county's primary goals for the management of groundwater relate directly to land use:

- ensure an adequate supply of water for current and future community demand where central services are provided;
- protect the integrity of community well water supplies where groundwater is the primary source of community water (MPS Section 2.12, page 2.12-2).

The MPS allows land use policies to be added to the MPS, secondary planning strategies, the Land Use Bylaw (LUB) and other planning documents in order to ensure the protection of county aquifers (MPS Section 2.12.3, page 2.12-3) Table 3.2.1 and Table 3.2.2 provide examples of municipal planning strategy policies and land use bylaws that are relevant to the protection of groundwater.

Table 3.2.1 Municipality of the County of Kings Municipal Planning Strategy Policies related to Land Use and Groundwater Protection

Policy	Section	Description (emphasis added)
2.12.3.1 MPS	General Groundwater Supply and Management Policies	In addition to making general statements of intent respecting groundwater resources within the Municipality, Council shall undertake **additional amendments** to this Strategy, as necessary, to institute wellfield protection measures for specific groundwater supply areas within the Municipality
2.12.3.2 MPS	General Groundwater Supply and Management Policies	Pursuant to policy 2.12.3.1 above, Council shall implement wellfield protection regulations through the General Provisions section of the Land Use Bylaw. Such **Regulations in the Bylaw(s) will apply to all zones, and where more restrictive, shall override other zone regulations.**
2.12.3.3 MPS	General Groundwater Supply and Management Policies	Council shall identify well protection areas on maps appended to the Land Use Bylaw. **These maps shall officially recognize the existence of central water supply Wellheads, Wellfields, Well Capture and Recharge areas**, or other relevant classifications as identified in either the New Minas Sector Plan, a Secondary Planning Strategy, or referenced in technical studies and documents prepared for public (Municipal or Village) and private water utilities in Kings County.
2.12.3.4 MPS	General Groundwater Supply and Management Policies	Council shall, in considering proposals to amend the Municipal Planning Strategy to accommodate a **change in Growth Centre or Rural District boundary within a water supply protection or water resource management area**, as identified on a relevant Land Use Bylaw map schedule, have regard to the following matters: a. an assessment (submitted in a written report) by a qualified hydrogeologist or hydrogeological engineer, of the current yield of existing wells or wellfield, and ensure that development potential is contained within the **sustainable operating capacity of the water supply system** b. an assessment (submitted in a written report) by a qualified hydrogeologist or hydrogeological engineer, of the **risk of contamination** of the groundwater supply or **over-consumption** inherent in changing from one land use designation to another; and c. the **policies of this Strategy** including those for amending the Land Use Bylaw as contained in Part 6 of this Strategy; and d. **any relevant policies** of the New Minas Sector Plan, or inter-municipal planning document(s)
3.2.5.1-b MPS	Agricultural Districts	It shall be the policy of Council to permit commercial livestock uses in the Agricultural (A1) Zone provided that **livestock barns, feedlots, and manure storage and treatment facilities are more than 300 feet**

		from a watercourse, well or a dwelling on an adjacent property;
3.2.9.2.3-c	Agricultural Districts	In considering entering a Development Agreement, Council shall be satisfied that the applicant has demonstrated: c. that sufficient quantity and quality of water is available to serve the development **without negative impact on existing surface and/or groundwater supplies**
6.3.3.1-b MPS	Development Agreements	Conditions of Approval of Development Agreements … Council shall be satisfied: b. that the proposal is not premature or inappropriate by reason of: ii. the adequacy of municipal sewer and water services if services are to be provided. Alternatively, the **adequacy of the physical site conditions** for private on-site sewer and water systems iii. **the potential for creating, or contributing to, a pollution problem including the contamination of watercourses or the creation of erosion or sedimentation during construction** iv. the **adequacy of storm drainage** and the effect of same on adjacent uses
6.3.3.1-c MPS	Development Agreements	c. the Development Agreement may specify that controls are placed on the proposed development so as to reduce conflict with any adjacent or nearby land uses by reason of: xii. the suitability of the proposed site in terms of steepness of grades, soil and/or geological conditions, and the **relative location of watercourses, marshes, swamps, or bogs**
6.3.4.1-a MPS	Development Agreements	Council may require that any or all of the following information be submitted to the Municipality by the Developer with respect to any proposed development which is to be the subject of a Development Agreement under the *Municipal Government Act* namely: a. information as to the physical and environmental characteristics of the proposed site including information regarding topography, contours, elevations, dimensions, natural drainage, soils, **existing watercourses**, vegetative cover, size and location of the lands

Table 3.2.2 Land Use Bylaws related to Groundwater Protection

Policy	Section	Description
5.1.6 LUB	Uses Permitted by Development Agreement	**Expansion or redevelopment of existing non-conforming uses within the Wellfield Protection and the Wellfield Recharge Zones** as provided for in the Municipal Planning Strategy (2.12.7.6) and identified on the Coldbrook Urban Zoning and Wellfield Protection Zoning Map, schedule 5g, of the Land Use Bylaw
6.1.4 LUB	Commercial	No facilities for **storage of petroleum products or hazardous materials** regulated under the Dangerous Goods Management Regulations under Section 84 of the *Environment Act*, S.N.S. 1994-95,

		c.1, shall be permitted within **200 feet of a watercourse or well.**
10.1.1.16 LUB	Rural Zones	No **fuel, solvents, paints or other chemicals** in quantities over 500 litres, or bulk storage of tires associated with the business shall be stored within 200 feet of the residence, well, or adjacent residence or **well.**
10.1.4.1 LUB	Rural Zones	The siting of any buildings, tank or other structure with a capacity to hold 1,000 litres or more, used for the **storage of petroleum or other dangerous goods or hazardous wastes on a lot shall not be within 200 feet of a property line, well or watercourse.**
11.1.9.2 11.2.5.2 LUB	Commercial Livestock	New buildings, including **manure storage facilities, shall be located a minimum distance of three hundred (300) feet from a well, watercourse or a dwelling on an adjacent property.**
18.4 LUB	Water Supply Zone	The purpose of this designation is to **limit development within water supply areas. Development permits are issued only for agricultural uses (except intensive livestock and dwelling), existing land uses, forestry uses, single detached dwellings, small-scale wind turbines and water supply facilities. No permanent buildings are permitted within 200 feet of a water supply, and no agricultural or forestry use within 100 feet.**

3.3 Existing Wellfield Protection Areas in the Municipality of the County of Kings

Approximately half of the residents within the County draw water from private wells; the other half from independent central systems. County Council owns and operates the Greenwood Water Utility and a small system in Aylesford. Village Commissions of Canning, Port Williams and New Minas own and operate central water systems. The Town of Kentville has the Stead Water Commission, which serves Kentville and adjoining County areas including North Kentville and a limited area in the east end of Coldbrook.

The County of Kings already has several groundwater protection management plans in place. The County of Kings Municipal Planning Strategy Section 2.12 Water Resource Protection and Management, includes the policies that direct source water protection for those central water systems. These policies are:

- Groundwater Supply Management, Canning Water Supply
  (MPS Section 2.12.4, page 2.12-4)
- Groundwater Supply Management, Port Williams Water Supply
  (MPS Section 2.12.5, page 2.12-9)
- Groundwater Supply Management in Forestry and Country Residential Districts South of New Minas
  (MPS Section 2.12.6, page 2.12-17)
- Groundwater Supply Management, Coldbrook and the Kentville Wellfield Area
  (MPS Section 2.12.7, page 2.12-20)
- Groundwater Supply Management, South Berwick and Area
  (MPS Section 2.12.8, page 2.12-27)

4 Establishing a Wellfield Protection Area

The establishment of a Wellfield Protection Area that would be comprised of four Wellfield Protection Zones was recommended in CBCL Limited's March 2008, Greenwood Capture Zone Modelling Technical Report. Zones are delineated according to the level of risk posed by contaminants for entering the groundwater. The level of risk posed by a contaminant is dependent on the length of time it stays in the aquifer, and therefore groundwater travel time is an important consideration in protecting the wellfield from potential risk of contamination. Wellfield Protection Zones are useful for evaluating the level of risk posed to the groundwater by land uses in particular zones. The zones are also useful for informing land use planning decisions; they ensure that protection measures are appropriate based on the vulnerability of each zone.

It is recommended that the greatest protective measures are within Wellfield Protection Zone A and Wellfield Protection Zone B because they are closest to the wells. The recommended degree of protection decreases with distance from the well in Zones C and D. In zones closest to the wellheads a broad spectrum of contaminants poses a potential threat to the security of the water supply. These contaminants are of high risk even when released at low levels, or with poor mobility in groundwater. With increasing distance from the wellhead, the list of contaminants of concern becomes narrower, focusing on materials which readily dissolve and are transported over long distances. Figure 4.0 illustrates the recommended Wellfield Protection Zones for the Greenwood water supply based on the groundwater flow model analysis summarized in the Technical Report. Following are descriptions, adapted from the Technical Report, of potential contamination risks associated with land uses in each zone.

4.1 Wellfield Protection Zone A (25 metre radius)

The zone of critical importance is the area immediately around each of the wells. The Greenwood Capture Zone Modelling Technical Report recommended that Zone A be delineated according to a radius of 250 ft (76 m) around each wellhead, accounting for at least 15 days of travel time to the well heads. The Greenwood Water Utility Wellhead Protection Committee however decided to reduce this distance to 25 metres, which is the absolute minimum size for this zone. Zone A is based on the 25 metre radius and has been delineated in an oval shape in order to include the two adjacent wellheads in one zone. Activities in Zone A are strictly limited to operation of the wellheads. All contaminants of concern in Zones B, C, and D are also of concern in Zone A.

4.2 Wellfield Protection Zone B (Two Year Capture)

Wellfield Protection Zone B is defined by the 2-year capture zone. Contaminants of concern in Zone B have low mobility but pose a significant health risk to water users. The contaminants of greatest concern within this zone are bacteria (primarily E. Coli) and viruses found in municipal sewage and animal waste. Land uses associated with these contaminants include agriculture, and any type of chemical or fuel storage. Contaminants and land uses of concern in Zones C and D are also of concern in Zone B.

4.3 Wellfield Protection Zone C (Five Year Capture)

Wellfield Protection Zone C is defined by the 5-year capture zone, an area requiring restrictions on contaminants with moderate mobility and stability in the subsurface environment. Contaminants excluded from Zone C pose a health risk at moderate to low concentrations, and are subject to processes

Figure 4.0
Wellfield Protection Zones

Well Locations
Rivers & Streams
Water Body
Zone A
Zone B
Zone C
Zone D

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of adsorption and biodegradation. These materials are generally attenuated over periods of time of less than five years. Petroleum hydrocarbon users fall within this category, including service stations, automotive painting and repair shops, fuel storage and transfer of any kind, and auto salvage operations. All contaminants of concern in Zone D are also of concern in Zone C.

4.4 Wellfield Protection Zone D (Twenty-Five Year Capture)

Wellfield Protection Zone D is defined by the 25-year capture zone, created to manage contaminants which pose a health risk at low concentrations, and which are readily transported over large distances and longer time frames. Zone D also represents the outer boundary of the Wellhead Protection Area as a whole. Dense non-aqueous phase liquids (DNAPLs) such as trichloroethylene and perchloroethylene, which are found in dry cleaning chemicals and degreasers, have the tendency to penetrate deep aquifers and are concerns in Zone D. Chloride, nitrate, and some metals which are readily transported in the groundwater have the ability to arrive at the well head in high concentrations. Land use activities associated with these contaminants include landfills, dry cleaning facilities, metal shops, automobile service shops, sewage disposal facilities, bulk salt storage, as well as bulk storage of fuels and chemicals including pesticides and fertilizers.

5 Land Use & Risk Analysis of Potential Sources of Contamination

A land use inventory was performed in the wellfield area, including a review of available zoning maps, aerial photographs and a field survey.

5.1 Land Use Zoning in the Wellfield Protection Area

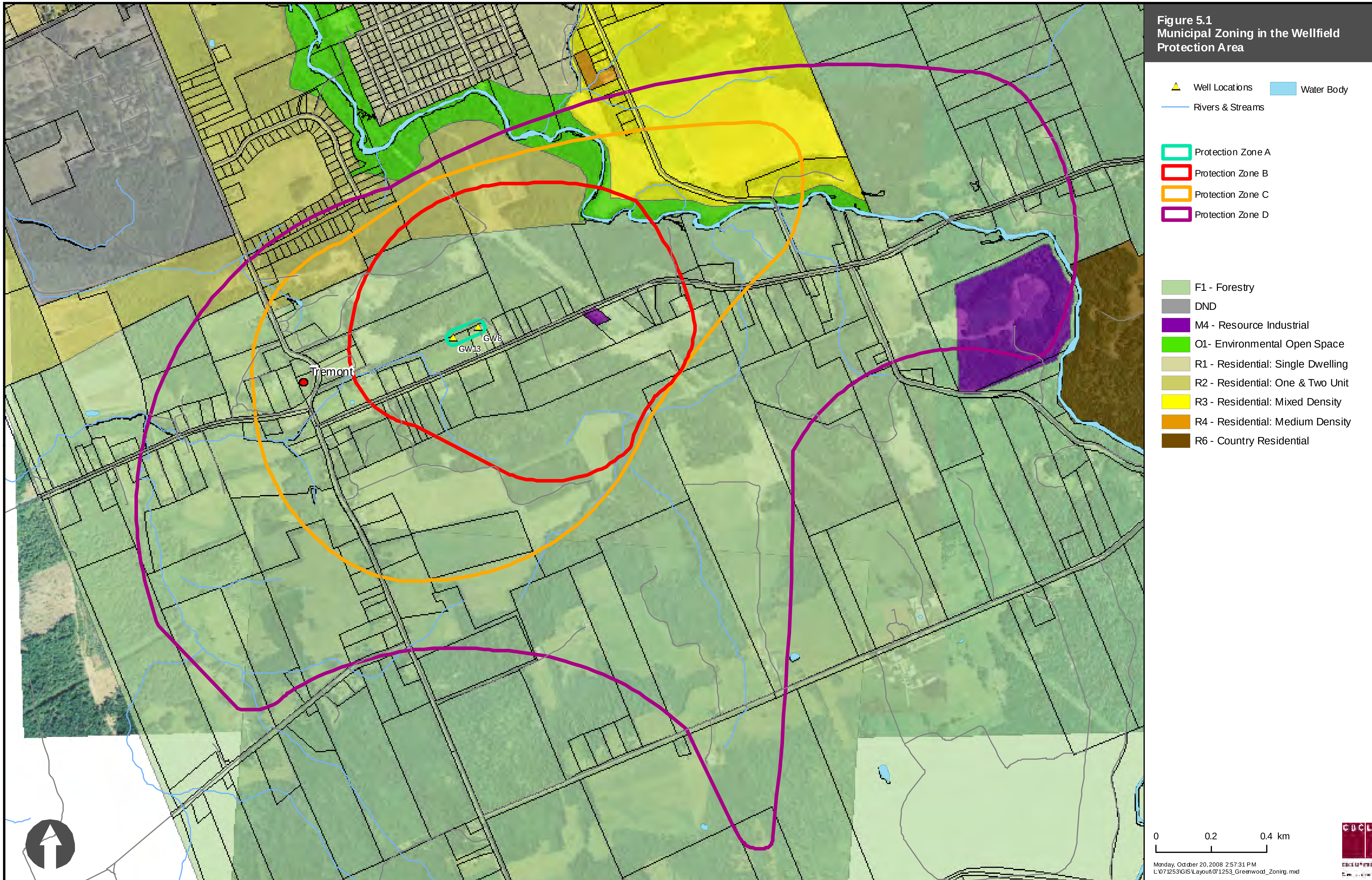
As shown on Figure 1.1, Well GW13 is located at PID number 55309199 (893 Meadowvale Road, Tremont). Well GW8 is located at PID number 55105951 (907 Meadowvale Road, Tremont). Both land parcels are owned by the Municipality of the County of Kings.

Figure 5.1 illustrates the land use zoning in the Wellfield Protection Area. Land parcels containing the wellheads and all other parcels in the recommended Wellfield Protection Zone A are zoned F1, Forestry. Land use in this zone is primarily related to the wellfield, although north of Well GW13 a portion of Zone A is occupied by an active aggregate resource extraction pit.

Land within the recommended Wellfield Protection Zone B is primarily zoned F1, Forestry, with one parcel zoned M4, Resource Industrial. A swath of land in the northern part of Zone B is zoned R2, One and Two Unit Residential. A small piece of land in the northeast corner is zoned O1, Environmental Open Space surrounding the Fales River. A small corner of one land parcel zoned R3, Residential Mixed Density also falls within Zone B. Actual land use is primarily forested land and dispersed (or fairly large-lot) residential development along Meadowvale Road. Also within Zone B is a Nova Scotia Power Inc. substation, a number of aggregate related industries, a livestock operation, a small engine repair shop, a heavy machinery maintenance and storage area, and part of the Village of Greenwood Sewage Treatment Plant.

Wellfield Protection Zone C is primarily zoned F1, Forestry with areas in the north and northeast zoned R2, One and Two Unit Residential, R3, Residential Mixed Density, and O1, Environmental Open Space.

Figure 5.1
Municipal Zoning in the Wellfield Protection Area



Land use in the area is primarily agricultural with some large-lot residential development along Tremont Mountain Road. There is also an aggregate related industry and two cemeteries located near the Meadowvale Road / Tremont Mountain Road intersection. The central northern portion of the zone is primarily forested with the exception of a portion the Village of Greenwood Sewage Treatment Plant.

Wellfield Protection Zone D is also mainly zoned F1, Forestry with areas in the north and northeast zoned R2, One and Two Unit Residential, R3, Residential Mixed Density, and O1, Environmental Open Space. There is also a fairly large parcel in the east zoned M4, Resource Industrial. Land in this zone is primarily a mix of agricultural, forestry, and large-lot residential with a small area of residential development in the northern edge along Terra Nova Drive. More intensive uses in the zone include an abattoir, a salvage yard, and an aggregate related industry.

5.2 Risk Analysis of Potential Contaminant Sources

Following the land use inventory, a risk analysis of identified potential contaminants was performed based on:

- Contaminant type (e.g., pathogens, hydrocarbons, persistent organic compounds);
- Contaminant source and timing
- Groundwater travel time (e.g., from within the 25 metre radius, 2 year, 5 year, and 25 year capture zones);
- Aquifer vulnerability (e.g., thickness of confining till units);
- Opportunities for avoidance and abatement of impact or best management; and
- Short and long-term existing, potential and perceived consequences of impact.

Table 5.2 summarizes known potential contaminant sources within the Wellfield Protection Area. The location of known potential contaminant sources is mapped in Figure 5.2. The land use issues pertaining to the existing potential contaminant sources are discussed further in the following sections.

Table 5.2: Summary of Risk Analysis

Activity/ Cause	Contamination Issue	Subsurface/ Surface	Point/ Non-point	Timing	Risk	Map Reference
Zone A						
Aggregate Resource Extraction Use	Petroleum hydrocarbons, bacteria in storm water run-off	Subsurface	Point	All year	High	1
Zone B						
Livestock Operation (horses)	Bacteria, nutrients, dissolved organic carbon	Surface	Point	All year	Moderate	2
Small Engine Repair Shop	Petroleum hydrocarbons, solvents	Surface	Point	All year	Moderate	3
NSPI Substation	PCBs	Surface	Point	All year	Low	4
Aggregate Related Industry	Petroleum hydrocarbons	Subsurface	Point	All year	Moderate	5
Aggregate Related Industry	Petroleum hydrocarbons	Subsurface	Point	All year	Moderate	6
Aggregate Related Industry	Petroleum hydrocarbons	Subsurface	Point	All year	Low	7
Heavy Machinery Maintenance & Storage	Petroleum hydrocarbons, solvents	Surface	Point	All year	Moderate	8
Zones B & C						
Greenwood Sewage Treatment Plant	Bacteria, nutrients, pharmaceuticals, dissolved organic carbon, chloride	Surface	Point	All year	Moderate	9
Zone C						
Cemetery	Bacteria, nutrients, dissolved organic carbon	Subsurface	Non-point	All year	Low	10
Cemetery	Bacteria, nutrients, dissolved organic carbon	Subsurface	Non-point	All year	Low	11
Aggregate Related Industry	Petroleum hydrocarbons	Subsurface	Point	All year	Low	12
Zone D						
Abattoir	Bacteria, nutrients, dissolved organic carbon, heavy metals (if contained in pest controls)	Surface	Point	All year	Low	13
Salvage yard	Petroleum hydrocarbons, solvents, metals, PAHs, battery acid	Surface / Subsurface	Point	All year	Moderate to Low	14
Aggregate Related Industry	Petroleum hydrocarbons	Subsurface	Point	All year	Low	15

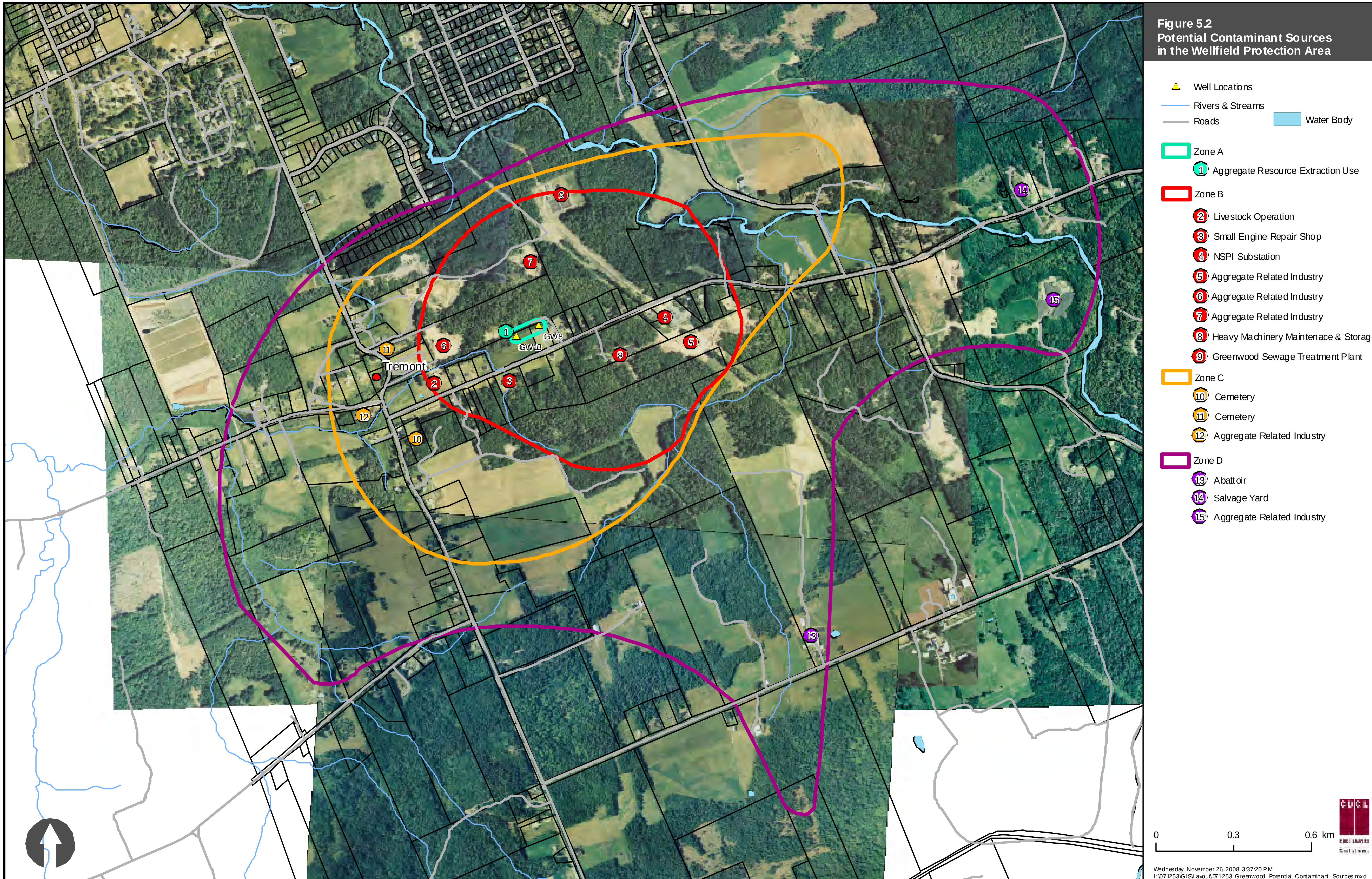


Figure 5.2
Potential Contaminant Sources in the Wellfield Protection Area

6 Land Use Planning Instruments

6.1 Wellfield Protection Zones: Special Overlay Zones

Land use planning is an important tool for protecting groundwater sources within the Greenwood community. It is recommended that land use provisions and restrictions be differentiated according to the zones determined by the Greenwood Capture Zone Modelling Technical Report. The four Wellfield Protection Zones represent different levels of vulnerability and risk to groundwater contamination. The Wellfield Protection Zones are distinguished by the time it would take a contaminant to reach the wellhead.

In accordance with the County of Kings MPS and LUB policies protecting other groundwater sources in the county, it is recommended that Council should establish a hierarchy of land use restrictions. The recommended Wellfield Protection Zones will not replace existing zoning in the plan area. The Wellfield Protection Zones will function as special overlay zones where developments must comply with the requirements of the specific existing zoning as well as with the requirements of the overlay Wellfield Protection Zones. Where the Wellfield Protection Zones are more stringent they will supersede or override the provisions of other zones. It is recommended that the proposed Wellfield Protection Zones be added to all relevant zoning and land use maps in the County of Kings MPS and LUB.

Land uses which pose a risk to the safety of the water supply will be restricted in one of two ways. Land uses of particularly high risk will be prohibited in certain zones. New uses which can be managed and conducted with best practices to minimize risk will be permitted through a development agreement in certain zones.

6.2 Non-conforming uses

Some land uses which will be prohibited or only permitted by development agreement after the adoption of the Greenwood Wellfield Protection Plan currently exist in the wellhead protection area. The contaminants associated with these uses and the level of risk they pose to groundwater were summarized in Table 5.2. These uses are protected under Section 238 of the *Municipal Government Act* and may continue as non-conforming uses.

Figure 5.2 shows the location of existing potential contaminant sources, which would become non-conforming uses in the proposed Greenwood Wellfield Protection Area.

As municipal infrastructure, it is not possible to designate the Greenwood Sewage Treatment Plant (No. 9 on Figure 5.2) as a non-conforming use. See Section 11.3 for a discussion of the source water protection measures to be instituted at the plant.

Abattoirs will be permitted as development agreement uses in Zone D. Therefore, the existing abattoir (No. 13 on Figure 5.2) cannot be declared a non-conforming use. For a discussion of this issue and proposed land use planning controls for abattoirs in Zone D, please see Section 10.2.

According to the MGA, a non-conforming use of land may not be extended beyond the boundaries of the existing lot containing the use, be changed to another use (except for those permitted within the proposed zones), or be recommenced if discontinued for a continuous period of six months. Where there is a non-conforming use in a structure, the previous restrictions apply. Additionally, the use cannot be expanded throughout the structure, and if the structure is destroyed by fire, more than 75% of market value, it cannot be rebuilt or repaired, unless it is occupied by a permitted land use after it is repaired or rebuilt.

The County of Kings MPS differentiates between urban and rural non-conforming use. Since the proposed Wellfield Protection Zones extend from rural land into the urban area of Greenwood, both polices are relevant. Policies regarding rural non-conforming uses provide for greater flexibility than set out in the MGA, to allow for their expansion by development agreement. Policy 3.7.10.2 of the County of Kings MPS outlines the terms of a development agreement Council shall consider regarding rural non-conforming uses. Additional conditions have been placed on non-conforming uses in rural land zoned Environmental Open Space (O1). Of particular interest in regard to wellfield protection is policy 3.7.10.3c, which specifies:

> "the proposed use of the facility and site will not involve any storage of potential pollutants such as fuels, chemicals, pesticides, manure, or any other substance with the potential to pollute surface or groundwater resources"

The County of Kings MPS allows the expansion or change in an urban non-conforming use provided that no greater impact on the surrounding land uses is anticipated.

It is recommended that amendments be made to the MPS, section 6.3.2, to include a policy allowing the consideration of expanding or changing non-conforming uses within the Greenwood Wellfield Protection Zones B, C and D by development agreement.

6.3 Development Agreements

A development agreement is a legal agreement between a landowner and the Municipality, outlining the terms of the development. A development agreement provides Council with a greater degree of specific control over a land use as well as the form and character of the development. Section 6.3 of the County of Kings MPS and Section 5 of the LUB state which developments are subject to a development agreement and the criteria that may be considered. The development agreement runs with the land until it is discharged by the municipality. It is recommended that Council amend Section 5 of the LUB to allow proposals for development agreements within the Greenwood Wellfield Protection Zones B, C and D.

In accordance with the MGA and the County of Kings MPS, the following controls should be specified in development agreements because they are of particular importance when planning for the quality and quantity of groundwater in the Wellfield Protection Zones:

- the type of use
- the location and positioning of outlets for air, water and noise
- maintenance of the development
- buffering, landscaping, screening and access control
- the suitability of the proposed site in terms of steepness of grades, soil and/or geological conditions, and the relative location of watercourses, marshes, swamps, or bogs

- easements for the construction, maintenance or improvement of watercourses, ditches, land drainage works, stormwater systems, wastewater facilities, water systems and other utilities;
- grading or alteration in elevation or contour of the land and provision for the disposal of storm and surface water;
- the construction, in whole or in part, of a stormwater system, wastewater facilities and water system;
- the subdivision of land;
  (Kings MPS, Section 6.3.3.1c; MGA, Section 227[1])

Generally speaking, when Council is considering a development agreement proposal, for either a new development or an expansion or change to an existing non-conforming use, Council should consider policies outlined in the County of Kings MPS Section 6.3.3.1. Several policies in this section have special bearing for the prevention of groundwater contamination:

ii. the adequacy of municipal sewer and water services if services are to be provided. Alternatively, the adequacy of the physical site conditions for private on-site sewer and water systems

iii. the potential for creating, or contributing to, a pollution problem including the contamination of watercourses or the creation of erosion or sedimentation during construction

iv. the adequacy of storm drainage and the effect of same on adjacent uses

ix. the suitability of the proposed site in terms of steepness of grades, soil and/or geological conditions, and the relative location of watercourses, marshes, swamps or bogs
(Kings MPS, Section 6.3.3.1b)

In addition, it is recommended that Council ensures that proposed developments are in conformance with all applicable Provincial and Federal regulations, and that landowners have acquired necessary permits and licenses. Proposed developments should also be reasonably consistent with all other policies outlined in the County of Kings MPS and LUB. When considering a new development or expansion or change to an existing non-conforming use by development agreement in a Wellfield Protection Zone, Council may require the property owner to submit a management plan demonstrating practices committed to groundwater protection. In addition, Council may require that an additional study be completed by a qualified expert to assess the potential impact a proposed development would have on the groundwater.

The following sections outline recommendations for land use in each Wellfield Protection Zone. The lists of recommended prohibited uses and uses considered by development agreement are intended to help guide future land use planning decisions. Some of the prohibited land uses are not allowed under current zoning, but are included to guide decision makers in the future if land use zoning changes. Additional recommendations are made as to specific land use and groundwater protection matters that Council may consider when reviewing a proposal for a development agreement within each zone. The land use provisions and restrictions outlined for the Wellfield Protection Zones have been established with input from the Greenwood Water Utility Wellhead Protection Committee, following their review of the Greenwood Capture Zone Modelling Technical Report submitted by CBCL in March 2008. The

7 Wellfield Protection Zone A (25 Metre Radius)

7.1 Zone A Prohibited Uses

It is recommended that land uses in Zone A be restricted to the operation of the wells. All other land uses are prohibited.

7.2 Zone A Non-Conforming Uses

In accordance with Section 238 of the *Municipal Government Act*, the following non-conforming land use will continue to be permitted in Zone A in its current form and scope:

- Aggregate Resource Extraction Use (No. 1 on Figure 5.2)

This zone represents the land immediately adjacent to the wellheads, which is the most vulnerable to groundwater contamination (*See Section 4.1)*. Council should not consider a development agreement for any new development, nor expansion or change to intensify the non-conforming use, as the intent of this zone is to limit land use to the operation of the well.

8 Wellfield Protection Zone B (Two Year Capture)

8.1 Zone B Prohibited Uses

It is recommended that the following land uses be prohibited in Zone B:

- Abattoirs
- Aggregate related industries
- Asphalt plant
- Auto body repair shop
- Automotive painting shop
- Automobile scrap yard
- Automobile washing facility
- Any assembly or manufacturing operation
- Cemeteries
- Commercial chlorinated organic compounds or solvents storage or distribution
- Commercial salt storage or distribution in excess of 908 kilograms (1 Tonne)
- Commercial fertilizer storage or distribution in excess of 908 kilograms (1 Tonne)
- Commercial pesticide and herbicide storage or distribution
- Commercial petroleum fuels or solvents storage or distribution
- Commercial manure storage or distribution in excess of 908 kilograms (1 Tonne)
- Commercial greenhouses
- Composting facilities
- Dry cleaning facilities
- Engine repair or service shop
- Feed preparation industries
- Fertilizer production, mixing or blending
- Food processing
- Gas stations, including gas bars and service stations

- Heavy equipment repair, service, storage, or sales, including aggregate, agricultural and forestry equipment parts, sales and service
- Landfills and waste transfer stations
- Livestock operations, including hamlet or commercial livestock operations and fish farms.
- Sheet Metal, Welding and Machine Shop
- Power utility substations
- Recycling depot
- Scrap and salvage storage and/or processing
- Septic Disposal Service
- Septic Tank Service
- Soil mixing
- Transport and trucking
- Transportation services
- White metals and hazardous household waste salvage

8.2 Zone B Development Agreement Permitted Uses

Proposed new land uses that Council would consider by development agreement in Zone B include:

- Agricultural operations

Because of its proximity to the wellheads, this zone represents land with a high level of vulnerability to groundwater contamination. The contaminants of greatest concern within this zone are bacteria (primarily E. Coli) and viruses found in municipal sewage and animal waste, as well as any type of fuel or chemical storage and transfer (*See Section 4.2)*.

When considering a proposal for a development agreement for an agricultural operation, Council should ensure that the proposed operation will not pose any increased risk to groundwater. Agricultural operations considered by development agreement in Zone B will not include a livestock operation (hamlet or commercial), commercial manure storage, fertilizer mixing, nor any of the prohibited agriculture-related land uses included in Section 8.1. Council should consider all MPS and MGA policies when considering development agreement proposals with special attention paid to those with the greatest potential to eliminate risk to groundwater. In addition, Council may wish to consider whether or not the agricultural operator has participated, or is willing to participate, in the Environmental Farm Plan Program. Council may request management plans that demonstrate commitment to best management practices and adherence to Provincial guidelines. Council may require that management plans include details regarding pest management, storage of petroleum and chemicals, as well as fertilizer, pesticide, sewage sludge and manure applications. Furthermore, Council may request details regarding the agricultural operation's plan for human and animal waste disposal systems on site. All aspects of the proposed agricultural operation must meet federal and provincial regulations, particularly those made under the *Environment Act.* Council may require, through development agreement, more stringent conditions on agricultural operations in Zone B in order to reduce the risk of contaminating Greenwood's water supply.

8.3 Zone B Non-Conforming Uses

It is recommended that the following non-conforming land uses will continue to be permitted in Zone B:

- Livestock operation (No. 2 on Figure 5.2)
- Small engine repair shop (No. 3 on Figure 5.2)
- NSPI substation (No. 4 on Figure 5.2)
- Aggregate related industry (Nos. 5-7 on Figure 5.2)
- Heavy machinery maintenance and storage facility (No. 8 on Figure 5.2)

If considering a proposal to expand or change the use of the livestock operation by development agreement, Council should have regard to all of the matters discussed above for an agricultural operation. Special attention should be given to animal waste storage, disposal and manure application. Council may require that landowners submit a management plan that demonstrates adherence to Nova Scotia's Manure Management Guidelines and specifies practices that reduce the risk of groundwater contamination.

If considering a proposal to expand or change the use of the small engine repair shop by development agreement, heavy machinery maintenance and storage facility, and/or the power substation, Council should have regard to the potential for increased risk of groundwater contamination through fuel or chemical leaks, petroleum hydrocarbons and solvents. Council may require that the landowner submit a management plan that outlines how fuel leaks will be prevented. Details regarding fuel storage and handling may be necessary in order to inform Council in their decision making process. Landowners must comply with Provincial Petroleum Management Regulations and Council may require, through development agreement, more stringent conditions in order to reduce the risk of contaminating Greenwood's water supply.

If considering a proposal to expand or change the use of the aggregate related industries, Council should have regard to the potential for increased risk of groundwater contamination through fuel leaks from equipment, as well as sediment and runoff. Council may require landowners to submit information about physical and environmental characteristics of the proposed site including topography, drainage, soil types, groundwater, existing watercourses, and vegetation. Council may also require information about the extent of land being cleared and may stipulate that the landowner have appropriate studies conducted by a qualified expert to assess the risk of impact on the quality and quantity of the groundwater. In addition, Council may wish to review a management plan that demonstrates commitment to best practices that reduce the risk of groundwater contamination.

9 Wellfield Protection Zone C (Five Year Capture)

9.1 Zone C Prohibited Uses

It is recommended that the following land uses be prohibited in Zone C:

- Abattoirs
- Aggregate related industries
- Automobile scrap yard
- Cemeteries
- Commercial storage of chlorinated organic compounds or solvents storage or distribution in excess of 900 Litres (200 Gallons)
- Commercial salt storage or distribution in excess of 90, 800 Kilograms (100 Tonnes)

- Commercial storage or distribution of petroleum fuels or solvents
- Composting facilities
- Dry cleaning facilities
- Feed preparation industries
- Fertilizer production, mixing or blending
- Gas stations, including gas bars and service stations
- Heavy equipment repair, service, storage, or sales, including aggregate, agricultural and forestry equipment parts, sales and service
- Livestock operations, including hamlet or commercial livestock operations and fish farms
- Scrap and salvage storage and/or processing
- Septic Disposal Service
- Septic Tank Service
- White metals and hazardous household waste salvage

9.2 Zone C Development Agreement Permitted Uses

There is no need to list uses that are permitted by development agreement for this zone, as all uses of concern are prohibited by existing zoning. If changes to the zoning are proposed, Council will need to be cognizant of the Wellhead Protection Plan and control uses accordingly.

9.3 Zone C Non-Conforming Uses

The following non-conforming land use will continue to be permitted in Zone C:

- Two cemeteries (Nos. 10 & 11 on Figure 5.2)
- Aggregate related industry (No. 12 on Figure 5.2)

If considering a proposal to expand either of the cemeteries, Council should have regard to the potential for increased risk of groundwater contamination through bacteria, nutrient loading, and dissolved organic carbon. Council may request information about the location of new graves, related roads, landscaping or any other changes to the site. Council may also wish to review information about the site including topography, drainage, soil types, groundwater, existing watercourses, and vegetation. Council may also require information about the extent of land being included in the cemetery expansion and may stipulate that the landowner have appropriate studies conducted by a qualified expert to assess the risk of impact on the quality and quantity of the groundwater. In addition Council may wish to review a management plan that demonstrates commitment to best practices that reduce the risk of groundwater contamination, including but not limited to distance between graves and the water table, prevention of water entering graves and control and disposal of water that has entered graves.

If considering a proposal to expand or change the use of the aggregate related industry in Zone C, Council should have regard to the potential for increased risk of groundwater contamination through fuel leaks from equipment, sediment and runoff. Council may require landowners to submit information about physical and environmental characteristics of the proposed site including topography, drainage, soil types, groundwater, existing watercourses, and vegetation. Council may also require information about the extent of land being cleared and may stipulate that the landowner have appropriate studies conducted by a qualified expert to assess the risk of impact on the quality and quantity of the groundwater. In addition, Council may wish to review a management plan that demonstrates commitment to best practices that reduce the risk of groundwater contamination.

10 Wellfield Protection Zone D (Twenty-Five Year Capture)

10.1 Zone D Prohibited Uses

It is recommended that the following land uses be prohibited in Zone D:

- Aggregate related industries
- Automobile scrap yard
- Commercial storage of chlorinated organic compounds or solvents storage or distribution in excess of 900 Litres (200 Gallons)
- Commercial storage of salt or distribution in excess of 90,800 Kilograms (100 Tonnes)
- Commercial pesticide and herbicide storage or distribution in excess of 900 Litres (200 Gallons)
- Commercial petroleum fuels or solvents storage or distribution in excess of 45, 000 Litres (10,000 Gallons)
- Dry cleaners
- Gas stations, including gas bars and service stations
- Heavy equipment repair, service, storage, or sales, including aggregate, agricultural and forestry equipment parts, sales and service
- Scrap and salvage storage and/or processing
- Septic Disposal Service
- Sheet Metal, Welding and Machine Shop
- White metals and hazardous household waste salvage

10.2 Zone D Development Agreement Permitted Uses

Proposed new land uses that Council would consider by development agreement in Zone D include:

- Abattoirs
- Auto body repair shop
- Automotive painting shop
- Livestock operations
- Septic Tank Service
- Small engine repair or service shop

Groundwater in Zone D is vulnerable to contamination from land uses which involve petroleum hydrocarbons, chlorinates and nitrates, and storage of chemicals that could potential contaminants of ground water (*See Section 4.4*).

A proposed expansion or change in the use of the existing abattoir (No. 13 on Figure 5.2) shall only be by development agreement. New proposed abattoirs will only be considered by development agreement. When considering development agreement proposals for new abattoirs or a change to the existing abattoir, Council should have regard to the potential for increased risk of groundwater contamination through bacteria, viruses, nutrient loading, dissolved organic carbon and other contaminants carried in wastewater runoff containing animal faeces, blood, fat, paunch and intestinal contents, animal trimmings and urine. All waste should be disposed of off-site and outside of the Wellfield Protection Area. Council may request detailed information about the expansion of existing buildings, the location of new buildings, related roads, wastewater and solid waste disposal management/systems, landscaping or any other changes on the site. Council may also wish to review information about the site including topography, drainage, soil types, groundwater, existing watercourses, and vegetation. Council may also stipulate that the landowner have appropriate studies conducted by a qualified expert to assess the risk of impact on the quality and quantity of the groundwater. The abattoir must continue to retain a licence and comply with regulations in the Nova Scotia *Meat Inspection Act*. In addition, Council may wish to review a management plan that demonstrates commitment to best practices that reduce the risk of groundwater contamination, including but not limited to information about solid waste and wastewater disposal practices, facility and equipment operation, sanitation, maintenance, live animal holding areas and storage areas.

If considering proposals for auto body repair shop, automotive painting shop, automobile washing facility and/or an engine repair or service shop, Council should have regard to the potential for increased risk of groundwater contamination through runoff containing toxic chemicals, such as solvents and petroleum products. Council may require the landowner to submit a management plan that includes details about the location, storage and/or handling of petroleum products (gas, diesel, oil), paint, paint thinner, dip tanks, parts washers, spray solvents/cleaners, detergents, antifreeze and batteries. Council may also consider whether or not the landowner is carrying out best practices regarding equipment maintenance, containment and clean up of spills, chemical/automotive parts disposal, waste water disposal, and minimizing use of toxic chemicals. Furthermore, Council may stipulate that the landowner have appropriate studies conducted by a qualified expert to assess the risk of impact on the quality and quantity of the groundwater.

If considering a proposal for a livestock operation, Council may wish to consider whether or not the operator has participated, or is willing to participate, in the Environmental Farm Plan Program. Council may request management plans that demonstrate commitment to best management practices and adherence to Provincial guidelines. Council may require that management plans include details regarding pest management, storage of petroleum and chemicals, as well as fertilizer, pesticide, sewage sludge and manure applications. Special attention should be given to animal waste storage, disposal and manure application. Furthermore, Council may request details regarding the agricultural operation’s plan for human and animal waste disposal systems on site. All aspects of the proposed agricultural and livestock operations must meet federal and provincial regulations, particularly those made under the Environment Act. Council may require that landowners submit a management plan that demonstrates adherence to Nova Scotia’s Manure Management Guidelines and specifies practices that reduce the risk of groundwater contamination.

If considering a proposal for a septic tank service operation, Council may wish to consider the prohibition of overnight parking of fully or partially loaded sewage pumping trucks to reduce the chances of spills.

10.3 Zone D Non-Conforming Uses

The following non-conforming land use will continue to be permitted in Zone D:

- Salvage yard (No. 14 on Figure 5.2)

- Aggregate Related Industry (No. 15 on Figure 5.2)

If considering proposals to expand or change the use of the salvage yard by development agreement, Council should have regard to the potential for increased risk of groundwater contamination through runoff containing toxic chemicals, such as metals, solvents and petroleum products. Council may require the landowner to submit a management plan that includes details about the location, storage and/or handling of petroleum products (gas, diesel, oil), paint, paint thinner, spray solvents/cleaners, antifreeze, automotive parts, and batteries. Council may also consider whether or not the landowner is carrying out best practices regarding equipment maintenance, containment and clean up of spills, chemical/automotive parts disposal, waste water disposal, and minimizing use of toxic chemicals. Furthermore, Council may stipulate that the landowner have appropriate studies conducted by a qualified expert to assess the risk of impact on the quality and quantity of the groundwater.

If considering a proposal to expand or change the use of the aggregate related industry in Zone D, Council should have regard to the potential for increased risk of groundwater contamination through fuel leaks from equipment, sediment and runoff. Council may require landowners to submit information about physical and environmental characteristics of the proposed site including topography, drainage, soil types, groundwater, existing watercourses, and vegetation. Council may also require information about the extent of land being cleared and may stipulate that the landowner have appropriate studies conducted by a qualified expert to assess the risk of impact on the quality and quantity of the groundwater. In addition, Council may wish to review a management plan that demonstrates commitment to best practices that reduce the risk of groundwater contamination.

11 Additional Groundwater Protection Strategies

The municipality may also consider initiatives and policies that are beyond the scope of land use planning legislation, but which can impact residents' land use practices and therefore contribute to the protection of the groundwater supply.

11.1 Public Education

It is recommended that the County of Kings together with the Greenwood Water Utility make efforts to communicate to all residents in the Greenwood and the surrounding area about the Wellfield Protection Plan.

The County of Kings MPS demonstrates commitment to educating the public about their role in protecting groundwater and states as a goal for managing groundwater:

- Foster groundwater protection and water conservation practices among county residents, institutions and businesses dependent on public and private wells.
  (County of Kings MPS Section 2.12.2, page 2.12-2)

The County of Kings MPS includes as a stated objectives for achieving groundwater supply goals:

- implementing community awareness programs relating to both private well and community well water supplies;
- promoting responsible groundwater management and conservation practices; and

- acting in partnership with other government agencies, and municipalities, village commissions, institutions, interest groups and industry to achieve sustainable use of groundwater resources. (County of Kings MPS Section 2.12.2, pages 2.12-2&3)

11.1.1 Inform the Public About the Wellfield Protection Plan

The Greenwood Water Utility should make Greenwood and surrounding area residents aware of the Wellfield Protection Plan, including the boundaries of the Wellfield Protection Area and the strategies being undertaken to protect groundwater. The Utility shall consider informing the public through means including but not limited to:

- a public open house,
- semi-permanent displays and/or take-home printed fact sheets at places like the grocery store, churches, post office, and the Greenwood Military Family Resource Centre,
- mail out of information flyers or booklets,
- information posted on the County and Village websites,
- and an advertisement in the local newspaper.

11.1.2 Public Awareness Through Informative Signage

Signs can assist in educating the public about the boundaries of the Wellfield Protection Zones and raise awareness about groundwater protection in general. Signage should be erected at locations where Wellfield Protection Area boundaries intersect with roads, informing people they are entering an important and sensitive area. The Greenwood Water Utility should erect signs particularly at the boundaries of Zones A and B along the Meadowvale Road. The Greenwood Water Utility should also investigate other appropriate locations to erect signage in order to inform the public about the sensitivity and importance of the Wellfield Protection Area they are about to enter.

11.1.3 Wellfield Protection Area Residents as Groundwater Stewards

Domestic oil tanks are a potential risk in Wellfield Zone B, as identified in Table 5.2. Residents within the Wellfield Protection Area can become groundwater stewards with assistance and information from the Greenwood Water Utility. It is recommended that the Greenwood Water Utility inform residents within the Wellfield Protection Area about potential sources of risk to groundwater on their properties such as oil tanks, septic systems, pesticide use on home gardens, and storage of fuel and other chemicals.

The Greenwood Water Utility should send a letter to all property owners within the Wellfield Protection Area informing them of the Wellfield Protection Area boundaries, as shown on an easily discernable map. This letter will emphasize the importance of groundwater protection and the increased sensitivities of each Wellfield Protection Zone. Residents will be informed about the risk associated potential domestic contaminants and encouraged to implement best management practices outlined in publications including, but not limited to:

- On-site sewage disposal (septic systems)
- A Homeowners Guide to Oil Tank Safety
- Home Garden Pest Control
- Composting Yard Trimmings and Leaves (Waste Reduction Fact Sheet)
- Sustainable Gardening
- Pollution Prevention: At Work and at Home

The County of Kings and the Greenwood Water Utility will make staff available to answer inquiries from homeowners working towards groundwater protection measures.

11.2 Work With Property Owners of Non-Conforming Uses

The County together with the Greenwood Water Utility may want to contact landowners and operators of existing non-conforming uses within the Wellfield Protection Area in order to obtain specific information on practices and future plans for use of the land. The land owners should be informed of the vulnerability of groundwater and the Greenwood wellheads to extractive activities and the importance of protecting the water supply. The Municipality may wish to solicit voluntary agreements from the landowners to use best management practices with respect to the use of the property, including the provision of containment and clean-up materials for any heavy equipment used on-site and the implications of non-conforming use designation.

11.2.1 Best Management Practices

Nova Scotia has published several best practice management guides for agriculture, forestry, commercial activities, recreation, as well as construction and development. Many of Nova Scotia Environment's recommended resources can be found on the NSE website (http://www.gov.ns.ca/nse/pubs/). In the guidelines for developing a municipal source water protection plan, NSE also recommends the US Environmental Protection Agencies management measures for controlling pollutants of groundwater (http://www.epa.gov/watertrain/pdf/swpbmp.pdf, http://www.epa.gov/owow/nps/pubs.html). NSE also highlights the American National Water Program as a resource for best management practices for agriculture and other land uses (http://www.usawaterquality.org/).

Greenwood Water Utility staff may wish to direct property owners of non-conforming uses towards certain aforementioned best management practice resources in order to minimize risk from their land use activities.

11.3 Increase Monitoring at Sewage Treatment Plant to Reduce Risk of Groundwater Contamination

The Municipality recognizes the risk posed by the Greenwood Sewage Treatment Plant and is committing to develop additional operation procedures and actions that will increase the monitoring of the plant and decrease the risk of any problems. This plan will be developed as part of the overall source water protection plan. The development of the overall source water protection plan is not part of this land use planning process and will be developed by the engineering department at a later date

11.4 Develop A Source Water Protection Plan

The Greenwood Water Utility should develop a full source water protection plan as outlined by NSE. The sourcewater protection plan will include land use elements discussed in this report as well as a contingency plan that will outline actions that need to be taken in the case of a water supply emergency, as well as a monitoring plan for the Water Utility that will indicate whether or not source water protection measures are have the desired effect.

Within the Contingency Plan, the Greenwood Water Utility should inform emergency responders about the Wellfield Protection Area and indicate that the Utility should be contacted immediately in the case of a hazardous substance spill within the area. The Greenwood Water Utility should also identify alternative sources of water and means of distributing safe drinking water to Greenwood residents. Furthermore, the Utility needs to develop a plan for communicating with residents who rely on the public water source about a water emergency, including boil water advisories. According to NSE’s guidelines for developing a source water protection management plan, the contingency plan should include:

- General procedures for routine emergencies or major emergencies within a water supply area
- A procedure for equipment becoming inoperable in a major emergency and/or due to power failure
- A procedure for dealing with spills or releases
- A boil water advisory procedure
- Facility-specific information on the hazardous material stored or transported in the source water area.
- Provision for annual review and update by the utility.

11.5 Develop a Monitoring Program to Evaluate the Effectiveness of the Greenwood Wellfield Protection Plan

According to NSE’s guidelines for developing a source water protection management plan, municipalities should develop a monitoring program to evaluate the effectiveness of the protection plan. The monitoring program should help the Greenwood Water Utility determine how well the Greenwood Wellfield Protection Plan is being implemented as well as how well the Plan is able to protect the quality and quantity of the groundwater supply. The monitoring plan should

- Confirm the parameters to be measured
- Confirm the locations and frequency of sampling
- Establish baseline data
- Record results and determine if conditions are satisfactory and/or changing
- Alter Protection Plan accordingly until results are satisfactory, and continue monitoring and evaluation program
- Use water quantity measurements to aid in evaluation of the protection plan.

The collection of groundwater quality and water level information can be used to assess groundwater trends and baseflow conditions over time and serve as an early warning system for water quality and hydraulic impacts to a wellfield and local aquatic habitat. The results from the raw water samples collected as part of the regular testing program can be used in the groundwater monitoring program. Groundwater level information should be collected from both of the production wells.

Additional groundwater monitoring locations should be identified to provide an overall indication of the health of the Wellfield Protection Area. The parameters to be measured would be based on existing land use concerns (the wastewater treatment facility in particular) and the type of substances the Wellfield Protection Zones are designed to manage. The groundwater monitoring program would involve the development of a sampling protocol, the collection of baseline data and on-going routine monitoring, and would also include criteria for initiating contingency plans.

The Wellfield Protection Plan should be subject to periodic review. Based on the outcome of the review, recommendations may be made by the Greenwood Wellfield Protection Plan Steering Committee to modify or strengthen components of the plan. It is recommended that the Wellfield Protection Plan is reviewed at the same time as the County of Kings Municipal Planning Strategy review, which happens every five years.

Mechanisms for evaluation of the effectiveness of the Wellfield Protection Plan include the following:

- Summary of recommendations and actions to date;
- Comparison of recommended land use and actual land use;
- Review of the results of the monitoring program compared to baseline data;
- Review of adequacy and effectiveness of Emergency Measures Plan; and
- Update of the groundwater model based on any new hydrogeological information obtained, or any change to the wellfield characteristics or pumping rates.

12 Action Plan

The County of Kings and the Greenwood Water Utility should set goals for implementing the Greenwood Wellfield Protection Plan. Table 12.1 provides recommended timeframes for implementing the main recommendations for the Greenwood Wellfield Protection Plan.

Table 12.1: Implementation Recommendations for the Greenwood Wellfield Protection Plan

Land Use Planning Actions	Responsibility	Timeframe
Amend the County of Kings MPS and LUB to incorporate the Greenwood Wellfield Protection Plan	**County of Kings Council**	**By December 2009**

Additional Groundwater Protection Strategies	Responsibility	Timeframe
Educate the Public regarding the Greenwood Wellfield Protection Plan and Plan Area	Greenwood Water Utility	Upon acceptance of the Wellfield Protection Plan and throughout the following year
Work with property owners of non-conforming uses to reduce potential contamination risk	Greenwood Water Utility	Ongoing
Increase monitoring of the sewage treatment plant to reduce potential contamination risk	Greenwood Water Utility	Ongoing
Develop a Source Water Protection Plan	Greenwood Water Utility	By March 2010
Develop a Monitoring Program	Greenwood Water Utility with County of Kings Council	By December 2009 – June 2010

Appendix A

Summary of Change in Permitted Land Use Within the Wellfield Protection Area

Figure 5.1 shows land use zoning within the Wellfield Protection Area.

12.1 Zone D

Wellfield Protection Zone D is the outermost zone in the Wellfield Protection Area, representing the land farthest from the wells and the 25 year groundwater capture zone. Zone D is mainly zoned Forestry (F1) with areas in the north and northeast zoned for One and Two Unit Residential (R2), Residential Mixed Density (R3), and Environmental Open Space (O1). There is also a fairly large parcel in the east zoned Resource Industrial (M4).

ZONE D
All existing uses are allowed to continue as non-conforming uses.

ZONE D	
Currently Permitted in Forestry (F1) Zone	**Permitted after Wellfield Protection Zone D is overlaid on F1 Zone**
• Agricultural Uses as part of the farm operation excluding livestock operations • Bunkhouses • Double Wide Mobile Homes • Duplexes • Existing Community Facilities • Existing Gun Ranges • Fish Farm • Fishing Uses • Forestry Uses • Greenhouses • Kennels • Mini Homes • Mobile Homes • Multi-sectional Modular Homes • Nonprofit Camps • Nurseries • Radio Controlled Aircraft Fields • Residential Care Facilities • Seasonal Dwellings • Semi-Detached Dwellings • Single Detached Dwellings • Small-Scale Wind Turbines • Wildlife Rescue and Rehabilitation Centre	• Agricultural Uses as part of the farm operation excluding livestock operations • Bunkhouses • Double Wide Mobile Homes • Duplexes • Existing Community Facilities • Existing Gun Ranges • Fish Farm *(by development agreement)* • Fishing Uses • Forestry Uses • Greenhouses • Kennels • Mini Homes • Mobile Homes • Multi-sectional Modular Homes • Nonprofit Camps • Nurseries • Radio Controlled Aircraft Fields • Residential Care Facilities • Seasonal Dwellings • Semi-Detached Dwellings • Single Detached Dwellings • Small-Scale Wind Turbines • Wildlife Rescue and Rehabilitation Centre

Uses Subject to Conditions (Outlined in LUB Section 10.1 & 11.2)	Uses Still Subject to Conditions (Outlined in LUB Section 10.1 & 11.2)
• Bed and Breakfast Operations • Commercial Livestock Operations • Farm Market Outlets • Farm Tenement Buildings • Home Day Care • Homes for Special Care • Recycling Depots • Rural Home Occupations • Tourist Commercial Facilities for Lodging, Food Services and Ancillary Uses	• Bed and Breakfast Operations • Commercial Livestock Operations *(by development agreement)* • Farm Market Outlets • Farm Tenement Buildings • Home Day Care • Homes for Special Care • Recycling Depots • Rural Home Occupations • Tourist Commercial Facilities for Lodging, Food Services and Ancillary Uses

ZONE D	
Currently Permitted in Residential One and Two Unit (R2) Zone	**Permitted after Wellfield Protection Zone D is overlaid on R2 Zone**
• Duplexes • Existing Farms subject to R1 Zone requirements • Existing Residential Uses • Multi Sectional Modular Homes • Residential Care Facilities • Semi-Detached Dwellings • Single Detached Dwellings	• Duplexes • Existing Farms subject to R1 Zone requirements • Existing Residential Uses • Multi Sectional Modular Homes • Residential Care Facilities • Semi-Detached Dwellings • Single Detached Dwellings
Uses Subject to Conditions (Outlined in LUB Section 8.1)	**Uses Still Subject to Conditions (Outlined in LUB Section 8.1)**
• Bed and Breakfast Operations • Cemeteries • Churches • Home Based Businesses • Home Day Care • Urban Home Occupations	• Bed and Breakfast Operations • Cemeteries • Churches • Home Based Businesses • Home Day Care • Urban Home Occupations

ZONE D	
Currently Permitted in Residential Mixed Density (R3) Zone	**Permitted after Wellfield Protection Zone D is overlaid on R3 Zone**
• Converted Dwellings to a Maximum of 8 Residential Units • Duplexes • Existing Farms • Multi Sectional Modular Homes • Multi Unit Residential to a Maximum of 8 Residential Units • Residential Care Facilities • Semi-Detached Dwellings	• Converted Dwellings to a Maximum of 8 Residential Units • Duplexes • Existing Farms • Multi Sectional Modular Homes • Multi Unit Residential to a Maximum of 8 Residential Units • Residential Care Facilities • Semi-Detached Dwellings

• Single Detached Dwellings • Town Houses to a Maximum of 8 Units	• Single Detached Dwellings • Town Houses to a Maximum of 8 Units
Uses Subject to Conditions **(Outlined in LUB Section 8.1 & 8.5)**	**Uses Still Subject to Conditions** **(Outlined in LUB Section 8.1 & 8.5)**
• Bed and Breakfast Operations • Cemeteries • Churches • Home Based Businesses • Home Day Care • Urban Home Occupations	• Bed and Breakfast Operations • Cemeteries • Churches • Home Based Businesses • Home Day Care • Urban Home Occupations

ZONE D	
Currently Permitted in Environmental Open Space (O1) Zone	**Permitted after Wellfield Protection Zone D is overlaid on O1 Zone**
• Agricultural Uses • Flood Control Facilities • Fishing Uses • Forestry Uses • Radio Controlled Aircraft Fields	• Agricultural Uses *(Livestock operations only considered by development agreement)* • Flood Control Facilities • Fishing Uses • Forestry Uses • Radio Controlled Aircraft Fields

ZONE D	
Currently Permitted in Resource Industrial (M4) Zone	**Permitted after Wellfield Protection Zone D is overlaid on M4 Zone**
• Aggregate Equipment Parts, Sales and Service • Aggregate Related Industries • Agricultural Equipment Parts, Sales and Service • Agricultural Related Industries including processing of crops and livestock, including sorting, grading, packaging, slaughtering (abattoirs), manufacturing and packaging of food, livestock feed, fertilizer and similar uses. • Bulk Chemical Storage • Bulk Fuel Storage • Cold Storage Facilities • Composting Facilities • Existing Uses as of the date of enactment of this provision • Fishing Equipment Parts, Sales and Service • Fishing Related Industries • Forestry Equipment Parts, Sales and	• ~~Aggregate Equipment Parts, Sales and Service~~ • ~~Aggregate Related Industries~~ • ~~Agricultural Equipment Parts, Sales and Service~~ • Agricultural Related Industries including processing of crops and livestock, including sorting, grading, packaging, slaughtering (abattoirs) *(slaughtering/abattoirs considered by development agreement)*, manufacturing and packaging of food, livestock feed, fertilizer and similar uses. • Bulk Chemical Storage • Bulk Fuel Storage • Cold Storage Facilities • Composting Facilities • Existing Uses as of the date of enactment of this provision • Fishing Equipment Parts, Sales and Service • Fishing Related Industries • ~~Forestry Equipment Parts, Sales and~~

Service • Forestry Related Industries Forestry Industry Uses means any business which is directly involved in, and whose principal purpose is, the harvesting, milling, sawing, processing, storage or transport of lumber, sawdust and Christmas trees. • Light Industrial Commercial (M1) Zone Uses Within Existing Structures o Accessory Commercial Uses o Accessory Gas Bars o Arenas o Automobile Parts, Sales, Rentals and Service o Automotive Painting, Engine and Body Repair o Building and Construction Contractors o Building Supplies and Equipment Sales o Bus Depots and Maintenance Facilities o Cold Storage Facilities o Commercial Greenhouses o Crematoria o Electrical and Electronics Shop o Existing Heavy Industries Specified in 7.2.10 o Fire Stations o Hatcheries for Poultry and Fish o Heavy Equipment Parts, Sales and Service o Heavy Equipment Storage and Maintenance o Indoor Recreation Uses o Laundry and Dry Cleaning Establishment o Kennels o Manufacturing and Bottling of Beverages o Manufacturing, Assembly or Fabrication Plants o Mini Warehouses o Nurseries and Garden Centres o Outdoor Commercial Displays	~~Service~~ • Forestry Related Industries Forestry Industry Uses means any business which is directly involved in, and whose principal purpose is, the harvesting, milling, sawing, processing, storage or transport of lumber, sawdust and Christmas trees. • Light Industrial Commercial (M1) Zone Uses Within Existing Structures o Accessory Commercial Uses ~~o Accessory Gas Bars~~ o Arenas o Automobile Parts, Sales, Rentals and Service *(by development agreement)* o Automotive Painting, Engine and Body Repair *(by development agreement)* o Building and Construction Contractors o Building Supplies and Equipment Sales o Bus Depots and Maintenance Facilities *(by development agreement)* o Cold Storage Facilities o Commercial Greenhouses o Crematoria o Electrical and Electronics Shop o Existing Heavy Industries Specified in 7.2.10 o Fire Stations o Hatcheries for Poultry and Fish *(by development agreement as a livestock operation)* o Heavy Equipment Parts, Sales and Service o Heavy Equipment Storage and Maintenance o Indoor Recreation Uses o Laundry ~~and Dry Cleaning~~ Establishment o Kennels o Manufacturing and Bottling of Beverages o Manufacturing, Assembly or Fabrication Plants o Mini Warehouses o Nurseries and Garden Centres o Outdoor Commercial Displays

o Plumbing Shop o Printing Establishment o Recycling Depots o Residential Uses - Existing o Retail Warehouse Outlet o Rural Home Occupations o Self Contained Processing Plants o Septic Tank Service o Sheet Metal, Welding and Machine Shop o Transport and Trucking o Transportation Services o Veterinary Clinics o Warehousing o Wholesale Bakery o Wholesale Distributors and Suppliers • Peat Moss Packaging and Processing • Septic Disposal Service • Small-Scale Wind Turbines • Transport and Trucking • Warehousing and Storage • Waste Transfer Stations • Well Drilling Services	o Plumbing Shop o Printing Establishment o Recycling Depots o Residential Uses - Existing o Retail Warehouse Outlet o Rural Home Occupations o Self Contained Processing Plants o ~~Septic Tank Service~~ o ~~Sheet Metal, Welding and Machine Shop~~ o Transport and Trucking o Transportation Services o Veterinary Clinics o Warehousing o Wholesale Bakery o Wholesale Distributors and Suppliers • Peat Moss Packaging and Processing • ~~Septic Disposal Service~~ • Small-Scale Wind Turbines • Transport and Trucking • Warehousing and Storage • Waste Transfer Stations • Well Drilling Services

12.2 Zone C

Wellfield Protection Zone C is primarily zoned Forestry (F1), with areas in the north and northeast zoned One and Two Unit Residential (R2), Residential Mixed Density (R3), and Environmental Open Space (O1).

ZONE C
All existing uses are allowed to continue as non-conforming uses.

ZONE C	
Currently Permitted in Forestry (F1) Zone	**Permitted after Wellfield Protection Zone C is overlaid on F1 Zone**
• Agricultural Uses as part of the farm operation excluding livestock operations • Bunkhouses • Double Wide Mobile Homes • Duplexes • Existing Community Facilities • Existing Gun Ranges • Fish Farm • Fishing Uses • Forestry Uses • Greenhouses	• Agricultural Uses as part of the farm operation excluding livestock operations • Bunkhouses • Double Wide Mobile Homes • Duplexes • Existing Community Facilities • Existing Gun Ranges • ~~Fish Farm~~ • Fishing Uses • Forestry Uses • Greenhouses

• Kennels • Mini Homes • Mobile Homes • Multi-sectional Modular Homes • Nonprofit Camps • Nurseries • Radio Controlled Aircraft Fields • Residential Care Facilities • Seasonal Dwellings • Semi-Detached Dwellings • Single Detached Dwellings • Small-Scale Wind Turbines • Wildlife Rescue and Rehabilitation Centre	• Kennels • Mini Homes • Mobile Homes • Multi-sectional Modular Homes • Nonprofit Camps • Nurseries • Radio Controlled Aircraft Fields • Residential Care Facilities • Seasonal Dwellings • Semi-Detached Dwellings • Single Detached Dwellings • Small-Scale Wind Turbines • Wildlife Rescue and Rehabilitation Centre
Uses Subject to Conditions **(Outlined in LUB Section 10.1 & 11.2)**	**Uses Still Subject to Conditions** **(Outlined in LUB Section 10.1 & 11.2)**
• Bed and Breakfast Operations • Commercial Livestock Operations • Farm Market Outlets • Farm Tenement Buildings • Home Day Care • Homes for Special Care • Recycling Depots • Rural Home Occupations • Tourist Commercial Facilities for Lodging, Food Services and Ancillary Uses	• Bed and Breakfast Operations • ~~Commercial Livestock Operations~~ • Farm Market Outlets • Farm Tenement Buildings • Home Day Care • Homes for Special Care • Recycling Depots • Rural Home Occupations • Tourist Commercial Facilities for Lodging, Food Services and Ancillary Uses

ZONE C	
Currently Permitted in Residential One and Two Unit (R2) Zone	**Permitted after Wellfield Protection Zone C is overlaid on R2 Zone**
• Duplexes • Existing Farms subject to R1 Zone requirements • Existing Residential Uses • Multi Sectional Modular Homes • Residential Care Facilities • Semi-Detached Dwellings • Single Detached Dwellings	• Duplexes • Existing Farms subject to R1 Zone requirements • Existing Residential Uses • Multi Sectional Modular Homes • Residential Care Facilities • Semi-Detached Dwellings • Single Detached Dwellings
Uses Subject to Conditions **(Outlined in LUB Section 8.1)**	**Uses Still Subject to Conditions** **(Outlined in LUB Section 8.1)**
• Bed and Breakfast Operations • Cemeteries • Churches • Home Based Businesses • Home Day Care • Urban Home Occupations	• Bed and Breakfast Operations • Cemeteries • Churches • Home Based Businesses • Home Day Care • Urban Home Occupations

ZONE C	
Currently Permitted in Residential Mixed Density (R3) Zone	**Permitted after Wellfield Protection Zone C is overlaid on R3 Zone**
• Converted Dwellings to a Maximum of 8 Residential Units • Duplexes • Existing Farms • Multi Sectional Modular Homes • Multi Unit Residential to a Maximum of 8 Residential Units • Residential Care Facilities • Semi-Detached Dwellings • Single Detached Dwellings • Town Houses to a Maximum of 8 Units	• Converted Dwellings to a Maximum of 8 Residential Units • Duplexes • Existing Farms • Multi Sectional Modular Homes • Multi Unit Residential to a Maximum of 8 Residential Units • Residential Care Facilities • Semi-Detached Dwellings • Single Detached Dwellings • Town Houses to a Maximum of 8 Units
Uses Subject to Conditions (Outlined in LUB Section 8.1 & 8.5)	**Uses Still Subject to Conditions** (Outlined in LUB Section 8.1 & 8.5)
• Bed and Breakfast Operations • Cemeteries • Churches • Home Based Businesses • Home Day Care • Urban Home Occupations	• Bed and Breakfast Operations • ~~Cemeteries~~ • Churches • Home Based Businesses • Home Day Care • Urban Home Occupations

ZONE C	
Currently Permitted in Environmental Open Space (O1) Zone	**Permitted after Wellfield Protection Zone C is overlaid on O1 Zone**
• Agricultural Uses • Flood Control Facilities • Fishing Uses • Forestry Uses • Radio Controlled Aircraft Fields	• Agricultural Uses *(Livestock operations prohibited)* • Flood Control Facilities • Fishing Uses • Forestry Uses • Radio Controlled Aircraft Fields

12.3 Zone B

Land within the recommended Wellfield Protection Zone B is primarily zoned Forestry (F1), with one parcel zoned Resource Industrial (M4). A swath of land in the northern part of Zone B is zoned One and Two Unit Residential (R2). A small piece of land in the northeast corner is zoned Environmental Open Space (O1), surrounding the Fales River. A small corner of one land parcel zoned Residential Mixed Density (R3), also falls within Zone B.

ZONE B
All existing uses are allowed to continue as non-conforming uses.

ZONE B	
Currently Permitted in Forestry (F1) Zone	**Permitted after Wellfield Protection Zone B is overlaid on F1 Zone**
• Agricultural Uses as part of the farm operation excluding livestock	• Agricultural Uses as part of the farm operation excluding livestock

operations • Bunkhouses • Double Wide Mobile Homes • Duplexes • Existing Community Facilities • Existing Gun Ranges • Fish Farm • Fishing Uses • Forestry Uses • Greenhouses • Kennels • Mini Homes • Mobile Homes • Multi-sectional Modular Homes • Nonprofit Camps • Nurseries • Radio Controlled Aircraft Fields • Residential Care Facilities • Seasonal Dwellings • Semi-Detached Dwellings • Single Detached Dwellings • Small-Scale Wind Turbines • Wildlife Rescue and Rehabilitation Centre	operations *(by development agreement)* • Bunkhouses • Double Wide Mobile Homes • Duplexes • Existing Community Facilities • Existing Gun Ranges • ~~Fish Farm~~ • Fishing Uses • Forestry Uses • ~~Greenhouses~~ • Kennels • Mini Homes • Mobile Homes • Multi-sectional Modular Homes • Nonprofit Camps • Nurseries • Radio Controlled Aircraft Fields • Residential Care Facilities • Seasonal Dwellings • Semi-Detached Dwellings • Single Detached Dwellings • Small-Scale Wind Turbines • Wildlife Rescue and Rehabilitation Centre
Uses Subject to Conditions	**Uses Still Subject to Conditions**
• Bed and Breakfast Operations • Commercial Livestock Operations • Farm Market Outlets • Farm Tenement Buildings • Home Day Care • Homes for Special Care • Recycling Depots • Rural Home Occupations • Tourist Commercial Facilities for Lodging, Food Services and Ancillary Uses	• Bed and Breakfast Operations • ~~Commercial Livestock Operations~~ • Farm Market Outlets • Farm Tenement Buildings • Home Day Care • Homes for Special Care • ~~Recycling Depots~~ • Rural Home Occupations • Tourist Commercial Facilities for Lodging, Food Services and Ancillary Uses

ZONE B	
Currently Permitted in Resource Industrial (M4) Zone	**Permitted after Wellfield Protection Zone B is overlaid on M4 Zone**

• Aggregate Equipment Parts, Sales and Service
• Aggregate Related Industries
• Agricultural Equipment Parts, Sales and Service
• Agricultural Related Industries including processing of crops and livestock, including sorting, grading, packaging, slaughtering (abattoirs), manufacturing and packaging of food, livestock feed, fertilizer and similar uses.
• Bulk Chemical Storage
• Bulk Fuel Storage
• Cold Storage Facilities
• Composting Facilities
• Existing Uses as of the date of enactment of this provision
• Fishing Equipment Parts, Sales and Service
• Fishing Related Industries
• Forestry Equipment Parts, Sales and Service
• Forestry Related Industries Forestry Industry Uses means any business which is directly involved in, and whose principal purpose is, the harvesting, milling, sawing, processing, storage or transport of lumber, sawdust and Christmas trees.
• Light Industrial Commercial (M1) Zone Uses Within Existing Structures
  o Accessory Commercial Uses
  o Accessory Gas Bars
  o Arenas
  o Automobile Parts, Sales, Rentals and Service
  o Automotive Painting, Engine and Body Repair
  o Building and Construction Contractors
  o Building Supplies and Equipment Sales
  o Bus Depots and Maintenance Facilities
  o Cold Storage Facilities
	• ~~Aggregate Equipment Parts, Sales and Service~~
	• ~~Aggregate Related Industries~~
	• ~~Agricultural Equipment Parts, Sales and Service~~
	• Agricultural Related Industries including ~~processing of crops and livestock~~, including sorting, grading, packaging, ~~slaughtering (abattoirs), manufacturing~~ and packaging of food, ~~livestock feed, fertilizer and similar uses.~~
	• ~~Bulk Chemical Storage~~
	• ~~Bulk Fuel Storage~~
	• Cold Storage Facilities
	• ~~Composting Facilities~~
	• Existing Uses as of the date of enactment of this provision
	• Fishing Equipment Parts, Sales and Service
	• Fishing Related Industries
	• ~~Forestry Equipment Parts, Sales and Service~~
	• Forestry Related Industries Forestry Industry Uses means any business which is directly involved in, and whose principal purpose is, the harvesting, milling, sawing, ~~processing~~, storage or ~~transport of lumber, sawdust and Christmas trees.~~
	• Light Industrial Commercial (M1) Zone Uses Within Existing Structures
	  o Accessory Commercial Uses
	  o ~~Accessory Gas Bars~~
	  o Arenas
	  o ~~Automobile Parts, Sales, Rentals and Service~~
	  o ~~Automotive Painting, Engine and Body Repair~~
	  o Building and Construction Contractors
	  o Building Supplies and Equipment Sales
	  o ~~Bus Depots and Maintenance Facilities~~
	  o Cold Storage Facilities

o Commercial Greenhouses o Crematoria o Electrical and Electronics Shop o Existing Heavy Industries Specified in 7.2.10 o Fire Stations o Hatcheries for Poultry and Fish o Heavy Equipment Parts, Sales and Service o Heavy Equipment Storage and Maintenance o Indoor Recreation Uses o Laundry and Dry Cleaning Establishment o Kennels o Manufacturing and Bottling of Beverages o Manufacturing, Assembly or Fabrication Plants o Mini Warehouses o Nurseries and Garden Centres o Outdoor Commercial Displays o Plumbing Shop o Printing Establishment o Recycling Depots o Residential Uses - Existing o Retail Warehouse Outlet o Rural Home Occupations o Self Contained Processing Plants o Septic Tank Service o Sheet Metal, Welding and Machine Shop o Transport and Trucking o Transportation Services o Veterinary Clinics o Warehousing o Wholesale Bakery o Wholesale Distributors and Suppliers • Peat Moss Packaging and Processing • Septic Disposal Service • Small-Scale Wind Turbines • Transport and Trucking • Warehousing and Storage • Waste Transfer Stations • Well Drilling Services	~~o Commercial Greenhouses~~ o Crematoria o Electrical and Electronics Shop o Existing Heavy Industries Specified in 7.2.10 o Fire Stations ~~o Hatcheries for Poultry and Fish~~ ~~o Heavy Equipment Parts, Sales and Service~~ ~~o Heavy Equipment Storage and Maintenance~~ o Indoor Recreation Uses o Laundry ~~and Dry Cleaning~~ Establishment o Kennels ~~o Manufacturing and Bottling of Beverages~~ ~~o Manufacturing, Assembly or Fabrication Plants~~ o Mini Warehouses o Nurseries and Garden Centres o Outdoor Commercial Displays o Plumbing Shop o Printing Establishment ~~o Recycling Depots~~ o Residential Uses - Existing o Retail Warehouse Outlet o Rural Home Occupations ~~o Self Contained Processing Plants~~ ~~o Septic Tank Service~~ ~~o Sheet Metal, Welding and Machine Shop~~ ~~o Transport and Trucking~~ ~~o Transportation Services~~ o Veterinary Clinics o Warehousing o Wholesale Bakery o Wholesale Distributors and Suppliers • Peat Moss Packaging and Processing ~~• Septic Disposal Service~~ • Small-Scale Wind Turbines ~~• Transport and Trucking~~ • Warehousing and Storage ~~• Waste Transfer Stations~~ • Well Drilling Services

ZONE B	
Currently Permitted in Residential One and Two Unit (R2) Zone	**Permitted after Wellfield Protection Zone B is overlaid on R2 Zone**
• Duplexes • Existing Farms subject to R1 Zone requirements • Existing Residential Uses • Multi Sectional Modular Homes • Residential Care Facilities • Semi-Detached Dwellings • Single Detached Dwellings	• Duplexes • Existing Farms subject to R1 Zone requirements • Existing Residential Uses • Multi Sectional Modular Homes • Residential Care Facilities • Semi-Detached Dwellings • Single Detached Dwellings
Uses Subject to Conditions **(Outlined in LUB Section 8.1)**	**Uses Still Subject to Conditions** **(Outlined in LUB Section 8.1)**
• Bed and Breakfast Operations • Cemeteries • Churches • Home Based Businesses • Home Day Care • Urban Home Occupations	• Bed and Breakfast Operations • ~~Cemeteries~~ • Churches • Home Based Businesses • Home Day Care • Urban Home Occupations

ZONE B	
Currently Permitted in Residential Mixed Density (R3) Zone	**Permitted after Wellfield Protection Zone B is overlaid on R3 Zone**
• Converted Dwellings to a Maximum of 8 Residential Units • Duplexes • Existing Farms • Multi Sectional Modular Homes • Multi Unit Residential to a Maximum of 8 Residential Units • Residential Care Facilities • Semi-Detached Dwellings • Single Detached Dwellings • Town Houses to a Maximum of 8 Units	• Converted Dwellings to a Maximum of 8 Residential Units • Duplexes • Existing Farms • Multi Sectional Modular Homes • Multi Unit Residential to a Maximum of 8 Residential Units • Residential Care Facilities • Semi-Detached Dwellings • Single Detached Dwellings • Town Houses to a Maximum of 8 Units
Uses Subject to Conditions **(Outlined in LUB Section 8.1 & 8.5)**	**Uses Still Subject to Conditions** **(Outlined in LUB Section 8.1 & 8.5)**
• Bed and Breakfast Operations • Cemeteries • Churches • Home Based Businesses • Home Day Care • Urban Home Occupations	• Bed and Breakfast Operations • ~~Cemeteries~~ • Churches • Home Based Businesses • Home Day Care • Urban Home Occupations

ZONE B	
Currently Permitted in Environmental Open Space (O1) Zone	**Permitted after Wellfield Protection Zone B is overlaid on O1 Zone**
• Agricultural Uses • Flood Control Facilities • Fishing Uses • Forestry Uses • Radio Controlled Aircraft Fields	• Agricultural Uses *(by development agreement)* • Flood Control Facilities • Fishing Uses • Forestry Uses • Radio Controlled Aircraft Fields

12.4 Zone A

Within Wellfield Protection Zone A, all land is Currently Zoned Forestry (F1). This is the Zone which has the shortest groundwater travel time to the wells is within 25 metres of the wellheads. It is essential to restrict land use within Zone A in order to protect drinking water. The more stringent requirements of Wellfield Protection Zone A restrict all uses other than those related to the operation of the wells. The majority of land in Zone A is owned by the Municipality of the County of Kings.

ZONE A
All existing uses are allowed to continue as non-conforming uses.

ZONE A	
Currently Permitted in F1 Zone	**Permitted after Wellfield Protection Zone A is overlaid on F1 Zone**
• Agricultural Uses as part of the farm operation excluding livestock operations • Bunkhouses • Double Wide Mobile Homes • Duplexes • Existing Community Facilities • Existing Gun Ranges • Fish Farm • Fishing Uses • Forestry Uses • Greenhouses • Kennels • Mini Homes • Mobile Homes • Multi-sectional Modular Homes • Nonprofit Camps • Nurseries • Radio Controlled Aircraft Fields • Residential Care Facilities • Seasonal Dwellings • Semi-Detached Dwellings • Single Detached Dwellings	• ~~Agricultural Uses as part of the farm operation excluding livestock operations~~ • ~~Bunkhouses~~ • ~~Double Wide Mobile Homes~~ • ~~Duplexes~~ • ~~Existing Community Facilities~~ • ~~Existing Gun Ranges~~ • ~~Fish Farm~~ • ~~Fishing Uses~~ • ~~Forestry Uses~~ • ~~Greenhouses~~ • ~~Kennels~~ • ~~Mini Homes~~ • ~~Mobile Homes~~ • ~~Multi-sectional Modular Homes~~ • ~~Nonprofit Camps~~ • ~~Nurseries~~ • ~~Radio Controlled Aircraft Fields~~ • ~~Residential Care Facilities~~ • ~~Seasonal Dwellings~~ • ~~Semi-Detached Dwellings~~ • ~~Single Detached Dwellings~~

• Small-Scale Wind Turbines • Wildlife Rescue and Rehabilitation Centre	• ~~Small-Scale Wind Turbines~~ • ~~Wildlife Rescue and Rehabilitation Centre~~
Uses Subject to Conditions	**Uses Subject to Conditions or New Uses Considered by Development Agreement**
• Bed and Breakfast Operations • Commercial Livestock Operations • Farm Market Outlets • Farm Tenement Buildings • Home Day Care • Homes for Special Care • Recycling Depots • Rural Home Occupations • Tourist Commercial Facilities for Lodging, Food Services and Ancillary Uses	• ~~Bed and Breakfast Operations~~ • ~~Commercial Livestock Operations~~ • ~~Farm Market Outlets~~ • ~~Farm Tenement Buildings~~ • ~~Home Day Care~~ • ~~Homes for Special Care~~ • ~~Recycling Depots~~ • ~~Rural Home Occupations~~ • ~~Tourist Commercial Facilities for Lodging, Food Services and Ancillary Uses~~

Appendix D

Land Use Bylaw #56 and Municipal Planning Strategy – Greenwood Well Field

Municipality of Kings

- Automotive Salvage Yards
- Commercial Bulk Storage of Petroleum Fuel, excluding Gasoline or Service Stations
- Commercial or Bulk Storage of Salt
- Commercial Storage of Petroleum Solvents
- Commercial Storage, Processing or Production of Pesticide, Herbicide or Fertilizer
- Dry Cleaning

2.12.8.7 Notwithstanding other provisions of this Strategy within the Zone of Influence (Zone I) and Zone of Contribution (Zone C) the following uses shall be permitted only by Development Agreement provided the use is permitted in the underlying zone or a zone the proposed location would otherwise be eligible to be rezoned to. In addition to other provisions contained in this Strategy, Council in considering an application for approval of a Development Agreement shall ensure that the proposal does not increase the potential for contamination of groundwater:

- All Uses within the Agricultural Industrial (M3) Zone with the exception of Fire Stations
- All Uses within the Hamlet Industrial (M5) Zone
- Gasoline and or Automotive Service Stations

2.12.8.8 Existing uses within the Zone of Influence (Zone I) and Zone of Contribution (Zone C), which pursuant to Policy 2.12.8.6 have otherwise been identified as being prohibited, shall be permitted to continue to operate in their current form and scope as provided for by the Land Use Bylaw and may be considered for expansion or redevelopment only by Development Agreement. In addition to provisions contained in Part 3.7.9, Rural Non-conforming Uses, Council in considering an application for approval of a Development Agreement shall ensure that the proposal does not increase the potential for contamination of groundwater.

2.12.9 Companion Policies: Groundwater Supply and Management, Greenwood Water Supply

The Village of Greenwood, situated within the County of Kings, receives its drinking water from groundwater. In 2008 the County commissioned CBCL Limited in partnership with Terry W. Hennigar WATER Consulting to develop a groundwater flow model for the Village of Greenwood. The groundwater model delineated a Wellfield Protection

Area around the Village of Greenwood's wells. The groundwater flow model was informed by area geology, precipitation, soil types, groundwater flow and pumping well capability. The Greenwood Capture Zone Modelling: Technical Report established four capture zones corresponding to groundwater travel time to the wells.

Following the submission of the Technical Report, a planning exercise was undertaken involving local residents, a County Councillor, and a representative from CFB Greenwood. This wellfield committee further refined the land use and development implications concerning water quality protection, and transfered the technical recommendations into the municipal planning context. The planning exercise was based on the Provincial recommendations for developing a municipal source water protection plan, and in response to the Drinking Water Strategy for Nova Scotia. CBCL Limited prepared Land Use Planning Recommendations for the Greenwood Wellfield Protection Plan, which outlines land use and development policies that reduce the potential risks of groundwater contamination from existing land uses and prevents the potential for future contamination resulting from particular types of new land uses and developments.

The land use recommendations are differentiated by four Wellfield Protection Zones, which were defined based on the groundwater capture zones:

- Wellfield Protection Zone A (25 metre radius)
- Wellfield Protection Zone B (Two year capture)
- Wellfield Protection Zone C (Five year capture)
- Wellfield Protection Zone D (Twenty-Five year capture)

The Greenwood Wellfield draws Groundwater Under the Direct Influence (GUDI) of surface water, which implies an immediate vulnerability to contaminants released at the ground surface. This means that it is especially important to limit the potential risk of contamination through land use controls that adequately protect the groundwater.

The land use planning recommendations will be implemented through the Municipal Land Use Bylaw, which provides a direct means for regulating future development and ensures that the risks of groundwater contamination are managed within acceptable limits established by community residents. Certain operational and management issues are however beyond the scope of matters which a Land Use Bylaw may address. Additional groundwater protection strategies will be undertaken by the Greenwood Water Utility and the County of Kings including but not limited to increasing general awareness through public education, working with property owners of non-conforming uses within the Wellfield Protection Area, increasing monitoring at the sewage treatment plant, and completing a source Water Protection Plan that includes a contingency plan and monitoring plan.

2.12.9.1 Council shall implement protective measures in the General Provisions section of the Land Use Bylaw, pursuant to the *Municipal Government Act* for the purposes of promoting groundwater protection in the Greenwood Wellfield Protection Area.

2.12.9.2 In addition to provisions contained in this section, Council intends to work with the Village of Greenwood to explore administrative and management initiatives that support the protection of groundwater within the Wellfield Protection Area, but that are beyond the scope of municipal planning legislation. These efforts may include, but are not limited to, public awareness and education programs, water conservation, and contingency planning for supply and distribution management. Specific administrative and management measures may also include restrictions on the application of road salt (and other de-icing products), the use and application of pesticides, herbicides and fertilizers, agricultural production and waste management, private well drilling and groundwater production, aggregate extraction and forestry development.

2.12.9.3 Council shall institute in the General Provisions section of the Land Use Bylaw four groundwater protection zones shown on Schedule 6g, the Urban Zone and Wellfield Protection Zone map for the Growth Centre of Greenwood. The provisions shall include the following overlay zones:

Wellfield Protection Zone A

Wellfield Zone A comprises the lands immediately adjacent to the wellheads (generally within 25 metres of the wellhead), which are the most vulnerable to groundwater contamination. Land uses in Zone A shall be restricted to the operation of the wells. All other land uses shall be prohibited. Council will not consider a development agreement for any new development, nor expansion or change to intensify any non-conforming uses, as the intent of this zone is to limit land use to the operation of the well.

Wellfield Protection Zone B

Wellfield Protection Zone B comprises the area from the boundary of Zone A to the outer edge of the 2-year capture zone. Because of its proximity to the wellheads, this zone represents land with a high level of vulnerability to groundwater contamination. Contaminants of concern in Zone B have low mobility but pose a significant health risk to water users. The contaminants of greatest concern within this zone are bacteria (primarily E. Coli) and viruses found in municipal sewage and animal waste. Land uses associated with these contaminants include agriculture, and any type of chemical or fuel storage. Contaminants that are of concern in Zones C and D are also of concern in Zone B. Land uses that are likely to involve these contaminants of concern shall be prohibited in the Land Use Bylaw.

Rather than completely prohibiting certain land uses in Zone B, Council intends (where underlying zoning would otherwise permit) to allow the following land uses as new or expanded uses only by development agreement:

- Auto Repair, including painting and body repair
- Automobile washing facility
- Manufacturing, assembly or fabrication plants
- Commercial greenhouses
- Service Shops, including small engine repair
- Transportation Services
- Transport & trucking

When considering development agreements to permit the above land uses Council shall have regard to Greenwood Wellfield Policy 2.12.9.6.

Wellfield Protection Zone C

Wellfield Protection Zone C is defined by the 2-year to 5-year capture zone, an area requiring restrictions on contaminants with moderate mobility and stability in the subsurface environment. Contaminants excluded from Zone C pose a health risk at moderate to low concentrations, and are subject to processes of adsorption and biodegradation. These materials are generally attenuated over periods of time of less than five years. Petroleum hydrocarbon users fall within this category, including service stations, automotive painting and repair shops, fuel storage and transfer of any kind, and auto salvage operations. All contaminants that are a concern in Zone D are also of concern in Zone C. Land uses that are likely to involve these contaminants of concern shall be prohibited in the Land Use Bylaw.

Rather than completely prohibiting certain land uses in Zone C, Council intends (where underlying zoning would otherwise permit) to allow the following land uses as new or expanded uses only by development agreement:

- Auto Repair, including painting and body repair

When considering development agreements to permit the above land uses Council shall have regard to Greenwood Wellfield Policy 2.12.9.6.

Wellfield Protection Zone D

Wellfield Protection Zone D is defined by the 5-year to 25-year capture zone, created to manage contaminants which pose a health risk at low concentrations, and which are readily transported over large distances and longer time frames. Zone D also represents the outer boundary of the Wellhead Protection Area as a whole. Dense non-aqueous phase liquids (DNAPLs) such as trichloroethylene and perchloroethylene, which are found in dry cleaning chemicals and degreasers, have the tendency to penetrate deep aquifers and are of concern in Zone D. Chloride, nitrate, and some metals which are readily transported in the groundwater have the ability to arrive at the well head in high concentrations. Land uses that are likely to involve these contaminants of concern shall be prohibited in the Land Use Bylaw.

Rather than completely prohibit certain land uses in Zone D, Council intends (where underlying zoning would otherwise permit) to allow the following land uses as new or expanded uses only by development agreement:

- Abattoirs
- Livestock operations and Fish Farms
- Septic Tank Service

When considering development agreements to permit the above land uses Council shall have regard to Greenwood Wellfield Policy 2.12.9.6.

2.12.9.4 Wellfield restrictions for Zone A, B, C and D shall apply to all underlying zones and where more stringent, the requirement of the wellfield zones shall supersede the provisions of any zone or other general provisions.

2.12.9.5 Existing uses within Wellfield Protection Zone A, B, C and D that have been identified as being prohibited shall become non-conforming. The expansion or redevelopment of these non-conforming uses shall be considered only by development agreement. In addition to the provisions contained in Part 3.7, Rural Non-conforming Uses, Council shall have regard to Policy 2.12.9.8.

2.12.9.6 Cemeteries that become non-conforming shall be permitted to expand as-of-right within property boundaries that existed on November 1, 2011.

2.12.9.7 Council shall provide more flexibility to land uses that have become non-conforming as a result of wellfield protection restrictions than is provided for in the Municipal Government Act. Therefore, Council shall enable the following within the Land Use Bylaw:

a. Structures containing non-conforming uses that have been up to (100%) destroyed by fire or otherwise may be rebuilt.

Any expansion, however, may only be considered by development agreement.

b. Non-conforming uses may not be recommenced if discontinued for a period of one (1) year. (rather than after six months)

2.12 .9.8 In considering development agreements within the Wellfields for the expansion of non-conforming uses, or for new or expanded uses that are only permitted by development agreement, Council shall ensure that the following criteria are met:

a. The proposal does not include accessory uses that would otherwise be prohibited by wellfield policies or bylaws.

b. Appropriate controls are placed on the development in order to minimize the risks of contamination to ground water resources.

c. The general development agreement policies contained in Part 6 of this Strategy.

In considering the above development agreements, Council may require the following information:

a. Studies, conducted by a qualified person, to assess the risk of the proposal on ground water quality and quantity, as well as recommend measures to minimize any negative impacts.

b. Management plans for the storage, disposal or handling of any potential pollutants, such as, but not limited to chemicals, manure, petroleum products, batteries, solvents and other substances that pose a risk to ground water quality.

c. Drainage studies and plans aimed at reducing risks of ground water contamination.

PART 2	ENACTED DATE	SECTION
	September 15, 2003	2.12

PART 2	AMENDED	SECTION
	April 5, 2005	2.12.5
	April 26, 2005	2.12.6
	July 5, 2005	2.12.4 / 2.12.4.1 / 2.12.4.2 / 2.12.4.3 / 2.12.4.4 / 2.12.4.5 / 2.12.4.6 / 2.12.4.7 / 2.12.5 / 2.12.5.1 / 2.12.5.2 / 2.12.5.3 / 2.12.5.4 / 2.12.5.5 / 2.12.5.6 / 2.12.5.6.1 / 2.12.5.6.2 / 2.12.5.7 / 2.12.5.8 / 2.12.5.9 / 2.12.5.10 / 2.12.5.11 / 2.12.5.12 / 2.12.6 / 2.12.6.1 / 2.12.6.2 / 2.12.6.3 / 2.12.6.4 / 2.12.6.5 / 2.12.6.6
	July 27, 2006	2.12.7
	August 3, 2006	2.12.8
	January 25, 2007	2.12.4.7
	May 21, 2009	2.12.5 / 2.12.8
	January 12, 2012	2.12.9 Greenwood Water Supply (File F-3-142)

3.15 GROUNDWATER RESOURCE MANAGEMENT, SOUTH BERWICK AND AREA GROUNDWATER SUPPLY AREA

3.15.1 The provisions of all other Zones notwithstanding, the land use restrictions set out in subsection 3.15.2 shall apply to development of lands situated within the South Berwick and Area Groundwater Supply Area as delineated on the South Berwick Hamlet and Wellfield Protection Zones Map, Schedule 16h, of the Land Use Bylaw.

3.15.2 **Prohibited Uses, Zone of Contribution (Zone C) and Zone of Influence (Zone I)**

Notwithstanding any other provisions contained in this Bylaw the following uses shall be prohibited from locating within the Zone of Contribution (Zone C) and the Zone of Influence (Zone I):

Automotive Salvage Yards
Commercial Bulk Storage of Petroleum Fuel, excluding Gasoline or Service Stations
Commercial or Bulk Storage of Salt
Commercial Storage of Petroleum Solvents
Commercial Storage, Processing or Production of Pesticide, Herbicide or Fertilizer
Dry Cleaning

3.16 GROUND WATER RESOURCE MANAGEMENT, GREENWOOD WELLFIELD AREA

a. Aside from the operation of the well, all land uses shall be prohibited within Wellfield Protection Zone A delineated on the Greenwood Urban Zoning and Wellfield Protection Map. All existing land uses shall be non-conforming. Notwithstanding the Rural Non-Conforming Uses Policies, non-conforming uses located with Zone A shall not be eligible to expand or change in use by development agreement.

b. The following restrictions shall apply to development of lands situated within Wellfield Protection Zones B, C and D delineated on the Urban Zoning and Wellfield Protection Map. The restricted land uses, listed below, do not apply to Rural Home Occupations.

Land Use	Wellfield Protection		
	Zone B	Zone C	Zone D
Abattoirs	Not Permitted	Not Permitted	Permitted by Development Agreement
Aggregate related industries	Not Permitted	Not Permitted	Not Permitted
Agricultural Related Industries (including feed preparation, fertilizer production and food processing)	Not Permitted	Not Permitted	Permitted
Auto Repair (including Auto body repair and painting)	Permitted by Development Agreement	Permitted by Development Agreement	Permitted by Development Agreement
Automobile washing facility	Permitted by Development Agreement	Permitted	Permitted
Cemeteries	Not Permitted	Not Permitted	Permitted
Composting facilities	Not Permitted	Not Permitted	Permitted
Dry Cleaners	Not Permitted	Not Permitted	Not Permitted
Fish Farms	Not Permitted	Not Permitted	Permitted by Development Agreement
Gas stations, including gas bars and service stations	Not Permitted	Not Permitted	Not Permitted
Greenhouses	Permitted by Development Agreement	Permitted	Permitted
Heavy equipment, parts, sales and service	Not Permitted	Not Permitted	Not Permitted
Manufacturing, assembly and fabrication plants	Permitted by Development Agreement	Permitted	Permitted
New Commercial Livestock Operations (operations that existed on November 1, 2011 are permitted)	Not Permitted	Not Permitted	Permitted by Development Agreement
Power utility substations * if subject to Municipal regulations in the future	Not Permitted	Permitted	Permitted
Recycling depot	Not Permitted	Permitted	Permitted
Salvage Yard	Not Permitted	Not Permitted	Not Permitted
Scrap Operation	Not Permitted	Not Permitted	Not Permitted
Septic Tank Service	Not Permitted	Not Permitted	Permitted by Development Agreement
Service Shop	Permitted by Development Agreement	Permitted by Development Agreement	Permitted by Development Agreement

Sheet Metal, Welding and Machine Shop	Not Permitted	Permitted	Permitted
Soil mixing	Not Permitted	Permitted	Permitted
Storage or distribution of chlorinated organic compounds or solvents in excess of 900 Litres (200 Gallons)	Not Permitted	Not Permitted	Not Permitted
Storage or distribution of salt in excess of 908 kilograms (1 Tonne)	Not Permitted	Not Permitted - in excess of 90,800 Kilograms (100 Tonnes)	Not Permitted - in excess of 90,800 Kilograms (100 Tonnes)
Storage or distribution of fertilizer in excess of 908 kilograms (1 Tonne)	Not Permitted	Permitted	Permitted
Storage or distribution of pesticide and herbicide in excess of 900 Litres (200 Gallons)	Not Permitted	Not Permitted	Not Permitted
Storage or distribution of petroleum fuels or solvents in excess of 45,000 Litres (10,000 Gallons)	Not Permitted	Not Permitted	Not Permitted
Storage or distribution of manure of 908 kilograms (1 Tonne)	Not Permitted	Permitted	Permitted
Transport and trucking including Transportation services	Permitted by Development Agreement	Permitted	Permitted
Waste transfer stations	Not Permitted	Permitted	Permitted
White metals and hazardous household waste salvage	Not Permitted	Not Permitted	Not Permitted

3.17 URBAN FLOODPLAIN OVERLAY ZONE

In addition to the underlying zone requirements, the Land Use Bylaw requirements set out in this subsection shall apply to all development located within the Urban Floodplain (UF1) Zone and Urban Floodplain Warning (UF2) Zone, shown on Schedule 10g, Urban Floodplain Zoning Inset.

3.17.1 Urban Floodplain (UF1) Zone

3.17.1.1 New buildings and additions must be flood proofed to a storm surge height of 28.2 feet above mean sea level. These requirements, however, are waived for the following:

- Vertical additions that do not expand the building footprint.
- Additions to buildings that existed on October 14, 2010. The addition, however, shall not extend beyond the property boundary that existed on October

14, 2010. The grade of the ground floor must be no lower than the ground floor of the existing building. Basements are not permitted.

- Accessory structures with a maximum building footprint of 150 square feet.

3.17.1.2 Prior to any development taking place, regardless of the scale, the property owner must provide written acknowledgement indicating that the development is located within an area indentified as being vulnerable to the predicted worst case storm surge and sea level rise scenario of 34 feet above mean sea level, representing the estimated extent of the 1869 Saxby Gale plus a sea level rise of 25 inches.

3.17.2 **Urban Floodplain Warning (UF2) Zone**

3.17.2.1 Prior to any development taking place, regardless of the scale, the property owner must provide written acknowledgement indicating that the development is located within an area indentified as being vulnerable to the predicted worst case storm surge and sea level rise scenario of 34 feet above mean sea level, representing the estimated extent of the 1869 Saxby Gale plus a sea level rise of 25 inches.

PART 3	AMENDED DATE	SECTION
	October 6, 1992	3.2.3 / 3.2.14 / 3.7.7 / 3.7.10 / 3.7.10.1 d / 3.7.10.3 a, d, g
	October 4, 1993	3.1.2 / 3.1.5 / 3.2.8 / 3.2.8.1 / 3.2.8.2 / 3.2.8.4 / 3.3.2.1 / 3.3.7 / 3.3.7.3
	January 22, 1996	3.2.12
	May 20, 1997	3.7.5.9 / 3.7.7.1 g / 3.7.10.1 / 3.7.10.3 b / 3.7.12 / 3.7.12.4 / 3.7.13 / 3.7.14 / 3.7.15 / 3.7.16
	August 5, 1997	3.7.12.4
	December 2, 1997	3.7.14
	July 7, 1998	3.2.15 / 3.7.6.9
	February 2, 1999	3.7.6.10 / 3.7.10.1 l / 3.7.10.2
	March 26, 1999	3.7.15
	September 4, 2001	3.2.9.1 / 3.2.12 / 3.9
	September 15, 2003	3.10
	December 6, 2004	3.11
	April 5, 2005	3.12
	April 26, 2005	3.13
	July 5, 2005	3.2.1.3 / 3.2.8.2 / 3.2.8.3 / 3.2.8.4 / 3.2.8.5 / 3.2.8.6 / 3.2.8.7 / 3.2.11 / 3.2.12 / 3.2.13 / 3.2.14 / 3.2.15 / 3.2.15.1 / 3.2.15.2 / 3.2.15.2 c / 3.3.3.1 / 3.3.3.2 / 3.7.1.1 / 3.7.5.5 / 3.7.6.10 / 3.7.10.1 c, d, g, h, i, j, k, l / 3.7.10.2 / 3.7.10.3 / 3.7.10.3 i / 3.9.1 / 3.10 / 3.10.1 / 3.10.2 / 3.10.3 / 3.10.4 / 3.11 / 3.11.1 / 3.11.2 / 3.11.3 / 3.13.3
	July 27, 2006	3.14
	August 3, 2006	3.15
	August 31, 2006	3.16 / 3.17
	January 25, 2007	3.10.1
	October 25, 2007	3.11.4
	April 3, 2008	3.7.15
	August 28, 2008	3.7.7.3
	May 21, 2009	3.2.8.1 / 3.2.8.2 / 3.2.8.3 / 3.2.8.4 / 3.2.8.5 / 3.2.8.6 / 3.2.8.7 / 3.2.8.8 / 3.2.13 / 3.2.15.2 c / 3.2.16 f / 3.7.1.1 / 3.7.5.5. / 3.7.10.1 c, d / 3.7.10.3 i / 3.11.1
	May 28, 2010	3.2.16 d / 3.2.16 e / 3.2.16 f / 3.2.16 g / 3.2.16 h / 3.2.16 i 3.2.16 j / 3.2.16 k / 3.2.16 l
	October 14, 2010	3.1.6 / 3.8 / 3.16
	June 2, 2011	3.2.16 k 600 ft radius in second bullet deleted
	October 28, 2011	3.7.10.2A inserted Centreville DCDA
	January 12, 2012	3.2.11 replaced / 3.16 inserted Greenwood Wellfield Area (File F-3-142)
	January 19, 2012	3.8 a replaced (File P11-10 Setback)

Note: Numbering of Sections within this Bylaw may be different from the Amended Date.

Appendix E

Risk Assessment Worksheet

CBCL Limited

Table 5.2: Summary of Risk Analysis

Activity/ Cause	Contamination Issue	Subsurface/ Surface	Point/ Non-point	Timing	Risk	Map Reference
Zone A						
Aggregate Resource Extraction Use	Petroleum hydrocarbons, bacteria in storm water run-off	Subsurface	Point	All year	High	1
Zone B						
Livestock Operation (horses)	Bacteria, nutrients, dissolved organic carbon	Surface	Point	All year	Moderate	2
Small Engine Repair Shop	Petroleum hydrocarbons, solvents	Surface	Point	All year	Moderate	3
NSPI Substation	PCBs	Surface	Point	All year	Low	4
Aggregate Related Industry	Petroleum hydrocarbons	Subsurface	Point	All year	Moderate	5
Aggregate Related Industry	Petroleum hydrocarbons	Subsurface	Point	All year	Moderate	6
Aggregate Related Industry	Petroleum hydrocarbons	Subsurface	Point	All year	Low	7
Heavy Machinery Maintenance & Storage	Petroleum hydrocarbons, solvents	Surface	Point	All year	Moderate	8
Zones B & C						
Greenwood Sewage Treatment Plant	Bacteria, nutrients, pharmaceuticals, dissolved organic carbon, chloride	Surface	Point	All year	Moderate	9
Zone C						
Cemetery	Bacteria, nutrients, dissolved organic carbon	Subsurface	Non-point	All year	Low	10
Cemetery	Bacteria, nutrients, dissolved organic carbon	Subsurface	Non-point	All year	Low	11
Aggregate Related Industry	Petroleum hydrocarbons	Subsurface	Point	All year	Low	12
Zone D						
Abattoir	Bacteria, nutrients, dissolved organic carbon, heavy metals (if contained in pest controls)	Surface	Point	All year	Low	13
Salvage yard	Petroleum hydrocarbons, solvents, metals, PAHs, battery acid	Surface / Subsurface	Point	All year	Moderate to Low	14
Aggregate Related Industry	Petroleum hydrocarbons	Subsurface	Point	All year	Low	15

<u>Appendix F</u>

Operations and Maintenance Manual; Greenwood Sewage Treatment Plant

CBCL Limited

Contents

Appendices

Statement of Ownership

Chapter 1 General

1.1 Background

The Municipality of the County of Kings established a groundwater monitoring program at the Greenwood Sewage Treatment Plant (STP) in May 2010. The groundwater monitoring program is in place to ensure that the STP is not releasing contaminants to the underlying aquifer. Nearby municipal wells draw water from an area encompassing the STP, underscoring the need for diligent monitoring. The aerial photo below shows the location of the STP, Greenwood well field, and surrounding features.

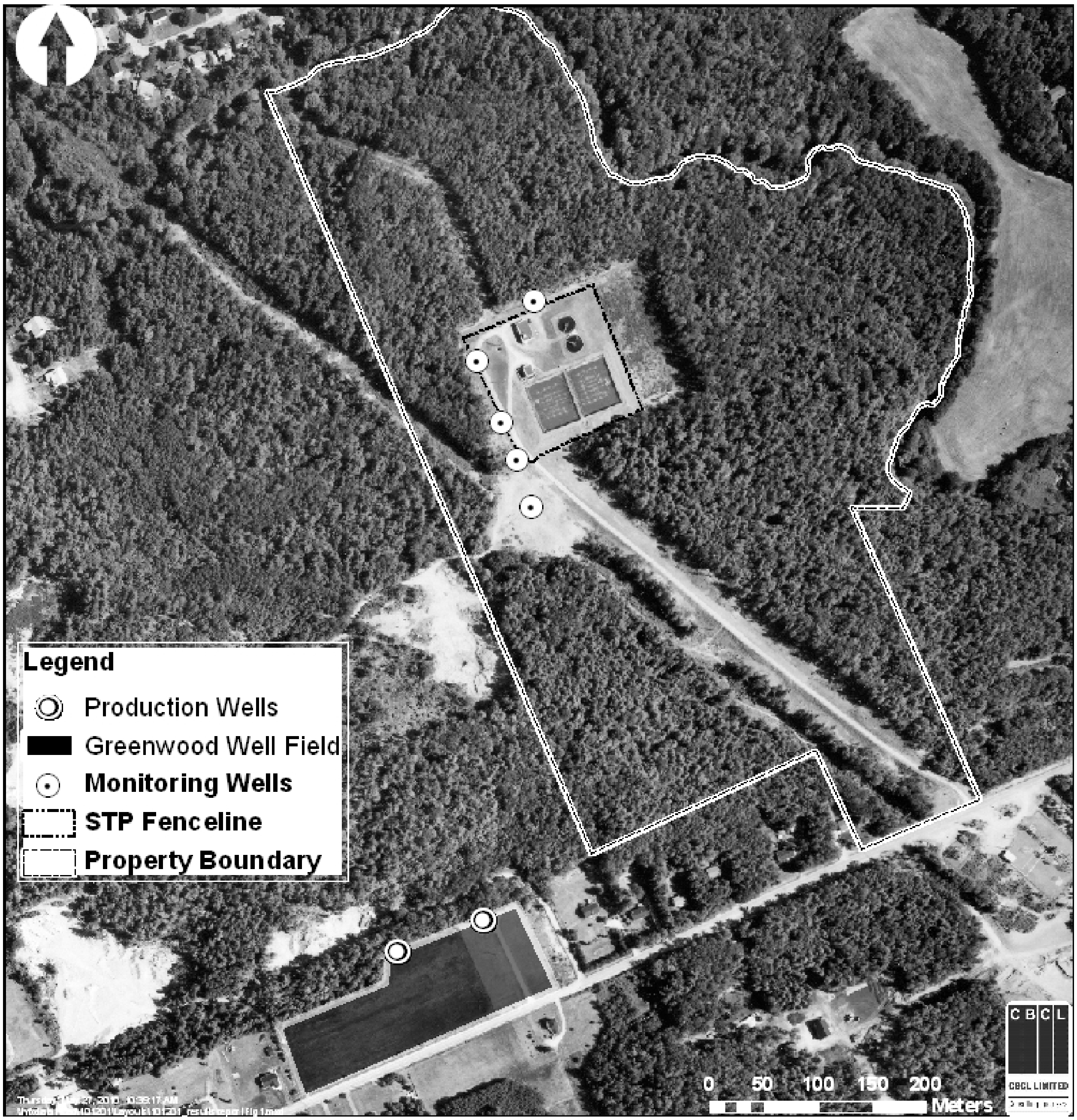


Figure 1. Greenwood Sewage Treatment Plant and Municipal Well Field

Monitoring wells were placed around the STP in locations between the STP and the Greenwood Well Field. Computer modeling indicated that groundwater flowing between the STP and the Greenwood Well field flows past these monitoring wells. Early detection of contaminants by the monitoring network will provide a way to prevent contaminants from the STP from entering the town water supply.

The Greenwood well field is located 450 m to the southwest of the treatment plant. Two high capacity wells draw water from a gravel aquifer in this area. Residential subdivisions are located 450 m to the west and 350 m to the north of the STP. The Fales River is 100 m from the STP at its closest point (to the northeast). There are several active and abandoned pits in the area. The STP is accessed from Meadowvale Road 450 metres to the south.

Technical support for this document may be found in the CBCL Report "Greenwood Sewage Treatment Plant: Groundwater Monitoring Program Design Report" (January 2010). A description of the field program undertaken to install the monitoring network and collect baseline samples may be found in the CBCL Report "Greenwood Sewage Treatment Plant: Groundwater Monitoring Program Field Program Results", (June 2010).

1.2 Glossary

Term	**Definition**
BOD_5	Biochemical oxygen demand
COD	Chemical oxygen demand
BTEX	Benzene, toluene, ethyl benzene and xylenes
m/BTOC	Metres below top of casing (for well measurements)
CCME	Canadian Council of Ministers of the Environment
DO	Dissolved oxygen
GCDWQ	CCME Guidelines for Canadian Drinking Water Quality
mbg	Meters below grade (for well measurements)
NH3	Ammonia
NTU	Nephelometric turbidity units
PPB	Parts per billion (equivalent to micrograms per litre: µg/L)
PPM	Parts per million (equivalent to milligrams per litre: mg/L)
SOP	Standard Operating Procedure
STP	Sewage Treatment Plant
TPH	Total Petroleum Hydrocarbons
TSS	Total suspended solids
USEPA	United States Environmental Protection Agency
VOCs	Volatile Organic Compounds

1.3 Roles and Responsibilities

The Designated Operator (as defined in the Operation and Maintenance Manual for the Greenwood Sewage Treatment Plant) will be responsible for setting and altering STP monitoring procedures on a daily basis, including communication of these requirements to other STP operators. The Designated Operator will be required to train other operators in new procedures and principles of groundwater monitoring. The Municipality of the County of Kings may wish to subcontract some of the groundwater monitoring work to a qualified consulting firm, including sampling collection, required updates and maintenance of the monitoring database, and interpretation of the results.

Chapter 2 Health and Safety

2.1 General

The groundwater monitoring program requires that personnel work on and around the STP site. For general conduct and requirements of work on the STP site, refer to the Operation and Maintenance Manual for the plant, prepared by ABL Environmental Consultants Ltd. in November 1998. Section 2.1 "Risk of Infection" of the manual provides general instructions for work at the STP. These procedures should be considered to be in effect for groundwater sampling work.

Groundwater sampling work does not require that the sampler approach or enter any of the STP buildings, lagoons, or clarifiers. At no time should the sampler approach any feature other than the monitoring well network as part of the work described in this manual. As such, the potential for contact with raw sewage, open water, and treatment chemicals will be minimized.

The collection of groundwater samples requires contact with groundwater from each monitoring well. Although the risk of exposure via contaminated groundwater is lower than in other parts of the STP, all personnel should assume that any groundwater sampled has been adversely affected by STP contaminants. Precautions are intended to prevent exposure to bacteria, viruses, and chemical constituents.

2.2 Personal Protective Equipment

The following personal protective equipment is required:

- Disposable rubber gloves
- Eye protection
- Rubber boots
- Protective Outerwear

Groundwater samplers should wear disposable rubber gloves and eye protection when handling the well casings, Waterra sample tubing, and sample bottles. Rubber boots and dedicated outerwear will provide a means of preventing groundwater from coming into contact with everyday footwear and clothing. Rubber boots and outerwear should be rinsed and removed before leaving the job site. Care should be taken at all times to avoid actions which could splash or spray sample water on the sampler. After filling and sealing, the outside of each sample bottle should be rinsed and dried before transferring to a cooler.

Operation of the aerators and lagoons may result in noxious and/or toxic vapours in the general vicinity of the STP. If the Designated Operator has determined that poor air quality is a problem on the day of sampling, an alternative sampling day should be considered.

Chapter 3 Record Keeping

An effective monitoring program relies on accurate record keeping. Monitoring data are to include the following:

- Water levels
- Field Measurements
- Laboratory Analytical Data

3.1 Log Sheet

A log sheet should be established and stored on the STP premises. The groundwater monitoring log sheet should be appended to or stored with the established Log Book for other STP monitoring practices. The groundwater monitoring log sheet should follow the format as provided in Appendix A.

A new log sheet is to be completed each week to record measurements performed at the monitoring well head by STP staff. Data to be recorded includes water levels and field measured chemical parameters (pH, temperature, conductivity, and dissolved oxygen). The log should also be used to indicate quarterly, semi-annual, and annual sampling events.

3.2 Monitoring Reports

A brief summary of sampling data should be generated following each groundwater sampling event. These reports and accompanying laboratory data tables are to be filed by date and maintained in a location known to the Designated Operator and supervising Engineer. Monitoring reports and/or data tables must be readily available for consultation in the event that new sampling data show unusual or unexpected conditions.

3.3 Data Management

A computer spreadsheet or database should be established for on-going data input, management, and consultation. All new data should be entered into the database as it is generated. The database will provide an immediate and effective source of information in the event that a change is noted and requires confirmation against established background data. The database should include fields for weekly water level and field parameter measurement, and any laboratory data collected.

Chapter 4 Sampling, Testing, and Reporting

4.1 Wastewater Contaminants in Groundwater

Contaminant sources at the Greenwood STP relate to the sewage transmission and handling infrastructure of the plant. Releases could occur as leaks in decaying infrastructure, spills or overflows due to unforeseen operational problems, or accidental releases of reagents. The primary Contaminants of Concern are:

- bacteria;
- viruses;
- nitrate, nitrite, and ammonia; and
- dissolved organic carbon (DOC) and biochemical oxygen demand (BOD_5).

Other potential contaminants associated with sewage handling and treatment may include:

- Pharmaceuticals and Personal Care Products [PPCPs] (e.g. acetaminophen, caffeine, codeine, nicotine, antidepressants, antibiotics, and estrogenic steroids);
- Liquid sodium hydroxide, liquid Alum, Liquid sodium hypochlorite; and
- Products of illegal dumping (volatile organic compounds [VOCs], petroleum products, metals).

Contaminants such as bacteria and viruses show poor mobility in groundwater, meaning that underground leaks are of lesser concern than spills or overflows at the ground surface. Overland flow followed by infiltration or flow along water courses has the greatest potential to affect down gradient receptors. High groundwater pressures induced by a leaking aeration basin or pressurized force main also have the potential to drive contaminants farther from the STP than under natural conditions. A list of targeted sampling parameters is provided in Section 4.4.

As many sewage related contaminants travel slowly in groundwater, detection can be delayed with respect to the timing of the initial spill or leak. Selected indicator parameters move at or close to the speed of the groundwater, and provide the earliest warning that a subsurface leak has occurred. Early detection focuses on concentrations of *nitrate, chloride, conductivity, and boron*. An unexpected concentration of one of these species can provide the first indications of impacts developing up gradient of the monitoring location. Unexpected changes in water levels in a monitoring well could also be indicative of a problem.

4.2 Sampling Locations

The monitoring well network has been placed to intercept contaminants flowing from the STP toward potential receptors. Four locations are in the path of groundwater flowing from the STP to the Greenwood well field (MW1A, MW2A, MW3A, and MW4A). Monitoring well MW5A is located between the STP and the Fales River. The monitoring well locations are shown on the Figure below.

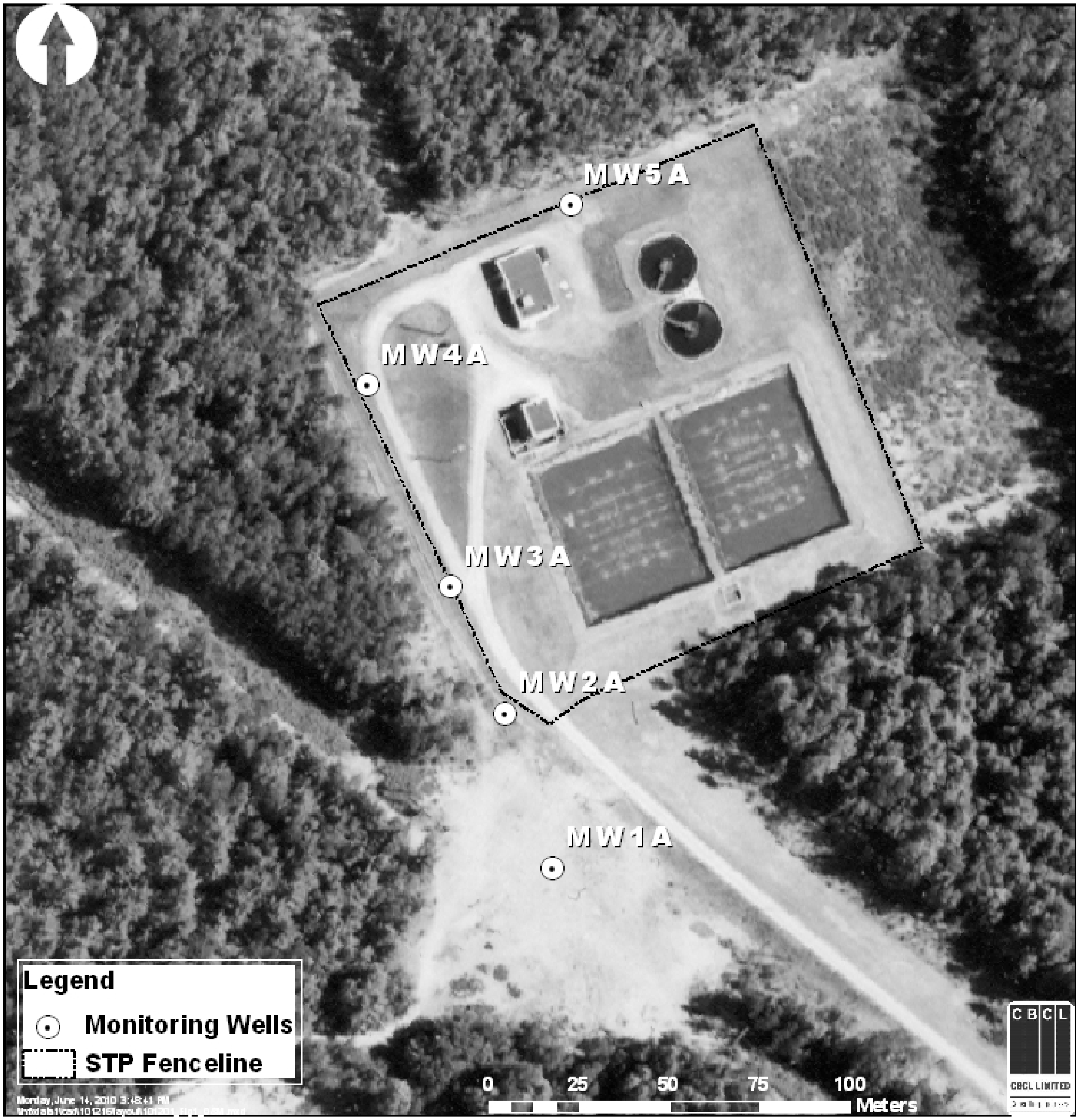


Figure 2. Monitoring Well Locations

Each monitoring well is screened across the water table in the sand aquifer underlying the STP. These wells are intended to intercept shallow groundwater flow paths originating just below the STP, or at the ground surface where infiltration of overflowing sewage would infiltrate. The monitoring wells were completed with black 6”diameter protective steel casings. The wells are constructed of white 2” diameter PVC riser piper and machine slotted well screens. An information package for each well is provided in Appendix B. Each information package provides the well location, the borehole log and well construction details, and a summary table listing the well construction details and baseline chemistry for the well.

4.3 Sampling Methodology

Groundwater samples are to be collected using methods consistent with industry standards and protocols. The following methodology is provided as a guideline; it is assumed that the sampler will have adequate background and training in groundwater sampling techniques. For a more detailed methodology and theoretical background, refer to the EPA document "Groundwater Well Sampling", attached in Appendix C for reference.

4.3.1 Accessing the Well

In order to sample each well the cap of the protective casing must be removed, followed by the PVC cap or j-plug on the 2-inch monitoring well. The interior well cap should be placed in a clean dry place while sampling; do not place the cap on the ground. Where nested wells are present, each individual well should be accessed, sampled, and closed before moving to the next well. Each well in the nest requires a new pair of disposable gloves. Ensure that both the interior well cap and exterior casing lid are replaced before moving to the next location. Uncovered wells create a pathway for contaminants travelling from the ground surface directly into the aquifer. Contaminants can be introduced by vandals, insects, and airborne particulates.

4.3.2 Static Water Level

A water level meter or equivalent device should be used to measure the static water level prior to disturbing the column of water. The water level sensor should be lowered into the well adjacent to the Waterra sample tubing *without adjusting or removing the tubing*. Removal of the Waterra tubing will alter the static water level and could produce a false reading. The water level should be measured to the lip of the white PVC casing.

4.3.3 Well Purging

The Waterra tubing in each monitoring well is equipped with a footvalve to allow for pumping. The top section of the tubing has been folded to allow the full length of tubing to be stored inside the monitoring well. Tubing is stored in the well to avoid contamination caused by contact with the ground or other surfaces. Do not remove the Waterra tubing after sampling or store it in an alternate location.

The water in each well casing must be pumped out prior to sampling. Purging draws stagnant water out of the well and ensures that the sample is drawn from the sand aquifer contributing to the well. Each well should be pumped dry, or pumped until a minimum of three well volumes have been removed. Avoid making contact between the bottom of the well casing and the footvalve while pumping, as this can damage the casing and/or footvalve, and stirs up silt that has accumulated in the bottom of the well. Water should be pumped from the well into a graduated bucket to allow measurement of the purged volume of water and observation of the physical characteristics of the water. Purged water will be used for field measurements (Section 4.3.4). The target purge volume may be calculated as follows:

Purge Volume (L) = (Static Water Level (m BTOC) – Depth of Well (m BTOC)) x 2.024 litres/metre x 3

Example

Monitoring Well MW1A:

Depth of well = 7.93 metres BTOC (from Appendix B)

Static Water level = 2.32 metres BTOC

Purge Volume = (8.52 – 2.32) x 2.024 x 3
Purge Volume = 5.61 x 2.024 x 3
Purge Volume = 11.35 x 3
Purge Volume = 34.1 litres

If there is no physical evidence of contamination, the purged water can be poured out at a location at least 3 metres downgradient of the well head. If contamination is evident or suspected based on past sampling events, wastewater must be collected and transferred to a licensed disposal facility or returned to the treatment stream.

The target volume, actual volume purged, and physical characteristics of the water should be recorded on the Groundwater Monitoring Log.

4.3.4 Field Parameters

A water quality meter should be used to measure the purge water prior to sampling. The water quality meter should be equipped with sensors to measure pH, conductivity, temperature and dissolved oxygen. The sensor tips must be calibrated prior to use and immersed fully in the purge water. The sensors should be swirled gently in the water for at least one minute or until the meter indicates a stable reading. The sensors should be rinsed with distilled water following measurement. Refer to the product manual for specific instructions on use, calibration, and care.

Field parameters are to be measured on a weekly basis, and prior to quarterly, semi-annual, and annual sample collection. Field parameters should be recorded on the Groundwater Monitoring Log.

4.3.5 Sample Collection

Water may be pumped directly from the Waterra tubing into the sample bottles. Avoid making contact between the tip of the Waterra tubing and the mouth of the sample bottle. Bottles containing preservatives should not be allowed to overflow. Hold the sample cap or store it on a clean rubber glove while filling the bottles; do not allow the caps to contact the ground, well head, clothing, or other surfaces near the well head. Bottles should be filled completely so that no air is stored in the bottle headspace (no bubbles are visible after the cap is on and the bottle is turned upside down).

Particular care is required for bacteria sample collection. It is imperative that foreign matter is not introduced into the sample bottles, and that the bottle neck, mouth, and lid do not contact any surfaces such as the Waterra tubing and rubber gloves of the sampler. Any such contact or contamination of the sample could result in a false positive result for bacteria.

4.3.6 Sample Preservation

Samples for metals analysis must be filtered in the field using a 0.45 micron filter. Filtered samples are to be preserved in the field using concentrated high purity nitric acid.

4.3.7 Sample Storage and Transmission

Samples must be stored in a cooler with ice packs to maintain the sample temperature at or below $4^{o}C$ for storage and during transfer to the laboratory. Samples should be transferred to the lab on the day of sampling or within 24 hours of sampling. The receiving laboratory will provide a Chain of Custody to be completed before leaving the samples with the lab. The Chain of Custody must indicate the name of each sample (the monitoring well ID), the number of bottles submitted, the analyses required, and the date and time of sampling.

4.4 Sample Schedule

Field measurements and samples are to be collected according to the following schedule:

Table 1. List of Required Measurements, Laboratory Analyses, and Sample Schedule

Field Measurements	**Frequency**	**Duplicate**
Water Level	Weekly	N/A
Field Parameters (pH, conductivity, temperature, and dissolved oxygen)	Weekly	N/A
Laboratory Analyses		
Total and Fecal coliform, E.coli. (most probable number)	Quarterly	Semi-Annual
Biochemical Oxygen Demand (BOD_5)	Quarterly	Semi-Annual
Ammonia and Total Kjeldahl Nitrogen (TKN)	Semi-Annual	Annual
General Chemistry (incl. nitrate, nitrate, phosphorous, chloride, boron)	Semi-Annual	Annual
Dissolved Organic Carbon (DOC)	Annual	Annual
Dissolved Metals (Filtered)	Annual	Annual
Bacteria, Ammonia, TKN, General Chemistry, DOC, metals	Special[1]	Special[1]
Volatile Organic Compounds (VOCs)	Special[2]	N/A
TPH/BTEX (Atlantic PIRI)	Special[2]	N/A

[1] Sampled immediately if there are any indications of a spill or changes in groundwater quality
[2] Sampled if there is evidence that chemical contaminants could have entered the groundwater environment surrounding the STP.

The sample schedule satisfies Schedule 1 of the document “NSE Guidelines for the Handling, Treatment, and Disposal of Septage”. The frequency of measurement is intended to provide advance warning of changing groundwater quality in the event of an unknown leak. Groundwater modelling suggested that the time of travel from the STP to the municipal well field is less than two years. Weekly field measurements provide a cost effective and timely indication of changing water quality. Quarterly samples will ensure that the most immediate threats are detected before they are transported for any significant distance from the STP. Semi-annual and annual samples will provide a broader confirmation that the quality of water in the aquifer underlying the STP is not changing.

In the event that there are any indications that the groundwater quality is changing, a set of samples is to be collected immediately and submitted to the laboratory for rush analysis (as indicated under note “1” in Table 1.). The locations for sampling will depend on the nature and location of the observed change, and on any available information concerning leaks or spills. In the event that chemical contaminants enter the groundwater environment as a result of activity on the STP, VOC and/or TPH/BTEX samples may be needed.

Unexpected increases or decreases in water levels at a given well are considered to be possible indicators that changes in water quality could follow. These changes must be evaluated by a Qualified Person in the context of precipitation patterns and the groundwater flow regime.

In the event that total coliforms are elevated but have not been elevated in the past, a second confirmatory sample is required to eliminate the possibility of a false positive.

4.5 Quality Assurance and Quality Control

The sampling program should include additional sampling to ensure that samples are of high quality and are representative of the formation sampled. QA/QC samples further ensure that laboratory QA/QC protocols are effective. Standard QA/QC procedures include one duplicate sample for each set of 10 samples collected. Field and trip blanks are also typically submitted for larger sample sets. The recommended QA/QC sample schedule is indicated in Table 1.

4.6 Reporting and Regulatory Compliance

Field testing and laboratory sample results should be reviewed and compared to past results as they are generated. The Groundwater Monitoring Log Sheet should be consulted to determine if the groundwater quality is changing. In the event that a change is identified, the Designated STP operator and Supervising Engineer should be notified immediately. Confirmatory sampling may be required.

The results of the sampling program should be compiled and reported on an annual basis. The annual report is to contain summary tables for all results, laboratory analytical reports, and Groundwater Monitoring Log sheets. The report should contain a brief commentary on the results, including identification and interpretation of any unexpected results or long term trends in the groundwater chemistry. Changing groundwater chemistry should be evaluated using time-series graphs if possible.

The annual report must be forwarded to Nova Scotia Environment for compliance review.

4.7 Regulatory Guidelines

Groundwater contaminant concentrations are to be evaluated with respect to the Canadian Council of Ministers of the Environment (CCME) Guidelines for Canadian Drinking Water Quality (GCDWQ). The receptor of greatest concern is the Greenwood municipal well field. The CCME GCDWQ are provided in Appendix D.

Chapter 5 Description of Monitoring Network and Groundwater Flow Regime

5.1 Groundwater Flow

A conceptual model of groundwater flow in the STP area was developed based on a computer model of groundwater flow. The groundwater flow model was prepared for the Village of Greenwood by CBCL Limited in March, 2008 to determine the catchment area of the well field. The model was used to establish a Well Head Protection Area (WHPA) for Greenwood's two production wells.

Figure 3 shows the conceptual model of groundwater flow in the STP area. The surface layer of sandy silt acts as a semi-confining unit for the underlying sand unit. Flow in the silt unit starts as local rainfall and melt water infiltrating downward into the underlying sand unit. Groundwater flows in the sand unit horizontally away from the STP; under non-pumping conditions flow in the sand unit is to the north, discharging to the Fales River. Groundwater modelling suggested that when the well field is pumping, groundwater in the sand unit under the STP is drawn toward the well field.

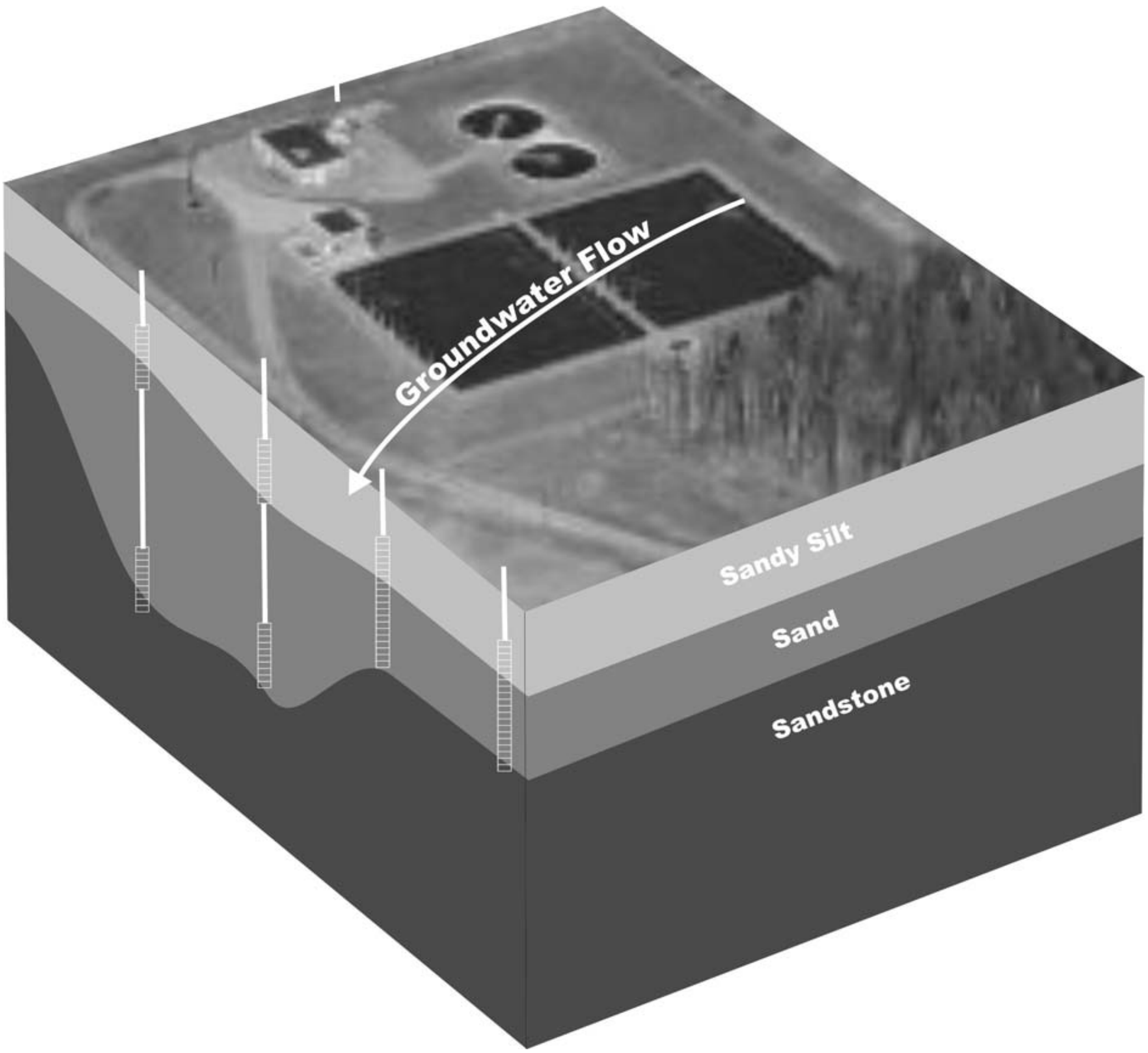


Figure 3. Conceptual Model of Groundwater Flow

5.2 Transport Processes

The closest ecological receptor is the Fales River to the north and northwest of the STP. Groundwater modeling suggested that under pumping conditions, flow paths originating to the north of the STP are captured by the river. All water flowing beneath or originating on the plant site is captured by the Greenwood well field, which supplies drinking water to the village of Greenwood. Residential areas are located to the north and northwest of the STP, and to the west of the well field. Private wells in these locations do not appear to intersect pathways of transport, and are not considered to be at risk. Figure 4 shows the paths of groundwater flowing from the STP to the Greenwood Well Field.

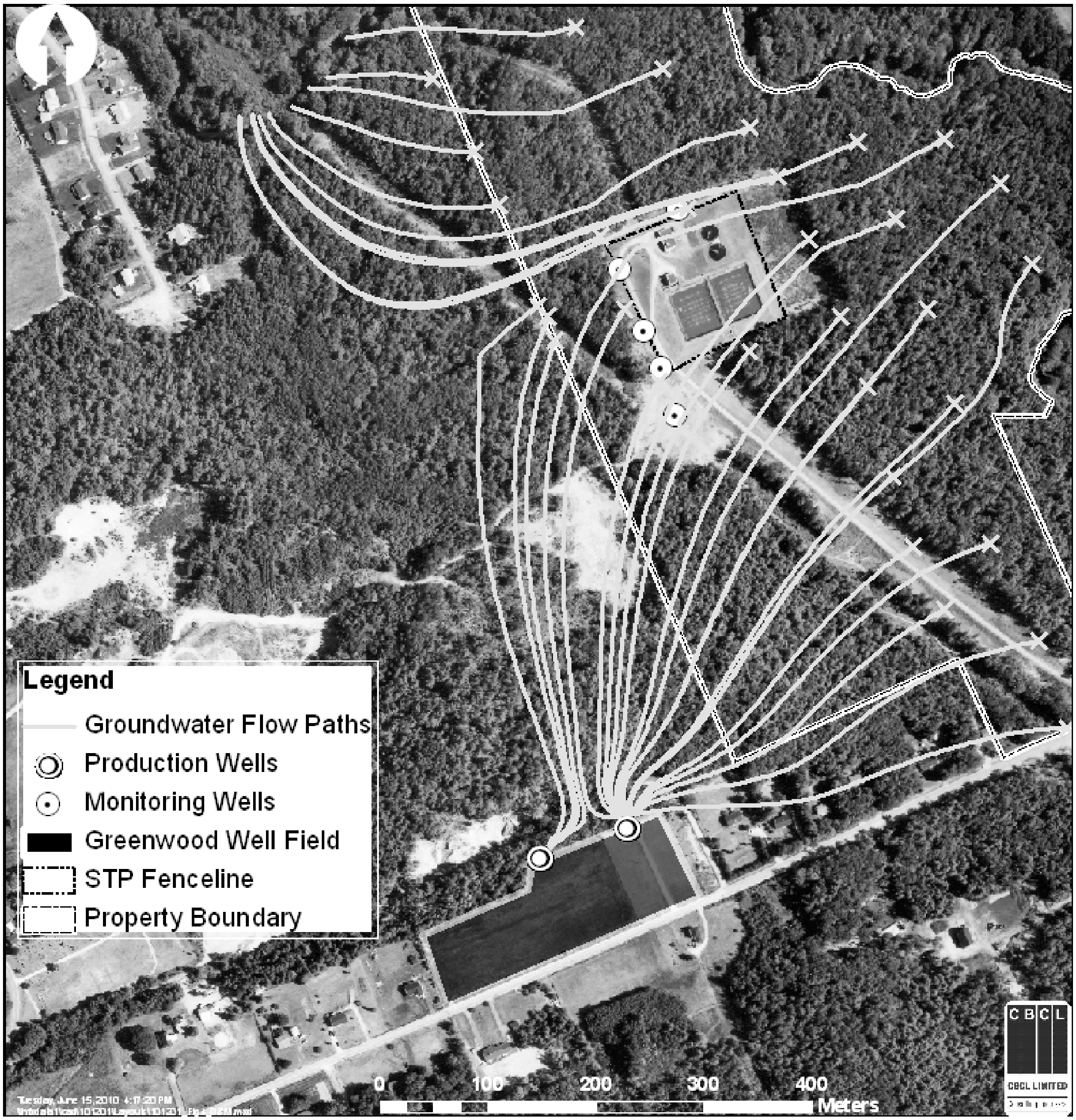


Figure 4. Groundwater Flow Paths Connecting STP and Greenwood Well Field

5.3 Monitoring Wells

Monitoring wells were installed at five locations around the STP. These locations were selected to intersect groundwater flow paths connecting the STP and the Greenwood well field (CBCL, 2010). Nested wells at two locations (MW3A/B and MW4A/B), and single well screens at three locations (MW1A, MW2A, and MW5A) provided a monitoring network best suited to the stratigraphic profile encountered. The length of the well screen was adjusted to suit the thickness and position of the targeted zone; nested monitoring wells were constructed using 1.5 m screens whereas single wells were constructed using 3.0 m screens. Shallow screens for monitoring wells MW3B and MW4B targeted the top of the saturated zone in a zone of interbedded sandy silt and silty fine sand. Deeper screens for monitoring wells MW3A and MW4A were installed closer to the bedrock surface. The sequence of saturated fine sand and silt was limited or absent at locations MW1A, MW2A, and MW5A. These wells were constructed using 3.0 m screens.

Chapter 6 Routine Maintenance

6.1 Well Head Inspection

Each well head should be inspected weekly when water levels and field measurements are collected. The ground surface around the well should be checked for signs of cave-in, settling, and signs of surface water pooling around the well. Any indications of pooling or potential conduits between the well casing and the formation should be addressed and corrected immediately. Mounding and compacting of fine grained soil around the well head is generally sufficient to prevent further pooling.

The protective casing should be checked for signs of wear including rusting of the casing and hinges, or evidence of damage by vehicles on the site. The casing lid and annulus should be checked and kept clear of insect nests or build-up of debris. The locks and hinges will require regular oiling to avoid seizing in the winter months.

6.2 Interior Casing Inspection

If the protective casing has been damaged, the interior PVC casing should be checked for evidence of breaks, leaks and bends. The water level tape should drop freely to the base of the well with no obstructions in the well. The interior casing should have a PVC cap that is clearly labeled. Replace missing caps promptly and ensure that the label is legible. The total depth of the well should be measured routinely to check the amount of siltation that has occurred.

6.3 Well Development

Each well was developed at the time of installation to remove fine material from around the sand pack and establish a good connection with the surrounding formation. Over time the wells could accumulate additional fine material. If cloudy sedimentation persists in well samples, the well should be redeveloped by surging and pumping with the Waterra tubing until the pumped water runs clear or exhibits turbidity less than 100 NTU.

Chapter 7 Troubleshooting

Insufficient Water Volume

Lower water levels are expected from May to September of each year, with a minimum occurring in early to mid September. Higher water levels can be expected from October to April of each year, with maximum levels most often observed in early November and early April.

If the water level in a monitoring well is too low to obtain a sample, it may be necessary to wait until the well recovers. Insufficient Water Volume should be noted in the groundwater monitoring log. The following techniques may be useful in obtaining samples:
-clean the sensor on the water level tape to ensure that it is not coated with muck or other debris, and recheck the water level
-sample the well after a rainfall event
-measure field parameters in a small cup rather than a bucket
-attempt low flow sampling (methodology not described in this document)
-allow the well to recover for 30 to 60 minutes; make several visits to each well, staggering pumping and sampling to minimize wait times

If a small amount of water can be drawn into the Waterra tubing, but there is not enough flow to prime the pump and obtain a steady flow, carefully withdraw the tubing from the well, taking care to coil the tubing and keep it off of the ground. Slowly rotate the tubing to allow any water to drain into the sample bottles or bucket.

If the sample volume is limited, fill the laboratory bottles before drawing off water to measure field parameters. Fill the bottles in the following order:

1. General Chemistry
2. Metals
3. Bacteria
4. BOD_5
5. Ammonia
6. DOC

High Sample Turbidity

If samples are consistently cloudy it may be necessary to re-develop the well. Surge and pump the well vigorously until dry and repeat several times or until the water stream runs clear. Effective well development can take several hours. Do not introduce water into the well under any circumstances.

Check the well head and casing to ensure that surface water is not leaking into the borehole annulus or inner casing.

Waterra Tubing Cracked / Pumping Not Working

Recheck the well depth and static water level to ensure that there is sufficient water column for pumping. If the water column is less than 0.3 to 0.4 metres deep it may be difficult to prime the pump.

The Waterra tubing may develop cracks over time. Folds in the tubing are the most susceptible to cracking, and can cause the pump to lose suction. If small cracks appear at the fold near the top of the Waterra tubing, attempt to cover these holes using electrical tape or a 4 to 6 inch sleeve of tight rubber tubing. If cracks cannot be repaired the Waterra tubing must be replaced.

The footvalve may become clogged or wear out over time. If there are no cracks in the Waterra tubing and sufficient water column but flow is limited, carefully withdraw and coil the Waterra tubing. Take care not to allow the coiled tubing to make contact with the ground or other surfaces. The coiled tubing can be stored on clean plastic sheeting if necessary. Unscrew the footvalve and check to see that the ball-valve is present and moves freely up and down the column of the footvalve. Defective footvalves must be replaced.

Waterra Tubing Stuck in Well

If improperly stored by the previous user, the Waterra tubing may be lodged or stored too deeply in the PVC casing to retrieve by hand. A coat hanger or long hook is generally sufficient to reach tubing that is stored too deeply in the well.

If the bent top-section of the Waterra tubing has been removed or cracked off, it may be possible to retrieve the tubing using a piece of threaded rod. The threaded rod must be fed into and screwed into the open end of the Waterra tubing.

If the tubing is accessible but lodged in the well avoid using direct force to pull the tubing up. Pulling the pump up against an obstruction can cause the footvalve to break off of the tubing. Attempt to loosen the tubing by rotating several times and using any give to dislodge the obstruction.

Inner Casing is Blocked

If the Waterra tubing cannot be fed into the well or has become impossible to dislodge, damage to the interior casing has likely occurred. This is most frequently caused by objects or debris tossed into the well, vehicle traffic, or frost-heave damage. Occasionally extreme cold can cause the water at the top of the casing to freeze.

In most circumstances blocked or damaged casings render the well unusable. Document the depth of the obstruction (recheck during warmer weather if necessary) in the log, along with any evidence for the cause of the damage. Damaged wells may need to be re-drilled.

Outer Casing is Damaged

Damage to the outer casing can restrict access to the well. If necessary the outer casing may be carefully cut-off and removed by a licensed well driller or pump installer. If the interior PVC casing is intact, the outer casing should be replaced.

References

ABL Environmental Consultants Ltd,1998. Operation and Maintenance Manual for Greenwood Sewage Treatment Plant.

CBCL Limited, 2008. Greenwood Capture Zone Modelling: Technical Report. Prepared for the Municipality of the County of Kings.

CBCL Limited, 2010. Greenwood Sewage Treatment Plant: Groundwater Monitoring Program – Design Report. Prepared for the Municipality of the County of Kings.

CBCL Limited, 2010. Greenwood Sewage Treatment Plant: Groundwater Monitoring Program – Field Program Results. Prepared for the Municipality of the County of Kings.

CBCL Limited, 1998. CBCL Limited Standard Operating Procedures.

Health Canada, 2004. Summary of Guidelines for Canadian Drinking Water Quality. Prepared by the Federal-Provincial-Territorial Committee on Drinking Water of the Federal-Provincial-Territorial Committee on Health and the Environment.

Nova Scotia Environment and Labour, 2006. Guidelines for the Handling, Treatment, and Disposal of Septage.

Nova Scotia Environment and Labour. NSE Guide for Water Utilities and Municipalities – Step 5: Develop a Monitoring Program to Evaluate the Effectiveness of a Source Water Protection Plan.

United States Environmental Protection Agency, 1995. Standard Operating Procedure for Groundwater Well Sampling, SOP #2007, Date: 1/26/95.

Appendix A

Groundwater Monitoring Log Sheet Template

Groundwater Monitoring Log Sheet

Date:	Weather:	Name of Sampler:

Parameters Sampled (check when complete):

Weekly
- q Water Level
- q Field Parameters

Quarterly
- q Water Level
- q Field Parameters
- q E.coli and Total coliforms
- q BOD5

Semi-Annual
- q Water Level
- q Field Parameters
- q E.coli and Total coliforms
- q BOD5
- q Ammonia and TKN
- q General Chemistry

Annual
- q Water Level
- q Field Parameters
- q E.coli and Total coliforms
- q BOD5
- q Ammonia and TKN
- q General Chemistry
- q DOC
- q Dissolved (Filtered) Metals

Measurements

Well	Time	Water Level	pH	Conductivity	Temperature	DO	Comments, Well Condition
MW1A							
MW2A							
MW3A							
MW3B							
MW4A							
MW4B							
MW5A							

Purging Notes

Well	Water Level (below top of casing)	Well Depth (below top of casing)	Water Column Height (metres)	Casing Volume (Litres)	Target Volume (Litres)	Actual Volume Purged (Litres)	Colour	Odour
MW1A								
MW2A								
MW3A								
MW3B								
MW4A								
MW4B								
MW5A								

Water Column Height (metres) = Well Depth - Water Level

Casing Volume (litres) = Water Column Height x 2.024

Target Volume (litres) = Casing Volume x 3

Appendix B

Monitoring Well Information Packages

Monitoring Well MW1A

Location

Monitoring Well MW1A is a single well located in the open area to the south of the STP facility. The well head can be reached by following the western fence line of the STP to the south to a point almost underneath the overhead power lines. The well is approximately 40 metres from the gate of the STP.

Well Information

Well Name	MW1A	
Northing	348132	USTM NAD83 Zone 20
Easting	4980118	
Stick-up	0.94	m
Top of Screen	3.94	mbg
Bottom of Screen	6.99	mbg
Bottom of Screen	7.93	m b/TOC
Bedrock Surface	8.33	mbg
Well Diameter	0.051	m
Borehole Diameter	0.184	m
Static Water Level	5.31	m b/TOC
Screened Formation	Medium Sand	

Baseline Chemistry (May 2010)

Anion Sum	me/L	1.34	Aluminum (Al)	ug/L	<5
Bicarb. Alkalinity (as CaCO3)	mg/L	46	Antimony (Sb)	ug/L	<2
Calculated TDS	mg/L	65	Arsenic (As)	ug/L	<2
Carb. Alkalinity (as CaCO3)	mg/L	<10	Barium (Ba)	ug/L	7
Cation Sum	me/L	1.07	Beryllium (Be)	ug/L	<2
Hardness	mg/L	42.6	Bismuth (Bi)	ug/L	<2
Ion Balance (% Difference)	%	11.4	Boron (B)	ug/L	8
Langelier Index (@ 20C)	N/A	-0.96	Cadmium (Cd)	ug/L	<0.017
Langelier Index (@ 4C)	N/A	-1.28	Chromium (Cr)	ug/L	<1
Saturation pH (@ 20C)	N/A	8.76	Cobalt (Co)	ug/L	<1
Saturation pH (@ 4C)	N/A	9.08	Copper (Cu)	ug/L	<2
pH		7.8	Iron (Fe)	ug/L	<50
Reactive Silica as SiO2	mg/L	12.5	Lead (Pb)	ug/L	<0.5
Chloride	mg/L	11	Manganese (Mn)	ug/L	3
Fluoride	mg/L	0.1	Molybdenum (Mo)	ug/L	<2
Sulphate	mg/L	5	Nickel (Ni)	ug/L	<2
Alkalinity	mg/L	46	Selenium (Se)	ug/L	<1
True Color	TCU	<5	Silver (Ag)	ug/L	<0.1
Turbidity	NTU	7200	Strontium (Sr)	ug/L	44
Electrical Conductivity	umho/cm	135	Thallium (Tl)	ug/L	<0.1
Nitrate + Nitrite as N	mg/L	0.11	Tin (Sn)	ug/L	<2
Nitrate as N	mg/L	0.11	Titanium (Ti)	ug/L	<2
Nitrite as N	mg/L	<0.05	Uranium (U)	ug/L	0.9
Ammonia as N	mg/L	0.05	Vanadium (V)	ug/L	<2
Total Organic Carbon	mg/L	3	Zinc (Zn)	ug/L	<5
Dissolved Organic Carbon	mg/L	0.7	Sodium	mg/L	4.1
Ortho-Phosphate as P	mg/L	0.02	Potassium	mg/L	1.3
Phosphorus	mg/L	<0.02	Calcium	mg/L	14.1
Hydroxide	mg/L	<5	Magnesium	mg/L	1.8
Biochemical Oxygen Demand	mg/L	<2			
Total Suspended Solids	mg/L	8300			
Total Kjeldahl Nitrogen as N	mg/L	2.4			
Total Coliforms	MPN/100mL	<2			
Escherichia coli	MPN/100mL	<2			

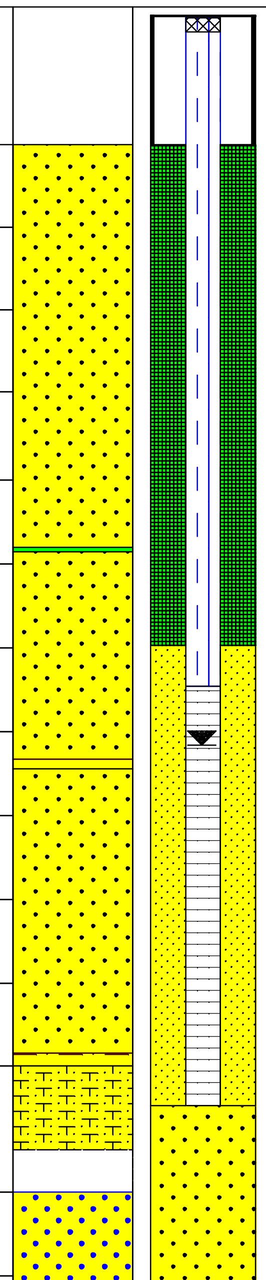
CBCL LIMITED
Consulting Engineers

Monitor Well: MW1A

Project Number: 101201.00
Project: Greenwood STP GW Monitoring Program
Location: Greenwood, NS
Contractor: Logan Geotech
Rig Type: CME85
Completion Date: May 3, 2010

Depth (m)	Description	Penetration Resistance N Blows/30cm	Recovery (%)
0	Brown medium grain SAND, cobbles throughout; dry, no odour.	7	41.7
		9	65
-1		9	71.7
-2		14	86.7
		17	100
-3	Iron oxidized black SLATE; dry, no odour.	19	70
	Brown medium grain SAND, cobbles throughout; moist, no odour.	15	66.7
-4	Brown medium grain SAND, cobbles throughout; wet, no odour.	12	68.3
	Brown SILT; wet, no odour.		
-5	Brown medium grain SAND, cobbles throughout; wet, no odour.	5	83.3
		8	96.7
-6		3	100
	Brown SILT; wet, no odour.	3	21.7
-7	Brown SILTY SAND; wet, no odour.		
	Augered through heaving sand to 7.62m.		
-8	Weak, red SANDSTONE; no odour; refusal at 8.33m.	38	80
			23.3

Graphic / Well Column



Stick Up ProtectiveCasing
Bentonite Plug
Sand Pack
PVC Screen
Static Water Level @ 4.369m
Bottom of Screen @ 6.99m
Native Material Backfilled Below Screen

Monitoring Well MW2A

Location

Monitoring Well MW2A is a single well located outside of the west fence near the gate of the STP facility. The well head is the first to be reached by following the western fence line northward from the gate. The well is approximately 15 metres from the gate of the STP.

Well Information

Well Name	MW2A	
Northing	348119	USTM NAD83 Zone 20
Easting	4980161	
Stick-up	0.95	m
Top of Screen	2.80	mbg
Bottom of Screen	5.85	mbg
Bottom of Screen	6.80	m b/TOC
Bedrock Surface	7.75	mbg
Well Diameter	0.051	m
Borehole Diameter	0.184	m
Static Water Level	4.8	m b/TOC
Screened Formation	Medium Sand	

Baseline Chemistry (May 2010)

Anion Sum	me/L	3.67	Aluminum (Al)	ug/L	<5
Bicarb. Alkalinity (as CaCO3)	mg/L	52	Antimony (Sb)	ug/L	<2
Calculated TDS	mg/L	194	Arsenic (As)	ug/L	<2
Carb. Alkalinity (as CaCO3)	mg/L	<10	Barium (Ba)	ug/L	32
Cation Sum	me/L	3.21	Beryllium (Be)	ug/L	<2
Hardness	mg/L	77.1	Bismuth (Bi)	ug/L	<2
Ion Balance (% Difference)	%	6.6	Boron (B)	ug/L	12
Langelier Index (@ 20C)	N/A	-0.61	Cadmium (Cd)	ug/L	<0.017
Langelier Index (@ 4C)	N/A	-0.93	Chromium (Cr)	ug/L	<1
Saturation pH (@ 20C)	N/A	8.51	Cobalt (Co)	ug/L	<1
Saturation pH (@ 4C)	N/A	8.83	Copper (Cu)	ug/L	<2
pH		7.9	Iron (Fe)	ug/L	<50
Reactive Silica as SiO2	mg/L	12.6	Lead (Pb)	ug/L	0.6
Chloride	mg/L	89	Manganese (Mn)	ug/L	30
Fluoride	mg/L	<0.1	Molybdenum (Mo)	ug/L	<2
Sulphate	mg/L	5	Nickel (Ni)	ug/L	<2
Alkalinity	mg/L	52	Selenium (Se)	ug/L	<1
True Color	TCU	<5	Silver (Ag)	ug/L	<0.1
Turbidity	NTU	3000	Strontium (Sr)	ug/L	156
Electrical Conductivity	umho/cm	405	Thallium (Tl)	ug/L	<0.1
Nitrate + Nitrite as N	mg/L	0.16	Tin (Sn)	ug/L	<2
Nitrate as N	mg/L	0.16	Titanium (Ti)	ug/L	<2
Nitrite as N	mg/L	<0.05	Uranium (U)	ug/L	0.7
Ammonia as N	mg/L	0.04	Vanadium (V)	ug/L	<2
Total Organic Carbon	mg/L	2.5	Zinc (Zn)	ug/L	<5
Dissolved Organic Carbon	mg/L	0.6	Sodium	mg/L	36.9
Ortho-Phosphate as P	mg/L	0.01	Potassium	mg/L	2.5
Dissolved Phosporous	mg/L	<0.02	Calcium	mg/L	24.6
Hydroxide	mg/L	<5	Magnesium	mg/L	3.8
Biochemical Oxygen Demand	mg/L	<2			
Total Suspended Solids	mg/L	9580			
Total Kjeldahl Nitrogen as N	mg/L	4.2			
Total Coliforms	MPN/100mL	<2			
Escherichia coli	MPN/100mL	<2			

Monitor Well: MW2A

Project Number: 101201.00
Project: Greenwood STP GW Monitoring Program
Location: Greenwood, NS
Contractor: Logan Geotech
Rig Type: CME85
Completion Date: May 3, 2010

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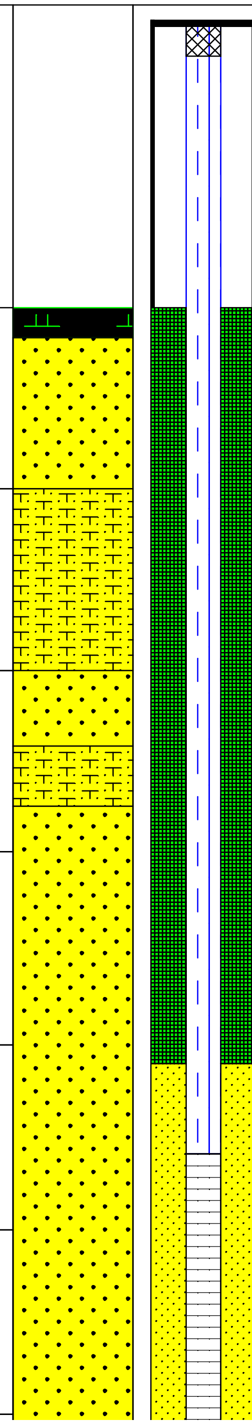
Depth (m)	Description	Penetration Resistance N Blows/30cm	Recovery (%)
1			
0	Grass/roots	13	91.7
	Orange/brown, medium SAND with small cobbles throughout; dry, no odour.		
	Grey/brown, medium SAND with root mass; dry, no odour.		
-1	Red/brown SILTY SAND with small cobbles throughout; dry, no odour.	16	85
	Brown, medium SAND with small cobbles throughout; dry, no odour.	27	88.3
	Brown SILTY SAND; dry, no odour.		
	Light brown, medium SAND with small cobbles throughout; dry, no odour.	18	88.3
-2	Light brown, medium SAND grading to finer grain with depth; dry, no odour.		
	Light brown, medium/fine SAND grading to coarser grain with depth; small cobbles throughout; no odour, moist @ 3.3m.	11	70
-3		4	60

Graphic / **Well Column**



Stick Up ProtectiveCasing

Bentonite Plug

Sand Pack

PVC Screen

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Monitor Well: **MW2A**

Project Number: 101201.00

Project: Greenwood STP GW Monitoring Program

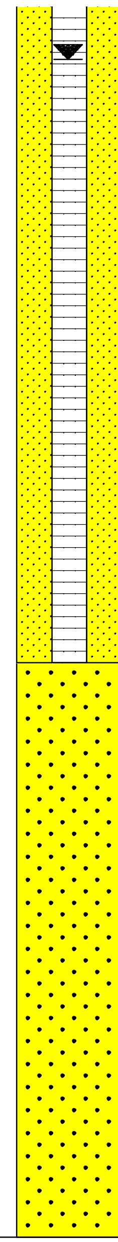
Location: Greenwood, NS

Contractor: Logan Geotech

Rig Type: CME85

Completion Date: May 3, 2010

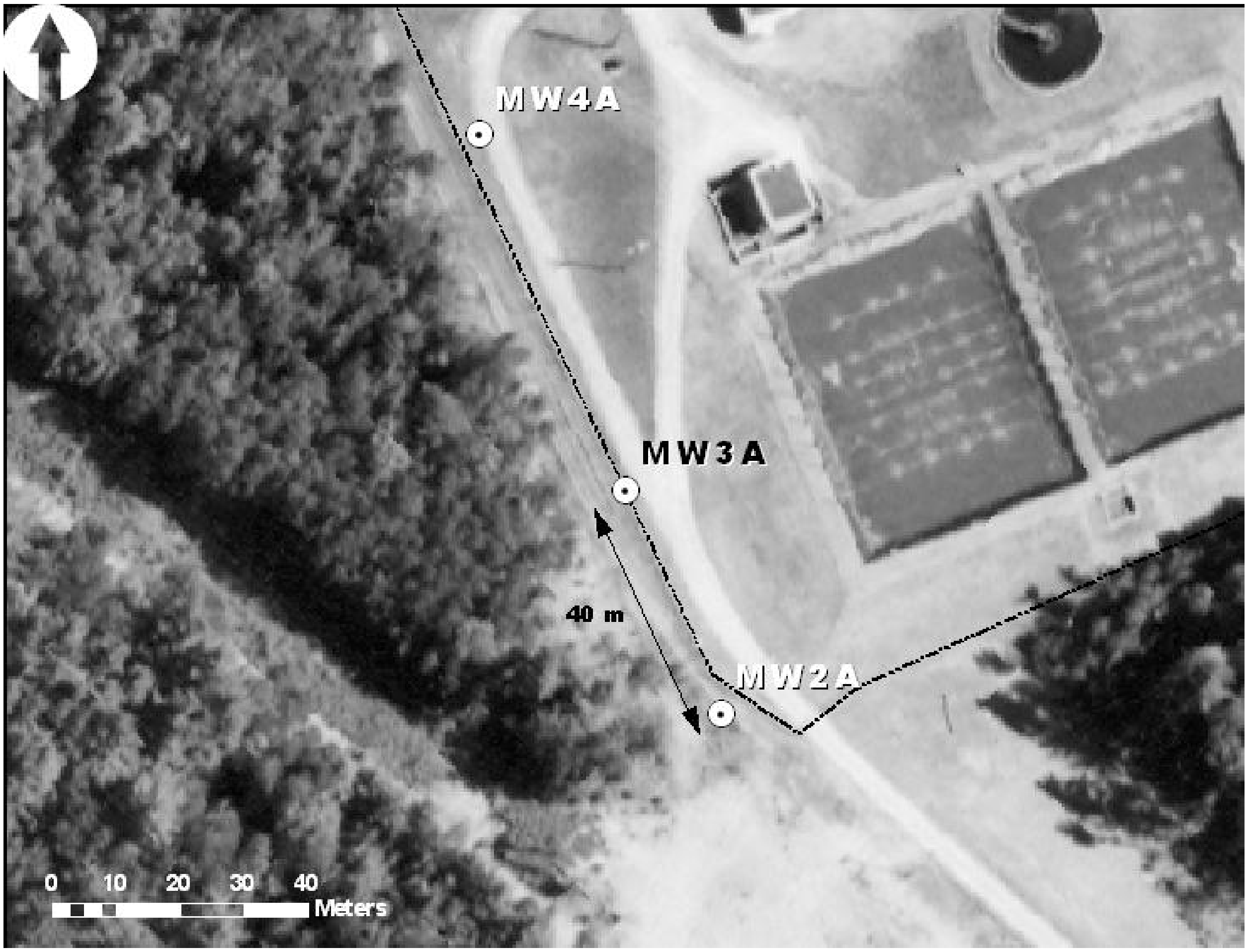
Depth (m)	Description	Penetration Resistance N Blows/30cm	Recovery (%)	Graphic	Well Column
-4	Brown coarse grain SAND with cobbles throughout; wet, no odour.	2	21.7		Static Water Level @ 3.854m
	Brown SILTY SAND; wet, no odour	8	100		
	Brown coarse SAND with minor cobbles throughout; wet, no odour.				
-5	Augered from 4.88m to 5.79m due to heaving sand.				
-6	Brown coarse SAND; wet, no odour (possible upheave).	24	100		Bottom of Screen @ 5.85m
	Brown SILTY SAND; wet, no odour.				Native Material Backfilled Below Screen
-7	Augered from 6.4m to 7.31m due to heaving sand.				
	Weak red SANDSTONE; no odour; refusal @ 7.75m.	89/432	50		End of Hole @ 7.75m



Monitoring Well Nest MW3A / MW3B

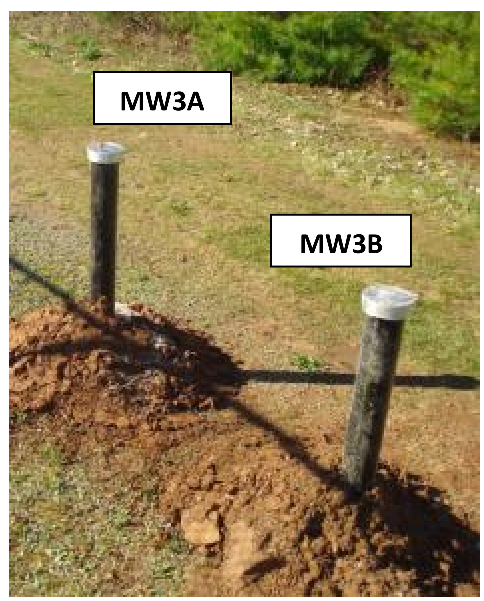
Location

Monitoring Well MW3A /MW3B consists of two wells clustered in a single nest. The well nest is located outside of the west fence of the STP across from the aeration lagoons. This nest is the second monitoring location to be reached by following the western fence line north from the gate.



Well Information

Well Name	MW3A	MW3B	
Northing	348104	348104	USTM NAD83
Easting	4980196	4980196	Zone 20
Stick-up	0.93	0.88	m
Top of Screen	4.18	1.79	mbg
Bottom of Screen	5.70	3.31	mbg
Bottom of Screen	6.63	4.19	m b/TOC
Bedrock Surface	7.92	7.92	mbg
Well Diameter	0.051	0.051	m
Borehole Diameter	0.184	0.184	m
Static Water Level	4.06	4.11	m b/TOC
Screened Formation	Medium Sand	Silty Sand	



Baseline Chemistry (May 2010)

MW3A

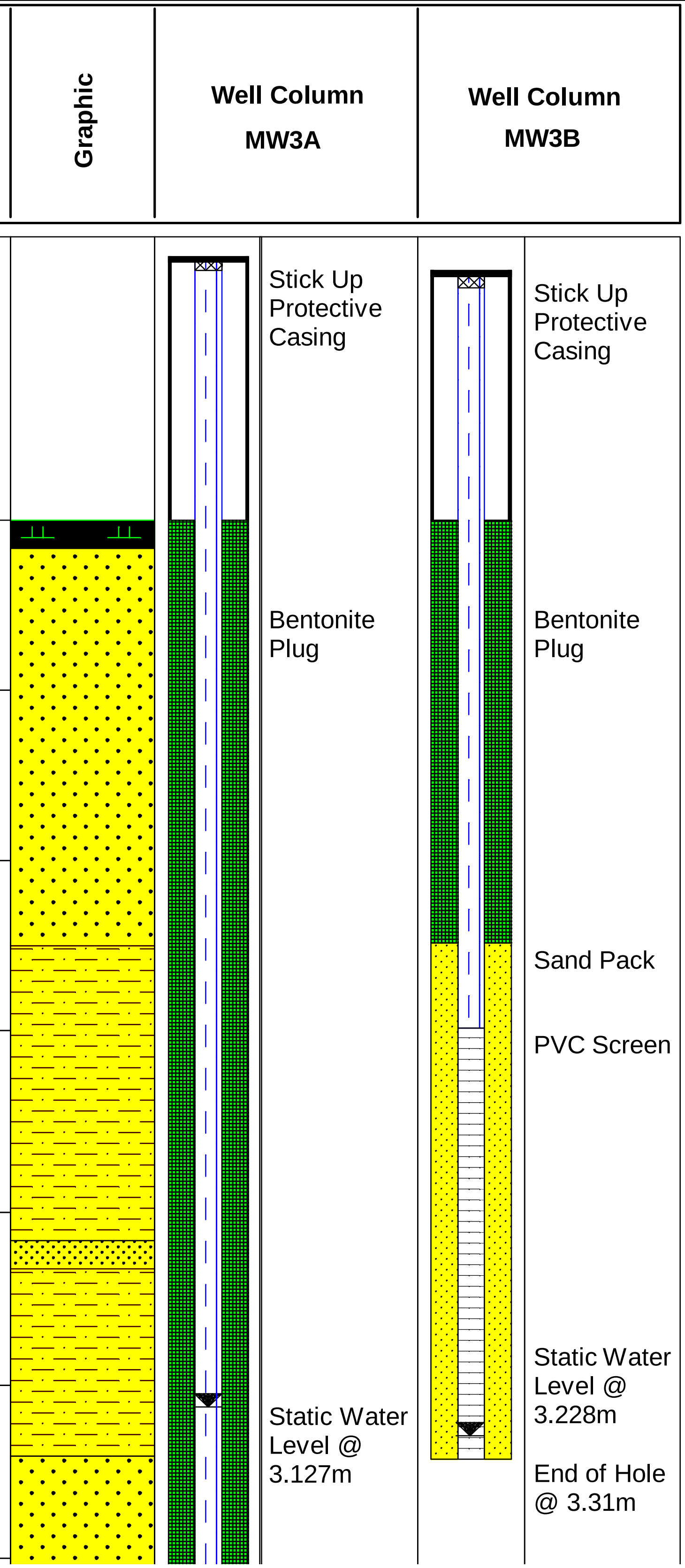
Anion Sum	me/L	1.13	Aluminum (Al)	ug/L	<5
Bicarb. Alkalinity (as CaCO3)	mg/L	28	Antimony (Sb)	ug/L	<2
Calculated TDS	mg/L	56	Arsenic (As)	ug/L	<2
Carb. Alkalinity (as CaCO3)	mg/L	<10	Barium (Ba)	ug/L	9
Cation Sum	me/L	0.82	Beryllium (Be)	ug/L	<2
Hardness	mg/L	25.2	Bismuth (Bi)	ug/L	<2
Ion Balance (% Difference)	%	15.8	Boron (B)	ug/L	8
Langelier Index (@ 20C)	N/A	-1.72	Cadmium (Cd)	ug/L	<0.017
Langelier Index (@ 4C)	N/A	-2.04	Chromium (Cr)	ug/L	<1
Saturation pH (@ 20C)	N/A	9.22	Cobalt (Co)	ug/L	<1
Saturation pH (@ 4C)	N/A	9.54	Copper (Cu)	ug/L	<2
pH		7.5	Iron (Fe)	ug/L	<50
Reactive Silica as SiO2	mg/L	14.1	Lead (Pb)	ug/L	<0.5
Chloride	mg/L	16	Manganese (Mn)	ug/L	20
Fluoride	mg/L	<0.1	Molybdenum (Mo)	ug/L	<2
Sulphate	mg/L	5	Nickel (Ni)	ug/L	<2
Alkalinity	mg/L	28	Selenium (Se)	ug/L	<1
True Color	TCU	5	Silver (Ag)	ug/L	<0.1
Turbidity	NTU	4800	Strontium (Sr)	ug/L	43
Electrical Conductivity	umho/cm	115	Thallium (Tl)	ug/L	<0.1
Nitrate + Nitrite as N	mg/L	0.21	Tin (Sn)	ug/L	<2
Nitrate as N	mg/L	0.09	Titanium (Ti)	ug/L	<2
Nitrite as N	mg/L	0.12	Uranium (U)	ug/L	0.3
Ammonia as N	mg/L	<0.03	Vanadium (V)	ug/L	<2
Total Organic Carbon	mg/L	2.6	Zinc (Zn)	ug/L	<5
Dissolved Organic Carbon	mg/L	1.5	Sodium	mg/L	6.4
Ortho-Phosphate as P	mg/L	0.01	Potassium	mg/L	1.5
Dissolved Phosporous	mg/L	<0.02	Calcium	mg/L	7.8
Hydroxide	mg/L	<5	Magnesium	mg/L	1.4
Biochemical Oxygen Demand	mg/L	<2			
Total Suspended Solids	mg/L	7860			
Total Kjeldahl Nitrogen as N	mg/L	1.6			
Total Coliforms	MPN/100mL	<2			
Escherichia coli	MPN/100mL	<2			

CBCL LIMITED
Consulting Engineers

Monitor Well: MW3A and 3B

Project Number: 101201.00
Project: Greenwood STP GW Monitoring Plan
Location: Greenwood, NS
Contractor: Logan Geotech
Rig Type: CME85
Completion Date: May 3, 2010

Depth (m)	Description	Penetration Resistance N Blows/30cm	Recovery (%)
1			
0	Grass/roots	10	86.7
	Red/brown, medium grain, loose SAND with cobbles throughout; dry, no odour.		
	Red/brown, medium grain, loose SAND; dry, no odour.	10	76.7
-1			
	Orange/brown, medium grain, loose SAND with small cobbles throughout; dry, no odour.	12	93.3
	Red/brown SILT with very thin lenses of fine grain, light brown sand; dry, no odour.	11	100
-2			
	Light brown FINE SAND; dry, no odour.	8	100
	Red/brown SILT with very thin lenses of fine grain, light brown sand; silt is moist, sand is wet; no odour.		
-3		9	83.3
	Brown, coarse SAND; wet, no odour.		



CBCL LIMITED
Consulting Engineers

Monitor Well: MW3A and 3B
Project Number: 101201.00
Project: Greenwood STP GW Monitoring Plan
Location: Greenwood, NS
Contractor: Logan Geotech
Rig Type: CME85
Completion Date: May 3, 2010

Depth (m)	Description	Penetration Resistance N Blows/30cm	Recovery (%)	Graphic	Well Column MW3A	Well Column MW3B
		12	95			
-4						
		5	100		Sand Pack	
					PVC Screen	
-5	Sand is heaving; augered to 5.49m.					
	Brown, medium grain SAND; wet, no odour.	12	91.7			
	Brown, coarse grain SAND; wet, no odour.					
-6	Brown, medium grain SAND; wet, no odour.					
	Sand is heaving; augered to 7.31m.				Native Material Backfilled Below Screen	
-7						
	Brown, medium grain SAND; wet, no odour.	42	83.3			
	Red, weak SANDSTONE; no odour.				End of Hole @ 7.92m	
-8						

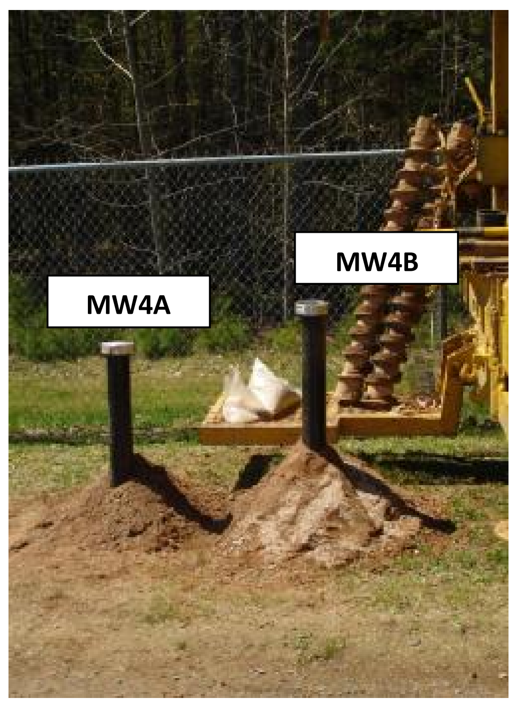
Monitoring Well Nest MW4A / MW4B

Location

Monitoring Well MW4A /MW4B consists of two wells clustered in a single nest. The well nest is located inside of the west fence of the STP across from the clarifiers and main control building. This nest is the third monitoring location to be reached by following the western fence line north from the gate.

Well Information

Well Name	MW4A	MW4B	
Northing	348081	348081	USTM NAD83
Easting	4980252	4980252	Zone 20
Stick-up	0.84	0.95	m
Top of Screen	3.92	2.01	mbg
Bottom of Screen	5.44	3.53	mbg
Bottom of Screen	6.28	4.48	m b/TOC
Bedrock Surface	7.62	7.62	mbg
Well Diameter	0.051	0.051	m
Borehole Diameter	0.184	0.184	m
Static Water Level	5.09	dry	m b/TOC
Screened Formation	Medium Sand	Silty Sand	



Baseline Chemistry (May 2010)

MW4A

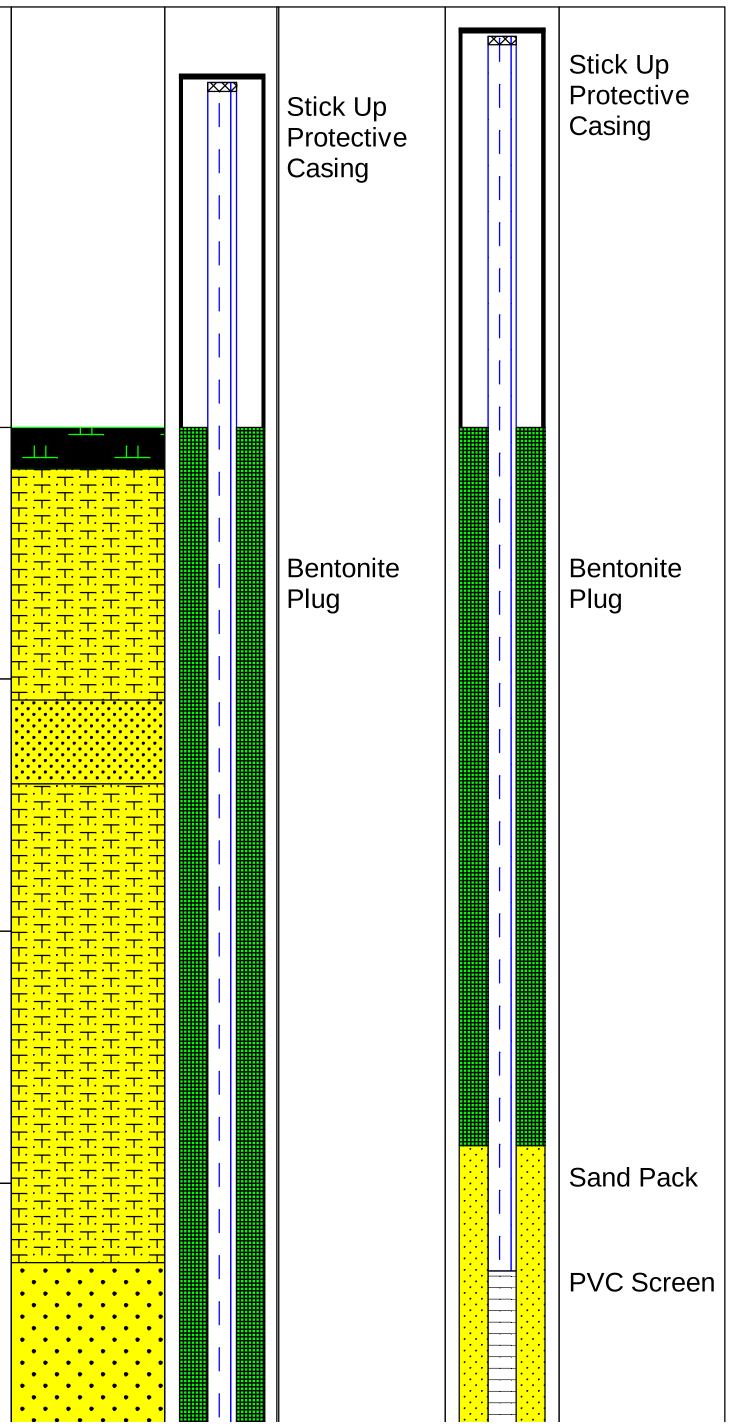
Anion Sum	me/L	1.73	Aluminum (Al)	ug/L	<5
Bicarb. Alkalinity (as CaCO3)	mg/L	24	Antimony (Sb)	ug/L	<2
Calculated TDS	mg/L	99	Arsenic (As)	ug/L	<2
Carb. Alkalinity (as CaCO3)	mg/L	<10	Barium (Ba)	ug/L	20
Cation Sum	me/L	1.72	Beryllium (Be)	ug/L	<2
Hardness	mg/L	23.1	Bismuth (Bi)	ug/L	<2
Ion Balance (% Difference)	%	0.2	Boron (B)	ug/L	9
Langelier Index (@ 20C)	N/A	-2.62	Cadmium (Cd)	ug/L	0.038
Langelier Index (@ 4C)	N/A	-2.94	Chromium (Cr)	ug/L	1
Saturation pH (@ 20C)	N/A	9.42	Cobalt (Co)	ug/L	1
Saturation pH (@ 4C)	N/A	9.74	Copper (Cu)	ug/L	<2
pH		6.8	Iron (Fe)	ug/L	<50
Reactive Silica as SiO2	mg/L	11.4	Lead (Pb)	ug/L	<0.5
Chloride	mg/L	38	Manganese (Mn)	ug/L	61
Fluoride	mg/L	<0.1	Molybdenum (Mo)	ug/L	<2
Sulphate	mg/L	6	Nickel (Ni)	ug/L	<2
Alkalinity	mg/L	24	Selenium (Se)	ug/L	<1
True Color	TCU	<5	Silver (Ag)	ug/L	<0.1
Turbidity	NTU	2200	Strontium (Sr)	ug/L	39
Electrical Conductivity	umho/cm	183	Thallium (Tl)	ug/L	<0.1
Nitrate + Nitrite as N	mg/L	0.71	Tin (Sn)	ug/L	<2
Nitrate as N	mg/L	0.62	Titanium (Ti)	ug/L	<2
Nitrite as N	mg/L	0.09	Uranium (U)	ug/L	0.2
Ammonia as N	mg/L	0.04	Vanadium (V)	ug/L	<2
Total Organic Carbon	mg/L	2.5	Zinc (Zn)	ug/L	<5
Dissolved Organic Carbon	mg/L	1.6	Sodium	mg/L	28
Ortho-Phosphate as P	mg/L	<0.01	Potassium	mg/L	1.5
Dissolved Phosporous	mg/L	<0.02	Calcium	mg/L	6.1
Hydroxide	mg/L	<5	Magnesium	mg/L	1.9
Biochemical Oxygen Demand	mg/L	<2			
Total Suspended Solids	mg/L	4700			
Total Kjeldahl Nitrogen as N	mg/L	1			
Total Coliforms	MPN/100mL	<2			
Escherichia coli	MPN/100mL	<2			

CBCL LIMITED
Consulting Engineers

Monitor Well: **MW4A and 4B**
Project Number: 101201.00
Project: Greenwood STP GW Monitoring Plan
Location: Greenwood, NS
Contractor: Logan Geotech
Rig Type: CME85
Completion Date: May 4, 2010

Depth (m)	Description	Penetration Resistance N Blows/30cm	Recovery (%)
1			
0	Grass/roots	9	70
	Brown medium grain SILTY SAND with cobbles throughout; dry, no odour.		
	White/grey FINE SAND; dry, no odour.	5	70
	Orange/brown SILTY SAND; dry, no odour.		
-1		4	91.7
		24	90
-2	Brown, medium grain, loose SAND, minor small cobbles; moist, no odour.		

Graphic | Well Column MW4A | Well Column MW4B

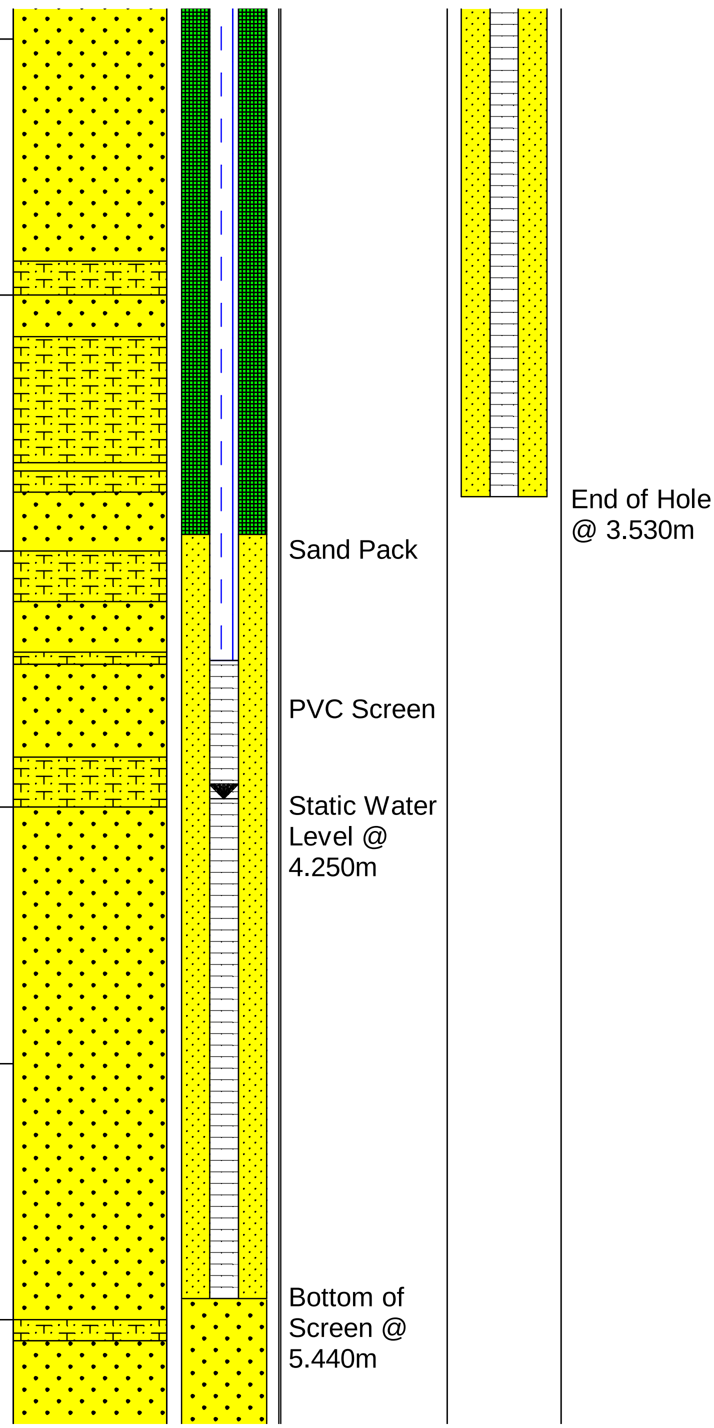


CBCL LIMITED
Consulting Engineers

Monitor Well: MW4A and 4B
Project Number: 101201.00
Project: Greenwood STP GW Monitoring Plan
Location: Greenwood, NS
Contractor: Logan Geotech
Rig Type: CME85
Completion Date: May 4, 2010

Depth (m)	Description	Penetration Resistance N Blows/30cm	Recovery (%)
		48	100
-3	Brown SILTY SAND; wet, no odour.		
	Brown, medium SAND; wet, no odour.	32	81.7
	Red/brown SILTY SAND; wet, no odour.		
	Brown, medium SAND; wet, no odour.		
	Red/brown SILTY SAND; wet, no odour.		
	Brown, medium SAND; wet, no odour.	32	100
	Red/brown SILTY SAND; wet, no odour.		
-4	Brown, medium SAND; wet, no odour.		
	Red/brown SILTY SAND; wet, no odour.		
	Brown, medium SAND; wet, no odour.		
	Red/brown SILTY SAND; wet, no odour.	16	56.7
	Brown, coarse SAND; wet, no odour.		
		14	100
-5			
	Red/brown SILTY SAND; wet, no odour.	17	41.7
	Brown, coarse SAND; wet, no odour.		

Graphic | Well Column MW4A | Well Column MW4B



CBCL LIMITED
Consulting Engineers

Monitor Well: **MW4A and 4B**
Project Number: 101201.00
Project: Greenwood STP GW Monitoring Plan
Location: Greenwood, NS
Contractor: Logan Geotech
Rig Type: CME85
Completion Date: May 4, 2010

Depth (m)	Description	Penetration Resistance N Blows/30cm	Recovery (%)	Graphic	Well Column MW4A	Well Column MW4B
-6	Red/brown SILTY SAND; wet, no odour.				Native Material Backfilled Below Screen	
	Coarse sand is heaving; augered to 7m.					
-7	Brown, coarse SAND, possible heave; wet, no odour.	77/229	100		End of Hole @ 7.62m	

Monitoring Well MW5A

Location

Monitoring Well MW5A is a single well located inside of the north fence at the back of the STP facility. Standing at the north fence and facing south, the well head is positioned between the main control building and the clarifiers. The well is approximately 15 metres from the main control building.

Well Information

Well Name	MW5A	
Northing	348135	USTM NAD83
Easting	4980308	Zone 20
Stick-up	1.05	m
Top of Screen	1.11	mbg
Bottom of Screen	4.16	mbg
Bottom of Screen	5.21	m b/TOC
Bedrock Surface	5.41	mbg
Well Diameter	0.051	m
Borehole Diameter	0.184	m
Static Water Level	4.91	m b/TOC
Screened Formation	Medium Sand	

Baseline Chemistry (May 2010)

Anion Sum	me/L	1.06	Aluminum (Al)	ug/L	22
Bicarb. Alkalinity (as CaCO3)	mg/L	23	Antimony (Sb)	ug/L	<2
Calculated TDS	mg/L	56	Arsenic (As)	ug/L	<2
Carb. Alkalinity (as CaCO3)	mg/L	<10	Barium (Ba)	ug/L	27
Cation Sum	me/L	0.85	Beryllium (Be)	ug/L	<2
Hardness	mg/L	27.2	Bismuth (Bi)	ug/L	<2
Ion Balance (% Difference)	%	10.8	Boron (B)	ug/L	5
Langelier Index (@ 20C)	N/A	-2.18	Cadmium (Cd)	ug/L	0.03
Langelier Index (@ 4C)	N/A	-2.5	Chromium (Cr)	ug/L	<1
Saturation pH (@ 20C)	N/A	9.28	Cobalt (Co)	ug/L	<1
Saturation pH (@ 4C)	N/A	9.6	Copper (Cu)	ug/L	<2
pH		7.1	Iron (Fe)	ug/L	<50
Reactive Silica as SiO2	mg/L	6.3	Lead (Pb)	ug/L	<0.5
Chloride	mg/L	14	Manganese (Mn)	ug/L	49
Fluoride	mg/L	<0.1	Molybdenum (Mo)	ug/L	<2
Sulphate	mg/L	7	Nickel (Ni)	ug/L	<2
Alkalinity	mg/L	23	Selenium (Se)	ug/L	<1
True Color	TCU	<5	Silver (Ag)	ug/L	<0.1
Turbidity	NTU	2300	Strontium (Sr)	ug/L	40
Electrical Conductivity	umho/cm	105	Thallium (Tl)	ug/L	<0.1
Nitrate + Nitrite as N	mg/L	0.82	Tin (Sn)	ug/L	<2
Nitrate as N	mg/L	0.75	Titanium (Ti)	ug/L	<2
Nitrite as N	mg/L	0.07	Uranium (U)	ug/L	<0.1
Ammonia as N	mg/L	0.03	Vanadium (V)	ug/L	<2
Total Organic Carbon	mg/L	2.5	Zinc (Zn)	ug/L	6
Dissolved Organic Carbon	mg/L	1.7	Sodium	mg/L	6.5
Ortho-Phosphate as P	mg/L	<0.01	Potassium	mg/L	0.8
Dissolved Phosporous	mg/L	<0.02	Calcium	mg/L	8.4
Hydroxide	mg/L	<5	Magnesium	mg/L	1.5
Biochemical Oxygen Demand	mg/L	<2			
Total Suspended Solids	mg/L	4370			
Total Kjeldahl Nitrogen as N	mg/L	1.1			
Total Coliforms	MPN/100mL	**690**	->To be rechecked		
Escherichia coli	MPN/100mL	<2			

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Consulting Engineers

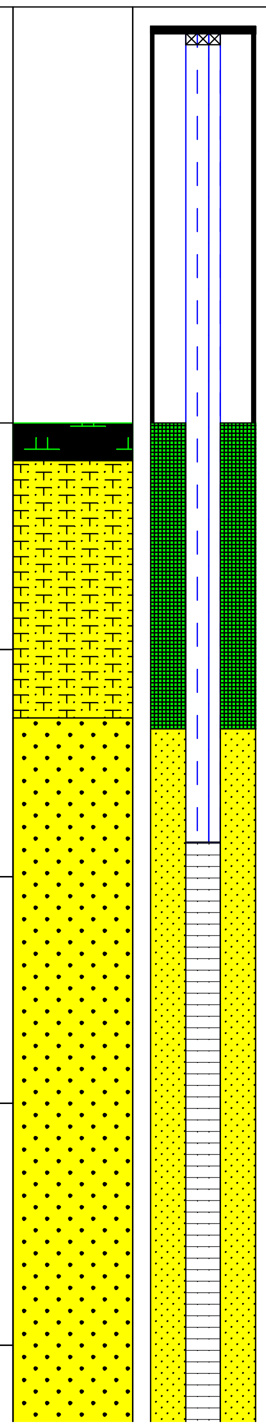
Monitor Well: MW5A

Project Number: 101201.00
Project: Greenwood STP GW Monitoring Program
Location: Greenwood, NS
Contractor: Logan Geotech
Rig Type: CME85
Completion Date: May 4, 2010

Depth (m)	Description	Penetration Resistance N Blows/30cm	Recovery (%)
0	Grass/roots	8	61.7
	Red/brown SILTY SAND with small cobbles throughout; dry, no odour.		
	Brown SILTY SAND with small/medium cobbles throughout; dry, no odour.	8	81.7
	Orange/brown, medium SAND; dry, no odour.		
	Brown (slightly orange) medium SAND, small to medium cobbles throughout; moist, no odour.	23	88.3
		25	83.3
	Brown medium SAND with cobbles throughout; moist, no odour.	45	100

Depth scale: 1, 0, -1, -2

Graphic / **Well Column**

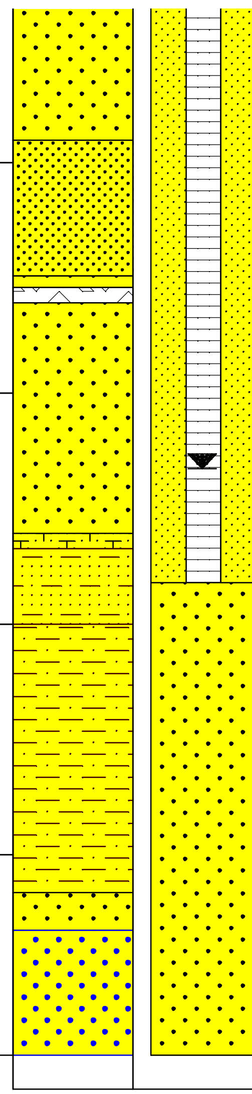


Monitor Well: **MW5A**
Project Number: 101201.00
Project: Greenwood STP GW Monitoring Program
Location: Greenwood, NS
Contractor: Logan Geotech
Rig Type: CME85
Completion Date: May 4, 2010

CBCL LIMITED
Consulting Engineers

Depth (m)	Description	Penetration Resistance N Blows/30cm	Recovery (%)
-3	Brown FINE SAND; moist, no odour.	26	75
	Brown coarse SAND; wet, no odour.		
	Grey CRUSHED ROCK; dry, no odour.		
	Brown coarse SAND; wet, no odour.	27	85
	Light brown to brown, medium to coarse grain SAND, cobbles throughout; wet, no odour.		
-4	Brown SILTY SAND; wet, no odour.		
	Brown SILT and coarse grain SAND; wet, no odour.		
	Red/brown, very compact SILT; wet, no odour.	10	50
		90/533	97.5
-5	Brown, medium to coarse grain SAND; wet, no odour.		
	Weak, red SANDSTONE; refusal @ 5.41m; no odour.		

Graphic / **Well Column**



Static Water Level @ 3.860m

Bottom of Screen @4.16m

End of Hole @ 5.410m

Appendix C

USEPA Standard Operating Procedure for Groundwater Well Sampling

GROUNDWATER WELL SAMPLING

SOP#: 2007
DATE: 01/26/95
REV. #: 0.0

1.0 SCOPE AND APPLICATION

The objective of this standard operating procedure (SOP) is to provide general reference information on sampling of ground water wells. This guideline is primarily concerned with the collection of water samples from the saturated zone of the subsurface. Every effort must be made to ensure that the sample is representative of the particular zone of water being sampled. These procedures are designed to be used in conjunction with analyses for the most common types of ground water contaminants (e.g., volatile and semi-volatile organic compounds, pesticides, metals, biological parameters).

These are standard (i.e., typically applicable) operating procedures which may be varied or changed as required, dependent upon site conditions, equipment limitations or limitations imposed by the procedure. In all instances, the ultimate procedures employed should be documented and associated with the final report.

Mention of trade names or commercial products does not constitute U.S. Environmental Protection Agency (EPA) endorsement or recommendation for use.

2.0 METHOD SUMMARY

In order to obtain a representative groundwater sample for chemical analysis it is important to remove stagnant water in the well casing and the water immediately adjacent to the well before collection of the sample. This may be achieved with one of a number of instruments. The most common of these are the bailer, submersible pump, non-contact gas bladder pump, inertia pump and suction pump. At a minimum, three well volumes should be purged, if possible. Equipment must be decontaminated prior to use and between wells. Once purging is completed and the correct laboratory-cleaned sample containers have been prepared, sampling may proceed. Sampling may be conducted with any of the above instruments, and need not be the same as the device used for purging. Care should be taken when choosing the sampling device as some will affect the integrity of the sample. Sampling should occur in a progression from the least to most contaminated well, if this information is known.

The growing concern over the past several years over low levels of volatile organic compounds in water supplies has led to the development of highly sophisticated analytical methods that can provide detection limits at part per trillion levels. While the laboratory methods are extremely sensitive, well controlled and quality assured, they cannot compensate for a poorly collected sample. The collection of a sample should be as sensitive, highly developed and quality assured as the analytical procedures.

3.0 SAMPLE PRESERVATION, CONTAINERS, HANDLING, AND STORAGE

The type of analysis for which a sample is being collected determines the type of bottle, preservative, holding time, and filtering requirements. Samples should be collected directly from the sampling device into appropriate laboratory cleaned containers. Check that a Teflon liner is present in the cap, if required. Attach a sample identification label. Complete a field data sheet, a chain of custody form, and record all pertinent data in the site logbook.

Samples shall be appropriately preserved, labelled, logged, and placed in a cooler to be maintained at 4EC. Samples must be shipped well before the holding time is up and ideally should be shipped within 24 hours of sample collection. It is imperative that samples be shipped or delivered daily to the analytical laboratory in order to maximize the time available for the laboratory to perform the analyses. The bottles should be shipped with adequate packing and cooling to ensure that they arrive intact.

Sample retrieval systems suitable for the valid collection of volatile organic samples are: positive displacement bladder pumps, gear driven submersible pumps, syringe samplers and bailers (Barcelona, 1984; Nielsen, 1985). Field conditions and other constraints will limit the choice of appropriate systems. The focus of concern must remain to provide a valid sample for analysis, one which has been subjected to the least amount of turbulence possible.

Treatment of the sample with sodium thiosulfate preservative is required only if there is residual chlorine in the water that could cause free radical chlorination and change the identity of the original contaminants. It should not be used if there is no chlorine in the water.

Holding time for volatiles analysis is seven days. It is imperative that the sample be shipped or delivered daily to the analytical laboratory. The bottles must be shipped on their sides to aid in maintaining the airtight seal during shipment, with adequate packing and cooling to ensure that they arrive intact.

For collection of volatile organic samples, refer to the work plan to ensure that 40 mL glass sample vials with Teflon lined septa are ordered and in sufficient numbers. Check sampling supplies; field kit for chlorine, preservatives, Parafilm, foam sleeves and coolers. Due to the extreme trace levels at which volatile organics are detectable, cross contamination and introduction of contaminants must be avoided. Trip blanks are incorporated into the shipment package to provide a check against cross contamination.

4.0 INTERFERENCES AND POTENTIAL PROBLEMS

4.1 General

The primary goal in performing ground water sampling is to obtain a representative sample of the ground water body. Analysis can be compromised by field personnel in two primary ways: (1) taking an unrepresentative sample, or (2) by incorrect handling of the sample. There are numerous ways of introducing foreign contaminants into a sample, and these must be avoided by following strict sampling procedures and utilizing trained field personnel.

4.2 Purging

In a nonpumping well, there will be little or no vertical mixing of the water, and stratification will occur. The well water in the screened section will mix with the ground water due to normal flow patterns, but the well water above the screened section will remain isolated, become stagnant, and may lack the contaminants representative of the ground water. Persons sampling should realize that stagnant water may contain foreign material inadvertently or deliberately introduced from the surface, resulting in an unrepresentative sample. To safeguard against collecting nonrepresentative stagnant water, the following guidelines and techniques should be adhered to during sampling:

1. As a general rule, all monitor wells should be pumped or bailed prior to sampling. Purge water should be containerized on site or handled as specified in the site specific project plan. Evacuation of a minimum of one volume of water in the well casing, and preferably three to five volumes, is recommended for a representative sample. In a high-yielding ground water formation and where there is no stagnant water in the well above the screened section, evacuation prior to sample withdrawal is not as critical. However, in all cases where the monitoring data is to be used for enforcement actions, evacuation is recommended.

2. When purging with a pump (not a bailer), the pump should be set at the screened interval, or if the well is an open-rock well, it should be set at the same depth the sample will be collected. When sampling a screened well, the sample should also be collected from the same depth the pump was set at.

3. The well should be sampled as soon as possible after purging.

4. Analytical parameters typically dictate whether the sample should be collected through the purging device, or through a separate sampling instrument.

5. For wells that can be pumped or bailed to dryness with the equipment being used, the well should be evacuated and allowed to

recover prior to collecting a sample. If the recovery rate is fairly rapid and time allows, evacuation of more than one volume of water is preferred. If recovery is slow, sample the well upon recovery after one evacuation.

6. A non-representative sample can also result from excessive pre-pumping of the monitoring well. Stratification of the leachate concentration in the ground water formation may occur, or heavier-than-water compounds may sink to the lower portions of the aquifer. Excessive pumping can dilute or increase the contaminant concentrations from what is representative of the sampling point of interest.

4.3 Materials

Materials of construction for samplers and evacuation equipment (bladders, pump, bailers, tubing, etc.) should be limited to stainless steel, Teflon[R], and glass in areas where concentrations are expected to be at or near the detection limit. The tendency of organics to leach into and out of many materials make the selection of materials critical for trace analyses. The use of plastics, such as PVC or polyethylene, should be avoided when analyzing for organics. However, PVC may be used for evacuation equipment as it will not come in contact with the sample, and in highly contaminated wells, disposable equipment (i.e., polypropylene bailers) may be appropriate to avoid cross-contamination.

Materials of construction (bladders/ pumps, bailers, tubing, etc.) suitable for collecting and handling Volatile Organic Samples should be limited to stainless steel, Teflon and glass in areas which detection limit range concentrations are expected. The tendency of organics to leach into and out of many materials, make the selection of materials critical for these trace analyses. The use of plastics, e.g., PVC etc., should be avoided. There are numerous ways of introducing foreign contaminants into a sample, and these must be avoided by following strict sampling procedures and utlization of trained personnel.

4.4 Advantages/Disadvantages of Certain Equipment

4.4.1 Bailers

Advantages

- Only practical limitations on size and materials
- No power source needed
- Portable
- Inexpensive, so it can be dedicated and hung in a well, thereby reducing the chances of cross contamination
- Minimal outgassing of volatile organics while sample is in bailer
- Readily available
- Removes stagnant water first
- Rapid, simple method for removing small volumes of purge water

Disadvantages

- Time-consuming to flush a large well of stagnant water
- Transfer of sample may cause aeration
- Stoppers at the bottom of the bailer usually leak thus the bailer must be brought to the surface rapidly
- If the bailer is allowed to hit the bottom of the well boring, gravel can displace the ball valve not allowing the bailer to hold water

4.4.2 Submersible Pumps

Advantages

- Portable and can be transported to several wells
- Depending upon the size of the pump and the pumping depths, relatively high pumping rates are possible
- Generally very reliable and does not require priming

Disadvantages

- Potential for effects on analysis of trace organics
- Heavy and cumbersome to deal with, particularly in deeper wells
- Expensive
- Power source needed
- Sediment in water may cause problems with the pumps
- Impractical in low yielding or shallow wells

4.4.3 Non-Contact Gas Bladder Pumps

Advantages

- Maintains integrity of sample
- Easy to use
- Can sample from discrete locations within the monitor well

Disadvantages

- Difficulty in cleaning, though dedicated tubing and bladder may be used
- Only useful to about 100 feet
- Supply of gas for operation, gas bottles and/or compressors are often difficult to obtain and are cumbersome
- Relatively low pumping rates
- Requires air compressor or pressurized gas source and control box

4.4.4 Suction Pumps

Advantages

- Portable, inexpensive, and readily available

Disadvantages

- Restricted to areas with water levels within 20 to 25 feet of the ground surface
- Vacuum can cause loss of dissolved gasses and volatile organics
- Pump must be primed and vacuum is often difficult to maintain during initial stages of pumping

4.4.5 Inertia Pumps

Advantages

- Portable, inexpensive, and readily available
- Offers a rapid method for purging relatively shallow wells

Disadvantages

- Restricted to areas with water levels within 70 feet of the ground surface
- May be time consuming to purge wells with these manual pumps
- Labor intensive
- WaTerra pumps are only effective in 2-inch diameter wells

5.0 EQUIPMENT APPARATUS

5.1 Equipment Checklist

5.1.1 General

- Water level indicator
  - electric sounder
  - steel tape
  - transducer
  - reflection sounder
  - airline
- Depth sounder
- Appropriate keys for well cap locks
- Steel brush
- HNU or OVA (whichever is most appropriate)
- Logbook
- Calculator
- Field data sheets and samples labels

- Chain of custody records and seals
- Sample containers
- Engineer's rule
- Sharp knife (locking blade)
- Tool box (to include at least: screwdrivers, pliers, hacksaw, hammer, flashlight, adjustable wrench)
- Leather work gloves
- Appropriate Health & Safety gear
- 5-gallon pail
- Plastic sheeting
- Shipping containers
- Packing materials
- Bolt cutters
- Ziploc plastic bags
- Containers for evacuation liquids
- Decontamination solutions
- Tap water
- Non phosphate soap
- Several brushes
- Pails or tubs
- Aluminum foil
- Garden sprayer
- Preservatives
- Distilled or deionized water
- Fire extinguisher (if using a generator for your power source)

5.1.2 Bailers

- Clean, decontaminated bailers of appropriate size and construction material
- Nylon line, enough to dedicate to each well
- Teflon coated bailer wire
- Sharp knife
- Aluminum foil (to wrap clean bailers)
- Five gallon bucket

5.1.3 Submersible Pump

- Pump(s)
- Generator (110, 120, or 240 volt) or 12 volt battery if inaccessible to field vehicle - amp meter is useful
- 1" black PVC coil tubing - enough to dedicate to each well
- Hose clamps
- Safety cable
- Tool box supplement
  - pipe wrenches
  - wire strippers
  - electrical tape
  - heat shrink
  - hose connectors
  - Teflon tape
- Winch, pulley or hoist
- Gasoline for generator/gas can
- Flow meter with gate valve
- 1" nipples and various plumbing (i.e., pipe connectors)
- Control box (if necessary)

5.1.4 Non-Gas Contact Bladder Pump

- Non-gas contact bladder pump
- Compressor or nitrogen gas tank
- Batteries and charger
- Teflon tubing - enough to dedicate to each well
- Swagelock fitting
- Toolbox supplements - same as submersible pump
- Control box (if necessary)

5.1.5 Suction Pump

- Pump
- 1" black PVC coil tubing - enough to dedicate to each well
- Gasoline - if required
- Toolbox
- Plumbing fittings
- Flow meter with gate valve

5.1.6 Inertia Pump

- Pump assembly (WaTerra pump, piston pump)
- Five gallon bucket

6.0 REAGENTS

Reagents may be utilized for preservation of samples and for decontamination of sampling equipment. The preservatives required are specified by the analysis to be performed. Decontamination solutions are specified in ERT SOP #2006, Sampling Equipment Decontamination.

7.0 PROCEDURE

7.1 Preparation

1. Determine the extent of the sampling effort, the sampling methods to be employed, and the types and amounts of equipment and supplies needed (i.e, diameter and depth of wells to be sampled).

2. Obtain necessary sampling and monitoring equipment, appropriate to type of contaminant being investigated. For collection of volatile organic samples, refer to the work plan to ensure that 40 mL glass sample vials with Teflon lined septa are ordered and in sufficient numbers. Check sampling supplies; field kit for chlorine, preservatives, Parafilm, foam sleeves and coolers. Due to extreme trace levels at which volatile organics are detectable, cross contamination and introduction of contaminants must be avoided. Trip blanks are incorporated into the shipment package to provide a check against cross contamination.

3. Decontaminate or preclean equipment, and ensure that it is in working order.

4. Prepare scheduling and coordinate with staff, clients, and regulatory agency, if appropriate.

5. Perform a general site survey prior to site entry in accordance with the site specific Health and Safety Plan.

6. Identify and mark all sampling locations.

7.2 Field Preparation

1. Start at the least contaminated well, if known.

2. Lay plastic sheeting around the well to minimize likelihood of contamination of equipment from soil adjacent to the well.

3. Remove locking well cap, note location, time of day, and date in field notebook or appropriate log form.

4. Remove well casing cap.

5. Screen headspace of well with an appropriate monitoring instrument to determine the presence of volatile organic compounds and record in site logbook.

6. Lower water level measuring device or equivalent (i.e., permanently installed transducers or airline) into well until water surface is encountered.

7. Measure distance from water surface to reference measuring point on well casing or protective barrier post and record in site logbook. Alternatively, if no reference point, note that water level measurement is from top of steel casing, top of PVC riser pipe, from ground surface, or some other position on the well head.

   If floating organics are of concern, this can be determined by measuring the water level with an oil/water interface probe which measures floating organics.

8. Measure total depth of well (at least twice to confirm measurement) and record in site logbook or on field data sheet.

9. Calculate the volume of water in the well and the volume to be purged using the calculations in Section 8.0.

10. Select the appropriate purging and sampling equipment.

11. If residual chlorine is suspected, use the Hach Field Test Kit for chlorine to determine if there is residual chlorine in the water to be sampled. If there is, treat the sample vial with a crystal of sodium thiosulfate prior to sample collection.

7.3 Purging

The amount of flushing a well receives prior to sample collection depends on the intent of the monitoring program as well as the hydrogeologic conditions. Programs where overall quality determination of water resources are involved may require long pumping periods to obtain a sample that is representative of a large volume of that aquifer. The pumped volume can be determined prior to sampling so that the sample is a collected after a known volume of the water is evacuated from the aquifer, or the well can be pumped until the stabilization of parameters such as temperature, electrical conductance, pH, or turbidity has occurred.

However, monitoring for defining a contaminant plume requires a representative sample of a small volume of the aquifer. These circumstances require that the well be pumped enough to remove the stagnant water but not enough to induce flow from other areas. Generally, three well volumes are considered effective, or calculations can be made to determine, on the basis of the aquifer parameters and well dimensions, the appropriate volume to remove prior to sampling.

During purging, water level measurements may be taken regularly at 15-30 second intervals. This data may be used to compute aquifer transmissivity and other hydraulic characteristics. The following well evacuation devices are most commonly used. Other evacuation devices are available, but have been omitted in this discussion due to their limited use.

7.3.1 Bailers

Bailers are the simplest purging device used and have many advantages. They generally consist of a rigid length of tube, usually with a ball check-valve at the bottom. A line is used to lower the bailer into the well and retrieve a volume of water. The three most common types of bailer are PVC, Teflon, and stainless steel.

This manual method of purging is best suited to shallow or narrow diameter wells. For deep, larger diameter wells which require evacuation of large volumes of water, other mechanical devices may be more appropriate.

7.3.1.1 Operation

Equipment needed will include a clean decontaminated bailer, Teflon or nylon line, a sharp knife, and plastic sheeting.

1. Determine the volume of water to be purged as described in 8.0, calculations.

2. Lay plastic sheeting around the well to prevent contamination of the bailer line with foreign materials.

3. Attach the line to the bailer and slowly lower until the bailer is completely submerged, being careful not to drop the bailer to the water, causing turbulence and the possible loss of volatile organic contaminants.

4. Pull bailer out ensuring that the line either falls onto a clean area of plastic sheeting or never touches the ground.

5. Empty the bailer into a pail until full to determine the number of bails necessary to achieve the required purge volume.

6. Thereafter, pour the water into a container and dispose of purge waters as specified in the site specific sampling plan.

7.3.2 Submersible Pumps

The use of submersible pumps for sample collection is permissible provided they are constructed of suitably noncontaminating materials. The chief drawback, however, is the difficulty avoiding cross-contamination between wells. Although some units can be disassembled easily to allow surfaces contacted by contaminants to be cleaned, field decontamination may be difficult and require solvents that can affect sample analysis. The use of submersible pumps in multiple well-sampling programs, therefore, should be carefully considered against other sampling mechanisms (bailers, bladder pumps). In most cases, a sample can be collected by bailer after purging with a submersible pump, however, submersible pumps may be the only practical sampling device for extremely deep wells (greater than 300 feet of water). Under those conditions, dedicated pump systems should be installed to eliminate the potential for cross-contamination of well samples.

Submersible pumps generally use one of two types of power supplies, either electric or compressed gas or air. Electric powered pumps can run off a 12 volt DC rechargeable battery, or a 110 or 220 volt AC power supply. Those units powered by compressed air normally use a small electric or gas-powered air compressor. They may also utilize compressed gas (i.e., nitrogen) from bottles. Different size pumps are available for different depth or diameter monitoring wells.

7.3.2.1 Operation

1. Determine the volume of water to be purged as described in 8.0 Calculations.

2. Lay plastic sheeting around the well to prevent contamination of pumps, hoses or lines with foreign materials.

3. Assemble pump, hoses and safety cable, and lower the pump into the well. Make sure the pump is deep enough so all the water is not evacuated. (Running the pump without water may cause damage.)

4. Attach flow meter to the outlet hose to measure the volume of water purged.

5. Use a ground fault circuit interrupter (GFCI) or ground the generator to avoid possible electric shock.

6. Attach power supply, and purge the well until the specified volume of water has been evacuated (or until field parameters, such as temperature, pH, conductivity, etc, have stabilized). Do not allow the pump to run dry. If the pumping rate exceeds the well recharge rate, lower the pump further into the well, and continue pumping.

7. Collect and dispose of purge waters as specified in the site specific sampling plan.

7.3.3 Non-Contact Gas Bladder Pumps

For this procedure, an all stainless-steel and Teflon Middleburg-squeeze bladder pump (e.g., IEA, TIMCO, Well Wizard, Geoguard, and others) is used to provide the least amount of material interference to the sample (Barcelona, 1985). Water comes into contact with the inside of the bladder (Teflon) and the sample tubing, also Teflon, that may be dedicated to each well. Some wells may have permanently installed bladder pumps, (i.e., Well Wizard, Geoguard), that will be used to sample for all parameters.

7.3.3.1 Operation

1. Assemble Teflon tubing, pump and charged control box.

2. Procedure for purging with a bladder pump is the same as for a submersible pump (Section 7.3.2.1).

3. Be sure to adjust flow rate to prevent violent jolting of the hose as sample is drawn in.

7.3.4 Suction Pumps

There are many different types of suction pumps. They include: centrifugal, peristaltic and diaphragm. Diaphragm pumps can be used for well evacuation at a fast pumping rate and sampling at a low pumping rate. The peristaltic pump is a low volume pump that uses rollers to squeeze the flexible tubing thereby creating suction. This tubing can be dedicated to a well to prevent cross contamination. Peristaltic pumps, however, require a power source.

7.3.4.1 Operation

1. Assembly of the pump, tubing, and power source if necessary.

2. Procedure for purging with a suction pump is exactly the same as for a submersible pump (Section 7.3.2.1).

7.3.5 Inertia Pumps

Inertia pumps such as the WaTerra pump and piston pump, are manually operated. They are most appropriate to use when wells are too deep to bail by hand, or too shallow or narrow (or inaccessible) to warrant an automatic (submersible, etc.) pump. These pumps are made of plastic and may be either decontaminated or discarded.

7.3.5.1 Operation

1. Determine the volume of water to be purged as described in 8.0, Calculations.

2. Lay plastic sheeting around the well to prevent contamination of pumps or hoses with foreign materials.

3. Assemble pump and lower to the appropriate depth in the well.

4. Begin pumping manually, discharging water into a 5 gallon bucket (or other graduated vessel). Purge until specified volume of water has been evacuated (or until field parameters such as temperature, pH,

conductivity, etc. have stabilized).

5. Collect and dispose of purge waters as specified in the site specific project plan.

7.4 Sampling

Sample withdrawal methods require the use of pumps, compressed air, bailers, and samplers. Ideally, purging and sample withdrawal equipment should be completely inert, economical to manufacture, easily cleaned, sterilized, reusable, able to operate at remote sites in the absence of power resources, and capable of delivering variable rates for sample collection.

There are several factors to take into consideration when choosing a sampling device. Care should be taken when reviewing the advantages or disadvantages of any one device. It may be appropriate to use a different device to sample than that which was used to purge. The most common example of this is the use of a submersible pump to purge and a bailer to sample.

7.4.1 Bailers

The positive-displacement volatile sampling bailer is perhaps the most appropriate for collection of water samples for volatile analysis. Other bailer types (messenger, bottom fill, etc.) are less desirable, but may be mandated by cost and site conditions.

7.4.1.1 Operation

1. Surround the monitor well with clean plastic sheeting. If using the GPI bailer, insert a vial into the claim and assemble the unit.

2. Attach a line to a clean decontaminated bailer.
3. Lower the bailer slowly and gently into the well, taking care not to shake the casing sides or to splash the bailer into the water. Stop lowering at a point adjacent to the screen.

4. Allow bailer to fill and then slowly and gently retrieve the bailer from the well avoiding contact with the casing, so as not to knock flakes of rust or other foreign materials into the bailer. If using the GPI bailer for collecting volatile organic samples, once at the surface, remove the bailer from the cable. Carefully open the GPI bailer unit and remove the vial. Begin slowly pouring from the bailer, and collect the duplicate samples from the midstream sample.

5. Remove the cap from the sample container and place it on the plastic sheet or in a location where it won't become contaminated. See Section 7.7 for special considerations on VOA samples.

6. Begin slowly pouring from the bailer.

7. Filter and preserve samples as required by sampling plan.

8. Cap the sample container tightly and place prelabeled sample container in a carrier.

9. Replace the well cap.

10. Log all samples in the site logbook and on field data sheets and label all samples.

11. Package samples and complete necessary paperwork.

12. Transport sample to decontamination zone for preparation for transport to analytical laboratory.

7.4.2 Submersible Pumps

Although it is recommended that samples not be collected with a submersible pump due to the reasons stated in Section 4.4.2, there are some situations where they may be used.

7.4.2.1 Operation

1. Allow the monitor well to recharge after purging, keeping the pump just above screened section.

2. Attach gate valve to hose (if not already fitted), and reduce flow of water to a manageable sampling rate.

3. Assemble the appropriate bottles.

4. If no gate valve is available, run the water

down the side of a clean jar and fill the sample bottles from the jar.

5. Cap the sample container tightly and place prelabeled sample container in a carrier.

6. Replace the well cap.

7. Log all samples in the site logbook and on the field data sheets and label all samples.

8. Package samples and complete necessary paperwork.

9. Transport sample to decontamination zone for preparation for transport to the analytical laboratory.

10. Upon completion, remove pump and assembly and fully decontaminate prior to setting into the next sample well. Dedicate the tubing to the hole.

7.4.3 Non-Contact Gas Bladder Pumps

The use of a non-contact gas positive displacement bladder pump is often mandated by the use of dedicated pumps installed in wells. These pumps are also suitable for shallow (less than 100 feet) wells. They are somewhat difficult to clean, but may be used with dedicated sample tubing to avoid cleaning. These pumps require a power supply and a compressed gas supply (or compressor). They may be operated at variable flow and pressure rates making them ideal for both purging and sampling.

Barcelona (1984) and Nielsen (1985) report that the non-contact gas positive displacement pumps cause the least amount of alteration in sample integrity as compared to other sample retrieval methods.

7.4.3.1 Operation

1. Allow well to recharge after purging.

2. Assemble the appropriate bottles.

3. Turn pump on, increase the cycle time and reduce the pressure to the minimum that will allow the sample to come to the surface.

4. Cap the sample container tightly and place prelabeled sample container in a carrier.

5. Replace the well cap.

6. Log all samples in the site logbook and on field data sheets and label all samples.

7. Package samples and complete necessary paperwork.

8. Transport sample to decontamination zone for preparation for transport to analytical laboratory.

9. On completion, remove the tubing from the well and either replace the Teflon tubing and bladder with new dedicated tubing and bladder or rigorously decontaminate the existing materials.

10. Nonfiltered samples shall be collected directly from the outlet tubing into the sample bottle.

11. For filtered samples, connect the pump outlet tubing directly to the filter unit. The pump pressure should remain decreased so that the pressure build up on the filter does not blow out the pump bladder or displace the filter. For the Geotech barrel filter, no actual connections are necessary so this is not a concern.

7.4.4 Suction Pumps

In view of the limitations of these type pumps, they are not recommended for sampling purposes.

7.4.5 Inertia Pumps

Inertia pumps may be used to collect samples. It is more common, however, to purge with these pumps and sample with a bailer (Section 7.4.1).

7.4.5.1 Operation

1. Following well evacuation, allow the well to recharge.

2. Assemble the appropriate bottles.

3. Since these pumps are manually operated,

the flow rate may be regulated by the sampler. The sample may be discharged from the pump outlet directly into the appropriate sample container.

4. Cap the sample container tightly and place prelabeled sample container in a carrier.

5. Replace the well cap.

6. Log all samples in the site logbook and on field data sheets and label all samples.

7. Package samples and complete necessary paperwork.

8. Transport sample to decontamination zone for preparation for transport to the analytical laboratory.

9. Upon completion, remove pump and decontaminate or discard, as appropriate.

7.4.6. Sample Retrieval - Syringe

A limited number of commercial syringe type samplers are available, (IEA, TIMCO, etc.) some are homemade devices. These devices are claimed to provide good quality samples for volatile analysis, but are severely limited in sample volume and are specific to sampling for volatiles. Essentially, they operated with an evacuated chamber that is lowered down the well, and allowed to fill with the pressure of the water. The entire mechanism is then brought to the surface with the sample. The sample may then be transferred to a sample vial, or the entire unit may be sent as the sample container.

1. Evacuate the syringe if necessary, and lower the sampling device to just below the well screen.

2. Remove the constriction from the device and allow the sample to fill the syringe, apply slight suction as necessary.

3. Bring unit to the surface. If necessary, transfer the sample to vials, as outlined in steps 2 through 7 above.

7.5 Filtering

For samples requiring filtering, such as total metals analysis, the filter must be decontaminated prior to and between uses. Filters work by two methods. A barrel filter such as the "Geotech" filter works with a bicycle pump, used to build up positive pressure in the chamber containing the sample which is then forced through the filter paper (minimum size 0.45 µm) into a jar placed underneath. The barrel itself is filled manually from the bailer or directly via the hose of the sampling pump. The pressure must be maintained up to 30 lbs/in^2 by periodic pumping.

A vacuum type filter involves two chambers; the upper chamber contains the sample and a filter (minimum size 0.45 µm) divides the chambers. Using a hand pump or a Gilian type pump, air is withdrawn from the lower chamber, creating a vacuum and thus causing the sample to move through the filter into the lower chamber where it is drained into a sample jar. Repeated pumping may be required to drain all the sample into the lower chamber. If preservation of the sample is necessary, this should be done after filtering.

7.6 Post Operation

After all samples are collected and preserved, the sampling equipment should be decontaminated prior to sampling another well to prevent cross-contamination of equipment and monitor wells between locations.

1. Decontaminate all equipment.

2. Replace sampling equipment in storage containers.

3. Prepare and transport ground water samples to the laboratory. Check sample documentation and make sure samples are properly packed for shipment.

7.7 Special Considerations for VOA Sampling

The proper collection of a sample for volatile organics requires minimal disturbance of the sample to limit volatilization and therefore a loss of volatiles from the sample.

Sample retrieval systems suitable for the valid collection of volatile organic samples are: positive displacement bladder pumps, gear driven submersible pumps, syringe samplers and bailers (Barcelona, 1984; Nielsen, 1985). Field conditions and other constraints will limit the choice of appropriate systems. The focus of concern must be to provide a valid sample for analysis, one which has been subjected to the least amount of turbulence possible.

The following procedures should be followed:

1. Open the vial, set cap in a clean place, and collect the sample during the middle of the cycle. When collecting duplicates, collect both samples at the same time.

2. Fill the vial to just overflowing. Do not rinse the vial, nor excessively overflow it. There should be a convex meniscus on the top of the vial.

3. Check that the cap has not been contaminated (splashed) and carefully cap the vial. Place the cap directly over the top and screw down firmly. Do not overtighten and break the cap.

4. Invert the vial and tap gently. Observe vial for at least ten (10) seconds. If an air bubble appears, discard the sample and begin again. It is imperative that no entrapped air is in the sample vial.

5. Immediately place the vial in the protective foam sleeve and place into the cooler, oriented so that it is lying on its side, not straight up.

6. The holding time for VOAs is seven days. Samples should be shipped or delivered to the laboratory daily so as not to exceed the holding time. Ensure that the samples remain at 4EC, but do not allow them to freeze.

8.0 CALCULATIONS

If it is necessary to calculate the volume of the well, utilize the following equation:

$$\textbf{\textit{Well volume}} = \boldsymbol{n r^2 h\ (cf)} \qquad [\textit{Equation } 1]$$

where:

n	=	pi
r	=	radius of monitoring well (feet)
h	=	height of the water column (feet) [This may be determined by subtracting the depth to water from the total depth of the well as measured from the same reference point.]
cf	=	conversion factor (gal/ft^3) = 7.48 gal/ft^3 [In this equation, 7.48 gal/ft^3 is the necessary conversion factor.]

Monitor well diameters are typically 2", 3", 4", or 6". Knowing the diameter of the monitor well, there are a number of standard conversion factors which can be used to simplify the equation above.

The volume, in gallons per linear foot, for various standard monitor well diameters can be calculated as follows:

$$\boldsymbol{v(gal/ft) = n r^2\ (cf)} \qquad [\textit{Equation } 2]$$

where:

n	=	pi
r	=	radius of monitoring well (feet)
cf	=	conversion factor (7.48 gal/ft^3)

For a 2" diameter well, the volume per linear foot can be calculated as follows:

$$\begin{aligned} \boldsymbol{vol/linear\ ft} &= \boldsymbol{n r^2\ (cf)} \qquad [\textit{Equation } 2] \\ &= \mathbf{3.14\ (1/12}\ \boldsymbol{ft})^2\ \ \mathbf{7.48}\ \boldsymbol{gal/ft^3} \\ &= \mathbf{0.1632}\ \boldsymbol{gal/ft} \end{aligned}$$

Remember that if you have a 2" diameter well, you must convert this to the radius in feet to be able to use the equation.

The conversion factors for the common size monitor wells are as follows:

Well diameter	2"	3"	4"	6"
Volume (gal/ft.)	0.1632	0.3672	0.6528	1.4688

If you utilize the conversion factors above, Equation

1 should be modified as follows:

$$\textbf{\textit{Well volume}} = (\textbf{\textit{h}})(\textbf{\textit{cf}}) \qquad [\textit{Equation } 3]$$

where:

h	=	height of water column (feet)
cf	=	the conversion factor calculated from Equation 2

The well volume is typically tripled to determine the volume to be purged.

9.0 QUALITY ASSURANCE/ QUALITY CONTROL

There are no specific quality assurance (QA) activities which apply to the implementation of these procedures. However, the following general QA procedures apply:

1. All data must be documented on field data sheets or within site logbooks.

2. All instrumentation must be operated in accordance with operating instructions as supplied by the manufacturer, unless otherwise specified in the work plan. Equipment checkout and calibration activities must occur prior to sampling/operation and they must be documented.

3. The collection of rinsate blanks is recommended to evaluate potential for cross contamination from the purging and/or sampling equipment.

4. Trip blanks are required if analytical parameters include VOAs.

10.0 DATA VALIDATION

This section is not applicable to this SOP.

11.0 HEALTH AND SAFETY

When working with potentially hazardous materials, follow U.S. EPA, OSHA or REAC health and safety guidelines. More specifically, depending upon the site specific contaminants, various protective programs must be implemented prior to sampling the first well. The site health and safety plan should be reviewed with specific emphasis placed on the protection program planned for the well sampling tasks. Standard safe operating practices should be followed such as minimizing contact with potential contaminants in both the vapor phase and liquid matrix through the use of respirators and disposable clothing.

When working around volatile organic contaminants:

1. Avoid breathing constituents venting from the well.

2. Pre-survey the well head-space with an FID/PID prior to sampling.

3. If monitoring results indicate organic constituents, sampling activities may be conducted in Level C protection. At a minimum, skin protection will be afforded by disposable protective clothing.

Physical hazards associated with well sampling:

1. Lifting injuries associated with pump and bailers retrieval; moving equipment.

2. Use of pocket knives for cutting discharge hose.

3. Heat/cold stress as a result of exposure to extreme temperatures and protective clothing.

4. Slip, trip, fall conditions as a result of pump discharge.

5. Restricted mobility due to the wearing of protective clothing.

6. Electrical shock associated with use of submersible pumps is possible. Use a GFCI or a copper grounding stake to avoid this problem.

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Appendix D

CCME Guidelines for Canadian Drinking Water Quality

Summary of Guidelines for Canadian Drinking Water Quality

Prepared by the
Federal–Provincial–Territorial Committee on Drinking Water
of the
Federal–Provincial–Territorial Committee
on Health and the Environment

April 2004

The *Guidelines for Canadian Drinking Water Quality* are published by Health Canada. In order to keep interested parties informed of changes to the Guidelines between publication of new editions, this summary table is updated and published every spring on Health Canada's website (www.hc-sc.gc.ca/waterquality). The April 2004 "Summary of Guidelines for Canadian Drinking Water Quality" supercedes all previous versions, including that contained in the published booklet.

Membership of the Federal–Provincial–Territorial Committee on Drinking Water and Secretariat

Provincial and Territorial Representatives

Alberta	Department of Environment	Mr. Karu Chinniah
British Columbia	Ministry of Health Services	Mr. Barry Boettger
Manitoba	Department of Water Stewardship	Mr. Don Rocan
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Committee Secretary

Health Canada (Water Quality and Health Bureau, Safe Environments Programme, Healthy Environments and Consumer Safety Branch) — Mr. David Green

New, Revised and Reaffirmed Guidelines

New, revised and reaffirmed guidelines for chemical, physical and microbiological parameters are presented in Table 1.

Table 1
New, Revised and Reaffirmed Guidelines* for Chemical, Physical and Microbiological Parameters since the Publication of the Sixth Edition of the *Guidelines for Canadian Drinking Water Quality*

Parameter	Guideline (mg/L)	Previous guideline (mg/L)	Year approved
Chemical and Physical Parameters			
Aluminum	0.1**	None	1998
Antimony	IMAC 0.006	None	1997
Bromate	IMAC 0.01	None	1998
Cyanobacterial toxins (as Microcystin-LR)	0.0015	None	2002
Fluoride	MAC 1.5	MAC 1.5	1996
Formaldehyde	None required – see Table 3	None	1997
Uranium	IMAC 0.02	MAC 0.1	1999
Microbiological Parameters			
Bacteria	***		Ongoing
Protozoa	***		Ongoing
Viruses	***		Ongoing

* MAC = maximum acceptable concentration; IMAC = interim maximum acceptable concentration.
** Refer to note 1 in Table 2.
*** Refer to section on Summary of Guidelines for Microbiological Parameters.

Table 2
Consultation Guidelines

Parameter	Proposed Guideline* (mg/L)		Consultation Concludes
	MAC	AO	
Arsenic	0.005		Fall/Winter 2004
Bacteriological (4 documents)			Jan. 13, 2005
Bromodichloromethane (BDCM)**	0.016		Jan. 7, 2005
Chloral hydrate	NGP		Fall/Winter 2004
Chlorite Chlorate	1.0 1.0		Fall/Winter 2004
Methyl *tertiary*-butyl ether (MTBE)		0.015	Fall/Winter 2004
Haloacetic Acids (HAAs)			TBD
Trihalomethanes (THMs)	0.1		Jan. 7, 2005
Trichloroethylene (TCE)	0.005		April 5, 2004

* MAC = Maximum Acceptable Concentration;
AO = Aesthetic Objective;
NGP = No Guideline Proposed.
** Refer to Trihalomethane document.

Summary of Guidelines for Microbiological Parameters

Bacteria (Under Review)

The maximum acceptable concentration (MAC) for bacteriological quality of public, semi-public, and private drinking water systems is no coliforms detectable per 100 mL. However, because coliforms are not uniformly distributed in water and are subject to considerable variation in public health significance, drinking water that fulfills the following conditions is considered to conform to this MAC:

Public Drinking Water Supply Systems

1. No sample should contain *Escherichia coli*. *E. coli* indicates recent faecal contamination and the possible presence of enteric pathogens that may adversly affect human health. If *E. coli* is confirmed, the appropriate agencies should be notified, a boil water advisory should be issued, and corrective actions taken.

2. No consecutive samples from the same site or not more than 10% of samples from the distribution system in a given calendar month should show the presence of total coliform bacteria. The ability of total coliforms to indicate the presence of faecal pollution is less reliable than *E. coli*. However, this group of bacteria is a good indicator of quality control. The presence of total coliforms does not necessarily require the issuance of a boil water advisory but corrective actions should be taken.

Semi-public and Private Drinking Water Supply Systems

1. No sample should contain *E. coli*. As stated above, the presence of *E. coli* indicates faecal contamination and the possible presence of enteric pathogens; therefore the water is unsafe to drink. If *E. coli* is detected, a boil water advisory should be issued and corrective actions taken.

2. No sample should contain total coliform bacteria. In non-disinfected well water, the presence of total coliform bacteria in the absence of *E. coli* indicates the well is prone to surface water infiltration and therefore at risk of faecal contamination. In disinfected water systems, the presence of total coliform bacteria indicates a failure in the disinfection process. In both disinfected and non-disinfected systems, total coliform detection may also indicate the presence of biofilm in the well or plumbing system. The degree of response to the presence of total coliform bacteria, in the absence of *E. coli*, may be site specific and can vary between jurisdictions.

Protozoa (Under Review)

Numerical guidelines for the protozoa *Giardia* and *Cryptosporidium* are not proposed at this time. Routine methods available for the detection of protozoan cysts and oocysts suffer from low recovery rates and do not provide any information on their viability or human infectivity. Nevertheless, until better monitoring data and information on the viability and infectivity of cysts and oocysts present in drinking water are available, measures to reduce the risk of illness as much as possible should be implemented. If viable, human-infectious cysts or oocysts are present or suspected to be present in source waters or if *Giardia* or *Cryptosporidium* has been responsible for past waterborne outbreaks in a community, a treatment regime and a watershed or wellhead protection plan (where feasible) or other measures known to reduce the risk of illness should be implemented.

Viruses (Under Review)

Numerical guidelines for human enteric viruses are not proposed at this time. There are more than 120 types of human enteric viruses, many of which are non-culturable. Testing is complicated, expensive, not available for all viruses, and beyond the capabilities of most laboratories involved in routine water quality monitoring. The best means of safeguarding against the presence of human enteric viruses are based upon the application of adequate treatment and the absence of faecal indicator organisms, such as *Escherichia coli*.

Boil Water Advisories

General guidance on the issuing and rescinding of boil water advisories is provided. In the event of an advisory, a rolling boil for 1 minute is considered adequate.

Summary of Guidelines for Chemical and Physical Parameters

Parameters with Guidelines

Guidelines for all chemical and physical parameters, including all new, revised and reaffirmed maximum acceptable concentrations (MACs), interim maximum acceptable concentrations (IMACs) and aesthetic objectives (AOs), are listed in Table 3. For more information on the drinking water guideline for any particular compound, please refer to the Supporting Documentation for the parameter of concern.

Table 3
Summary of Guidelines for Chemical and Physical Parameters

Parameter	Maximum Acceptable Concentration (mg/L)	Aesthetic Objectives (mg/L)	Reason/ Comment
aldicarb	0.009		
aldrin + dieldrin	0.0007		
aluminum [1]			
antimony	0.006 [2]		
arsenic	0.025		
atrazine + metabolites	0.005		
azinphos-methyl	0.02		
barium	1.0		
bendiocarb	0.04		
benzene	0.005		
benzo[a]pyrene	0.00001		
boron	5		
bromate	0.01		
bromoxynil	0.005		
cadmium	0.005		
carbaryl	0.09		
carbofuran	0.09		
carbon tetrachloride	0.005		
chloramines (total)	3.0		
chloride		≤250	
chlorpyrifos	0.09		
chromium	0.05		
colour		≤15 TCU [4]	
copper [2]		≤1.0	
cyanazine	0.01		
cyanide	0.2		
cyanobacterial toxins (as microcystin-LR) [3]	0.0015		
diazinon	0.02		
dicamba	0.12		
dichlorobenzene, 1,2- [5]	0.20	≤0.003	
dichlorobenzene, 1,4- [5]	0.005	≤0.001	
dichloroethane, 1,2-	0.005		
dichloroethylene, 1,1-	0.014		
dichloromethane	0.05		
dichlorophenol, 2,4-	0.9	≤0.0003	
dichlorophenoxyacetic acid, 2,4- (2,4-D)	0.1		
diclofop-methyl	0.009		
dimethoate	0.02		
dinoseb	0.01		
diquat	0.07		
diuron	0.15		
ethylbenzene		≤0.0024	

Parameter	**Maximum Acceptable Concentration (mg/L)**	**Aesthetic Objectives (mg/L)**	**Reason/ Comment**
fluoride [6]	1.5		
glyphosate	0.28		
iron		≤0.3	
lead [2]	0.010		
malathion	0.19		
manganese		≤0.05	
mercury	0.001		
methoxychlor	0.9		
metolachlor	0.05		
metribuzin	0.08		
monochlorobenzene	0.08	≤0.03	
nitrate [7]	45		
nitrilotriacetic acid (NTA)	0.4		
odour		Inoffensive	
paraquat (as dichloride)	0.01 [8]		
parathion	0.05		
pentachlorophenol	0.06	≤0.030	
pH		6.5–8.5 [9]	
phorate	0.002		
picloram	0.19		
selenium	0.01		
simazine	0.01		
sodium [10]		≤200	
sulphate [11]		≤500	
sulphide (as H_2S)		≤0.05	
taste		Inoffensive	
temperature		≤15°C	
terbufos	0.001		
tetrachloroethylene	0.03		
tetrachlorophenol, 2,3,4,6-	0.1	≤0.001	
toluene		≤0.024	
total dissolved solids (TDS)		≤500	
trichloroethylene	0.05		
trichlorophenol, 2,4,6-	0.005	≤0.002	
trifluralin	0.045		
trihalomethanes (total) [12]	0.1		
turbidity	1 NTU [13]	≤5 NTU [13,14]	
uranium	0.02		
vinyl chloride	0.002		
xylenes (total)		≤0.3	
zinc [2]		≤5.0	

Notes:

1. A health-based guideline for aluminum in drinking water has not been established. However, water treatment plants using aluminum-based coagulants should optimize their operations to reduce residual aluminum levels in treated water to the lowest extent possible as a precautionary measure. *Operational guidance values* of less than 100 µg/L total aluminum for conventional treatment plants and less than 200 µg/L total aluminum for other types of treatment systems are recommended. Any attempt to minimize aluminum residuals must not compromise the effectiveness of disinfection processes or interfere with the removal of disinfection by-product precursors.
2. Because first-drawn water may contain higher concentrations of metals than are found in running water after flushing, faucets should be thoroughly flushed before water is taken for consumption or analysis.
3. The guideline is considered protective of human health against exposure to other microcystins (total microcystins) that may also be present.
4. TCU = true colour unit.
5. In cases where total dichlorobenzenes are measured and concentrations exceed the most stringent value (0.005 mg/L), the concentrations of the individual isomers should be established.
6. It is recommended, however, that the concentration of fluoride be adjusted to 0.8–1.0 mg/L, which is the optimum range for the control of dental caries.
7. Equivalent to 10 mg/L as nitrate–nitrogen. Where nitrate and nitrite are determined separately, levels of nitrite should not exceed 3.2 mg/L.
8. Equivalent to 0.007 mg/L for paraquat ion.
9. No units.
10. It is recommended that sodium be included in routine monitoring programmes, as levels may be of interest to authorities who wish to prescribe sodium-restricted diets for their patients.
11. There may be a laxative effect in some individuals when sulphate levels exceed 500 mg/L.
12. The IMAC for trihalomethanes is expressed as a running annual average. It is based on the risk associated with chloroform, the trihalomethane most often present and in greatest concentration in drinking water. The guideline is designated as interim until such time as the risks from other disinfection by-products are ascertained. The preferred method of controlling disinfection by-products is precursor removal; however, any method of control employed must not compromise the effectiveness of water disinfection.
13. NTU = nephelometric turbidity unit.
14. At the point of consumption.

Parameters without Guidelines

Since 1978, some chemical and physical parameters have been identified as not requiring a numerical guideline. Table 4 lists these parameters.

The reasons for parameters having no numerical guideline include the following:

- currently available data indicate no health risk or aesthetic problem (e.g., calcium);
- data indicate the compound, which may be harmful, is not registered for use in Canada (e.g., 2,4,5-TP) or is not likely to occur in drinking water at levels that present a health risk (e.g., silver); or
- the parameter is composed of several compounds for which individual guidelines may be required (e.g., pesticides [total]).

Table 4
Summary List of Parameters without Guidelines

Parameter	Parameter
ammonia	mirex
asbestos	phenols
calcium	phthalic acid esters (PAE)
chlordane (total isomers)	polycyclic aromatic hydrocarbons (PAH) [2]
dichlorodiphenyltrichloroethane (DDT) + metabolites	radon
endrin	resin acids
formaldehyde	silver
gasoline	tannin
hardness [1]	temephos
heptachlor + heptachlor epoxide	total organic carbon
lignin	toxaphene
lindane	triallate
magnesium	trichlorophenoxyacetic acid, 2,4,5- (2,4,5-T)
methyl-parathion	trichlorophenoxypropionic acid, 2,4,5- (2,4,5-TP)

Notes:

1. Public acceptance of hardness varies considerably. Generally, hardness levels between 80 and 100 mg/L (as $CaCO_3$) are considered acceptable; levels greater than 200 mg/L are considered poor but can be tolerated; those in excess of 500 mg/L are normally considered unacceptable. Where water is softened by sodium ion exchange, it is recommended that a separate, unsoftened supply be retained for culinary and drinking purposes.
2. Other than benzo[a]pyrene.

Summary of Guidelines for Radiological Parameters

In setting dose guidelines for radionuclides in drinking water, it is recognized that water consumption contributes only a portion of the total radiation dose and that some radionuclides present are natural in origin and therefore cannot be excluded. Consequently, maximum acceptable concentrations (MACs) for radionuclides in drinking water have been derived based on a committed effective dose of 0.1 mSv* from one year's consumption of drinking water. This dose represents less than 5% of the average annual dose attributable to natural background radiation.

To facilitate the monitoring of radionuclides in drinking water, the reference level of dose is expressed as an activity concentration, which can be derived for each radionuclide from published radiological data. The National Radiological Protection Board has calculated dose conversion factors (DCFs) for radionuclides based on metabolic and dosimetric models for adults and children. Each DCF provides an estimate of the 50-year committed effective dose resulting from a single intake of 1 Bq** of a given radionuclide.

The MACs of radionuclides in public water supplies are derived from adult DCFs, assuming a daily water intake of 2 L, or 730 L/year, and a maximum committed effective dose of 0.1 mSv, or 10% of the International Commission on Radiological Protection limit on public exposure:

$$\text{MAC (Bq/L)} = \frac{1 \times 10^{-4}\ \text{(Sv/year)}}{730\ \text{(L/year)} \times \text{DCF (Sv/Bq)}}$$

* Sievert (Sv) is the unit of radiation dose. It replaces the old unit, rem (1 rem = 0.01 Sv).
** Becquerel (Bq) is the unit of activity of a radioactive substance, or the rate at which transformations occur in the substance. One becquerel is equal to one transformation per second and is approximately equal to 27 picocuries (pCi).

When two or more radionuclides are found in drinking water, the following relationship should be satisfied:

$$\frac{C_1}{MAC_1} + \frac{c_2}{MAC_2} + \ldots \frac{c_i}{MAC_i} \leq 1$$

where c_i and MAC_i are the observed and maximum acceptable concentrations, respectively, for each contributing radionuclide.

MACs for radionuclides that should be monitored in water samples are listed in Table 5. If a sample is analysed by gamma-spectroscopy, additional screening for radionuclides that may be present under certain conditions can be performed. MACs for these radionuclides are given in Table 6. MACs for a number of additional radionuclides, both natural and artificial, can be found in the sixth edition of the guidelines booklet.

Water samples may be initially screened for radioactivity using techniques for gross alpha and gross beta activity determinations. Compliance with the guidelines may be inferred if the measurements for gross alpha and gross beta activity are less than 0.1 Bq/L and 1 Bq/L, respectively, as these are lower than the strictest MACs. Sampling and analyses should be carried out often enough to accurately characterize the annual exposure. If the source of the activity is known, or expected, to be changing rapidly with time, then the sampling frequency should reflect this factor. If there is no reason to suppose that the source varies with time, then the sampling may be done annually. If measured concentrations are consistent and well below the reference levels, this would be an argument for reducing the sampling frequency. On the other hand, the sampling frequency should be maintained, or even increased, if concentrations are approaching the reference levels. In such a case, the specific radionuclides should be identified and individual activity concentrations measured.

Table 5
Primary List of Radionuclides – Maximum Acceptable Concentrations

Radionuclide		Half-life $t_{1/2}$	DCF (Sv/Bq)	MAC (Bq/L)
Natural Radionuclides				
Lead-210	^{210}Pb	22.3 years	1.3×10^{-6}	0.1
Radium-224	^{224}Ra	3.66 days	8.0×10^{-8}	2
Radium-226	^{226}Ra	1600 years	2.2×10^{-7}	0.6
Radium-228	^{228}Ra	5.76 years	2.7×10^{-7}	0.5
Thorium-228	^{228}Th	1.91 years	6.7×10^{-8}	2
Thorium-230	^{230}Th	7.54×10^{4} years	3.5×10^{-7}	0.4
Thorium-232	^{232}Th	1.40×10^{10} years	1.8×10^{-6}	0.1
Thorium-234	^{234}Th	24.1 days	5.7×10^{-9}	20
Uranium-234	^{234}U	2.45×10^{5} years	3.9×10^{-8}	4*
Uranium-235	^{235}U	7.04×10^{8} years	3.8×10^{-8}	4*
Uranium-238	^{238}U	4.47×10^{9} years	3.6×10^{-8}	4*
Artificial Radionuclides				
Cesium-134	^{134}Cs	2.07 years	1.9×10^{-8}	7
Cesium-137	^{137}Cs	30.2 years	1.3×10^{-8}	10
Iodine-125	^{125}I	59.9 days	1.5×10^{-8}	10
Iodine-131	^{131}I	8.04 days	2.2×10^{-8}	6
Molybdenum-99	^{99}Mo	65.9 hours	1.9×10^{-9}	70
Strontium-90	^{90}Sr	29 years	2.8×10^{-8}	5
Tritium**	^{3}H	12.3 years	1.8×10^{-11}	7000

* The activity concentration of natural uranium corresponding to the chemical guideline of 0.02 mg/L is about 0.5 Bq/L.
** Tritium is also produced naturally in the atmosphere in significant quantities.

Table 6
Secondary List of Radionuclides – Maximum Acceptable Concentrations (MACs)

Radionuclide		Half-life $t_{1/2}$	DCF (Sv/Bq)	MAC (Bq/L)
Natural Radionuclides				
Beryllium-7	^{7}Be	53.3 days	3.3×10^{-11}	4000
Bismurh-210	^{210}Bi	5.01 days	2.1×10^{-9}	70
Polonium-210	^{210}Po	138.4 days	6.2×10^{-7}	0.2
*Artificial Radionuclides***				
Americium-241	^{241}Am	432 years	5.7×10^{-7}	0.2
Antimony-122	^{122}Sb	2.71 days	2.8×10^{-9}	50
Antimony-124	^{124}Sb	60.2 days	3.6×10^{-9}	40
Antimony-125	^{125}Sb	2.76 years	9.8×10^{-10}	100
Barium-140	^{140}Ba	12.8 days	3.7×10^{-9}	40
Bromine-82	^{82}Br	35.3 hours	4.8×10^{-10}	300
Calcium-45	^{45}Ca	165 days	8.9×10^{-10}	200
Calcium-47	^{47}Ca	4.54 days	2.2×10^{-9}	60
Carbon-14	^{14}C	5730 years	5.6×10^{-10}	200
Cerium-141	^{141}Ce	32.5 days	1.2×10^{-9}	100
Cerium-144	^{144}Ce	284.4 days	8.8×10^{-9}	20
Cesium-131	^{131}Cs	9.69 days	6.6×10^{-11}	2000
Cesium-136	^{136}Cs	13.1 days	3.0×10^{-9}	50
Chromium-51	^{51}Cr	27.7 days	5.3×10^{-11}	3000
Cobalt-57	^{57}Co	271.8 days	3.5×10^{-9}	40
Cobalt-58	^{58}Co	70.9 days	6.8×10^{-9}	20
Cobalt-60	^{60}Co	5.27 years	9.2×10^{-8}	2
Gallium-67	^{67}Ga	78.3 hours	2.6×10^{-10}	500
Gold-198	^{198}Au	2.69 days	1.6×10^{-9}	90
Indium-111	^{111}In	2.81 days	3.9×10^{-10}	400
Iodine-129	^{129}I	1.60×10^{7} years	1.1×10^{-7}	1
Iron-55	^{55}Fe	2.68 years	4.0×10^{-10}	300
Iron-59	^{59}Fe	44.5 days	3.1×10^{-9}	40
Manganese-54	^{54}Mn	312.2 days	7.3×10^{-10}	200
Mercury-197	^{197}Hg	64.1 hours	3.3×10^{-10}	400
Mercury-203	^{203}Hg	46.6 days	1.8×10^{-9}	80
Neptunium-239	^{239}Np	2.35 days	1.2×10^{-9}	100
Niobium-95	^{95}Nb	35.0 days	7.7×10^{-10}	200
Phosphorus-32	^{32}P	14.3 days	2.6×10^{-9}	50
Plutonium-238	^{238}Pu	87.7 years	5.1×10^{-7}	0.3
Plutonium-239	^{239}Pu	2.41×10^{4} years	5.6×10^{-7}	0.2
Plutonium-240	^{240}Pu	6560 years	5.6×10^{-7}	0.2
Plutonium-241	^{241}Pu	14.4 years	1.1×10^{-8}	10

* The activity concentration of natural uranium corresponding to the chemical guideline of 0.1 mg/L (see separate criteria summary on uranium in the Supporting Documentation) is about 2.6 Bq/L.

** Tritium and ^{14}C are also produced naturally in the atmosphere in significant quantities.

Table 6 (cont'd)

Radionuclide		**Half-life $t_{1/2}$**	**DCF (Sv/Bq)**	**MAC (Bq/L)**
Rhodium-105	^{105}Rh	35.4 hours	5.4×10^{-10}	300
Rubidium-81	^{81}Rb	4.58 hours	5.3×10^{-11}	3000
Rubidium-86	^{86}Rb	18.6 days	2.5×10^{-9}	50
Ruthenium-103	^{103}Ru	39.2 days	1.1×10^{-9}	100
Ruthenium-106	^{106}Ru	372.6 days	1.1×10^{-8}	10
Selenium-75	^{75}Se	119.8 days	2.1×10^{-9}	70
Silver-108m	^{108m}Ag	127 years	2.1×10^{-9}	70
Silver-110m	^{110m}Ag	249.8 days	3.0×10^{-9}	50
Silver-111	^{111}Ag	7.47 days	2.0×10^{-9}	70
Sodium-22	^{22}Na	2.61 years	3.0×10^{-9}	50
Strontium-85	^{85}Sr	64.8 days	5.3×10^{-10}	300
Strontium-89	^{89}Sr	50.5 days	3.8×10^{-9}	40
Sulphur-35	^{35}S	87.2 days	3.0×10^{-10}	500
Technetium-99	^{99}Tc	2.13×10^{5} years	6.7×10^{-10}	200
Technetium-99m	^{99m}Tc	6.01 hours	2.1×10^{-11}	7000
Tellurium-129m	^{129m}Te	33.4 days	3.9×10^{-9}	40
Tellurium-131m	^{131m}Te	32.4 hours	3.4×10^{-9}	40
Tellurium-132	^{132}Te	78.2 hours	3.5×10^{-9}	40
Thallium-201	^{201}Tl	3.04 days	7.4×10^{-11}	2000
Ytterbium-169	^{169}Yb	32.0 days	1.1×10^{-9}	100
Yttrium-90	^{90}Y	64 hours	4.2×10^{-9}	30
Yttrium-91	^{91}Y	58.5 days	4.0×10^{-9}	30
Zinc-65	^{65}Zn	243.8 days	3.8×10^{-9}	40
Zirconium-95	^{95}Zr	64.0 days	1.3×10^{-9}	100

Appendix G

Greenwood Water Utility Source Water Protection Committee Policy

Municipality of the County of Kings

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Greenwood Water Utility Source Water Protection Committee Policy

Creation Date: August 28, 2012
Approval Date: September 18, 2012
Revision Date: September 2, 2014
May 3, 2016

Policy Category: Engineering & Public Works
Next Review Date: September 2015
Replaces:

1. Committee Mandate:

The function of the Greenwood Source Water Protection Committee ("*the Committee*") is to advise Municipal Council and staff on the development and maintenance of a mutually beneficial, locally developed and administered Source Water Protection Program that protects the water source(s) of the Greenwood Water Utility ("*the Utility*").

2. Authority:

Nova Scotia Environment requires the Municipality to implement certain policies and procedures to safeguard the source waters of the Greenwood Water Utility as part of the Greenwood Water Utility's operating permits. Per Section 23(1) (c) and Section 24 of the Municipal Government Act, Municipal Council authorizes the formation of the Committee and authorizes it to conduct the activities outlined in this Policy on its behalf.

3. Definitions:

3.1 "EPW" means the Engineering and Public Works section of the Municipality of the County of Kings.

3.2 "Source Water Protection Program" means a program developed by the stakeholders of a water utility to protect and monitor the health of a source water supply.

3.3 "Source Water Protection Area Boundary" means the area of land which contributes water to the Utility's production wells.

4. Committee Composition:

The Committee shall be composed of stakeholders of the Utility. The Committee will consist of the following:

- Planning Advisor (Municipality's Manager of Community Development or designate)

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Greenwood Water Utility Source Water Protection Committee Policy

- Engineering Advisor (Municipality's Manager of EPW, Lands and Parks Services or designate)
- District Councillor
- Citizen Representative appointed by Council for a two year term commencing in the fall of the appointment year
- A Commissioner from the Village of Greenwood appointed by Council for a two year term commencing on the first day of May of the appointment year
- Representative of Nova Scotia Environment
- Representative from the Greenwood Water Utility (employee of the Municipality)
- Representative from 14 Wing Greenwood (Ex officio, non-voting)

The Chair shall be the District Councillor. The Vice-Chair will be appointed by members of the Committee.

5. Related Policies, Procedures and Legislation:

Environment Act 1994-95, Province of Nova Scotia
Greenwood Wellfield Approval for Water Withdrawal No. 2004-039399-A01, Province of Nova Scotia
Greenwood Water Utility Approval to Operate No. 2009-066399-A01, Province of Nova Scotia
Water for Life: Nova Scotia's Water Resource Management Strategy, Province of Nova Scotia
Water and Wastewater Facilities and Public Drinking Water Supplies Regulations, Province of Nova Scotia

6. Responsibilities:

The Committee is responsible for advising Council about the following issues:

6.1 *Source Water Protection Area Boundary*

a) Identify and delineate the source water supply area.
b) Assess the delineated boundary to ensure it adequately encompasses the source water supply area and meets the needs of the stakeholders.
c) Recommend changes to the delineated area, as required, within the confines of the regulations.

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6.2 *Identify Potential Contaminates and Assess Risks*
a) Identify and document potential sources of contamination.
b) Assess the risk they pose to the source water supply area.
c) Recommend to staff and Council as appropriate any changes in laws, policies, or regulations governing the Utility.

6.3 *Source Water Protection Management Plan*
a) Review and comment on the Plan and any proposed amendment thereto.
b) Work with and consult community members and the Village of Greenwood when drafting the Source Water Protection Plan or revisions thereto.
c) Work with staff to develop community education and awareness strategies on the Plan.
d) Review monitoring results at an acceptable frequency, at least annually, to verify the continued quality of the source water to ensure the management plan is effective and current to conditions within the supply area.

6.4 *Compliance with Laws, Regulations and Guidelines*
Review as required, reports from staff and others relating to the Utility's compliance with laws, regulations and other obligations governing the Source Water Protection Plan.

7. Operating Procedures and Principles:

The Committee shall conduct itself in accordance with the following principles and procedures:

7.1 *Committee Values*
The Committee and staff are expected to operate in compliance with the Municipal Code of Conduct, and the policies, laws, and regulations governing the Municipality. The Committee is expected to use a consensus-based approach to its decision making.

7.2 *Communications*
The Committee members will maintain direct, open, frank communications with staff, Council and other key advisors as appropriate.

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7.3 *Policy Development*

Review and comment on all applicable materials to help staff and Council to establish technically sound and achievable goals using a combination of management practices as referred by NSE; Acquisition of Land, By-laws, Best Management Practices, Contingency Plans, Designation, and Education. The Committee may invite experts or other appropriate resource person(s) to provide advice on matters before it and may in good faith rely upon any reports and findings they provide.

7.4 *Meetings*

Meetings shall be held semi-annually at a time to be established by the Committee. Special meetings may be convened throughout the year at the request of the Chair, the Utility Representative, or at the written request by a majority of the Committee's member. A copy of the minutes of each meeting shall be provided to each member in a timely fashion.

7.5 *Accountability and Reporting*

The Committee is accountable to Council. The Committee shall report to Council as often as necessary but at least annually. Reporting shall normally be done through the Committee's Chair.

7.6 *Committee Self Assessment*

The Committee shall annually review, discuss and assess its performance. The Committee will review this Policy on an annual basis and recommend any changes to this Policy that may be considered appropriate.

8. Quorum and Decision Making:

A quorum consists of a majority of the voting members of the Committee. The Committee shall use a consensus-based approach in its decision making. The Chair may put the matter to a vote if they deem that a consensus is not achievable. Each Committee member is entitled to one (1) vote and decisions shall be majority vote of those present. The Chair presiding at any meeting of the Committee shall have a vote in all matters considered by the Committee. In the event of a tie the motion is defeated. In the absence of the Chair of the Committee, the Vice-Chair will preside over the meeting.

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