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A Physical and Geochemical Characterization of Southwestern Ontario's Breathing Well Region

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Graduate Program in Geology
A thesis submitted in partial fulfillment of the requirements for the degree in Master of Science
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A Physical and Geochemical Characterization of Southwestern Ontario's Breathing Well Region

(Spine title: Physical and Geochemical Characterization of a Breathing Well Region)

(Thesis format: Integrated - Article)

by

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Department of Earth Sciences
Graduate Program in Geology

A thesis submitted in partial fulfillment
of the requirements for the degree of
Master of Science

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The University of Western Ontario
London, Ontario, Canada

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THE UNIVERSITY OF WESTERN ONTARIO
School of Graduate and Postdoctoral Studies

CERTIFICATE OF EXAMINATION

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	Dr. Elizabeth Webb
Dr. Stewart Hamilton	Dr. Katrina Moser

The thesis by

Candace Nicole Freckelton

entitled:

A Physical and Geochemical Characterization of Southwestern Ontario's Breathing Well Region

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Date	Chair of the Thesis Examination Board

Abstract

The geology and groundwater geochemistry are described for a 1400km^2 breathing well zone within a Middle Devonian, karstic carbonate aquifer system in southwestern Ontario. Breathing wells are unusual because they draw in or emit large volumes of air, depending on fluctuations in atmospheric pressure which causes an exchange of gases between the atmosphere and the subsurface. To better understand this connection, geochemical, hydraulic, and barometric data were used to investigate interconnectivity within the breathing well zone. Spatial and temporal analyses reveal that a significant amount of unsaturated void space exists within the Lucas Formation, and that hypoxic and high CO_2 gases are emitted during low atmospheric pressure periods. The groundwater chemistry displays elevated trace metals (e.g. Ag, Cu, Pb, Zn) and SO_4^{2-} resulting from combined evaporite dissolution and sulphide oxidation. This study provides data useful in understanding the type of environment in which breathing wells are found, and the nature of the subsurface vadose zone gases and groundwater movement in these systems.

Keywords

Breathing wells, karst, geochemistry, stable isotopes, hydrogeology, sulfide oxidation, evaporite dissolution, barometric logging

This thesis is dedicated to my father,

who inspired and taught me the value of hard work.

Acknowledgments

Over the past few years, I have received support and encouragement from a great number of individuals. Firstly, I would like to express my deep gratitude to both of my supervisors Dr. Fred Longstaffe and Dr. Stew Hamilton, who supported the thesis as it moved from an idea to a completed study. Fred, our weekly meetings and conversations were thought provoking and invaluable. Thank you for your expert knowledge, advice and patience, in addition to your continual support for the project. Stew, thank you for introducing me to the breathing well phenomena. Your knowledge in the field provided me with the necessary training for this project and your countless hours of continual guidance, encouragement, and support were very much appreciated. Each of you played different but equally important roles throughout my thesis, inspiring me to learn and push myself to my full potential and in the end providing me with a wide ranging skill set that I will be able to use in my future career. I am truly fortunate to have had the opportunity to work with you both. Thank you.

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I would also like to graciously thank the 10 homeowners who participated in the local component of the study- your time, patience and interest in the project was very much appreciated. I am also grateful to Ron Hopper from W.D. Hopper and Sons Ltd., who took the time to share and discuss his knowledge on the breathing well zone. Additionally, I would like to take this opportunity to thank the large number of people who helped collect water samples (rain, shine, or snow!): EP, AL, NB, RSN, JF, TM, HB, KL, AB, and RM.

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Table of Contents

List of Tables

List of Figures

List of Appendices

Chapter 1

1 Introduction

1.1 Background Introduction

Southwestern Ontario is one of Canada's most densely populated rural areas. A significant portion of its population relies on groundwater for domestic, municipal and agricultural purposes. In this area the majority of groundwater wells are drilled into a Middle Devonian carbonate aquifer. This area and aquifer is of particular interest, as it contains a zone of 'breathing wells' (Figure. 1.1). 'Breathing wells' (also known as blowing wells) either 'inhale' or 'exhale' large volumes of air depending on fluctuations in atmospheric pressure, and this can be audible and quite loud on unsealed wells. During periods of high atmospheric pressure, air is drawn into the subsurface, and during low-pressure events, air is expelled (Bates and Jackson, 1987).

For a well to breathe certain conditions must exist; in particular, the well must be drilled through a confining layer and the uncased portion must penetrate a porous and permeable unsaturated zone of sufficient size to exchange air with the subsurface (Figure 1.2). The degree of exchange between the surface and subsurface is dependent on ambient atmospheric pressure and the volume of unsaturated void space in the subsurface. During periods of low pressure, gas expelled from the well is typically hypoxic, having concentrations of oxygen ($O_{2\,(g)}$) as low as 1.7 %, and carbon dioxide ($CO_{2\,(g)}$) levels as high as 3.4 % (above atmospheric concentrations). The exhaled concentrations are significantly different from atmospheric concentrations, which are 20.9 % $O_{2\,(g)}$ and 0.04 % $CO_{2\,(g)}$.

The majority of the wells in the breathing well zone (BWZ) are drilled through thick glacial overburden that overlies the Dundee Formation limestone, and are finished in the uppermost unit of the Detroit River Group; the Lucas Formation. Subsurface drill records indicate the Lucas Formation consists of limestone and dolostone interbedded

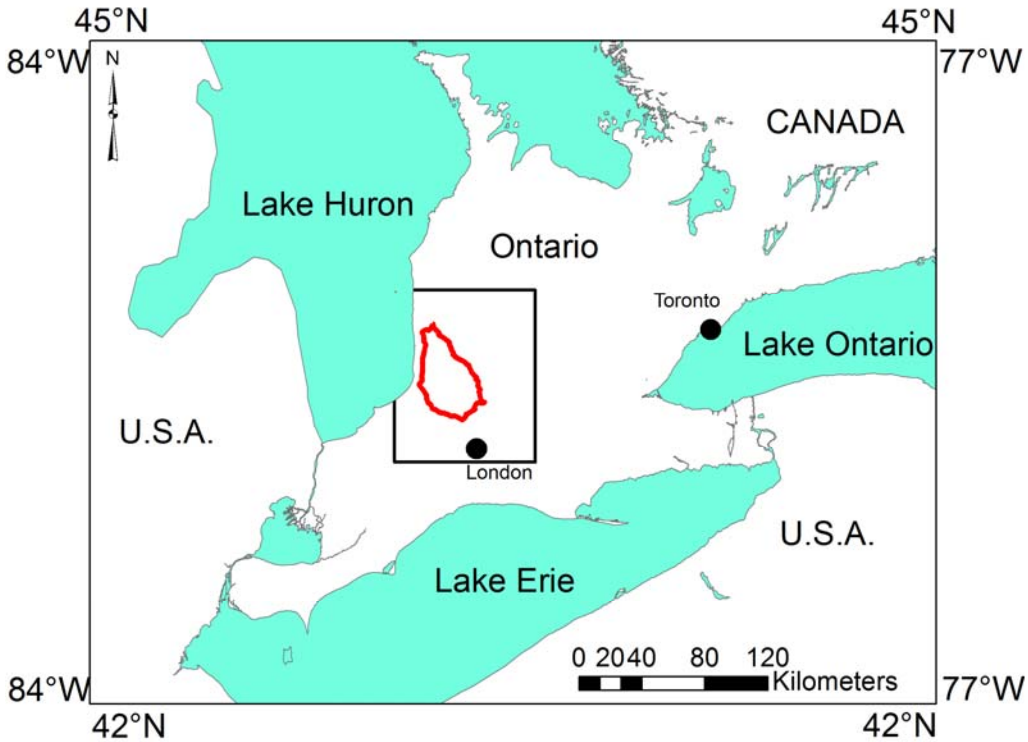


Figure 1.1. Map of the study area. The black box outlines the boundaries of the regional study area. The red line outlines the breathing well zone (BWZ), as defined by Hopper, pers. Comm., 2009.

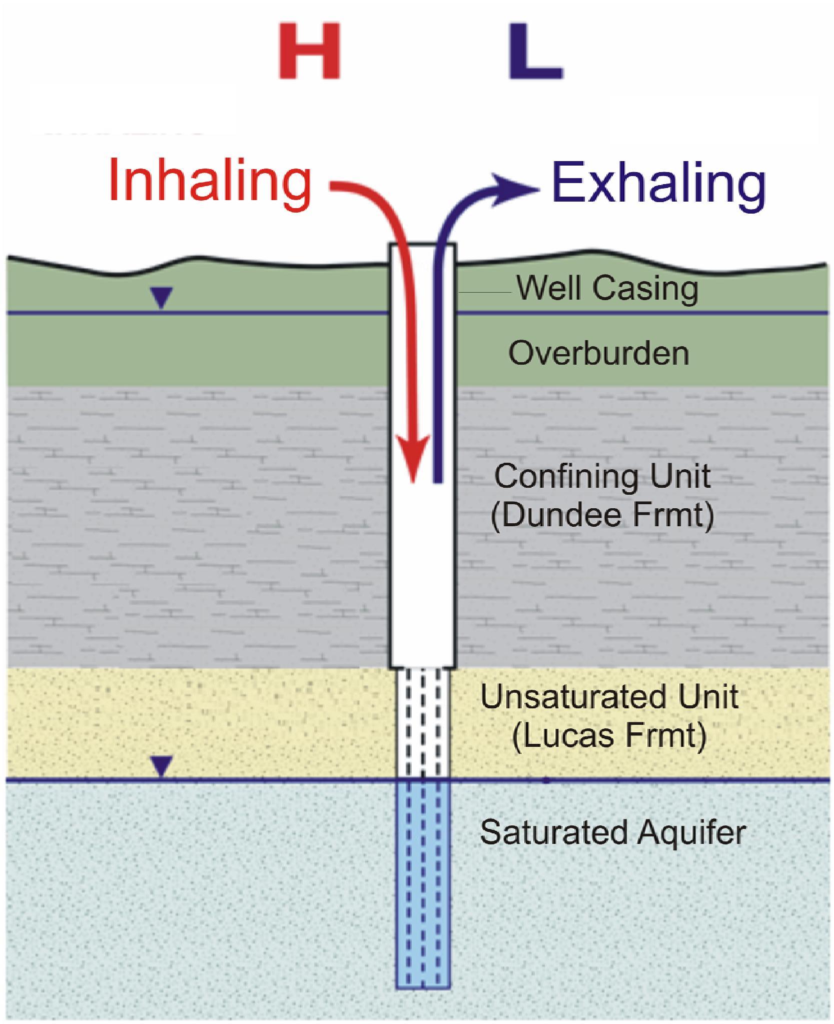


Figure 1.2. Schematic of a breathing well. A rise in atmospheric pressure causes the well to draw in ambient air into the unsaturated zone, whereas a fall in atmospheric pressure causes air in the unsaturated zone to be expelled into the atmosphere. The well typically has been drilled through an upper confining unit, and completed into a partially unsaturated zone, which facilitates gas exchange (*modified from* Hill, 2004).

with anhydrite-rich dolostone, anhydrite and halite, and is considered to be karstic in nature (Armstrong and Carter, 2010; Johnson et al., 1992). Karst, by classical definition, is a landscape that contains caves and extensive groundwater systems developed in soluble rocks, such as carbonate or evaporites. Such environments have unique landforms and hydrologic features that develop because of the rock's solubility and secondary porosity (Ford and Williams, 2007). Intrastratal karstification is a process that can occur when circulating waters preferentially dissolve a particular unit, such as an evaporite containing gypsum, anhydrite and/or salt that is enclosed within a rock sequence overlain by less soluble or insoluble strata. This process is most common when the less soluble overlying units are shales, but can also occur in carbonate rocks (Ford and Williams, 2007). As will be shown, it is likely that this type of karstification is occurring in and around the BWZ.

Previous geological studies have noted that karstification is consistently associated with the Lucas Formation, and is related to evaporite beds that comprise its intertidal facies (Hurley et al., 2008; Waterloo Hydrogeologic Inc. (WHI), 2006). Dissolution of these interbedded evaporites produces karstic features that vary from significant microporosity and vug cavities (up to 5 cm in length) within the carbonate facies to rubbly unlithified limestone and minor clay-rich beds containing features typical of paleokarst breccia (Armstrong and Carter, 2010; Hurley et al., 2008; WHI, 2006), and meter-scale cavern-like voids (Hopper, pers. Comm., 2009; Union Gas Ltd., pers. Comm., 2010). This void space in the Lucas Formation is capped by the overlying limestones of the Dundee Formation. When these voids are unsaturated an environment is created that enables the wells to 'breathe'.

Although breathing wells are a rare phenomenon, subsurface air movement in karstic caves is common in nearly all cave environments, and will vary in degree depending the number of cave entrances (Cigna, 1967; Lewis, 1991; Wigley, 1967; Wigley and Brown, 1976). Air movement within caves can arise for a variety of reasons including thermally induced chimney effects, air entrainment by flowing water, gravitational drainage of air, resonance of air in large chambers, external wind weather patterns and, in the case of breathing wells, atmospheric barometric pressure changes. The speed of air movement is generally greater in caves with large volumes, small cave entrances, and/or exposure to rapid external pressure changes (Wigley and Brown, 1976). Such 'breathing' caves are known to occur in porous and permeable limestone, and the volume that responds to external pressure changes is much greater than the macroscopically observable cave volume (Wigley, 1967; Wigley and Brown, 1976). Breathing caves are known from South Australia (Hill, 1966), the United States (Miller, 1938; Sartor and Lamar, 1962), and Europe (Massen et al., 1998).

Karst aquifers, in general, are heterogeneous systems both topographically and in the subsurface. The degree of variability depends on the extent of rock-water reactions in combination with environmental conditions, such as climate and geology. Karstic aquifers can be classified as autogenic, allogenic, or mixed (Figure 1.3). In an autogenic system, diffuse recharge infiltrates through unsaturated karstic bedrock to the water table. In an allogenic system, recharging water is derived from adjacent non-karst catchment areas, and infiltrates into the aquifer via point sources, such as sinkholes. In the most common situation, that is, a mixed system, the aquifer receives both autogenic and allogenic recharge (Goldscheider et al., 2007).

The southwestern Ontario BWZ contains point source features such as sinkholes (dolines) (Figure 1.4), and disappearing (sinking) streams (Brunton and Dodge, 2008). The sinkholes, which are closed, sub-circular depressions, are usually less than 5 m deep and 9 m in diameter (Karrow, 1974; 1977). Some sinkholes have open bottoms and are capable of being direct quick inputs of surface water flow; most, however, have closed bottoms and drain slowly. These surficial karstic features tend to be observable in areas where glacial overburden is thin and where either the Lucas or Dundee formations form the subcrop (Brunton and Dodge, 2008; Hurley et al., 2008; International Water Consultants (IWC), 2003; Karrow, 1974, 1977; WHI., 2003, 2003, as stated by WHI, 2006).

Previous reports have suggested that the local distribution of sinkholes is spatially associated with areas where the Lucas Formation bedrock aquifer is characterized by a significant drop in water level (~100 m TOC). Previous studies, however, have been unsuccessful in defining correlations between Lucas Formation karstification and the position of the water table or stratigraphic controls like the Dundee-Lucas contact (Brunton and Dodge, 2008; Hurley et al., 2008; IWC, 2003). Assessment of the extent and nature of local

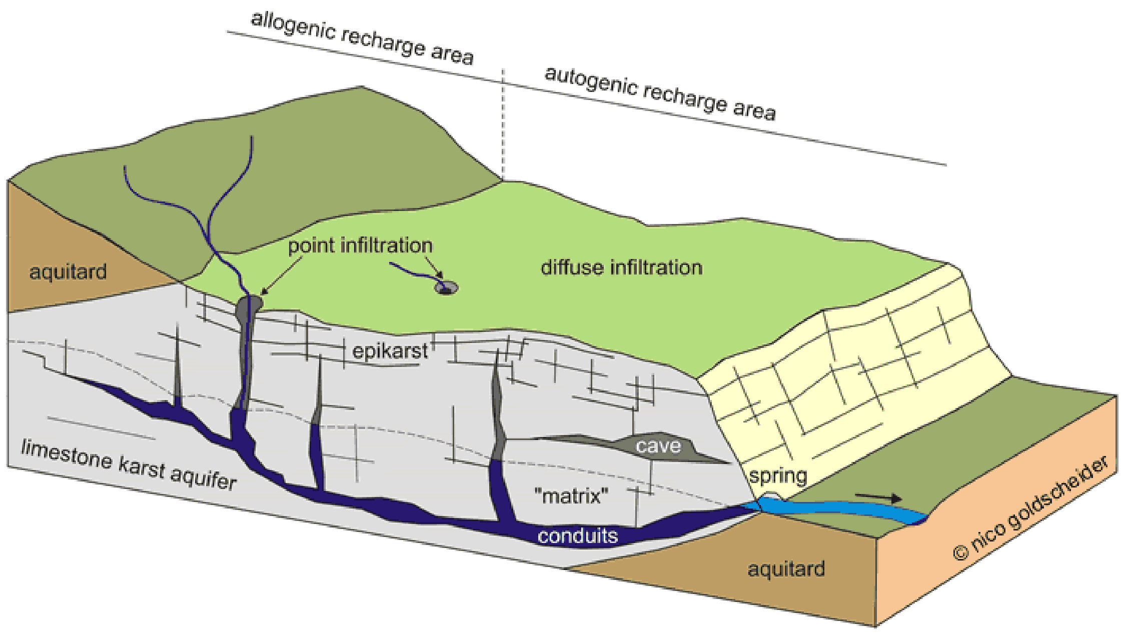
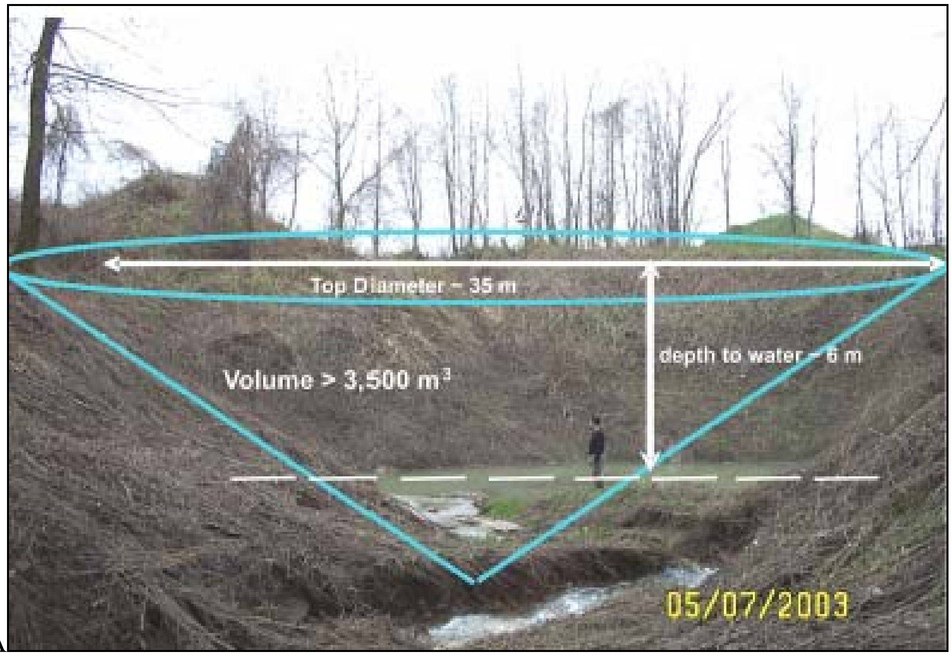


Figure 1.3. Schematic hydrology within a heterogenous karstic environment. Recharge occurs via diffuse and/or point sources (Goldscheider et al., 2007).



A


B

Figure 1.4. Photographs of sinkholes in the BWZ. (A) Tucker-Smith sinkhole (Hurley et al., 2008). (B) Typical sinkhole (~465600E, 4810500N based on the UTM grid NAD 83, Zone 17 North).

sinkhole development, and its possible stratigraphic controls, has been impeded by the thick cover of glacial overburden (Abbey et al., 2004; Brunton et al., 2005; Brunton and Dodge, 2008).

Subsurface karst development primarily results from chemical erosion, where acidic surface waters and groundwater dissolve soluble minerals. Such reactions enhance the karst aquifer's permeability, hydraulic conductivity and groundwater storage capacity. Permeability, the measure of a material's ability to transmit fluid (Schwartz and Zhang, 2003), is controlled by the interconnectivity of the host bedrock's porosity. Porosity is the ratio of the volume of aggregate pores voids to the total bulk volume (Ford and Williams, 2007). Primary porosity (also termed matrix porosity) forms during the genesis of the rock and consists mostly of void spaces between mineral crystals and grains. Secondary porosity forms after rock genesis, principally as fractures and develops by dissolution along cracks and fissures, which can be enlarged into conduit-like structures, increasing hydraulic conductivity. Fast, turbulent groundwater flow is common in environments with interconnected fractures and conduits, whereas slower, diffuse flow is typical of areas containing smaller fissures. An aquifer's porosity and permeability, and its ability to become karstic, is dependent on lithology (Ford and Williams, 2007; Goldscheider and Bartolomé, 2007). The degree to which a rock becomes karstified depends on mineralogy, original lithological purity and the extent of diagenesis. The most extensive karst develops in soluble rocks that are dense, massive, pure, coarsely crystalline, and fractured (Ford and Williams, 2007). Large cavities will tend to form in highly cemented rocks dominated by fracture flow; cavities develop as the fractures become enlarged into conduits over time (Goldscheider and Bartolomé, 2007).

Evidence for subsurface karst development in the BWZ has been documented in previous geological and geophysical studies; drill cores, for example, contain vugs (up to 5 cm in length) that likely result from evaporite dissolution (Hurley et al., 2008; WHI. 2006). These reports also concluded that subsurface karstic features almost certainly extend over a much greater area than apparent from sinkhole development, noting the existence of hydraulic connection between sinkholes and nearby monitoring wells. In these areas, rises in water level along with influxes of geochemically 'fresh' water commonly occurred following precipitation events (Hurley et al., 2008; WHI, 2006).

Lucas Formation geology and geochemistry, and its associated karstic features, have been discussed in several reports (Abbey et al., 2004; Brunton and Dodge, 2008; Birchard et al., 2004; Hurley et al., 2008; IWC, 2003; Karrow, 1974, 1977; WHI, 2003, 2004, 2006) in addition, local drillers have been aware of the BWZ for many years (Hopper, pers. Comm., 2009). However, the BWZ has never been specifically examined or discussed in a holistic fashion in scientific literature. This thesis builds upon the current knowledge of regional karstic features in the Lucas Formation by adding new information about its breathing well system. The overall goal is to develop a better understanding of the unique surface-subsurface interconnection in the BWZ.

1.2 Research Objectives

A regional spatial and local temporal physical and geochemical study has been undertaken here to examine the nature of surface-subsurface interconnectivity in the 1400 km^2 BWZ, and to determine its relationship to an underground karstic network in the Lucas Formation. The regional study area, which contains the BWZ, is ~9,000 km^2 (Figure 1.5).

The first objective was to delineate the areal distribution of the BWZ and characterize the BWZ's hydrogeological and physical features. This has been addressed by:

(a) Creating stratigraphic maps of the subcropping Dundee, Lucas, and Amherstburg formations, and an isopach map for the Lucas Formation;
(b) Determining groundwater flow in the BWZ by measuring water levels and creating hydraulic gradient elevation maps;
(c) Determining the relationship between local atmospheric and subsurface pressure, and assessing the degree of spatial interconnectivity within the unsaturated zone, using barometric pressure logging instruments emplaced into the breathing wells.

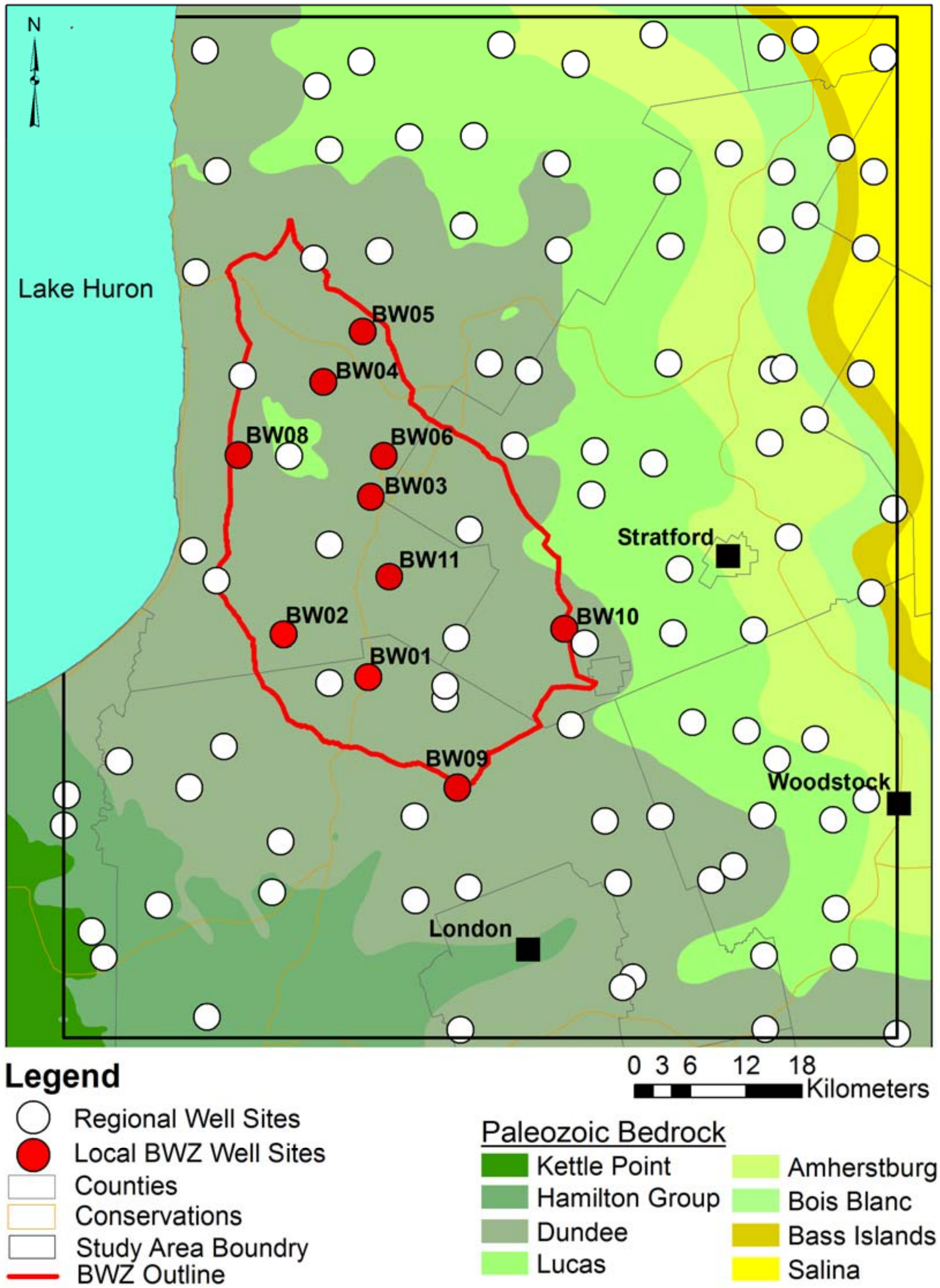


Figure 1.5. Map of sampling sites. The black box outlines the regional study area and the red line outlines the BWZ (Hopper, pers. Comm., 2009). White and red dots are locations where water chemistry was obtained as part of the regional study. Red dots represent locations that were sampled monthly over a one-year as part of the local study.

The second objective was to describe the hydrochemistry of the BWZ and its surrounding region, through regional and local studies. The regional study examined groundwater from 102 wells that are located both within and around the BWZ. Data for the regional study was obtained from a pre-existing data set provided by the Ontario Geological Survey's Ambient Groundwater Sampling Program. For each well, 92 geochemical parameters were measured, including temperature, pH, electrical conductivity, oxidation-reduction potential, total and fecal coliform bacteria concentrations, dissolved gas contents, chemistry (major, minor and trace elements), stable isotopes (oxygen, $\delta^{18}O_{H2O}$; hydrogen, $\delta^{2}H_{H2O}$,) and tritium (^{3}H) in water. Multivariates statistical analyses, and in particular, Hierarchical Cluster Analysis (HCA) and Principal Component Analysis (PCA), were performed on this dataset to:

(a) Classify the regional hydrochemical water facies and identify the most influential variables controlling groundwater chemistry;

(b) Develop a conceptual model for hydrochemical processes in the regional study area, so that their influences on the BWZ can be better understood.

The local hydrogeochemical study involved examining 10 wells located within the BWZ. This entailed the monthly sampling of groundwater chemistry over one year. The same parameters as in the regional study were measured, in addition to the stable isotopic compositions of dissolved sulphate ($\delta^{34}S_{SO4}$, $\delta^{18}O_{SO4}$) and enriched Tritium ($E^{3}H$). These data have been used to:

(a) Define the local water facies;

(b) Determine the nature of rock-water interaction influencing water chemistry;

(c) Investigate the interconnectivity of the local flow system;

(d) Identify the mechanism(s) causing oxygen depletion in gases emitted from the breathing wells.

The nature of the BWZ is of significant interest to the general public. It is important for residents to understand the dangers associated with having a breathing well, which can present health hazards arising from the emission of hypoxic gases. Individuals using breathing wells have been affected by hypoxic gas emissions in Alberta, Canada, with the most serious cases resulting in death. Serious risk arises when breathing wells are constructed in confined spaces, such as well pits, or other situations where air circulation is poor (Lewis, 1999; Hill, 2004). Another hazard is that carbonate aquifers that contain significant karstic development, are highly sensitive to surface contamination. Land use within the BWZ is intensely agricultural, including cash crop farming and livestock operations. Local surface runoff has the potential to directly and quickly contaminate aquifers – posing a serious risk to those who rely on groundwater in this area.

1.3 Thesis Structure

Chapter 2 defines the BWZ and characterizes its physical environment through the use of barologger instruments, manual water level readings, and local geological databases. Results include barometric and hydraulic gradient water level maps of the BWZ, and stratigraphic and isopach maps of the most significant bedrock formations associated with the BWZ. Groundwater and exhaled gas compositions are presented in Chapter 3. Regional groundwater facies and associated geochemical processes have been determined and classified using multivariate statistics. Water stable isotope compositions are used to determine the origin and movement of groundwater in the BWZ, and compositional and isotopic methods have been used to evaluate the nature of subsurface gas-water-rock interactions, in particular, the mechanisms causing $O_{2\,(g)}$ depletion and $CO_{2\,(g)}$ enrichment of exhaled gases. Chapter 4 summarizes the major findings of the research, and provides suggestions for future work.

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Chapter 2

2 A Physical Characterization of Southwestern Ontario's Breathing Well Region

2.1 Introduction

A contiguous area of breathing wells occurs in a 1400 km^2 zone in southwestern Ontario. Breathing wells ("blowing wells") are water wells that respond to changes in barometric pressure, causing the wells to either inhale or exhale (Bates and Jackson, 1987). Certain conditions must exist for such a phenomenon to occur; in particular, the un-cased part of the well must encounter a confined, unsaturated zone situated above the water table (Hill, 2004). During periods of high atmospheric pressure, air is transferred into the unsaturated zone, and when the atmospheric pressure drops, gas is exhaled from the well. Loud sounds arising from the inhalation and exhalation will commonly distinguish a breathing well from a non-breathing well, but this behaviour does not occur in all situations. Breathing wells that have a slow transfer of air can be silent. The gas emitted from a breathing well is typically different in composition compared to that of the atmosphere. Inhaled atmospheric air has oxygen and carbon dioxide concentrations of 20.9 and 0.04 % respectively, whereas the air that is exhaled is hypoxic with O_2 levels as low as 1.7 and CO_2 levels up to 3.4 %. A study of oxygen-deficient breathing wells in Alberta, Canada, determined that the magnitude of the breathing events was dependent on the amplitude and length of the barometric pressure cycle. In that system, O_2 was consumed by subsurface organic and inorganic reactions and resulted in elevated levels of CO_2 and N_2, the latter resulting from denitrification (Hill, 2004).

Southwestern Ontario's breathing well zone (BWZ) is situated in a major aquifer called the Detroit River Bedrock Aquifer (Figure 2.1, MacRitchie et al., 1994), which is named after the geological unit that comprises it. A significant number of people in this area obtain their water supply from wells drilled into this aquifer. The local landscape is heavily agricultural and the majority of groundwater usage is for domestic and farming

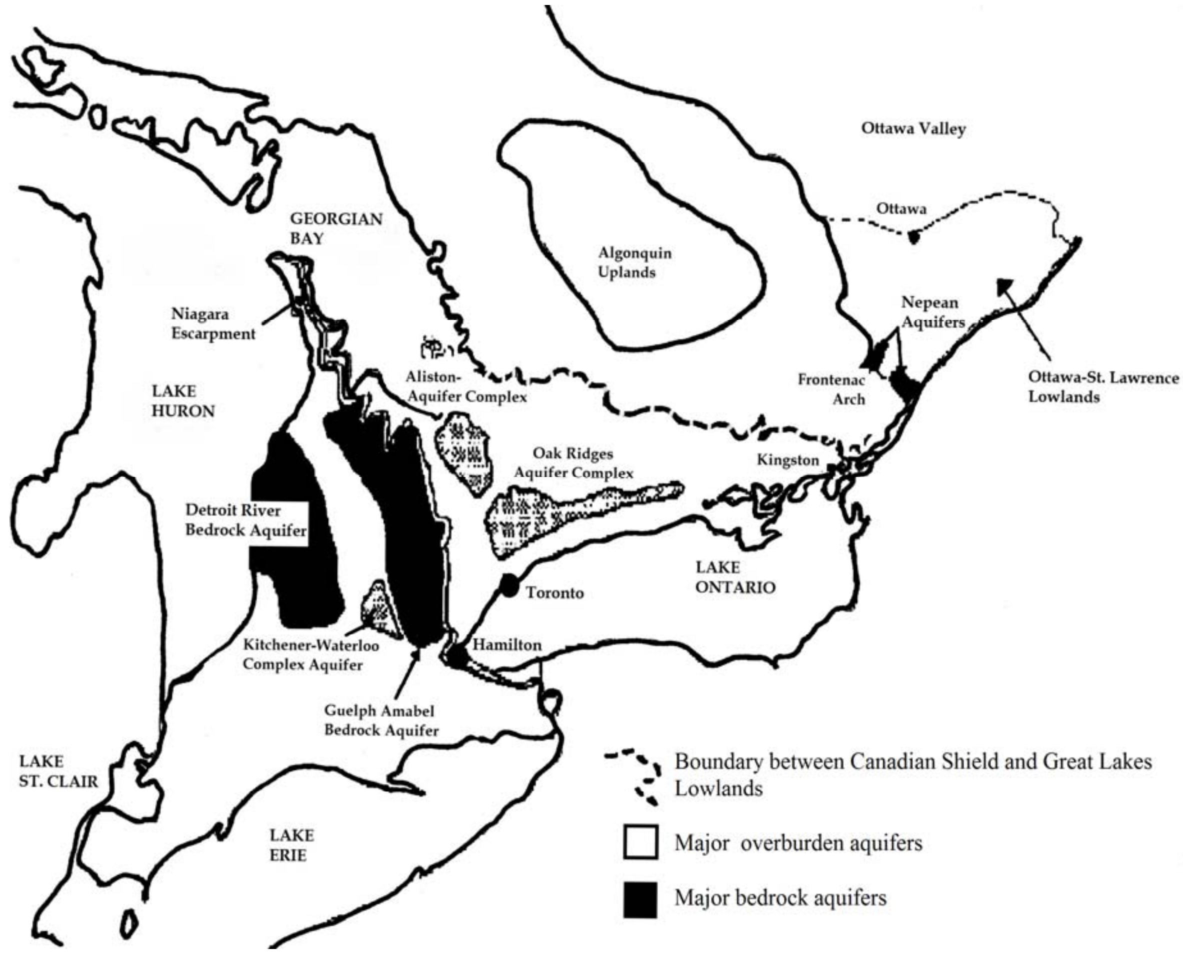

Figure 2.1. Map of the major physiographic and hydrogeologic features within southern Ontario, including the major overburden and bedrock aquifers (*modified from* MacRitchie et al., 1994). The breathing well zone (BWZ) is located in the Detroit River Bedrock Aquifer.

purposes (cash crop farming and livestock operations; International Water Consultants (IWC), 2003). The breathing wells are drilled and cased through overburden and into bedrock and left uncased within the Dundee and underlying Lucas Formations. The Lucas Formation is the uppermost unit of the Detroit River Group, and consists of limestone, dolostone, anhydrite rich beds and locally, sandy limestone (Armstrong and Carter, 2010). In the BWZ, the Lucas Formation hosts subsurface karstic features with the unsaturated void space that facilitates the 'breathing' of the wells. Despite local drillers having been aware of the BWZ system for many years (Hopper, pers. Comm., 2009), its distribution and interconnectivity remain poorly understood.

Sinkholes and disappearing streams are present within and around the BWZ. These features are located in areas where glacial overburden is thin in the northwestern part of the BWZ and where both the Lucas and Dundee formations form the subcrop (Brunton et al., 2005; Brunton and Dodge, 2008; Hurley et al., 2005, 2008; IWC, 2003; Karrow, 1974, 1977; Waterloo Hydrogeologic Inc. (WHI) 2003, 2004, 2006). Such karstic features can provide a direct surface-subsurface linkage, making aquifers highly susceptible to biological and chemical contamination from surface runoff.

This chapter is one of two that report research that is designed to gain a better understanding of southwestern Ontario's BWZ. The objective of this chapter is to delineate the areal distribution of the BWZ, and characterize its physical features such as the underlying bedrock formations, groundwater flow movement, and gas flow movement – with respect to interconnectivity in both the atmosphere-subsurface and the vadose zone. This research will provide a better understanding of the geological and hydrogeological controls on the breathing events. It should be noted that some of the information and results discussed in this paper has been previously documented in Freckelton et al. (2010).

2.2 Site Description

2.2.1 Study Area

This study includes a regional investigation of an area located in central southwestern Ontario that is ~9,000 km^2 in size that centrally encompasses the 1400 km^2 BWZ. The area straddles the jurisdictions of the Ausable Bayfield Conservation Authority (ABCA), the Upper Thames River Conservation Authority (UTRCA), and the Maitland Valley Conservation Authority (MVCA), and includes the municipalities of Huron, Perth and Middlesex Counties (Figure 1.5).

2.2.2 Regional Geological Setting

The study area lies within the Western St. Laurence Platform, where relatively flat lying Paleozoic sedimentary rocks overlie a faulted Precambrian basement. Across southern Ontario, the surface stratigraphy decreases in age from Ordovician sedimentary rocks in the east to Silurian and Devonian sedimentary rocks in the west. These units were deposited primarily in shallow epicontinential seas, and consist of flat-lying shale, limestone, dolostone and sandstone (Johnson et al., 1992).

The Algonquin and Findlay Arches, the Chatham Sag, and the Michigan and Appalachian Basins are significant structural features in southwestern Ontario (Figure 2.2). The Algonquin Arch is a broad basement ridge that bisects southwestern Ontario in a northeasterly-southwesterly direction, dipping regionally 3 to 6 m/km (Armstrong and Carter, 2010). It is separated from the more southern Findlay Arch by a structural low called the Chatham Sag. The Appalachian and Michigan Basins are bisected by the Algonquin Arch and contain sedimentary strata that dip toward the basin centers at 3.5 to 12 m/km (Armstrong and Carter, 2010) (Figure 2.2). Each basin was exposed to different depositional conditions and hence lithologies vary on either side of the Arch. The Appalachian Basin lies to the east of the Algonquin Arch and is an elongated foreland basin composed of siliclastic and terrigenous sediments. The Michigan Basin is a circular, intracratonic basin located west of the Algonquin Arch and is predominantly

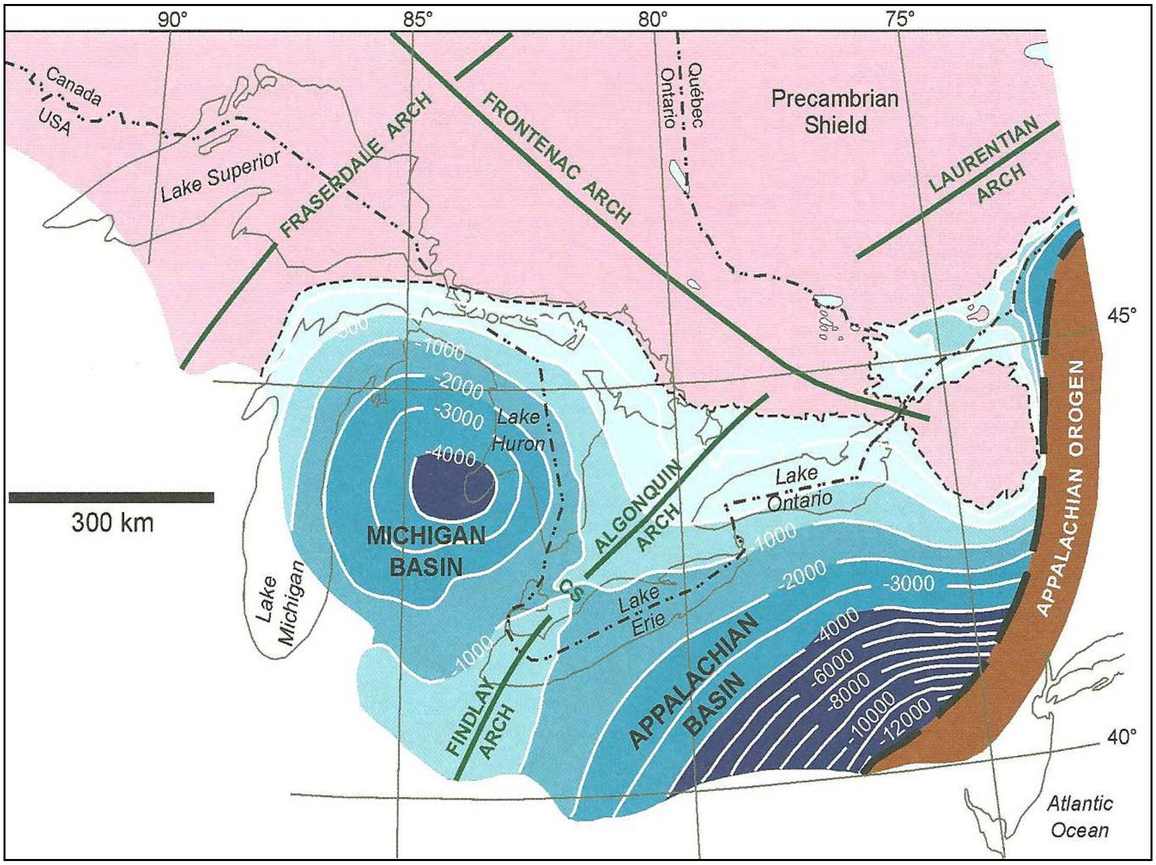

Figure 2.2. Major structural features of southern Ontario, including the Algonquin Arch, the Michigan Basin and the Appalachian Basin (after Armstrong and Carter, 2010; Johnson et al., 1992).

composed of evaporite-bearing carbonates (Armstrong and Carter, 2010; Johnson et al., 1992).

2.2.3 Local Stratigraphy

The study area is situated in the Lake Huron drainage basin, which has a major influence on both surface and groundwater flow direction; regionally, groundwater travels in a westward direction. The study area is covered by thick glacial overburden composed of till plains and moraine that overlie the Paleozoic strata. The till is composed of a heterogeneous mixture of clay, sand, pebbles, and boulders. There are four major till units in the regional study area: Elma Till, Rannoch Till, St. Joseph Till, and Tavistock Till. The northeastern Elma Till consists of silt, sandy silt and clayey silt in ground moraines and drumlins. The central Rannoch Till consists of silt to silty clay in ground moraine and end moraines (Mitchell, Dublin, Lucan, Seaforth and Centralia moraines). The western St. Joseph Till consists of silt to silty clay that forms the Wyoming moraine, and is situated parallel to the shore of Lake Huron. The southeast Tavistock Till is made of silty clay to clayey silt, and occurs as ground moraine interbedded with glaciolacustrine sediments. Glaciolacustrine and glaciofluvial sand and gravel deposits are also found in kames, eskers, and outwash areas (Barnett, 1992; Karrow, 1974, 1977). The till generally has low permeability and does not readily produce water. As a result, the majority of the groundwater wells tap bedrock aquifers (IWC, 2003).

In the regional study area, there are eight subcropping Paleozoic formations: Kettle Point, Hamilton, Dundee, Lucas, Amherstburg, Bois Blanc, Bass Island, and Salina (Figures 1.5 and 2.3). The study area is dominated by the Middle Devonian Dundee and Lucas formations. The Dundee Formation is composed of medium- to thick-bedded, grey to tan to brown, richly fossiliferous micritic limestone and minor dolostone, with bituminous partings and chert (Armstrong and Carter, 2010). It has an average thickness of 35 to 45 m and was deposited in lagoonal and open shelf and deep water environments (Johnson et al., 1992). The Dundee Formation crops out in several locations near the Thames, Ausable and Maitland Valley rivers (Hurley et al., 2008; Karrow, 1977).

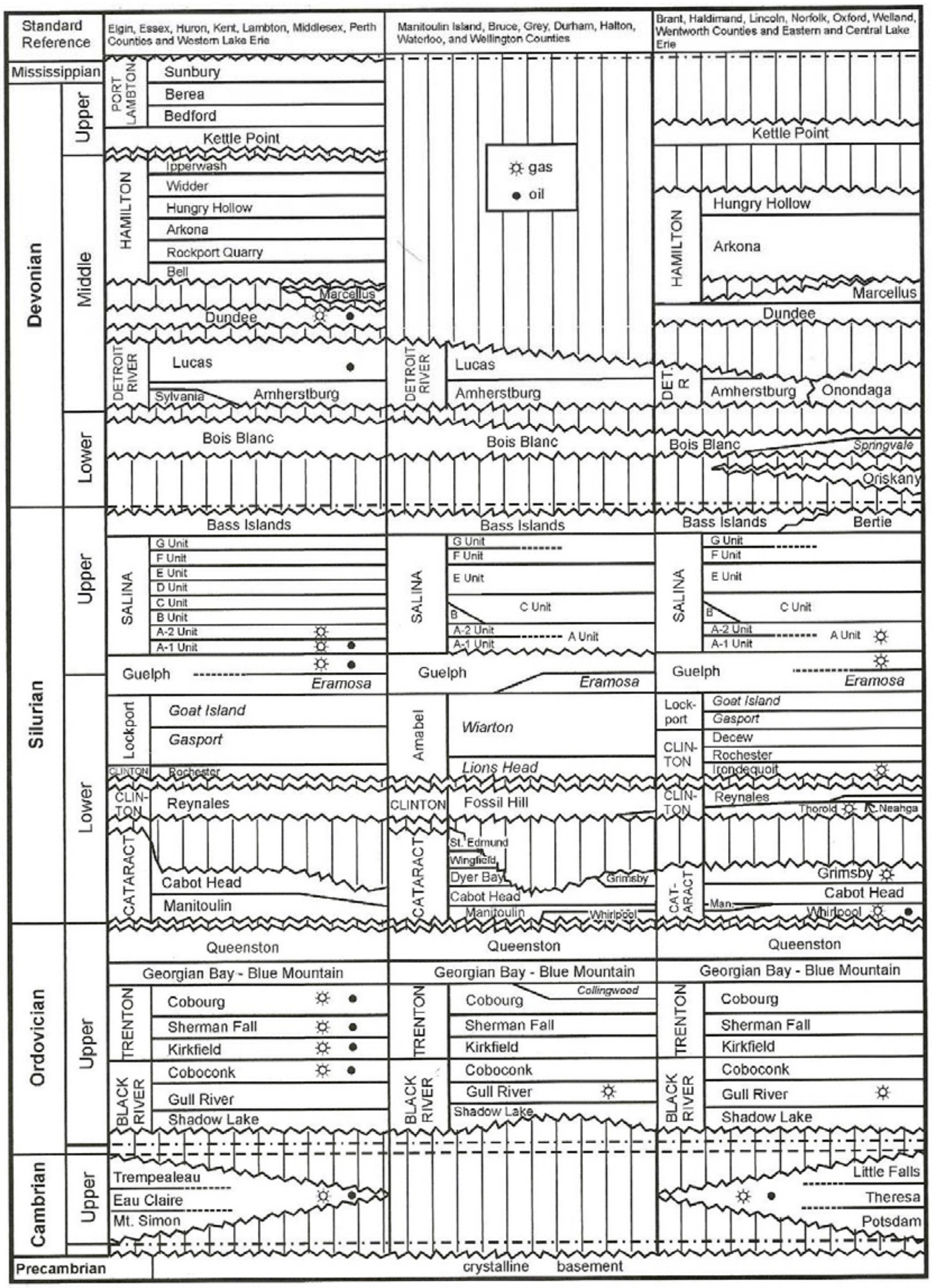

Figure 2.3. Subsurface Paleozoic stratigraphy of southwestern Ontario (from Armstrong and Carter 2010, *modified from* Winder and Sanford, 1972).

A sharp, disconformable erosional contact exists between the Dundee and Lucas formations. The Lucas Formation consists of thin- to medium-bedded light grey to brown, dolostone and limestone interbedded with thin anhydritic dolostone, anhydrite and halite (Johnson et al., 1985, 1992). It ranges in thickness from 40 to 75 m, and was deposited in very shallow marine to evaporitic environments. This unit is commonly brecciated and contains needle-like moldic porosity, suggestive of evaporite dissolution (Armstrong and Carter, 2010; Johnson et al., 1992).

The Lucas Formation is complex, having a range of depositional and diagenetic facies represented by three subdivisions: (1) Lucas Formation (Undifferentiated); (2) Anderdon Member limestone; and (3) Anderdon Member sandy limestone. A sandy lithofacies, called the Columbus sands, is also present in the Lucas Formation; however there is uncertainty as to its specific stratigraphic placement within Ontario. Following Armstrong and Carter (2010), this unit is considered here to be part of the Anderdon Member. The Lucas Formation (Undifferentiated) is composed of light to grey brown, thin- to medium-bedded, fine-crystalline, poorly fossiliferous, laminated limestone and dolostone with dark bituminous laminations. This unit is visible in the St. Marys Quarry (Figure 2.4), in outcrops at Goderich (around the Maitland River), and in Amherstburg Formation quarries (Armstrong and Carter, 2010; Uyeno et al., 1982). This subdivision contains needle-like porosity that likely results from evaporite dissolution. Near Amherstburg and Goderich, anhydrite and gypsum beds are present together with carbonate breccias that appear to be related to evaporite dissolution (Armstrong and Carter, 2010). The Anderdon Member consists of light to dark-grey brown, thin- to medium-bedded, fine-grained, micritic and sparsely fossiliferous limestone that alternates with coarse-grained, very fossiliferous, bioclastic limestone. Stromatoporoids (Figure 2.4B) and amphipora are the main fossils in the bioclastic beds, with rugose and tabulate corals being less abundant (Armstrong and Carter, 2010; Uyeno et al., 1982). This unit commonly occurs on the western side of the Algonquin Arch, in Essex, Elgin, Norfolk and Oxford counties (Armstrong and Carter, 2010; Sanford, 1967). The Anderdon Member sandy limestone is medium- to massive-bedded, medium- to coarse-grained,

Figure 2.4. Photographs of outcrop from St. Marys Quarry (A) Contact between the Dundee Formation and the Lucas Formation (Undifferentiated), St. Marys Quarry; (B) Stromatoporoid in the Lucas Formation, St. Marys Quarry.

and fossiliferous and tends to occur toward the top of the Anderdon Member (Armstrong and Carter, 2010).

The Amherstburg Formation of the Detroit River Group conformably underlies the Lucas Formation, and is a tan to grey-brown, fossiliferous, bituminous, commonly cherty limestone and dolostone. This unit was deposited in a shallow marine environment, and is 40 to 60 m thick (Armstrong and Carter, 2010; Johnson et al., 1992). In Bruce and Huron counties, the Amherstburg Formation contains stromatoporoid-dominated bioherms, which are also known as the Formosa Reef limestone or Formosa Reef Facies (Armstrong and Carter, 2010; Fagerstrom, 1961; Tsujita et al., 2001; Uyeno et al., 1982).

2.2.4 Depositional Facies of the Lucas Formation

Birchard et al. (2004) described the depositional facies and distribution of the Lucas Formation, as summarized below. The Lucas Formation is thickest in the center of the Michigan Basin and thins in a southeast direction away from the basin center across southwestern Ontario. The lithology of the Lucas Formation varies depending on its position relative to the Algonquin Arch, and whether it lies within the Michigan or Appalachian basins. The Lucas Formation within the Michigan Basin was deposited in a low-energy, shallow water, evaporitic environment, whereas the Lucas Formation located in the Appalachian Basin would have been deposited in a higher energy, deeper water, more open marine depositional system (Birchard et al., 2004). North of the Algonquin Arch (within the Michigan Basin), the Lucas Formation consists mainly of carbonate platform dolostone, with interbeds of anhydrite and/or anhydritic dolostone. On the southern side of the Algonquin Arch (in the Appalachian Basin), the Lucas Formation is composed primarily of dense micritic and sandy limestone, reflective of a higher energy marine environment (Birchard et al., 2004; Sanford, 1967).

The BWZ is situated on the Michigan Basin side of the Algonquin Arch, where the depositional environment ranged from sabka tidal flats to an intertidal setting in a low energy environment. As a result, the local lithology comprises repeated sequences of anhydrite and anhydritic dolostone interbeds capping dolomite, indicating an environment in which minor sea level fluctuations occurred during deposition (Birchard et al., 2004). The BWZ lies in two of Birchard et al.'s (2004) depositional zones (Zones 4 and 5) (Figure 2.5). The eastern portion of the BWZ lies in Zone 4, which consists of interbedded finely crystalline limestone and dolomite with fair to poor porosity. The western portion of the BWZ is located in Zone 5, which consists of dense to microcrystalline dolostone. In summary, interbeds of dolomitic limestone and calcareous dolostone decrease and the abundance and thickness of anhydritic dolostone and nodular anhydrite interbeds increase further westward into the Michigan Basin, which may influence the physical nature of the BWZ.

2.2.5 Karstic Features

The presence of karst within the region containing the BWZ has been discussed in several previous studies (Abbey et al., 2004; Birchard et al., 2004; Brunton and Dodge, 2008; Brunton et al., 2005; Hurley et al., 2005; 2008; IWC, 2003; Karrow, 1974, 1977; Waterloo Hydrogeologic Inc., 2003, 2004, 2006). Karst is a landscape that develops in soluble rocks including limestone, marble and gypsum that in the subsurface is typified by caves and extensive solution-enhanced aquifer systems (Ford and Williams, 2007). As precipitation and surface runoff interact with atmospheric carbon dioxide and infiltrate into the subsurface, carbonic acid is formed and contributes to chemical weathering. During dissolution, fault lines, joint sets and bedding planes within subcropping carbonate formations become enlarged. Karstic groundwater environments can therefore contain void space in a wide variety of configurations that affect their capacity for transmitting and storing water (Ford and Williams, 2007). Porosity within the bedrock exists in the bedrock matrix as primary porosity, along bedding planes, joints and faults as secondary porosity, and within channel conduits and caves (Ford and Williams, 2007). Groundwater flow and residency can vary dramatically in such environments, ranging from slow and laminar to fast and turbulent (Worthington, 2003). The degree of physical variability in the aquifer can have a significant effect on water chemistry, particularly through rapid influx of contaminated surface water.

Topographic features, such as sinkholes and disappearing streams, have been documented and mapped in and around the BWZ (Figure 2.6 A-D). Karrow (1977) described numerous sinkholes within the subcropping Dundee Formation. IWC (2003) and

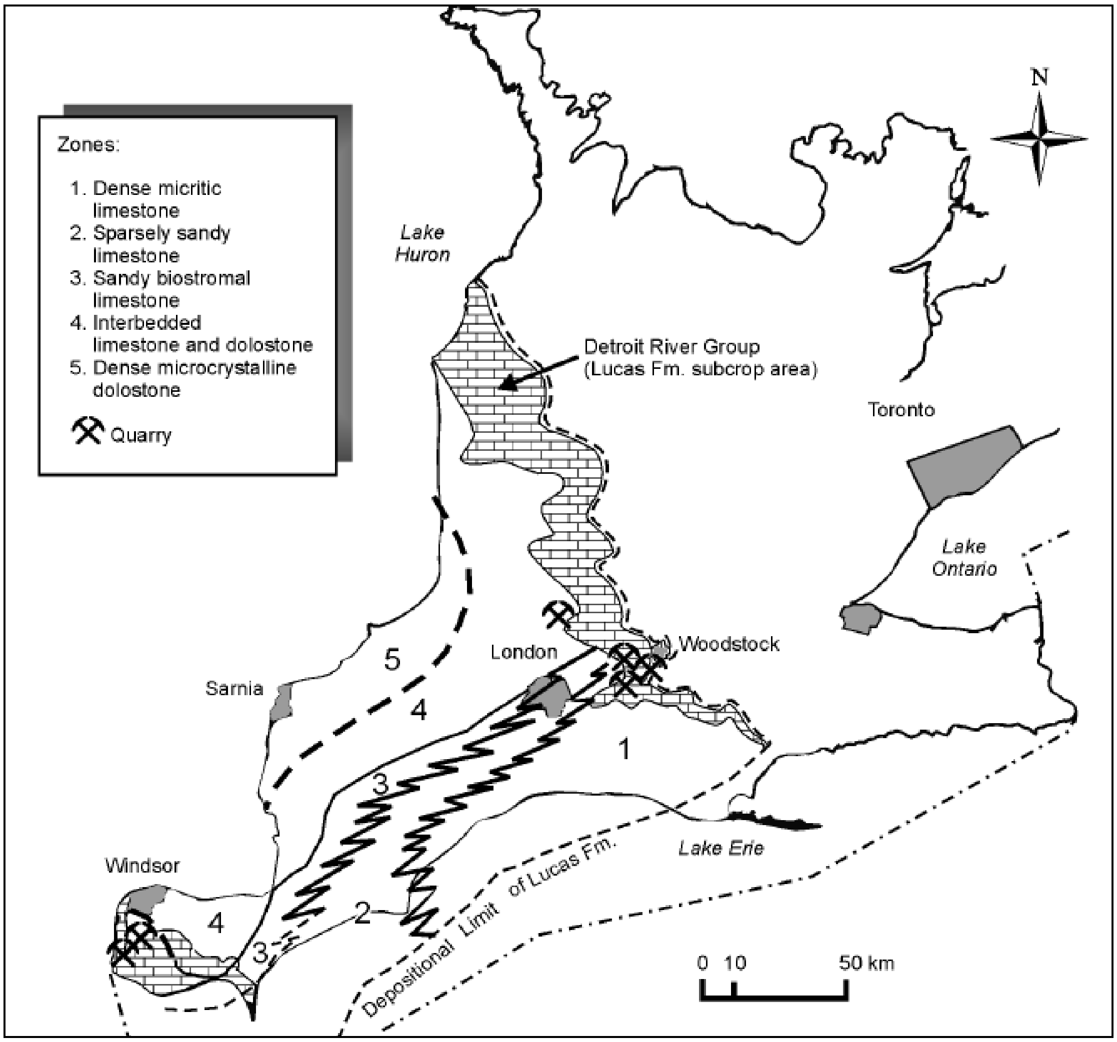

Figure 2.5. Diagenetic and/or depositional zones of the Lucas Formation, as described by Birchard et al. (2004) (see text). The BWZ overlaps zones 4 and 5 (Birchard et al., 2004).

WHI (2003, 2004; 2006), working together with the Ausable-Bayfield Conservation Authority (ABCA), the municipalities of West Perth and Huron East, and the Ontario Ministry of the Environment (MOE), also identified sinkholes in West Perth and Huron counties. These reports concluded that subsurface karst likely extends over a much greater area than currently represented by sinkholes. The distribution of sinkholes seems to be spatially related to an area where the Lucas Formation water table drops sharply over a relatively short lateral distance (Hurley et al., 2005, 2008; IWC, 2003).

There have been no reports of significant cave systems within the southwestern Ontario's Lucas Formation (Brunton and Dodge, 2008), but large cavern-like voids, which lie both above and below the water table have been recognized within wells located in the BWZ (Hopper, pers. Comm., 2009; Union Gas Ltd., pers. Comm., 2010) (Figure 2.6C & D). Drill cores of the Lucas Formation in the BWZ also contain alternating limestone and dolostone beds with abundant but disconnected vugs (up to 5 cm in length), and unlithified limestone and minor clay-rich beds typical of paleokarst breccia (Hurley et al., 2008) (Figure 2.7). The vugs are interpreted as molds resulting from dissolution of evaporite minerals. Other secondary minerals include calcite, which has filled fractures, and iron and manganese oxides, which indicate interaction with oxygenated water (Hurley et al., 2008).

Karstic cavern systems resulting from evaporite dissolution have reported from Middle Devonian strata of northern Lower Michigan, USA (Black, 1983; 1997). It is believed that meteoric water enters these areas through fault extensions, dissolving evaporites (Black, 1997). Submerged karstic systems also exist in areas around Lakes Huron and Michigan. These systems serve as a hydraulic base for groundwater, with outlets beneath Lakes Huron and Michigan. Brecciation and collapse of the Detroit River Group has occurred as a result of anhydrite swelling and dissolution (Black, 1997). Lake-bottom sinkholes in northern Lake Huron also discharge groundwater from adjacent Silurian-Devonian carbonate aquifers (Biddanda et al., 2006).

Karstification of the Lucas Formation likely results from several processes. Following deposition, the Lucas Formation underwent uplift and subaerial weathering,

Figure 2.6. Photographs of study area. (A) Submerged conduit at the base of a sinkhole (photograph from Hurley et al., 2008); (B) Disappearing stream (photograph from Hurley et al., 2008); (C) Down-hole photograph of a cavern-shaped void situated above the water table (Hopper, pers. Comm., 2009); (D) Down-hole photograph of a cavern-shaped void below the water table; 131.1m below surface (Union Gas Ltd., pers. Comm., 2010).

A

B

C

Figure 2.7. Photographs of drill cores of the Lucas Formation from the northern part of the BWZ. (A) Vuggy features in limestone; (B) Vugs filled by light blue celestite; (C) Brecciation of the Lucas Formation. Photographs are from the Hensal Road -1 borehole (from Hurley et al., 2008).

forming the regional unconformity between it and the overlying Dundee Formation. During uplift, fractures, faults and solution channels developed in the upper portion of the Lucas Formation, creating pathways for groundwater (Hurley et al., 2008). Most known karstification in the Lucas Formation occurs mainly along contacts between various facies of the variably dolomitized sediments deposited during sabka cycles. Areas that have been most affected are brecciated carbonate units associated with rocks that are, or were formerly, anhydrite- and gypsum-rich (Hurley et al., 2008).

2.3 Methodology

Geological drill records were obtained from Ministry of Natural Resources (MNR)'s Ontario Oil, Gas & Salt Resource Library. This information was used to create stratigraphic and isopach maps of the study area using the geospatial processing program ArcMAP Version 10. Bedrock contacts between formations were confirmed by examining rock cuttings from the Dundee, Lucas and Amherstburg formations. The unconformable contact between the Lucas and overlying Dundee formations was identified based on the presence (Dundee Formation) or absence (Lucas Formation) of *Tasmanites* spore cases, as suggested by Armstrong and Carter (2010). The conformable contact between the overlying Lucas Formation and underlying Amherstburg Formation was identified by a marked change from lighter coloured, micritic limestone and dolostone (Lucas Formation) to dark brown, fine to coarse-crystalline, bituminous, occasionally cherty, skeletal limestone (Amherstburg Formation).

Subsurface stratigraphic maps of the Dundee, Lucas and Amherstburg formations were made by kriging geological information obtained from the MNR data well records, using ArcMAP's spatial analyst. Kriging is a geostatistical method for interpolating values between scattered datapoints in order to approximate a uniform grid of data that can then be used to produce contour or surface maps. The interpolated values were used to create formation layers. The isopach map for the Lucas Formation was created by subtracting the Lucas's top and bottom elevation values. A transaction map of the local study area was created using data for elevation, drift thickness, depth to rock, subcropping formation, static water level, well depth, and the formation in which the well was completed. This information was compiled from a variety of sources: the MNR's Oil, Gas, and Salt Resource well record database; the OGS's Ambient Groundwater Mapping Program Database (Hamilton, 2011); and Ontario Ministry of Environment (MOE) water well records (MOE, 2011).

On a more local scale, ten breathing well sites were selected from the Ontario Geological Survey (OGS) Ambient Groundwater Geochemistry Program for further investigation. Well selection was made on a subjective basis as determined on their spatial location within the BWZ, and the individual homeowner interest in the study. Permission was obtained from private homeowners to monitor and sample their wells monthly between November 2009 and October 2010. Subsurface barometric pressure was measured using Solinst LT Barologgers®. Each barologger was emplaced 30 meters down-hole from the top of drill casing at each well, and programmed to record the well's temperature and barometric pressure at 15 minute intervals. To limit air exchange between atmosphere and the top of the well, each well cap was sealed to the well casing using silicone. All barologgers were calibrated and altitude-corrected to meters above sea level. At site BW06, near the centre of the BWZ, a barologger (BW07) was kept outside of the well to measure local atmospheric temperature and pressure. Implicit to this methodology is the assumption that the wells do not leak air during breathing phases. There are several reasons why leakage is unlikely. Domestic wells in the area must be sealed by pump installers because in winter leakage of cold air into the casing could freeze water supply pipes in minutes. Leakage in the annulus around the casing is unlikely for the same reason and because overburden is thick and therefore the steel-cased portion of the well is substantial. Finally, the large and sustained pressure differences between the atmosphere and the barometric pressure in the well, that are described in the results, are themselves evidence of a good barrier between the two systems.

Other calculations made using the subsurface barometric data were the well's breathing intensity and subsurface lag time response to atmospheric pressure events. Breathing intensity was estimated by securing a bag over the well and measuring the time it took to fill with exhaled gas. This is recognized that this is not the ideal method to measure pressure, and more sophisticated protocols should be used in future investigations. The lag time of each well's response to atmospheric pressure changes was determined by examining the barologger data. Over the course of one year, each significant barometric event was examined and compared.

Water level measurements were taken intermittently throughout the year at each of the 10 sites using a water-level tape measure. Global positioning system (GPS) elevation measurements were taken at the top of each well casing location (and corrected to ground elevation) using a Leica Viva GNSS GS15 unit GPS receiver with a CD15 controller. The device functions as a real time kinematic (RTK) rover and was connected, via cellular telephone, to the Leica Geosystem's SmartNet, real-time differential correction server. The geospatial processing program ArcMAP version 10 was used to create the subsurface stratigraphy geospatial maps, and Surfer version 8 was used to create the elevation and water-level contour maps.

2.4 Results

Bedrock surface elevation maps for the Dundee, Lucas and Amherstburg formations are displayed in Figure 2.8 (A, B, C). A gradual westerly decrease in bedrock elevation is observed for each stratigraphic unit occurs as units dip toward Lake Huron. The Lucas Formation isopach map display that the unit is thickest (95 - 122 m) in the center and northeastern areas of the BWZ, and gradually thins to the northwest and southeast (17-56 m) (Figure 2.8 D).

Well construction and stratigraphic information for the regional well sites are listed in Appendix A (n=102). Wells within the BWZ (n=21), typically have greater average well depths (86m vs. 53m from Top of Casing (TOC)) and average static water levels (65m vs. 16m TOC) than those outside of the BWZ (n=81). Levels measured here for the BWZ are consistent with earlier reports of water table depths of 100 m TOC in areas of karst development in the region (WHI, 2006). Furthermore, 70 % of wells located in the

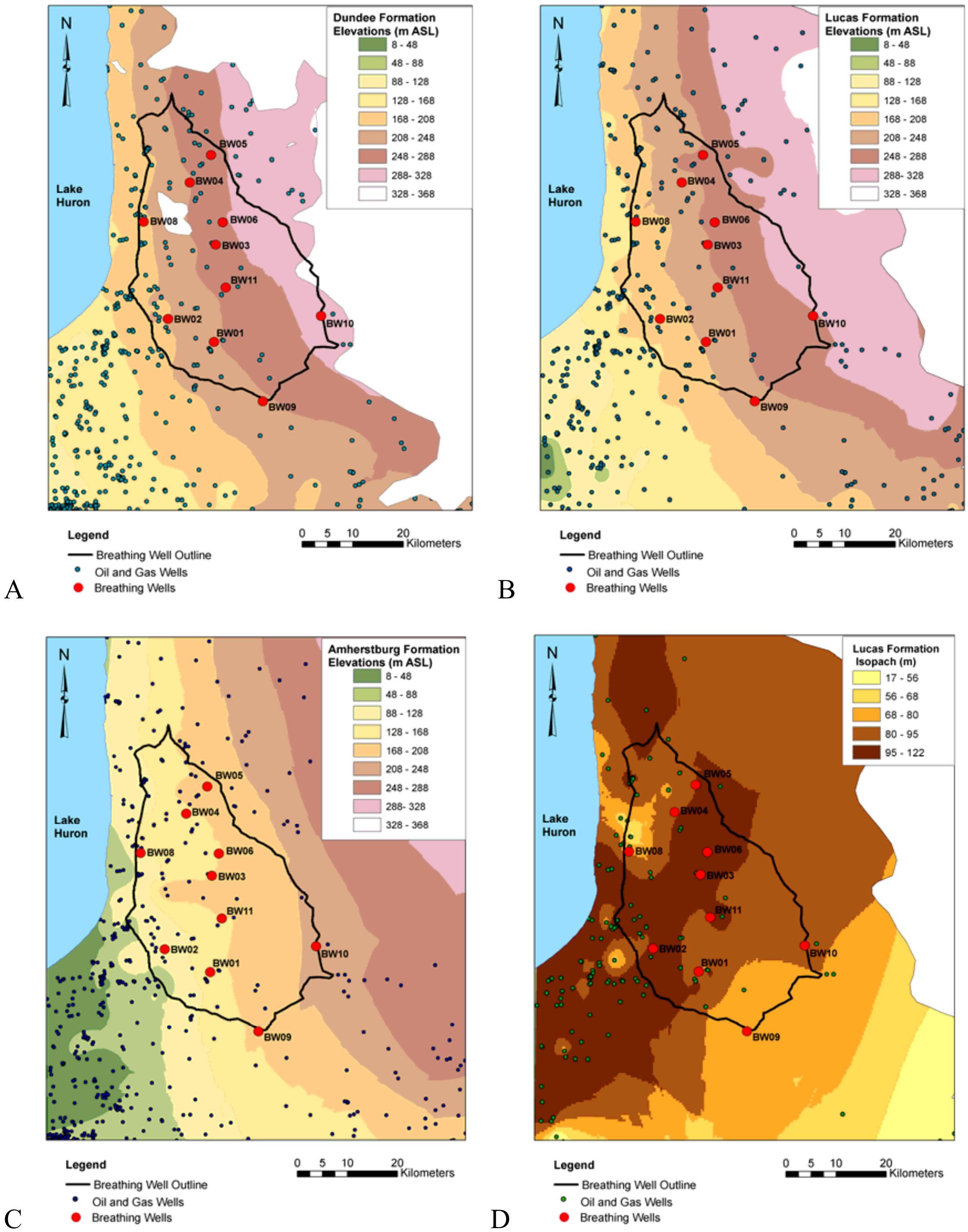

Figure 2.8. Maps of geological surfaces. (A) Top of Dundee Formation; (B) Top of Lucas Formation; (C) Top of Amherstburg Formation (i.e. bottom of the Lucas), and (D) Isopach of the Lucas Formation. Data for the geological surfaces was obtained from the MNR's Oil, Gas and Salt Resource Library.

BWZ are completed within the Lucas Formation, as opposed to wells outside the BWZ (40%) (Figure 2.9A, B, & C).

A transect graph was made for the 10 wells existing within the BWZ that were examined as part of the local study (Figure 2.10). In figure 2.10, the surface elevation values were obtained from the GPS elevations calculations and bedrock elevations were determined from surrounding oil and gas drill records. Well depths were obtained from MOE water well records and water levels were measured by hand, using a water level tape (Table 2.1). It is observed that a thick glacial overburden (~25 m) overlies the BWZ (Figure 2.10), and that the ground surface elevation decreases in a westerly direction across the BWZ (Figures 2.10 & 2.11A). All 10 wells are drilled through the Dundee Formation and finished in the Lucas Formation. Most well sites have water levels below the top of the Dundee-Lucas contact by 13 to 49 m. Sites BW08 and BW09 have water levels slightly above the Dundee-Lucas contact by 5 to 7 m and make the shallowest penetration into the Lucas Formation by 2 and 12 m, respectively.

Water level measurements from the 10 local wells vary from 271 to 178 m ASL. The hydraulic gradient surface undergoes a westward decrease, with a distinct steeping of the gradient in the center of the BWZ followed by a broadening farther to the west (Figure 2.11B). Fluctuation in the water levels of individual wells was generally very small over the one-year study period (Table 2.2).

Atmospheric pressure readings recorded by barologger BW07 (located on ground surface at site BW06) were comparable to those recorded at both London and Goderich airports and the results were almost identical after altitude correction. Therefore, the changes in atmospheric pressure considered herein were applied to the surface of the BWZ for that time period. However, the patterns of subsurface barometric pressure changes in the BWZ are different from one another and usually differ from atmospheric pressure at most well sites (Figures 2.12 to 2.15). Over the one-year study period (Oct 2009 to Nov 2010), subsurface barometric pressure in the BWZ fluctuated between 97.73 and 103.14 kPa. Three patterns of pressure behaviour are identified based on the frequency and amplitude of barometric

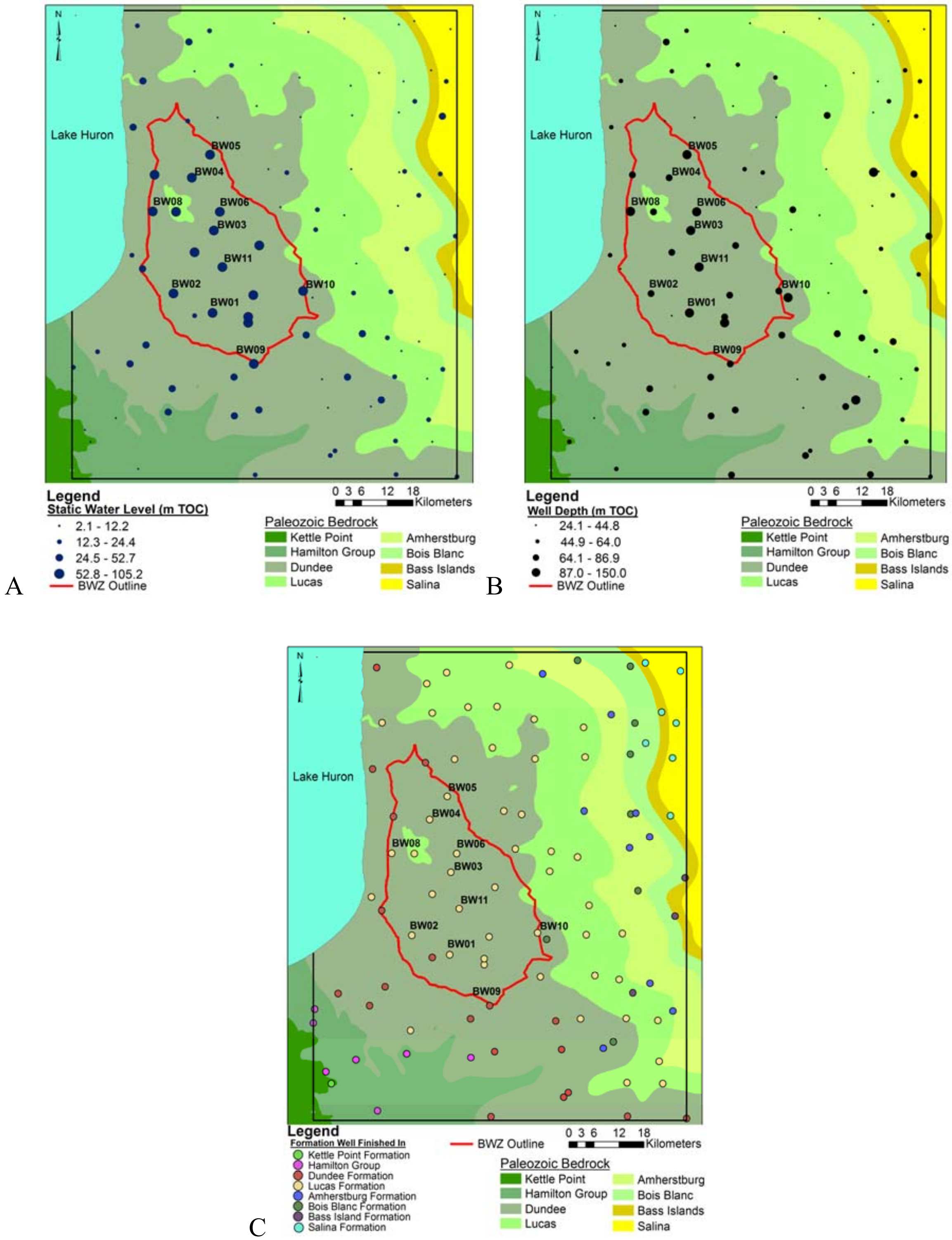

Figure 2.9. Spatial Maps of Study Area. (A) Static water levels (m TOC); (B) Well depth levels (m TOC); (C) Paleozoic bedrock unit in which the well has been completed.

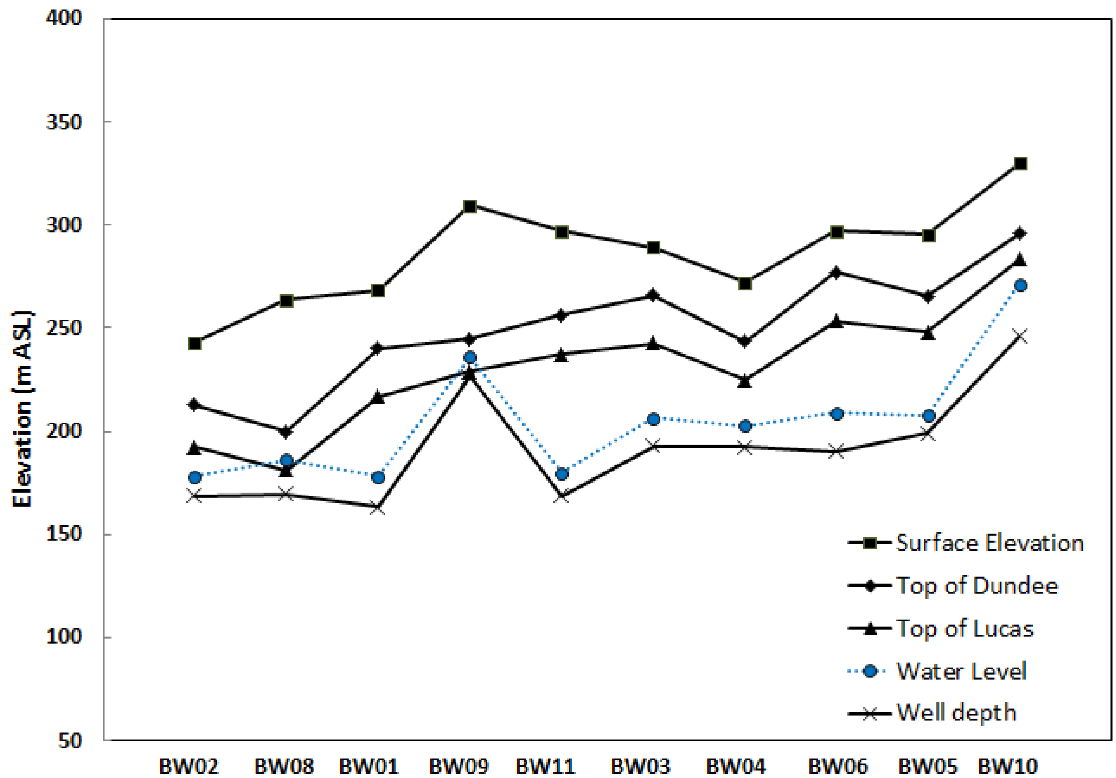

Figure 2.10. West to east diagram of wells in the BWZ (see Figure 1.5 for site locations).

Table 2.1. Well construction data for the ten monitored wells from the BWZ.

Station	Station	*Elevation	*Drift thickness	‡Top of Dundee	‡Top of Lucas	*Water level elevation	†Bottom of well	†Unit well finished in
		m ASL	m	m ASL	m ASL	m ASL	m ASL	
08-AG-010	BW01	268.5	28.4	240.1	216.8	178.4	163.3	Lucas
08-AG-167	BW02	243.2	30.5	212.7	192.4	178.4	168.8	Lucas
08-AG-183	BW03	289.4	23.2	266.2	242.7	206.3	193.0	Lucas
08-AG-087	BW04	272.2	28.7	243.5	224.8	202.4	192.3	Lucas
08-AG-211	BW05	295.3	29.6	265.7	248.1	207.6	198.9	Lucas
08-AG-223	BW06	297.2	20.1	277.1	253.6	212.3	190.5	Lucas
08-AG-105	BW08	264.0	64.1	199.9	181.1	186.4	169.4	Lucas
07-AG-026	BW09	309.6	64.7	244.9	229.0	236.3	226.6	Dundee
08-AG-021	BW10	330.0	34.2	295.8	283.6	270.9	246.1	Lucas
08-AG-012	BW11	297.0	40.6	256.4	237.5	188.3	168.9	Lucas

*Well elevation and water levels were measured as part of this study. Water levels are an average of all measurements on all dates. † Drift thickness, Well depth and unit the well was finished in were obtained from MOE records. ‡Top of Dundee and Lucas formations were obtained from the MNR records.

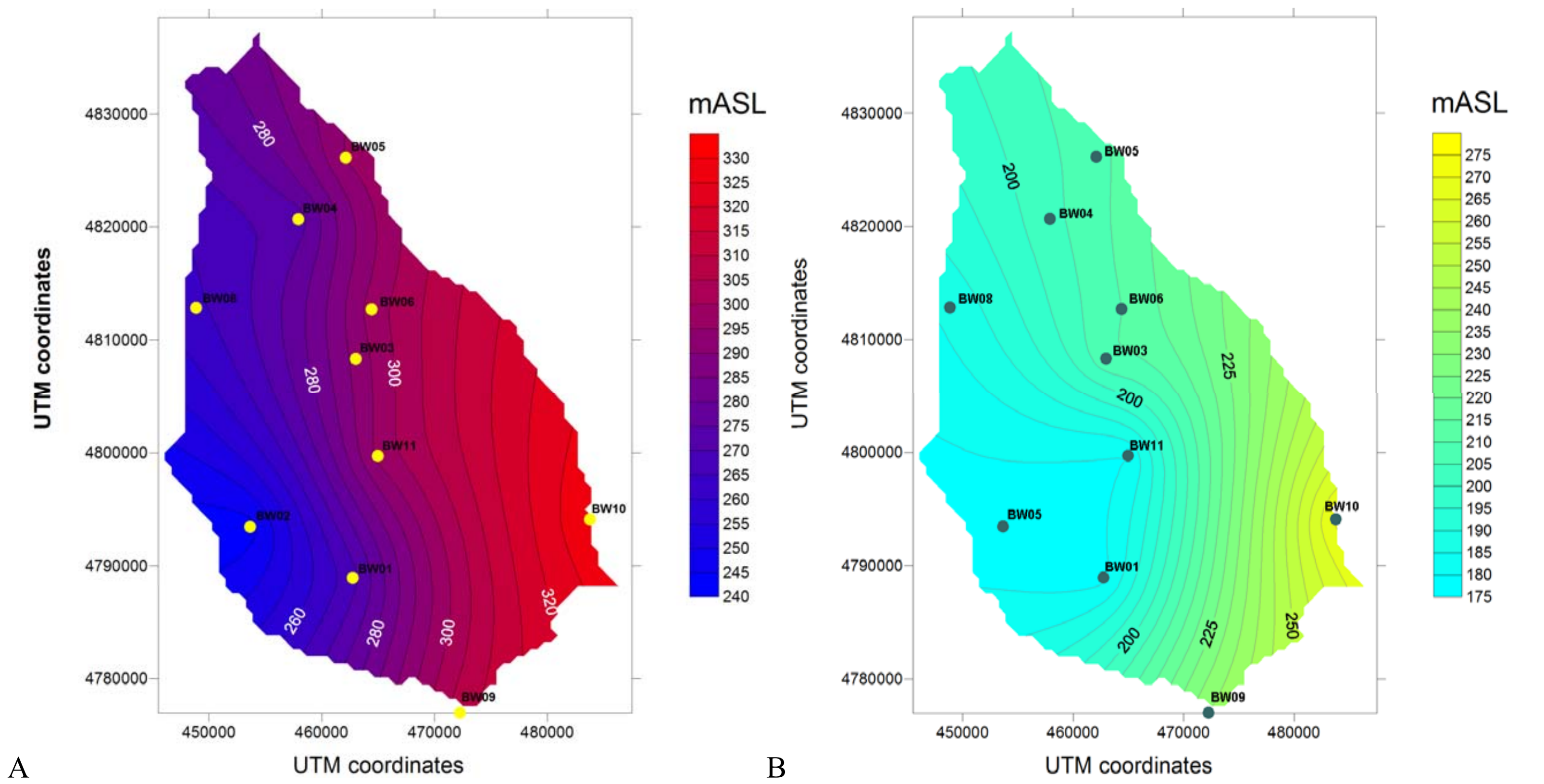

Figure 2.11. (A) Surface elevation for the BWZ with contours shown in meters above sea level (m ASL) at 5 m intervals; (B) Hydraulic gradient data for the BWZ (Nov 11, 2009) with contours shown in 5 m intervals (m ASL).

Table 2.2. Water level elevations for the BWZ, November 2009 to October 2010.

		Site Location									
Sample month	Average Total Precipitation*	BW01	BW02	BW03	BW04	BW05	BW06	BW08	BW09	BW10	BW11
	(mm)					(m ASL)					
Oct-09	79.2	-	-	-	-	-	-	-	-	-	-
Nov-09	16.8	178.5	178.5	206.4	202.7	207.8	209	186.2	236.2	271.2	180
Dec-09	27.6	-	-	-	-	-	-	-	-	-	-
Jan-10	26.7	-	-	-	-	-	-	-	-	-	-
Feb-10	14.9	-	-	-	-	-	-	-	-	-	-
Mar-10	8.8	-	-	-	-	-	-	-	-	-	-
Apr-10	28.7	-	-	-	-	-	-	-	-	-	-
May-10	71.2	-	-	-	-	-	-	-	-	-	-
Jun-10	182.7	178.4	178.3	206.2	202.3	207.5	213.4	186.1	236.6	270.1	187.4
Jul-10	89.9	178.4	178.5	206.1	202.4	207.5	213.5	-	-	271.1	193
Aug-10	12.8	-	-	-	-	-	-	-	-	-	-
Sep-10	93.5	-	-	-	-	-	-	-	-	-	-
Oct-10	34.4	178.4	178.5	206.3	202.2	207.5	213.4	186.8	236.1	271.1	192.9

* Average Total Precipitation was taken as the total amount of precipitation that fell on that month. Data obtained from Environment Canada. "-" symbolizes parameter not measured

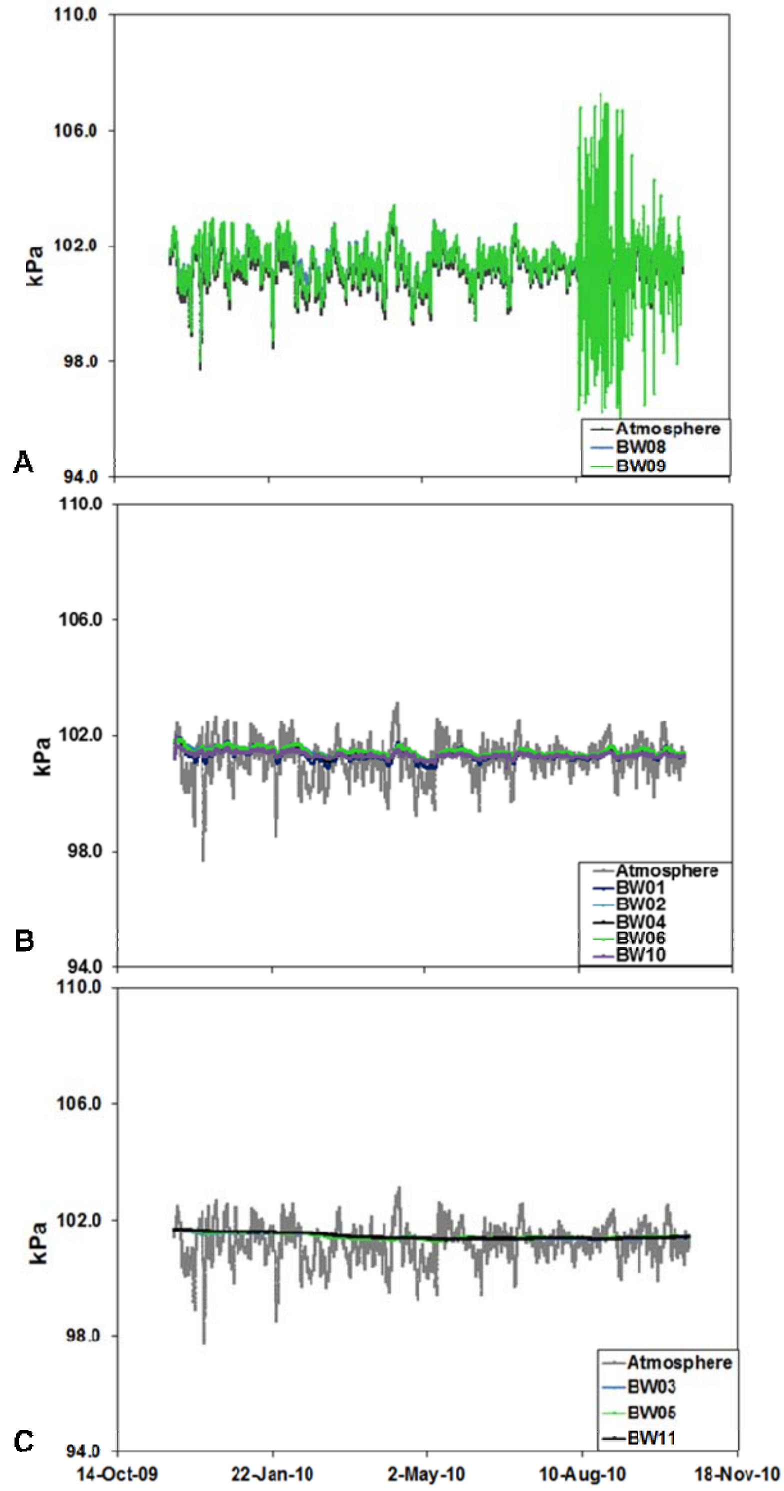

Figure 2.12. Barometric pressure cycles for group 1, 2 and 3 in comparison to yearly ambient atmospheric pressure between October 2009 and November 2010. (A) Wells BW08 and BW09; (B) Wells BW01, BW02, BW04, BW06, BW10; (C) Wells BW03, BW05, BW11.

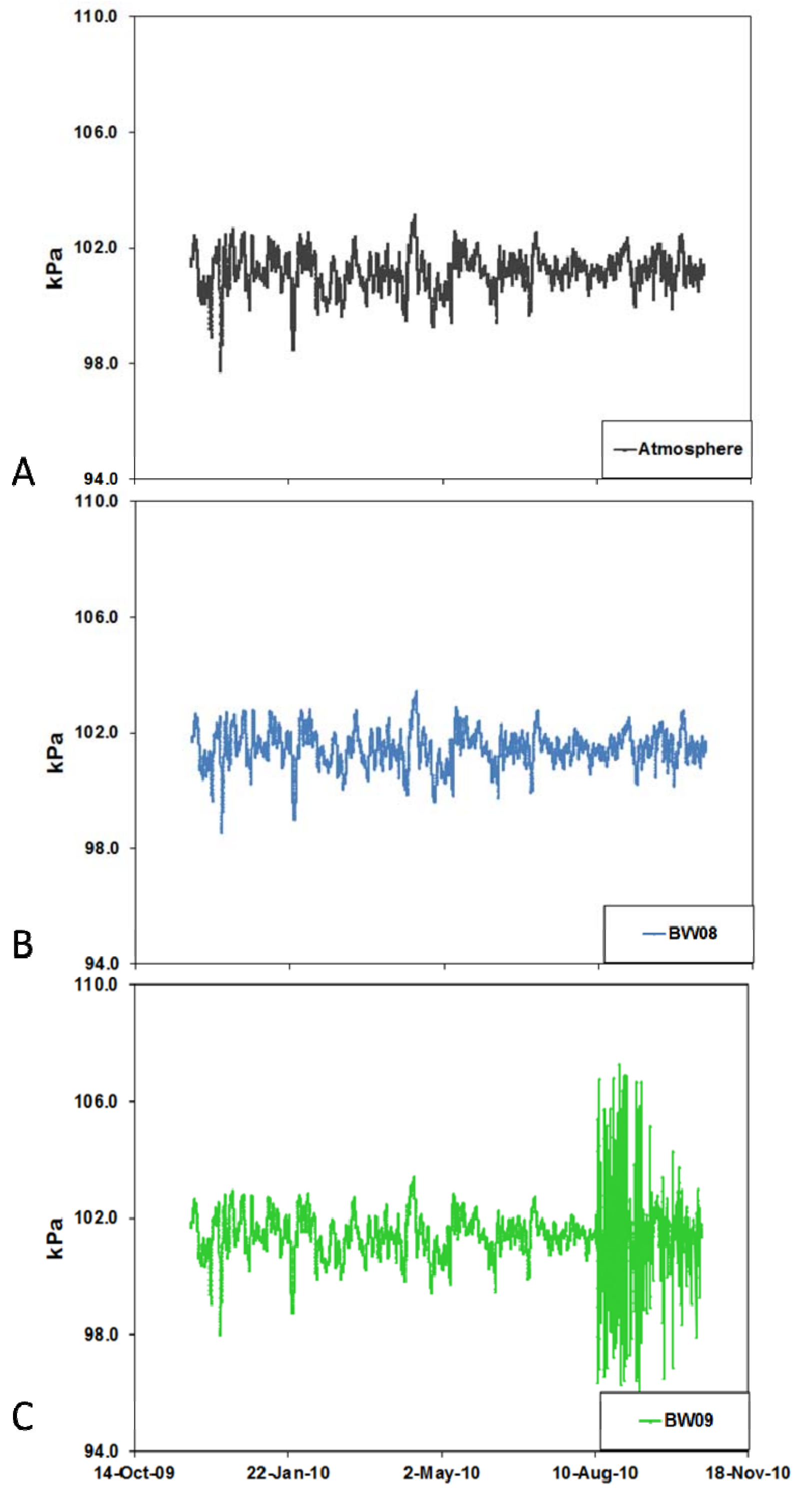

Figure 2.13. Barometric pressure cycles for group 1 between October 2009 and November 2010: (A) Ambient atmospheric pressure; (B) Local site BW08; (C) Local site BW09. The large variation observed at site BW09 is the result of barologger malfunction. These sites displayed a high interconnectivity to the atmosphere.

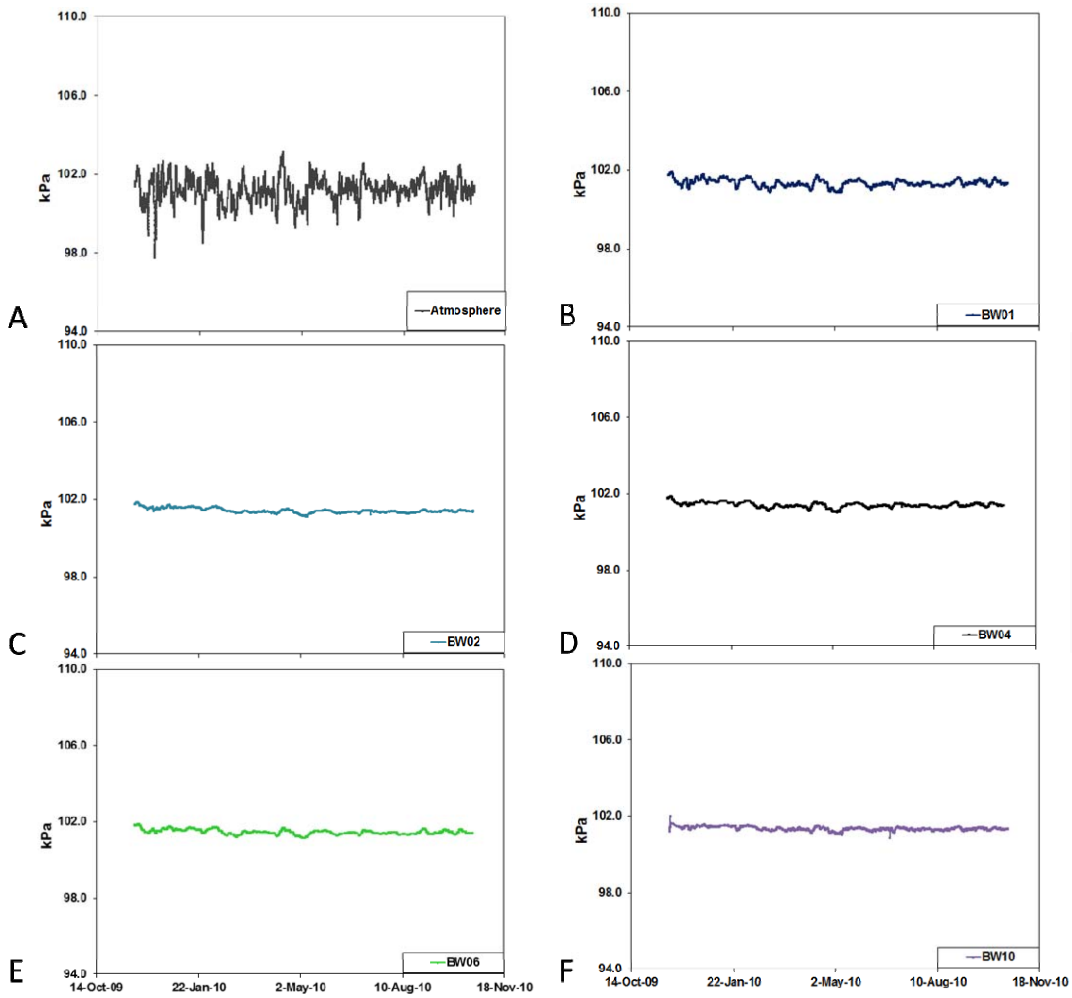

Figure 2.14. Barometric pressure cycles for group 2 between October 2009 and November 2010: (A) Ambient atmospheric pressure; (B) Local site BW01; (C) Local site BW02; (D) Local site BW04; (E) Local site BW06; (F) Local site BW10. These sites displayed a moderate degree of interconnectivity to the atmosphere.

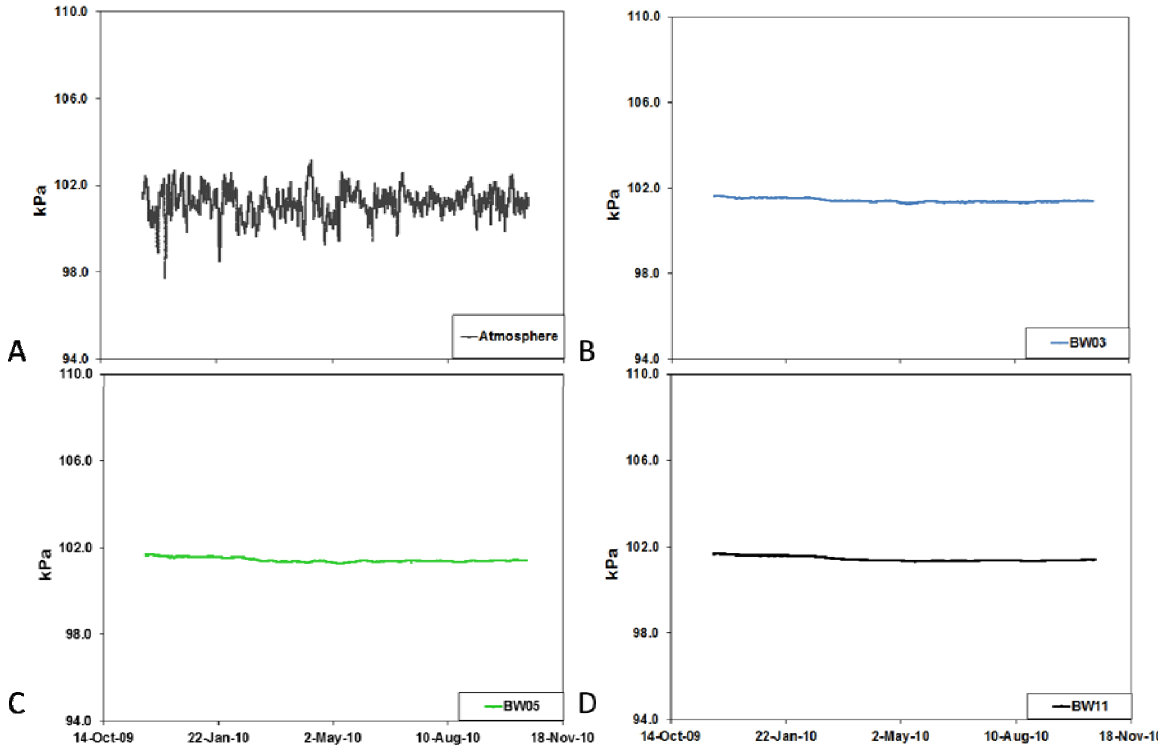

Figure 2.15. Barometric pressure cycles for group 2 between October 2009 and November 2010: (A) Ambient atmospheric pressure; (B) Local site BW03; (C) Local site BW05; (D) Local site BW11. These sites displayed a low degree of interconnectivity to the atmosphere.

fluctuations. Group 1 (Figure 2.12A & 2.13; BW08 and BW09) displayed an instantaneous response to atmospheric pressure fluctuations and hence is the group most connected to the atmosphere. Group 2 (BW01, BW02, BW04, BW06, and BW10) displayed an attenuated pattern of atmospheric pressure variations, suggesting that it is only moderately connected to the atmosphere (Figure 2.12B & 2.14). Group 3 (BW03, BW05, BW11) displayed little to no atmospheric pressure fluctuations throughout the year, suggesting that it has the least atmospheric connection (Figure 2.12C & 2.15).

The intensity to which wells exhaled and inhaled also varied spatially, field observations showed that sites BW08 and BW09 never displayed a 'breathing' behaviour, and therefore labeled as "non-breathing", while sites BW02 and BW10 had weak breathing, relative to sites BW06 and BW11 that had moderate breathing rates. Sites BW01, BW03, BW04, and BW05 were considered to be strong breathing wells. Each group displayed a lag time with respect to atmospheric pressure fluctuations (Figure 2.16).   Group 1 (non-breathing wells) displayed no lag time showing pressure changes being virtually instantaneous. Group 2 (moderately connected to the atmosphere) had lag time of 3 days or less. Group 3 (limited contact with the atmosphere) had the longest lag time, ranging from 6 to 9 days.

2.5 Discussion

2.5.1 Hydraulic flow in the BWZ

The horizontal hydraulic gradient and groundwater flow into the BWZ appears to occur from the northeast and eastern edges of the BWZ, with a general westward direction toward Lake Huron (Figure 2.11B). The observed steep hydraulic gradient in the center of the BWZ is consistent with reports by IWC (2003). The sudden change in horizontal gradients from steep in the east to flat in the centre and west indicates a change in transmissivity of the bedrock aquifer. Qualitatively, the eastern edge of the BWZ appears to have a lower transmissivity, where a sudden drop in flow gradients occurs from 271 to 178 m ASL over a ~15 km distance. This is in marked contrast to the center-western portion of the

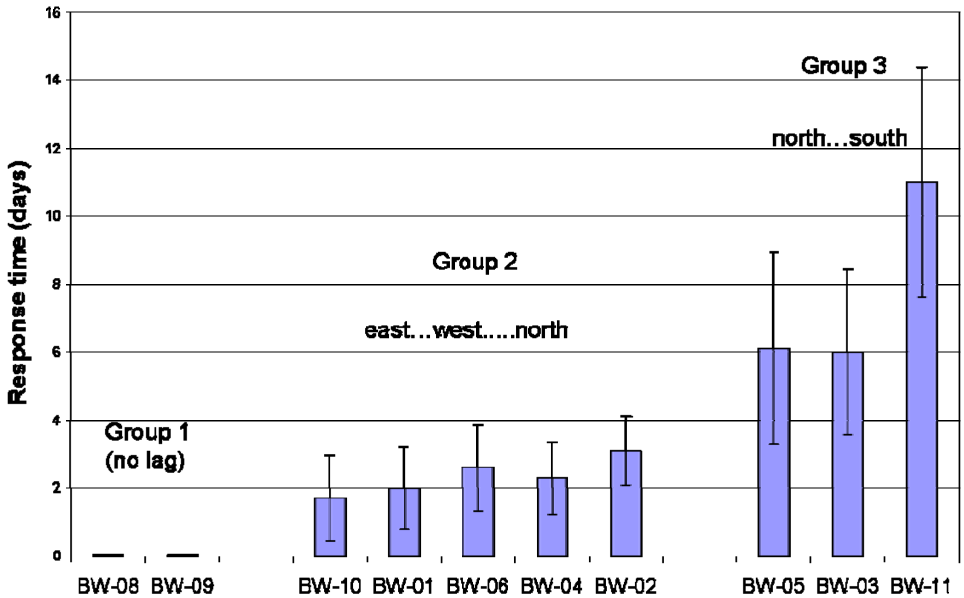

Figure 2.16. Average lag between major atmospheric pressure events and the corresponding barometric response in the breathing wells. Major changes in local ambient atmospheric pressure obtained at local site BW06 were compared against changes in barometric pressure in the wells. The error bars show ±1 standard deviation of the averaged response times.

BWZ, where the flow gradient change is ~5m for roughly the same distance. The flattening of the hydraulic surface indicates an environment with significantly higher transmissivity, and is suggestive that groundwater in this area is flowing through an area of significantly higher permeability.

It should also be noted that in the southwestern section of the BWZ, about 20 km from the southeastern edge of Lake Huron (near site BW02), the hydraulic gradient surface flattens out at ~178 m ASL (Figures 1.5 and 2.11B). When compared to Lake Huron's elevation of 177 m ASL, the presence of this broad hydraulic gradient region raises the possibility of karstic-driven hydraulic connection between the bedrock aquifer and the lake that extends further inland within the BWZ than outside of it. Biddanda et al. (2006) documented significant discharge of groundwater from submerged sinkholes and seeps in northwestern Lake Huron. The hydraulic gradient data suggest a similar process may occur on the eastern side of the lake.

The limited variation in water levels in the BWZ over the one-year sampling period (excepting site BW11) (Table 2.2; Figure 2.17) are suggestive of an aquifer that experiences high storativity. The significant amount of unsaturated porous space in the vadose zone would allow for little to no variation in waterlevels, even if recharge events were increased. It is therefore possible that the storativity of the BWZ groundwater aquifer is influencing the water level measurements.

2.5.2 Magnitude of breathing events in the BWZ

The exhaled gas flow measurements demonstrated that the magnitude and duration of breathing varied amongst the 10 locally monitored wells in the BWZ as follows: Group 1 (non-breathing), group 2 (moderately connected), group 3 (poorly connected). Regionally, non-breathing wells exist in areas where the Lucas Formation is thin (17-56 m), and active breathing occurs in areas where the Lucas Formation is thicker (95-122 m) (Figure 2.8D). Considering that a significant amount of void space must exist in the subsurface in order for the wells to breathe, and the duration in that wells inhale or exhale after the onset of a major atmospheric pressure event, the Lucas Formation must contain a vast area of unsaturated

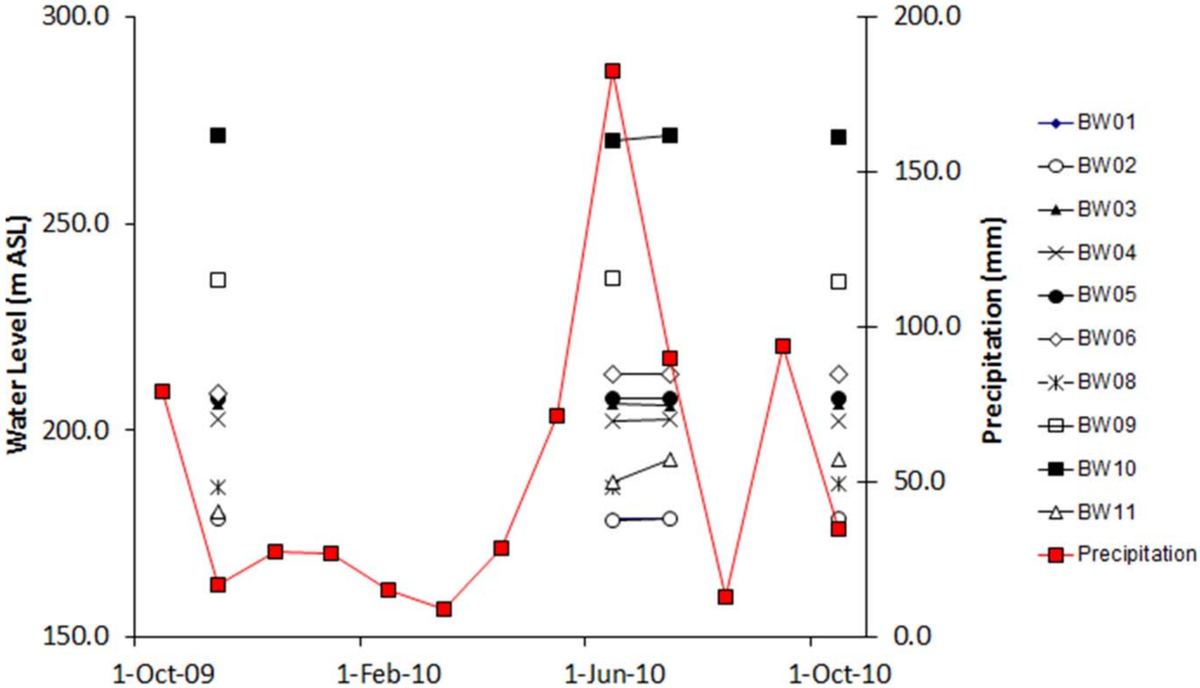

Figure 2.17. Hydrograph from October 2009 to November 2010. Water levels did not fluctuate significantly over the one-year time period for the 10 sites examined within the BWZ.

space. In Figure 2.10 it is apparent that Group 1 “non-breathing” wells are situated in areas where the well is drilled just below the Dundee-Lucas contact. More importantly, the well water levels are above the Lucas formation, which apparently results in a lack of unsaturated void space and eliminates their capacity to breathe. Figure 2.18 is an east to west representation of unsaturated void space clustered in groups based on breathing magnitude. As expected, the weakest breathing events occur at wells where the unsaturated unit is thinnest; moderate and strong breathing occurred at wells where the unsaturated interval of the Lucas Formation is between 22.1 to 57.5 m thick. The colours represent the approximate west-east position of the well and show that the location of the well in the BWZ is also an important factor contributing to the strength of the breathing. Spatially, the stronger breathing tends to occur at the center portion, where a narrow band of wells experience the strongest breathing events of the BWZ.

2.5.3 Spatial Barometric relationship in the BWZ

Significant subsurface barometric pressure fluctuations were observed during monitoring of the BWZ (Figure 2.12 to 2.15), ranging from 97.73 and 103.14 kPa. Generally, atmospheric pressure fluctuations caused by diurnal changes in the atmosphere arising from thermal and gravitational effects and by regional-scale weather patterns, with the latter being much more significant (Massmann and Farrier, 1992).

It was observed that three groups of wells existed within the BWZ. The most well connected wells (Group 1) are located 43 km apart but show very similar pressure patterns that, at the scale shown, are indistinguishable from the atmospheric pattern (Figure 2.13). By comparison, the down-hole pressure patterns observed for the other two groups indicate decreasing atmospheric influence from Groups 2 (BW01, BW02, BW04, BW06, and BW10; Figure 2.14), to 3 (BW03, BW05, and BW11; Figure 2.15) respectively. Figure 2.19 illustrates the spatial variance of wells subsurface gas flow movement, where over a 24 hour period on April 20, 2010 atmospheric pressure dropped from 101.6 to 100.8 kPa. Sites BW08 and BW09 (~101.9 to 101.2kPa) tracked this pressure drop most closely. Other wells showed less change, with sites located in the center of the BWZ being least affected.

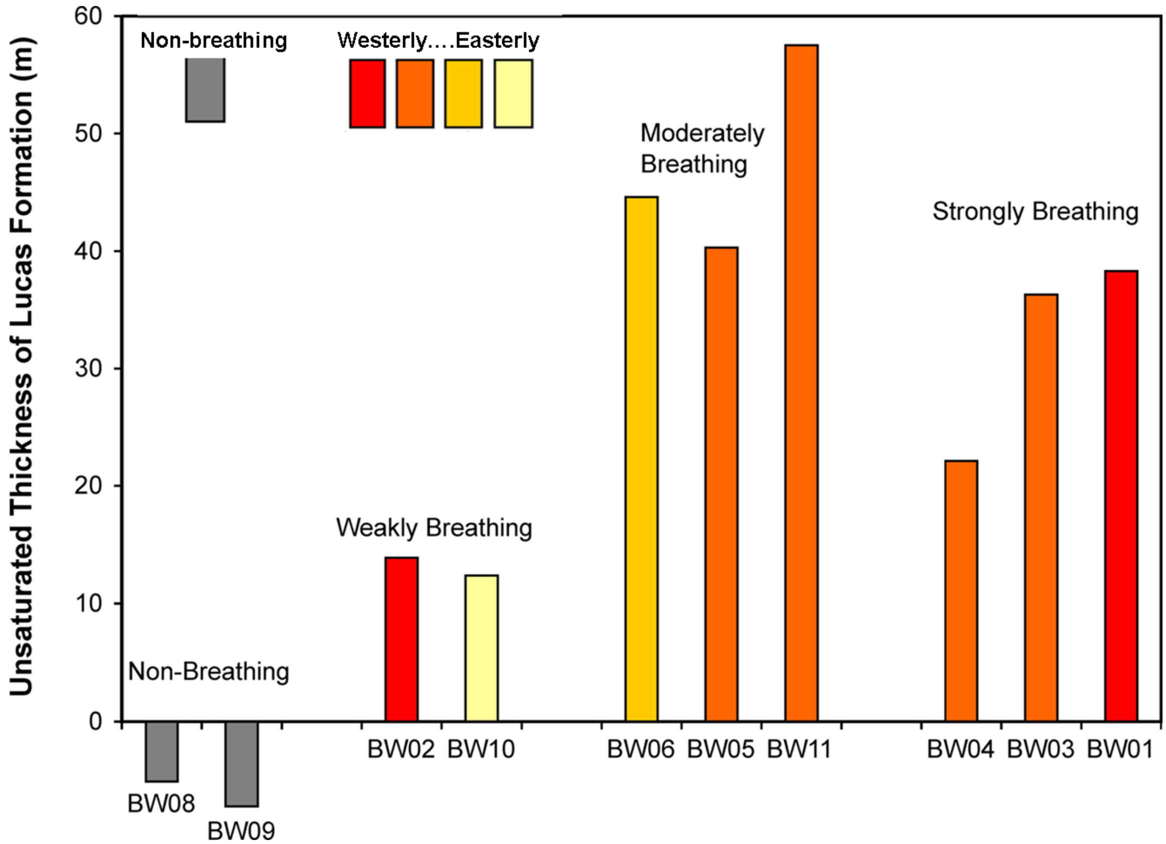

Figure 2.18. Chart showing unsaturated thickness of the Lucas Formation for each well. Wells are clustered into groups based on the strength of their breathing. Colours are an attempt to represent their approximate west-east configuration on a line perpendicular to the north-northwest axis of the BWZ. The figure demonstrates that unsaturated thickness is important but beyond 20 m of thickness, location of the well in the western half of the BWZ is of greater significance to the strength of breathing.

The classification of the three subsurface barometric groups demonstrates the interconnectivity of unsaturated zone and suggests that there are different subsurface gas flow systems. The spatial pattern that the groups form is in marked contrast to the pattern of hydraulic gradient interconnectivity in the system, but this is to be expected as the groundwater flow is dominated by gravity whereas the subsurface barometric gas movement is controlled by atmospheric pressure changes. It is the lag time measurements that best represent the possible pathways for subsurface air flow movement. In the non-breathing well's (BW08 and BW09) there is no lag is observed which is a result of little to no unsaturated space present in the Lucas Formation, and suggesting little to no subsurface spatial interconnectivity. Weakly, moderate and strong breathing wells appear to vary with respect to their lag times. Lag group 2 is comprised of weak, moderate and strong breathing wells, and lag group 3 is comprised of moderate to strong breathing wells (Figure 2.18). This is likely a result of variance in the vertical structures and features within the subsurface.

Each lag group, however has an identical subsurface pattern (Figure 2.12 & 2.16), suggesting that they are interconnected in the subsurface. Contrasting lag times between groups 2 and 3 suggests that there are two main flow systems: an eastward and northward flowing system and a southward flowing system. In group 2 the order of wells with respect to increasing lag time is BW10, BW01, BW04, BW06, and BW02. This suggests that air traveling in the subsurface possibly originates some where in the east (near site BW10), flows westward and gradually moves to the north. BW02, which shows a slightly different pattern to the other 4 in the group, takes the longest to respond indicating a poor connection to the subsurface gas conduit that connects the others. In group 3, the order of increasing lag time is BW03, BW05 and BW11. Unlike group 2, the wells do not have a sequential flow path. Site BW03 responds sooner than BW05 but this difference is slight, and the overall atmospheric connection is quite weak compared to other wells in the region. It is possible that the presence of sinkholes in this part of the BWZ, may provide multiple weak connections with the atmosphere.

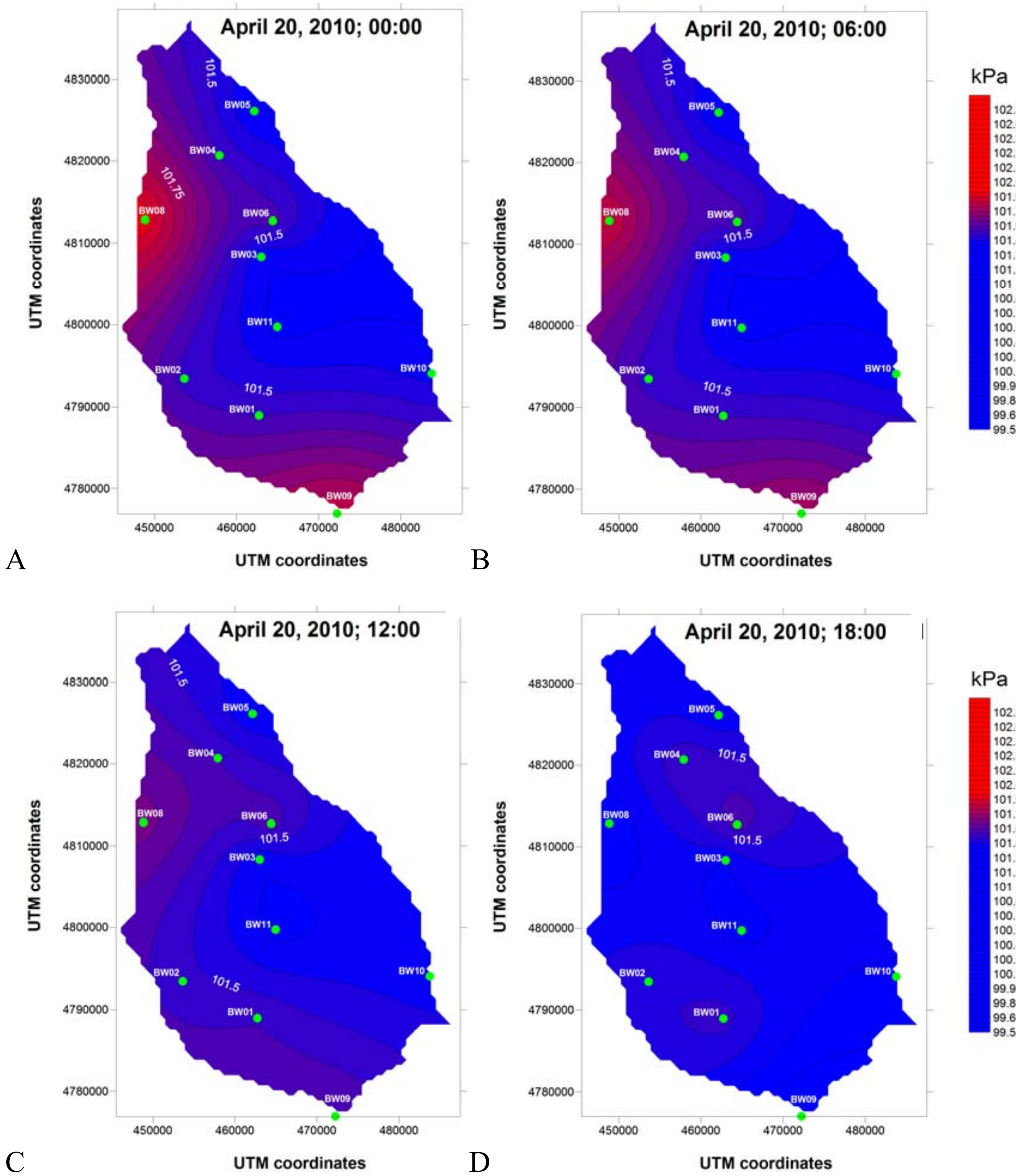

Figure 2.19. Altitude-corrected barometric pressure changes in the BWZ within a 24-hour period (April 20, 2010): (A) 00.00 hr; (B) 06:00 hr; (C) 12:00 hr, and (D) 18:00 hr, Eastern Standard Time. The change in barometric pressure between these diagrams represents the onset of a blowing phase due to the transition of an atmospheric low pressure system after a period of sustained high pressure.

2.6 Conclusions

This study demonstrates that Southwestern Ontario's BWZ has a variable hydraulic and subsurface barometric system. The local hydrogeological conditions of the BWZ, relative to the Lucas Formation aquifer elsewhere in southwestern Ontario, include deep static water levels, a sharp steepening in the hydraulic gradient from west to east in its central region, and a westerly groundwater flow direction. This difference in water level reflects a substantial increase in bedrock transmissivity, which likely reflects enhanced karst development at the western part of the BWZ. Hydraulically, there is only one system but with two different flow regimes. The easterly one is characterized by steep westward hydraulic gradients and moderate transmissivity and the westerly one by almost flat gradients and extremely high transmissivity.

The breathing events are controlled by changes in atmospheric pressure; however, their magnitude varies both spatially and temporally. Some local BWZ sites are well connected to the atmosphere, matching its fluctuations almost instantaneously (sites BW08 and BW09), while other sites have very limited to no atmospheric connection (e.g., site BW11). Sites with the strongest atmospheric connection breathe the least and are located on the edge of the BWZ corresponding to areas where (i) the Lucas Formation is thinnest, (ii) wells are completed within the uppermost portions of the Lucas Formation, and (iii) static water levels lie within or near the overlying Dundee Formation. Wells that have the strongest breathing events appear to be located in the western-center portion of the BWZ and correspond to areas where (i) the Lucas Formation is thicker, (ii) wells penetrate 20 to 57 m of unsaturated Lucas Formation (iii) and static water levels lie within the Lucas.

There appears to be two subsurface gas flow systems within the BWZ; a north trending system that is moderately connected to the atmosphere with an atmospheric lag response of less than 2 days and a southern trending flow system with a weak atmospheric connection that has a lag response time of 4 to 9 days. This area and concept, however, warrant further investigation.

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Chapter 3

3 A Regional and Local Hydrochemical Characterization of Southwestern Ontario's Breathing Well Region

3.1 Introduction

A zone of breathing water wells (BWZ) in a carbonate bedrock aquifer exists in southwestern Ontario in an area susceptible to karstic development and processes. Breathing wells are water wells that, depending on atmospheric pressure fluctuations, either inhale or exhale air (Bates and Jackson, 1987). Certain subsurface conditions are required for a well to breathe; the well must have been drilled though a confining layer and be uncased, in the unsaturated zone, and considerable void space mush exist above the water table. One phenomenon associated with breathing wells is that the exhaled gases are commonly hypoxic. While atmospheric concentration of oxygen (O_2) and carbon dioxide (CO_2) (~21.0 % and 0.04 %, respectively) are drawn into the well, concentrations as low as 1.7 % O_2 and as high as 3.4 % CO_2 are emitted. Similar observations were made for breathing wells located in Alberta, Canada (Hill, 2004), where strong movement exists for gas exchange between the atmosphere and subsurface, as determined by barometric pressure measurements. In Alberta exhaled gas compositions were reported as 0.6 % CO_2, 8.7 % O_2, and 90.7 % Nitrogen (N) (Hill, 2004). It was found that gases emitted during falling barometric pressure events were produced by subsurface organic and inorganic reactions that consumed available O_2 and produced CO_2 and N (from subsurface denitrification of NO_3^-).

The BWZ in southwestern Ontario results from the occurrence of significant unsaturated void space within the Lucas Formation. This Middle Devonian carbonate formation is composed of limestone and dolostone interbedded with mostly anhydrite evaporites. Karstic dissolution features, such as collapsed breccia and cavern-like void spaces, exist both above and below the water table within the Lucas Formation, providing unsaturated space for gas exchange between the atmosphere and subsurface. Carbonate aquifers that are porous, fractured and contain karstic features, such as the Lucas Formation, are commonly poorly understood because of their inherent spatial heterogeneity. They can experience a range of karstic modification, varying from the classic conduit-dominated, fast-flowing, subsurface networks to environments comprising small-scale fissures and fractures, and bedrock matrices with interconnected microporosity that facilitate diffuse flow of water (Ford and Williams, 2007; Worthington, 2003).

The BWZ region in southwestern Ontario is riddled with karstic features, such as sinkholes and disappearing streams. However, the degree to which these features extend into the subsurface is poorly understood. The geology, hydrogeology and karstic features of the Lucas Formation and the sinkhole region have been discussed in several studies (e.g., Abbey et al., 2004; Armstrong and Carter, 2010; Birchard et al., 2004; Brunton and Dodge, 2008; Brunton et al., 2005; Hurley et al. 2005, 2008; International Water Consultants (IWC), 2003; Johnson et al., 1992; Karrow, 1974, 1977; Singer, 2003). However, the BWZ and its water chemistry have been described only briefly in the past (Freckelton et al., 2010; Hamilton and Braunder, 2008; Hamilton and Freckelton, 2009; Hurley et al., 2008; IWC, 2003; Waterloo Hydrogeologic Inc. (WHI), 2003; 2004; 2006). Previous water quality analysis of the area reported greater surface and aquifer interconnectivity in monitoring wells near sinkholes compared to wells farther from sinkholes. However, in bromide tracer tests, bromide was not detected in any of the monitoring wells (Hurley et al., 2008; WHI, 2006).

The Lucas bedrock aquifer is the primary source of both agricultural and potable water within the study area, and hence it is of great public interest to understand this aquifer and its breathing behaviour. It is particularly vulnerable to natural and anthropogenic influences because of its potential for rapid receipt of surface runoff. This investigation, therefore, is aimed at understanding the hydrodynamics and hydrochemistry of the breathing well zone aquifer system at both regional and local scales. Spatial and temporal heterogeneity are typical of karstic environments, and water chemistry can vary significantly over short distances and time (Goldscheider et al., 2007). Hence, the primary objectives of this study are to: (1) Identify the major hydrochemical facies, determine the origin, and define the geochemical evolution of the groundwater; (2) Characterize the hydrochemical variability of groundwater within the BWZ over a one-year period, and identify the main reactions controlling the hydrochemistry; and (3) Determine the cause of oxygen depletion in exhaled gases from the breathing wells. Parameters include major, minor and trace element concentrations in the groundwater, the stable isotopic compositions of oxygen and hydrogen in the groundwater ($\delta^{2}H_{H2O}$ & $\delta^{18}O_{H2O}$), sulphur and oxygen in dissolved sulphate ($\delta^{34}S_{SO4}$ & $\delta^{18}O_{SO4}$), and the tritium content of the groundwater (^{3}H and $E^{3}H$), in addition to compositional analysis of the expelled gases from the breathing wells.

3.2 Geological and Hydrogeological Setting

3.2.1 Geological Setting

The regional study area is situated in the central part of southwestern Ontario (~43°22'N, 81°45'W), and is 9,000 km^2 in size (Figure 1.1 and 1.5). This area mainly encompasses the townships of Huron and Perth counties, and is bounded by Lake Huron on its western edge. The local BWZ study area is located in the center of the regional study area and is 1400 km^2 in size.

Regionally, thick glacial overburden (up to 85m) overlies the Paleozoic strata; hence bedrock outcrops are rare. During the Pleistocene glaciation continental ice sheets covered all of Ontario, and advanced and retreated several times. The glaciers scoured the bedrock, reworked previous glacial deposits, and deposited new surficial material that consists of laterally extensive subglacial till sheets and outwash composed of clay, sand and gravel, which are now situated in till plains and moraines. The till sheets act as aquitards and the smaller-scale fluvial sands and kame deposits as aquifers (Barnett, 1992; WHI, 2006). Groundwater aquifers are also found in the underlying carbonate bedrock. The majority of the overburden till has low permeability, and therefore most wells are completed into the deeper bedrock aquifer (IWC, 2003).

Numerous sinkholes have been identified in areas of thin overburden within the study region, particularly in the St. Marys region (Karrow, 1977) and southern portions of Huron County (Clinton, Zurich and Hensall areas) (Hurley et al., 2008; IWC, 2003; WHI, 2003, 2004, 2006). Sinkholes are considered to be topographic indicators of subsurface karst, and are circular to sub-circular cone-shaped surficial depressions (Ford and Williams, 2007).

Sinkhole diameters in the BWZ are up to ~35 m and depths are up to~10 m (Hurley et al., 2008; WHI, 2003, 2004; 2006).

The Precambrian basement beneath the Paleozoic sediments in the study area consists of metamorphosed crystalline rocks of the Canadian Shield. The earliest sedimentary strata were deposited during the Late Cambrian to Early Ordovician, a time when Ontario was located in tropical latitudes and intermittently covered by inland seas (Armstrong and Carter, 2010). During the Silurian and Devonian periods, intervals of uplift and subsidence of the Canadian Shield modified depositional environments to alternate between shallow and deep, facilitating deposition of up to 1500 m of interbedded shallow-water carbonates and sandstones, and deeper-water shales and siltstones. A broad basement ridge, called the Algonquin Arch, trends southwestward across southern Ontario. During the Paleozoic the Algonquin Arch influenced sediment deposition, causing the strata to either dip southeast towards the Appalachian Basin or westward into the Michigan Basin. The foreland Appalachian Basin has a regional dip of 6 m/km, is elongated in shape, reaches a maximum thickness of 13,000 m, and is siliclastic in nature (Johnson et al., 1992; Winder and Sanford, 1972). The intracratonic Michigan basin is circular in shape, has a regional dip of 6 to 9 m/km, reaches a maximum thickness of ~4,800 m and consists predominantly of carbonate rocks (Johnston et al., 1992; Winder and Sanford, 1972). During much of the Paleozoic, the Algonquin Arch ridge acted as an open shallow-water barrier or a transition zone between the Michigan and Appalachian basins. Intermittent uplift of the Algonquin Arch continued until the late Devonian, resulting in lateral shallowing of the bedrock strata over the arch. Prior to glaciation, there was a 300 million year period of non-deposition, where the Paleozoic bedrock surface was exposed to erosion and weathering. During the period of prolonged exposure, the upper bedrock surface experienced intense fracturing, thus increasing its transmissivity (WHI, 2006).

The subcropping Paleozoic bedrock within the regional study area, in order of oldest to youngest, consists of the Salina, Bass Island, and Bois Blanc Formations, Detroit River Group (Amherstburg and Lucas formations), Dundee Formation, Hamilton Group, and Kettle Point Formation (Figures 1.5 and 2.3). The Salina and Bass Island Formations are the youngest Silurian rocks in southwestern Ontario, and are located in the northeastern corner of the study area. The Salina Formation is divided into eight lithostratigraphic members (A-1, A-2, B, C, D, E, F, and G), which are successions of evaporites (halite) and evaporitic carbonates and shales deposited in a subtidal through supratidal to terrestrial environment. The Salina Formation in the Michigan Basin area is dominated by carbonates and evaporites, whereas in the Appalachian Basin, it becomes progressively argillaceous and dolomitic as it becomes younger (Johnston et al., 1992). The Bass Island Formation is the uppermost Silurian unit, lying conformably on the Salina Formation, and is composed of sparsely fossiliferous, brown to tan microcrystalline dolostones, bituminous streaks, and evaporite mineral molds. This unit was deposited in an intertidal to supratidal environment (Johnson et al., 1992). The lower Devonian Bois Blanc Formation rests on the Devonian-Silurian unconformity above the Bass Island Formation. The Bois Blanc is composed of blue-grey chert nodules and fossiliferous limestone deposited in a shallow marine environment (Johnson et al., 1992). The Middle Devonian Detroit River Group is comprised of the Amherstburg and Lucas formations. The Amherstburg Formation conformably and gradationally overlies the Bois Blanc Formation, and is composed of fossiliferous, bituminous, commonly cherty limestones and dolostones deposited in a shallow marine environment (Johnson et al., 1992). The Lucas Formation is composed of microcrystalline limestone and dolostone, which alternate with mainly anhydrite evaporitic beds and local sandy limestones. Needle-like porosity in this unit is likely a result of evaporite mineral dissolution. The Lucas Formation formed in a peritidal sabka setting (Armstrong and Carter, 2010; Johnson et al., 1992; WHI, 2006).

The Dundee Formation, which makes an unconformable contact with the Lucas Formation, is a richly fossiliferous, medium- to thick-bedded, grey to tan to brown micritic limestone, with minor dolostone. These rocks were deposited by shallow seas several million years after the Lucas Formation had been deposited (Armstrong and Carter, 2010; Johnson et al., 1992). This unit is the dominant subcropping bedrock in the study area, but in certain locations, the underlying Lucas Formation forms ‘windows’ through the Dundee Formation, particularly in the northwestern part of the BWZ (near the towns of Hensall and Zurich). The Hamilton Group overlies the Dundee Formation and is composed of calcareous shales and limestones deposited in a shallow marine environment. The Hamilton Group is subdivided into six formations named the Bell, Rockport Quarry, Arkona, Hungry Hollow, Widder and Ipperwash Formations (Singer et al., 2003), but it is considered as a single unit for this study. The southwestern most unit in the study area is the late Devonian Kettle Point Formation, which disconformably overlies the Hamilton Group. The Kettle Point Formation is composed of brown to black, organic-rich shale, silty shale and siltstone, interbedded with less abundant grey-green, organic-poor silty shale, and has little or no carbonate content. This unit was deposited in a marine environment (Johnson et al., 1992).

3.2.2 Hydrogeological Setting

The study area lies within the Lake Huron Basin Watershed with regional groundwater recharge occurring in the east/northeast of the study area, and westward flow gradients toward Lake Huron (Freckelton et al., 2010; IWC, 2003). Regionally, the Lucas Formation bedrock aquifer is the most commonly used aquifer; the overlying Dundee Formation does not contain significant amounts of water, except where it is fractured or along the contact with glacial drift (Armstrong and Carter, 2010).

In Huron Country, water elevations from the Dundee Formation range from 146 m ASL to 293 m ASL; water elevations from the Lucas Formation are deeper and range from 141 m ASL to 358 m ASL (IWC, 2003). The hydraulic gradient surface follows the general trend of the topography, with local recharge occurring in areas of higher elevation and discharging to lower elevations near the edge of Lake Huron Variation in the BWZ's hydraulic gradient occurs, with northeastern broad gradients in contrast to central tight gradients (Figure 2.11B). Water levels in the BWZ varied between 180 and 265 m ASL. These features are likely a result of a change in transmissivity within the bedrock aquifer (Freckelton et al., 2010; IWC, 2003). Likewise, hydraulic conductivity values of wells from Huron County range from 10^{-4} to 10^{-5} m/s, with values as high as 10^{-3} m/s reported (IWC, 2003). Such values are typical of karstic terrains (10^{-7} to 10^{-3} m/s), whereas (non-karstic) limestone and dolostone have lower values ($10^{-6.5}$ to $10^{-9.5}$ m/s) (Freeze and Cherry, 1979).

The upper portion of the Lucas Formation contains karstic features such as evaporite dissolution brecciation, and large vuggy zones (up to 5 cm in length) (Figure 2.7) (Hurley et al., 2008; WHI 2006). Their development was likely facilitated by extended subaerial exposure and weathering, which led to development of fractures, faults and solution channels in the upper portion of the Lucas Formation prior to Dundee Formation deposition (Hurley et al., 2008; WHI, 2006). However, previous studies have not been able to confirm a correlation among the position of the water table and hydraulic conductivity (Hurley et al., 2008).

3.3 Methods

The regional and the local investigations were conducted in two separate sampling campaigns. The regional geochemical dataset contains information for 102 wells that surround the BWZ and was obtained from the Ontario Geological Survey's (OGS) Ambient Groundwater Sampling Program dataset (Hamilton, 2011). Water samples were obtained from wells drilled into 8 different formations (from oldest to youngest): Salina (n=7), Bass Island (3), Bois Blanc (8), Amherstburg (9), Lucas (48), Dundee (19), Hamilton Group (7), and Kettle Point (1) (Figure 2.9C). For the local study, 10 wells within the BWZ were selected and water samples obtained monthly (from November 2009 to October 2010). These sites were originally sampled once as part of the OGS's Ambient Groundwater Sampling Program, and selected for more detailed study based on their geographical distribution within the BWZ. All of these wells are drilled into the Lucas Formation or near to the Lucas-Dundee unconformable contact with the overlying Dundee Formation (Figure 2.10).

Sample collection, and field and laboratory methods for the both the regional and local campaigns are described below. Additional information concerning field techniques and quality control procedures for the OGS Ambient Groundwater Sampling program are provided by Hamilton et al. (2007), Hamilton and Braunder (2008), Hamilton and Freckelton (2009), and Hamilton et al. (2010, 2011).

3.3.1 Sampling and Laboratory Procedures

Water samples were collected from residential domestic wells and farm wells. Fresh, untreated well water was retrieved using the existing pump and distribution systems. Special care was taken to bypass treatment systems, where present. As required, a 3 or 15 m long nylon-braided, 22 mm inside diameter, clear polyvinyl chloride (PVC) hose was attached to the sampling point using a nylon garden-hose attachment. The other end of the hose was attached to a manifolded group of similar hoses that divided into three separate lines. One line was connected to a flow-cell, the second to a 0.95 cm silicone rubber sampling hose, and the third to a plastic quick-connect fitting attached to a garden-hose for high-flow purging. Water was purged through this system at a high flow rate until stable readings for temperature, pH, conductivity, and oxidation-reduction potential were detected. These measurements were made using a YSI® model 600LXM sonde with an Archer® hand-held field personal computer interface equipped with HydroPlusCE® logging software, which was connected to the flow cell. The pH and conductivity electrodes were calibrated in the field using appropriate standards prior to sampling. The YSI equipment was not used during freezing months and instead, a fixed purge volume was used, based on past experience of the purging requirements of each well.

3.3.1.1 Sample Collection

Water was typically collected from each regional sampling site in 10 separate bottles, which were then used for the following measurements: cations, anions, mercury, iodide, bacteria, nitrate (NO_3^-) /nitrite (NO_2^-), ammonia (NH_3)/total Kjeldahl nitrogen (TKN)/organic nitrogen, dissolved inorganic carbon (DIC)/dissolved organic carbon (DOC), dissolved gases (i.e., methane (CH_4), carbon dioxide ($CO_{2(g)}$), and water stable isotopes (δ^2H and $\delta^{18}O$). Parameters measured in the field included alkalinity, dissolved hydrogen sulphide (H_2S), and dissolved oxygen (DO). When the field measurement equipment was being used during the monthly sampling campaign, the same measurements were made. Typically, however, only four water bottles were collected at each local site each month, and used for analysis of cations/metals, anions, water stable isotopes (δ^2H and $\delta^{18}O$), and DO. On specific dates, additional samples were collected during the local campaign for measurement of the concentration and stable isotopic compositions of dissolved sulphate ($\delta^{34}S_{SO4}$ and $\delta^{18}O_{SO4}$), and non and enriched Tritium (^3H and E^3H).

Water samples for cations, anions and mercury (Hg) were pressure-filtered into 60 mL polyethylene bottles and filtered on site using 0.45 µm Millipore™ Durapore® (polyvinlidene fluoride (PVDF)) membrane filters and rubber-free polypropylene syringes. Cation/metals and mercury were then acidified using 1 % (vol.) J.T. Baker® Ultrapure nitric acid (HNO_3) (to pH<2) and 2 % (vol.) Fisher Chemical Optima grade (HCl) acid, respectively. Iodide (I^-) was sampled in 60 mL polyethylene bottles, not filtered, and preserved with 3 % 0.2 M nickel acetate ($Ni(CH_3COO)_2$). Nickel acetate was added to precipitate sulphide (S^{2-}), which could interfere with I^- analysis. Bacteria (total and fecal coliform) samples were collected in 250 mL sterile HDPE bottles, unfiltered, and preserved using sodium thiosulfate pentahydrate ($Na_2S_2O3\ 5H_2O$). Nitrate (NO_3^- as N) and nitrite (NO_2^- as N) were sampled in 60 mL PET (polyethyene terephthalate) bottles, unpreserved and unfiltered. Ammonia ($NH_3 + NH_4$ as N), total Kjeldahl nitrogen (TKN as N) and organic nitrogen were sampled in 60 mL amber bottles, unfiltered, and preserved with sulphuric acid (H_2SO_4). Samples for DIC and DOC were unfiltered, unpreserved and sampled in a 125 mL polyethylene bottle. Dissolved gases were sampled using 1L (total volume 1175 mL) boro-silicate glass graduates storage bottles filled with 600 mL of water. After 24 hours the 575 mL headspace was measured for CH_4, CO_2 and O_2, using a Linweld® Eagle portable multigas detector. A two-point calibration for the measured methane was achieved using 2 methane standards (50 % and 1 % (10,000 ppm) CH_4, respectively) and using fresh air as a zero methane adjustment. Carbon dioxide was calibrated using 2.5 % CO_2 in a balance of air, and for oxygen, using air (20.9 % O_2). Dissolved gas concentrations in the water were then calculated using Henry's Law (Hamilton, 2011; S. Hamilton, pers. Comm. (2012)).

For δ^2H and $\delta^{18}O$ of water, 60 mL polyethylene bottles were completely filled with unfiltered water. Samples for dissolved sulphate (SO_4^{2-}) isotopic analysis were collected in 1 L glass bottles, unfiltered and unpreserved. Samples collected for measurement of Tritium samples were unfiltered, unpreserved and placed into polyethylene bottles: 50 mL for non-enriched tritium (^3H) and 250 mL for enriched tritium (E^3H). All water samples were placed immediately in coolers with ice packs for transport to the laboratory and maintained at

4 °C until analysis was completed.

The composition of the exhaled well gases was determined both in field and in the laboratory. In the field, well gas analysis (CH_4, O_2 and CO_2) was accomplished by emplacing 1 m long, 0.6 cm ID silicone rubber tubing attached to a Linweld® Eagle portable multigas detector into the well casing during blowing phases. The top of the well was then loosely covered to restrict contamination by atmospheric gases but to still allow exhalation of gases. Gas samples obtained for laboratory analysis were stored in 1 L PET (polyethyene terephthalate) bottles with butyl septum lids. They were collected in the field by placing a 1 m long, 0.6 mm ID silicone rubber tubing into the well, through which gases were pumped using a peristaltic pump into an inverted gas sample bottle filled with well water and submerged in a 20 L bucket filled with well water. A bactericide capsule was added to the gas sample bottle once it was full. The bottle was then tightly sealed using a cap-mounted septum, and placed into an ice-filled cooler.

3.3.1.2 Analytical Methods

Alkalinity, hydrogen sulphide (H_2S) and DO concentrations were measured directly at the sample site. Alkalinity was determined by titration to the bromocresol green-methyl red end point using a HACH 16900-01 digital titrator (detection range: 10 to 4,000 mg/L). Bicarbonate (HCO_3^-) was determined using a direct linear conversion from alkalinity (alkalinity was divided by 0.8202), which assumes that all alkalinity is due to bicarbonate. Dissolved H_2S concentration was determined by the methylene-blue method using a HACH model 2238-01 test kit, with an upper limit of 11.25 mg/L. DO concentrations were also measured using a HACH Azide modification of Winkler Method 8215 (Hach Company, 2006), using a 16900 digital titrator and a 300 mL biological oxygen demand (BOD) bottle.

Iodide (I^-) was measured in the field within 24 hours of sampling. During 2007 and 2008, analyses were made using an Orion 9453BN Iodide Ion Selective Electrode (ISE) connected to a personal computer via an Orion Sensorlink PCMCIA card. This configuration allows continuous logging and real-time data recording of I^- in mV, which were then converted to ppb. During 2009, the same model of probe was used with an Orion 4-Star portable pH/ISE meter with units reported in parts per billion (ppb). The probe for both instruments was calibrated using 10^{-5} M (1267 ppb) and 10^{-7} M (12.67 ppb) iodide standards.

Major and minor cation and anion concentrations were determined at Geoscience Laboratories (GeoLabs) in Sudbury, Ontario, Canada. Cation concentrations, other than Hg, were determined either by Inductively Coupled Plasma -Mass Spectroscopy (ICP–MS) or Inductively Coupled Plasma-Atomic Emission Spectroscopy (ICP–AES). Elements analyzed by ICP-MS (GeoLabs method reference codes: IMX-CUS, IMW-100 and IMC-100) were determined using a Perkin Elmer Elan 9000 ICP–MS instrument for both open and closed-beaker digestions. Precision and accuracy range from ±10 % relative standard deviation (RSD) close to the limits of quantification (LoQ) to 2 – 8 % RSD at moderate to high concentrations for most elements. For Sb, Bi, Mo, Sn, W, Cu, Hf, Pb and Ni, however, precision of better than ±10 % RSD requires concentrations that are at least 10 to 100 times the limit of quantification (Burnham, 2008; Burnham and Schweyer, 2004). Elements analyzed by ICP-AES were determined using a Teledyne Leeman Laboratories Prodigy ICP AES-Radial View instrument (Geolabs method reference codes: IAX-CUS, IAW-CUS, IAW-200). Precision for this method is better than ±5 % (2σ) of the true value of the sample at concentrations exceeding the lower limit of quantification (LLoQ). The LLoQ is defined as the average procedural blank plus 10 times its standard deviation. The accuracy of this method is better than ±5 % (Pamer, 2007).

Anion concentrations were analyzed by Ion Chromatography (IC), using a dual-pump system ion chromatograph, Dionex model ICS-3000, (Geolabs reference method ICW-100 or ICW-CUS). Three IC methods were used: carbonate eluent, potassium hydroxide eluent, and Dual analysis (Pamer, 2011). Hg samples were analyzed by Atomic fluorescence spectrometer, using a bromine/chlorine (BrCl) overnight digestion method (Geolabs reference method HGW-100) (Palmer, 2008) adapted from the EPA 1631e and EPA 245.7 protocols (Telliard, 2002; 2005).

Bacterial (total and fecal coliform), NO_3^-, NO_2^-, NH_3/NH_4, TKN, and organic nitrogen samples were analyzed by SGS Analytical laboratories in Lakefield, Ontario, Canada, within 24 hours of collection. Total coliform counts were determined using membrane filtration following the Ontario Ministry of the Environment and Energy (OMOE) protocol (SGS reference method MTH-MICRO-1; MICROMF-E3407A procedure). Fecal Coliform counts were also determined by membrane filtration (SGS reference method MTH-MICRO-4: 9222 D Fecal Coliform Filter Procedure) (Standard Methods for the Examination of Water and Waste Water 21st edition). NO_3^- (as N) and NO_2^- (as N) were analyzed using a Dionex Ion Chromatograph (SGS reference method MTH-CHR-1) following the United States Environmental Protection Agency (EPA) protocol 300.1 (Hautman and Munch, 1997). NH_3 /NH_4 (as N) were analyzed using a Skalar Segmented Flow Autoanalyzer (SGS reference method MTH-EWL-37) following the 4500-NH_3G protocol (Standard Methods for the Examination of Water and Waste Water 21st edition). TKN (as N) was determined using a Skalar segmented flow autoanalyzer (SGS reference method MTH-EWL-32), following protocols 4500-N C and 4500-NO_3^- F (Standard Methods for the Examination of Water and Waste Water 21st edition).

Stable oxygen, hydrogen, and sulphur isotopic results are reported in the standard δ-notation in parts per thousand (‰) relative to Vienna Standard Ocean Mean Water (VSMOW) for oxygen and hydrogen and VCDT for sulphur (Coplen, 1996; Krouse and Coplen, 1997). Stable isotopic analyses of hydrogen (δ^2H) and oxygen ($\delta^{18}O$) in water were performed at the Laboratory for Stable Isotope Science (LSIS) at the University of Western Ontario, London, Ontario, Canada, using a Picarro® L1102-I δ^2H and $\delta^{18}O$ Water Isotope Analyzer and a two-point VSMOW-SLAP calibration. For oxygen, in-house water standards analyzed during this study had average $\delta^{18}O$ values of -13.0±0.1 ‰ (n=21) and -7.2±0.1 ‰ (n=72), which compare well with their accepted values of –13.08 ‰ and -7.27 ‰, respectively. Reproducibility for samples was better than ±0.04 (n=16). For hydrogen, in-house water standards analyzed during this study had average δ^2H values of -107.8 ± 0.6 ‰ (n=21) and -54.9±0.6 ‰ (n=72), which compare well with their accepted values of –108.1 ‰ and -56 ‰, respectively. Reproducibility for samples was better than ±0.14 (n=16). Sulphate isotopic analyses ($\delta^{34}S_{SO4}$ and $\delta^{18}O_{SO4}$) were performed by the University of Waterloo-Environmental Isotope Laboratory (uwEILAB) using Ba-sulphate precipitation (Morrison et al., 1996; 1997; Rees, 1984) and a Micromass IsoChrom-EA. Radioisotope analysis of groundwater tritium (^3H), both enriched and non-enriched, were performed at IT^2

Isotope Tracer Technologies Inc. in Waterloo, Ontario, Canada. Tritium concentrations were counted directly for non-enriched tritium samples. However, in many cases low levels of tritium were not measurable, and therefore those samples underwent an enrichment process during analysis. For enriched sample measurement, the electrolytic enrichment process (concentration ≥15x) and liquid scintillation counting (LSC) (Protocol 1.0 Rev. 0.4 2010-05-12; Taylor, 1975) procedures were used. Results are reported in tritium units (TU) calibrated to NIST SRM-4361 where 1 TU is equivalent to 3.26 pCi/L or 0.11815 Bq/L. The detection limit for non-enriched samples is 6 TU for 250 mL samples. For enriched samples it is 0.8 ± 0.8 TU for 250 mL samples.

Compositional chemistry of gas samples were measured by Isotech Laboratories in Champaign, Illinois, USA. The analysis was performed using a Shimadzu 2014 gas chromatograph (GC) equipped with thermal conductivity (TCD) and flame ionization (FID) detectors, and were reproducible to ±0.2 ‰.

3.3.2 Quality Control and Statistical Analysis

Materials for analysis at Geoscience Laboratories and SGS Laboratories were submitted in batches containing samples from both 2009 and 2010 field campaigns, and included (blind) duplicates (10 %), blanks and standards. Duplicates were taken from random locations, blanks were composed of ultrapure distilled and deionized water treated with the same preservatives as samples, and standards included various certified reference materials and spiked standards. CANMET certified reference standard SLRS-4 was used for cations (metals) and Hg, and an internal Bulk standard (BLK-1) was used for anions. NO_3 and NO_2 standards were composed of BLK-1 spiked with 5mg/L (as N) $NaNO_3$; TKN and NH_3 standards were composed of BLK-1 spiked with 5 mg/L (as N) NH_3.

Aqueous solutions are electrically neutral and hence a balance should exist between the measured abundances of cations and anions (Freeze and Cherry, 1979). This can be tested by calculation of charge balance errors (CBE) (equation 1).

$$\% \text{ CBE} = [\Sigma\text{cations} - \Sigma\text{anions}] / [\Sigma\text{cations}+\Sigma\text{anions}] \times 100 \qquad (1)$$

The regional data set (n=102) has a CBE ±10 % for 94 of the samples. Of the 8 of samples with CBE ≥ ±10 % CBE, 7 of them display an anion excess. These samples are 07-AG-049, 07-AG-094, 07-AG-109, 07-AG-125, 07-AG-155, 08-AG-015, are 08-AG-046 and 08-AG-232. No samples in the regional dataset have CBE > ±23 %. For the local study of the BWZ (n=106), two samples were not included into the dataset because of softener contamination so only data for 104 samples were used. Furthermore data are incomplete for 50 samples because they are missing HCO_3^-. For the remaining 48 samples the CBE is ≤ ±10 %, except for one sample (10-BW03-07), which has an anion excess of 11.4 %.

Chemical results for the regional and the local (BWZ) studies were maintained in separate databases. Descriptive statistics were performed on both datasets. Multivariate statistical analyses were performed using STATISTICA® Release 10 (StatSoft Inc., 1995) for the regional dataset only. They were not utilized for data from the one-year, multiple sampling of the BWZ, as such approaches are generally not effective on smaller spatial scales and/or in situations where chemical variability is minimal (Thyne et al., 2004). Two types of multivariate methods were used in this study, Hierarchical Cluster Analysis (HCA), and Principal Component Analysis (PCA). HCA was used to classify the regional groundwater into water facies subsets. PCA was used to determine the most significant variables defining the groundwater facies and to indicate geochemical reactions influencing regional groundwater chemistry.

Additionally, K-means cluster analysis was performed on a portion of the regional isotopic data with the purpose of understanding the spatial movement of groundwater through the BWZ. K-means is a partitioning algorithm operated in two steps. First, a certain number of centroids are placed among the data points, and then each point is attached to the nearest centroid. Second, the centroid positions are then recalculated using the average distance of each point. A set of cluster centers is then established that best represents the natural distribution of the data. Five centroids were arbitrarily selected for the purpose of this analysis (Schuenemeyer and Drew, 2011; Statsoft, 1995).

3.3.3 Geochemical Saturation Indices

The groundwater chemistry, field pH, temperature, along with a calculated pCO_2 data (determined from the dissolved CO_2 gas in the groundwater), and mineral solubility products (Table 3.1) were used with the computer program PHREEQC (Parkhurst and Appelo, 1999) to calculate BWZ groundwater saturation indices (SI) for minerals common in the local lithology (i.e. anhydrite, calcite, celestite, dolomite, gypsum, halite and fluorite). The SIs measure the extent to which a water has equilibrated chemically with a mineral, and re expressed as: SI = log(IAP/KSP), where IAP is the ion-activity product and KSP is the solubility product. Undersaturated phases (SI<< 0) dissolve; oversaturated phases (SI>>0) precipitate from solution. Equilibrium is represented by SI = 0±0.1 (an error of ±0.05 pH units creates an uncertainty of ±0.05 in mineral SI values.

3.4 Results

3.4.1 Groundwater Chemistry

The regional dataset contains information on 102 observation sites (Appendix A to R) and the local dataset contains information on 10 wells from within the BWZ that were sampled monthly over one year (Appendix S to HH). Regionally, water samples had an average temperature of 9.28°C and a median of 9.01°C (range, 7.71 – 12.73°C), with higher values located in the southeastern area (Figure 3.1A; Table 3.2). Groundwater pH ranged between 6.8 and 8.8 with higher values occurring in the southern area (Figure 3.1B; Table 3.2). The range of pH values is normal for natural ground waters, and indicates that HCO_3^- is the predominant dissolved carbonate species (Langmuir, 1997). The average conductivity in the regional study area was 727 µS/cm with a median of 547 µS/cm (range, 289 –2795 µS/cm) (Figure 3.1C; Table 3.2). The oxidation- reduction potential (ORP) averaged -170.0 mV with a median of -177.0 mV (range, -460.3 to +72.2 mV), with positive readings being found within the BWZ (Figure 3.1D; Table 3.2).

Table 3.1. PHREEQC Solubility Products. Mineral solubility products for minerals within the BWZ (PHREEQC, 2011).

Mineral	**Reaction**	**Solubility product**
Calcite	$CaCO_3 = CO_3^{2-} + Ca^{2+}$	-8.48
Dolomite	$CaMg(CO_3)_2 = Ca^{2+} + Mg^{2+} + 2\ CO_3^{2-}$	-17.09
Gypsum	$CaSO_4{:}2H_2O = Ca^{2+} + SO_4^{2-} + 2\ H_2O$	-4.58
Anhydrite	$CaSO_4 = Ca^{2+} + SO_4^{2-}$	-4.36
Celestite	$SrSO_4 = Sr^{2+} + SO_4^{2-}$	-6.63
Halite	$NaCl = Na^{+} + Cl^{-}$	1.582
Fluorite	$CaF_2 = Ca^{2+} + 2\ F^{-}$	-10.6

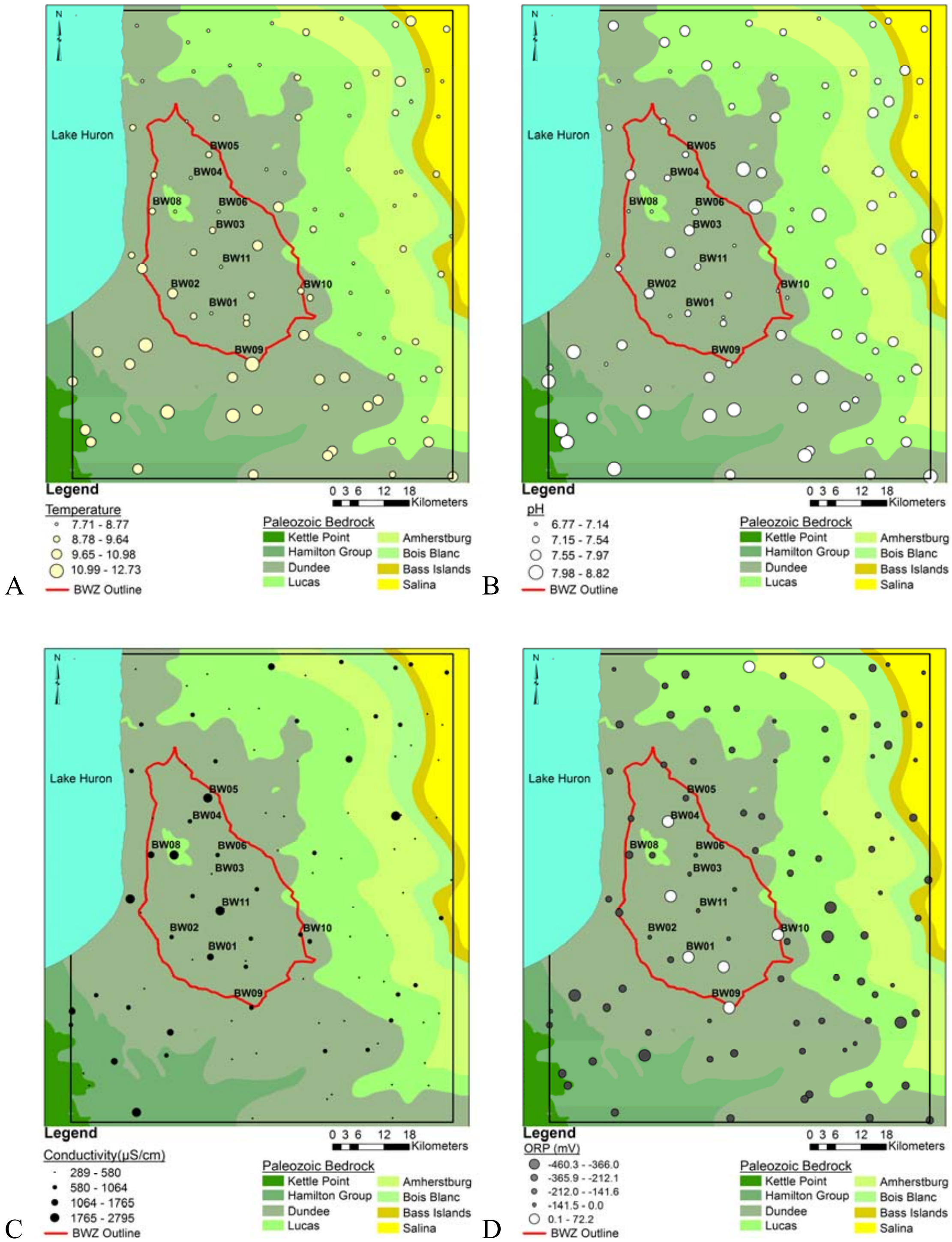


Figure 3.1. Regional physical parameter measurements. (A) Temperature (°C); (B) pH; (C) conductivity (µS/cm); (D) Oxidation-reduction Potential (ORP) (mV).

Table 3.2. Regional Parameter Statistics

Parameter	Unit	Valid N	Mean	Standard Deviation	Median	Minimum	Maximum
Temperature	°C	99	9.28	0.93	9.01	7.71	12.73
pH	pH units	102	-	-	-	6.8	8.8
Conductivity	µS/cm	102	727	538	547	289	2795
ORP mV	mV Ag-AgCl	99	-170.0	104.0	-177.0	-460.3	72.2
DIC	mg/L	102	48.7	17.1	48.5	13.9	88.9
DOC	mg/L	102	0.9	0.7	0.7	<0.1	6.0
Total Coliform	counts/100mL	102	6.4	41.4	0.0	0.0	400.0
Fecal Coliform	counts/100mL	102	0.1	0.4	0.0	0.0	2.0
Dissolved Oxygen	% saturation	102	1.6	7.7	0.0	0.0	60.2
Dissolved Methane	% saturation	102	1.288	8.306	0.003	0.000	81.775
Dissolved Hydrogen Sulphide	mg/L S^{2-}	102	0.539	2.184	0.010	0.000	18.000
$\delta^{18}O$ (H2O)	‰VSMOW	102	-11.1	1.0	-11.06	-16.86	-9.63
$\delta^{2}H$(H2O)	‰VSMOW	102	-74	7	-74	-118	-55
3H (H2O)	TU	74	15	26	5	5	148
Ca^{2+}	mg/L	102	65.7	72.1	44.7	2.8	379.1
Mg^{2+}	mg/L	102	23.6	16.9	20.7	1.6	123.8
K^{+}	mg/L	102	1.5	2.5	1.1	0.7	24.9
Na^{+}	mg/L	102	38.9	59.3	22.6	3.1	450.1
HCO_3^{-}	mg/L	102	253.1	58.7	251.5	102.0	495.0
SO_4^{2-}	mg/L	102	106.2	212.4	28.0	<0.04	1227.8
Cl^{-}	mg/L	102	20.4	70.6	2.0	0.3	575.0
F^{-}	mg/L	102	1.4	0.5	1.4	0.1	2.6
Fe^{2+}	mg/L	102	0.583	0.726	0.316	<0.003	3.420
Sr^{2+}	mg/L	102	10.7	15.1	2.6	0.1	56.0
Si	mg/L	102	5.3	1.3	5.3	2.9	8.6
Br^{-}	mg/L	102	0.12	0.28	<0.1	<0.1	2.87
I^{-}	µg/L	87	40	60	16	<5	300
PO_4^{2-}	mg/L	102	0.09	0.06	<0.1	<0.1	0.52
NO_3^{-}	mg/L as N	102	0.240	0.804	0.008	<0.013	6.600
NO_2^{-}	mg/L as N	102	0.016	0.027	0.004	<0.003	0.107
$NH_3^{+}NH_4^{+}$	mg/L as N	102	0.17	0.12	0.15	<0.01	0.74
Organic N	mg/L as N	102	0.09	0.12	0.06	<0.01	0.88
TKN	mg/L as N	102	0.27	0.18	0.23	<0.05	1.15
Sr/Ca	Ratio	102	0.22	0.36	0.07	0.001	1.80
Mg/Ca	Ratio	102	0.47	0.17	0.43	0.09	0.95
Na/Cl	Ratio	102	16.88	17.70	10.96	0.42	79.28
Cl/Br	Ratio	16	158.95	194.71	38.93	3.95	596.93
Ag	µg/L	102	0.009	0.008	<0.005	<0.005	0.033
Al	µg/L	102	<5	4	<5	<5	36
As	µg/L	102	2.63	3.83	0.74	<0.03	21.12
B	mg/L	102	0.22	0.41	0.08	0.01	2.29
Ba	µg/L	102	138.92	342.41	72.55	4.83	3351.00
Be	µg/L	102	<0.01	0.003	<0.01	<0.01	0.03
Bi	µg/L	100	0.0118	0.0161	0.002	<0.0002	0.0375
Cd	µg/L	102	0.03	0.05	0.01	<0.01	0.52
Ce	µg/L	102	0.004	0.012	<0.002	<0.002	0.110
Co	µg/L	102	0.044	0.063	0.021	<0.005	0.289
Cr	µg/L	102	0.03	0.03	<0.02	<0.02	0.25
Cs	µg/L	102	0.0055	0.0081	0.0031	0.0008	0.0700
Cu	µg/L	102	1.2	1.8	0.5	<0.2	11.4

Parameter	Unit	Valid N	Mean	Standard Deviation	Median	Minimum	Maximum
Dy	µg/L	102	<0.001	0.001	<0.001	<0.001	0.015
Er	µg/L	102	<0.001	0.001	<0.001	<0.001	0.007
Eu	µg/L	102	<0.0004	0.0002	<0.0004	<0.0004	0.0027
Ga	µg/L	102	0.008	0.005	0.006	<0.002	0.035
Gd	µg/L	102	0.002	0.003	<0.001	<0.001	0.029
Hf	µg/L	102	<0.004	0.007	<0.004	<0.004	0.077
Hg	ng/L	102	<1.5	0.7	<1.5	<1.5	6.2
Ho	µg/L	102	0.0002	0.0003	<0.0001	<0.0001	0.0027
La	µg/L	102	0.004	0.008	0.003	<0.001	0.064
Li	µg/L	102	7.8	12.6	4.8	0.6	92.4
Lu	µg/L	102	<0.0001	0.0001	<0.0001	<0.0001	0.0009
Mn	µg/L	102	24.1	30.1	11.5	<1	149.0
Mo	µg/L	102	6.27	9.59	3.60	0.02	69.50
Nb	µg/L	102	<0.001	0.001	<0.001	<0.001	0.005
Nd	µg/L	102	0.005	0.009	<0.003	<0.003	0.083
Ni	µg/L	102	<1.0	1.6	0.4	<0.1	10.1
Pb	µg/L	102	0.066	0.105	0.038	<0.002	0.740
Pr	µg/L	102	0.0007	0.0020	<0.0004	<0.0004	0.0199
Rb	µg/L	102	1.269	0.979	0.856	0.222	4.250
Sb	µg/L	102	0.02	0.03	<0.01	<0.01	0.23
Sc	µg/L	102	0.2	0.2	0.2	<0.1	0.7
Se	µg/L	102	0.3	0.8	<0.2	<0.2	8.0
Sm	µg/L	102	<0.001	0.002	<0.001	<0.001	0.015
Sn	µg/L	102	<0.01	0.01	<0.01	<0.01	0.10
Ta	µg/L	102	0.0005	0.0004	0.0005	<0.0003	0.0026
Tb	µg/L	102	<0.0001	0.0003	<0.0001	<0.0001	0.0026
Th	µg/L	102	<0.001	0.001	<0.001	<0.001	0.011
Ti	µg/L	102	0.6	1.3	0.2	<0.1	7.5
Tl	µg/L	102	0.020	0.075	<0.001	<0.001	0.697
Tm	µg/L	102	<0.0001	0.0001	<0.0001	<0.0001	0.0010
U	µg/L	102	0.6599	1.7536	0.1513	<0.0002	16.1000
V	µg/L	102	0.058	0.106	0.028	0.005	0.812
W	µg/L	102	0.02	0.03	<0.01	<0.01	0.14
Y	µg/L	102	0.1457	0.2118	0.0419	0.0034	0.7498
Yb	µg/L	102	<0.001	0.001	<0.001	<0.001	0.006
Zn	µg/L	102	78.8	154.8	11.9	<1.0	749.0
Zr	µg/L	102	<0.1	0.3	<0.1	<0.1	3.0

"-" symbolizes parameter not measured. “<” symbolizes parameter is below detection limit.

Concentrations of Ca^{2+}, Mg^{2+}, HCO_3^-, and SO_4^{2-} were elevated in the BWZ relative to the regional study area; elevated Sr^{2+} concentrations were also observed in the eastern portion of the BWZ and to its north (Figures 3.2 and 3.3). Concentrations of Na^+, K^+, and Cl^- were lower within the BWZ relative to the regional study area; the latter has particularly enriched concentrations of these ions to the south (Figures 3.2 and 3.3). Elevated concentrations of certain metals (Ag, Y, Tl, Zn) were observed in the BWZ relative to the regional study area (Figures 3.4). Most groundwater sampled during the regional campaign can be classified as Ca-Mg-HCO_3-SO_4 water (Piper, 1944); Na-Ca-Cl waters were also present (Figure 3.5A).

During the one-year sampling period, average values of physical parameters for the BWZ groundwater were: temperature 11.23˚C; pH 7.0 to 7.7; conductivity, 1033 µS/cm, and ORP, -54.7 mV (Table 3.3). Five water types were observed to occur in the BWZ: Ca-Mg-SO_4, Ca-Sr-HCO_3, Ca-Mg-HCO_3, Ca-Na-HCO_3, and Na-Ca-Cl (Figure 3.5B). Major ion concentrations displayed little variation throughout the year, though slight increases in some (e.g., Ca^{2+}, Mg^{2+}, Sr^{2+}) during the spring may reflect aquifer recharge at that time (Figure 3.6 and 3.7, A-D). Due to equipment unavailability, HCO_3^- was not measured for all 12 months. It was also noted that at site BW10, there was a sudden drop in SO_4 that occurred around June 2010. In general, the waters were well mixed, with limited to no seasonal variation, consistent with a slow moving well mixed flow systems compared to high velocity (typical karstic conduit) groundwater system. Calculated saturation indices are summarized in Table 3.4

3.4.2 Dissolved and Exhaled Gas Compositions

Groundwater in the regional study area has average DO concentrations (% saturation) of 1.6 %, but a median value of 0.0 % saturation (Table 3.2). The average value is a result of a high measurement reading of 60.2 % which was measured in the most northern portion of the study area. In the southernmost part of the BWZ, elevated DO levels ranged as high as 34.4 % (Figure 3.8A). Furthermore, during the local study DO concentrations (0 – 46.0 %) were noticed to occur within the BWZ (Table 3.2). Regional groundwater had an average dissolved CH_4 saturation of 1.288 % saturation (range: 0 – 81.775 %) (Figure 3.8B; Table 3.1), and the average saturation within BWZ groundwater was 0.007 % (range: 0 –

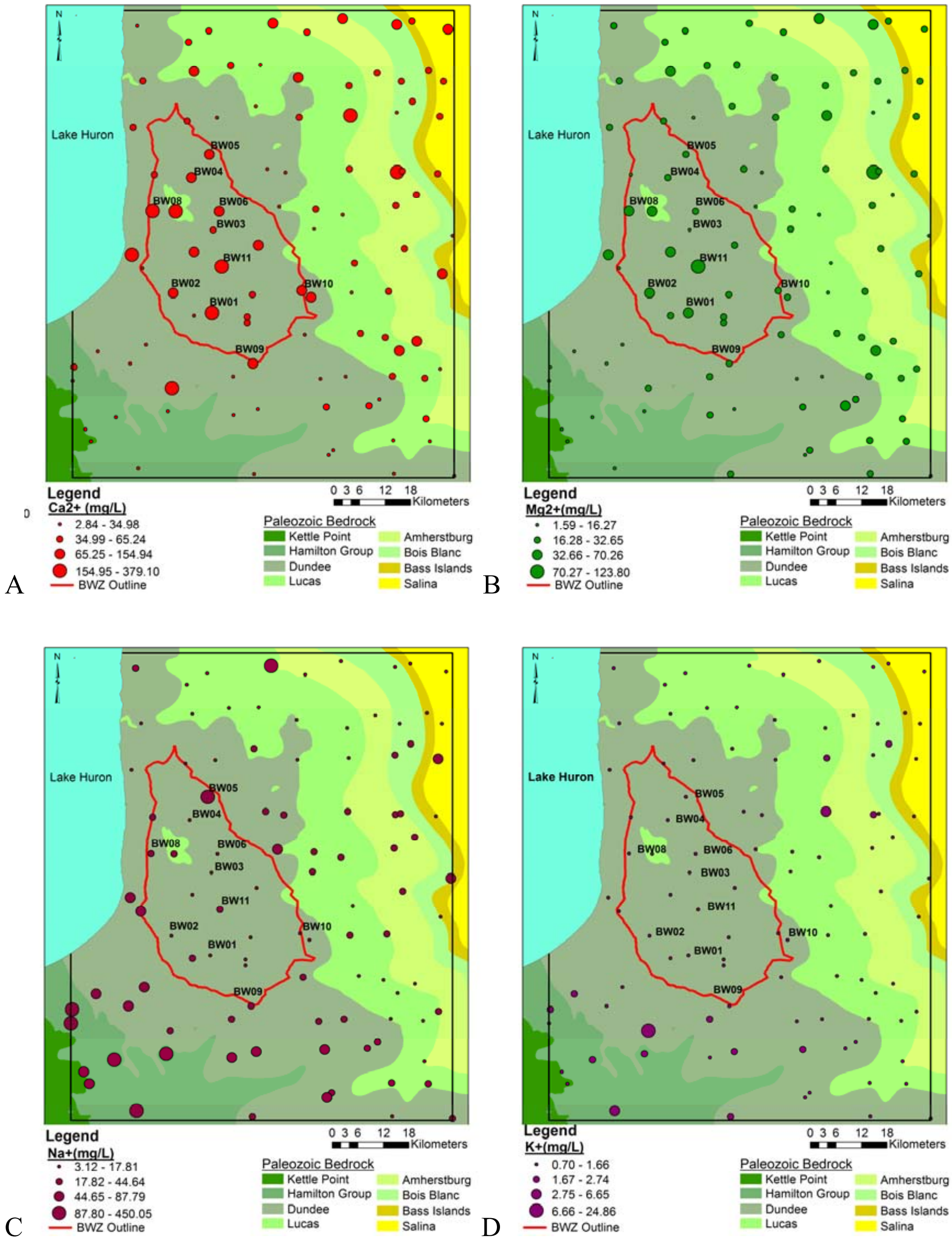


Figure 3.2. Regional major ion concentrations. (A) Ca^{2+} (mg/L); (B) Mg^{2+} (mg/L); (C) Na^{+} (mg/L); (D) K^{+} (mg/L).

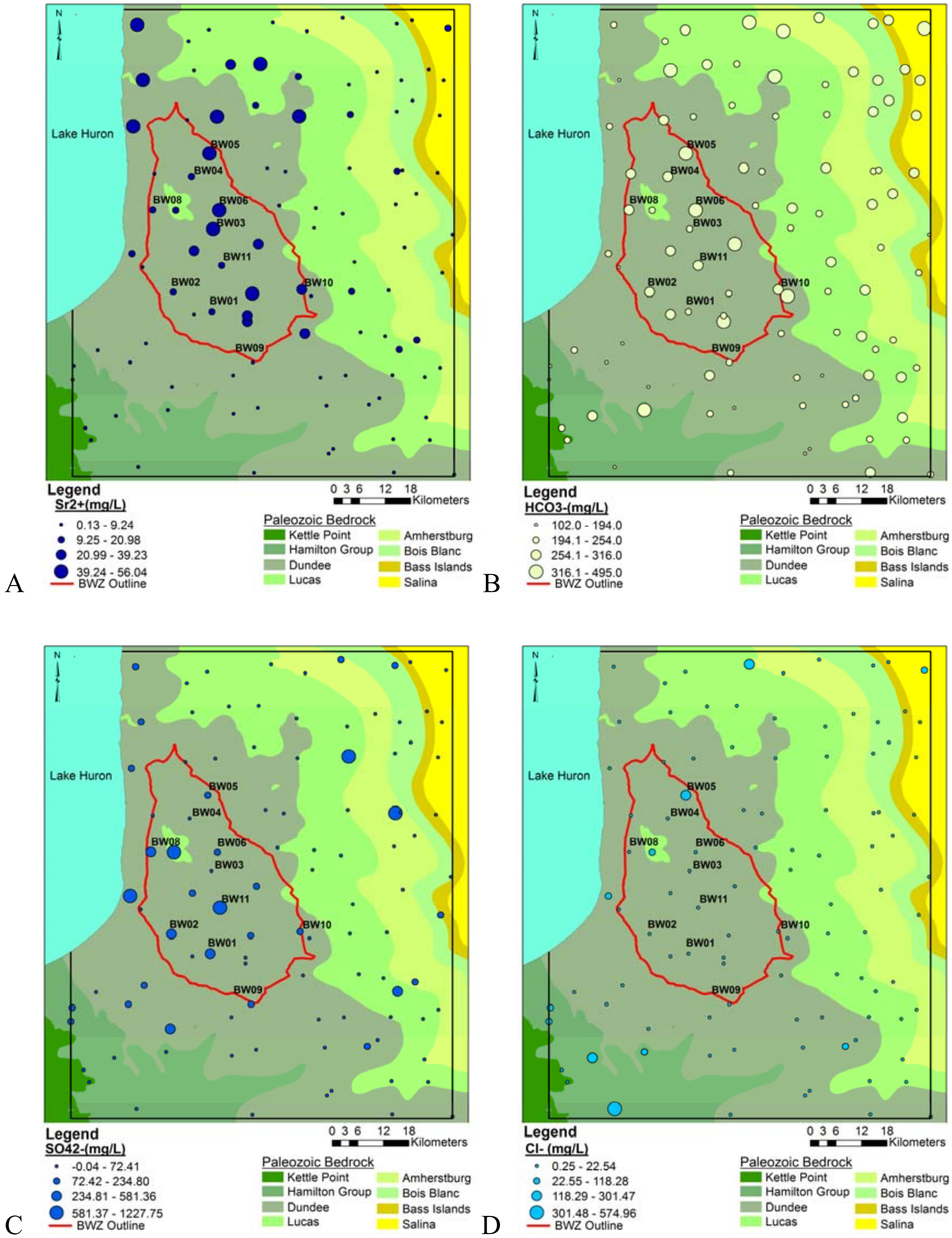


Figure 3.3. Regional major ion concentrations. (A) Sr^{2+} (mg/L); (B) HCO_3^- (mg/L); (C) SO_4^{2-} (mg/L); (D) Cl^- (mg/L).

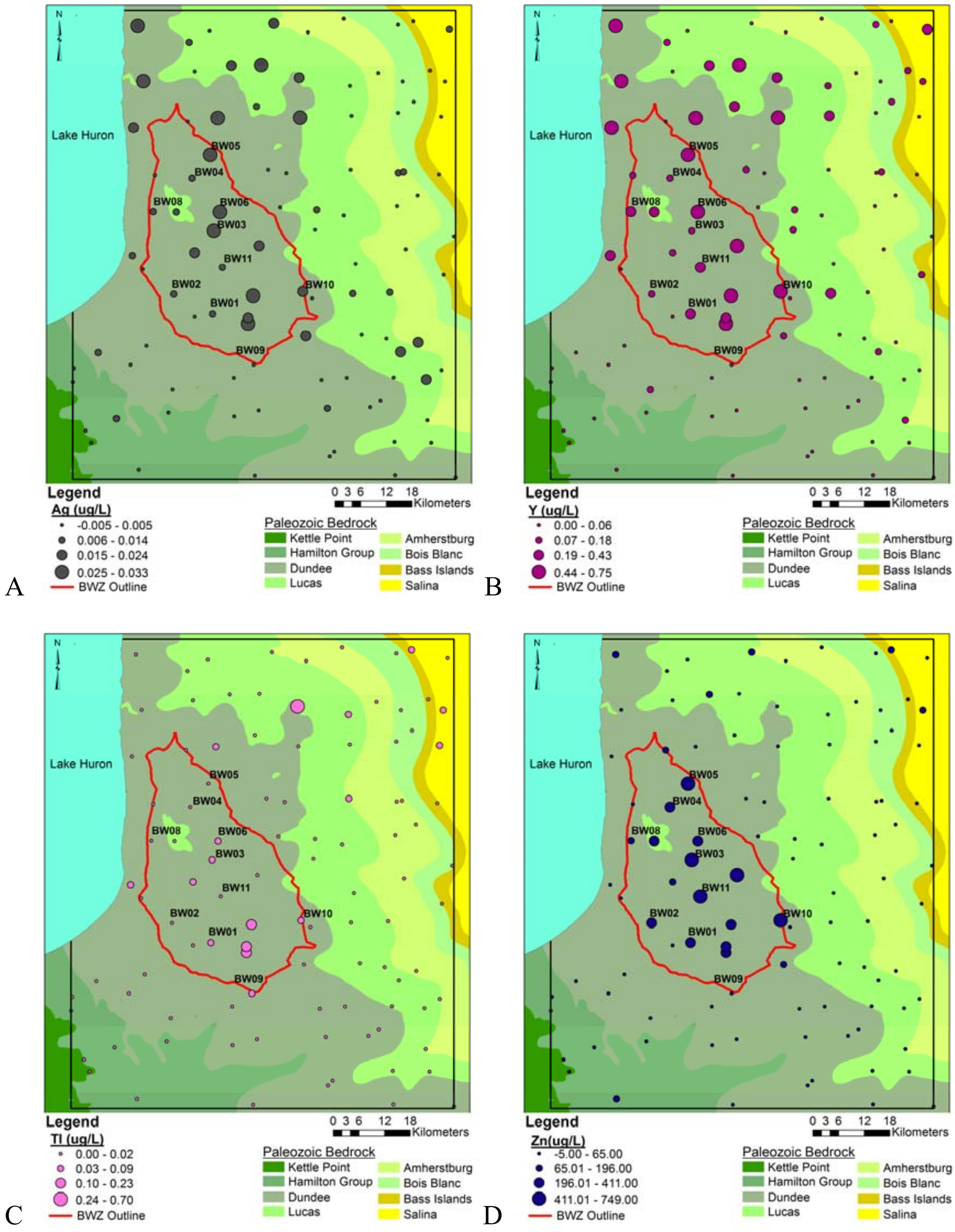


Figure 3.4. Regional trace element concentrations in µg/L. (A) Ag (µg/L); (B) Y; (C) Tl; (D) Zn.

Table 3.3. Local Parameter Statistics.

		All					
Parameter	**Unit**	**Valid N**	**Mean**	**Standard Deviation**	**Median**	**Minimum**	**Maximum**
Temperature	°C corrected	46	11.23	1.37	11.02	9.09	16.07
pH	pH units	32	-	-	-	7.0	7.7
Conductivity	µS/cm	37	1033	595	757	12	2268
ORP mV	mV Ag-AgCl	46	-54.7	115.1	-71.1	-264.3	170.3
DIC	mg/L	10	60.8	8.2	60.0	48.0	76.1
DOC	mg/L	10	0.6	0.2	0.5	0.4	1.2
Total Coliform	counts/100mL	9	0.0	0.0	0.0	0.0	0.0
Fecal Coliform	counts/100mL	9	0.0	0.0	0.0	0.0	0.0
Dissolved Oxygen	% saturation	76	9.8	11.4	6.7	0.0	46.0
Dissolved Methane	% saturation	10	0.007	0.007	0.005	0.000	0.021
Dissolved Hydrogen Sulphide	mg/L S^{2-}	10	0.200	0.113	0.185	0.060	0.400
Exhaled Oxygen (g) Field	%	31.0	14.3	5.3	17.4	1.7	20.9
Exhaled Carbon Dioxide (g) Field	%	31.0	0.7	0.7	0.5	0.0	3.4
Exhaled Oxygen + Argon (g) Laboratory	v/v	10	17.3	3.5	18.5	10.9	20.7
Exhaled Carbon Dioxide (g) Laboratory	v/v	10	0.6	0.4	0.5	0.2	1.3
Exhalled Nitrogen(g) Laboratory	v/v	10	82.1	3.4	81.2	78.8	88.6
$\delta^{18}O$ (H2O)	‰VSMOW	106	-11.5	0.3	-11.6	-12.1	-10.6
$\delta^{2}H$(H2O)	‰VSMOW	106	-76	2	-77	-81	-71
$E^{3}H$	TU	10	2.3	2.1	1.0	0.8	6.1
$\delta^{18}O$ (SO_4)	‰VSMOW	18	10.2	5.6	12.9	0.3	16.8
$\delta^{34}S$(SO_4)	‰VCDT	18	16.0	11.4	21.9	-1.5	27.0
Ca^{2+}	mg/L	104	124.8	60.9	96.6	29.1	253.8
Mg^{2+}	mg/L	104	44.5	30.4	34.1	19.6	143.7
K^{+}	mg/L	104	0.9	0.2	0.9	0.5	1.5
Na^{+}	mg/L	104	41.0	83.8	11.1	4.8	340.0
HCO_3^{-}	mg/L	57	286.2	41.3	282.0	205.0	415.0
SO_4^{2-}	mg/L	104	294.9	280.7	145.6	38.7	1098.8
Cl^{-}	mg/L	104	44.4	113.4	10.1	0.3	432.5
F^{-}	mg/L	104	1.4	0.4	1.4	0.7	2.7
Fe^{2+}	mg/L	104	0.637	1.098	0.057	<0.003	5.270
Sr^{2+}	mg/L	104	24.7	15.0	18.9	2.5	51.8
Si	mg/L	104	4.7	0.9	4.5	3.2	6.9
Br^{-}	mg/L	104	0.03	0.04	<0.02	<0.02	0.33
I^{-}	µg/L	10	5	3	<5	<5	15
PO_4^{2-}	mg/L	104	<0.04	0.004	<0.04	<0.04	0.04
NO_3^{-}	mg/L as N	92	0.709	0.911	0.053	<0.002	3.022
NO_2^{-}	mg/L as N	104	<0.003	0.004	<0.003	<0.003	0.023
$NH^{3+}NH^{4+}$	mg/L as N	10	0.09	0.04	0.09	<0.04	0.15
Organic N	mg/L as N	10	0.07	0.07	<0.05	<0.05	0.22
TKN	mg/L as N	10	0.13	0.11	0.10	<0.05	0.32

Parameter	Unit	Valid N	All Mean	Standard Deviation	Median	Minimum	Maximum
Sr/Ca	Ratio	104	0.28	0.30	0.16	0.03	1.68
Mg/Ca	Ratio	104	0.35	0.10	0.32	0.21	0.70
Na/Cl	Ratio	104	4.12	6.02	1.96	0.36	41.14
Cl/Br	Ratio	104	811.75	1455.43	368.84	17.70	8706.76
Ag	µg/L	104	0.021	0.013	0.017	<0.005	0.083
Al	µg/L	104	4	0.2	4	<5	6
As	µg/L	104	0.87	1.31	0.18	<0.03	4.70
B	mg/L	104	0.08	0.06	0.07	0.01	0.24
Ba	µg/L	104	101.79	69.67	90.70	9.17	286.00
Be	µg/L	104	0.007	1.3×10^{-17}	0.008	<0.01	0.008
Bi	µg/L	104	<0.0500	0.0090	<0.0500	<0.0500	0.1300
Cd	µg/L	104	0.03	0.03	0.02	<0.01	0.29
Ce	µg/L	104	0.0023	0.0025	<0.002	<0.002	0.016
Co	µg/L	104	0.036	0.047	0.010	<0.005	0.233
Cr	µg/L	104	0.04	0.06	<0.02	<0.02	0.36
Cs	µg/L	104	0.0034	0.0015	0.0032	0.0004	0.0075
Cu	µg/L	104	5.0	17.2	1.5	<0.2	137.2
Dy	µg/L	104	<0.001	0.00023	<0.001	<0.001	0.008
Er	µg/L	104	<0.001	0.0009	<0.001	<0.001	0.0014
Eu	µg/L	104	0.0003	0.0001	0.0003	<0.0004	0.0011
Ga	µg/L	104	0.004	0.002	0.003	<0.002	0.010
Gd	µg/L	104	<0.0013	0.0007	0.0011	<0.001	0.0034
Hf	µg/L	104	0.003	0.0004	0.003	<0.004	0.007
Hg	ng/L	10	<1.5	0.0	<1.5	<1.5	1.1
Ho	µg/L	104	0.00013	0.00009	0.00008	<0.0001	0.00059
La	µg/L	104	0.003	0.002	0.002	<0.001	0.018
Li	µg/L	104	5.5	2.8	4.5	1.9	12.9
Lu	µg/L	104	<0.0001	0.00003	<0.0001	<0.0001	0.0002
Mn	µg/L	104	13.9	17.6	6.5	1.5	96.0
Mo	µg/L	104	5.00	4.00	3.86	0.53	19.90
Nb	µg/L	104	<0.001	0.0004	<0.001	<0.001	0.003
Nd	µg/L	104	<0.003	0.001	0.002	<0.003	0.011
Ni	µg/L	104	2.7	7.9	1.5	<0.1	60.5
Pb	µg/L	104	0.165	0.342	0.054	<0.002	2.625
Pr	µg/L	104	0.0005	0.0004	0.0003	<0.0004	0.0037
Rb	µg/L	104	0.704	0.196	0.660	0.355	1.112
Sb	µg/L	104	0.03	0.05	0.02	<0.01	0.41
Sc	µg/L	104	<0.1	0.03	0.1	<0.1	0.2
Se	µg/L	104	<0.2	0.04	<0.2	<0.2	0.4
Sm	µg/L	104	<0.001	0.0004	<0.001	<0.001	0.003
Sn	µg/L	104	<0.01	0.01	<0.01	<0.01	0.07
Ta	µg/L	104	0.0005	0.0003	<0.0003	<0.0003	0.0015
Tb	µg/L	104	<0.0001	0.0001	<0.0001	<0.0001	0.0006
Th	µg/L	104	0.002	0.003	<0.001	<0.001	0.016
Ti	µg/L	104	0.2	0.2	<0.1	<0.1	1.4
Tl	µg/L	104	0.032	0.036	0.017	<0.001	0.136
Tm	µg/L	104	<0.0001	0.00003	<0.0001	<0.0001	0.0003
U	µg/L	104	1.0671	1.0596	0.7290	0.1660	4.7100

Parameter	Unit	Valid N	Mean	Standard Deviation	Median	Minimum	Maximum
V	µg/L	104	0.037	0.038	0.021	0.002	0.160
W	µg/L	104	<0.01	0.01	<0.01	<0.01	0.04
Y	µg/L	104	0.1228	0.0759	0.0941	0.0151	0.3120
Yb	µg/L	104	<0.001	0.0000	<0.001	<0.001	<0.001
Zn	µg/L	104	363.8	420.8	227.0	23.0	1916.0
Zr	µg/L	104	<0.1	0.02	<0.1	<0.1	0.3

"-" symbolizes parameter not measured. “<” symbolizes parameter is below detection limit.

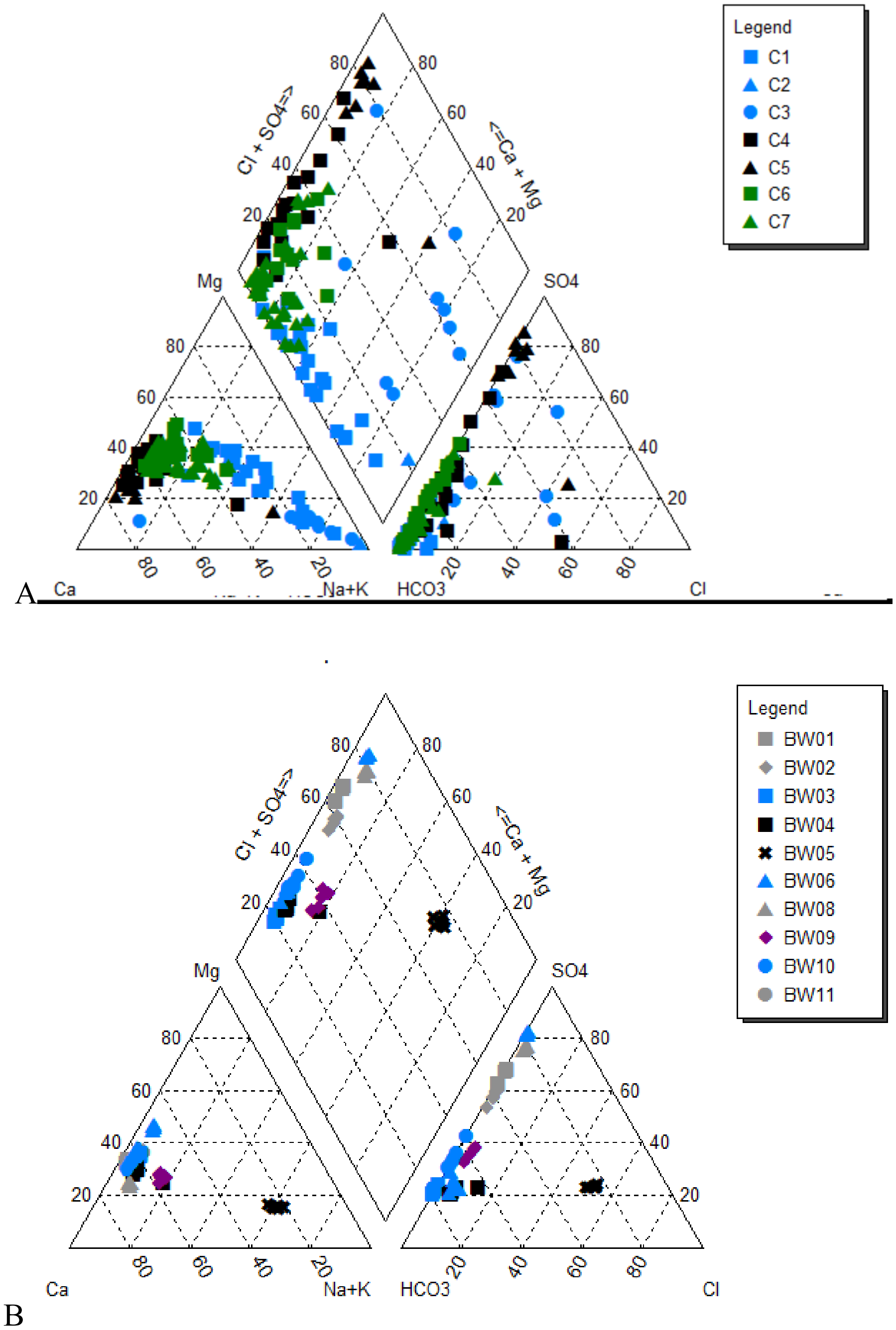


Figure 3.5. Piper (1944) trilinear plots. (A) Regional groundwater compositions. Seven clusters have been identified using Hierarchical Cluster Analysis (HCA; Figure 3.9), and are here organized according to geographic zones: Northern Zone = Grey, BWZ = Black; Southern Zone = Green. (B) BWZ groundwater compositions, according to water facies: Grey = Ca-Mg-SO_4; Blue = Ca-Sr-HCO_3; Black = Ca-Mg-HCO_3; Purple = Ca-Na- HCO_3; Dark Blue = Na-Ca-Cl.

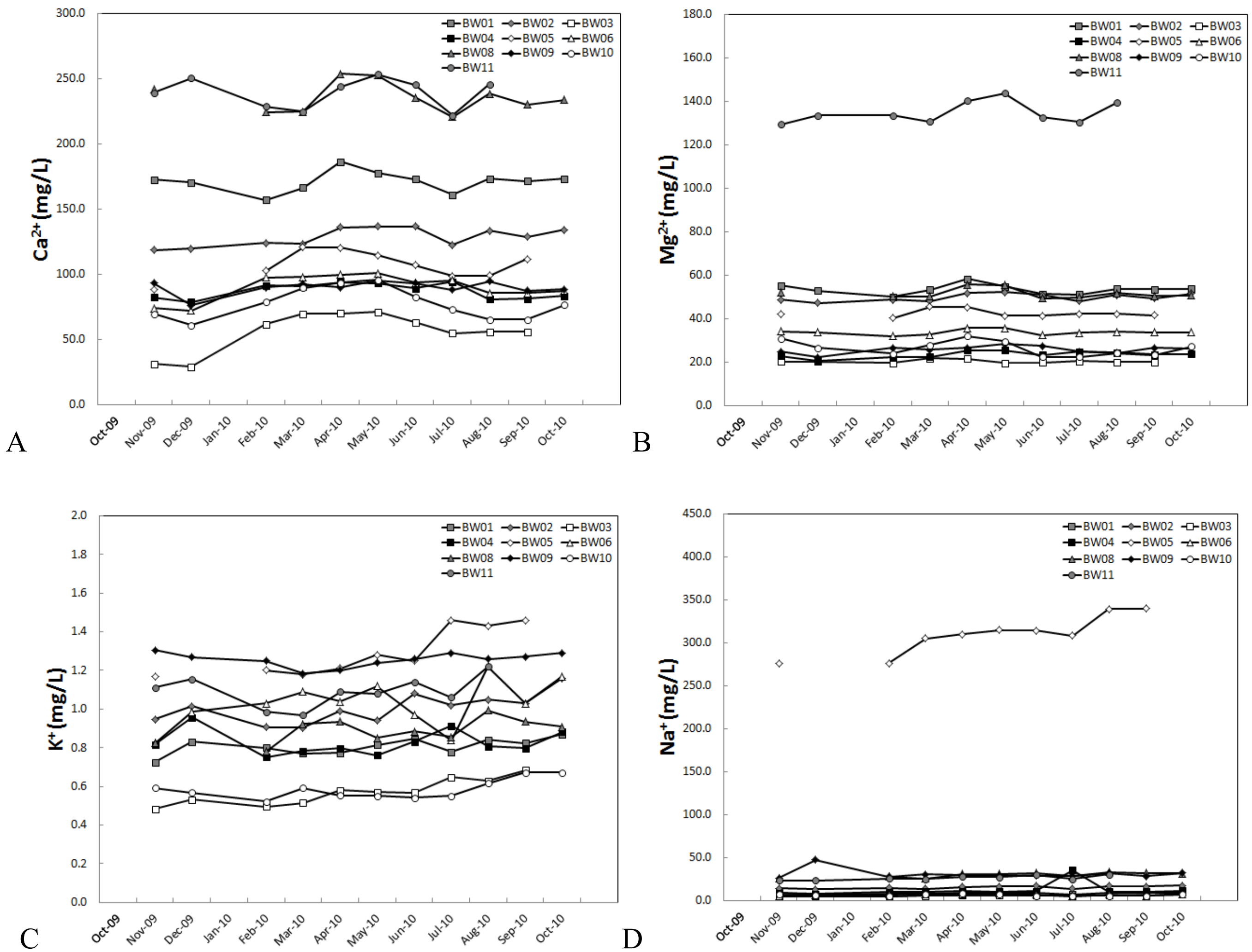


Figure 3.6. Groundwater chemical composition (mg/L) *vs* time in the BWZ. (A) Ca^{2+}; (B) Mg^{2+}; (C) K^{+}; (D) Na^{+}.

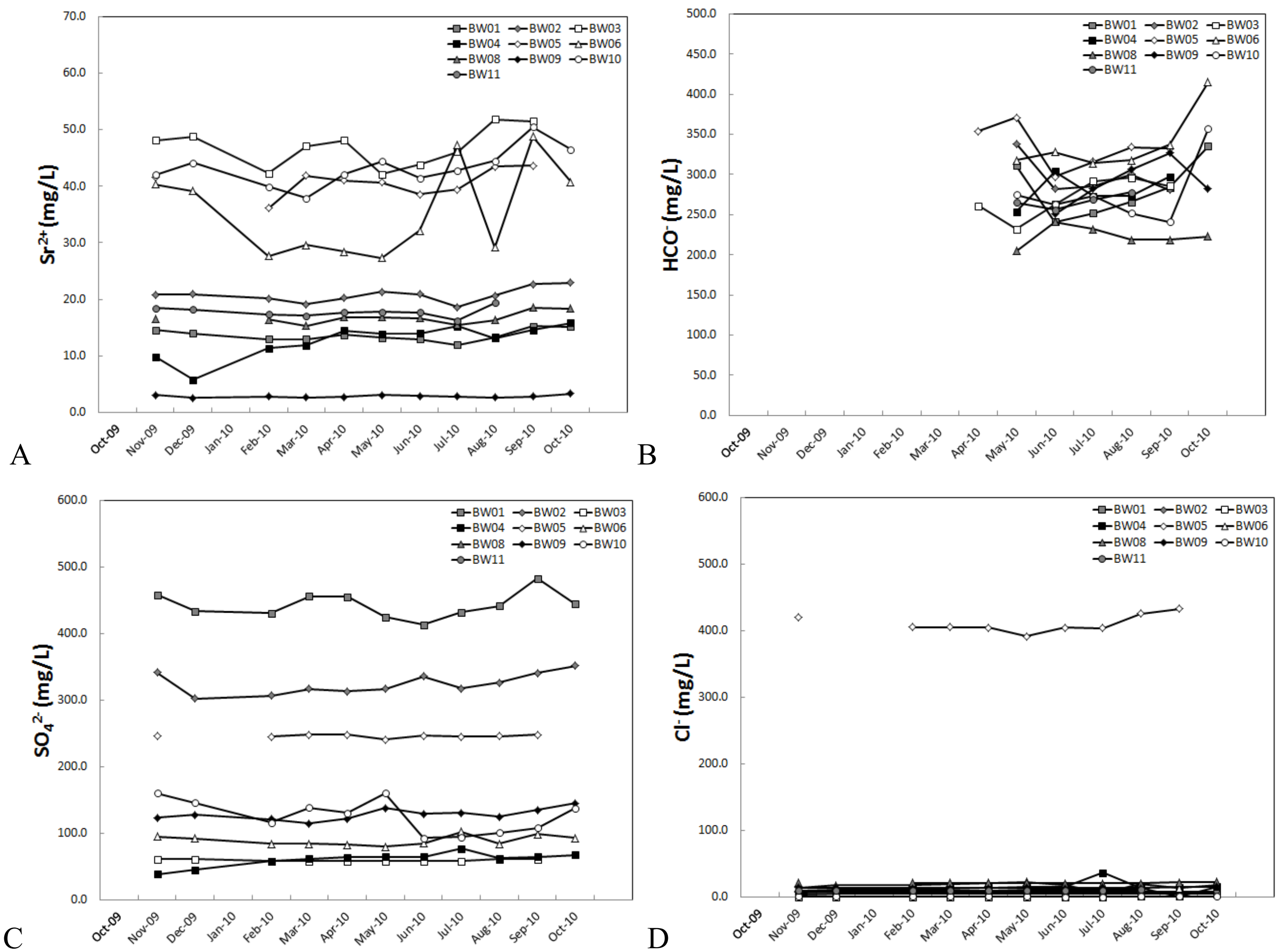


Figure 3.7. Groundwater chemical composition (mg/L) *vs* time in the BWZ. (A) Sr^{2+}; (B) HCO_3^-; (C) SO_4^{2-}; (D) Cl.

Table 3.4. Saturation Indices. PHREEQC saturation indices for minerals present within the Lucas Formation: anhydrite, calcite, celestite, dolomite, gypsum, halite, and fluorite. SI values ±0.1 are saturated (in equilibrium), SI values >0.1 are oversaturated, and SI values <0.1, undersaturated.

Sample	**Water Facies**	**log *p*CO_2**	**TDS mg/L**	**Anhydrite SI**	**Calcite SI**	**Celestite SI**	**Dolomite SI**	**Gypsum SI**	**Halite SI**	**Fluorite SI**
10-BW01-07	Ca-Mg-SO_4-HCO_3	-1.91	915	-1.06	-0.05	-0.22	-0.49	-0.8	-8.96	-0.28
10-BW02-07	Ca-Mg-SO_4-HCO_3	-1.85	858	-1.22	-0.05	-0.07	-0.38	-0.96	-8.46	-0.52
10-BW03-07	Ca-Sr-HCO_3-SO_4	-2.16	438	-2.08	-0.05	-0.35	-0.51	-1.82	-10.3	-0.41
10-BW04-07	Ca-Mg-HCO_3-SO_4	-1.93	528	-1.96	0	-0.8	-0.48	-1.7	-8.34	-0.91
10-BW05-07	Na-Ca-Cl-SO_4	-1.97	1523	-1.48	0.18	0.03	0.05	-1.23	-5.51	-0.68
10-BW06-07	Ca-Sr-HCO_3-SO_4	-1.82	605	-1.86	-0.02	-0.37	-0.37	-1.6	-8.48	-0.42
10-BW08-07	Ca-Mg-SO_4-HCO_3	-2.13	1263	-0.8	0.24	0.01	-0.04	-0.55	-7.78	-0.08
10-BW09-07	Ca-Na-HCO_3-SO_4	-1.96	579	-1.69	0	-1.23	-0.41	-1.43	-7.96	-0.77
10-BW10-07	Ca-Sr-HCO_3-SO_4	-2.11	516	-1.84	0.08	-0.19	-0.25	-1.59	-10.2	-0.88
10-BW11-07	Ca-Mg-SO_4-HCO_3	-1.91	1703	-0.72	0.12	0.09	0.19	-0.47	-8.14	-0.33

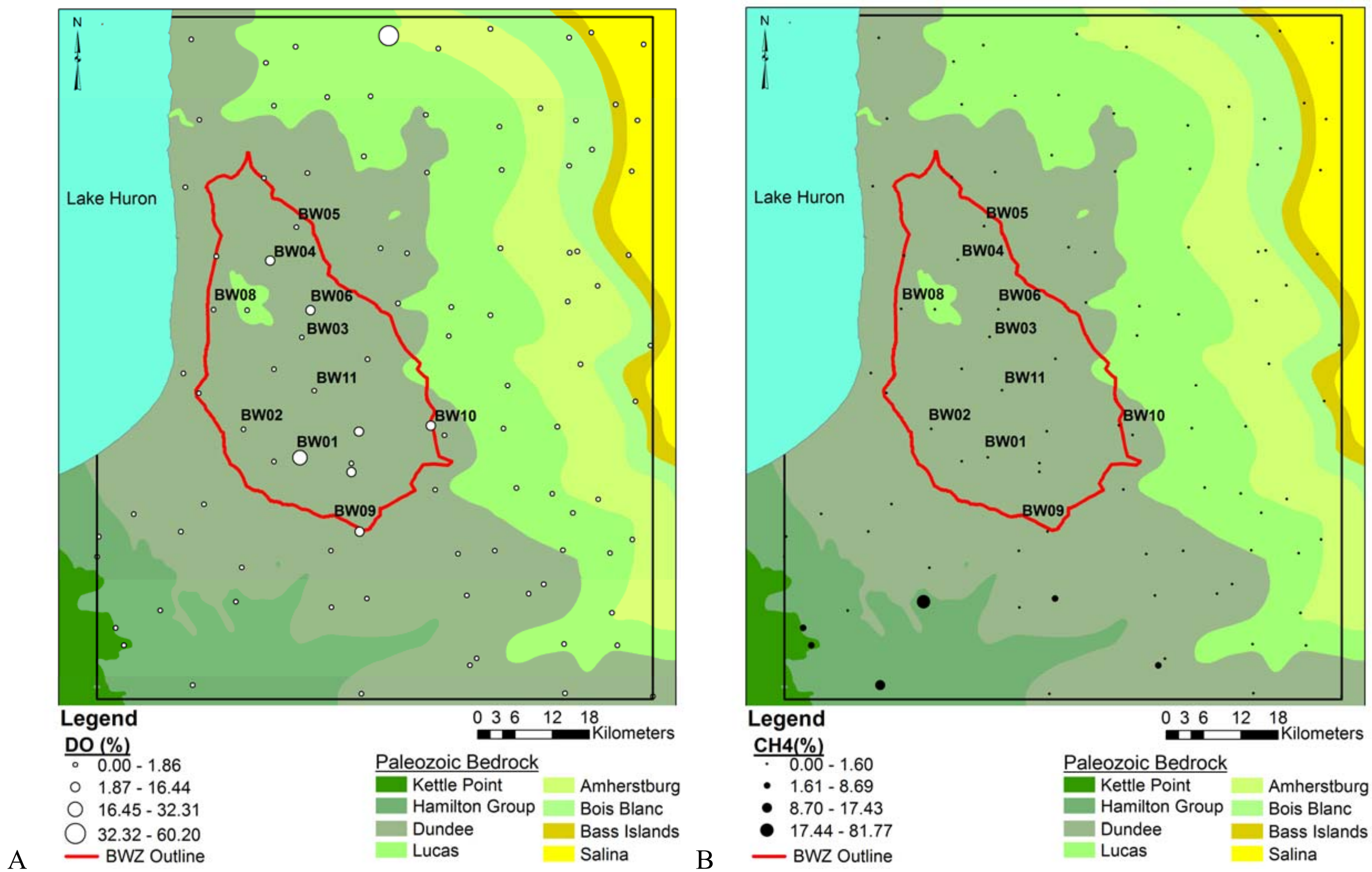


Figure 3.8. Regional groundwater dissolved gas concentrations. (A) Dissolved Oxygen (DO) (% saturation); (B) Dissolved Methane (CH_4) (% saturation).

0.021 %) (Table 3.2). Measured exhaled gas concentrations within the BWZ ranged from 1.7 to 20.9 % for O_2 and 0.0 to 3.4 % for CO_2 (Table 3.3). Site BW02 had the lowest O_2 (1.7 %), and highest CO_2 concentrations (3.4 %). Site BW08 had the lowest CO_2 concentration (0.0 %) and site BW09, the highest O_2 concentrations (20.9 %). No breathing episodes were observed at sites BW08 and BW09 during the one-year of monitoring. The atmospheric concentrations of $O_{2} + Ar_{(g)}$ is 215000 ppmv, $CO_{2\,(g)}$ is 410 ppmv, and N_2(g) is 784600.

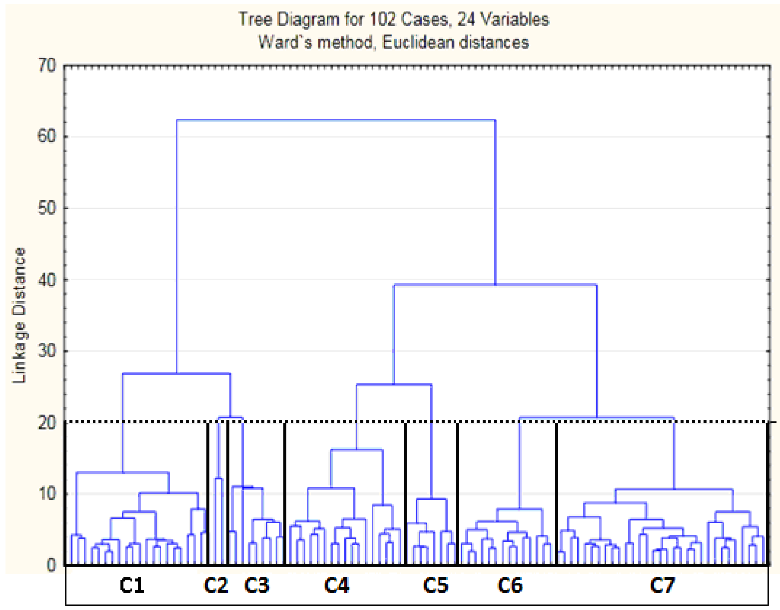
3.4.3 Regional Groundwater Chemistry Multivariate Statistics

The general composition of the regional groundwater, as determined using a Piper plot, is Ca-Mg-HCO_3-SO_4, with minor Na-Ca-Cl (Figure 3.5A). However, such classifications overlook the importance of other ions (e.g., Sr^{2+}; Figure 3.3A) that occur in elevated concentrations in parts of the regional study area and the BWZ. Hence, multivariate statistical techniques, first Hierarchical Cluster Analysis (HCA) and then Principal Component Analysis (PCA), were performed on the regional groundwater dataset to better understand geochemical variability in the area. The purpose of HCA is to determine multi-variant similarities between samples in a population. It places samples into groups, so that a relation between the groups can be discovered (Davis, 1986). PCA was then applied to determine what components or groups of hydrochemical variables, best represented variations between groups identified using HCA. PCA transforms particular variables, so that the original dimensionality among them is reduced. Once reduced, the relationship among the variables can be observed (Schuenemeyer and Drew, 2011).

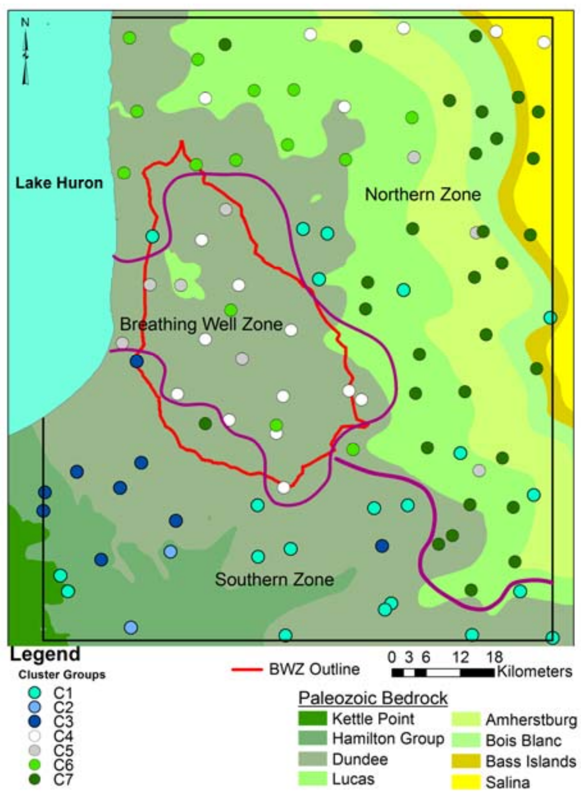
A total of 24 of the 88 measured chemical parameters from the 102 regional observations sites were used in this analysis: pH, conductivity, DIC, DOC, DO, H_2S, CH_4, water isotopes ($\delta^{18}O$ and $\delta^{2}H$), Ca^{2+}, Mg^{2+}, K^{+}, Na^{+}, HCO_3^{-} ,SO_4^{2-}, Cl^{-}, F^{-}, Fe^{2+}, Sr^{2+}, Si, B^{-}, Ba, Mn, and Zn. For results below detection limit, a value of 75 % of the detection limit was used (Güler et al., 2002; Van Trump and Miesch, 1977). Parameter exclusion of the other 64 parameters measured was based on one or more of the following reasons: (i) a high percentage (40 to 100 %) of censored values (i.e., values that lie below detection limit), (ii) very low concentrations (<0.01 mg/L), (iii) the variable was an additive parameter (e.g., total dissolved solids (TDS)), and/or (iv) missing data from several sites. Bacteriological parameters were also excluded from the analysis. The majority of the 24 parameters showed a positive skewed distribution, with a few being negativity skewed. A Kolmogorov-Smirnov normality test showed that pH, HCO_3^-, F^-, Si, and $\delta^{18}O$ were normally distributed (p-values >0.2). All other parameters had non-normal distributions (p-values <0.05) and were log-transformed. All parameters were then standardized prior to the multivariate statistical analyses and standardized Z scores calculated.

To perform the HCA, all parameters were clustered according to sample sites, using the Euclidean distance measure and Ward's linkage method. Both are the most common approaches used in HCA for hydrochemical studies (Cloutier et al., 2008; Güler et. al., 2002; Thyne et al., 2004). The Euclidean distance measure groups observation sites with the largest similarity first, and the Ward's method links similar samples together using analysis of variance to assess the distances between cluster groups (StatSoft Inc., 1995). Sampling sites were joined to similar sampling sites, and then successively connected to the next most similar sampling sites (Güler et al., 2002; Thyne et al., 2004). In the present HCA analysis, a phenon line was drawn at a linkage distance of 20, which yields seven cluster groups (C1-C7) (Figure 3.9A). Several possible linkage distances were explored, each producing a different number of cluster groups. The linkage distance of 20 was chosen because each of the seven cluster groups it yielded display distinct hydrochemical signatures. The linkage distances between cluster groups C2 and C3, and between C6 and C7, are the shortest, suggesting that their hydrochemistry is most similar compared to the other groups. Cluster groups C1, C2 and C3 attach to the other clusters at a longer linkage distance indicating they are likely less geochemically distinct compared to the other cluster groups.

Three distinct regions within the study area are apparent from the HCA: (1) Northern Zone, (2) BWZ, and (3) Southwestern Zone (Figure 3.9B). The Northern Zone comprises groups C6 and C7, and contains water obtained mostly from wells drilled into the Detroit River Group (Lucas and Amherstburg formations). Group C6 samples are rich in Ca^{2+}, Sr^{2+}, Mg^{2+}, HCO_3^-, and Fe^{2+} (Ca-Sr-HCO_3 water); group C7 is rich in Ca^{2+}, Mg^{2+}, HCO_3^-, Fe^{2+}, and Mn^{2+} (Ca-Mg-HCO_3 water) (Figure 3.9A and B; Table 3.5). Relative to other groundwater in



A



B

Figure 3.9. HCA Diagrams. (A) HCA dendrogram for the regional groundwater composition. Seven cluster groups are present below the phenon line (dotted line); (B) Geospatial map of HCA groupings 1 to 7.

Table 3.5. Hierarchical Cluster Group Averages.

		Cluster Groups						
		Southern Zone			Breathing Well Zone		Northern Zone	
Parameter Number of samples	Units	C1 21	C2 2	C3 9	C4 17	C5 8	C6 14	C7 31
Drift thickness	M	50	59	38.6	26.6	52.8	28.4	35.8
Well Depth	M	58.8	68.3	47.9	73.3	85.5	54.8	51.9
Water Level	mTOC	19.3	30.7	21.6	46.3	47.9	26.4	14.7
Temperature	(°C)	9.83	11.15	10.10	9.30	8.81	8.94	8.85
pH		8.0	8.4	7.6	7.3	7.1	7.5	7.5
Conductivity	(µS/cm)	367	1633	883	873	2085	523	527
DIC	Mg/L	37.4	41.9	26.5	72.1	47.3	49.8	50.3
DOC	Mg/L	0.7	1.1	1.3	0.5	0.7	0.7	1.1
Dissolved Oxygen	% saturation	0.0	0.0	0.0	9.5	0.0	0.0	0.0
Dissolved Hydrogen Sulphide	mg/L S^{2-}	0.988	9.004	1.553	0.003	0.014	0.009	0.016
Dissolved Methane	% saturation	1.353	49.603	0.114	0.004	0.003	0.006	0.082
$\delta^{18}O$	‰VSMOW	-10.6	-14.8	-10.9	-11.5	-11.1	-11.8	-10.9
$\delta^{2}H$	‰VSMOW	-71	-104	-72	-76	-74	-79	-72
Water Facies		Na-Ca-HCO_3	Na-Ca-Cl	Na-Ca-HCO_3	Ca-Mg-HCO_3	Ca-Mg-SO_4	Ca-Sr-HCO_3	Ca-Mg-HCO_3
Ca^{2+}	Mg/L	22.5	13.2	41.4	94.9	262	40.2	50.3
Mg^{2+}	Mg/L	14.1	7.7	10.4	30.3	65.4	19.9	22.1
K^{+}	Mg/L	1.2	3.9	4.3	1.0	1.5	1.0	1.4
Na^{+}	Mg/L	38.9	301.4	104.6	19.2	57.5	14.6	19.8
HCO_3^-	Mg/L	221.0	252.5	175.2	315.4	255.1	244.0	266.8
SO_4^{2-}	Mg/L	9.1	19.7	152.1	115.4	712.8	49.6	28.1
Cl^-	Mg/L	3.0	303.9	50.6	23.5	51.9	1.2	3.8
F^-	Mg/L	1.5	1.7	1.9	1.1	1.5	1.8	1.1
Fe^{2+}	Mg/L	0.288	0.314	0.055	0.256	1.598	0.471	0.921
Sr^{2+}	Mg/L	1.9	0.7	1.6	18.8	19.9	32.6	3.4
Si	Mg/L	5.3	3.4	4.2	5.1	4.7	6.1	5.8
B	Mg/L	0.32	2.03	0.75	0.04	0.11	0.06	0.07
Ba	Mg/L	0.28	0.33	0.03	0.12	0.03	0.15	0.1
Mn	Mg/L	0.009	0.012	0.004	0.013	0.045	0.022	0.043
Zn	Mg/L	0.01	0.04	0.02	0.22	0.22	0.11	0.02

"-" symbolizes parameter not measured. “<” symbolizes parameter is below detection limit.

the regional study area, these clusters have low conductivity (~500 µS/cm), the lowest concentration of Cl^-, the highest concentrations of Si, relatively high concentrations of Fe^{2+} and Mn^{2+}, and particularly for C6, high Sr^{2+} (Table 3.5). The BWZ is characterized by HCA groups C4 and C5, which represent the Ca-Mg-HCO_3 (southwest) to Ca-Mg-SO_4 (northeast) water facies transition (Figures 3.5A and 3.9B). Group C4 also has elevated concentrations of SO_4^{2-}, Sr^{2+} and Zn, elevated DO (avg. 9.5 % saturation), and an average conductivity of 873 µS/cm.

Group C5 also has elevated concentrations of HCO_3^-, Fe^{2+}, Sr^{2+}, Mn^{2+} and Zn, with no DO and an average conductivity that is significantly higher (2085 µS/cm) (Table 3.6) than other groups. The Southwestern Zone comprises HCA groups C1, C2 and C3, which are highly mineralized Na-Ca-HCO_3 (C1, C3) or Na-Ca-Cl (C2) water facies (Figure 3.9B). Conductivity varies significantly within the southwestern zone (C1, avg. 367 µS/cm; C2, avg. 1633 µS/cm; C3, avg. 883 µS/cm) (Table 3.5). The more mineralized C2 and C3 waters are located in the southwestern part of the regional study area, whereas C1 sites are concentrated to the east, where the Dundee Formation subcrops. It occurs adjacent to group C7 (Ca-Mg-HCO_3), which is concentrated over areas where the Lucas Formation subcrops. These less mineralized areas may be receiving proximal groundwater recharge.

Principal components (PCs) were extracted using the Kaiser Criterion and the Cattell scree test methods. The Kaiser Criterion method discriminates against components with eigenvalues < 1 (Kaiser, 1958). Eigenvalues are a measure of the amount of variance extracted by a given component (Pentecost, 1999). The Cattell scree test is a graphical method, where eigenvalues are plotted versus PCs, with the objective of identifying the appropriate number of PCs to use in the statistical analysis. For the dataset considered here, the eigenvalue versus PC curve flattens at a total of six PCs (Figure 3.10). Hence six PCs are used in the discussion that follows; remaining PCs with eigenvalues < 1 (i.e., below the factorial scree line) are not considered further (Cattell, 1966; StatSoft Inc., 1995).

The percentage of total variance in the groundwater dataset explained by PC1 is 26.2 %, followed by PC2 14.5 %, PC3 11.0 %, PC4 8.0 %, PC5 6.7 % and PC6 4.5 %, summing to a cumulative total of explained variance of 70.9 % (Table 3.6). A Varimax-normalized

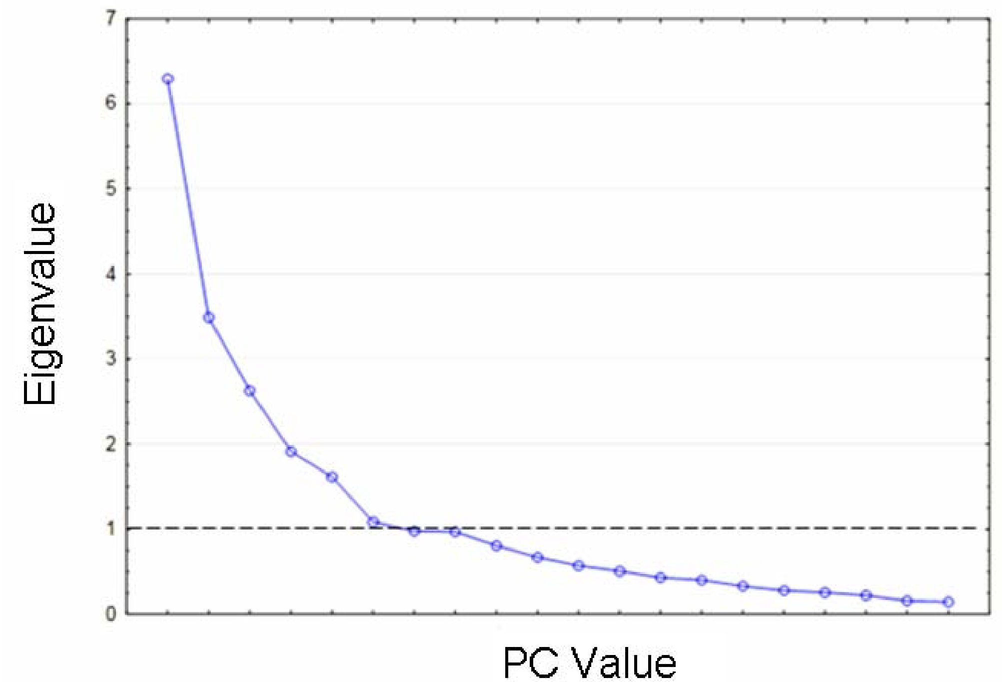


Figure 3.10. Eigenvalue *vs* PC number for regional groundwater dataset. The dashed line indicates eigenvalues = 1, and represents the 'factorial scree' line used in this study. Only the PC numbers with eigenvalues ≥1 have been considered in the statistical analysis.

Table 3.6. PCA Eigenvalues and Factor loadings. Principal Component Factor Loadings and explained variance for the six components with Varimax normalized rotation. Values shown in red: loadings >± 0.7.

Extraction: Principal components						
	PC1	**PC2**	**PC3**	**PC4**	**PC5**	**PC6**
Eigenvalue	6.3	3.5	2.6	1.9	1.6	1.1
% Total Variance	26.2	14.5	11.0	8.0	6.7	4.5
Cumulative Eigenvalue	6.3	9.8	12.4	14.3	15.9	17.0
Cumulative %	26.2	40.8	51.7	59.7	66.4	70.9
Factor Loadings (Varimax normalized) ; (Marked loadings are >.700000)						
pH	-0.76	0.05	-0.04	0.07	-0.32	-0.06
Conductivity	0.62	0.67	0.22	0.00	0.10	0.18
DIC	0.15	-0.15	0.26	-0.01	0.62	0.47
DOC	-0.14	0.12	-0.16	-0.10	-0.07	-0.53
DO	0.12	0.10	-0.05	0.60	0.39	0.28
H_2S	-0.20	0.14	0.29	0.32	-0.13	-0.65
CH_4(aq)	-0.65	0.39	0.32	0.03	-0.02	-0.19
$\delta^{18}O$	-0.02	0.11	0.92	0.02	0.03	0.13
$\delta^{2}H$	0.01	0.02	0.95	0.03	0.06	0.06
Ca^{2+}	0.81	0.13	-0.02	-0.20	0.38	0.20
Mg^{2+}	0.76	-0.01	-0.01	-0.29	0.34	0.19
K^{+}	0.04	0.59	0.07	-0.12	-0.11	-0.31
Na^{+}	-0.37	0.67	-0.09	0.12	-0.41	-0.09
HCO_3^{-}	0.09	-0.11	0.15	-0.01	0.68	0.23
SO_4^{2-}	0.83	0.16	-0.04	0.18	-0.08	0.10
Cl^{-}	0.10	0.78	0.11	0.27	0.07	-0.03
F^{-}	-0.13	0.00	0.21	0.14	-0.81	0.26
Fe^{2+}	0.07	-0.16	-0.03	-0.83	0.06	0.06
Sr^{2+}	0.58	-0.28	0.25	0.02	-0.17	0.41
Si^{4+}	0.13	-0.50	0.08	-0.30	0.30	-0.38
B	-0.42	0.50	-0.07	0.07	-0.63	-0.17
Ba	-0.37	-0.38	0.31	-0.12	0.30	0.09
Mn	0.10	0.00	-0.05	-0.80	0.26	-0.03
Zn	0.37	0.07	0.25	0.13	0.10	0.65
Expl.Var	4.39	2.91	2.41	2.21	2.93	2.18
Prp.Totl	0.18	0.12	0.10	0.09	0.12	0.09

rotation, as commonly used in hydrogeochemical studies (Adams et al., 2001; Cloutier et al., 2008; Thyne et al., 2004), was applied to the 6 PCs. Varimax-normalized rotation was chosen as it maximizes the variance between each of the principal components and as a result, creates extreme positive or negative, or near-zero values (Davis, 1986). The first two PCs explain the most significant variance within the data set (40.8 %), where PC1 has strong positive factor loadings for Ca^{2+}, Mg^{2+}, SO_4^{2-} and conductivity, a moderate positive association for Sr^{2+}, a strong negative correlation with pH, and a moderate negative correlation with CH_4. PC2 is characterized by high positive factor loadings for Cl^-, moderate positive loadings for Na^+, K^+ and conductivity, and a moderate negative loading for Si.

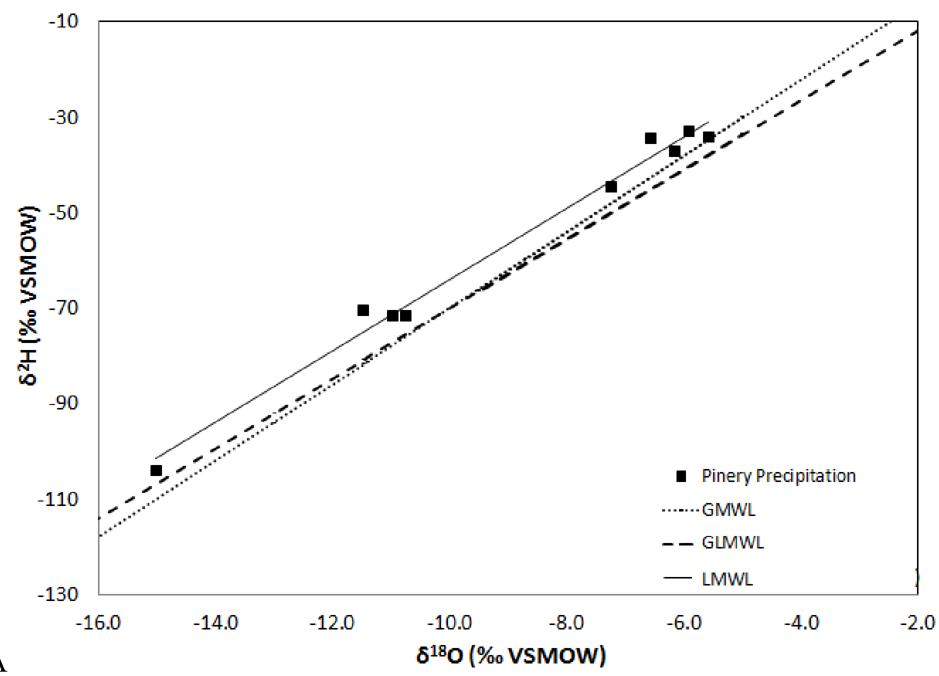
3.4.4 Isotopic Compositions of Groundwater

Local precipitation in the study area, as measured at nearby Pinery Provincial Park (Figure 1.5) had average monthly δ^2H (-104 to -33 ‰) and δ^{18}O (-15.0 to -5.6 ‰) values from November 2009 to Sept 2010 (Table 3.3; F.J. Longstaffe, pers. Comm., 2011). Typical seasonal variations were observed, with higher δ^{18}O and δ^2H values obtained during warmer seasons, and lower values during cooler seasons (Gat, 1980; Clark and Fritz, 1997). These data form an unweighted Local Meteoric Water Line (LMWL) (equation 2):

$$\delta^2H = 7.5\ (\delta^{18}O) + 10.8\ (R^2 = 0.9875,\ n=9) \qquad (2)$$

This relationship is broadly similar to Craig's (1961) Global Meteoric Waterline (GMWL) ($\delta^2H = 8[\delta^{18}O] + 10$) and the Great Lakes Meteoric Water Line (GLMW) ($\delta^2H = 7.3\ [\delta^{18}O] + 3.0$) (FJ. Longstaffe, pers. Comm., 2011) (Figure 3.11A). Deuterium excess (*d*-excess) was calculated following Dansgaard (1964) ($d = \delta D - 8[\delta^{18}O]$). The *d*-excess values for Pinery Provincial Park range from 10.5 to 21.5 over the period studied (Table 3.7). Similar *d*-excess values have been reported for this area previously (Gage, 2001; Huddart, 1999).

Groundwater sampled during the regional study has a wide range in δ^2H (-118 to -55 ‰) and δ^{18}O (-16.9 to -9.6 ‰) values (Figure 3.11B, Table 3.2). Most samples plot above both GMWL and the GLMWL, and define a trend line of $\delta^2H = 7.1\ (\delta^{18}O) + 5.0$, similar to the LMWL. Groundwater in the BWZ followed a similar pattern during the one-year study, with δ^2H and δ^{18}O values ranging from -81 to -71 ‰ and -12.1 to -10.6 ‰, respectively



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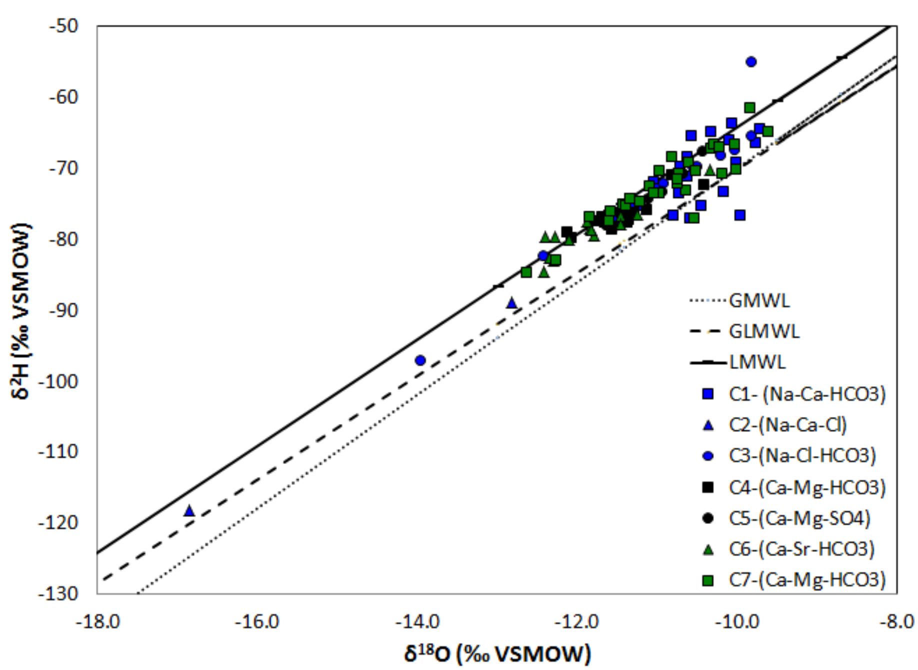

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Figure 3.11. δ^2H *vs* $\delta^{18}O$ of meteoric water from the regional study area. GMWL = Global Meteoric Water Line; GLMWL = Great Lakes Meteoric Water Line (FJ. Longstaffe, pers. Comm., 2011); LMWL = Local Meteoric Water Line (Pinery Provincial Park): (A) Monthly precipitation from Pinery Provincial Park (FJ. Longstaffe, pers. Comm., 2011); (B) Average groundwater δ^2H and $\delta^{18}O$ values are -74 and -11.1 ‰, respectively. Samples are grouped according to Hierarchical cluster analysis groups C1-C7.

Table 3.7. Pinery Precipitation $\delta^{18}O$, $\delta^{2}H$ and d-excess Values. Monthly composite precipitation samples from Pinery Provincial Park, November 2009 to October 2010 (data from FJ. Longstaffe, pers. Comm., 2011).

Date	$\delta^{18}O$ (H_2O) ‰ VSMOW	$\Delta^{2}H$ (H_2O) ‰ VSMOW	d-excess ‰
Nov-09	-11.5	-70	21.5
Dec-09	n/a	n/a	n/a
Jan-10	n/a	n/a	n/a
Feb-10	-15	-104	16.3
Mar-10	-11	-72	16.3
Apr-10	-5.6	-34	10.5
May-10	-5.9	-33	14.4
Jun-10	-7.3	-44	13.7
Jul-10	-6.2	-37	12.3
Aug-10	-6.6	-34	18.3
Sep-10	-10.8	-72	14.7
Oct-10	-	-	-

"-" symbolizes parameter not measured.

(Figure 3.12A & B). Site BW09 has the highest average values (δ^2H = -72 ‰; $\delta^{18}O$ = -10.9 ‰) and BW03, the lowest (δ^2H = -80 ‰; $\delta^{18}O$ = -12.0 ‰). The range in groundwater isotopic compositions is much smaller than observed for local precipitation (Figure 3.12A).

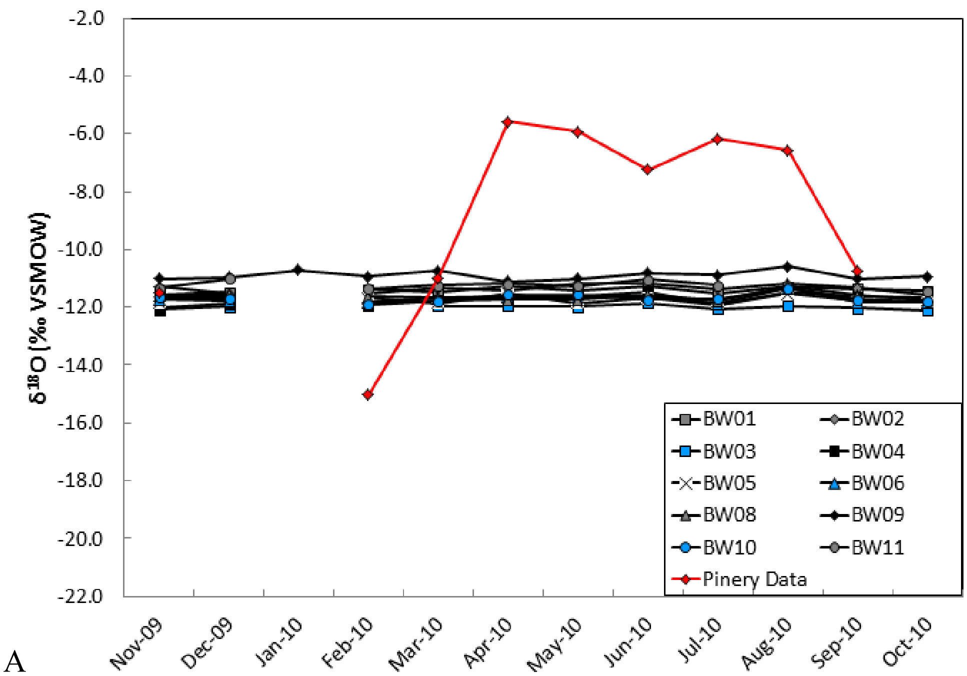
Groundwaters sampled during the regional sampling campaign were measured for non-enriched tritium (^3H) where concentrations varied from <6 (detection limit) to 148 TU, suggesting variable ages for these waters. Enriched tritium (E^3H) was later measured only once for the 10 BWZ wells and results varied from <0.8 (detection limit) to 6.1 TU (Tables 3.2 and 3.3). Results from the dissolved sulphate isotopic analysis displayed summer (July 2010) $\delta^{18}O_{SO4}$ and $\delta^{34}S_{SO4}$ groundwater values in the BWZ that ranged from +2.0 to +16.8 ‰ and -1.5 to 27.0 ‰, respectively. Samples collected in the fall (October 2011) displayed similar compositions ($\delta^{18}O_{SO4}$ = +0.3 to +16.5 ‰; $\delta^{34}S_{SO4}$ = -1.5 to +26.9 ‰) (Table 3.2).

3.5 Discussion

3.5.1 Regional Groundwater Classification

3.5.1.1 Water Facies and Water- Rock interactions in the Regional Groundwater

The general composition of the regional groundwater, as determined using a Piper plot, is Ca-Mg-HCO_3-SO_4, with minor Na-Ca-Cl (Figure 3.5A). However, such classifications overlook the importance of other ions (e.g., Sr^{2+}; Figure 3.3A) present in high concentrations at certain locations within the regional study area. Hence multivariate statistical techniques, first Hierarchical Cluster Analysis (HCA) and then Principal Component Analysis (PCA), were performed to better understand the chemical variability of the regional groundwaters, and to identify the most influential rock-water interactions.



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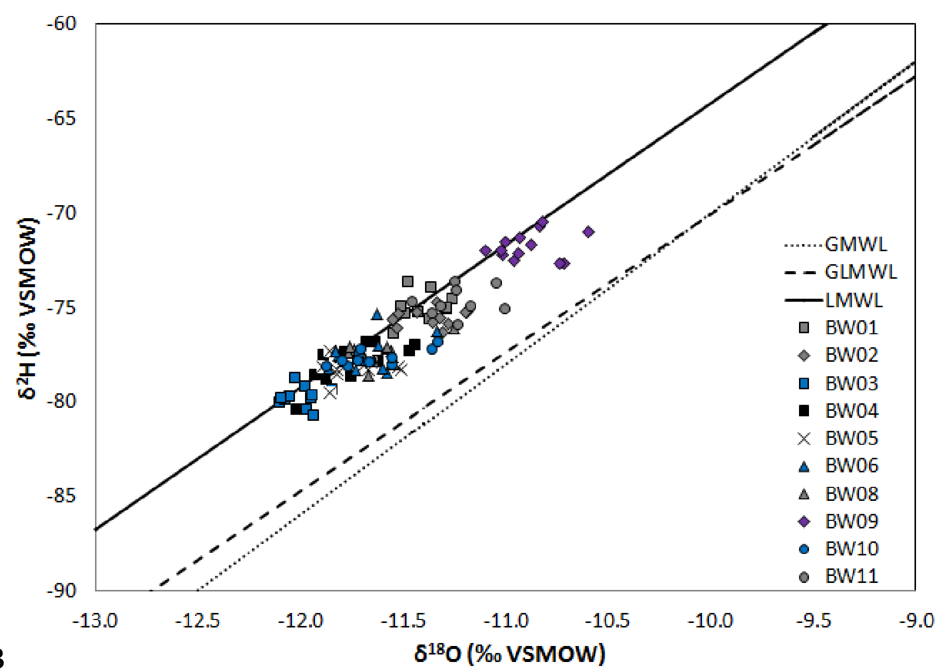

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Figure 3.12. Groundwater stable isotopic compositions of the BWZ from November 2009 to October 2010: (A) BWZ groundwater $\delta^{18}O$ *vs* time for the ten BWZ sites; (B) BWZ groundwater $\delta^{2}H$ *vs* $\delta^{18}O$. GMWL = Global Meteoric Water Line; GLMWL = Great Lakes Meteoric Water Line; LML = Local Meteoric Water Line (Pinery Provincial Park).

The HCA classification identified 7 primary water facies within the regional study area, each having a spatial coherence: (1) Northern Zone, comprised of HCA groups C6 and C7 and containing the Ca-Mg-HCO_3 and Ca-Sr-HCO_3 water facies; (2) BWZ, primarily consisting of HCA groups C4 and C5, and containing Ca-Mg-SO_4 and Ca-Mg-HCO_3 water facies plus showing some C6 and C7 water facies, and (3) Southern Zone, consisting of groups C1, C2, and C3, and containing the Na-Ca-Cl and Na-Ca-HCO_3 water facies.

The northern Zone is located in an area of both topographic and potentiometric highs, that are the upgradient portion of the regional study area, and the dilute nature of the northern waters (C6 and C7) represent this. The Ca-Mg-HCO_3 groundwater signature is a result of water-rock interactions between the aquifer and the Detroit River Group Formation, which consists of limestone and dolostone. The elevated Sr^{2+} concentrations in C6 waters may result partly from dissolution of carbonate minerals, in which Sr^{2+} substitutes for Ca^{2+} in the crystal lattice, and of celestite ($SrSO_4$), which is known to occur in the area (Hurley et al., 2008; WHI, 2006).

The BWZ (HCA groups C4 and C5, minor C6 and C7) is located in the center portion of the regional study are, which is down gradient to the northern zone. The water facies, Ca-Mg-HCO_3 and Ca-Mg-SO_4, are suggestive of water interaction with evaporite minerals such as gypsum, anhydrite and celestite dissolution, and possibility the oxidation of sulphides. Elevated metal concentrations (Fe^{2+}, Mn^{2+} and Zn) in both C4 and C5 groundwater may be the result of down-gradient flow of oxidized C4 water towards C5 waters, and oxidation of sulphides along the flow path. The majority of Group C4 and C5 sites are finished in the Lucas Formation and contain breathing wells.

The Southern Zone (HCA groups C1, C2 and C3) is located in an area south of the BWZ but is somewhat upgradient, and contains Na-Ca-HCO_3 and Na-Ca-Cl water facies. These water facie compositions are likely are the product carbonate dissolution followed by cation exchange reactions with the addition of variable amount of NaCl (ie. halite or shale). The majority of the southwestern zone groundwater occurs in the carbonate-rich Dundee and Lucas Formations and the calcareous shales and limestones of the overlying Hamilton Group. Cation exchange (ion exchange) reactions commonly affect water associated with shale-rich units (Langmuir, 1997). Typically, cation exchange occurs when Ca-HCO_3 water is flushed through units of marine origin, exchanging sediment-bound Na^+ for water-borne Ca^{2+}, thereby creating a Na-HCO_3 water type facies. Evidence for such cation exchange is most prominent for the C3 waters, where moderate concentrations of HCO_3 (avg. 175 mg/L) coexist with low Cl^- (avg. 50 mg/L), and high Na^+ (avg. 105 mg/L) (Table 3.6), and has been proposed by Mellor (2008) for Hamilton Group groundwater. In C2 waters, both Na^+ (avg. 301 mg/L) and Cl^- (avg. 304 mg/L) concentrations are high (Table 3.6). NaCl can come from dissolution of halite, or from road salt but considering the Na-HCO_3^- association, and the spatial association with the Hamilton Group and Kettle point shales, interaction with formational waters from this unit is most likely. C3 sites that overly the Hamilton Group also have elevated Cl^-. The southwestern region, and C2 groundwater in particular, has elevated boron concentrations (Table 3.7), an element commonly found in marine shales (Hackley et al., 2010; Hem, 1989), and possibly derived by interaction with either of these shale groups.

The PCA classification identified two PC's that could explain 40.8% of the variance observed within the dataset. Figure 3.13A displays the variable factor loadings for PC1 and PC2. The position of the hydrochemical variables on the diagram, and their relation to each other, provides information about geochemical regimes within the regional groundwater. A close association exists among Ca^{2+}, SO_4^{2-}, Mg^{2+}, along with Sr^{2+}. Despite the aquifer being situated in a predominantly carbonate bedrock, the closer association of Ca^{2+} with SO_4^{2-} than HCO_3^- in PC1 and suggests that Ca^{2+} is derived from sulphate mineral dissolution. Close association exists among Na^+, Cl^-, K^+, B^- and CH_4, in PC2, which suggests salt (e.g. halite/ sylvite or formational waters) and shale influence. Accordingly, PC1 can be interpreted as being dominated by dissolution of gypsum ($CaSO_4$•$2H_20$), anhydrite ($CaSO_4$) and celestite ($SrSO_4$), whereas PC2 can be interpreted as strongly influenced by shale and halide-enriched shale formational waters.

To decipher which geochemical processes are affecting which HCA group, the PC factor scores for all samples are shown on a PC2 *vs* PC1 plot in Figure 3.13B. HCA group C5 has the most positive values of PC1, suggesting that the Ca-Mg-SO_4 waters in the BWZ are strongly influenced by sulphate dissolution. By comparison, HCA group C2 has the most

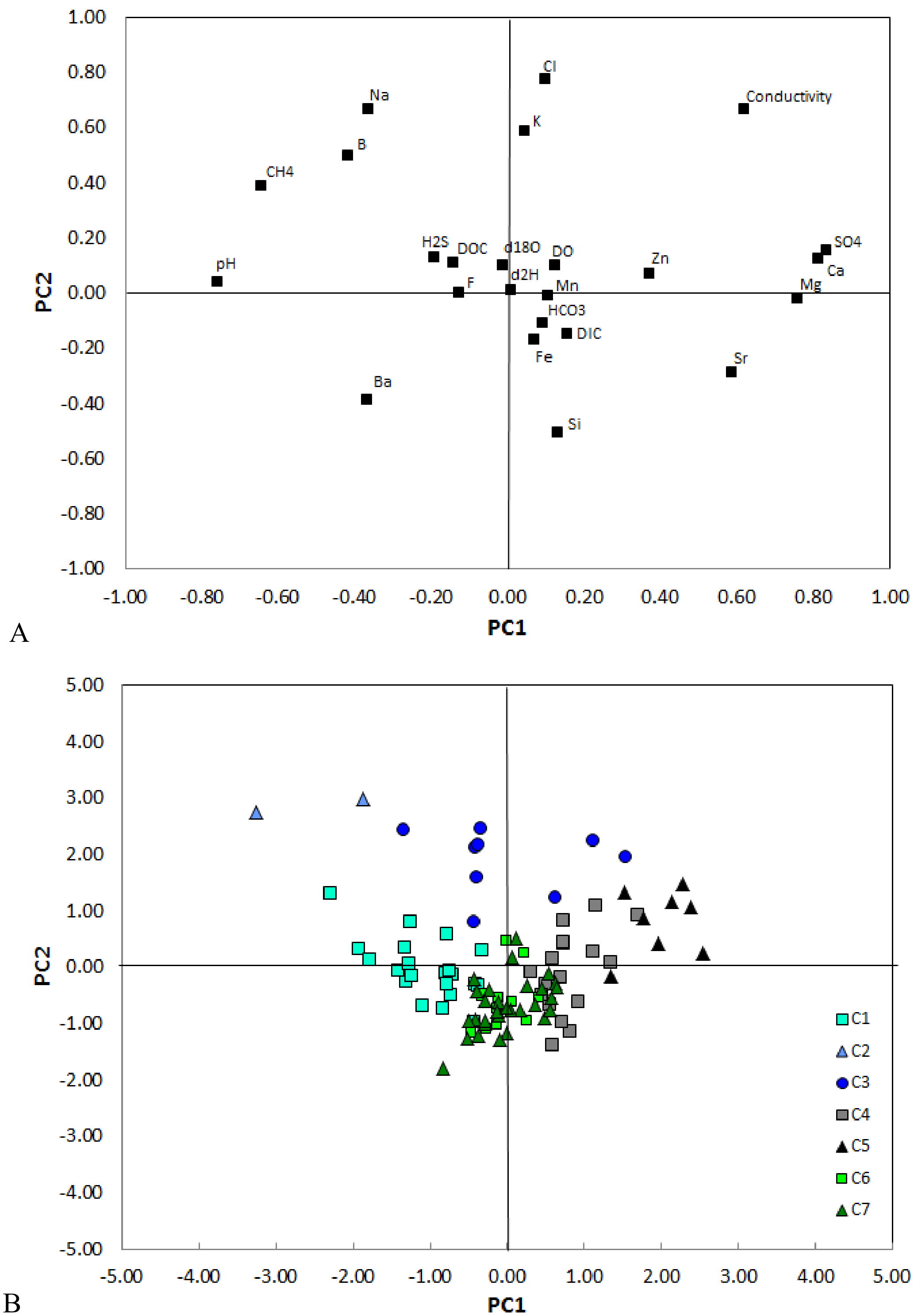


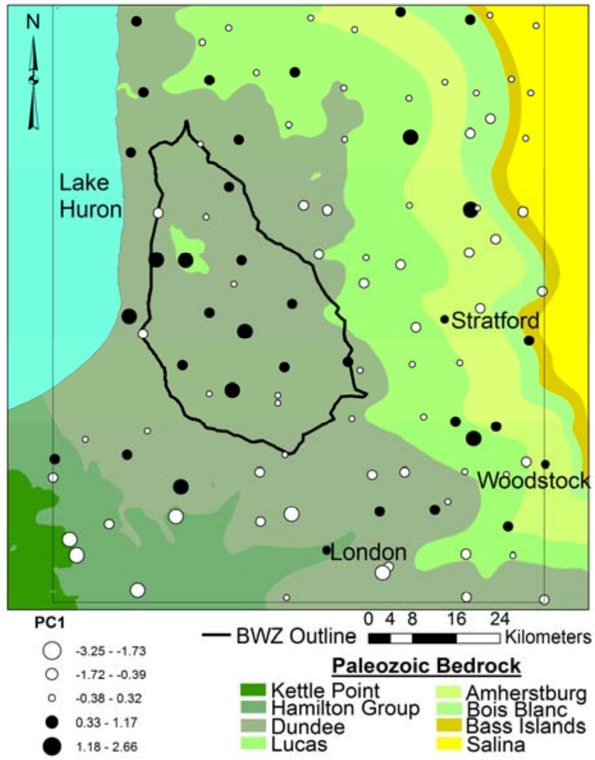
Figure 3.13. Principal component ordination charts. (A) Loadings for PC2 (salinity-shale influence) *vs* PC1 (sulphate influence) with Varimax-normalized rotation; (B) Principal component scores PC2 versus PC1. Samples are categorized according to cluster group (C1-C7).

negative values of PC1 and highest values of PC2, consistent, as would be expected, with a stronger control of salt influence on the composition of these Na-Ca-Cl groundwaters. The distribution in the regional scores also shows that some HCA groups (i.e. C1) have broader score distribution and hence more heterogeneous water chemistry than other groups (i.e. C4 and C7). A broad score distribution can indicate dilution or abrupt variations in vertical-horizontal connectivity within an aquifer (Thyne et al., 2004). The geographic distributions of PC1 and PC2 are illustrated in Figure 3.14A and B, following the concept of Cloutier et al. (2008). High positive scores for PC1 (i.e. sulphate influence) are concentrated in the BWZ, whereas negative scores are associated with the southern portion of the regional study area (Figure 3.14A). The PC2 scores are shown where high positive scores for PC2 (salt – shale influence) are most pronounced in the southwestern part of the regional study area (Figure 3.14B).

3.5.1.2 Origin of the Regional Groundwater

The oxygen and hydrogen isotopic compositions of freshwater serve as useful tracers of its origin and history (Clark and Fritz, 1997). In the regional study area, somewhat higher deuterium excess values of local precipitation and, more generally, the LMWL relative to the GMWL or the GLMWL (Figure 3.11A & B) reflect complex origins for precipitation in the region. Precipitation in southwestern Ontario is delivered by several different air masses, each with unique isotopic compositions reflecting relative humidity and temperature at the site of its formation, plus admixture of water vapour from more local sources (Gat et al., 1994; Machavaram and Krishnamurthy, 1995). Higher deuterium excess commonly reflects lower relative humidity in the source area. In the regional study area, the highest deuterium excess of precipitation typically occurs in the cooler months and lowest values in warmer months (Table 3.7).

This variation is largely a result of winter regional air masses having less humid, colder continental/Arctic origins, and summer air masses having more humid, warmer tropical-Atlantic origins (Fritz et al., 1987; Merlivat and Jouzel, 1979). Re-evaporation from



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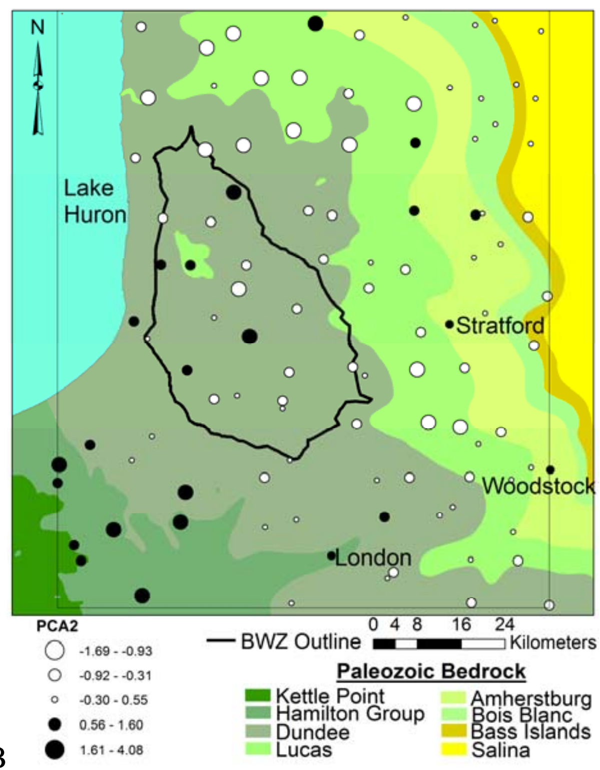

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Figure 3.14. Multivariate geospatial maps: (A) PC1; (B) PC2. The colour and size of circles indicate the level (positive or negative) and degree of component loadings, respectively.

the Great Lakes also serves to increase the deuterium excess of moisture masses in the region (Dansgaard, 1964). The moisture carrying capacity of an air mass is strongly linked to temperature, with greater capacity associated with warmer seasons. As a result, the δ-values of the precipitation condensed from these air masses are typically higher in the summer than in the winter (Fricke and O'Neil, 1999; Gat, 1980), thus creating the characteristic seasonal pattern that is evident in Figure 3.12A.

Regional groundwater has δ^2H and $\delta^{18}O$ values that track along or just below the LMWL (Figure 3.11B), as expected for an aquifer dominated by local recharge. The generally high *d*-excess values of the groundwater, along with its lower δ^2H (<-60 ‰) and $\delta^{18}O$ (<-9.5 ‰) values relative to local precipitation suggests that most recharge occurs during cooler months (e.g., snowmelt). The northern zone has $\delta^{18}O$ values ranging from -12.4 to -9.6 ‰ and δ^2H values ranging from -85 to -61 ‰. The larger range obtained for the southwestern zone ($\delta^{18}O$ = -16.9 to -9.7 ‰; δ^2H = -118 to -55 ‰) mostly arises because of a few samples with anomalous isotopic compositions that likely reflect additional processes (such as subsurface mixing with older water recharged during a cooler climatic period) (Mazor, 2004). The narrow range obtained for the BWZ ($\delta^{18}O$ = -12.1 to -10.5 ‰; δ^2H = -80 to -67 ‰) indicates a well mixed aquifer system.

3.5.2 Local BWZ Groundwater Classification

Regional sampling suggests that BWZ groundwater is composed principally of Ca-Mg-HCO_3 and Ca-Mg-SO_4 waters (cluster groups C4 and C5), and is regionally anomalous in SO_4^{2-}, Sr^{2+}, Fe^{2+} and Zn^{2+} concentrations. Monthly sampling of the BWZ during the one-year study reveals a finer structure in its water facies, in order of most abundant to least they are (1) Ca-Mg-SO_4, (2) Ca-Sr-HCO_3, (3) Ca-Mg-HCO_3 , (4) Ca-Na-HCO_3 and (5) Na-Ca-Cl. The Ca-Mg-SO_4- facies is most abundant within the BWZ, and is dominant in the deepest wells (163 to 168 m ASL) with the deepest water levels (178-186 m ASL). Despite different concentrations of ions, all of these waters have been affected by the same general reactions involving interaction with carbonate and evaporite minerals, as demonstrated by Figure 3.15.

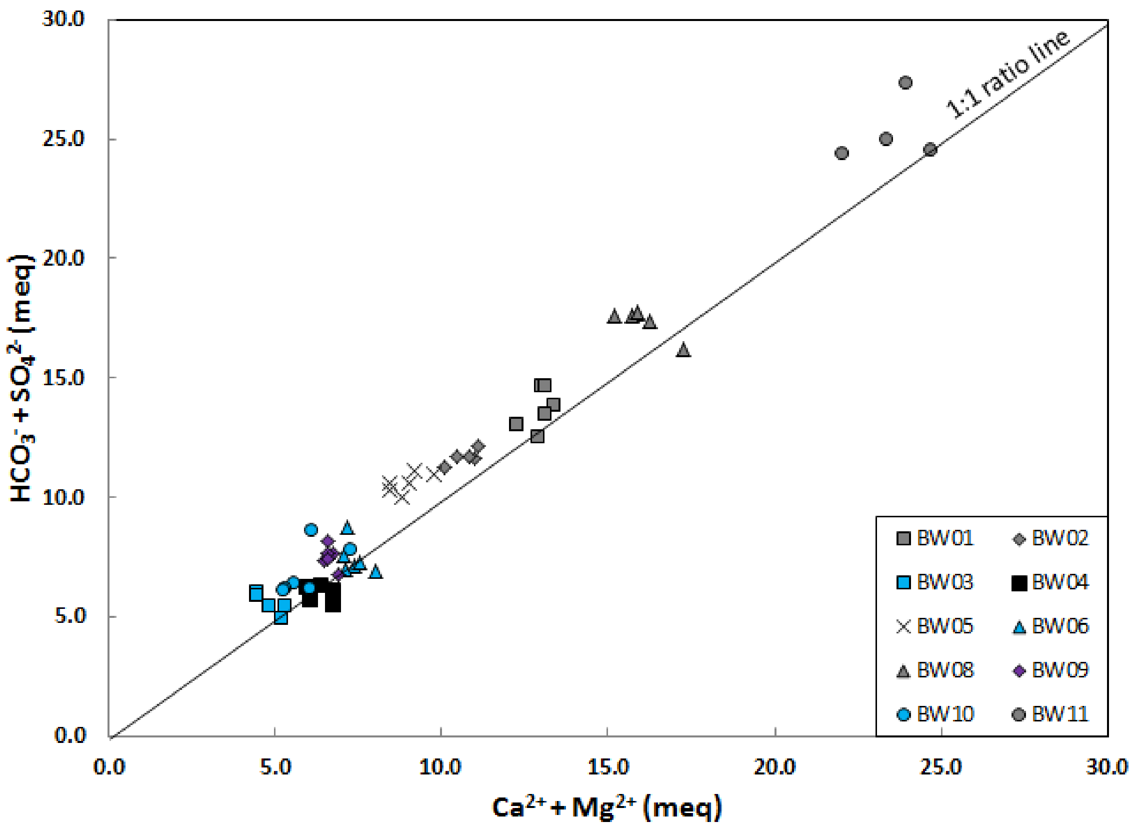


Figure 3.15. Chemistry of BWZ groundwater: $HCO_3 + SO_4^{2-}$ *vs* $Ca^{2+} + Mg^{2+}$ (meq). The symbols represent the following water facies: Grey = Ca-Mg-SO_4; Blue symbols= Ca-Sr-HCO_3; Black= Ca-Mg-HCO_3; Purple = Ca-Na-HCO_3 and the 'X' = Na-Ca-Cl.

Deviations from the 1:1 trend, observed for the Ca-Mg-SO_4 and Na-Ca-Cl waters, and to a lesser extent for the Ca-Sr-HCO_3, indicate that additional processes have contributed to water chemistry. Elevated concentrations of several elements (e.g. Fe^{2+}, Ag^{+}, Cu^{2+}, Pb^{2+}, Y^{3+}, Tl^{3+}, Zn^{2+}) apparent in the regional investigation were confirmed in the more detailed sampling of the BWZ. The following section describes the 5 water facies.

3.5.2.1 Ca-Mg-SO_4 Facies

The most common water type in the BWZ is the Ca-Mg-SO_4 water facies , which occurs in its west-central area (sites BW01, BW02, BW08, and BW11; Figure 3.16). Concentrations of SO_4^{2-} in these waters are significantly higher than the other BWZ water facies, ranging from 324.4 to 989.5 mg/L (Table 3.8). These sites also have elevated grouped averages of Sr^{2+} (13.6 to 20.8 mg/L), and Fe^{2+} (0.019 to 3.260 mg/L), Zn (47.9 to 1460.4 µg/L). The elevated SO_4^{2-} concentration in this groundwater is likely a product of anhydrite and/or gypsum dissolution. On a plot of Ca^{2+} *vs* SO_4^{2-}, groundwater dominated by anhydrite/gypsum dissolution should fall along a 1:1 dissolution line, which is the case for many samples from the Ca-Mg-SO_4 water facies (Figure 3.17A). Gypsum/anhydrite has high solubility and fast reaction rates and where present its dissolution can dominate groundwater chemistry. Gypsum will usually be completely removed from the mineral system before celestite or carbonate rocks undergo significant dissolution, because of the common ion effect. The Ca-Mg-SO_4 waters are undersaturated with respect to both gypsum and anhydrite, and at saturation or slightly over saturated with respect to celestite, calcite and dolomite (Table 3.4). Hence, this suggests that dissolution of carbonates and celesite has occurred. Groundwater from sites BW08 and BW11 plot above the 1:1 Ca:SO_4^{2-} line in Figure 3.17A. This anion excess becomes balanced when Mg^{2+} is added in addition to Ca^{2+} (Figure 3.17B). This indicates dolomite dissolution, and explains the presense of Mg^{2+} in the groundwater. The Ca-Mg-SO_4 groundwater is either at saturation (BW01, BW02) or slightly oversaturated with respect to calcite (BW08 and BW11) (Table 3.4). At the latter two sites, the groundwater is also at equilibrium or slightly oversaturated with respect to dolomite and undersaturated with respect to gypsum and anhydrite, as expected for dolomite dissolution.

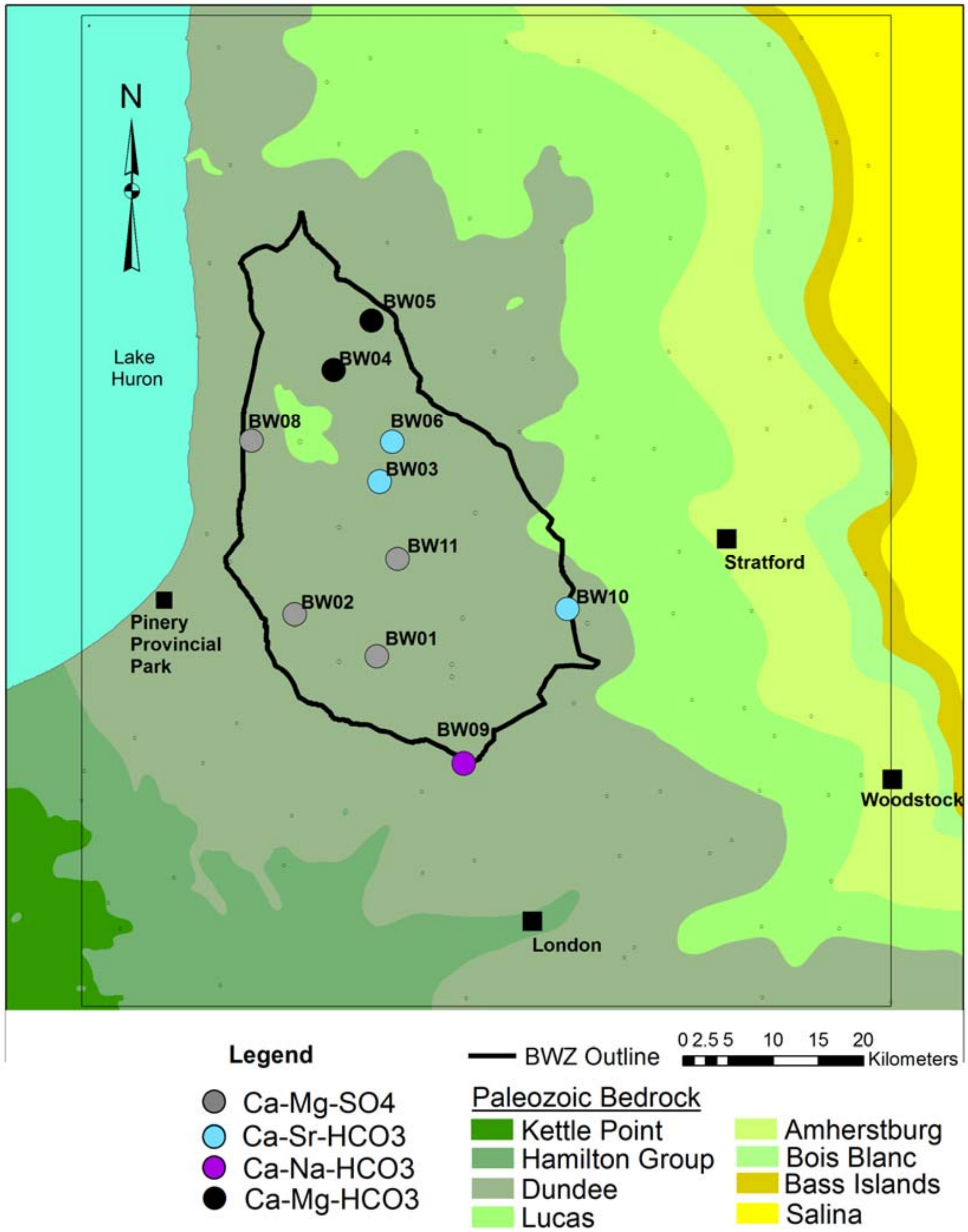


Figure 3.16. Spatial map of the BWZ groundwater facies.

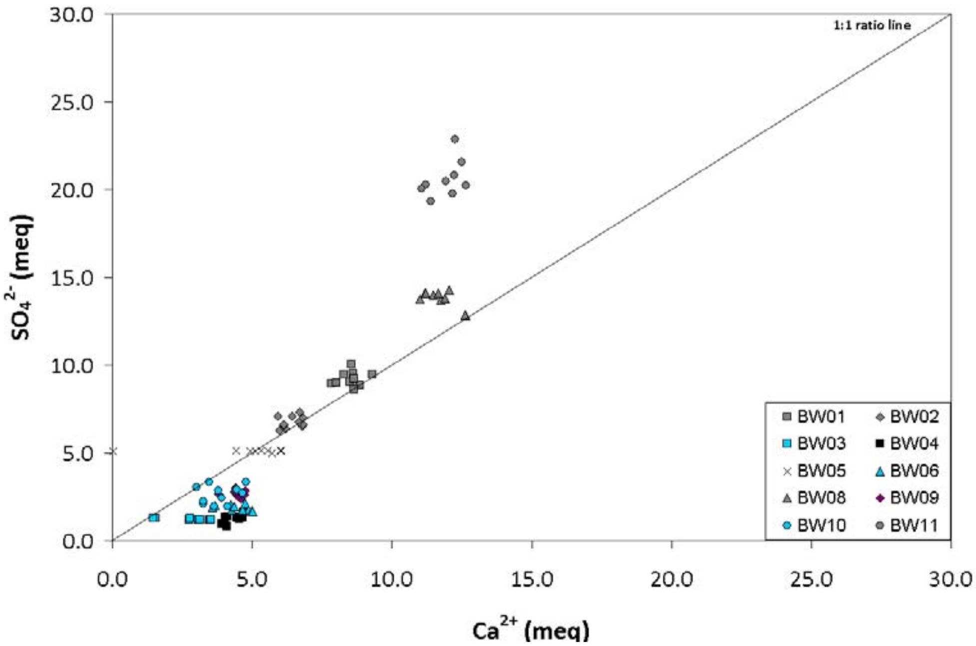
Table 3.8. Local BWZ Station (BW01-BW11) Compositional Averages

Parameter	Unit	BW01	BW02	BW03	BW04	BW05	BW06	BW08	BW09	BW10	BW11
Temperature	°C corrected	10.78	11.47	10.83	9.47	10.49	10.54	11.09	11.86	13.44	14.19
pH	pH units	7.3	7.3	7.5	7.3	7.3	7.3	7.4	7.4	7.4	7.1
Conductivity	µS/cm	866	1005	540	596	2238	703	1488	753	624	1982
ORP mV	mV Ag-AgCl	23.6	-126.2	-113.9	-5.9	-138.2	9.1	-159.1	18.8	39.2	-190.6
DIC	mg/L	59.4	66.6	58.8	64.2	67.5	76.1	48.0	60.6	56.0	51.2
DOC	mg/L	0.5	0.5	0.4	0.4	0.5	0.6	0.8	1.2	0.5	0.5
Total Coliform	counts/100mL	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-
Fecal Coliform	counts/100mL	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-
Dissolved Oxygen	% saturation	32.3	1.9	1.6	11.0	0.7	14.7	0.8	9.6	9.9	0.4
Dissolved Methane	% saturation	0.004	0.018	0.005	0.000	0.006	0.004	0.004	0.007	0.000	0.021
Dissolved Hydrogen Sulphide	mg/L S2-	-	0.180	-	-	0.188	-	0.223	-	-	-
Oxygen (g) Field	%	18.2	12.2	14.8	18.2	9.8	7.0	15.9	20.9	17.7	15.6
Carbon Dioxide (g) Field	%	0.7	1.5	0.3	0.3	0.4	1.3	0.0	0.0	1.3	0.2
Oxygen + Argon (g) Laboratory	v/v	19.3	17.7	18.3	19.4	10.9	11.0	17.1	20.7	20.2	18.6
Carbon Dioxide (g) Laboratory	v/v	0.8	0.9	0.3	0.4	0.6	1.3	0.2	0.5	0.9	0.3
Nitrogen (g) Laboratory	v/v	79.9	81.4	81.4	80.3	88.6	87.7	82.7	78.8	78.9	81.1
$\delta^{18}O$ (H_2O)	‰VSMOW	-11.4	-11.4	-12.0	-11.7	-11.7	-11.7	-11.6	-10.9	-11.7	-11.2
$\delta^{2}H(H_2O)$	‰VSMOW	-75	-75	-80	-78	-78	-77	-77	-72	-78	-75
^{3}H	TU	1.2	0.8	0.8	4.5	0.8	6.1	2.0	5.4	0.8	0.8
$\delta^{18}O$ (SO_4)	‰VSMOW	14.3	1.5	16.0	10.8	13.0	5.2	13.0	13.5	2.2	16.7
$\delta^{34}S(SO_4)$	‰CDT	27.0	-1.5	20.4	15.5	25.0	3.8	26.8	23.4	1.2	26.1
Water Facies		Ca-Mg-SO_4	Ca-Mg-SO_4	Ca-Sr-HCO_3	Ca-Mg-HCO_3	Na-Ca-Cl	Ca-Sr-HCO_3	Ca-Mg-SO_4	Ca-Na-HCO_3	Ca-Sr-HCO_3	Ca-Mg-SO_4
Ca^{2+}	mg/L	171.1	128.5	56.2	87.1	107.0	89.9	236.8	89.8	77.3	239.2
Mg^{2+}	mg/L	53.5	49.8	20.3	23.6	42.5	33.8	51.7	25.8	26.4	134.8
K^{+}	mg/L	0.8	1.0	0.6	0.8	1.3	1.0	0.9	1.3	0.6	1.1
Na^{+}	mg/L	8.4	15.5	5.7	12.4	309.2	6.7	30.2	31.2	6.5	26.5
HCO_3^{-}	mg/L	281.5	297.4	271.7	281.0	334.0	338.3	223.2	286.5	276.8	267.0
SO_4^{2-}	mg/L	443.0	324.4	59.2	60.6	245.8	89.1	658.8	129.7	126.0	989.5
Cl^{-}	mg/L	4.5	7.9	0.4	14.8	410.2	16.7	21.2	12.7	0.7	10.1

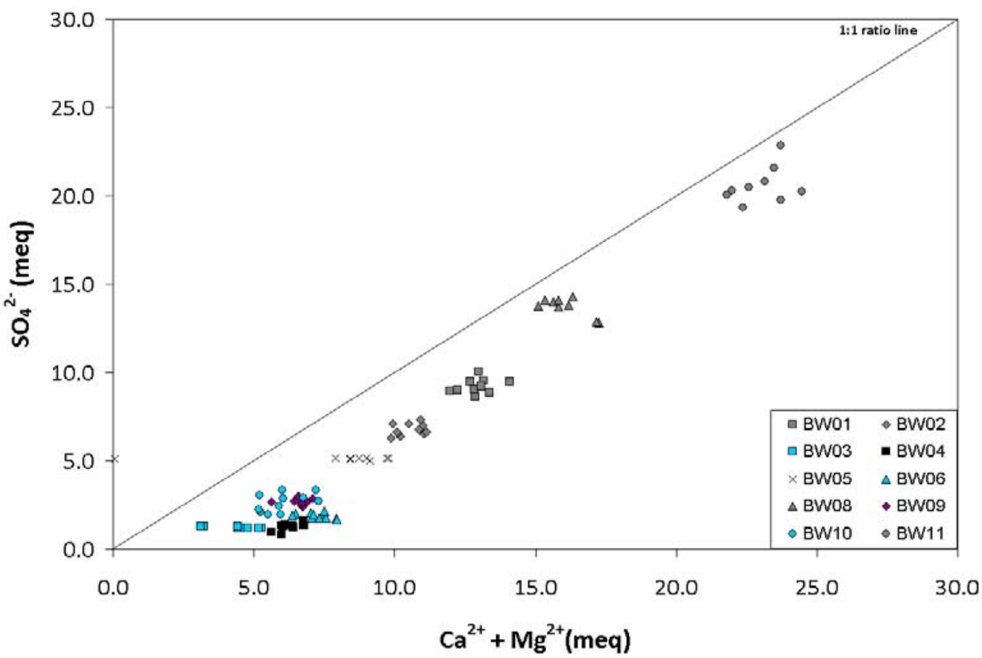
Parameter	Unit	BW01	BW02	BW03	BW04	BW05	BW06	BW08	BW09	BW10	BW11
F^-	mg/L	1.6	1.3	1.6	0.8	1.3	1.5	1.8	1.0	1.0	2.1
Fe^{2+}	mg/L	0.019	0.585	0.361	0.011	1.168	0.028	1.632	0.058	0.028	3.260
Sr^{2+}	mg/L	13.6	20.8	47.0	12.6	40.7	35.5	16.8	2.9	43.3	17.8
Si	mg/L	4.7	3.4	5.6	3.9	4.8	6.1	4.4	4.1	5.6	4.1
Br^-	mg/L	<0.02	0.03	<0.02	<0.02	0.08	0.05	0.03	0.03	<0.02	0.06
I^-	µg/L	4	4	4	4	15	4	6	4	4	5
PO_4^{2-}	mg/L	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
NO_{3-}	mg/L as N	2.477	<0.002	0.004	1.824	0.003	0.648	0.003	0.940	0.034	0.003
NO_2^-	mg/L as N	0.004	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	0.007	0.004	<0.003
$NH_3^+NH_4^+$	mg/L as N	0.11	0.06	0.07	<0.04	0.07	<0.04	0.10	0.13	0.15	0.10
Organic N	mg/L as N	<0.05	<0.05	0.06	<0.05	<0.05	<0.05	0.22	0.19	<0.05	<0.05
TKN	mg/L as N	0.08	0.06	0.13	<0.05	<0.05	<0.05	0.32	0.32	0.11	0.11
Sr/Ca	Ratio	0.08	0.16	0.92	0.14	0.38	0.40	0.07	0.03	0.58	0.07
Mg/Ca	Ratio	0.31	0.39	0.40	0.27	0.40	0.38	0.22	0.29	0.35	0.56
Na/Cl	Ratio	1.91	1.97	15.09	0.85	0.75	0.44	1.43	5.52	10.09	2.61
Cl/Br	Ratio	266.84	350.66	23.92	855.33	5195.39	381.14	809.74	466.73	41.62	409.36
Ag	µg/L	0.012	0.018	0.037	0.012	0.041	0.028	0.014	<0.005	0.035	0.016
Al	µg/L	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
As	µg/L	0.10	0.16	1.65	0.08	3.58	0.30	3.42	0.18	0.04	0.12
B	mg/L	0.06	0.09	0.02	0.02	0.11	0.02	0.17	0.10	0.03	0.22
Ba	µg/L	46.28	85.79	150.15	265.79	117.12	116.34	26.29	85.29	93.45	9.58
Be	µg/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Bi	µg/L	<0.0500	<0.0500	<0.0500	<0.0500	<0.0500	<0.0500	<0.0500	<0.0500	<0.0500	<0.0500
Cd	µg/L	0.05	<0.01	<0.01	0.03	0.03	0.05	0.02	0.05	0.04	<0.01
Ce	µg/L	<0.002	<0.002	<0.002	0.004	<0.002	<0.002	0.004	<0.002	0.003	<0.002
Co	µg/L	0.004	0.014	0.110	0.007	0.081	0.009	0.092	0.024	0.030	0.016
Cr	µg/L	<0.02	<0.02	0.04	0.08	0.04	0.04	0.07	0.06	<0.02	<0.02
Cs	µg/L	0.002	0.004	0.003	0.002	0.004	0.005	0.003	0.002	0.006	0.005
Cu	µg/L	3.2	2.1	0.3	4.4	0.4	1.4	0.8	18.8	13.8	1.1
Dy	µg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Er	µg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Eu	µg/L	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004
Ga	µg/L	<0.002	0.003	0.006	<0.002	0.007	0.003	0.004	<0.002	0.003	0.005
Gd	µg/L	<0.0010	<0.0010	0.0017	0.0022	<0.001	0.0014	<0.0011	<0.0010	<0.0010	<0.001
Hf	µg/L	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004

Parameter	Unit	BW01	BW02	BW03	BW04	BW05	BW06	BW08	BW09	BW10	BW11
Hg	ng/L	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5
Ho	µg/L	0.0002	<0.0001	<0.0001	0.0002	0.0002	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
La	µg/L	0.003	0.002	0.002	0.004	0.003	0.003	0.005	0.002	0.003	0.006
Li	µg/L	5.2	4.3	3.4	2.2	10.0	7.0	6.5	4.8	2.5	11.0
Lu	µg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Mn	µg/L	6	13	14	2	11	4	25	4	7	63
Mo	µg/L	3.6	4.4	3.4	0.6	5.2	15.3	7.4	4.4	2.9	2.6
Nb	µg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Nd	µg/L	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
Ni	µg/L	1.3	3.0	0.6	5.0	1.3	0.9	1.3	1.7	7.1	4.4
Pb	µg/L	0.07	<0.05	<0.05	0.37	0.06	0.10	<0.05	0.48	0.34	<0.05
Pr	µg/L	0.0005	0.0003	<0.0004	0.0005	0.0007	0.0006	0.0007	<0.0004	<0.0004	<0.0004
Rb	µg/L	0.6	0.7	0.6	0.6	1.0	0.7	0.8	0.7	0.4	1.1
Sb	µg/L	<0.01	<0.01	<0.01	0.02	0.03	0.07	<0.01	0.11	0.05	<0.01
Sc	µg/L	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Se	µg/L	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	0.3	<0.2	<0.2
Sm	µg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Sn	µg/L	<0.01	<0.01	<0.01	<0.01	0.03	<0.01	<0.01	<0.01	<0.01	<0.01
Ta	µg/L	0.0005	0.0005	0.0005	<0.0003	0.0006	0.0004	0.0006	0.0004	0.0004	0.0004
Tb	µg/L	0.0002	<0.0001	<0.0001	<0.0001	0.0002	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Th	µg/L	0.003	0.002	<0.001	<0.001	0.002	<0.001	0.004	<0.001	<0.001	0.003
Ti	µg/L	0.2	0.2	<0.1	<0.1	0.2	<0.1	0.4	<0.1	<0.1	0.4
Tl	µg/L	0.071	0.005	0.031	0.013	0.007	0.026	0.004	0.114	0.021	0.008
Tm	µg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
U	µg/L	1.5716	3.9323	0.2001	0.7283	0.7358	0.9239	0.5117	0.5106	0.5241	0.7929
V	µg/L	0.067	0.012	0.010	0.115	0.048	0.023	0.007	0.056	0.008	0.010
W	µg/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.02	0.04	<0.01
Y	µg/L	0.0750	0.1008	0.2329	0.0675	0.2006	0.1720	0.0846	0.0179	0.2142	0.0816
Yb	µg/L	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008
Zn	µg/L	429.9	265.2	547.0	180.4	251.8	252.2	47.9	45.8	324.8	1460.4
Zr	µg/L	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1

"-" symbolizes parameter not measured. “<” symbolizes parameter is below detection limit.



A



B

Figure 3.17. Chemistry of BWZ groundwater: (A) SO_4^{2-} *vs* Ca^{2+} (meq); (B) SO_4^{2-} *vs* Ca^{2+} + Mg^{2+}(meq). The symbols represent the following water facies: Grey = Ca-Mg-SO_4; Blue symbols= Ca-Sr-HCO_3; Black = Ca-Mg-HCO_3; Purple = Ca-Na-HCO_3 and the 'X' = Na-Ca-Cl.

Sulphate can also be produced by sulphide oxidation (equations 3 to 6), in addition to evaporite dissolution. Further more, sulphuric acid (H_2SO_4) a byproduct of sulphide oxidation, will produce Ca^{2+} and Mg^{2+} when neutralized with carbonates (equation 7):

$$FeS_2(s) + 7/2\ O_{2(aq)} + H_2O \rightarrow Fe^{2+} + 2SO_4^{2-} + 2H^+ \quad (3)$$

$$FeS_2(s) + 14Fe^{3+} + 8H_2O \rightarrow 15Fe^{2+} + 2SO_4^{2-} + 16H^+ \quad (4)$$

$$ZnS + 2O_2 \rightarrow Zn^{2+} + SO_4^{2-} \quad (5)$$

$$ZnS + 8\ Fe^{3+} + 4H_2O \rightarrow Zn^{2+} + 8Fe^{2+} + SO_4^{2-} + 8H^+ \quad (6)$$

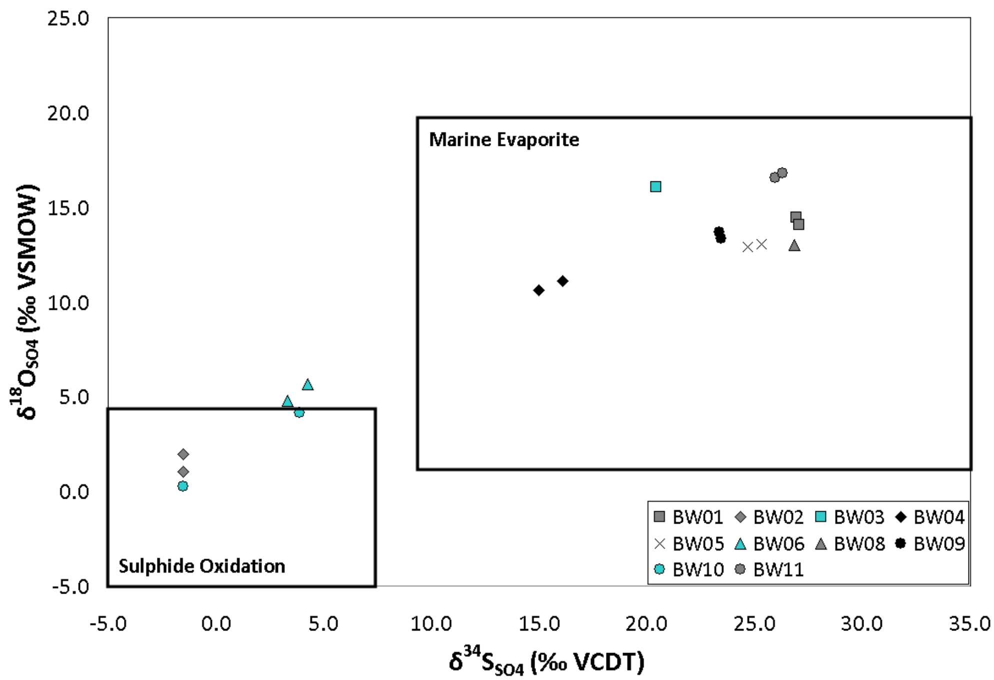
$$CaMg(CO_3)_{2\ (s)} + H_2SO_4 = Ca^{2+} + Mg^{2+} + SO_4^{2-} + 2HCO_3^- \quad (7)$$

The presence of sulphides such as pyrite and marcasite (FeS_2) and sphalerite ([Zn, Fe]S_2) is well known in Lucas Formation-equivalent units of the Michigan and Appalachian Basin. The Findlay Arch mineral district, for example, in northeastern Ohio, contains Devonian sulphides in small amounts within carbonate lithologies. Pyrite and marcasite occur in lenticular masses that can be centimeters-thick, as breccia cements, and as finely disseminated crystals; likewise, sphalerite is locally common as irregular masses or as crystals in large vugs and pockets within brecciated dolomite (Botoman and Stieglitz, 1978; Carlson, 1990; 1994). It is likely that such phases also are present in the Lucas Formation, particularly given the elevated concentrations of Fe^{2+} and Zn^{2+} that are characteristic of the Ca-Mg-SO_4 groundwaters.

The sulphur ($\delta^{34}S_{SO4}$) (and oxygen ($\delta^{18}O_{SO4}$) – see below) isotopic compositions of sulphate have previously proven useful for identifying sources of groundwater sulphate (Dogramaci et al., 2001; Eberts and George, 2000; Hosono et al., 2010; Lee and Krothe, 2003; Li et al., 2010; Otero et al., 2008). Groundwater SO_4^{2-} can originate from a wide range of sources, including anthropogenic materials (chemical fertilizers, detergents, polluted precipitation), seawater aerosols, soils, sulphate mineral dissolution, and oxidation of reduced sulphide minerals (Krouse and Mayer, 2000). Sulphur not involved in the sedimentary cycle (primary igneous rocks) has a narrow range of $\delta^{34}S$ values close to 0 ‰, whereas sulphur from sediments have a much wider range of $\delta^{34}S$ values (Thode, 1991). For example, marine evaporites such as gypsum and anhydrite have δ^{34}S values reflecting the isotopic composition of dissolved SO_4^{2-} in the ocean at the time of deposition, generally +10 to +30 ‰ during the Paleozoic Era (Krouse and Mayer, 2000). Devonian evaporites typically have δ^{34}S values ranging from +17 to +25 ‰, but values as high as +30 ‰ are known (Claypool et al., 1980; Holser and Kaplan, 1966). Reduced inorganic sulphur compounds, such as sulphide minerals, which are common within marine carbonate and evaporites, are typically much poorer in ^{34}S (Clark and Fritz, 1997; Krouse and Mayer, 2000). Values in the Findlay Arch District, northwestern Ohio, for example, range from -24.2 to +7.0 ‰ for pyrite/marcasite, -0.9 to +4.8 ‰ for sphalerite, and -3.4 to +0.6 ‰ for galena (PBS) (Carlson, 1994).

The sulphate stable isotopic compositions of BWZ groundwater fall into two groups: (1) low $\delta^{34}S_{SO4}$ (-1.5 to +4.3 ‰) with low $\delta^{18}O_{SO4}$ (-1.0 to +5.6 ‰), and (2) high $\delta^{34}S_{SO4}$ (+14.8 to +27.1 ‰) with high $\delta^{18}O_{SO4}$ (+11.1 to +16.8 ‰) (Figure 3.18A). There is also a systematic relationship between δ^{34}S values and SO_4^{2-} concentrations (Figure 3.18B). Sites BW01, BW08 and BW11 from the Ca-Mg-SO_4-HCO_3 facies and sites BW03, BW04 and BW09 (Ca-Mg-HCO_3-SO_4 and Ca-Sr-HCO_3-SO_4 facies) plot within the range of marine evaporites (δ^{34}S = +15 to +28 ‰), which matches Claypool's (1980) 'best estimate' curve for middle Devonian sediments (Figure 3.19), and have elevated SO_4^{2-} concentrations (58 to 1099 with an average of the site medians of 408 mg/L). In contrast, samples from sites BW02, BW06 and BW10 (Ca-Sr-HCO_3-SO_4 and Ca-Mg-SO_4-HCO_3 facies) have much lower δ^{34}S values (-1.5 to +4.2 ‰), and lower SO_4^{2-} concentrations (80 to 360 with an average of the site medians of 177 mg/L) and plot within the sulphide oxidation field. The results indicate that at most sites in the BWZ the largest proportion of SO_4^{2-} in groundwater is produced by evaporite dissolution, but at sites BW02, BW06 and BW10 locally contributions are from sulphide oxidation.

The $\delta^{18}O_{SO42}$ values provide additional information regarding the redox conditions during sulphide oxidation. Sulphates formed by sulphide oxidation should show a relationship between $\delta^{18}O_{SO42}$ and $\delta^{18}O_{H2O}$, since the sulphate will contain oxygen derived both from molecular oxygen and from water (Krouse, 1980; Longinelli, 1989; Torran and



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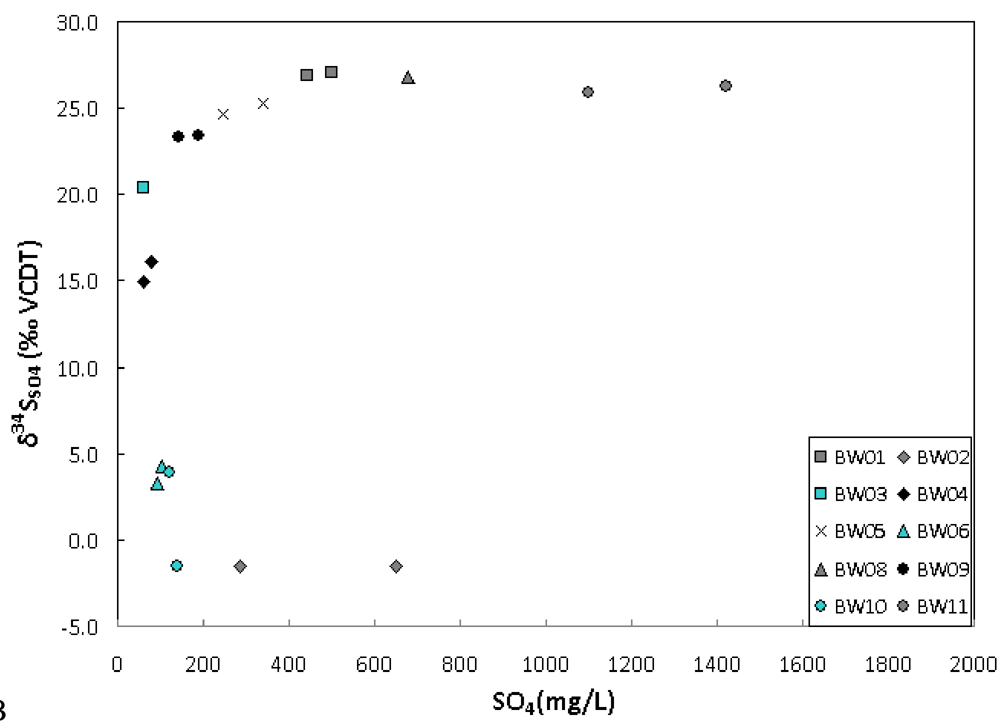

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Figure 3.18. Isotopic composition of sulphate in BWZ groundwater: (A) $\delta^{18}O$ *vs* $\delta^{34}S$. The boxes delineate commonly observed ranges in nature (Krouse and Mayer, 2000). (B) $\delta^{34}S$-SO_4 *vs* SO_4. The symbols represent the following water facies: Grey = Ca-Mg-SO_4; Blue symbols= Ca-Sr-HCO_3; Black = Ca-Mg-HCO_3; Purple = Ca-Na-HCO_3 and the 'X' = Na-Ca-Cl.

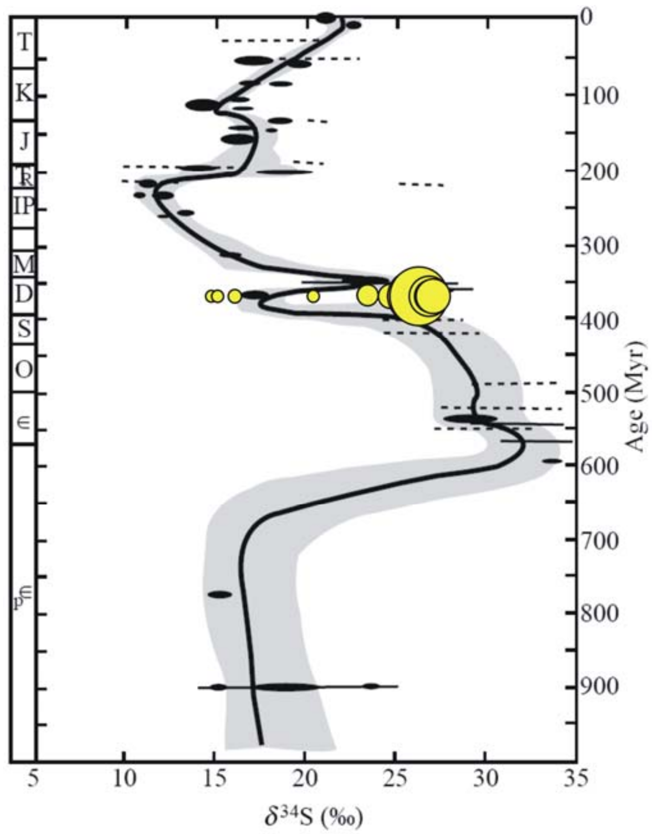


Figure 3.19. Claypool's 'best estimate curve' with respect to the isotopic composition of sulphate in the BWZ groundwater. For evaporite derived sulphate, there is coherence between the result obtained from the groundwater and the Claypool's range for the age of the Lucas Formation and the $\delta^{34}S$ values. The circles represent the values of $\delta^{34}S$ found in the local BWZ waters and the size of the circle pertains to the sulphate concentration for that sample (*modified from* Claypool, 1980*)*.

Harris, 1989). As observed in Reactions 3-7, pyrite and sphalerite oxidation can follow two different pathways (Langmuir, 1997). The oxygen isotopic fractionation between sulphate and water ($\Delta^{18}O_{SO4 - H2O}$) can be used to evaluate the relative importance of which reaction pathway was involved in the production of sulphate (Taylor et al., 1984). Low values of $\Delta^{18}O_{SO4 - H2O}$ (~1-4) indicate a saturated, anaerobic environment dominated by processes like those shown in equations 4 or 6. Higher values (~16 to 20) suggest an unsaturated (wet/dry) aerated environment, as represented by equations 3 or 5. Values of $\Delta^{18}O_{SO4 - H2O}$ for sites BW02, BW06 and BW10 (Ca-Sr-HCO_3 and Ca-Mg-SO_4 facies) range from +12 to +18 ‰ (avg. 15 ‰), suggesting that sulphide oxidation is occurring dominantly in an aerated environment, and dominated by Reactions 3 and 5.

Although the range of SO_4^{2-} concentrations for sites BW02, BW06 and BW10 is lower than for the evaporite-SO_4^{2-} dominated sites (Figure 3.18B), such concentrations indicate that a significant mass of sulphide is being oxidized. If the sulphide oxidized is pyrite and complete oxidation under Reaction 3 is assumed, the corresponding pH generated would be low (~2 or 3) in a non-buffered environment. In the highly buffered carbonate-rich environment of the BWZ, neutralization of this amount of acidity would not strongly influence the pH or the already high concentrations of bicarbonate. However, the pCO_2 is likely to be influenced. The average calculated pCO_2 (Table 3.4) in the sulphide-SO_4 dominated wells (0.012 atm.; S.D. = 0.004) is slightly higher than in the evaporite-SO_4 dominated wells (0.010 atm.; S.D. = 0.003) but with a significant overlap in their standard deviations. However, the averages of laboratory and field measured CO_2 (1.03/1.04 %; SD = 0.23/0.40) in the exhaled gas from the sulphide-SO_4 wells are much greater, at 2.5 and 3.7 times respectively, that of the other wells (0.41/0.28; SD=0.08/0.12). Therefore H_2CO_3 produced by sulphide oxidation-related carbonate dissolution may be partitioning into vapour-phase CO_2.

3.5.2.2 Ca-Sr-HCO_3 Facies

The Ca-Sr-HCO_3-SO_4 water facies occurs in the east-central parts of the BWZ (sites BW03, BW06, BW10; Figure 3.16), and is characterized by its elevated concentrations Sr^{2+} (ranging from 35.5 to 47 mg/L) relative to the regional average (10.7 mg/L Table 3.8).

Groundwater typically accumulates Sr^{2+} from atmospheric aerosols, seawater, and dissolution of minerals, especially calcite and dolomite, where Sr^{2+} substitutes for Ca^{2+} in the crystal lattice, strontianite ($SrCO_3$) and celestite ($SrSO_4$) (Essenberg, 1997; Feulner and Hubble, 1960; Kilchmann et al., 2004; Levine et al., 2002). Essenburg (1997) documented high Sr/Ca ratios (1.7 to 60) in groundwater in contact with celestite from the Salina Formation in Ohio. Given celestite's association with other evaporites, Sr^{2+} and SO_4^{2-} concentrations are also commonly strongly correlated (Hunker and Mudry, 2007; Kilchmann et al., 2004). However, celestite solubility limits the amount of Sr^{2+} in the presence of elevatated SO_4^{2-} (e.g. > 50 mg/L) in water to about 40 mg/L. More generally, elevated groundwater Sr^{2+} concentrations are commonly associated with karstic carbonates, and can even be used to identify areas of potential karstification (Levine et al., 2002).

Celestite dissolution is the most likely cause of elevated Sr^{2+} concentrations in this water facies. Celestite occurs as vug infilling in the Lucas Formation carbonates within the BWZ (Hurley et al., 2008). Sr/Ca ratios of the Ca-Sr-HCO_3 groundwaters are higher than the regional mean of 0.22, having station averages between 0.40 to 0.92 (Table 3.8). On a bivariate plot of SO_4^{2-} *vs* Sr^{2+} samples from this water facies plot on or close to the 1:1 theoretical celestite dissolution line (Figure 3.20). Finally, all of the samples from this water facies are undersaturated with respect to celestite, and given the high Sr^{2+} concentrations, this suggests there is active celesite dissolution (Table 3.4).

3.5.2.3 Ca-Mg-HCO_3 & Ca-Na-HCO_3 Facies

The Ca-Mg-HCO_3 and Ca-Na-HCO_3 water facies encompasses sites BW04 and BW09, respectively, and are located at the northern and southern edges of the BWZ (Figure 3.16), up gradient from more sulphate-rich water facies (i.e. Ca-Mg-SO_4). The lower sulphate concentrations indicate less interaction with evaporites, which may be less abundant in this portion of the BWZ, perhaps because of their earlier dissolution. The compositions of these facies are largely controlled by interaction with carbonates. The Lucas Formation contains both calcite ($CaCO_3$) and dolomite ($CaMg(CO_3)_2$), which react with slightly acidic groundwater (equations 8 and 9):

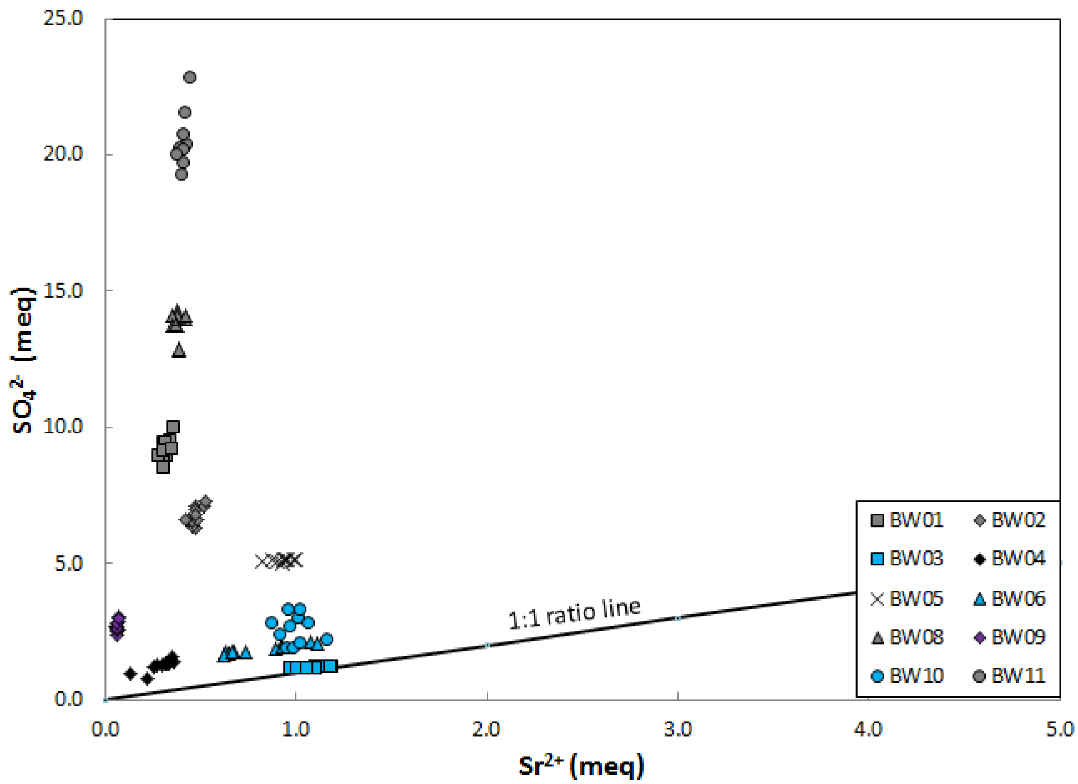


Figure 3.20. SO_4^{2-} *vs* Sr^{2+} (meq) of groundwater in the BWZ. The symbols represent the following water facies: Grey = Ca-Mg-SO_4; Blue symbols= Ca-Sr-HCO_3; Black = Ca-Mg-HCO_3; Purple = Ca-Na-HCO_3 and the 'X' = Na-Ca-Cl.

$$Calcite: CaCO_3 + H_2O + CO_{2(g)} = Ca^{2+} + 2HCO^{3-} \quad (8)$$

$$Dolomite: CaMg(CO_3)_2 + 2H_2O + 2CO_{2(g)} = Ca^{2+} + Mg^{2+} + 4HCO^{3-} \quad (9)$$

Water in contact with these rock types can be affected by incongruent dissolution of carbonate phases (i.e. one mineral dissolves while another precipitates). Mineral solubility depends on variables such as pH, temperature and partial pressure of CO_2, and the equilibrium constant (Ksp) of the mineral (Freeze and Cherry, 1979). The equilibrium constant of calcite is much lower than dolomites, $10^{-8.48}$ versus $10^{-17.9}$. Therefore calcite is much more soluble than dolomite and a solution will generally reach equilibrium faster with calcite than dolomite. When water already in equilibrium with calcite contacts dolomite, it will dissolve until its equilibrium is reached. Dolomite dissolution, however, will increase Ca^{2+} concentrations to the point where calcite oversaturation is reached, causing it to precipitate. As a result of calcite precipitation, Ca^{2+} and HCO_3^- are removed from the water, causing further dolomite dissolution, and leading to an increase in the Mg^{2+}/Ca^{2+} ratio of the groundwater (Freeze and Cherry, 1979). All groundwaters in the BWZ are in equilibrium or slightly saturated with calcite (Table 3.4). In the waters from site BW04 and BW09, dolomite is slightly undersaturated (Table 3.4) and may be in the early stages of incongruent dolomite dissolution. The Mg/Ca molar ratio in these groundwaters is ≤ ~0.5, which suggests that combined calcite and dolomite dissolution is occuring. The Ca-Na-HCO_3 water facies is likely a result of groundwater mixing with inflowing Na-Ca-HCO3 waters from the southern regional waters.

3.5.2.4 Na-Ca-Cl Facies

The Na-Ca-Cl facies is observed in water from only one well (BW05) at the northeastern edge of the BWZ (Figure 3.16). Its average Na^+ (309.2 mg/L) and Cl^- concentrations (410.2 mg/L) are significantly higher than other groundwater from the BWZ (average Na^+ = 15.9 mg/L; average Cl^- = 9.9 mg/L) (Table 3.8). Elevated Na^+ and Cl^- concentrations in groundwater can arise from both anthropogenic and natural sources. Anthropogenic sources include agricultural chemicals, animal waste, septic tank effluent, road de-icers; natural sources can include mineral dissolution, sea water infiltration, basinal brines and airborne aerosols, Halogen element concentrations (Cl^-, Br^-, I^-) can be used to distinguish among these possibilities. In general, halogens behave conservatively in groundwater; they do not readily exchange with rocks during water-rock interaction (Davis et al., 1998). Bromine (Br^-), however, behaves more conservatively than Cl^-. In particular, brines formed by evaporite dissolution versus seawater evaporation have different patterns of Cl/Br ratios. In seawater, the Br^- concentration is ~67 mg/L and the Cl/Br_{molar} ratio = ~650. As seawater evaporites, the residual brine attains higher Br^- concentrations and the Cl/Br ratio is lowered (to ~50), as Br^- is not incorporated into the precipitating halite. Conversely, during evaporite dissolution, the dissolving halite will contain very little Br^-, thus producing high Cl/Br ratios (1000 to 10,000) in groundwater (McCaffrey et al., 1987; Davis, 1998).

Site BW05 has average Cl^- and Br^- concentrations of 410.2 and 0.08 mg/L, respectively, yielding a Cl/Br_{molar} ratio of 5195.39 (Table 3.3). This is in comparison with a ratio of the regional average, which yields a ratio of 152.92, is quite high (Table 3.2). Additionally, groundwater with chemistry dominated by halite dissolution should have Cl^- *vs* Na^+ concentrations that plot along a 1:1 equivalence line (molar ratio of 1) (Mazor, 2004). Samples from site BW05 have an average Na/Cl ratio of 0.75, having a ratio close to 1 is suggestive that the salt possibly a result of halite dissolution. These factors suggest that halite dissolution is the source of groundwater salinity at this site. Halite is known to occur as inclusions within the Lucas Formation (Hurley et al., 2008; Johnston et al., 1992), although the concentrations here are much higher than anywhere else in the BWZ. This well is located in the Seaforth area where 19th century brine wells had been used to extract salt from the Salina Formation. Anecdotal evidence suggests one exists within several kilometres of BW05 (Hopper, pers. Comm., 2009). Without the elevated Na^+ and Cl^- concentrations, the water from BW05 would belong in the Ca-Mg-HCO_3 facies.

3.5.2.5 Groundwater Age

Tritium (T or ^3H) is a radioisotope with a half-life of 12.3 years that can be used to identify the age of groundwater recharge (Clark and Fritz, 1997). At low concentrations, ^3H is naturally produced by cosmic radiation, but its atmospheric concentration increased significantly between 1951 and 1980 because of thermonuclear testing. Pre-bomb ^3H concentrations in the United States likely ranged from 2 to 8 TU, and in the Ottawa region values ranged ~15 TU. This compares will concentrations of up to 10,000 TU during the testing (Kaufman and Libby, 1954; McMahon et al., 2011; Thatcher, 1962), which have since diminished substantially given the short half-life of ^{3}H. Taking into account the radioactive decay of Tritium, water that is ~70 years old and started with a pre-bomb value of 15 TU would have 3.59 % of its original tritium retained and would therefore would have a tritium value of 0.5. Therefore, in the BWZ water with higher values than the enriched detection limit of 0.8 would indicate post-1950s recharge. It is for this reason that $E^{3}H$ is a better tool for quantitatively age dating the BWZ groundwater, as the detection limit for non-enriched tritium is 6 T.U. The $E^{3}H$ data suggest that groundwater from sites BW02, BW03, BW05, BW10 and BW11 (TU= <0.8) were recharged prior to 1950. Groundwater from sites BW01, BW04 and BW08 appear to be a mixture of water recharged prior to 1960 and recent recharge (TU = 0.8 to 4), and sites BW06 and BW09 may contain groundwater of recent origin and may be as little as 5 to 10 years old. (TU = 5-7). It should be noted that when sites BW02 and BW03 were previously sampled for non-enriched tritium their values were significantly higher (12.6 and 18.29 ±6 TU) than the $E^{3}H$ measured values. This may be due to the poorer precision of the non-enriched method. It may also indicate fluctuation between apparently young and older groundwater suggesting that these sites may possibly be part of a groundwater flow network with greater geologic heterogeneity and hydraulic dispersion than the other sites.

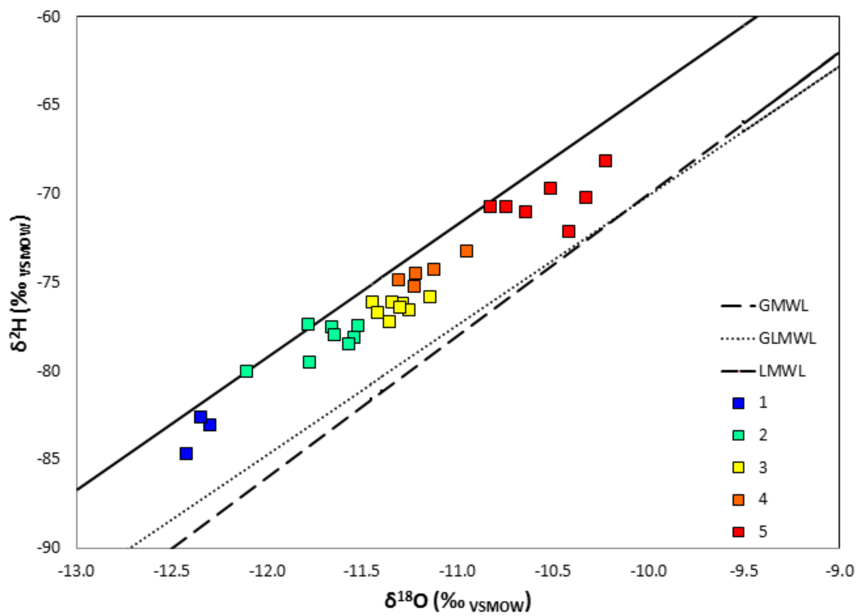
3.5.2.6 Groundwater Movement in the BWZ

The multivariate statistical analysis presented earlier shows that the regional aquifer contains numerous water facies and experiences several possible geochemical processes. In the central part of the regional aquifer the BWZ receives water inputs of various origins by vertical infiltration down through the Dundee Formation and horizontal groundwater flow in the Lucas Aquifer originating from outside the BWZ.

Karstic systems are commonly spatially heterogeneous, which influences their ability to store and transmit water (see Chapter 2). Surface recharge occurs in the BWZ through sinkholes and disappearing streams (Abbey et al., 2004; Brunton et al., 2005; Brunton and Dodge, 2008; Waterloo Hydrogeologic, 2006; Hurley et al., 2006). These topographic features enable surface water to travel vertically through the otherwise confining Dundee Formation. Evidence for this was observed in the groundwater's seasonal isotopic signal, where it closely follows the LMWL (Figure 3.12B), thus indicating its origin from local precipitation dominated by snowmelt and cooler season rain. The much smaller variation in the stable isotopic composition of the groundwater relative to local precipitation (e.g. ~2 ‰ *vs* ~11 ‰ in $\delta^{18}O$, respectively) during the one-year period of sampling suggests deep advective dispersion within the BWZ.

Such a homogeneous isotopic signature can be characteristic of groundwater flow through a diffuse network system having a moderate residence time (see Chapter 2). Karstic systems with large conduits, high transmissivity and low storage facilitating rapid flow commonly display sharp deviations in isotopic compositions from average groundwater during major storm or snowmelt events (Clark and Fritz, 1997; Criss et al, 2007). Despite the presence of surficial point-source recharge areas (i.e. sinkholes), the consistently well-mixed isotopic signal of the BWZ suggests that the groundwater is not experiencing a turbulent, low storage flow through conduits or fractures, but rather a well mixed environment, probably a result of high transmissivity and high storage.

Horizontal variation of groundwater δ-values within the BWZ can examined as a function of mixing among end-members. On the δ^2H *vs* $\delta^{18}O$ plot, monthly samples from individual sites cluster closely together, with the most northern site, BW03, having the most depleted water isotope values and the most southern site, BW09, the most enriched (Figure 3.21). Groundwater δ-values from other sites plot between these two end- members, suggesting water mixing with infiltration (from the Dundee leaky aquitard) along a flow path. To investigate the groundwater flow path within the BWZ, 31 sites were examined from the BWZ and immediately surrounding area using a K-means partitioning algorithm. Group 1, which is located in the most northern area of the BWZ (Figure 3.21B), contains samples with the lowest δ^2H and $\delta^{18}O$ values, and can be considered



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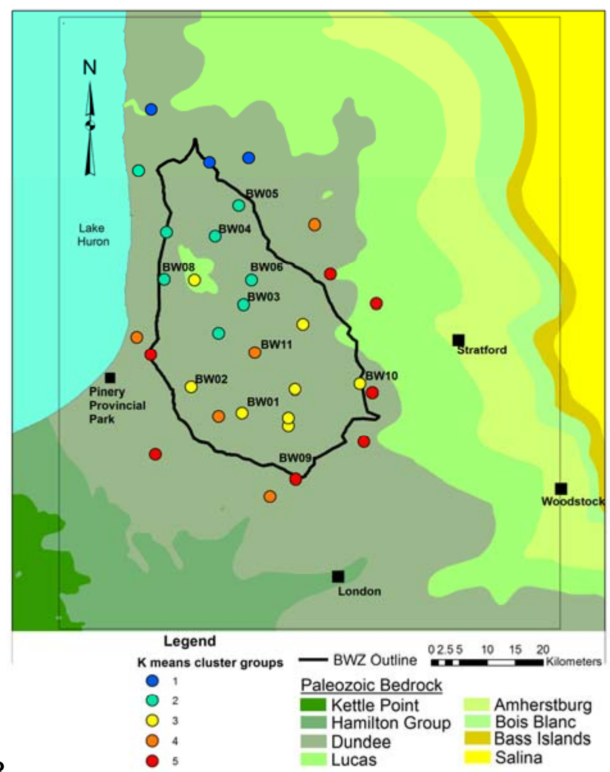

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Figure 3.21. Hydrogen and oxygen isotopic variation of groundwater in the BWZ and immediately surrounding region: (A) δ^2H *vs* δ^{18}O of five clusters of groundwater isotopic compositions. (B) Spatial distribution of the K-means cluster groups.

as one end-member of the system. The most depleted group is 1, which is located north of the BWZ, whereas group 5, the most enriched group is located in the south. The gradual southward isotopic enrichment observed from group 1 to 5 is typical for $\delta^{18}O$ as changes in latitude and temperature occur. Given that this isotopic signal is relatively prevalent $\delta^{18}O$ suggests that the Lucas aquifer receives minor surface water influences, most likely as a result of water leakage of the overlying Dundee Formation. Interestingly, the isotopic gradient changes in the middle of the BWZ, where more depleted waters are brought into the center (group 2) and most of the group 3 waters are located. This isotopic signal fits well with the groundwater flow map (Figure 2.11B), where in the northern and southern waters flows east to west, and a split in the middle occurs where water goes both southwest and west. At this split point the water likely flows slowly (having low transmissivity) westward into Lake Huron. This is the same point where more depleted waters (K2) enter into the center of the BWZ (Figure 3.21B).

3.6 Conclusions

The 1400 km^2 BWZ of southwestern Ontario occurs due to the penetration of wells through the semi-confining Dundee Formation and into a significant thickness of unsaturated void space in the upper Lucas Formation. No other breathing well system that has been discovered by the literature review is of this order of magnitude in surface area or has more than a few dozen wells associated with it. The southwestern Ontario BWZ involves many thousands of wells, serving more than ten thousand people in rural areas and more than 20 towns and villages.

Three hydrochemical groundwater zones were identified in the regional study area using multivariate statistical analysis (HCA, PCA): (1) Northern Zone, (2) Breathing Well Zone (BWZ), and (3) Southern Zone. The Northern Zone is topographically high, and its groundwater is characterized by low electrical conductivity and dissolved solids; this is a likely area of groundwater recharge. Its predominant water type is Ca-HCO_3 (HCA groups C6 & C7) with elevated concentrations of Mg^{2+} and/or Sr^{2+} reflecting carbonate and celestite dissolution. The Southern Zone is topographically lower and dominated by Na-Ca-HCO_3 and Na-Ca-Cl groundwaters (C1, C2 and C3 cluster groups). Groundwater in this zone is affected by carbonate dissolution, cation exchange with bedrock and the influence of halide-rich shale formational waters in the Kettle Point Formation and possibly the Hamilton Group. The BWZ contains Ca-Mg-HCO_3 and Ca-Mg-SO_4 waters (C4 and C5 cluster groups) with high concentrations of Sr^{2+}, Fe^{2+} and Zn. This hydrochemistry suggests important roles for carbonate and evaporite dissolution, and sulphide oxidation in the evolution of this groundwater.

Monthly sampling of groundwater and periodic sampling of exhaled gases from the BWZ over a one-year period has provided additional information concerning its hydrochemistry. Five water facies are present: (1) Ca-Mg-HCO_3; (2) Ca-Sr-$HCO_{3;}$ (3) Ca-Mg-SO_4, (4) Ca-Na-HCO_3 and (5) Na-Ca-Cl. These groundwater compositions reflect varying intensities of carbonate and evaporite dissolution of the Lucas Formation. Groundwater at the northeastern edge of the BWZ is rich in Sr^{2+} and low in SO_4^{2-}, likely because of celestite dissolution in the absence of anhydrite or gypsum. Groundwater enriched in SO_4^{2-} is present down-gradient, near the western edge of the BWZ, suggesting an area of gypsum/evaporite dissolution. Elevated concentrations of Fe^{2+} and Zn, along with Ag, Cu, Pb, Ti and Tl, are characteristic of the BWZ groundwater. Sulphate isotopic data suggest that these metals are contributed to the groundwater by sulphide oxidation (sphalerite and/or pyrite). However, the component of total SO_4^{2-} from the dissolution of marine evaporites (gypsum, anhydrite, and celestite) is much higher except at stations BW-02, BW-06 and BW-10. Molar ratios of Na/Cl and Cl/Br suggested that a high salinity area in the northern part of the BWZ (site BW05) is the product of halite dissolution possibly related to leakage from 19th Century brine wells in the area. These ratios southwest of the BWZ show that elevated salinity is primarily due to interaction with shale formational waters .

Topographic indicators of subsurface karstic processes are present across the BWZ landscape (i.e. sinkholes and disappearing streams). However, no geochemical evidence was obtained for rapid, vertical transmission of surface water into the Lucas Formation aquifer, as would be the case for a predominantly conduit driven karstic system. The seasonal variations of hydrogen and oxygen isotopes in the local precipitation do not occur in groundwater δ^2H

and $\delta^{18}O$ values. Attenuation of these seasonal signals in the aquifer suggests that the BWZ groundwater is well-mixed, and appears to resist sudden perturbations from precipitation or spring-melt events. A well mixed system will often mask the seasonal signals, and suggests the BWZ aquifer to potentially have a higher storativity compared to most karst systems. This observation is supported by tritium concentrations in BWZ groundwater, where ages ranged between modern (5 to 10 years) and sub-modern (older than 1950) water in some areas.

Given the high storativity of the aquifer and widely diffuse nature of the flow, the elevated DO levels in BWZ groundwater appear to be a consequence of the breathing events, rather than from the rapid recharge into the subsurface of surface waters with elevated DO. Measured sulphate isotopes in the groundwater, specifically the $\Delta^{18}O_{SO4 - H2O}$ values, demonstrate sulphide oxidation to be occurring in an aerated environment. Sulphide oxidation will often produces sulfuric acid (H_2SO_4) which dissolves the surrounding carbonate bedrock. This appears to be occurring a relatively minor rate as the calculated pCO_2 of the dissolved gas in the groundwater is slightly elevated in locations of sulphide oxidation. Therefore H_2CO_3 produced by sulphide oxidation-related carbonate dissolution may be partitioning into vapour-phase CO_2. The increased oxygen promotes CO_2 formation by (1) causing sulphide oxidation and acid production, which dissolves carbonate and increases pCO_2 and (2) promoting the growth of heterotropic (i.e. organic matter eating) bacteria that directly respirate CO_2. Therefore, the cause of the oxygen-depleted gas that is expelled from the breathing wells is both microbial respiration and sulphide oxidation. This is further supported by the sulphur isotope measurements that demonstrate sulphide oxidation processes are occurring.

In summary, the data presented in this study indicates that the BWZ is a karstified aquifer system that has high storativity and high transmissivity, containing water derived from modern and sub-modern sources. The degree of karstification of the BWZ is controlled by the evaporite content, mineralogy (mostly anhydrite/gypsum and celestite) and dissolution rate in the Lucas Formation but is also augmented by the very high CO_2 levels in the vapour phase, and pCO_2 in the fluid phase, which promote carbonate dissolution.

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Chapter 4

4 Conclusion and Future Work

The 1400km^2 breathing well zone in southwestern Ontario, Canada was characterized using both hydrogeological and geochemical methods. The study's main findings are summarized below.

Barometric analyses revealed a significant amount of gas is exchanged between the surface and subsurface but with variable lag time. The exhaled gases are hypoxic, having levels of $O_{2\,(g)}$ as low as 1.7 %, and $CO_{2\,(g)}$ as high as 3.4 %. The exchange of gas is controlled by changes in atmospheric pressure and the magnitude of the exchange varies spatially and temporally. Two wells show almost direct connection to the atmosphere (sites BW08 and BW09), whereas other sites have little to no atmospheric connection (ex. BW11). Temporal monitoring of the breathing events suggests that two distinct subsurface gas flow systems exist; one that trends northward and other southward. The north-trending system is located on the eastern edge of the zone and has a lag time of less than 2 days, whereas the other is located in the westward half and has a lag response time of 4 to 9 days.

Stratigraphic and water well records demonstrate that 'non-breathing' wells (i) are located in areas where the Lucas Formation is the thinnest (ii) are completed in the upper most portion of the Lucas Formation and (iii) the hydraulic gradient (water level) is above the Dundee-Lucas contact. In contrast 'breathing wells" (i) occur in areas of thick Lucas Formation; (ii) have a significant amount of unsaturated void space in the Lucas formation (iii) have water levels located within the Lucas; and (iv) breathe the strongest in the western portion of the BWZ. The Lucas Formation thins in 2 areas within the BWZ, near site BW08 and BW09. It remains unknown whether this is a result of structural high in the underlying Amherstburg Formation, or an erosional topographic depression in the Lucas Formation at the Dundee-Lucas Formational contact. Additional coring or examination of well records in areas of thin Lucas may provide future insight.

Local hydraulic flow is westerly toward Lake Huron, with a significant drop in the hydraulic gradient surface of nearly 100 m from the eastern edge to the centre of the BWZ. The drop in water levels likely results from karstic development in the Lucas that has increased the bedrock's transmissivity. The hydraulic gradients show two flow regimes: a steep eastern gradient reflecting higher than regional transmissivity and a flat western gradient indicating extremely high transmissivity. In the center west area of the BWZ, nearly 20km inland from the edge of Lake Huron the hydraulic gradient surface is 180 m ASL, which is very close to the lake level elevation of ~176 m ASL. This suggests that a subsurface-lake connection may exist, similar to that in northern Lake Huron. Additional research, would be needed to provide insight into this possibility. Water levels were not observed to change more than a few centimeters over the 1 year study period. A possible explanation for this is that the Lucas karstic aquifer has very high storage potential (specific yield), resulting from the high porosity in the Lucas Formation bedrock. Pump tests, in addition to implementation of dataloggers could test this idea.

Results from the multivariate statistical regional characterization revealed three geochemical zones: northern, the central breathing well zone and southern. The topographically higher northern zone contains a predominantly Ca-HCO_3 groundwater facies with very high concentrations of Mg^{2+}, Sr^{2+} and SO_4^{2-} and relatively low conductivity (~500 µS/cm). This area is likely a zone of freshwater recharge. The topographically lower southern zone comprises a mixture of Na-HCO_3 and Na-Cl waters, with elevated concentrations of Ca^{2+} and SO_4^{2-}. Conductivity varies widely in the southern zone, from averages of ~360 µS/cm to ~800 µS/cm to ~1600 µS/cm. More mineralized groundwater is found in the southwestern corner of the regional study area. The BWZ, which is located in the center of the regional study area, consists of Ca-Mg-HCO_3 and Ca-Mg-SO_4 groundwaters, with elevated Sr concentrations and high conductivity.

Upon close inspection the BWZ contains 5 water sub-facies: Ca-Mg-SO_4; Ca-Sr-HCO_3; Ca-Mg-HCO_3; Ca-Na-HCO_3 and Na-Ca-Cl. These facies are the result of carbonate (calcite and dolomite) and evaporite (anhydrite/gypsum, celestite and halite) dissolution, in addition to sulphide oxidation. Elevated Sr^{2+} concentrations are produced by celestite dissolution, which occurs in the northern upgradient region. In this area, dissolution of anhydrite/gypsum is minor and may already have gone to completion. This is supported by the significantly lower anhydrite/gypsum solubility product relative to that of celestite. This means that SO_4^{2-} has to be at concentrations that are well below anhydrite/gypsum saturation in order for celestite to dissolve. A localized salinity anomaly at the northern edge of the BWZ reflects the influence of halite dissolution that may be related to abandoned 19th Century brine wells. Down-gradient, toward the center of the BWZ, sulphate-rich groundwaters are undersaturated in gypsum/anhydrite, and at saturation or slightly oversaturated with respect to calcite, which may be a result of sulphate dissolution. Sulphate isotopes revealed that the source of sulphate in the groundwater is a result of both evaporite dissolution and sulphide oxidation. Furthermore the oxygen isotopic fractionation between sulphate and water ($\Delta^{18}O_{SO4 - H2O}$) suggest that the sulphide oxidation is occurring in an aerated environment. The influx of atmospheric gases into the subsurface is therefore creating a constant but limited supply of oxygen, which is facilitating the oxidation of sulphide minerals present in the Lucas Formation. This process would also account for the high metal concentrations (Fe^{2+}, Ag, Cu, Pb, Ti, Tl and especially, Zn) measured in BWZ groundwater. These anomalies warrant additional investigation, including examination of Lucas Formation drill cores for sulphides, isotopic analysis of those sulphides, and more detailed study of the sulphide oxidation process in the BWZ.

The constant influx of atmospheric gases has a significant effect on the geochemical and electrochemical nature of the groundwater. Areas in the BWZ experiencing sulphide oxidatation were measured to have the lowest $O_{2(g)}$ and highest $CO_{2(g)}$ in the exhaled gases. Sulphide oxidation produces sulfuric acid (H_2SO_4) which dissolves the surrounding host carbonate bedrock. This appears to be occurring to a minor degree as the calculated pCO_2 of the dissolved gas in the groundwater is slightly elevated in locations of sulphide oxidation and therefore H_2CO_3 produced by sulphide oxidation-related carbonate dissolution may be partitioning into vapour-phase CO_2. Such ideas need to be tested quantitatively. In particular, more sophisticated numerical approaches to the chemical and isotopic data for the groundwater and associated gases could prove useful in determining the rate of karstic void space development in the BWZ.

The stable isotopes of water, $\delta^{18}O$ and δ^2H, demonstrated that groundwater in the

BWZ, is from local meteoric precipitation, with a bias towards cooler season rain and snow/melt. Seasonal signals of recharging water are attenuated, indicating the groundwater is well mixed as it reaches the aquifer. These results complement the results from the physical characterization of the BWZ in that the aquifer experiences a high transmissivity environment with high storage. Aquifers with elevated storage would enable the mixing of groundwater to create a relativity homogenous isotopic groundwater signal. The spatial examination of $\delta^{18}O$ within and surrounding the BWZ reveal that the BWZ does not experience a uniform downward gradient of isotopic enrichment, instead the waters within the southern part of the BWZ are depleted relative to those waters on the outer edges. This could be a result of water movement within the aquifer both laterally, through the Lucas Formation and vertically downward, through the upper confining Dundee Formation. Tritium age dating showing that BWZ groundwater is a mixture of modern (5 to 10 year) to sub-modern (older than 1950) precipitation.

The geochemical data presented here suggest that the subsurface environment in the eastern half of the BWZ is a moderately connected, spatially variable moderately developed karstic system. The southwestern part of the BWZ is a more extensively developed and interconnected karstic system. Future growth of the BWZ will be strongly dependent on lithological and mineralogical variability of the Lucas Formation, where much of the unsaturated void space appears to be the product of evaporite dissolution. The breathing events themselves are directly contributing to the water and gas chemistry. Monitoring of groundwater chemistry over time may prove to be a useful tool for understanding the nature and growth of the BWZ, and its consequences for this important aquifer system in this heavily populated region.

Appendices

Appendix A. Station Parameters (Regional Study).

Sample	Sample Type	Elevation	Local drift thickness	Depth to Rock	Subcropping Unit	Static Water Level	Well Depth	Well Completion	Cluster Group
		mASL	m	m		mTOC	m		
07-AG-005	*RS	290.0	27.7	75.3	Dundee	12.2	75.3	Amherstburg	7
07-AG-006	RS	308.3	21.0	25.3	Lucas	8.6	25.3	Lucas	7
07-AG-008	RS	329.6	43.9	51.5	Lucas	2.7	51.5	Bass Island	5
07-AG-011	RS	290.0	36.0	43.3	Dundee	7.3	43.3	Dundee	3
07-AG-014	RS	299.6	31.1	107.3	Dundee	30.5	107.3	Bois Blanc	7
07-AG-016	RS	303.7	53.6	59.7	Lucas	21.0	59.7	Lucas	7
07-AG-020	RS	374.2	69.8	74.7	Lucas	31.1	74.7	Lucas	7
07-AG-021	RS	356.6	69.5	71.6	Lucas	20.9	71.6	Lucas	1
07-AG-025	RS	295.6	67.1	71.6	Dundee	31.5	71.6	Dundee	1
07-AG-026	**†BW09**	**292.6**	**64.6**	**82.9**	**Dundee**	**73.5**	**82.9**	**Lucas**	**4**
07-AG-029	RS	317.9	35.4	71.3	Dundee	39.6	71.3	Lucas	6
07-AG-030	RS	303.5	25.3	31.1	Dundee	10.7	31.1	Dundee	1
07-AG-032	RS	321.5	45.7	65.5	Dundee	30.5	65.5	Lucas	1
07-AG-036	RS	296.5	53.9	55.2	Lucas	19.8	55.2	Lucas	7
07-AG-038	RS	267.8	49.1	55.8	Lucas	7.7	55.8	Lucas	1
07-AG-040	RS	275.9	44.5	46.0	Dundee	15.2	46.0	Dundee	1
07-AG-049	RS	272.1	61.9	71.0	Dundee	36.6	71.0	Dundee	1
07-AG-050	RS	291.6	79.2	82.6	Dundee	33.8	82.6	Hamilton-Dundee	1
07-AG-056	RS	261.3	72.8	81.7	Dundee	24.4	81.7	Dundee	1
07-AG-092	RS	-	36.6	45.7	Kettle Point	2.1	45.7	Kettle Point	1
07-AG-094	RS	-	57.9	64.0	Hamilton	8.8	64.0	Hamilton	2
07-AG-109	RS	317.7	36.3	55.2	Lucas	16.5	55.2	Amherstburg	1
07-AG-125	RS	-	44.8	67.1	Amherstburg	11.6	67.1	Amherstburg	7
07-AG-145	RS	275.0	59.4	59.4	Dundee	19.3	59.4	Dundee	1
07-AG-152	RS	244.1	60.0	72.5	Hamilton	52.7	72.5	Hamilton-Dundee	2
07-AG-155	RS	286.6	67.7	68.3	Dundee	22.9	68.3	Dundee	1
07-AG-214	RS	285.9	71.0	75.3	Dundee	13.7	75.3	Dundee	1
08-AG-001	RS	209.7	51.8	53.0	Dundee	26.6	53.0	Dundee	3
08-AG-004	RS	230.4	27.7	34.1	Hamilton	3.0	34.1	Hamilton	3
08-AG-005	RS	223.6	39.6	83.8	Dundee	47.2	83.8	Lucas	3
08-AG-007	‡RSBWZ	249.6	27.4	36.0	Dundee	15.2	36.0	Dundee	7
08-AG-010	**BW01**	**-**	**28.3**	**105.2**	**Dundee**	**89.3**	**105.2**	**Lucas**	**4**
08-AG-012	**BW11**	**-**	**40.5**	**128.0**	**Dundee**	**105.2**	**128.0**	**Lucas**	**5**
08-AG-013	RSBWZ	-	24.4	75.9	Dundee	63.7	75.9	Lucas	4
08-AG-015	RSBWZ	-	38.7	97.5	Dundee	88.4	97.5	Lucas	4
08-AG-017	RS	330.5	48.2	63.4	Amherstburg	13.7	63.4	Bois Blanc	7
08-AG-020	RSBWZ	-	34.1	83.8	Dundee	68.6	83.8	Lucas	6
08-AG-021	**BW10**	**327.7**	**34.1**	**83.8**	**Dundee**	**58.5**	**83.8**	**Lucas**	**4**
08-AG-023	RS	352.9	29.6	65.5	Lucas	13.3	65.5	Lucas	7
08-AG-025	RS	334.4	27.7	39.6	Lucas	15.8	39.6	Lucas	7
08-AG-030	RS	330.2	47.5	71.0	Bois Blanc	14.3	71.0	Bass Island	1
08-AG-031	RS	309.1	42.7	51.8	Bass Islands	4.3	51.8	Bass Island	7
08-AG-043	RS	361.1	23.5	38.1	Lucas	7.6	38.1	Lucas	1
08-AG-046	RS	366.2	38.4	43.3	Amherstburg	7.9	43.3	Amherstburg	7
08-AG-050	RS	312.0	32.6	41.8	Lucas	15.2	41.8	Lucas	7
08-AG-053	RS	321.1	29.9	43.6	Lucas	9.1	43.6	Lucas	7

Sample	Sample Type	Elevation	Local drift thickness	Depth to Rock	Subcropping Unit	Static Water Level	Well Depth	Well Completion	Cluster Group
		mASL	m	m		mTOC	m		
08-AG-060	RSBWZ	322.4	17.1	77.7	Dundee	61.0	77.7	Lucas	4
08-AG-062	RS	409.4	44.5	53.0	Amherstburg	12.8	53.0	Amherstburg-Bois Blanc	7
08-AG-085	RS	209.2	33.5	56.7	Dundee	28.2	56.7	Dundee	6
08-AG-086	RSBWZ	297.7	37.8	43.3	Dundee	21.3	43.3	Dundee	6
08-AG-087	**BW04**	**268.1**	**28.7**	**79.9**	**Dundee**	**67.7**	**79.9**	**Lucas**	**4**
08-AG-100	RSBWZ	258.7	68.6	71.9	Dundee	57.8	71.9	Dundee	1
08-AG-102	RS	298.9	28.7	45.4	Lucas	4.3	45.4	Lucas	4
08-AG-103	RS	247.2	42.1	64.0	Dundee	36.6	64.0	Lucas	6
08-AG-105	**BW08**	**267.9**	**64.0**	**94.5**	**Dundee**	**77.7**	**94.5**	**Lucas**	**5**
08-AG-106	RS	212.3	24.4	35.7	Dundee	22.9	35.7	Dundee	6
08-AG-107	RS	303.9	31.4	74.7	Lucas	33.5	74.7	Lucas	6
08-AG-108	RS	314.0	26.5	53.3	Lucas	20.7	53.3	Lucas	7
08-AG-120	RS	-	14.6	34.1	Lucas	7.0	34.1	Lucas	4
08-AG-121	RS	337.1	21.0	48.2	Lucas	8.5	48.2	Lucas	6
08-AG-122	RS	342.1	42.4	56.1	Lucas	16.8	56.1	Lucas	6
08-AG-153	RS	320.7	48.8	49.7	Lucas	14.3	49.7	Lucas	7
08-AG-157	RS	356.9	59.7	74.7	Bass Islands	18.6	74.7	Salina	7
08-AG-162	RS	344.0	36.9	47.2	Dundee	15.8	47.2	Lucas	1
08-AG-164	RS	366.4	24.7	43.3	Amherstburg	6.1	43.3	Amherstburg	7
08-AG-165	RS	376.7	101.5	108.2	Amherstburg	11.0	108.2	Bois Blanc	5
08-AG-167	**BW02**	**240.7**	**30.5**	**74.4**	**Dundee**	**65.5**	**74.4**	**Lucas**	**4**
08-AG-181	RSBWZ	252.2	31.1	86.9	Dundee	78.6	86.9	Lucas	4
08-AG-183	**BW03**	**289.7**	**23.2**	**96.3**	**Dundee**	**78.0**	**96.3**	**Lucas**	**6**
08-AG-188	RS	251.5	35.4	37.2	Hamilton	9.1	37.2	Hamilton	1
08-AG-190	RSBWZ	182.5	30.8	41.5	Dundee	36.6	41.5	Dundee-Lucas	3
08-AG-193	RS	-	49.7	51.8	Dundee	29.0	51.8	Dundee	3
08-AG-194	RS	178.6	55.2	56.1	Dundee	19.5	56.1	Dundee	3
08-AG-197	RS	264.6	28.3	38.1	Dundee	6.1	38.1	Lucas	6
08-AG-202	RS	385.9	41.1	44.8	Amherstburg	16.8	44.8	Amherstburg	7
08-AG-203	RS	395.2	23.8	37.8	Bois Blanc	10.4	37.8	Bois Blanc	7
08-AG-205	RS	403.4	33.5	54.9	Bois Blanc	21.3	54.9	Salina	7
08-AG-206	RS	359.7	73.2	74.4	Lucas	5.8	74.4	Lucas	5
08-AG-207	RS	354.1	21.3	57.9	Lucas	7.3	57.9	Lucas	4
08-AG-208	RS	359.7	7.6	29.3	Dundee	2.1	29.3	Lucas	6
08-AG-211	**BW05**	**260.3**	**29.6**	**96.3**	**Dundee**	**86.0**	**96.3**	**Lucas**	**5**
08-AG-214	RS	299.4	14.3	32.6	Lucas	4.9	32.6	Lucas	6
08-AG-215	RS	165.5	35.1	45.7	Dundee	24.4	45.7	Lucas	5
08-AG-217	RSBWZ	230.5	35.1	85.3	Lucas	70.7	85.3	Lucas	5
08-AG-223	BW06	303.4	20.1	106.7	Dundee	91.4	106.7	Lucas	4
08-AG-225	RS	345.5	24.4	37.5	Dundee	7.0	37.5	Lucas	1
08-AG-227	RS	334.2	27.7	50.3	Dundee	8.5	50.3	Lucas	1
08-AG-228	RS	406.0	39.9	51.5	Salina	29.3	51.5	Salina	7
08-AG-231	RS	274.3	29.3	29.6	Lucas	12.8	29.6	Lucas	7
08-AG-232	RSBWZ	271.2	24.4	150.0	Dundee	10.0	150.0	Bois Blanc	4
08-AG-237	RS	-	24.4	35.7	Hamilton	16.8	35.7	Hamilton	3
08-AG-242	RS	341.6	24.1	38.1	Amherstburg	7.6	38.1	Amherstburg	7
08-AG-243	RS	346.2	15.5	32.0	Amherstburg	9.8	32.0	Bois Blanc	4
08-AG-246	RS	330.2	22.3	37.5	Lucas	3.0	37.5	Lucas	6
08-AG-247	RS	335.8	21.9	36.9	Amherstburg	5.8	36.9	Amherstburg-Bois Blanc	7
08-AG-248	RS	359.8	24.4	41.1	Bois Blanc	9.1	41.1	Bois Blanc	7

Sample	Sample Type	Elevation	Local drift thickness	Depth to Rock	Subcropping Unit	Static Water Level	Well Depth	Well Completion	Cluster Group
		mASL	m	m		mTOC	m		
08-AG-250	RS	378.8	23.8	57.6	Bass Islands	11.9	57.6	Salina	7
08-AG-251	RS	380.2	32.3	54.6	Salina	19.2	54.6	Salina	7
08-AG-252	RS	378.2	14.0	24.1	Salina	6.1	24.1	Salina	4
08-AG-253	RS	367.8	15.2	31.7	Bass Islands	5.8	31.7	Salina	4
08-AG-254	RS	353.8	33.2	39.3	Bois Blanc	10.1	39.3	Bois Blanc	7
08-AG-255	RS	197.6	32.0	32.0	Hamilton	8.5	32.0	Hamilton	3

* RS = Stations sampled as part of the regional study. †Stations in bold and numbered BW01-BW11 wells that were sampled as part of the local study. ‡RSBWZ – Regional wells located in the BWZ. "-" symbolizes parameter not measured. “<” symbolizes parameter is below detection limit.

Appendix B. Field Parameters (Regional Study).

Sample	Sample Type	Sample Date	Temperature	pH	Conductivity	Oxidation Reduction Potential	Dissolved Inorganic Carbon	Dissolved Organic Carbon
			(°C)		(µS/cm)	(mV Ag-AgCl)	(mg/L)	(mg/L)
07-AG-005	*RS	21-Jun-07	10.05	7.6	717	-107.5	19.1	0.7
07-AG-006	RS	21-Jun-07	9.54	7.5	533	-438.7	28.9	6.0
07-AG-008	RS	21-Jun-07	8.80	7.3	1064	-171.4	25.7	1.2
07-AG-011	RS	23-Jun-07	9.15	7.6	602	-188.5	15.7	1.1
07-AG-014	RS	23-Jun-07	9.87	7.4	471	-49.0	21.0	1.1
07-AG-016	RS	23-Jun-07	9.09	7.2	575	-	22.8	1.0
07-AG-020	RS	24-Jun-07	8.62	7.6	423	-169.2	22.2	0.6
07-AG-021	RS	24-Jun-07	8.65	7.6	501	-226.5	28.3	1.0
07-AG-025	RS	26-Jun-07	10.68	8.0	373	-85.0	36.0	<0.5
07-AG-026	**†BW09**	**26-Jun-07**	**11.39**	**7.4**	**630**	**55.1**	**36.1**	**<0.5**
07-AG-029	RS	26-Jun-07	10.98	7.9	448	-145.6	25.8	0.6
07-AG-030	RS	26-Jun-07	10.58	7.9	363	-208.2	33.6	0.8
07-AG-032	RS	26-Jun-07	10.18	8.2	291	-191.0	25.0	0.9
07-AG-036	RS	27-Jun-07	8.85	7.5	375	-209.8	42.8	1.6
07-AG-038	RS	27-Jun-07	10.00	7.7	361	-225.3	39.3	1.0
07-AG-040	RS	28-Jun-07	10.49	7.8	342	-225.7	46.9	0.6
07-AG-049	RS	29-Jun-07	10.16	8.3	323	-272.1	35.8	0.9
07-AG-050	RS	4-Jul-07	12.73	8.0	466	-190.8	34.9	<0.5
07-AG-056	RS	7-Jul-07	10.64	7.8	375	-276.4	35.3	0.7
07-AG-092	RS	12-Jul-07	10.45	8.2	363	-268.2	39.1	1.2
07-AG-094	RS	12-Jul-07	10.19	8.1	2555	-233.0	29.6	1.1
07-AG-109	RS	18-Jul-07	9.28	7.8	409	-246.4	36.0	1.2
07-AG-125	RS	18-Jul-07	9.15	7.8	652	-127.9	35.0	2.0
07-AG-145	RS	24-Jul-07	9.73	8.2	289	-227.9	34.5	0.6
07-AG-152	RS	24-Jul-07	12.11	8.8	710	-366.0	54.2	1.0
07-AG-155	RS	26-Jul-07	9.97	8.2	296	-241.0	40.9	1.4
07-AG-214	RS	5-Aug-07	9.15	7.7	412	-263.2	28.8	1.0
08-AG-001	RS	13-May-08	9.71	6.9	645	-309.4	13.9	1.8
08-AG-004	RS	13-May-08	9.74	7.6	1333	-274.3	27.7	0.7
08-AG-005	RS	13-May-08	-	7.3	1697	-164.7	30.0	2.0
08-AG-007	‡ RSBWZ	15-May-08	9.53	6.9	479	-145.9	60.4	0.7
08-AG-010	**BW01**	**15-May-08**	**8.66**	**7.3**	**1628**	**72.2**	**68.1**	**0.5**
08-AG-012	**BW11**	**15-May-08**	**8.70**	**7.4**	**2795**	**-75.7**	**55.1**	**0.6**
08-AG-013	RSBWZ	15-May-08	9.14	7.5	802	-14.2	64.7	0.4
08-AG-015	RSBWZ	15-May-08	9.26	7.4	801	40.3	75.9	0.6
08-AG-017	RS	16-May-08	8.90	7.6	571	-106.9	53.1	0.5
08-AG-020	RSBWZ	15-May-08	9.00	7.0	520	-	62.1	0.5
08-AG-021	**BW10**	**16-May-08**	**9.49**	**6.8**	**990**	**47.0**	**76.9**	**0.2**
08-AG-023	RS	16-May-08	8.44	7.1	662	-141.6	69.5	0.6
08-AG-025	RS	16-May-08	8.84	7.3	477	-184.5	49.9	<0.1
08-AG-030	RS	16-May-08	8.35	8.1	390	-235.1	34.8	1.4
08-AG-031	RS	16-May-08	9.09	7.5	794	-148.8	52.2	0.3
08-AG-043	RS	20-May-08	8.68	8.0	377	-194.5	44.4	0.6
08-AG-046	RS	20-May-08	7.98	7.8	464	-184.6	63.0	2.5
08-AG-050	RS	20-May-08	8.63	7.7	441	-447.2	53.2	1.5
08-AG-053	RS	20-May-08	8.21	7.8	413	-422.9	57.0	1.1
08-AG-060	RSBWZ	21-May-08	10.75	7.0	755	-108.1	84.5	2.2
08-AG-062	RS	21-May-08	7.98	7.4	409	-123.4	54.1	1.0
08-AG-085	RS	26-May-08	9.01	7.3	619	-151.1	72.5	0.2
08-AG-086	RSBWZ	26-May-08	8.74	7.5	462	-159.7	64.0	0.2
08-AG-087	**BW04**	**26-May-08**	**8.40**	**7.2**	**628**	**24.4**	**68.2**	**0.2**
08-AG-100	RSBWZ	26-May-08	8.85	7.6	403	-156.8	47.1	0.6
08-AG-102	RS	27-May-08	8.70	6.8	699	-260.4	85.8	0.2
08-AG-103	RS	27-May-08	8.44	7.0	592	-212.1	46.7	0.3

Sample	Sample Type	Sample Date	Temperature	pH	Conductivity	Oxidation Reduction Potential	Dissolved Inorganic Carbon	Dissolved Organic Carbon
			(°C)		(µS/cm)	(mV Ag-AgCl)	(mg/L)	(mg/L)
08-AG-105	**BW08**	**27-May-08**	**8.83**	**6.8**	**1451**	**-226.6**	**43.6**	**0.4**
08-AG-106	RS	28-May-08	7.71	7.6	517	-84.8	32.6	1.3
08-AG-107	RS	28-May-08	8.17	7.6	408	-144.1	38.9	0.8
08-AG-108	RS	28-May-08	8.00	7.6	456	-220.9	56.0	1.2
08-AG-120	RS	28-May-08	8.73	7.2	1475	64.6	63.0	0.6
08-AG-121	RS	28-May-08	8.64	7.5	580	-178.8	48.2	0.9
08-AG-122	RS	28-May-08	8.74	7.6	470	-145.2	41.7	2.9
08-AG-153	RS	9-Jun-08	8.46	7.5	499	-248.9	61.9	1.2
08-AG-157	RS	9-Jun-08	8.88	7.5	413	-240.6	52.2	0.7
08-AG-162	RS	9-Jun-08	8.50	7.9	362	-189.8	44.3	0.7
08-AG-164	RS	9-Jun-08	8.53	7.5	438	-60.6	56.3	0.7
08-AG-165	RS	9-Jun-08	8.56	6.8	2128	-	42.3	0.8
08-AG-167	**BW02**	**11-Jun-08**	**10.16**	**7.7**	**1009**	**-127.8**	**73.5**	**0.5**
08-AG-181	RSBWZ	11-Jun-08	9.36	7.9	915	38.6	67.9	0.5
08-AG-183	**BW03**	**11-Jun-08**	**9.23**	**8.0**	**527**	**-82.5**	**68.6**	**0.3**
08-AG-188	RS	18-Jun-08	10.23	8.8	335	-263.6	36.9	0.9
08-AG-190	RSBWZ	17-Jun-08	10.39	7.3	415	-222.8	36.0	0.8
08-AG-193	RS	17-Jun-08	11.83	7.6	513	-307.0	19.6	1.7
08-AG-194	RS	18-Jun-08	10.01	8.0	611	-460.3	38.5	2.2
08-AG-197	RS	19-Jun-08	9.14	7.2	646	-206.6	50.4	0.2
08-AG-202	RS	19-Jun-08	8.74	7.9	534	-163.0	56.8	0.2
08-AG-203	RS	19-Jun-08	8.88	7.8	403	-131.6	52.0	0.6
08-AG-205	RS	20-Jun-08	8.35	7.9	435	-233.8	53.8	1.0
08-AG-206	RS	20-Jun-08	8.60	7.3	1765	-150.4	46.2	0.8
08-AG-207	RS	20-Jun-08	9.29	7.3	640	-20.3	75.1	0.2
08-AG-208	RS	20-Jun-08	9.34	7.7	485	-136.5	48.8	0.4
08-AG-211	**BW05**	**19-Jun-08**	**8.91**	**7.2**	**2733**	**-173.8**	**64.7**	**0.8**
08-AG-214	RS	19-Jun-08	-	7.4	575	-188.5	50.3	0.8
08-AG-215	RS	22-Jun-08	9.64	7.0	2287	-187.9	45.1	0.4
08-AG-217	RSBWZ	22-Jun-08	8.47	7.1	2460	-162.2	55.7	0.2
08-AG-223	BW06	23-Jun-08	8.53	7.5	747	-56.5	88.9	0.4
08-AG-225	RS	23-Jun-08	10.39	8.4	313	-144.6	39.6	0.7
08-AG-227	RS	23-Jun-08	8.67	8.1	370	-160.0	44.0	0.4
08-AG-228	RS	24-Jun-08	8.77	7.0	551	-131.9	64.3	0.8
08-AG-231	RS	25-Jun-08	9.36	7.2	596	-201.5	53.4	1.4
08-AG-232	RSBWZ	25-Jun-08	8.95	7.1	851	-170.7	78.3	0.4
08-AG-237	RS	26-Jun-08	-	7.5	1250	-104.7	24.3	0.5
08-AG-242	RS	26-Jun-08	8.88	7.2	415	-177.0	57.5	0.1
08-AG-243	RS	26-Jun-08	8.54	6.8	730	5.7	72.4	1.2
08-AG-246	RS	30-Jun-08	9.10	7.4	476	-209.8	47.8	0.8
08-AG-247	RS	30-Jun-08	9.04	7.5	619	-199.3	64.4	0.4
08-AG-248	RS	30-Jun-08	10.50	7.4	631	-197.3	59.1	1.6
08-AG-250	RS	30-Jun-08	8.15	7.6	559	-197.7	57.3	1.7
08-AG-251	RS	2-Jul-08	8.23	7.4	542	-176.2	54.8	0.5
08-AG-252	RS	2-Jul-08	8.86	7.2	885	-11.8	83.7	1.5
08-AG-253	RS	2-Jul-08	9.94	7.3	650	-101.5	61.9	0.1
08-AG-254	RS	2-Jul-08	8.86	7.3	796	-219.9	56.4	0.4
08-AG-255	RS	3-Jul-08	9.85	8.4	882	-186.9	32.9	0.7

* RS = Stations sampled as part of the regional study. †Stations in bold and numbered BW01-BW11 wells that were sampled as part of the local study. ‡RSBWZ – Regional wells located in the BWZ. "-" symbolizes parameter not measured. “<” symbolizes parameter is below detection limit.

Appendix C. Bacteriological and Dissolved Gas Parameters (Regional Study).

Sample	Sample Type	Sample Date	Total Coliform	Fecal Coliform	Dissolved Oxygen (DO)	Dissolved Methane (CH^4)	Dissolved Hydrogen Sulphide (H_2S)
			counts/100mL	counts/100mL	% saturation	% saturation	mg/L S^{2-}
07-AG-005	*RS	21-Jun-07	<2	0.0	0.0	0.003	0.03
07-AG-006	RS	21-Jun-07	<2	0.0	0.0	1.602	0.12
07-AG-008	RS	21-Jun-07	<2	0.0	0.0	0.001	0.05
07-AG-011	RS	23-Jun-07	0.0	<1	0.0	0.010	0.16
07-AG-014	RS	23-Jun-07	0.0	<1	0.0	0.001	<0.01
07-AG-016	RS	23-Jun-07	0.0	<1	0.0	0.008	0.00
07-AG-020	RS	24-Jun-07	0.0	<1	0.0	0.022	0.00
07-AG-021	RS	24-Jun-07	2.0	<2	0.0	0.002	9.25
07-AG-025	RS	26-Jun-07	0.0	0.0	0.0	1.083	0.29
07-AG-026	**†BW09**	**26-Jun-07**	**0.0**	**0.0**	**23.7**	**0.019**	**0.05**
07-AG-029	RS	26-Jun-07	0.0	0.0	0.0	0.018	0.00
07-AG-030	RS	26-Jun-07	4.0	0.0	0.0	0.505	0.10
07-AG-032	RS	26-Jun-07	2.0	0.0	0.0	0.134	<0.01
07-AG-036	RS	27-Jun-07	0.0	0.0	0.0	0.113	0.07
07-AG-038	RS	27-Jun-07	0.0	0.0	0.0	0.008	1.75
07-AG-040	RS	28-Jun-07	2.0	<1	0.0	0.883	0.26
07-AG-049	RS	29-Jun-07	7.0	<1	0.0	5.307	2.00
07-AG-050	RS	4-Jul-07	0.0	0.0	0.0	0.019	<0.01
07-AG-056	RS	7-Jul-07	0.0	0.0	0.0	0.253	5.50
07-AG-092	RS	12-Jul-07	0.0	0.0	0.0	2.996	<0.01
07-AG-094	RS	12-Jul-07	0.0	0.0	0.0	17.431	<0.01
07-AG-109	RS	18-Jul-07	0.0	0.0	0.0	0.798	0.53
07-AG-125	RS	18-Jul-07	0.0	0.0	0.0	0.033	0.00
07-AG-145	RS	24-Jul-07	14.0	0.0	0.0	1.144	0.80
07-AG-152	RS	24-Jul-07	2.0	0.0	0.0	81.775	18.00
07-AG-155	RS	26-Jul-07	<2	0.0	0.0	4.915	<0.01
07-AG-214	RS	5-Aug-07	0.0	0.0	0.0	1.177	0.35
08-AG-001	RS	13-May-08	<2	<2	0.0	0.084	5.00
08-AG-004	RS	13-May-08	<2	<2	0.0	0.091	1.00
08-AG-005	RS	13-May-08	118.0	2.0	0.0	0.042	<0.01
08-AG-007	‡RSBWZ	15-May-08	0.0	0.0	0.0	0.019	0.00
08-AG-010	**BW01**	**15-May-08**	**0.0**	**0.0**	**34.4**	**0.000**	**0.00**
08-AG-012	**BW11**	**15-May-08**	**0.0**	**0.0**	**0.0**	**0.004**	**0.00**
08-AG-013	RSBWZ	15-May-08	0.0	0.0	8.6	0.000	0.00
08-AG-015	RSBWZ	15-May-08	0.0	0.0	6.2	0.006	0.00
08-AG-017	RS	16-May-08	0.0	0.0	0.0	0.021	0.00
08-AG-020	RSBWZ	15-May-08	0.0	0.0	0.0	0.005	0.00
08-AG-021	**BW10**	**16-May-08**	**0.0**	**0.0**	**26.0**	**0.003**	**0.00**
08-AG-023	RS	16-May-08	0.0	0.0	0.0	0.002	0.00
08-AG-025	RS	16-May-08	0.0	0.0	0.0	0.007	0.05
08-AG-030	RS	16-May-08	0.0	0.0	0.0	0.002	<0.01
08-AG-031	RS	16-May-08	0.0	0.0	0.0	0.002	<0.01
08-AG-043	RS	20-May-08	0.0	0.0	0.0	0.003	0.00
08-AG-046	RS	20-May-08	0.0	0.0	0.0	0.105	<0.01
08-AG-050	RS	20-May-08	0.0	0.0	0.0	0.006	0.01
08-AG-053	RS	20-May-08	0.0	0.0	0.0	0.008	0.00
08-AG-060	RSBWZ	21-May-08	0.0	0.0	0.0	0.031	0.00
08-AG-062	RS	21-May-08	0.0	0.0	0.0	0.000	0.00
08-AG-085	RS	26-May-08	0.0	0.0	0.0	0.000	0.00
08-AG-086	RSBWZ	26-May-08	0.0	0.0	0.0	0.000	0.00
08-AG-087	**BW04**	**26-May-08**	**0.0**	**0.0**	**1.7**	**0.000**	**0.00**
08-AG-100	RSBWZ	26-May-08	0.0	0.0	0.0	0.473	0.00
08-AG-102	RS	27-May-08	0.0	0.0	0.0	0.005	<0.01
08-AG-103	RS	27-May-08	0.0	0.0	0.0	0.000	0.00

Sample	Sample Type	Sample Date	Total Coliform	Fecal Coliform	Dissolved Oxygen (DO)	Dissolved Methane (CH_4)	Dissolved Hydrogen Sulphide (H_2S)
			counts/100mL	counts/100mL	% saturation	% saturation	mg/L S^{2-}
08-AG-105	**BW08**	**27-May-08**	**0.0**	**0.0**	**0.0**	**0.017**	**<0.01**
08-AG-106	RS	28-May-08	0.0	0.0	0.0	0.010	0.00
08-AG-107	RS	28-May-08	0.0	0.0	0.0	0.004	<0.01
08-AG-108	RS	28-May-08	0.0	0.0	0.0	0.008	<0.01
08-AG-120	RS	28-May-08	0.0	0.0	60.2	0.000	0.00
08-AG-121	RS	28-May-08	0.0	0.0	0.0	0.037	<0.01
08-AG-122	RS	28-May-08	0.0	0.0	0.0	0.009	0.00
08-AG-153	RS	9-Jun-08	0.0	0.0	0.0	0.075	0.00
08-AG-157	RS	9-Jun-08	0.0	0.0	0.0	0.506	0.00
08-AG-162	RS	9-Jun-08	0.0	0.0	0.0	0.030	0.00
08-AG-164	RS	9-Jun-08	0.0	0.0	0.0	0.000	0.00
08-AG-165	RS	9-Jun-08	0.0	0.0	0.0	0.000	0.00
08-AG-167	**BW02**	**11-Jun-08**	**0.0**	**0.0**	**0.0**	**0.000**	**0.00**
08-AG-181	BW	11-Jun-08	0.0	0.0	0.0	0.000	0.00
08-AG-183	**BW03**	**11-Jun-08**	**0.0**	**0.0**	**0.0**	**0.000**	**0.00**
08-AG-188	RS	18-Jun-08	0.0	0.0	0.0	8.686	0.10
08-AG-190	RSBWZ	17-Jun-08	0.0	0.0	0.0	0.039	0.06
08-AG-193	RS	17-Jun-08	0.0	0.0	0.0	0.000	2.00
08-AG-194	RS	18-Jun-08	0.0	0.0	0.0	0.758	5.75
08-AG-197	RS	19-Jun-08	0.0	0.0	0.0	0.000	0.06
08-AG-202	RS	19-Jun-08	0.0	0.0	0.0	0.000	0.00
08-AG-203	RS	19-Jun-08	0.0	0.0	0.0	0.000	0.02
08-AG-205	RS	20-Jun-08	6.0	0.0	0.0	0.000	0.00
08-AG-206	RS	20-Jun-08	1.0	0.0	0.0	0.000	<0.01
08-AG-207	RS	20-Jun-08	0.0	0.0	0.0	0.000	0.00
08-AG-208	RS	20-Jun-08	0.0	0.0	0.0	0.000	0.00
08-AG-211	**BW05**	**19-Jun-08**	**0.0**	**0.0**	**0.0**	**0.000**	**0.00**
08-AG-214	RS	19-Jun-08	0.0	0.0	0.0	0.000	0.00
08-AG-215	RS	22-Jun-08	3.0	0.0	0.0	0.000	0.04
08-AG-217	RSBWZ	22-Jun-08	0.0	0.0	0.0	0.000	0.01
08-AG-223	BW06	23-Jun-08	1.0	0.0	0.0	0.000	0.00
08-AG-225	RS	23-Jun-08	0.0	0.0	0.0	0.000	0.00
08-AG-227	RS	23-Jun-08	0.0	0.0	0.0	0.000	0.00
08-AG-228	RS	24-Jun-08	0.0	0.0	0.0	0.000	0.00
08-AG-231	RS	25-Jun-08	0.0	0.0	0.0	0.000	0.03
08-AG-232	RSBWZ	25-Jun-08	0.0	0.0	0.0	0.000	0.00
08-AG-237	RS	26-Jun-08	0.0	0.0	0.0	0.000	0.00
08-AG-242	RS	26-Jun-08	0.0	0.0	0.0	0.000	<0.01
08-AG-243	RS	26-Jun-08	25.0	0.0	0.0	0.000	0.00
08-AG-246	RS	30-Jun-08	0.0	0.0	0.0	0.000	0.05
08-AG-247	RS	30-Jun-08	0.0	0.0	0.0	0.000	0.03
08-AG-248	RS	30-Jun-08	0.0	0.0	0.0	0.000	0.04
08-AG-250	RS	30-Jun-08	3.0	0.0	0.0	0.000	0.06
08-AG-251	RS	2-Jul-08	1.0	0.0	0.0	0.000	0.00
08-AG-252	RS	2-Jul-08	2.0	0.0	0.0	0.000	0.00
08-AG-253	RS	2-Jul-08	46.0	2.0	0.0	0.000	0.00
08-AG-254	RS	2-Jul-08	400.0	0.0	0.0	0.000	<0.01
08-AG-255	RS	3-Jul-08	1.0	1.0	0.0	0.000	0.00

* RS = Stations sampled as part of the regional study. †Stations in bold and numbered BW01-BW11 wells that were sampled as part of the local study. ‡RSBWZ – Regional wells located in the BWZ. "-" symbolizes parameter not measured. “<” symbolizes parameter is below detection limit.

Appendix D. Isotopic Parameters (Regional Study).

Sample	Sample Type	Date	$\delta^{18}O$ (H_2O)	δ^2H(H_2O)	^3H (H_2O)
			‰VSMOW	‰VSMOW	TU
07-AG-005	*RS	21-Jun-07	-10.4	-67	-
07-AG-006	RS	21-Jun-07	-9.6	-65	-
07-AG-008	RS	21-Jun-07	-10.4	-67	-
07-AG-011	RS	23-Jun-07	-9.8	-65	-
07-AG-014	RS	23-Jun-07	-10.3	-67	-
07-AG-016	RS	23-Jun-07	-10.2	-67	-
07-AG-020	RS	24-Jun-07	-10.6	-77	-
07-AG-021	RS	24-Jun-07	-10.5	-75	-
07-AG-025	RS	26-Jun-07	-11.2	-75	-
07-AG-026	**†BW09**	**26-Jun-07**	**-10.8**	**-71**	**-**
07-AG-029	RS	26-Jun-07	-10.3	-70	-
07-AG-030	RS	26-Jun-07	-10.3	-65	-
07-AG-032	RS	26-Jun-07	-11.1	-72	-
07-AG-036	RS	27-Jun-07	-10.2	-71	-
07-AG-038	RS	27-Jun-07	-9.7	-64	-
07-AG-040	RS	28-Jun-07	-10.7	-73	-
07-AG-049	RS	29-Jun-07	-10.6	-77	-
07-AG-050	RS	4-Jul-07	-10.0	-76	-
07-AG-056	RS	7-Jul-07	-10.8	-77	-
07-AG-092	RS	12-Jul-07	-10.1	-64	-
07-AG-094	RS	12-Jul-07	-16.9	-118	-
07-AG-109	RS	18-Jul-07	-10.0	-69	-
07-AG-125	RS	18-Jul-07	-10.0	-70	-
07-AG-145	RS	24-Jul-07	-9.8	-66	-
07-AG-152	RS	24-Jul-07	-12.8	-89	-
07-AG-155	RS	26-Jul-07	-10.1	-66	-
07-AG-214	RS	5-Aug-07	-10.2	-73	-
08-AG-001	RS	13-May-08	-12.4	-82	<6
08-AG-004	RS	13-May-08	-10.6	-70	<6
08-AG-005	RS	13-May-08	-10.1	-67	-
08-AG-007	‡RSBWZ	15-May-08	-11.2	-74	<6
08-AG-010	**BW01**	**15-May-08**	**-11.5**	**-76**	**<6**
08-AG-012	**BW11**	**15-May-08**	**-11.1**	**-74**	**<6**
08-AG-013	RSBWZ	15-May-08	-11.3	-76	<6
08-AG-015	RSBWZ	15-May-08	-11.1	-76	<6
08-AG-017	RS	16-May-08	-11.0	-73	<6
08-AG-020	RSBWZ	15-May-08	-11.3	-77	<6
08-AG-021	**BW10**	**16-May-08**	**-11.4**	**-77**	**<6**
08-AG-023	RS	16-May-08	-10.7	-73	<6
08-AG-025	RS	16-May-08	-10.8	-71	<6
08-AG-030	RS	16-May-08	-10.7	-70	<6
08-AG-031	RS	16-May-08	-11.0	-70	<6
08-AG-043	RS	20-May-08	-10.6	-68	<6
08-AG-046	RS	20-May-08	-10.2	-67	<6
08-AG-050	RS	20-May-08	-10.8	-68	<6
08-AG-053	RS	20-May-08	-11.1	-72	<6
08-AG-060	RSBWZ	21-May-08	-11.3	-76	16
08-AG-062	RS	21-May-08	-10.6	-69	10
08-AG-085	RS	26-May-08	-11.8	-80	<6
08-AG-086	RSBWZ	26-May-08	-12.4	-85	<6
08-AG-087	**BW04**	**26-May-08**	**-11.8**	**-77**	**<6**
08-AG-100	RSBWZ	26-May-08	-11.5	-77	<6
08-AG-102	RS	27-May-08	-11.7	-77	<6
08-AG-103	RS	27-May-08	-12.3	-83	<6
08-AG-105	**BW08**	**27-May-08**	**-11.5**	**-78**	**<6**
08-AG-106	RS	28-May-08	-11.8	-79	<6
08-AG-107	RS	28-May-08	-12.3	-80	<6

Sample	Sample Type	Date	$\delta^{18}O$ (H_2O)	δ^2H(H_2O)	^3H (H_2O)
			‰VSMOW	‰VSMOW	TU
08-AG-108	RS	28-May-08	-12.6	-85	<6
08-AG-120	RS	28-May-08	-12.1	-80	<6
08-AG-121	RS	28-May-08	-12.4	-80	<6
08-AG-122	RS	28-May-08	-11.9	-77	<6
08-AG-153	RS	9-Jun-08	-10.0	-67	<6
08-AG-157	RS	9-Jun-08	-11.4	-75	8
08-AG-162	RS	9-Jun-08	-11.0	-73	<6
08-AG-164	RS	9-Jun-08	-11.4	-75	<6
08-AG-165	RS	9-Jun-08	-10.7	-71	<6
08-AG-167	**BW02**	**11-Jun-08**	**-11.3**	**-76**	**13**
08-AG-181	RSBWZ	11-Jun-08	-11.7	-78	<6
08-AG-183	**BW03**	**11-Jun-08**	**-12.1**	**-80**	**18**
08-AG-188	RS	18-Jun-08	-10.6	-65	62
08-AG-190	RSBWZ	17-Jun-08	-10.5	-70	25
08-AG-193	RS	17-Jun-08	-10.2	-68	78
08-AG-194	RS	18-Jun-08	-14.0	-97	<6
08-AG-197	RS	19-Jun-08	-12.4	-83	9
08-AG-202	RS	19-Jun-08	-10.8	-72	7
08-AG-203	RS	19-Jun-08	-10.8	-71	8
08-AG-205	RS	20-Jun-08	-10.5	-70	22
08-AG-206	RS	20-Jun-08	-10.8	-71	<6
08-AG-207	RS	20-Jun-08	-12.1	-79	7
08-AG-208	RS	20-Jun-08	-11.5	-77	<6
08-AG-211	**BW05**	**19-Jun-08**	**-11.7**	**-78**	**<6**
08-AG-214	RS	19-Jun-08	-11.8	-79	<6
08-AG-215	RS	22-Jun-08	-11.0	-73	<6
08-AG-217	RSBWZ	22-Jun-08	-11.4	-77	<6
08-AG-223	BW06	23-Jun-08	-11.6	-78	<6
08-AG-225	RS	23-Jun-08	-10.6	-71	<6
08-AG-227	RS	23-Jun-08	-11.3	-75	<6
08-AG-228	RS	24-Jun-08	-9.9	-61	<6
08-AG-231	RS	25-Jun-08	-11.9	-77	<6
08-AG-232	RSBWZ	25-Jun-08	-10.4	-72	<6
08-AG-237	RS	26-Jun-08	-9.8	-55	<6
08-AG-242	RS	26-Jun-08	-12.3	-83	148
08-AG-243	RS	26-Jun-08	-11.4	-78	100
08-AG-246	RS	30-Jun-08	-11.5	-78	51
08-AG-247	RS	30-Jun-08	-11.6	-77	35
08-AG-248	RS	30-Jun-08	-11.4	-74	103
08-AG-250	RS	30-Jun-08	-11.1	-73	57
08-AG-251	RS	2-Jul-08	-11.3	-74	30
08-AG-252	RS	2-Jul-08	-11.6	-76	40
08-AG-253	RS	2-Jul-08	-11.7	-77	17
08-AG-254	RS	2-Jul-08	-11.6	-76	<6
08-AG-255	RS	3-Jul-08	-10.9	-72	<6

* RS = Stations sampled as part of the regional study. †Stations in bold and numbered BW01-BW11 wells that were sampled as part of the local study. ‡RSBWZ – Regional wells located in the BWZ. "-" symbolizes parameter not measured. “<” symbolizes parameter is below detection limit.

Appendix E. Major Constituents (Regional Study)

Sample	Sample Type	Date	Ca^{2+}	Mg^{2+}	K^{+}	Na^{+}	HCO_3^{-}	SO_4^{2-}	Cl^{-}	F^{-}
			mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
07-AG-005	*RS	21-Jun-07	64.4	36.3	1.4	25.1	225.0	93.1	49.4	0.9
07-AG-006	RS	21-Jun-07	54.1	27.5	1.4	12.6	312.0	13.8	1.9	0.8
07-AG-008	RS	21-Jun-07	154.9	50.4	1.3	17.8	211.0	363.4	1.3	1.4
07-AG-011	RS	23-Jun-07	38.7	23.8	2.5	48.2	204.0	67.1	22.5	1.9
07-AG-014	RS	23-Jun-07	35.0	21.1	1.4	28.0	249.0	26.3	4.4	1.2
07-AG-016	RS	23-Jun-07	62.5	25.2	0.8	15.1	278.0	43.0	13.1	0.8
07-AG-020	RS	24-Jun-07	44.1	21.6	1.0	9.8	250.0	17.6	1.3	1.3
07-AG-021	RS	24-Jun-07	58.4	23.3	0.8	7.6	287.0	26.7	2.8	0.8
07-AG-025	RS	26-Jun-07	29.0	20.9	2.6	25.3	260.0	3.9	0.8	1.4
07-AG-026	**†BW09**	**26-Jun-07**	**84.9**	**24.0**	**1.1**	**22.1**	**248.0**	**85.5**	**13.0**	**1.1**
07-AG-029	RS	26-Jun-07	30.9	17.5	1.2	37.6	236.0	62.9	1.1	2.1
07-AG-030	RS	26-Jun-07	24.0	13.0	1.1	37.0	225.0	7.4	3.4	1.3
07-AG-032	RS	26-Jun-07	15.7	8.6	0.9	37.1	167.0	9.3	1.0	1.5
07-AG-036	RS	27-Jun-07	33.7	16.5	1.0	21.9	233.0	5.4	1.4	1.1
07-AG-038	RS	27-Jun-07	21.0	18.5	1.1	30.8	215.0	13.6	1.2	1.4
07-AG-040	RS	28-Jun-07	22.0	17.4	0.9	26.8	194.0	2.0	0.9	1.2
07-AG-049	RS	29-Jun-07	18.1	12.9	1.8	47.9	155.0	0.8	1.7	1.5
07-AG-050	RS	4-Jul-07	23.9	22.4	1.1	52.9	252.0	43.8	4.3	1.8
07-AG-056	RS	7-Jul-07	24.7	17.1	1.8	32.3	214.0	15.8	7.9	1.4
07-AG-092	RS	12-Jul-07	14.3	5.0	1.1	66.6	223.0	5.2	15.0	1.6
07-AG-094	RS	12-Jul-07	23.6	13.9	5.1	450.1	110.0	<0.04	575.0	1.7
07-AG-109	RS	18-Jul-07	32.0	21.7	1.4	27.3	212.0	1.2	0.9	1.6
07-AG-125	RS	18-Jul-07	83.5	30.9	1.7	17.3	240.0	114.8	0.7	1.1
07-AG-145	RS	24-Jul-07	13.8	13.2	1.1	38.2	237.0	0.9	1.2	1.0
07-AG-152	RS	24-Jul-07	2.8	1.6	2.7	152.8	395.0	39.5	32.8	1.7
07-AG-155	RS	26-Jul-07	9.0	7.9	1.1	48.8	156.0	0.1	2.0	1.3
07-AG-214	RS	5-Aug-07	30.2	24.3	1.3	15.5	280.0	1.2	0.5	1.2
08-AG-001	RS	13-May-08	15.1	7.2	1.2	87.8	113.0	140.7	8.0	1.8
08-AG-004	RS	13-May-08	7.9	4.3	2.3	216.6	257.0	57.7	177.3	2.2
08-AG-005	RS	13-May-08	220.9	20.1	24.9	41.7	190.0	537.2	15.0	1.1
08-AG-007	‡RSBWZ	15-May-08	32.8	24.1	1.3	22.9	267.0	2.8	0.3	1.4
08-AG-010	**BW01**	**15-May-08**	**200.5**	**51.4**	**0.9**	**9.2**	**230.0**	**431.6**	**4.2**	**1.4**
08-AG-012	**BW11**	**15-May-08**	**248.4**	**123.8**	**1.7**	**30.6**	**275.0**	**848.0**	**10.0**	**2.1**
08-AG-013	RSBWZ	15-May-08	46.4	23.3	0.7	6.1	243.0	87.9	2.8	2.1
08-AG-015	RSBWZ	15-May-08	55.6	19.7	1.1	16.6	495.0	54.0	0.8	1.6
08-AG-017	RS	16-May-08	47.2	17.7	1.3	21.8	240.0	8.2	2.5	1.1
08-AG-020	RSBWZ	15-May-08	51.2	16.7	0.9	10.7	249.0	44.2	0.3	1.4
08-AG-021	**BW10**	**16-May-08**	**94.7**	**30.3**	**0.9**	**11.9**	**282.0**	**224.1**	**0.7**	**0.7**
08-AG-023	RS	16-May-08	64.3	24.2	1.2	20.5	272.0	43.4	8.6	1.0
08-AG-025	RS	16-May-08	28.1	17.8	1.1	36.4	235.0	12.4	0.7	1.8
08-AG-030	RS	16-May-08	11.5	4.6	1.0	51.7	165.0	3.4	1.3	1.3
08-AG-031	RS	16-May-08	80.5	28.0	1.4	12.1	243.0	99.4	0.3	1.0
08-AG-043	RS	20-May-08	20.6	10.9	1.0	44.6	238.0	13.8	1.0	2.1
08-AG-046	RS	20-May-08	54.3	22.7	1.1	22.6	266.0	1.3	0.7	1.0
08-AG-050	RS	20-May-08	31.2	15.2	1.1	22.6	212.0	23.6	2.1	1.3
08-AG-053	RS	20-May-08	46.5	15.1	1.2	11.1	257.0	4.9	0.3	1.0
08-AG-060	RSBWZ	21-May-08	88.7	18.7	1.0	4.8	366.0	113.2	4.4	1.0
08-AG-062	RS	21-May-08	39.0	15.7	1.4	24.2	277.0	16.6	0.6	1.2
08-AG-085	RS	26-May-08	61.7	26.2	1.1	13.0	254.0	76.1	3.5	1.5
08-AG-086	RSBWZ	26-May-08	46.0	30.7	1.1	11.7	292.0	9.3	0.5	1.4
08-AG-087	**BW04**	**26-May-08**	**87.1**	**21.0**	**0.9**	**10.6**	**288.0**	**64.5**	**14.7**	**1.0**
08-AG-100	RSBWZ	26-May-08	40.8	15.0	0.8	23.1	260.0	21.9	1.7	1.6
08-AG-102	RS	27-May-08	87.9	37.4	1.1	8.1	333.0	52.9	19.1	1.5
08-AG-103	RS	27-May-08	38.9	21.5	1.0	13.1	188.0	105.5	0.6	2.4
08-AG-105	**BW08**	**27-May-08**	**228.0**	**47.5**	**1.0**	**31.1**	**282.0**	**581.4**	**21.2**	**1.7**
08-AG-106	RS	28-May-08	28.3	17.1	1.1	22.6	226.0	87.2	1.0	2.6
08-AG-107	RS	28-May-08	43.4	24.4	1.2	13.0	249.0	15.3	1.4	1.7

Sample	Sample Type	Date	Ca^{2+}	Mg^{2+}	K^{+}	Na^{+}	HCO_3^{-}	SO_4^{2-}	Cl^{-}	F^{-}
			mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
08-AG-108	RS	28-May-08	54.5	22.9	0.8	7.5	256.0	5.0	0.3	1.5
08-AG-120	RS	28-May-08	111.4	32.0	0.8	164.6	322.0	17.0	242.7	0.1
08-AG-121	RS	28-May-08	31.1	22.2	0.9	7.9	238.0	72.4	5.1	1.5
08-AG-122	RS	28-May-08	37.4	17.9	0.8	11.8	256.0	33.2	0.4	1.4
08-AG-153	RS	9-Jun-08	39.8	18.0	1.2	35.6	309.0	26.0	0.8	1.3
08-AG-157	RS	9-Jun-08	46.6	17.3	1.0	12.0	274.0	5.1	1.8	1.0
08-AG-162	RS	9-Jun-08	20.7	14.1	0.9	37.3	229.0	2.7	0.5	1.2
08-AG-164	RS	9-Jun-08	45.7	18.2	6.7	24.1	261.0	12.1	4.2	1.9
08-AG-165	RS	9-Jun-08	379.1	89.8	2.4	24.2	251.0	1227.8	4.8	0.4
08-AG-167	**BW02**	**11-Jun-08**	**120.7**	**37.7**	**1.2**	**17.1**	**262.0**	**315.4**	**7.5**	**1.0**
08-AG-181	RSBWZ	11-Jun-08	100.3	41.2	0.9	11.7	316.0	175.1	5.7	1.5
08-AG-183	**BW03**	**11-Jun-08**	**47.9**	**15.9**	**0.7**	**6.0**	**254.0**	**58.9**	**0.4**	**1.3**
08-AG-188	RS	18-Jun-08	6.7	2.7	0.9	72.6	198.0	0.2	12.6	2.3
08-AG-190	RSBWZ	17-Jun-08	11.8	6.4	0.9	70.7	189.0	57.3	2.2	2.2
08-AG-193	RS	17-Jun-08	11.6	4.6	0.9	81.4	116.0	148.7	5.1	1.8
08-AG-194	RS	18-Jun-08	11.6	5.7	2.5	82.2	213.0	44.7	17.1	2.0
08-AG-197	RS	19-Jun-08	32.8	16.0	1.0	13.4	250.0	51.1	0.3	1.6
08-AG-202	RS	19-Jun-08	56.7	21.4	1.4	23.3	254.0	66.7	0.9	0.9
08-AG-203	RS	19-Jun-08	33.8	14.6	1.3	33.1	291.0	7.3	1.3	1.5
08-AG-205	RS	20-Jun-08	36.8	16.3	2.7	31.3	280.0	4.3	0.7	1.5
08-AG-206	RS	20-Jun-08	334.7	54.8	2.0	16.5	234.0	814.2	1.1	1.0
08-AG-207	RS	20-Jun-08	83.2	22.7	0.8	3.1	338.0	54.3	6.1	1.5
08-AG-208	RS	20-Jun-08	40.0	17.6	1.0	12.5	241.0	46.5	0.8	1.9
08-AG-211	**BW05**	**19-Jun-08**	**93.0**	**32.7**	**1.4**	**255.2**	**325.0**	**226.8**	**301.5**	**1.6**
08-AG-214	RS	19-Jun-08	32.4	18.3	1.1	21.0	249.0	26.2	0.4	1.9
08-AG-215	RS	22-Jun-08	311.8	54.1	1.3	51.6	213.0	839.1	40.1	1.6
08-AG-217	RSBWZ	22-Jun-08	345.9	70.3	1.0	32.9	250.0	802.1	35.7	1.9
08-AG-223	BW06	23-Jun-08	90.9	30.5	1.1	6.4	381.0	99.0	12.4	1.6
08-AG-225	RS	23-Jun-08	11.4	6.5	0.7	59.0	208.0	4.0	2.5	2.0
08-AG-227	RS	23-Jun-08	24.0	16.9	0.9	34.2	265.0	13.8	0.6	1.9
08-AG-228	RS	24-Jun-08	50.4	20.0	1.4	49.2	305.0	39.8	1.2	0.4
08-AG-231	RS	25-Jun-08	65.2	20.5	1.1	10.8	268.0	14.7	3.0	0.8
08-AG-232	RSBWZ	25-Jun-08	108.4	27.4	1.4	6.2	342.0	29.4	12.8	0.5
08-AG-237	RS	26-Jun-08	38.7	14.7	2.4	147.1	102.0	234.8	89.5	1.7
08-AG-242	RS	26-Jun-08	53.2	20.6	0.8	11.5	327.0	4.7	0.6	1.5
08-AG-243	RS	26-Jun-08	110.5	41.8	0.7	4.2	281.0	116.0	9.8	1.1
08-AG-246	RS	30-Jun-08	40.4	17.2	0.9	10.4	234.0	5.1	0.9	1.9
08-AG-247	RS	30-Jun-08	58.7	23.2	1.1	8.4	292.0	13.3	1.9	1.1
08-AG-248	RS	30-Jun-08	54.1	27.6	1.2	10.3	292.0	19.3	8.6	0.9
08-AG-250	RS	30-Jun-08	44.2	25.3	1.4	11.6	278.0	6.6	0.8	1.0
08-AG-251	RS	2-Jul-08	45.1	21.0	1.2	11.1	261.0	8.5	2.8	1.0
08-AG-252	RS	2-Jul-08	83.7	29.0	0.9	15.7	361.0	25.9	35.4	0.2
08-AG-253	RS	2-Jul-08	57.6	27.5	1.1	8.3	274.0	16.6	7.4	0.4
08-AG-254	RS	2-Jul-08	73.6	37.2	1.6	10.6	267.0	110.6	1.3	0.9
08-AG-255	RS	3-Jul-08	16.2	6.9	1.5	165.6	193.0	80.2	118.3	2.4

* RS = Stations sampled as part of the regional study. †Stations in bold and numbered BW01-BW11 wells that were sampled as part of the local study. ‡RSBWZ – Regional wells located in the BWZ. "-" symbolizes parameter not measured. "<" symbolizes parameter is below detection limit.

Appendix F. Trace Constituents: Fe^{2+}, Sr^{2+}, Si, Br^{-}, I^{-} and PO_4^{2-} (Regional Study)

Sample	Sample Type	Date	Fe^{2+}	Sr^{2+}	Si	Br^{-}	I^{-}	$PO4^{2-}$
			mg/L	mg/L	mg/L	mg/L	µg/L	mg/L
07-AG-005	*RS	21-Jun-07	0.65	1.8	8.1	<0.1	-	<0.1
07-AG-006	RS	21-Jun-07	2.05	2.4	7.1	<0.1	-	<0.1
07-AG-008	RS	21-Jun-07	1.87	18.6	5.0	<0.1	10	<0.1
07-AG-011	RS	23-Jun-07	**0.07**	3.4	4.5	<0.1	-	<0.1
07-AG-014	RS	23-Jun-07	0.05	1.5	5.6	<0.1	11	<0.1
07-AG-016	RS	23-Jun-07	0.13	0.8	5.7	<0.1	6	<0.1
07-AG-020	RS	24-Jun-07	1.08	1.2	6.9	<0.1	5	<0.1
07-AG-021	RS	24-Jun-07	1.24	1.5	7.3	<0.1	-	<0.1
07-AG-025	RS	26-Jun-07	0.02	2.2	5.8	<0.1	-	<0.1
07-AG-026	**†BW09**	**26-Jun-07**	0.03	**2.5**	**3.7**	**<0.1**	**5**	**<0.1**
07-AG-029	RS	26-Jun-07	0.15	27.9	4.6	<0.1	10	<0.1
07-AG-030	RS	26-Jun-07	0.28	1.3	5.3	<0.1	-	<0.1
07-AG-032	RS	26-Jun-07	0.22	1.1	4.5	<0.1	75	<0.1
07-AG-036	RS	27-Jun-07	1.37	0.8	5.6	<0.1	-	<0.1
07-AG-038	RS	27-Jun-07	0.36	2.1	6.0	<0.1	-	<0.1
07-AG-040	RS	28-Jun-07	0.33	1.0	6.2	<0.1	-	<0.1
07-AG-049	RS	29-Jun-07	0.09	1.8	5.2	<0.1	-	<0.1
07-AG-050	RS	4-Jul-07	0.27	2.0	5.3	0.1	16	<0.1
07-AG-056	RS	7-Jul-07	0.04	2.4	5.7	<0.1	-	<0.1
07-AG-092	RS	12-Jul-07	0.09	0.4	4.1	0.1	300	<0.1
07-AG-094	RS	12-Jul-07	0.60	1.2	3.6	2.9	300	<0.1
07-AG-109	RS	18-Jul-07	0.23	1.7	4.2	<0.1	-	<0.1
07-AG-125	RS	18-Jul-07	0.19	16.4	5.4	<0.1	21	0.2
07-AG-145	RS	24-Jul-07	0.01	2.6	5.7	<0.1	-	<0.1
07-AG-152	RS	24-Jul-07	0.02	0.1	3.1	0.1	-	<0.1
07-AG-155	RS	26-Jul-07	0.29	0.7	5.3	<0.1	86	0.2
07-AG-214	RS	5-Aug-07	0.17	2.0	6.7	<0.1	-	<0.1
08-AG-001	RS	13-May-08	0.01	1.3	4.2	0.3	224	<0.1
08-AG-004	RS	13-May-08	0.02	0.5	3.9	0.6	64	<0.1
08-AG-005	RS	13-May-08	0.00	4.0	5.5	<0.1	32	0.5
08-AG-007	‡RSBWZ	15-May-08	0.08	3.0	7.3	<0.1	23	<0.1
08-AG-010	**BW01**	**15-May-08**	**0.01**	**14.6**	**4.8**	**<0.1**	**<5**	**0.1**
08-AG-012	**BW11**	**15-May-08**	**3.42**	**18.8**	**3.4**	**<0.1**	**10**	**<0.1**
08-AG-013	RSBWZ	15-May-08	0.06	49.0	4.0	<0.1	<5	0.1
08-AG-015	RSBWZ	15-May-08	0.02	37.9	4.8	<0.1	6	<0.1
08-AG-017	RS	16-May-08	0.50	0.7	6.4	<0.1	11	0.1
08-AG-020	RSBWZ	15-May-08	0.30	27.5	4.6	<0.1	6	0.1
08-AG-021	**BW10**	**16-May-08**	**0.02**	**33.4**	**5.6**	**<0.1**	**5**	**<0.1**
08-AG-023	RS	16-May-08	0.87	6.3	5.2	<0.1	33	<0.1
08-AG-025	RS	16-May-08	0.65	4.5	5.3	<0.1	74	<0.1
08-AG-030	RS	16-May-08	0.27	0.3	4.9	<0.1	62	<0.1
08-AG-031	RS	16-May-08	2.42	4.7	5.7	<0.1	15	<0.1
08-AG-043	RS	20-May-08	0.37	2.8	5.0	<0.1	125	<0.1
08-AG-046	RS	20-May-08	2.85	1.0	6.5	<0.1	49	<0.1
08-AG-050	RS	20-May-08	0.51	19.1	6.7	<0.1	83	<0.1
08-AG-053	RS	20-May-08	1.90	1.4	6.2	<0.1	92	<0.1
08-AG-060	RSBWZ	21-May-08	0.80	39.2	5.4	<0.1	13	<0.1
08-AG-062	RS	21-May-08	0.33	0.7	5.7	<0.1	14	<0.1
08-AG-085	RS	26-May-08	0.97	41.2	7.1	<0.1	11	0.2
08-AG-086	RSBWZ	26-May-08	0.85	2.2	7.9	<0.1	7	<0.1
08-AG-087	**BW04**	**26-May-08**	**0.01**	**13.5**	**4.0**	**<0.1**	**<5**	**<0.1**
08-AG-100	RSBWZ	26-May-08	1.01	3.9	5.0	<0.1	7	0.1
08-AG-102	RS	27-May-08	1.26	0.3	8.4	<0.1	35	0.1
08-AG-103	RS	27-May-08	0.10	47.8	5.7	<0.1	6	0.2
08-AG-105	**BW08**	**27-May-08**	**0.53**	**17.8**	**4.5**	**<0.1**	**19**	**<0.1**
08-AG-106	RS	28-May-08	0.18	47.6	4.8	<0.1	8	0.2
08-AG-107	RS	28-May-08	0.40	7.2	6.7	<0.1	231	<0.1

Sample	Sample Type	Date	Fe^{2+}	Sr^{2+}	Si	Br^{-}	I^{-}	$PO4^{2-}$
			mg/L	mg/L	mg/L	mg/L	µg/L	mg/L
08-AG-108	RS	28-May-08	3.06	1.3	8.6	<0.1	20	<0.1
08-AG-120	RS	28-May-08	0.04	0.1	4.3	<0.1	14	0.2
08-AG-121	RS	28-May-08	0.47	56.0	7.4	<0.1	26	0.1
08-AG-122	RS	28-May-08	0.74	30.8	7.2	<0.1	20	0.3
08-AG-153	RS	9-Jun-08	0.65	9.2	6.0	0.2	45	<0.1
08-AG-157	RS	9-Jun-08	0.93	0.5	6.7	<0.1	25	<0.1
08-AG-162	RS	9-Jun-08	0.34	3.5	5.1	<0.1	20	<0.1
08-AG-164	RS	9-Jun-08	0.04	2.9	4.6	<0.1	13	<0.1
08-AG-165	RS	9-Jun-08	0.21	12.0	7.1	0.2	18	<0.1
08-AG-167	**BW02**	**11-Jun-08**	**0.48**	**20.4**	**3.6**	**<0.1**	**11**	**<0.1**
08-AG-181	RSBWZ	11-Jun-08	0.02	29.8	4.7	0.1	<5	0.2
08-AG-183	**BW03**	**11-Jun-08**	**0.24**	**53.5**	**6.7**	**<0.1**	**<5**	**<0.1**
08-AG-188	RS	18-Jun-08	0.08	0.3	4.4	<0.1	20	<0.1
08-AG-190	RSBWZ	17-Jun-08	0.29	1.3	3.9	0.1	50	<0.1
08-AG-193	RS	17-Jun-08	0.02	0.7	3.9	0.2	179	<0.1
08-AG-194	RS	18-Jun-08	0.01	1.1	4.7	0.5	100	<0.1
08-AG-197	RS	19-Jun-08	0.54	48.2	6.5	<0.1	66	<0.1
08-AG-202	RS	19-Jun-08	0.89	3.6	5.8	<0.1	14	<0.1
08-AG-203	RS	19-Jun-08	0.68	0.7	4.7	<0.1	30	<0.1
08-AG-205	RS	20-Jun-08	0.83	3.9	3.9	<0.1	12	<0.1
08-AG-206	RS	20-Jun-08	2.63	14.4	3.4	0.1	73	<0.1
08-AG-207	RS	20-Jun-08	0.01	19.7	2.9	<0.1	6	<0.1
08-AG-208	RS	20-Jun-08	0.79	41.5	4.9	<0.1	8	<0.1
08-AG-211	**BW05**	**19-Jun-08**	**1.14**	**45.1**	**5.2**	**<0.1**	**21**	**<0.1**
08-AG-214	RS	19-Jun-08	0.60	21.0	5.4	<0.1	15	<0.1
08-AG-215	RS	22-Jun-08	2.57	13.7	5.2	0.1	53	<0.1
08-AG-217	RSBWZ	22-Jun-08	0.42	18.8	3.8	<0.1	12	<0.1
08-AG-223	BW06	23-Jun-08	0.02	43.5	5.9	<0.1	<5	<0.1
08-AG-225	RS	23-Jun-08	0.05	0.8	4.6	<0.1	34	<0.1
08-AG-227	RS	23-Jun-08	0.30	5.3	4.9	<0.1	6	<0.1
08-AG-228	RS	24-Jun-08	1.15	2.1	5.2	<0.1	18	<0.1
08-AG-231	RS	25-Jun-08	0.85	0.7	7.9	<0.1	21	<0.1
08-AG-232	RSBWZ	25-Jun-08	1.38	0.5	7.2	<0.1	8	<0.1
08-AG-237	RS	26-Jun-08	0.03	1.3	3.6	0.2	109	<0.1
08-AG-242	RS	26-Jun-08	0.78	2.0	5.1	<0.1	11	<0.1
08-AG-243	RS	26-Jun-08	0.15	0.6	5.3	<0.1	6	<0.1
08-AG-246	RS	30-Jun-08	0.25	4.1	5.5	<0.1	40	<0.1
08-AG-247	RS	30-Jun-08	0.99	1.7	4.9	<0.1	8	<0.1
08-AG-248	RS	30-Jun-08	0.54	0.6	5.4	<0.1	34	<0.1
08-AG-250	RS	30-Jun-08	0.82	2.7	3.8	<0.1	101	<0.1
08-AG-251	RS	2-Jul-08	0.09	2.5	3.7	<0.1	5	<0.1
08-AG-252	RS	2-Jul-08	0.06	12.0	5.9	<0.1	7	<0.1
08-AG-253	RS	2-Jul-08	0.01	2.6	6.2	<0.1	<5	<0.1
08-AG-254	RS	2-Jul-08	0.64	4.9	4.0	<0.1	6	<0.1
08-AG-255	RS	3-Jul-08	0.05	0.6	4.0	0.2	98	<0.1

* RS = Stations sampled as part of the regional study. †Stations in bold and numbered BW01-BW11 wells that were sampled as part of the local study. ‡RSBWZ – Regional wells located in the BWZ. "-" symbolizes parameter not measured. “<” symbolizes parameter is below detection limit.

Appendix G. Trace Constituents: NO_3^-, NO_2^- , $NH_3^+NH_4^+$, Organic N, and TKN (Regional Study)

Sample	Sample Type	Date	NO_3^-	NO_2^-	$NH_3^+NH_4^+$	Organic N	TKN
			mg/L_as_N	mg/L_as_N	mg/L_as_N	mg/L_as_N	mg/L_as_N
07-AG-005	*RS	21-Jun-07	0.084	<0.033	0.21	0.03	0.24
07-AG-006	RS	21-Jun-07	0.087	<0.033	0.53	0.28	0.81
07-AG-008	RS	21-Jun-07	0.091	0.103	0.16	<0.01	0.15
07-AG-011	RS	23-Jun-07	0.084	<0.008	0.15	0	0.15
07-AG-014	RS	23-Jun-07	0.095	<0.008	0.11	0	0.11
07-AG-016	RS	23-Jun-07	0.96	<0.008	0.11	0	0.11
07-AG-020	RS	24-Jun-07	<0.008	<0.008	0.11	0	0.11
07-AG-021	RS	24-Jun-07	<0.008	<0.008	0.12	0	0.12
07-AG-025	RS	26-Jun-07	0.09	0.107	0.26	0	0.26
07-AG-026	**†BW09**	**26-Jun-07**	**1.161**	**<0.003**	**<0.01**	**<0.05**	**<0.05**
07-AG-029	RS	26-Jun-07	0.09	0.107	0.19	0	0.19
07-AG-030	RS	26-Jun-07	0.09	<0.08	0.26	0	0.26
07-AG-032	RS	26-Jun-07	0.09	<0.08	0.23	0	0.23
07-AG-036	RS	27-Jun-07	0.088	0.106	0.33	0	0.33
07-AG-038	RS	27-Jun-07	0.092	<0.033	0.24	0.03	0.27
07-AG-040	RS	28-Jun-07	<0.1	<0.1	0.11	0.06	0.17
07-AG-049	RS	29-Jun-07	<0.1	<0.1	0.24	0	0.24
07-AG-050	RS	04-Jul-07	0.087	<0.008	0.16	0.01	0.17
07-AG-056	RS	07-Jul-07	0.085	<0.008	0.16	0.01	0.17
07-AG-092	RS	12-Jul-07	0.084	<0.008	0.11	0.02	0.13
07-AG-094	RS	12-Jul-07	0.027	<0.003	0.54	0.07	0.61
07-AG-109	RS	18-Jul-07	<0.1	<0.1	0.14	0.03	0.17
07-AG-125	RS	18-Jul-07	<0.1	<0.1	0.1	0.03	0.13
07-AG-145	RS	24-Jul-07	<0.1	<0.1	0.24	<0.01	0.23
07-AG-152	RS	24-Jul-07	<0.1	<0.1	0.17	0.06	0.23
07-AG-155	RS	26-Jul-07	<0.08	<0.08	0.16	0.01	0.17
07-AG-214	RS	05-Aug-07	<0.08	<0.08	0.19	0.01	0.2
08-AG-001	RS	13-May-08	<0.013	<0.005	0.22	0.26	0.48
08-AG-004	RS	13-May-08	<0.013	<0.005	0.39	0.05	0.44
08-AG-005	RS	13-May-08	6.6	<0.005	0.09	0.11	0.2
08-AG-007	‡RSBWZ	15-May-08	<0.013	<0.005	0.23	0.05	0.28
08-AG-010	**BW01**	**15-May-08**	**1.64**	**<0.005**	**<0.04**	**<0.05**	**0.14**
08-AG-012	**BW11**	**15-May-08**	**<0.013**	**<0.005**	**<0.04**	**<0.05**	**0.07**
08-AG-013	RSBWZ	15-May-08	<0.013	<0.005	<0.04	<0.05	0.13
08-AG-015	RSBWZ	15-May-08	0.207	<0.005	<0.04	<0.05	0.08
08-AG-017	RS	16-May-08	<0.013	<0.005	0.06	0.31	0.37
08-AG-020	RSBWZ	15-May-08	0.025	<0.005	0.24	0.09	0.33
08-AG-021	**BW10**	**16-May-08**	**0.044**	**<0.005**	**0.08**	**0.29**	**0.37**
08-AG-023	RS	16-May-08	<0.013	<0.005	0.13	0.25	0.38
08-AG-025	RS	16-May-08	<0.013	<0.005	0.12	0.53	0.65
08-AG-030	RS	16-May-08	<0.013	<0.005	0.12	0.4	0.52
08-AG-031	RS	16-May-08	<0.013	<0.005	<0.04	<0.05	0.27
08-AG-043	RS	20-May-08	<0.013	<0.005	0.19	0.12	0.31
08-AG-046	RS	20-May-08	<0.013	<0.005	0.27	0.88	1.15

Sample	Sample Type	Date	NO_3^-	NO_2^-	$NH_3^+NH_4^+$	Organic N	TKN
			mg/L_as_N	mg/L_as_N	mg/L_as_N	mg/L_as_N	mg/L_as_N
08-AG-050	RS	20-May-08	<0.013	<0.005	0.25	0.2	0.45
08-AG-053	RS	20-May-08	<0.013	<0.005	0.13	0.21	0.34
08-AG-060	RSBWZ	21-May-08	<0.013	<0.005	0.14	0.11	0.25
08-AG-062	RS	21-May-08	<0.013	<0.005	0.19	0.13	0.32
08-AG-085	RS	26-May-08	<0.013	<0.005	0.05	0.01	0.06
08-AG-086	RSBWZ	26-May-08	<0.013	<0.005	0.17	0.13	0.3
08-AG-087	**BW04**	**26-May-08**	**1.87**	**<0.005**	**<0.04**	**<0.05**	**<0.05**
08-AG-100	RSBWZ	26-May-08	<0.013	<0.005	0.08	0.1	0.18
08-AG-102	RS	27-May-08	<0.013	<0.005	0.04	0.03	0.07
08-AG-103	RS	27-May-08	<0.013	<0.005	0.1	0.02	0.12
08-AG-105	**BW08**	**27-May-08**	**<0.013**	**<0.005**	**0.09**	**0.2**	**0.29**
08-AG-106	RS	28-May-08	<0.013	<0.005	0.06	0.05	0.11
08-AG-107	RS	28-May-08	<0.013	<0.005	0.07	0.12	0.19
08-AG-108	RS	28-May-08	<0.013	<0.005	0.18	0.19	0.37
08-AG-120	RS	28-May-08	1.78	<0.005	<0.04	<0.05	<0.05
08-AG-121	RS	28-May-08	<0.013	<0.005	0.09	0.03	0.12
08-AG-122	RS	28-May-08	<0.013	<0.005	0.22	0.14	0.36
08-AG-153	RS	09-Jun-08	<0.013	<0.005	0.52	0.17	0.69
08-AG-157	RS	09-Jun-08	<0.013	<0.005	0.19	0.03	0.22
08-AG-162	RS	09-Jun-08	<0.013	<0.005	0.25	0.1	0.35
08-AG-164	RS	09-Jun-08	0.425	<0.005	0.21	<0.02	0.19
08-AG-165	RS	09-Jun-08	<0.013	<0.005	0.3	0.13	0.43
08-AG-167	**BW02**	**11-Jun-08**	**<0.013**	**<0.005**	**0.06**	**0**	**0.06**
08-AG-181	RSBWZ	11-Jun-08	0.244	0.017	0.05	0.09	0.14
08-AG-183	**BW03**	**11-Jun-08**	**<0.013**	**<0.005**	**<0.04**	**<0.05**	**0.08**
08-AG-188	RS	18-Jun-08	<0.013	<0.005	0.12	0	0.12
08-AG-190	RSBWZ	17-Jun-08	<0.013	<0.005	0.2	0.09	0.29
08-AG-193	RS	17-Jun-08	<0.013	<0.005	0.14	0.13	0.27
08-AG-194	RS	18-Jun-08	<0.013	<0.005	0.31	0.09	0.4
08-AG-197	RS	19-Jun-08	<0.013	<0.005	0.28	<0.01	0.27
08-AG-202	RS	19-Jun-08	<0.013	<0.005	0.18	0.03	0.21
08-AG-203	RS	19-Jun-08	<0.013	<0.005	0.24	0.07	0.31
08-AG-205	RS	20-Jun-08	<0.013	<0.005	0.3	0.18	0.48
08-AG-206	RS	20-Jun-08	<0.013	<0.005	0.37	0.07	0.44
08-AG-207	RS	20-Jun-08	1.2	0.017	0.08	0.03	0.11
08-AG-208	RS	20-Jun-08	<0.013	<0.005	0.13	0.06	0.19
08-AG-211	**BW05**	**19-Jun-08**	**<0.013**	**<0.005**	**0.1**	**0.04**	**0.14**
08-AG-214	RS	19-Jun-08	<0.013	<0.005	0.22	0.05	0.27
08-AG-215	RS	22-Jun-08	<0.013	<0.005	0.12	0.1	0.22
08-AG-217	RSBWZ	22-Jun-08	<0.013	<0.005	0.1	0.11	0.21
08-AG-223	BW06	23-Jun-08	0.39	<0.005	0.04	0.1	0.14
08-AG-225	RS	23-Jun-08	<0.013	<0.005	0.19	0.15	0.34
08-AG-227	RS	23-Jun-08	<0.013	<0.005	0.2	0.04	0.24
08-AG-228	RS	24-Jun-08	<0.013	<0.005	0.24	0.08	0.32
08-AG-231	RS	25-Jun-08	<0.013	<0.005	0.74	0.21	0.95
08-AG-232	RSBWZ	25-Jun-08	0.023	<0.005	0.15	0.07	0.22
08-AG-237	RS	26-Jun-08	0.043	<0.005	0.23	0.13	0.36

Sample	Sample Type	Date	NO_3^-	NO_2^-	$NH_3^+NH_4^+$	Organic N	TKN
			mg/L_as_N	mg/L_as_N	mg/L_as_N	mg/L_as_N	mg/L_as_N
08-AG-242	RS	26-Jun-08	<0.013	<0.005	0.1	<0.02	0.08
08-AG-243	RS	26-Jun-08	3.38	0.059	0.05	0.09	0.14
08-AG-246	RS	30-Jun-08	<0.013	<0.005	0.15	0.18	0.33
08-AG-247	RS	30-Jun-08	<0.013	<0.005	0.12	0.07	0.19
08-AG-248	RS	30-Jun-08	<0.013	<0.005	0.09	0.2	0.29
08-AG-250	RS	30-Jun-08	<0.013	<0.005	0.11	0.08	0.19
08-AG-251	RS	02-Jul-08	<0.013	<0.005	0.14	0.04	0.18
08-AG-252	RS	02-Jul-08	1.36	<0.005	0.07	0.14	0.21
08-AG-253	RS	02-Jul-08	0.862	<0.005	0.08	0.11	0.19
08-AG-254	RS	02-Jul-08	<0.013	<0.005	0.38	0.11	0.49
08-AG-255	RS	03-Jul-08	<0.013	<0.005	0.28	0.03	0.31

* RS = Stations sampled as part of the regional study. †Stations in bold and numbered BW01-BW11 wells that were sampled as part of the local study. ‡RSBWZ – Regional wells located in the BWZ. "-" symbolizes parameter not measured. "<" symbolizes parameter is below detection limit.

Appendix H. Compositional Ratios (Regional Study)

Sample	Sample Type	Date	Sr/Ca	Mg/Ca	Na/Cl	Cl/Br
			ratio	ratio	ratio	ratio
07-AG-005	*RS	21-Jun-07	0.03	0.56	0.51	-
07-AG-006	RS	21-Jun-07	0.04	0.51	6.7	-
07-AG-008	RS	21-Jun-07	0.12	0.33	14.13	-
07-AG-011	RS	23-Jun-07	0.09	0.61	2.14	-
07-AG-014	RS	23-Jun-07	0.04	0.6	6.39	-
07-AG-016	RS	23-Jun-07	0.01	0.4	1.15	-
07-AG-020	RS	24-Jun-07	0.03	0.49	7.87	-
07-AG-021	RS	24-Jun-07	0.02	0.4	2.72	-
07-AG-025	RS	26-Jun-07	0.08	0.72	30.48	-
07-AG-026	**†BW09**	**26-Jun-07**	0.03	0.28	1.7	-
07-AG-029	RS	26-Jun-07	0.9	0.57	34.15	-
07-AG-030	RS	26-Jun-07	0.05	0.54	10.94	-
07-AG-032	RS	26-Jun-07	0.07	0.55	36.74	-
07-AG-036	RS	27-Jun-07	0.02	0.49	15.44	-
07-AG-038	RS	27-Jun-07	0.1	0.88	25.66	-
07-AG-040	RS	28-Jun-07	0.05	0.79	30.45	-
07-AG-049	RS	29-Jun-07	0.1	0.71	27.53	-
07-AG-050	RS	04-Jul-07	0.08	0.94	12.31	30.71
07-AG-056	RS	07-Jul-07	0.1	0.69	4.1	-
07-AG-092	RS	12-Jul-07	0.02	0.35	4.45	106.86
07-AG-094	RS	12-Jul-07	0.05	0.59	0.78	200.33
07-AG-109	RS	18-Jul-07	0.05	0.68	31.76	-
07-AG-125	RS	18-Jul-07	0.2	0.37	24.08	-
07-AG-145	RS	24-Jul-07	0.19	0.95	33.21	-
07-AG-152	RS	24-Jul-07	0.04	0.56	4.67	272.92
07-AG-155	RS	26-Jul-07	0.08	0.87	24.89	-
07-AG-214	RS	05-Aug-07	0.07	0.8	29.17	-
08-AG-001	RS	13-May-08	0.08	0.47	11.03	26.53
08-AG-004	RS	13-May-08	0.06	0.55	1.22	290.64
08-AG-005	RS	13-May-08	0.02	0.09	2.77	-
08-AG-007	‡RSBWZ	15-May-08	0.09	0.73	67.38	-
08-AG-010	**BW01**	**15-May-08**	0.07	0.26	2.17	-
08-AG-012	**BW11**	**15-May-08**	0.08	0.5	3.08	-
08-AG-013	RSBWZ	15-May-08	1.06	0.5	2.21	-
08-AG-015	RSBWZ	15-May-08	0.68	0.35	21.28	-
08-AG-017	RS	16-May-08	0.02	0.38	8.61	-
08-AG-020	RSBWZ	15-May-08	0.54	0.33	42.68	-
08-AG-021	**BW10**	**16-May-08**	0.35	0.32	16.97	-
08-AG-023	RS	16-May-08	0.1	0.38	2.38	-
08-AG-025	RS	16-May-08	0.16	0.64	54.36	-
08-AG-030	RS	16-May-08	0.03	0.4	40.39	-
08-AG-031	RS	16-May-08	0.06	0.35	43.18	-
08-AG-043	RS	20-May-08	0.14	0.53	44.64	-
08-AG-046	RS	20-May-08	0.02	0.42	33.21	-
08-AG-050	RS	20-May-08	0.61	0.49	10.97	-

Sample	Sample Type	Date	Sr/Ca	Mg/Ca	Na/Cl	Cl/Br
			ratio	ratio	ratio	ratio
08-AG-053	RS	20-May-08	0.03	0.33	35.65	-
08-AG-060	RSBWZ	21-May-08	0.44	0.21	1.09	-
08-AG-062	RS	21-May-08	0.02	0.4	39.7	-
08-AG-085	RS	26-May-08	0.67	0.42	3.74	-
08-AG-086	RSBWZ	26-May-08	0.05	0.67	22.96	-
08-AG-087	**BW04**	**26-May-08**	0.16	0.24	0.72	-
08-AG-100	RSBWZ	26-May-08	0.1	0.37	13.66	-
08-AG-102	RS	27-May-08	0	0.43	0.43	-
08-AG-103	RS	27-May-08	1.23	0.55	21.06	-
08-AG-105	**BW08**	**27-May-08**	0.08	0.21	1.47	-
08-AG-106	RS	28-May-08	1.68	0.6	21.69	-
08-AG-107	RS	28-May-08	0.17	0.56	9.61	-
08-AG-108	RS	28-May-08	0.02	0.42	25.79	-
08-AG-120	RS	28-May-08	0	0.29	0.68	-
08-AG-121	RS	28-May-08	1.8	0.71	1.56	-
08-AG-122	RS	28-May-08	0.82	0.48	33.83	-
08-AG-153	RS	09-Jun-08	0.23	0.45	47.47	3.95
08-AG-157	RS	09-Jun-08	0.01	0.37	6.56	-
08-AG-162	RS	09-Jun-08	0.17	0.68	79.28	-
08-AG-164	RS	09-Jun-08	0.06	0.4	5.8	-
08-AG-165	RS	09-Jun-08	0.03	0.24	5.09	29.69
08-AG-167	**BW02**	**11-Jun-08**	0.17	0.31	2.27	-
08-AG-181	RSBWZ	11-Jun-08	0.3	0.41	2.05	43.69
08-AG-183	**BW03**	**11-Jun-08**	1.12	0.33	15.44	-
08-AG-188	RS	18-Jun-08	0.04	0.41	5.78	-
08-AG-190	RSBWZ	17-Jun-08	0.11	0.54	31.86	18.5
08-AG-193	RS	17-Jun-08	0.06	0.4	16.03	29.88
08-AG-194	RS	18-Jun-08	0.1	0.49	4.81	34.16
08-AG-197	RS	19-Jun-08	1.47	0.49	43.1	-
08-AG-202	RS	19-Jun-08	0.06	0.38	25.03	-
08-AG-203	RS	19-Jun-08	0.02	0.43	25.69	-
08-AG-205	RS	20-Jun-08	0.1	0.44	45.99	-
08-AG-206	RS	20-Jun-08	0.04	0.16	15.31	9
08-AG-207	RS	20-Jun-08	0.24	0.27	0.51	-
08-AG-208	RS	20-Jun-08	1.04	0.44	15.05	-
08-AG-211	**BW05**	**19-Jun-08**	0.49	0.35	0.85	-
08-AG-214	RS	19-Jun-08	0.65	0.56	59.91	-
08-AG-215	RS	22-Jun-08	0.04	0.17	1.29	286.21
08-AG-217	RSBWZ	22-Jun-08	0.05	0.2	0.92	-
08-AG-223	BW06	23-Jun-08	0.48	0.34	0.52	-
08-AG-225	RS	23-Jun-08	0.07	0.57	23.58	-
08-AG-227	RS	23-Jun-08	0.22	0.7	61.09	-
08-AG-228	RS	24-Jun-08	0.04	0.4	42.07	-
08-AG-231	RS	25-Jun-08	0.01	0.31	3.65	-
08-AG-232	RSBWZ	25-Jun-08	0	0.25	0.49	-
08-AG-237	RS	26-Jun-08	0.03	0.38	1.64	596.93
08-AG-242	RS	26-Jun-08	0.04	0.39	19.2	-

Sample	Sample Type	Date	Sr/Ca	Mg/Ca	Na/Cl	Cl/Br
			ratio	ratio	ratio	ratio
08-AG-243	RS	26-Jun-08	0.01	0.38	0.42	-
08-AG-246	RS	30-Jun-08	0.1	0.43	11.82	-
08-AG-247	RS	30-Jun-08	0.03	0.4	4.44	-
08-AG-248	RS	30-Jun-08	0.01	0.51	1.19	-
08-AG-250	RS	30-Jun-08	0.06	0.57	14.44	-
08-AG-251	RS	02-Jul-08	0.06	0.46	4.05	-
08-AG-252	RS	02-Jul-08	0.14	0.35	0.44	-
08-AG-253	RS	02-Jul-08	0.05	0.48	1.12	-
08-AG-254	RS	02-Jul-08	0.07	0.51	8.18	-
08-AG-255	RS	03-Jul-08	0.04	0.42	1.4	563.24

* RS = Stations sampled as part of the regional study. †Stations in bold and numbered BW01-BW11 wells that were sampled as part of the local study. ‡RSBWZ – Regional wells located in the BWZ. "-" symbolizes parameter not measured. “<” symbolizes parameter is below detection limit.

Appendix I. Trace Constituents: Ag, Al, As, B, Ba, Be (Regional Study)

Sample	Sample Type	Date	Ag	Al	As	B	Ba	Be
			µg/L	µg/L	µg/L	mg/L	µg/L	µg/L
07-AG-005	*RS	21-Jun-07	<0.005	5	10.28	0.13	57.4	<0.01
07-AG-006	RS	21-Jun-07	0.021	8	21.12	0.08	134.6	<0.01
07-AG-008	RS	21-Jun-07	0.015	13	0.08	0.07	23.16	<0.01
07-AG-011	RS	23-Jun-07	**0.006**	<5	0.08	0.23	21.06	<0.01
07-AG-014	RS	23-Jun-07	<0.005	<5	0.56	0.16	71.1	<0.01
07-AG-016	RS	23-Jun-07	<0.005	36	2.03	0.08	35.2	<0.01
07-AG-020	RS	24-Jun-07	<0.005	16	3.57	0.04	199.2	<0.01
07-AG-021	RS	24-Jun-07	<0.005	6	1.76	0.03	112.6	<0.01
07-AG-025	RS	26-Jun-07	<0.005	9	0.08	0.47	3351	<0.01
07-AG-026	**†BW09**	**26-Jun-07**	<0.005	**23**	**0.19**	**0.1**	**89.5**	**<0.01**
07-AG-029	RS	26-Jun-07	0.02	<5	0.05	0.13	55.6	<0.01
07-AG-030	RS	26-Jun-07	<0.005	5	<0.03	0.14	140.5	<0.01
07-AG-032	RS	26-Jun-07	<0.005	7	0.73	0.2	564	<0.01
07-AG-036	RS	27-Jun-07	<0.005	<5	0.66	0.07	95.7	<0.01
07-AG-038	RS	27-Jun-07	<0.005	<5	6.19	0.16	40.7	<0.01
07-AG-040	RS	28-Jun-07	<0.005	<5	0.45	0.13	112.5	<0.01
07-AG-049	RS	29-Jun-07	<0.005	<5	0.14	0.41	526	<0.01
07-AG-050	RS	04-Jul-07	<0.005	<5	2.83	0.54	57	<0.01
07-AG-056	RS	07-Jul-07	<0.005	<5	0.05	0.29	64.5	<0.01
07-AG-092	RS	12-Jul-07	<0.005	<5	0.11	1.13	32.6	<0.01
07-AG-094	RS	12-Jul-07	<0.005	<5	0.64	1.77	540	<0.01
07-AG-109	RS	18-Jul-07	<0.005	<5	1.37	0.15	108.4	<0.01
07-AG-125	RS	18-Jul-07	0.016	6	0.28	0.04	74.8	<0.01
07-AG-145	RS	24-Jul-07	<0.005	5	0.04	0.13	43.7	<0.01
07-AG-152	RS	24-Jul-07	<0.005	<5	0.18	2.29	113.9	<0.01
07-AG-155	RS	26-Jul-07	<0.005	<5	0.15	0.19	24.67	<0.01
07-AG-214	RS	05-Aug-07	<0.005	<5	0.04	0.06	74.3	<0.01
08-AG-001	RS	13-May-08	<0.005	<5	0.05	0.47	13.2	<0.01
08-AG-004	RS	13-May-08	0.009	<5	0.57	1.27	37.5	0.02
08-AG-005	RS	13-May-08	<0.005	<5	0.64	0.21	70.1	<0.01
08-AG-007	‡RSBWZ	15-May-08	<0.005	<5	0.09	0.13	35.3	<0.01
08-AG-010	**BW01**	**15-May-08**	**0.008**	**<5**	**0.16**	**0.05**	**43.8**	**<0.01**
08-AG-012	**BW11**	**15-May-08**	**0.01**	**<5**	**0.17**	**0.15**	**8.69**	**<0.01**
08-AG-013	RSBWZ	15-May-08	0.032	<5	0.58	0.02	41.3	<0.01
08-AG-015	RSBWZ	15-May-08	0.026	<5	1.02	0.06	196	<0.01
08-AG-017	RS	16-May-08	<0.005	<5	0.42	0.04	92.7	<0.01
08-AG-020	RSBWZ	15-May-08	0.019	<5	3.83	0.04	218	<0.01
08-AG-021	**BW10**	**16-May-08**	**0.021**	**<5**	**0.06**	**0.03**	**57.5**	**<0.01**
08-AG-023	RS	16-May-08	0.005	<5	5.28	0.06	73.9	<0.01
08-AG-025	RS	16-May-08	<0.005	<5	7.56	0.15	167	<0.01
08-AG-030	RS	16-May-08	<0.005	<5	5.54	0.12	62.2	<0.01
08-AG-031	RS	16-May-08	<0.005	<5	5.81	0.05	84.1	<0.01
08-AG-043	RS	20-May-08	<0.005	<5	6.75	0.15	108	<0.01
08-AG-046	RS	20-May-08	<0.005	<5	4.39	0.08	58.85	<0.01
08-AG-050	RS	20-May-08	0.012	<5	2.72	0.05	129	<0.01
08-AG-053	RS	20-May-08	<0.005	<5	2.03	0.03	108	<0.01
08-AG-060	RSBWZ	21-May-08	0.021	5	1.94	0.01	226	<0.01

Sample	Sample Type	Date	Ag	Al	As	B	Ba	Be
			µg/L	µg/L	µg/L	mg/L	µg/L	µg/L
08-AG-062	RS	21-May-08	<0.005	<5	3.72	0.06	94.6	<0.01
08-AG-085	RS	26-May-08	0.022	<5	1.66	0.08	80.7	<0.01
08-AG-086	RSBWZ	26-May-08	<0.005	<5	21	0.05	86.3	<0.01
08-AG-087	**BW04**	**26-May-08**	**0.008**	**<5**	**0.13**	**0.01**	**267**	**<0.01**
08-AG-100	RSBWZ	26-May-08	<0.005	<5	7.46	0.13	97.1	<0.01
08-AG-102	RS	27-May-08	<0.005	<5	3.69	0.02	70.2	<0.01
08-AG-103	RS	27-May-08	0.028	<5	0.13	0.06	63.5	<0.01
08-AG-105	**BW08**	**27-May-08**	**0.01**	**<5**	**3.7**	**0.14**	**24.9**	**<0.01**
08-AG-106	RS	28-May-08	0.029	<5	0.76	0.1	46	<0.01
08-AG-107	RS	28-May-08	0.007	<5	8.92	0.05	110	<0.01
08-AG-108	RS	28-May-08	<0.005	<5	2.43	0.02	226	<0.01
08-AG-120	RS	28-May-08	0.014	<5	0.82	0.01	41.2	<0.01
08-AG-121	RS	28-May-08	0.033	<5	7.55	0.01	86.5	<0.01
08-AG-122	RS	28-May-08	0.019	<5	0.11	0.03	745	<0.01
08-AG-153	RS	09-Jun-08	0.005	<5	0.54	0.1	263	<0.01
08-AG-157	RS	09-Jun-08	<0.005	<5	5.04	0.03	63.5	<0.01
08-AG-162	RS	09-Jun-08	<0.005	<5	2.91	0.15	62	<0.01
08-AG-164	RS	09-Jun-08	<0.005	<5	0.47	0.08	38.7	<0.01
08-AG-165	RS	09-Jun-08	0.008	<5	0.11	0.07	4.83	<0.01
08-AG-167	**BW02**	**11-Jun-08**	**0.012**	**<5**	**0.19**	**0.07**	**82.3**	**<0.01**
08-AG-181	RSBWZ	11-Jun-08	0.016	<5	0.19	0.12	54.3	<0.01
08-AG-183	**BW03**	**11-Jun-08**	**0.032**	**<5**	**1.82**	**0.02**	**152**	**<0.01**
08-AG-188	RS	18-Jun-08	<0.005	<5	0.08	1.84	12.65	0.01
08-AG-190	RSBWZ	17-Jun-08	<0.005	<5	0.63	0.53	41.8	<0.01
08-AG-193	RS	17-Jun-08	<0.005	<5	0.11	0.47	10.3	<0.01
08-AG-194	RS	18-Jun-08	0.009	<5	0.09	1.04	10.4	0.01
08-AG-197	RS	19-Jun-08	0.028	<5	8.71	0.05	128	<0.01
08-AG-202	RS	19-Jun-08	0.005	<5	0.1	0.06	61.7	<0.01
08-AG-203	RS	19-Jun-08	<0.005	<5	9.4	0.1	58.3	<0.01
08-AG-205	RS	20-Jun-08	<0.005	<5	1.65	0.14	119	<0.01
08-AG-206	RS	20-Jun-08	<0.005	13	3.95	0.11	10.9	0.01
08-AG-207	RS	20-Jun-08	0.015	<5	0.2	0.03	235	<0.01
08-AG-208	RS	20-Jun-08	0.026	<5	2.42	0.05	105	<0.01
08-AG-211	**BW05**	**19-Jun-08**	**0.029**	**<5**	**4.82**	**0.08**	**111**	**<0.01**
08-AG-214	RS	19-Jun-08	0.013	<5	2.55	0.08	213	<0.01
08-AG-215	RS	22-Jun-08	0.009	<5	4.99	0.17	11.3	<0.01
08-AG-217	RSBWZ	22-Jun-08	0.012	<5	0.64	0.09	8.14	<0.01
08-AG-223	BW06	23-Jun-08	0.027	<5	0.32	0.01	113	<0.01
08-AG-225	RS	23-Jun-08	<0.005	<5	0.54	0.24	71.5	<0.01
08-AG-227	RS	23-Jun-08	<0.005	<5	0.64	0.15	224.5	<0.01
08-AG-228	RS	24-Jun-08	<0.005	<5	6.95	0.13	62.9	<0.01
08-AG-231	RS	25-Jun-08	<0.005	<5	2.29	0.03	158	<0.01
08-AG-232	RSBWZ	25-Jun-08	<0.005	<5	1.45	0.02	263	<0.01
08-AG-237	RS	26-Jun-08	<0.005	<5	0.21	1.05	14.1	0.01
08-AG-242	RS	26-Jun-08	<0.005	<5	0.1	0.05	43.5	<0.01
08-AG-243	RS	26-Jun-08	<0.005	<5	1.11	0.02	22.7	<0.01
08-AG-246	RS	30-Jun-08	<0.005	<5	10.1	0.03	38.2	<0.01
08-AG-247	RS	30-Jun-08	<0.005	<5	9.84	0.04	77.4	<0.01
08-AG-248	RS	30-Jun-08	<0.005	<5	6.16	0.02	47.2	<0.01

Sample	Sample Type	Date	Ag	Al	As	B	Ba	Be
			µg/L	µg/L	µg/L	mg/L	µg/L	µg/L
08-AG-250	RS	30-Jun-08	<0.005	<5	6.94	0.04	63.4	<0.01
08-AG-251	RS	02-Jul-08	<0.005	<5	1.96	0.03	52.9	<0.01
08-AG-252	RS	02-Jul-08	0.008	<5	0.65	0.01	177	<0.01
08-AG-253	RS	02-Jul-08	<0.005	<5	0.32	0.03	73.6	<0.01
08-AG-254	RS	02-Jul-08	<0.005	<5	1.01	0.06	152	<0.01
08-AG-255	RS	03-Jul-08	<0.005	<5	0.25	1.48	23.5	0.03

* RS = Stations sampled as part of the regional study. †Stations in bold and numbered BW01-BW11 wells that were sampled as part of the local study. ‡RSBWZ – Regional wells located in the BWZ. "-" symbolizes parameter not measured. "<" symbolizes parameter is below detection limit.

Appendix J. Trace Constituents: Bi, Cd, Ce, Co, Cr (Regional Study)

Sample	Sample Type	Date	Bi	Cd	Ce	Co	Cr
			µg/L	µg/L	µg/L	µg/L	µg/L
07-AG-005	*RS	21-Jun-07	<0.05	0.02	<0.002	<0.005	0.04
07-AG-006	RS	21-Jun-07	<0.05	0.52	0.014	0.094	0.17
07-AG-008	RS	21-Jun-07	<0.05	0.03	<0.002	0.033	0.04
07-AG-011	RS	23-Jun-07	<0.05	0.03	<0.002	0.016	0.03
07-AG-014	RS	23-Jun-07	<0.05	0.01	<0.002	0.01	<0.02
07-AG-016	RS	23-Jun-07	<0.05	0.03	0.11	0.038	0.13
07-AG-020	RS	24-Jun-07	<0.05	<0.01	<0.002	<0.005	<0.02
07-AG-021	RS	24-Jun-07	<0.05	<0.01	<0.002	<0.005	0.02
07-AG-025	RS	26-Jun-07	<0.05	<0.01	0.002	0.021	<0.02
07-AG-026	**†BW09**	**26-Jun-07**	**<0.05**	**0.05**	**<0.002**	**0.042**	**0.04**
07-AG-029	RS	26-Jun-07	<0.05	0.05	<0.002	0.021	<0.02
07-AG-030	RS	26-Jun-07	<0.05	0.01	<0.002	0.021	<0.02
07-AG-032	RS	26-Jun-07	<0.05	0.07	<0.002	0.038	0.02
07-AG-036	RS	27-Jun-07	<0.05	0.01	0.002	0.02	<0.02
07-AG-038	RS	27-Jun-07	<0.05	0.03	<0.002	0.035	0.04
07-AG-040	RS	28-Jun-07	<0.05	0.02	<0.002	0.016	<0.02
07-AG-049	RS	29-Jun-07	<0.05	0.02	<0.002	0.036	<0.02
07-AG-050	RS	04-Jul-07	<0.05	0.1	<0.002	0.047	<0.02
07-AG-056	RS	07-Jul-07	<0.05	<0.01	<0.002	0.033	0.02
07-AG-092	RS	12-Jul-07	<0.05	<0.01	0.003	0.012	<0.02
07-AG-094	RS	12-Jul-07	<0.05	<0.01	<0.002	0.022	0.04
07-AG-109	RS	18-Jul-07	<0.05	<0.01	<0.002	0.013	<0.02
07-AG-125	RS	18-Jul-07	<0.05	<0.01	<0.002	<0.005	<0.02
07-AG-145	RS	24-Jul-07	<0.05	<0.01	0.003	0.026	<0.02
07-AG-152	RS	24-Jul-07	<0.05	<0.01	<0.002	0.125	0.07
07-AG-155	RS	26-Jul-07	<0.05	0.02	<0.002	0.069	<0.02
07-AG-214	RS	05-Aug-07	<0.05	<0.01	<0.002	<0.005	<0.02
08-AG-001	RS	13-May-08	0.03	<0.01	0.003	0.186	<0.02
08-AG-004	RS	13-May-08	0.02	0.02	<0.002	0.026	<0.02
08-AG-005	RS	13-May-08	0	<0.01	0.002	0.017	0.06
08-AG-007	‡RSBWZ	15-May-08	<0.002	0.01	<0.002	<0.005	<0.02
08-AG-010	**BW01**	**15-May-08**	**0**	**0.05**	**<0.002**	**<0.005**	**0.05**
08-AG-012	**BW11**	**15-May-08**	**0.01**	**<0.01**	**<0.002**	**<0.005**	**<0.02**
08-AG-013	RSBWZ	15-May-08	<0.002	0.01	0.002	0.066	0.04
08-AG-015	RSBWZ	15-May-08	<0.002	0.04	<0.002	0.115	<0.02
08-AG-017	RS	16-May-08	<0.002	0.01	<0.002	<0.005	<0.02
08-AG-020	RSBWZ	15-May-08	<0.002	0.03	0.015	0.218	<0.02
08-AG-021	**BW10**	**16-May-08**	**<0.002**	**0.05**	**<0.002**	**<0.005**	**<0.02**
08-AG-023	RS	16-May-08	<0.002	0.01	0.003	0.025	<0.02
08-AG-025	RS	16-May-08	<0.002	0.03	<0.002	0.031	<0.02
08-AG-030	RS	16-May-08	<0.002	0.06	0.002	0.033	<0.02
08-AG-031	RS	16-May-08	0	<0.01	<0.002	<0.005	<0.02
08-AG-043	RS	20-May-08	<0.002	0.03	<0.002	0.046	<0.02
08-AG-046	RS	20-May-08	0	0.05	<0.002	0.019	<0.02
08-AG-050	RS	20-May-08	<0.002	0.01	<0.002	<0.005	<0.02
08-AG-053	RS	20-May-08	<0.002	<0.01	<0.002	<0.005	<0.02
08-AG-060	RSBWZ	21-May-08	<0.002	0.02	<0.002	0.289	0.08

Sample	Sample Type	Date	Bi	Cd	Ce	Co	Cr
			µg/L	µg/L	µg/L	µg/L	µg/L
08-AG-062	RS	21-May-08	<0.002	0.02	<0.002	0.028	<0.02
08-AG-085	RS	26-May-08	0	0.02	<0.002	<0.005	<0.02
08-AG-086	RSBWZ	26-May-08	<0.002	<0.01	<0.002	<0.005	<0.02
08-AG-087	**BW04**	**26-May-08**	**0**	**0.03**	**0.002**	**<0.005**	**0.07**
08-AG-100	RSBWZ	26-May-08	<0.002	0.03	<0.002	0.014	<0.02
08-AG-102	RS	27-May-08	<0.002	<0.01	<0.002	0.04	0.07
08-AG-103	RS	27-May-08	<0.002	0.01	<0.002	<0.005	0.02
08-AG-105	**BW08**	**27-May-08**	**0**	**0.02**	**<0.002**	**<0.005**	**<0.02**
08-AG-106	RS	28-May-08	<0.002	0.03	<0.002	0.033	<0.02
08-AG-107	RS	28-May-08	<0.002	<0.01	<0.002	<0.005	<0.02
08-AG-108	RS	28-May-08	<0.002	<0.01	<0.002	<0.005	<0.02
08-AG-120	RS	28-May-08	0	0.05	<0.002	<0.005	0.25
08-AG-121	RS	28-May-08	<0.002	<0.01	<0.002	0.008	<0.02
08-AG-122	RS	28-May-08	<0.002	<0.01	<0.002	<0.005	0.02
08-AG-153	RS	09-Jun-08	0	0.01	<0.002	<0.005	<0.02
08-AG-157	RS	09-Jun-08	<0.0003	<0.01	0.002	<0.005	<0.02
08-AG-162	RS	09-Jun-08	<0.0003	0.02	<0.002	0.041	0.04
08-AG-164	RS	09-Jun-08	0	0.02	<0.002	<0.005	<0.02
08-AG-165	RS	09-Jun-08	0	<0.01	<0.002	<0.005	0.04
08-AG-167	**BW02**	**11-Jun-08**	**0**	**<0.01**	**<0.002**	**<0.005**	**<0.02**
08-AG-181	RSBWZ	11-Jun-08	<0.0002	0.03	0.005	<0.005	<0.02
08-AG-183	**BW03**	**11-Jun-08**	**<0.0002**	**<0.01**	**<0.002**	**0.093**	**<0.02**
08-AG-188	RS	18-Jun-08	<0.002	0.01	<0.002	0.018	<0.02
08-AG-190	RSBWZ	17-Jun-08	<0.002	0.14	<0.002	0.07	<0.02
08-AG-193	RS	17-Jun-08	<0.002	0.04	<0.002	0.146	<0.02
08-AG-194	RS	18-Jun-08	<0.002	<0.01	<0.002	0.264	<0.02
08-AG-197	RS	19-Jun-08	<0.002	0.02	<0.002	0.033	<0.02
08-AG-202	RS	19-Jun-08	<0.002	<0.01	0.009	0.058	<0.02
08-AG-203	RS	19-Jun-08	<0.002	0.02	0.003	0.108	<0.02
08-AG-205	RS	20-Jun-08	<0.002	<0.01	<0.002	0.021	<0.02
08-AG-206	RS	20-Jun-08	<0.002	0.01	0.015	0.193	<0.02
08-AG-207	RS	20-Jun-08	<0.002	0.03	<0.002	0.122	<0.02
08-AG-208	RS	20-Jun-08	<0.002	0.02	0.003	0.026	<0.02
08-AG-211	**BW05**	**19-Jun-08**	**<0.002**	**0.02**	**<0.002**	**0.064**	**0.05**
08-AG-214	RS	19-Jun-08	<0.002	0.02	<0.002	0.014	0.02
08-AG-215	RS	22-Jun-08	<0.002	0.04	0.003	<0.005	<0.02
08-AG-217	RSBWZ	22-Jun-08	<0.002	0.02	0.003	<0.005	<0.02
08-AG-223	BW06	23-Jun-08	<0.002	0.05	<0.002	<0.005	<0.02
08-AG-225	RS	23-Jun-08	<0.002	0.04	<0.002	0.045	<0.02
08-AG-227	RS	23-Jun-08	<0.002	0.02	<0.002	<0.005	<0.02
08-AG-228	RS	24-Jun-08	<0.002	<0.01	0.006	0.222	0.03
08-AG-231	RS	25-Jun-08	<0.002	<0.01	0.004	<0.005	<0.02
08-AG-232	RSBWZ	25-Jun-08	<0.002	<0.01	0.004	<0.005	0.08
08-AG-237	RS	26-Jun-08	<0.002	0.15	0.05	0.024	0.02
08-AG-242	RS	26-Jun-08	<0.002	0.01	<0.002	<0.005	<0.02
08-AG-243	RS	26-Jun-08	<0.002	0.04	<0.002	0.155	<0.02
08-AG-246	RS	30-Jun-08	<0.002	0.01	<0.002	0.045	<0.02
08-AG-247	RS	30-Jun-08	<0.002	0.01	<0.002	<0.005	0.11
08-AG-248	RS	30-Jun-08	<0.002	<0.01	0.009	0.178	<0.02
08-AG-250	RS	30-Jun-08	<0.002	0.01	0.004	0.055	<0.02

Sample	Sample Type	Date	Bi	Cd	Ce	Co	Cr
			µg/L	µg/L	µg/L	µg/L	µg/L
08-AG-251	RS	02-Jul-08	<0.002	0.02	0.006	0.159	<0.02
08-AG-252	RS	02-Jul-08	<0.002	<0.01	<0.002	<0.005	0.08
08-AG-253	RS	02-Jul-08	<0.002	0.05	<0.002	0.013	<0.02
08-AG-254	RS	02-Jul-08	<0.002	0.01	0.006	0.205	<0.02
08-AG-255	RS	03-Jul-08	<0.002	0.06	<0.002	0.042	<0.02

* RS = Stations sampled as part of the regional study. †Stations in bold and numbered BW01-BW11 wells that were sampled as part of the local study. ‡RSBWZ – Regional wells located in the BWZ. "-" symbolizes parameter not measured. "<" symbolizes parameter is below detection limit.

Appendix K. Trace Constituents: Cs, Cu, Dy, Er, Eu (Regional Study)

Sample	Sample Type	Date	Cs	Cu	Dy	Er	Eu
			µg/L	µg/L	µg/L	µg/L	µg/L
07-AG-005	*RS	21-Jun-07	0.009	0.34	<0.001	<0.001	<0.0004
07-AG-006	RS	21-Jun-07	0.002	2.02	0.001	<0.001	<0.0004
07-AG-008	RS	21-Jun-07	0.005	0.59	<0.001	<0.001	<0.0004
07-AG-011	RS	23-Jun-07	0.013	**6.84**	<0.001	<0.001	<0.0004
07-AG-014	RS	23-Jun-07	0.009	0.21	<0.001	<0.001	<0.0004
07-AG-016	RS	23-Jun-07	0.004	0.75	0.015	0.007	0.0027
07-AG-020	RS	24-Jun-07	0.001	0.54	<0.001	<0.001	<0.0004
07-AG-021	RS	24-Jun-07	0.023	<0.2	<0.001	<0.001	<0.0004
07-AG-025	RS	26-Jun-07	0.015	1.44	<0.001	<0.001	<0.0004
07-AG-026	**†BW09**	**26-Jun-07**	**0.002**	6.8	**<0.001**	**<0.001**	**<0.0004**
07-AG-029	RS	26-Jun-07	0.009	<0.2	<0.001	<0.001	<0.0004
07-AG-030	RS	26-Jun-07	0.011	0.64	<0.001	<0.001	<0.0004
07-AG-032	RS	26-Jun-07	0.006	0.91	<0.001	<0.001	<0.0004
07-AG-036	RS	27-Jun-07	0.001	0.55	<0.001	<0.001	<0.0004
07-AG-038	RS	27-Jun-07	0.002	0.34	<0.001	<0.001	<0.0004
07-AG-040	RS	28-Jun-07	0.007	<0.2	<0.001	<0.001	<0.0004
07-AG-049	RS	29-Jun-07	0.006	0.43	<0.001	<0.001	<0.0004
07-AG-050	RS	04-Jul-07	0.003	<0.2	<0.001	<0.001	<0.0004
07-AG-056	RS	07-Jul-07	0.012	<0.2	<0.001	<0.001	<0.0004
07-AG-092	RS	12-Jul-07	0.004	<0.2	<0.001	0.001	0.0004
07-AG-094	RS	12-Jul-07	0.07	0.64	<0.001	<0.001	<0.0004
07-AG-109	RS	18-Jul-07	0.007	<0.2	<0.001	<0.001	<0.0004
07-AG-125	RS	18-Jul-07	0.01	0.47	<0.001	<0.001	<0.0004
07-AG-145	RS	24-Jul-07	0.001	-0.2	0.001	<0.001	<0.0004
07-AG-152	RS	24-Jul-07	0.016	<0.2	<0.001	<0.001	<0.0004
07-AG-155	RS	26-Jul-07	0.005	0.22	<0.001	<0.001	<0.0004
07-AG-214	RS	05-Aug-07	0.01	0.21	<0.001	<0.001	<0.0004
08-AG-001	RS	13-May-08	0.009	0.3	<0.001	<0.001	<0.0004
08-AG-004	RS	13-May-08	0.025	0.3	<0.001	<0.001	<0.0004
08-AG-005	RS	13-May-08	0.011	3.38	0.001	<0.001	<0.0004
08-AG-007	‡RSBWZ	15-May-08	0.005	0.2	<0.001	<0.001	<0.0004
08-AG-010	**BW01**	**15-May-08**	**0.001**	**2.81**	**<0.001**	**<0.001**	**<0.0004**
08-AG-012	**BW11**	**15-May-08**	**0.003**	**1.83**	**<0.001**	**<0.001**	**<0.0004**
08-AG-013	RSBWZ	15-May-08	0.002	0.8	<0.001	<0.001	0.0005
08-AG-015	RSBWZ	15-May-08	0.007	1.78	<0.001	<0.001	<0.0004
08-AG-017	RS	16-May-08	0.002	0.7	<0.001	<0.001	<0.0004
08-AG-020	RSBWZ	15-May-08	0.003	2.16	0.001	0.001	<0.0004
08-AG-021	**BW10**	**16-May-08**	**0.004**	**7.08**	**<0.001**	**<0.001**	**<0.0004**
08-AG-023	RS	16-May-08	0.002	4.58	<0.001	<0.001	<0.0004
08-AG-025	RS	16-May-08	0.001	0.5	<0.001	<0.001	<0.0004
08-AG-030	RS	16-May-08	0.005	0.3	<0.001	<0.001	<0.0004
08-AG-031	RS	16-May-08	0.004	0.5	<0.001	<0.001	<0.0004
08-AG-043	RS	20-May-08	0.001	<0.2	<0.001	<0.001	<0.0004
08-AG-046	RS	20-May-08	0.001	11.4	<0.001	<0.001	<0.0004
08-AG-050	RS	20-May-08	0.002	0.4	<0.001	<0.001	<0.0004
08-AG-053	RS	20-May-08	0.001	<0.2	<0.001	<0.001	<0.0004
08-AG-060	RSBWZ	21-May-08	0.007	0.5	<0.001	<0.001	<0.0004
08-AG-062	RS	21-May-08	0.005	0.2	<0.001	<0.001	<0.0004

Sample	Sample Type	Date	Cs	Cu	Dy	Er	Eu
			µg/L	µg/L	µg/L	µg/L	µg/L
08-AG-085	RS	26-May-08	0.001	0.3	<0.001	<0.001	<0.0004
08-AG-086	RSBWZ	26-May-08	0.004	0.2	<0.001	<0.001	<0.0004
08-AG-087	**BW04**	**26-May-08**	**0.002**	**1.98**	**<0.001**	**<0.001**	**<0.0004**
08-AG-100	RSBWZ	26-May-08	0.002	2.85	<0.001	<0.001	<0.0004
08-AG-102	RS	27-May-08	0.001	0.4	<0.001	<0.001	<0.0004
08-AG-103	RS	27-May-08	0.005	0.3	<0.001	<0.001	<0.0004
08-AG-105	**BW08**	**27-May-08**	**0.002**	**1.56**	**<0.001**	**<0.001**	**<0.0004**
08-AG-106	RS	28-May-08	0.002	2.07	<0.001	<0.001	<0.0004
08-AG-107	RS	28-May-08	0.003	<0.2	<0.001	<0.001	<0.0004
08-AG-108	RS	28-May-08	0.002	0.4	<0.001	<0.001	<0.0004
08-AG-120	RS	28-May-08	0.002	5.88	0.002	<0.001	<0.0004
08-AG-121	RS	28-May-08	0.004	0.2	<0.001	<0.001	<0.0004
08-AG-122	RS	28-May-08	0.005	0.5	<0.001	<0.001	<0.0004
08-AG-153	RS	09-Jun-08	0.004	0.3	<0.001	<0.001	<0.0004
08-AG-157	RS	09-Jun-08	0.001	0.3	<0.001	<0.001	<0.0004
08-AG-162	RS	09-Jun-08	0.002	<0.2	<0.001	<0.001	<0.0004
08-AG-164	RS	09-Jun-08	0.001	0.6	<0.001	<0.001	<0.0004
08-AG-165	RS	09-Jun-08	0.006	3.41	<0.001	<0.001	<0.0004
08-AG-167	**BW02**	**11-Jun-08**	**0.003**	**1.21**	**<0.001**	**<0.001**	**<0.0004**
08-AG-181	RSBWZ	11-Jun-08	0.003	2.35	<0.001	<0.001	<0.0004
08-AG-183	**BW03**	**11-Jun-08**	**0.002**	**1.7**	**<0.001**	**<0.001**	**<0.0004**
08-AG-188	RS	18-Jun-08	0.009	0.25	0.002	0.002	<0.0004
08-AG-190	RSBWZ	17-Jun-08	0.007	0.4	<0.001	<0.001	<0.0004
08-AG-193	RS	17-Jun-08	0.011	0.4	<0.001	<0.001	<0.0004
08-AG-194	RS	18-Jun-08	0.004	0.3	<0.001	<0.001	<0.0004
08-AG-197	RS	19-Jun-08	0.003	0.3	<0.001	<0.001	<0.0004
08-AG-202	RS	19-Jun-08	0.001	0.6	<0.001	<0.001	<0.0004
08-AG-203	RS	19-Jun-08	0.001	<0.2	<0.001	<0.001	<0.0004
08-AG-205	RS	20-Jun-08	0.007	0.3	<0.001	<0.001	<0.0004
08-AG-206	RS	20-Jun-08	0.001	2.54	0.001	0.001	<0.0004
08-AG-207	RS	20-Jun-08	0.004	0.6	<0.001	<0.001	<0.0004
08-AG-208	RS	20-Jun-08	0.001	0.4	<0.001	<0.001	<0.0004
08-AG-211	**BW05**	**19-Jun-08**	**0.002**	**0.8**	**<0.001**	**<0.001**	**<0.0004**
08-AG-214	RS	19-Jun-08	0.002	0.3	<0.001	<0.001	<0.0004
08-AG-215	RS	22-Jun-08	0.003	2.27	<0.001	<0.001	<0.0004
08-AG-217	RSBWZ	22-Jun-08	0.002	2.71	<0.001	<0.001	<0.0004
08-AG-223	BW06	23-Jun-08	0.004	1.53	<0.001	<0.001	<0.0004
08-AG-225	RS	23-Jun-08	0.003	0.3	<0.001	<0.001	<0.0004
08-AG-227	RS	23-Jun-08	0.004	1.61	<0.001	<0.001	<0.0004
08-AG-228	RS	24-Jun-08	0.002	0.5	<0.001	<0.001	<0.0004
08-AG-231	RS	25-Jun-08	0.003	0.5	<0.001	<0.001	<0.0004
08-AG-232	RSBWZ	25-Jun-08	0.005	0.5	0.003	0.002	<0.0004
08-AG-237	RS	26-Jun-08	0.022	5.89	<0.001	<0.001	<0.0004
08-AG-242	RS	26-Jun-08	0.001	0.2	<0.001	<0.001	<0.0004
08-AG-243	RS	26-Jun-08	0.001	2.87	<0.001	<0.001	<0.0004
08-AG-246	RS	30-Jun-08	0.002	0.2	<0.001	<0.001	<0.0004
08-AG-247	RS	30-Jun-08	0.001	0.3	<0.001	<0.001	<0.0004
08-AG-248	RS	30-Jun-08	0.001	0.4	0.001	<0.001	<0.0004
08-AG-250	RS	30-Jun-08	0.002	0.5	0.001	<0.001	<0.0004
08-AG-251	RS	02-Jul-08	0.001	0.6	0.002	0.002	<0.0004

Sample	Sample Type	Date	Cs	Cu	Dy	Er	Eu
			µg/L	µg/L	µg/L	µg/L	µg/L
08-AG-252	RS	02-Jul-08	0.003	2.11	<0.001	<0.001	<0.0004
08-AG-253	RS	02-Jul-08	0.003	0.6	<0.001	<0.001	<0.0004
08-AG-254	RS	02-Jul-08	0.005	1.02	0.002	0.001	<0.0004
08-AG-255	RS	03-Jul-08	0.022	0.4	<0.001	<0.001	<0.0004

* RS = Stations sampled as part of the regional study. †Stations in bold and numbered BW01-BW11 wells that were sampled as part of the local study. ‡RSBWZ – Regional wells located in the BWZ. "-" symbolizes parameter not measured. “<” symbolizes parameter is below detection limit.

Appendix L. Trace Constituents: Ga, Gd, Hf, Hg, Ho (Regional Study)

Sample	Sample Type	Date	Ga	Gd	Hf	Hg	Ho
			µg/L	µg/L	µg/L	ng/L	µg/L
07-AG-005	*RS	21-Jun-07	0.004	<0.001	<0.004	<1.5	<0.0001
07-AG-006	RS	21-Jun-07	0.006	0.002	<0.004	<1.5	0.0002
07-AG-008	RS	21-Jun-07	0.011	<0.001	<0.004	<1.5	<0.0001
07-AG-011	RS	23-Jun-07	0.004	<0.001	<0.004	<1.5	<0.0001
07-AG-014	RS	23-Jun-07	0.005	<0.001	<0.004	<1.5	<0.0001
07-AG-016	RS	23-Jun-07	0.017	0.016	<0.004	<1.5	0.0027
07-AG-020	RS	24-Jun-07	0.005	0.002	<0.004	<1.5	<0.0001
07-AG-021	RS	24-Jun-07	0.006	<0.001	<0.004	<1.5	<0.0001
07-AG-025	RS	26-Jun-07	0.008	0.029	<0.004	<1.5	<0.0001
07-AG-026	**†BW09**	**26-Jun-07**	**0.005**	**0.002**	**<0.004**	**<1.5**	**<0.0001**
07-AG-029	RS	26-Jun-07	0.018	<0.001	<0.004	<1.5	0.0002
07-AG-030	RS	26-Jun-07	0.005	0.002	<0.004	<1.5	<0.0001
07-AG-032	RS	26-Jun-07	0.012	0.004	<0.004	<1.5	<0.0001
07-AG-036	RS	27-Jun-07	0.007	0.001	<0.004	<1.5	0.0002
07-AG-038	RS	27-Jun-07	0.005	<0.001	<0.004	<1.5	0.0002
07-AG-040	RS	28-Jun-07	0.005	<0.001	<0.004	6.2	<0.0001
07-AG-049	RS	29-Jun-07	0.004	0.005	<0.004	<1.5	<0.0001
07-AG-050	RS	04-Jul-07	0.004	<0.001	<0.004	<1.5	<0.0001
07-AG-056	RS	07-Jul-07	0.007	<0.001	<0.004	<1.5	<0.0001
07-AG-092	RS	12-Jul-07	0.004	<0.001	<0.004	<1.5	0.0002
07-AG-094	RS	12-Jul-07	0.011	0.006	<0.004	<1.5	<0.0001
07-AG-109	RS	18-Jul-07	0.005	0.002	<0.004	<1.5	<0.0001
07-AG-125	RS	18-Jul-07	0.008	<0.001	<0.004	1.6	<0.0001
07-AG-145	RS	24-Jul-07	0.009	<0.001	<0.004	1.8	<0.0001
07-AG-152	RS	24-Jul-07	0.02	0.001	<0.004	2.7	<0.0001
07-AG-155	RS	26-Jul-07	0.015	<0.001	<0.004	1.8	<0.0001
07-AG-214	RS	05-Aug-07	0.005	0.001	<0.004	<1.5	<0.0001
08-AG-001	RS	13-May-08	0.009	<0.001	<0.004	<1.5	<0.0001
08-AG-004	RS	13-May-08	0.006	<0.001	<0.004	<1.5	0.0001
08-AG-005	RS	13-May-08	0.005	0.002	<0.004	<1.5	0.0004
08-AG-007	‡RSBWZ	15-May-08	0.009	<0.001	<0.004	<1.5	0.0001
08-AG-010	**BW01**	**15-May-08**	**<0.002**	**0.001**	**<0.004**	**<1.5**	**0.0002**
08-AG-012	**BW11**	**15-May-08**	**0.017**	**<0.001**	**<0.004**	**<1.5**	**<0.0001**
08-AG-013	RSBWZ	15-May-08	0.004	<0.001	<0.004	<1.5	0.0002
08-AG-015	RSBWZ	15-May-08	0.005	0.003	<0.004	<1.5	0.0001
08-AG-017	RS	16-May-08	0.007	<0.001	<0.004	<1.5	<0.0001
08-AG-020	RSBWZ	15-May-08	0.018	0.004	<0.004	<1.5	0.0002
08-AG-021	**BW10**	**16-May-08**	**0.003**	**0.001**	**<0.004**	**<1.5**	**<0.0001**
08-AG-023	RS	16-May-08	0.006	0.001	<0.004	<1.5	0.0001
08-AG-025	RS	16-May-08	0.013	0.002	<0.004	<1.5	<0.0001
08-AG-030	RS	16-May-08	0.004	<0.001	<0.004	<1.5	0.0002
08-AG-031	RS	16-May-08	0.007	<0.001	<0.004	<1.5	<0.0001
08-AG-043	RS	20-May-08	0.012	0.001	<0.004	<1.5	<0.0001
08-AG-046	RS	20-May-08	0.007	<0.001	<0.004	3.4	<0.0001
08-AG-050	RS	20-May-08	0.006	0.001	<0.004	<1.5	<0.0001
08-AG-053	RS	20-May-08	0.018	<0.001	<0.004	<1.5	<0.0001
08-AG-060	RSBWZ	21-May-08	0.035	0.003	<0.004	<1.5	<0.0001

Sample	Sample Type	Date	Ga	Gd	Hf	Hg	Ho
			µg/L	µg/L	µg/L	ng/L	µg/L
08-AG-062	RS	21-May-08	0.018	<0.001	<0.004	<1.5	<0.0001
08-AG-085	RS	26-May-08	0.004	<0.001	<0.004	<1.5	0.0003
08-AG-086	RSBWZ	26-May-08	0.004	0.001	<0.004	<1.5	0.0001
08-AG-087	**BW04**	**26-May-08**	**<0.002**	**0.004**	**<0.004**	**<1.5**	**0.0003**
08-AG-100	RSBWZ	26-May-08	0.006	0.001	<0.004	<1.5	0.0001
08-AG-102	RS	27-May-08	0.004	<0.001	<0.004	<1.5	0.0003
08-AG-103	RS	27-May-08	0.003	<0.001	<0.004	<1.5	0.0002
08-AG-105	**BW08**	**27-May-08**	**0.004**	**<0.001**	**<0.004**	**<1.5**	**0.0001**
08-AG-106	RS	28-May-08	0.006	<0.001	<0.004	<1.5	<0.0001
08-AG-107	RS	28-May-08	0.003	0.002	<0.004	<1.5	<0.0001
08-AG-108	RS	28-May-08	0.006	0.002	<0.004	<1.5	0.0001
08-AG-120	RS	28-May-08	0.011	0.001	<0.004	<1.5	0.0004
08-AG-121	RS	28-May-08	0.007	0.001	<0.004	<1.5	0.0002
08-AG-122	RS	28-May-08	0.006	0.008	<0.004	<1.5	<0.0001
08-AG-153	RS	09-Jun-08	0.008	0.004	<0.004	<1.5	0.0002
08-AG-157	RS	09-Jun-08	0.014	<0.001	<0.004	<1.5	0.0002
08-AG-162	RS	09-Jun-08	0.006	0.001	<0.004	<1.5	0.0003
08-AG-164	RS	09-Jun-08	0.01	<0.001	<0.004	<1.5	<0.0001
08-AG-165	RS	09-Jun-08	0.006	<0.001	<0.004	<1.5	<0.0001
08-AG-167	**BW02**	**11-Jun-08**	**<0.002**	**<0.001**	**<0.004**	**<1.5**	**<0.0001**
08-AG-181	RSBWZ	11-Jun-08	0.003	<0.001	<0.004	<1.5	<0.0001
08-AG-183	**BW03**	**11-Jun-08**	**0.007**	**0.002**	**<0.004**	**2.2**	**<0.0001**
08-AG-188	RS	18-Jun-08	0.01	0.002	<0.004	<1.5	0.0006
08-AG-190	RSBWZ	17-Jun-08	0.006	<0.001	<0.004	<1.5	<0.0001
08-AG-193	RS	17-Jun-08	0.009	<0.001	<0.004	<1.5	0.0001
08-AG-194	RS	18-Jun-08	0.003	<0.001	<0.004	<1.5	<0.0001
08-AG-197	RS	19-Jun-08	0.003	0.002	<0.004	<1.5	<0.0001
08-AG-202	RS	19-Jun-08	0.013	0.003	<0.004	<1.5	0.0004
08-AG-203	RS	19-Jun-08	0.009	0.002	<0.004	<1.5	0.0002
08-AG-205	RS	20-Jun-08	0.007	<0.001	<0.004	<1.5	<0.0001
08-AG-206	RS	20-Jun-08	0.009	0.002	0.077	<1.5	0.0004
08-AG-207	RS	20-Jun-08	0.008	0.002	<0.004	<1.5	<0.0001
08-AG-208	RS	20-Jun-08	0.005	<0.001	<0.004	<1.5	0.0001
08-AG-211	**BW05**	**19-Jun-08**	**0.009**	**0.002**	**<0.004**	**<1.5**	**<0.0001**
08-AG-214	RS	19-Jun-08	0.007	0.002	<0.004	<1.5	<0.0001
08-AG-215	RS	22-Jun-08	0.005	<0.001	<0.004	<1.5	0.0001
08-AG-217	RSBWZ	22-Jun-08	0.003	<0.001	<0.004	<1.5	0.0002
08-AG-223	BW06	23-Jun-08	0.002	0.001	<0.004	<1.5	0.0001
08-AG-225	RS	23-Jun-08	0.008	0.001	<0.004	<1.5	<0.0001
08-AG-227	RS	23-Jun-08	0.008	0.003	<0.004	<1.5	<0.0001
08-AG-228	RS	24-Jun-08	0.014	0.002	<0.004	<1.5	0.0004
08-AG-231	RS	25-Jun-08	0.012	0.001	<0.004	<1.5	<0.0001
08-AG-232	RSBWZ	25-Jun-08	0.006	0.004	<0.004	<1.5	0.0005
08-AG-237	RS	26-Jun-08	0.006	<0.001	<0.004	<1.5	<0.0001
08-AG-242	RS	26-Jun-08	0.009	<0.001	<0.004	<1.5	0.0002
08-AG-243	RS	26-Jun-08	0.005	<0.001	<0.004	<1.5	0.0001
08-AG-246	RS	30-Jun-08	0.006	<0.001	<0.004	<1.5	0.0001
08-AG-247	RS	30-Jun-08	0.015	<0.001	<0.004	<1.5	<0.0001
08-AG-248	RS	30-Jun-08	0.009	0.003	<0.004	<1.5	0.0002
08-AG-250	RS	30-Jun-08	0.02	<0.001	<0.004	<1.5	0.0004

Sample	Sample Type	Date	Ga	Gd	Hf	Hg	Ho
			µg/L	µg/L	µg/L	ng/L	µg/L
08-AG-251	RS	02-Jul-08	0.016	0.002	<0.004	4.3	0.0009
08-AG-252	RS	02-Jul-08	<0.002	0.003	<0.004	<1.5	0.0002
08-AG-253	RS	02-Jul-08	0.007	0.002	<0.004	4.3	<0.0001
08-AG-254	RS	02-Jul-08	0.014	0.004	<0.004	1.8	0.0006
08-AG-255	RS	03-Jul-08	0.006	<0.001	<0.004	<1.5	0.0002

* RS = Stations sampled as part of the regional study. †Stations in bold and numbered BW01-BW11 wells that were sampled as part of the local study. ‡RSBWZ – Regional wells located in the BWZ. "-" symbolizes parameter not measured. “<” symbolizes parameter is below detection limit.

Appendix M. Trace Constituents: Ni, Pb, Pr, Rb, Sb, Sc (Regional Study)

Sample	Sample Type	Date	Ni	Pb	Pr	Rb	Sb	Sc
			µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
07-AG-005	*RS	21-Jun-07	0.2	0.191	<0.0004	0.6	<0.01	0.3
07-AG-006	RS	21-Jun-07	1.6	0.369	0.0015	0.4	0.03	0.3
07-AG-008	RS	21-Jun-07	<0.1	0.034	<0.0004	0.8	<0.01	<0.1
07-AG-011	RS	23-Jun-07	0.4	0.325	<0.0004	1.7	<0.01	0.2
07-AG-014	RS	23-Jun-07	0.2	0.093	<0.0004	1.1	<0.01	0.2
07-AG-016	RS	23-Jun-07	3.2	0.155	0.0199	0.9	0.06	0.3
07-AG-020	RS	24-Jun-07	0.2	0.027	<0.0004	0.3	<0.01	0.2
07-AG-021	RS	24-Jun-07	0.2	<0.002	<0.0004	0.5	<0.01	0.2
07-AG-025	RS	26-Jun-07	0.4	0.029	<0.0004	1.9	0.02	0.2
07-AG-026	**†BW09**	**26-Jun-07**	**1.9**	**0.283**	**<0.0004**	**0.6**	**0.06**	**0.2**
07-AG-029	RS	26-Jun-07	<0.1	0.026	<0.0004	0.8	<0.01	<0.1
07-AG-030	RS	26-Jun-07	<0.1	0.041	<0.0004	1.1	<0.01	<0.1
07-AG-032	RS	26-Jun-07	0.1	0.029	<0.0004	0.5	<0.01	<0.1
07-AG-036	RS	27-Jun-07	0.2	0.018	<0.0004	0.3	<0.01	0.2
07-AG-038	RS	27-Jun-07	0.2	0.013	<0.0004	0.5	<0.01	<0.1
07-AG-040	RS	28-Jun-07	0.1	0.015	<0.0004	0.6	<0.01	<0.1
07-AG-049	RS	29-Jun-07	0.1	0.02	<0.0004	0.8	<0.01	<0.1
07-AG-050	RS	04-Jul-07	0.3	0.005	<0.0004	0.4	<0.01	<0.1
07-AG-056	RS	07-Jul-07	<0.1	<0.002	<0.0004	1.8	<0.01	<0.1
07-AG-092	RS	12-Jul-07	<0.1	0.01	<0.0004	0.7	<0.01	<0.1
07-AG-094	RS	12-Jul-07	0.1	0.03	<0.0004	4.3	0.02	<0.1
07-AG-109	RS	18-Jul-07	0.2	0.007	<0.0004	1	<0.01	<0.1
07-AG-125	RS	18-Jul-07	0.2	0.024	<0.0004	1	<0.01	<0.1
07-AG-145	RS	24-Jul-07	<0.1	0.002	<0.0004	0.3	<0.01	<0.1
07-AG-152	RS	24-Jul-07	<0.1	0.013	<0.0004	1.9	<0.01	<0.1
07-AG-155	RS	26-Jul-07	<0.1	0.032	<0.0004	0.4	<0.01	<0.1
07-AG-214	RS	05-Aug-07	<0.1	0.007	<0.0004	1	<0.01	<0.1
08-AG-001	RS	13-May-08	<0.1	<0.05	0.0005	0.8	<0.01	<0.1
08-AG-004	RS	13-May-08	<0.1	<0.05	<0.0004	1.8	<0.01	<0.1
08-AG-005	RS	13-May-08	1.1	<0.05	0.0007	3.6	0.05	0.6
08-AG-007	‡RSBWZ	15-May-08	<0.1	<0.05	<0.0004	0.7	<0.01	<0.1
08-AG-010	**BW01**	**15-May-08**	**1.3**	**<0.05**	**0.0005**	**1.4**	**0.01**	**<0.1**
08-AG-012	**BW11**	**15-May-08**	**1.6**	**<0.05**	**<0.0004**	**1.9**	**0.02**	**0.2**
08-AG-013	RSBWZ	15-May-08	2.1	<0.05	0.0007	3	0.01	0.5
08-AG-015	RSBWZ	15-May-08	2.1	0.31	0.0005	2.6	0.01	0.6
08-AG-017	RS	16-May-08	0.4	<0.05	<0.0004	0.5	<0.01	0.2
08-AG-020	RSBWZ	15-May-08	0.9	<0.05	0.0019	2	<0.01	0.6
08-AG-021	**BW10**	**16-May-08**	**6.6**	**0.15**	**0.0005**	**2**	**0.05**	**0.4**
08-AG-023	RS	16-May-08	0.6	<0.05	0.0005	0.7	<0.01	0.4
08-AG-025	RS	16-May-08	0.9	0.06	<0.0004	0.7	0.01	0.3
08-AG-030	RS	16-May-08	0.3	<0.05	<0.0004	0.4	<0.01	<0.1
08-AG-031	RS	16-May-08	<0.1	<0.05	<0.0004	0.9	<0.01	<0.1
08-AG-043	RS	20-May-08	0.5	<0.05	<0.0004	0.4	<0.01	<0.1
08-AG-046	RS	20-May-08	0.5	<0.05	<0.0004	0.4	<0.01	<0.1
08-AG-050	RS	20-May-08	0.2	0.56	<0.0004	1.3	<0.01	0.2

Sample	Sample Type	Date	Ni	Pb	Pr	Rb	Sb	Sc
			µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
08-AG-053	RS	20-May-08	<0.1	<0.05	<0.0004	0.3	<0.01	<0.1
08-AG-060	RSBWZ	21-May-08	8.1	0.08	<0.0004	2.5	0.04	0.4
08-AG-062	RS	21-May-08	0.4	<0.05	<0.0004	0.5	<0.01	<0.1
08-AG-085	RS	26-May-08	0.5	<0.05	0.0009	2.2	<0.01	<0.1
08-AG-086	RSBWZ	26-May-08	0.3	0.06	<0.0004	0.6	<0.01	0.3
08-AG-087	**BW04**	**26-May-08**	**0.4**	**0.21**	**0.0008**	**1.1**	**0.02**	**0.4**
08-AG-100	RSBWZ	26-May-08	0.4	<0.05	<0.0004	0.6	<0.01	0.2
08-AG-102	RS	27-May-08	0.7	0.05	0.0005	0.4	<0.01	0.3
08-AG-103	RS	27-May-08	0.7	<0.05	0.0006	2.8	<0.01	0.4
08-AG-105	**BW08**	**27-May-08**	**<0.1**	**<0.05**	**0.0006**	**1.5**	**<0.01**	**0.1**
08-AG-106	RS	28-May-08	0.8	<0.05	0.0006	2.6	<0.01	0.1
08-AG-107	RS	28-May-08	<0.1	<0.05	<0.0004	0.7	<0.01	0.3
08-AG-108	RS	28-May-08	<0.1	<0.05	<0.0004	0.3	<0.01	<0.1
08-AG-120	RS	28-May-08	<0.1	<0.05	<0.0004	0.6	0.01	0.6
08-AG-121	RS	28-May-08	1	<0.05	0.0009	2.8	<0.01	0.2
08-AG-122	RS	28-May-08	0.7	<0.05	0.0007	1.7	<0.01	<0.1
08-AG-153	RS	09-Jun-08	0.4	<0.05	<0.0004	1.4	<0.01	<0.1
08-AG-157	RS	09-Jun-08	0.4	<0.05	<0.0004	0.3	<0.01	0.2
08-AG-162	RS	09-Jun-08	0.4	<0.05	0.0004	0.6	<0.01	<0.1
08-AG-164	RS	09-Jun-08	1.1	<0.05	<0.0004	1.2	0.06	<0.1
08-AG-165	RS	09-Jun-08	<0.1	<0.05	<0.0004	2.7	<0.01	0.3
08-AG-167	**BW02**	**11-Jun-08**	**2.5**	**<0.05**	**<0.0004**	**2.1**	**<0.01**	**0.2**
08-AG-181	RSBWZ	11-Jun-08	2	0.12	0.0005	2.7	0.05	0.5
08-AG-183	**BW03**	**11-Jun-08**	**0.8**	**<0.05**	**<0.0004**	**4**	**<0.01**	**0.5**
08-AG-188	RS	18-Jun-08	0.1	<0.05	<0.0004	0.7	<0.01	<0.1
08-AG-190	RSBWZ	17-Jun-08	0.2	<0.05	<0.0004	0.8	<0.01	<0.1
08-AG-193	RS	17-Jun-08	0.2	<0.05	<0.0004	0.7	<0.01	<0.1
08-AG-194	RS	18-Jun-08	<0.1	<0.05	<0.0004	1.3	<0.01	<0.1
08-AG-197	RS	19-Jun-08	0.6	<0.05	<0.0004	3.4	<0.01	0.4
08-AG-202	RS	19-Jun-08	0.6	<0.05	0.0013	0.6	<0.01	0.4
08-AG-203	RS	19-Jun-08	4.9	<0.05	0.0006	0.3	0.01	<0.1
08-AG-205	RS	20-Jun-08	0.7	<0.05	<0.0004	1.5	<0.01	0.2
08-AG-206	RS	20-Jun-08	2.7	<0.05	0.0017	1.7	<0.01	0.7
08-AG-207	RS	20-Jun-08	10.1	<0.05	<0.0004	1.8	0.23	0.5
08-AG-208	RS	20-Jun-08	1	<0.05	0.0001	3.3	0.01	0.3
08-AG-211	**BW05**	**19-Jun-08**	**1.8**	**<0.05**	**<0.0004**	**3.6**	**0.04**	**0.4**
08-AG-214	RS	19-Jun-08	0.8	<0.05	<0.0004	2.4	0.01	0.2
08-AG-215	RS	22-Jun-08	2.3	<0.05	0.0004	1.5	<0.01	0.5
08-AG-217	RSBWZ	22-Jun-08	1.9	<0.05	0.0004	2.1	<0.01	0.6
08-AG-223	BW06	23-Jun-08	0.9	0.09	<0.0004	3.9	0.06	0.4
08-AG-225	RS	23-Jun-08	0.2	0.07	<0.0004	0.4	<0.01	<0.1
08-AG-227	RS	23-Jun-08	0.2	<0.05	<0.0004	0.9	<0.01	0.1
08-AG-228	RS	24-Jun-08	1.5	<0.05	0.0006	0.6	<0.01	0.2
08-AG-231	RS	25-Jun-08	0.4	<0.05	<0.0004	0.2	<0.01	<0.1
08-AG-232	RSBWZ	25-Jun-08	0.2	<0.05	0.0005	0.3	0.01	0.4
08-AG-237	RS	26-Jun-08	0.9	0.74	0.0057	1.4	0.01	<0.1
08-AG-242	RS	26-Jun-08	2.1	<0.05	0.0005	0.4	0.02	0.4

Sample	Sample Type	Date	Ni	Pb	Pr	Rb	Sb	Sc
			µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
08-AG-243	RS	26-Jun-08	2.8	<0.05	<0.0004	0.4	0.05	0.1
08-AG-246	RS	30-Jun-08	1.1	<0.05	<0.0004	0.7	<0.01	0.3
08-AG-247	RS	30-Jun-08	1	<0.05	<0.0004	0.4	<0.01	0.1
08-AG-248	RS	30-Jun-08	3.5	<0.05	0.0008	0.3	<0.01	<0.1
08-AG-250	RS	30-Jun-08	0.5	<0.05	0.0006	0.7	0.01	0.3
08-AG-251	RS	02-Jul-08	0.5	<0.05	0.0008	0.6	0.01	0.2
08-AG-252	RS	02-Jul-08	0.9	0.11	<0.0004	1.6	0.04	0.4
08-AG-253	RS	02-Jul-08	0.3	<0.05	<0.0004	0.6	0.02	0.2
08-AG-254	RS	02-Jul-08	0.5	<0.05	0.0012	1.5	<0.01	0.2
08-AG-255	RS	03-Jul-08	<0.1	<0.05	<0.0004	1.3	<0.01	<0.1

* RS = Stations sampled as part of the regional study. †Stations in bold and numbered BW01-BW11 wells that were sampled as part of the local study. ‡RSBWZ – Regional wells located in the BWZ. "-" symbolizes parameter not measured. “<” symbolizes parameter is below detection limit.

Appendix N. Trace Constituents: Se, Ni, Pb, Pr, Rb (Regional Study)

Sample	Sample Type	Date	Se	Ni	Pb	Pr	Rb
			µg/L	µg/L	µg/L	µg/L	µg/L
07-AG-005	*RS	21-Jun-07	<0.2	0.2	0.191	<0.0004	0.6
07-AG-006	RS	21-Jun-07	<0.2	1.6	0.369	0.0015	0.4
07-AG-008	RS	21-Jun-07	<0.2	<0.1	0.034	<0.0004	0.8
07-AG-011	RS	23-Jun-07	<0.2	0.4	0.325	<0.0004	1.7
07-AG-014	RS	23-Jun-07	<0.2	0.2	0.093	<0.0004	1.1
07-AG-016	RS	23-Jun-07	0.3	3.2	0.155	0.0199	0.9
07-AG-020	RS	24-Jun-07	<0.2	0.2	0.027	<0.0004	0.3
07-AG-021	RS	24-Jun-07	<0.2	0.2	<0.002	<0.0004	0.5
07-AG-025	RS	26-Jun-07	<0.2	0.4	0.029	<0.0004	1.9
07-AG-026	**†BW09**	**26-Jun-07**	**0.3**	**1.9**	**0.283**	**<0.0004**	**0.6**
07-AG-029	RS	26-Jun-07	<0.2	<0.1	0.026	<0.0004	0.8
07-AG-030	RS	26-Jun-07	<0.2	<0.1	0.041	<0.0004	1.1
07-AG-032	RS	26-Jun-07	<0.2	0.1	0.029	<0.0004	0.5
07-AG-036	RS	27-Jun-07	<0.2	0.2	0.018	<0.0004	0.3
07-AG-038	RS	27-Jun-07	<0.2	0.2	0.013	<0.0004	0.5
07-AG-040	RS	28-Jun-07	<0.2	0.1	0.015	<0.0004	0.6
07-AG-049	RS	29-Jun-07	<0.2	0.1	0.02	<0.0004	0.8
07-AG-050	RS	04-Jul-07	0.3	0.3	0.005	<0.0004	0.4
07-AG-056	RS	07-Jul-07	<0.2	<0.1	<0.002	<0.0004	1.8
07-AG-092	RS	12-Jul-07	0.2	<0.1	0.01	<0.0004	0.7
07-AG-094	RS	12-Jul-07	8	0.1	0.03	<0.0004	4.3
07-AG-109	RS	18-Jul-07	<0.2	0.2	0.007	<0.0004	1
07-AG-125	RS	18-Jul-07	<0.2	0.2	0.024	<0.0004	1
07-AG-145	RS	24-Jul-07	<0.2	<0.1	0.002	<0.0004	0.3
07-AG-152	RS	24-Jul-07	0.8	<0.1	0.013	<0.0004	1.9
07-AG-155	RS	26-Jul-07	<0.2	<0.1	0.032	<0.0004	0.4
07-AG-214	RS	05-Aug-07	<0.2	<0.1	0.007	<0.0004	1
08-AG-001	RS	13-May-08	1.1	<0.1	<0.05	0.0005	0.8
08-AG-004	RS	13-May-08	2.2	<0.1	<0.05	<0.0004	1.8
08-AG-005	RS	13-May-08	<0.2	1.1	<0.05	0.0007	3.6
08-AG-007	‡RSBWZ	15-May-08	<0.2	<0.1	<0.05	<0.0004	0.7
08-AG-010	**BW01**	**15-May-08**	**<0.2**	**1.3**	**<0.05**	**0.0005**	**1.4**
08-AG-012	**BW11**	**15-May-08**	**<0.2**	**1.6**	**<0.05**	**<0.0004**	**1.9**
08-AG-013	RSBWZ	15-May-08	<0.2	2.1	<0.05	0.0007	3
08-AG-015	RSBWZ	15-May-08	<0.2	2.1	0.31	0.0005	2.6
08-AG-017	RS	16-May-08	<0.2	0.4	<0.05	<0.0004	0.5
08-AG-020	RSBWZ	15-May-08	<0.2	0.9	<0.05	0.0019	2
08-AG-021	**BW10**	**16-May-08**	**<0.2**	**6.6**	**0.15**	**0.0005**	**2**
08-AG-023	RS	16-May-08	<0.2	0.6	<0.05	0.0005	0.7
08-AG-025	RS	16-May-08	<0.2	0.9	0.06	<0.0004	0.7
08-AG-030	RS	16-May-08	<0.2	0.3	<0.05	<0.0004	0.4
08-AG-031	RS	16-May-08	<0.2	<0.1	<0.05	<0.0004	0.9
08-AG-043	RS	20-May-08	<0.2	0.5	<0.05	<0.0004	0.4
08-AG-046	RS	20-May-08	<0.2	0.5	<0.05	<0.0004	0.4
08-AG-050	RS	20-May-08	<0.2	0.2	0.56	<0.0004	1.3
08-AG-053	RS	20-May-08	<0.2	<0.1	<0.05	<0.0004	0.3
08-AG-060	RSBWZ	21-May-08	<0.2	8.1	0.08	<0.0004	2.5
08-AG-062	RS	21-May-08	<0.2	0.4	<0.05	<0.0004	0.5

Sample	Sample Type	Date	Se	Ni	Pb	Pr	Rb
			µg/L	µg/L	µg/L	µg/L	µg/L
08-AG-085	RS	26-May-08	<0.2	0.5	<0.05	0.0009	2.2
08-AG-086	RSBWZ	26-May-08	<0.2	0.3	0.06	<0.0004	0.6
08-AG-087	**BW04**	**26-May-08**	**<0.2**	**0.4**	**0.21**	**0.0008**	**1.1**
08-AG-100	RSBWZ	26-May-08	<0.2	0.4	<0.05	<0.0004	0.6
08-AG-102	RS	27-May-08	<0.2	0.7	0.05	0.0005	0.4
08-AG-103	RS	27-May-08	<0.2	0.7	<0.05	0.0006	2.8
08-AG-105	**BW08**	**27-May-08**	**<0.2**	**<0.1**	**<0.05**	**0.0006**	**1.5**
08-AG-106	RS	28-May-08	<0.2	0.8	<0.05	0.0006	2.6
08-AG-107	RS	28-May-08	<0.2	<0.1	<0.05	<0.0004	0.7
08-AG-108	RS	28-May-08	<0.2	<0.1	<0.05	<0.0004	0.3
08-AG-120	RS	28-May-08	<0.2	<0.1	<0.05	<0.0004	0.6
08-AG-121	RS	28-May-08	<0.2	1	<0.05	0.0009	2.8
08-AG-122	RS	28-May-08	<0.2	0.7	<0.05	0.0007	1.7
08-AG-153	RS	09-Jun-08	<0.2	0.4	<0.05	<0.0004	1.4
08-AG-157	RS	09-Jun-08	<0.2	0.4	<0.05	<0.0004	0.3
08-AG-162	RS	09-Jun-08	<0.2	0.4	<0.05	0.0004	0.6
08-AG-164	RS	09-Jun-08	<0.2	1.1	<0.05	<0.0004	1.2
08-AG-165	RS	09-Jun-08	<0.2	<0.1	<0.05	<0.0004	2.7
08-AG-167	**BW02**	**11-Jun-08**	**<0.2**	**2.5**	**<0.05**	**<0.0004**	**2.1**
08-AG-181	RSBWZ	11-Jun-08	<0.2	2	0.12	0.0005	2.7
08-AG-183	**BW03**	**11-Jun-08**	**<0.2**	**0.8**	**<0.05**	**<0.0004**	**4**
08-AG-188	RS	18-Jun-08	<0.2	0.1	<0.05	<0.0004	0.7
08-AG-190	RSBWZ	17-Jun-08	<0.2	0.2	<0.05	<0.0004	0.8
08-AG-193	RS	17-Jun-08	0.8	0.2	<0.05	<0.0004	0.7
08-AG-194	RS	18-Jun-08	2	<0.1	<0.05	<0.0004	1.3
08-AG-197	RS	19-Jun-08	<0.2	0.6	<0.05	<0.0004	3.4
08-AG-202	RS	19-Jun-08	<0.2	0.6	<0.05	0.0013	0.6
08-AG-203	RS	19-Jun-08	<0.2	4.9	<0.05	0.0006	0.3
08-AG-205	RS	20-Jun-08	<0.2	0.7	<0.05	<0.0004	1.5
08-AG-206	RS	20-Jun-08	<0.2	2.7	<0.05	0.0017	1.7
08-AG-207	RS	20-Jun-08	<0.2	10.1	<0.05	<0.0004	1.8
08-AG-208	RS	20-Jun-08	<0.2	1	<0.05	0.0001	3.3
08-AG-211	**BW05**	**19-Jun-08**	**<0.2**	**1.8**	**<0.05**	**<0.0004**	**3.6**
08-AG-214	RS	19-Jun-08	<0.2	0.8	<0.05	<0.0004	2.4
08-AG-215	RS	22-Jun-08	<0.2	2.3	<0.05	0.0004	1.5
08-AG-217	RSBWZ	22-Jun-08	<0.2	1.9	<0.05	0.0004	2.1
08-AG-223	BW06	23-Jun-08	<0.2	0.9	0.09	<0.0004	3.9
08-AG-225	RS	23-Jun-08	<0.2	0.2	0.07	<0.0004	0.4
08-AG-227	RS	23-Jun-08	<0.2	0.2	<0.05	<0.0004	0.9
08-AG-228	RS	24-Jun-08	<0.2	1.5	<0.05	0.0006	0.6
08-AG-231	RS	25-Jun-08	<0.2	0.4	<0.05	<0.0004	0.2
08-AG-232	RSBWZ	25-Jun-08	<0.2	0.2	<0.05	0.0005	0.3
08-AG-237	RS	26-Jun-08	0.3	0.9	0.74	0.0057	1.4
08-AG-242	RS	26-Jun-08	<0.2	2.1	<0.05	0.0005	0.4
08-AG-243	RS	26-Jun-08	<0.2	2.8	<0.05	<0.0004	0.4
08-AG-246	RS	30-Jun-08	<0.2	1.1	<0.05	<0.0004	0.7
08-AG-247	RS	30-Jun-08	<0.2	1	<0.05	<0.0004	0.4
08-AG-248	RS	30-Jun-08	<0.2	3.5	<0.05	0.0008	0.3
08-AG-250	RS	30-Jun-08	<0.2	0.5	<0.05	0.0006	0.7
08-AG-251	RS	02-Jul-08	<0.2	0.5	<0.05	0.0008	0.6

Sample	Sample Type	Date	Se	Ni	Pb	Pr	Rb
			µg/L	µg/L	µg/L	µg/L	µg/L
08-AG-252	RS	02-Jul-08	<0.2	0.9	0.11	<0.0004	1.6
08-AG-253	RS	02-Jul-08	<0.2	0.3	<0.05	<0.0004	0.6
08-AG-254	RS	02-Jul-08	<0.2	0.5	<0.05	0.0012	1.5
08-AG-255	RS	03-Jul-08	0.8	<0.1	<0.05	<0.0004	1.3

* RS = Stations sampled as part of the regional study. †Stations in bold and numbered BW01-BW11 wells that were sampled as part of the local study. ‡RSBWZ – Regional wells located in the BWZ. "-" symbolizes parameter not measured. “<” symbolizes parameter is below detection limit.

Appendix O. Trace Constituents: Sb, Sc, Se, Sm, Sn (Regional Study)

Sample	Sample Type	Date	Sb	Sc	Se	Sm	Sn
			µg/L	µg/L	µg/L	µg/L	µg/L
07-AG-005	*RS	21-Jun-07	<0.01	0.3	<0.2	<0.001	0.01
07-AG-006	RS	21-Jun-07	0.03	0.3	<0.2	<0.001	0.08
07-AG-008	RS	21-Jun-07	<0.01	<0.1	<0.2	<0.001	0.02
07-AG-011	RS	23-Jun-07	<0.01	0.2	<0.2	0.001	0.04
07-AG-014	RS	23-Jun-07	<0.01	0.2	<0.2	<0.001	<0.01
07-AG-016	RS	23-Jun-07	0.06	0.3	0.3	0.015	0.02
07-AG-020	RS	24-Jun-07	<0.01	0.2	<0.2	<0.001	<0.01
07-AG-021	RS	24-Jun-07	<0.01	0.2	<0.2	<0.001	<0.01
07-AG-025	RS	26-Jun-07	0.02	0.2	<0.2	0.009	0.09
07-AG-026	**†BW09**	**26-Jun-07**	**0.06**	**0.2**	**0.3**	**<0.001**	**0.02**
07-AG-029	RS	26-Jun-07	<0.01	<0.1	<0.2	<0.001	<0.01
07-AG-030	RS	26-Jun-07	<0.01	<0.1	<0.2	<0.001	<0.01
07-AG-032	RS	26-Jun-07	<0.01	<0.1	<0.2	0.002	0.01
07-AG-036	RS	27-Jun-07	<0.01	0.2	<0.2	0.001	<0.01
07-AG-038	RS	27-Jun-07	<0.01	<0.1	<0.2	0.001	<0.01
07-AG-040	RS	28-Jun-07	<0.01	<0.1	<0.2	<0.001	<0.01
07-AG-049	RS	29-Jun-07	<0.01	<0.1	<0.2	0.002	0.02
07-AG-050	RS	04-Jul-07	<0.01	<0.1	0.3	<0.001	<0.01
07-AG-056	RS	07-Jul-07	<0.01	<0.1	<0.2	<0.001	<0.01
07-AG-092	RS	12-Jul-07	<0.01	<0.1	0.2	<0.001	<0.01
07-AG-094	RS	12-Jul-07	0.02	<0.1	8	0.003	0.02
07-AG-109	RS	18-Jul-07	<0.01	<0.1	<0.2	0.002	<0.01
07-AG-125	RS	18-Jul-07	<0.01	<0.1	<0.2	<0.001	<0.01
07-AG-145	RS	24-Jul-07	<0.01	<0.1	<0.2	0.002	<0.01
07-AG-152	RS	24-Jul-07	<0.01	<0.1	0.8	0.001	<0.01
07-AG-155	RS	26-Jul-07	<0.01	<0.1	<0.2	<0.001	<0.01
07-AG-214	RS	05-Aug-07	<0.01	<0.1	<0.2	0.002	<0.01
08-AG-001	RS	13-May-08	<0.01	<0.1	1.1	<0.001	<0.01
08-AG-004	RS	13-May-08	<0.01	<0.1	2.2	<0.001	<0.01
08-AG-005	RS	13-May-08	0.05	0.6	<0.2	0.001	<0.01
08-AG-007	‡RSBWZ	15-May-08	<0.01	<0.1	<0.2	<0.001	0.01
08-AG-010	**BW01**	**15-May-08**	**0.01**	**<0.1**	**<0.2**	**0.001**	**0.01**
08-AG-012	**BW11**	**15-May-08**	**0.02**	**0.2**	**<0.2**	**<0.001**	**0.02**
08-AG-013	RSBWZ	15-May-08	0.01	0.5	<0.2	<0.001	0.02
08-AG-015	RSBWZ	15-May-08	0.01	0.6	<0.2	0.001	0.02
08-AG-017	RS	16-May-08	<0.01	0.2	<0.2	<0.001	<0.01
08-AG-020	RSBWZ	15-May-08	<0.01	0.6	<0.2	0.003	0.02
08-AG-021	**BW10**	**16-May-08**	**0.05**	**0.4**	**<0.2**	**<0.001**	**0.02**
08-AG-023	RS	16-May-08	<0.01	0.4	<0.2	<0.001	<0.01
08-AG-025	RS	16-May-08	0.01	0.3	<0.2	0.001	<0.01
08-AG-030	RS	16-May-08	<0.01	<0.1	<0.2	<0.001	<0.01
08-AG-031	RS	16-May-08	<0.01	<0.1	<0.2	0.001	<0.01
08-AG-043	RS	20-May-08	<0.01	<0.1	<0.2	<0.001	<0.01
08-AG-046	RS	20-May-08	<0.01	<0.1	<0.2	<0.001	0.01
08-AG-050	RS	20-May-08	<0.01	0.2	<0.2	<0.001	0.01
08-AG-053	RS	20-May-08	<0.01	<0.1	<0.2	<0.001	<0.01
08-AG-060	RSBWZ	21-May-08	0.04	0.4	<0.2	0.002	0.02

Sample	Sample Type	Date	Sb	Sc	Se	Sm	Sn
			µg/L	µg/L	µg/L	µg/L	µg/L
08-AG-062	RS	21-May-08	<0.01	<0.1	<0.2	<0.001	<0.01
08-AG-085	RS	26-May-08	<0.01	<0.1	<0.2	<0.001	0.02
08-AG-086	RSBWZ	26-May-08	<0.01	0.3	<0.2	0.001	0.01
08-AG-087	**BW04**	**26-May-08**	**0.02**	**0.4**	**<0.2**	**0.002**	**0.01**
08-AG-100	RSBWZ	26-May-08	<0.01	0.2	<0.2	<0.001	<0.01
08-AG-102	RS	27-May-08	<0.01	0.3	<0.2	<0.001	<0.01
08-AG-103	RS	27-May-08	<0.01	0.4	<0.2	<0.001	0.02
08-AG-105	**BW08**	**27-May-08**	**<0.01**	**0.1**	**<0.2**	**<0.001**	**0.02**
08-AG-106	RS	28-May-08	<0.01	0.1	<0.2	<0.001	0.02
08-AG-107	RS	28-May-08	<0.01	0.3	<0.2	<0.001	0.01
08-AG-108	RS	28-May-08	<0.01	<0.1	<0.2	0.002	0.01
08-AG-120	RS	28-May-08	0.01	0.6	<0.2	<0.001	<0.01
08-AG-121	RS	28-May-08	<0.01	0.2	<0.2	<0.001	0.02
08-AG-122	RS	28-May-08	<0.01	<0.1	<0.2	0.005	0.02
08-AG-153	RS	09-Jun-08	<0.01	<0.1	<0.2	0.002	<0.01
08-AG-157	RS	09-Jun-08	<0.01	0.2	<0.2	<0.001	<0.01
08-AG-162	RS	09-Jun-08	<0.01	<0.1	<0.2	0.001	<0.01
08-AG-164	RS	09-Jun-08	0.06	<0.1	<0.2	<0.001	<0.01
08-AG-165	RS	09-Jun-08	<0.01	0.3	<0.2	<0.001	0.1
08-AG-167	**BW02**	**11-Jun-08**	**<0.01**	**0.2**	**<0.2**	**0.001**	**<0.01**
08-AG-181	RSBWZ	11-Jun-08	0.05	0.5	<0.2	<0.001	0.01
08-AG-183	**BW03**	**11-Jun-08**	**<0.01**	**0.5**	**<0.2**	**0.001**	**<0.01**
08-AG-188	RS	18-Jun-08	<0.01	<0.1	<0.2	0.002	<0.01
08-AG-190	RSBWZ	17-Jun-08	<0.01	<0.1	<0.2	0.002	<0.01
08-AG-193	RS	17-Jun-08	<0.01	<0.1	0.8	<0.001	<0.01
08-AG-194	RS	18-Jun-08	<0.01	<0.1	2	<0.001	<0.01
08-AG-197	RS	19-Jun-08	<0.01	0.4	<0.2	0.002	<0.01
08-AG-202	RS	19-Jun-08	<0.01	0.4	<0.2	0.002	0.01
08-AG-203	RS	19-Jun-08	0.01	<0.1	<0.2	<0.001	<0.01
08-AG-205	RS	20-Jun-08	<0.01	0.2	<0.2	0.001	<0.01
08-AG-206	RS	20-Jun-08	<0.01	0.7	<0.2	<0.001	<0.01
08-AG-207	RS	20-Jun-08	0.23	0.5	<0.2	0.001	<0.01
08-AG-208	RS	20-Jun-08	0.01	0.3	<0.2	<0.001	0.02
08-AG-211	**BW05**	**19-Jun-08**	**0.04**	**0.4**	**<0.2**	**0.001**	**0.01**
08-AG-214	RS	19-Jun-08	0.01	0.2	<0.2	0.001	0.01
08-AG-215	RS	22-Jun-08	<0.01	0.5	<0.2	<0.001	<0.01
08-AG-217	RSBWZ	22-Jun-08	<0.01	0.6	<0.2	<0.001	0.01
08-AG-223	BW06	23-Jun-08	0.06	0.4	<0.2	0.001	0.01
08-AG-225	RS	23-Jun-08	<0.01	<0.1	<0.2	0.001	<0.01
08-AG-227	RS	23-Jun-08	<0.01	0.1	<0.2	0.002	<0.01
08-AG-228	RS	24-Jun-08	<0.01	0.2	<0.2	0.002	0.01
08-AG-231	RS	25-Jun-08	<0.01	<0.1	<0.2	0.002	<0.01
08-AG-232	RSBWZ	25-Jun-08	0.01	0.4	<0.2	0.002	<0.01
08-AG-237	RS	26-Jun-08	0.01	<0.1	0.3	0.002	0.02
08-AG-242	RS	26-Jun-08	0.02	0.4	<0.2	<0.001	<0.01
08-AG-243	RS	26-Jun-08	0.05	0.1	<0.2	<0.001	<0.01
08-AG-246	RS	30-Jun-08	<0.01	0.3	<0.2	<0.001	<0.01
08-AG-247	RS	30-Jun-08	<0.01	0.1	<0.2	<0.001	<0.01
08-AG-248	RS	30-Jun-08	<0.01	<0.1	<0.2	0.001	0.01

Sample	Sample Type	Date	Sb	Sc	Se	Sm	Sn
			µg/L	µg/L	µg/L	µg/L	µg/L
08-AG-250	RS	30-Jun-08	0.01	0.3	<0.2	0.001	0.01
08-AG-251	RS	02-Jul-08	0.01	0.2	<0.2	0.002	<0.01
08-AG-252	RS	02-Jul-08	0.04	0.4	<0.2	0.001	<0.01
08-AG-253	RS	02-Jul-08	0.02	0.2	<0.2	<0.001	<0.01
08-AG-254	RS	02-Jul-08	<0.01	0.2	<0.2	0.002	<0.01
08-AG-255	RS	03-Jul-08	<0.01	<0.1	0.8	<0.001	<0.01

* RS = Stations sampled as part of the regional study. †Stations in bold and numbered BW01-BW11 wells that were sampled as part of the local study. ‡RSBWZ – Regional wells located in the BWZ. "-" symbolizes parameter not measured. “<” symbolizes parameter is below detection limit.

Appendix P. Trace Constituents: Ta, Tb, Th, Ti, Tl (Regional Study)

Sample	Sample Type	Date	Ta	Tb	Th	Ti	Tl
			µg/L	µg/L	µg/L	µg/L	µg/L
07-AG-005	*RS	21-Jun-07	<0.0003	0.0003	0.002	<0.1	<0.001
07-AG-006	RS	21-Jun-07	<0.0003	<0.0001	0.002	0.3	<0.001
07-AG-008	RS	21-Jun-07	0.0003	<0.0001	<0.001	<0.1	<0.001
07-AG-011	RS	23-Jun-07	<0.0003	<0.0001	<0.001	<0.1	<0.001
07-AG-014	RS	23-Jun-07	<0.0003	<0.0001	<0.001	<0.1	<0.001
07-AG-016	RS	23-Jun-07	0.0003	0.0026	0.011	0.3	0.002
07-AG-020	RS	24-Jun-07	<0.0003	<0.0001	<0.001	<0.1	<0.001
07-AG-021	RS	24-Jun-07	<0.0003	<0.0001	<0.001	<0.1	<0.001
07-AG-025	RS	26-Jun-07	0.0003	<0.0001	<0.001	<0.1	<0.001
07-AG-026	**†BW09**	**26-Jun-07**	**<0.0003**	**<0.0001**	**<0.001**	**<0.1**	**0.077**
07-AG-029	RS	26-Jun-07	0.0005	0.0002	<0.001	<0.1	0.001
07-AG-030	RS	26-Jun-07	<0.0003	<0.0001	<0.001	<0.1	<0.001
07-AG-032	RS	26-Jun-07	<0.0003	<0.0001	<0.001	<0.1	<0.001
07-AG-036	RS	27-Jun-07	<0.0003	0.0002	<0.001	<0.1	<0.001
07-AG-038	RS	27-Jun-07	<0.0003	0.0001	<0.001	<0.1	<0.001
07-AG-040	RS	28-Jun-07	<0.0003	<0.0001	<0.001	<0.1	<0.001
07-AG-049	RS	29-Jun-07	<0.0003	<0.0001	<0.001	<0.1	<0.001
07-AG-050	RS	04-Jul-07	0.0004	<0.0001	<0.001	<0.1	<0.001
07-AG-056	RS	07-Jul-07	<0.0003	<0.0001	<0.001	<0.1	<0.001
07-AG-092	RS	12-Jul-07	0.0003	<0.0001	<0.001	<0.1	<0.001
07-AG-094	RS	12-Jul-07	<0.0003	<0.0001	<0.001	<0.1	<0.001
07-AG-109	RS	18-Jul-07	0.0005	<0.0001	<0.001	<0.1	<0.001
07-AG-125	RS	18-Jul-07	<0.0003	<0.0001	<0.001	<0.1	<0.001
07-AG-145	RS	24-Jul-07	<0.0003	<0.0001	<0.001	<0.1	<0.001
07-AG-152	RS	24-Jul-07	<0.0003	<0.0001	<0.001	<0.1	<0.001
07-AG-155	RS	26-Jul-07	<0.0003	<0.0001	<0.001	<0.1	<0.001
07-AG-214	RS	05-Aug-07	<0.0003	<0.0001	<0.001	<0.1	<0.001
08-AG-001	RS	13-May-08	0.0005	<0.0001	0.002	0.3	<0.001
08-AG-004	RS	13-May-08	0.0007	<0.0001	<0.001	<0.1	<0.001
08-AG-005	RS	13-May-08	0.0008	0.0003	<0.001	3.5	0.002
08-AG-007	‡RSBWZ	15-May-08	0.0008	<0.0001	<0.001	<0.1	<0.001
08-AG-010	**BW01**	**15-May-08**	**0.0005**	**0.0002**	**<0.001**	**1.8**	**0.064**
08-AG-012	**BW11**	**15-May-08**	**0.0009**	**<0.0001**	**<0.001**	**3.7**	**0.003**
08-AG-013	RSBWZ	15-May-08	0.0009	<0.0001	<0.001	0.6	0.116
08-AG-015	RSBWZ	15-May-08	0.001	0.0002	<0.001	0.6	0.226
08-AG-017	RS	16-May-08	0.0004	<0.0001	<0.001	<0.1	<0.001
08-AG-020	RSBWZ	15-May-08	<0.0003	0.0002	<0.001	0.7	0.136
08-AG-021	**BW10**	**16-May-08**	**0.0005**	**<0.0001**	**<0.001**	**1.1**	**0.046**
08-AG-023	RS	16-May-08	0.0005	<0.0001	<0.001	0.4	0.003
08-AG-025	RS	16-May-08	0.0009	0.0001	<0.001	<0.1	0.002
08-AG-030	RS	16-May-08	0.001	<0.0001	<0.001	<0.1	<0.001
08-AG-031	RS	16-May-08	0.0011	<0.0001	<0.001	0.3	<0.001
08-AG-043	RS	20-May-08	0.0011	<0.0001	<0.001	<0.1	0.006
08-AG-046	RS	20-May-08	0.001	<0.0001	<0.001	<0.1	<0.001
08-AG-050	RS	20-May-08	0.0009	<0.0001	<0.001	0.1	<0.001
08-AG-053	RS	20-May-08	0.0009	<0.0001	<0.001	<0.1	<0.001
08-AG-060	RSBWZ	21-May-08	0.0014	<0.0001	<0.001	0.7	<0.001
08-AG-062	RS	21-May-08	0.0004	<0.0001	<0.001	<0.1	0.002

Sample	Sample Type	Date	Ta	Tb	Th	Ti	Tl
			µg/L	µg/L	µg/L	µg/L	µg/L
08-AG-085	RS	26-May-08	<0.0003	0.0001	<0.001	0.2	0.011
08-AG-086	RSBWZ	26-May-08	0.001	0.0003	<0.001	<0.1	<0.001
08-AG-087	**BW04**	**26-May-08**	**0.0004**	**0.0003**	**<0.001**	**0.6**	**0.013**
08-AG-100	RSBWZ	26-May-08	<0.0003	<0.0001	<0.001	0.2	0.002
08-AG-102	RS	27-May-08	<0.0003	0.0003	<0.001	0.2	0.008
08-AG-103	RS	27-May-08	0.0009	0.0001	<0.001	0.5	<0.001
08-AG-105	**BW08**	**27-May-08**	**0.0005**	**0.0001**	**<0.001**	**2.1**	**0.022**
08-AG-106	RS	28-May-08	0.0005	<0.0001	<0.001	0.3	0.014
08-AG-107	RS	28-May-08	0.0006	<0.0001	<0.001	<0.1	<0.001
08-AG-108	RS	28-May-08	<0.0003	<0.0001	<0.001	<0.1	<0.001
08-AG-120	RS	28-May-08	<0.0003	0.0002	<0.001	0.6	0.004
08-AG-121	RS	28-May-08	0.0006	<0.0001	<0.001	0.2	<0.001
08-AG-122	RS	28-May-08	<0.0003	0.0001	<0.001	<0.1	<0.001
08-AG-153	RS	09-Jun-08	<0.0003	<0.0001	<0.001	0.3	<0.001
08-AG-157	RS	09-Jun-08	<0.0003	<0.0001	<0.001	<0.1	<0.001
08-AG-162	RS	09-Jun-08	<0.0003	0.0001	<0.001	<0.1	0.002
08-AG-164	RS	09-Jun-08	0.001	<0.0001	<0.001	<0.1	0.089
08-AG-165	RS	09-Jun-08	0.0009	<0.0001	<0.001	7.5	0.001
08-AG-167	**BW02**	**11-Jun-08**	**0.0005**	**<0.0001**	**<0.001**	**2.1**	**<0.001**
08-AG-181	RSBWZ	11-Jun-08	0.0014	<0.0001	<0.001	1.6	0.077
08-AG-183	**BW03**	**11-Jun-08**	**0.0026**	**<0.0001**	**<0.001**	**0.6**	**0.036**
08-AG-188	RS	18-Jun-08	0.0005	<0.0001	<0.001	<0.1	<0.001
08-AG-190	RSBWZ	17-Jun-08	0.0008	<0.0001	0.002	<0.1	<0.001
08-AG-193	RS	17-Jun-08	0.0004	<0.0001	<0.001	0.5	<0.001
08-AG-194	RS	18-Jun-08	0.0007	0.0001	0.002	<0.1	<0.001
08-AG-197	RS	19-Jun-08	0.0006	<0.0001	<0.001	<0.1	0.025
08-AG-202	RS	19-Jun-08	0.0005	<0.0001	<0.001	0.3	0.005
08-AG-203	RS	19-Jun-08	<0.0003	0.0002	<0.001	<0.1	0.005
08-AG-205	RS	20-Jun-08	0.0005	<0.0001	<0.001	0.3	<0.001
08-AG-206	RS	20-Jun-08	0.0005	0.0002	<0.001	5.9	0.011
08-AG-207	RS	20-Jun-08	<0.0003	<0.0001	<0.001	0.7	0.697
08-AG-208	RS	20-Jun-08	0.0008	<0.0001	<0.001	0.5	0.02
08-AG-211	**BW05**	**19-Jun-08**	**0.0004**	**<0.0001**	**<0.001**	**1.5**	**0.004**
08-AG-214	RS	19-Jun-08	0.0006	<0.0001	0.001	0.4	0.018
08-AG-215	RS	22-Jun-08	0.0006	<0.0001	<0.001	4.9	0.027
08-AG-217	RSBWZ	22-Jun-08	0.001	0.0002	<0.001	5.7	0.01
08-AG-223	BW06	23-Jun-08	0.0005	<0.0001	0.002	0.8	0.032
08-AG-225	RS	23-Jun-08	0.001	<0.0001	<0.001	<0.1	<0.001
08-AG-227	RS	23-Jun-08	0.0005	<0.0001	<0.001	<0.1	<0.001
08-AG-228	RS	24-Jun-08	0.0006	<0.0001	<0.001	0.4	0.027
08-AG-231	RS	25-Jun-08	0.0006	<0.0001	<0.001	0.4	<0.001
08-AG-232	RSBWZ	25-Jun-08	0.0009	0.0004	<0.001	0.4	0.001
08-AG-237	RS	26-Jun-08	0.0004	<0.0001	<0.001	1	<0.001
08-AG-242	RS	26-Jun-08	0.0005	<0.0001	<0.001	0.2	0.002
08-AG-243	RS	26-Jun-08	0.0009	<0.0001	0.002	0.6	0.015
08-AG-246	RS	30-Jun-08	0.0009	<0.0001	<0.001	<0.1	0.037
08-AG-247	RS	30-Jun-08	0.0006	<0.0001	<0.001	0.2	0.002
08-AG-248	RS	30-Jun-08	<0.0003	0.0002	<0.001	<0.1	0.007
08-AG-250	RS	30-Jun-08	0.0005	0.0001	<0.001	0.5	0.005
08-AG-251	RS	02-Jul-08	0.001	0.0003	<0.001	0.2	0.026

Sample	Sample Type	Date	Ta	Tb	Th	Ti	Tl
			µg/L	µg/L	µg/L	µg/L	µg/L
08-AG-252	RS	02-Jul-08	<0.0003	0.0002	<0.001	0.4	0.017
08-AG-253	RS	02-Jul-08	<0.0003	<0.0001	<0.001	0.2	0.025
08-AG-254	RS	02-Jul-08	0.0005	0.0004	<0.001	1.2	0.022
08-AG-255	RS	03-Jul-08	0.0004	<0.0001	<0.001	0.3	<0.001

* RS = Stations sampled as part of the regional study. †Stations in bold and numbered BW01-BW11 wells that were sampled as part of the local study. ‡RSBWZ – Regional wells located in the BWZ. "-" symbolizes parameter not measured. “<” symbolizes parameter is below detection limit.

Appendix Q. Trace Constituents: Tm, U, V, W, Y (Regional Study)

Sample	Sample Type	Date	Tm	U	V	W	Y
			µg/L	µg/L	µg/L	µg/L	µg/L
07-AG-005	*RS	21-Jun-07	<0.0001	0.0357	0.08	0.02	0.01
07-AG-006	RS	21-Jun-07	0.0001	0.0063	0.29	0.04	0.02
07-AG-008	RS	21-Jun-07	<0.0001	0.0221	0.06	0.07	0.09
07-AG-011	RS	23-Jun-07	<0.0001	0.0296	0.04	0.02	0.02
07-AG-014	RS	23-Jun-07	<0.0001	0.0448	0.03	0.01	0.01
07-AG-016	RS	23-Jun-07	0.001	2.428	0.24	<0.01	0.1
07-AG-020	RS	24-Jun-07	<0.0001	0.01	0.03	<0.01	0.01
07-AG-021	RS	24-Jun-07	<0.0001	0.0398	0.06	0.02	0.01
07-AG-025	RS	26-Jun-07	0.0002	0.0018	0.04	0.02	0.03
07-AG-026	**†BW09**	**26-Jun-07**	**<0.0001**	**0.513**	**0.08**	**0.02**	**0.02**
07-AG-029	RS	26-Jun-07	<0.0001	0.0443	0.06	<0.01	0.14
07-AG-030	RS	26-Jun-07	<0.0001	0.0052	0.05	0.02	0.01
07-AG-032	RS	26-Jun-07	<0.0001	0.0219	0.18	<0.01	0.01
07-AG-036	RS	27-Jun-07	0.0002	0.0559	0.04	<0.01	0.01
07-AG-038	RS	27-Jun-07	<0.0001	0.0308	0.12	0.03	0.01
07-AG-040	RS	28-Jun-07	0.0001	0.0044	0.04	0.05	0.01
07-AG-049	RS	29-Jun-07	0.0001	0.0014	0.09	0.04	0.01
07-AG-050	RS	04-Jul-07	<0.0001	0.2694	0.07	0.03	0.01
07-AG-056	RS	07-Jul-07	<0.0001	0.0104	0.05	0.04	0.01
07-AG-092	RS	12-Jul-07	0.0002	0.1263	0.06	0.12	0.01
07-AG-094	RS	12-Jul-07	0.0001	0.0005	0.02	0.03	0.01
07-AG-109	RS	18-Jul-07	<0.0001	0.0149	0.04	<0.01	0.01
07-AG-125	RS	18-Jul-07	<0.0001	0.0902	0.08	<0.01	0.06
07-AG-145	RS	24-Jul-07	0.0001	0.0007	0.08	0.09	0.01
07-AG-152	RS	24-Jul-07	<0.0001	0.0217	0.08	0.03	0
07-AG-155	RS	26-Jul-07	<0.0001	<0.0002	0.05	0.13	0
07-AG-214	RS	05-Aug-07	<0.0001	0.0229	0.02	0.03	0.01
08-AG-001	RS	13-May-08	<0.0001	0.01	0.03	0.13	0.02
08-AG-004	RS	13-May-08	<0.0001	0.0024	0.02	0.08	0.01
08-AG-005	RS	13-May-08	0.0002	0.3618	0.81	0.1	0.07
08-AG-007	‡RSBWZ	15-May-08	<0.0001	0.1514	0.01	<0.01	0.05
08-AG-010	**BW01**	**15-May-08**	**<0.0001**	**1.84**	**0.09**	**<0.01**	**0.23**
08-AG-012	**BW11**	**15-May-08**	**<0.0001**	**0.9126**	**0.01**	**<0.01**	**0.26**
08-AG-013	RSBWZ	15-May-08	<0.0001	0.5793	0.01	<0.01	0.72
08-AG-015	RSBWZ	15-May-08	<0.0001	2.12	0.03	<0.01	0.58
08-AG-017	RS	16-May-08	<0.0001	0.0562	0.02	0.04	0.01
08-AG-020	RSBWZ	15-May-08	0.0002	0.7402	0.01	<0.01	0.43
08-AG-021	**BW10**	**16-May-08**	**<0.0001**	**1.64**	**0.01**	**0.04**	**0.5**
08-AG-023	RS	16-May-08	0.0002	1.25	0.02	<0.01	0.11
08-AG-025	RS	16-May-08	<0.0001	0.2545	0.02	<0.01	0.09
08-AG-030	RS	16-May-08	<0.0001	0.1352	0.02	<0.01	0.01
08-AG-031	RS	16-May-08	<0.0001	0.2167	0.02	<0.01	0.08
08-AG-043	RS	20-May-08	<0.0001	0.1511	0.01	0.01	0.05
08-AG-046	RS	20-May-08	<0.0001	0.0345	0.04	0.02	0.02
08-AG-050	RS	20-May-08	<0.0001	0.0301	0.03	0.02	0.29
08-AG-053	RS	20-May-08	<0.0001	0.0113	0.05	0.01	0.03
08-AG-060	RSBWZ	21-May-08	<0.0001	0.3805	0.03	<0.01	0.56
08-AG-062	RS	21-May-08	<0.0001	0.025	0.03	<0.01	0.01

Sample	Sample Type	Date	Tm	U	V	W	Y
			µg/L	µg/L	µg/L	µg/L	µg/L
08-AG-085	RS	26-May-08	0.0001	1.15	0.01	<0.01	0.57
08-AG-086	RSBWZ	26-May-08	<0.0001	0.2509	0.01	<0.01	0.04
08-AG-087	**BW04**	**26-May-08**	**0.0002**	**0.8012**	**0.13**	**<0.01**	**0.18**
08-AG-100	RSBWZ	26-May-08	<0.0001	0.2659	0.01	<0.01	0.06
08-AG-102	RS	27-May-08	<0.0001	0.5872	0.01	<0.01	0.01
08-AG-103	RS	27-May-08	0.0001	0.2	0.01	<0.01	0.67
08-AG-105	**BW08**	**27-May-08**	**<0.0001**	**0.6026**	**0.01**	**<0.01**	**0.21**
08-AG-106	RS	28-May-08	<0.0001	0.1118	0.03	0.01	0.66
08-AG-107	RS	28-May-08	<0.0001	0.642	0.01	<0.01	0.11
08-AG-108	RS	28-May-08	<0.0001	0.0354	0.02	0.01	0.02
08-AG-120	RS	28-May-08	<0.0001	0.4029	0.21	<0.01	0.02
08-AG-121	RS	28-May-08	<0.0001	0.6036	0.01	<0.01	0.75
08-AG-122	RS	28-May-08	0.0002	0.0572	0.03	0.02	0.42
08-AG-153	RS	09-Jun-08	<0.0001	0.024	0.04	0.02	0.04
08-AG-157	RS	09-Jun-08	<0.0001	0.0418	0.03	<0.01	0
08-AG-162	RS	09-Jun-08	<0.0001	0.0794	0.02	<0.01	0.02
08-AG-164	RS	09-Jun-08	<0.0001	2.63	0.21	0.01	0.01
08-AG-165	RS	09-Jun-08	<0.0001	0.0269	0.02	<0.01	0.04
08-AG-167	**BW02**	**11-Jun-08**	**<0.0001**	**2.87**	**0.02**	**<0.01**	**0.08**
08-AG-181	RSBWZ	11-Jun-08	<0.0001	0.7529	0.08	<0.01	0.09
08-AG-183	**BW03**	**11-Jun-08**	**<0.0001**	**0.2203**	**0.01**	**0.01**	**0.18**
08-AG-188	RS	18-Jun-08	0.0003	0.0044	0.02	0.14	0.03
08-AG-190	RSBWZ	17-Jun-08	0.0001	0.1404	0.02	0.02	0.03
08-AG-193	RS	17-Jun-08	<0.0001	0.0166	0.05	0.11	0.01
08-AG-194	RS	18-Jun-08	<0.0001	0.0186	0.04	0.14	0.02
08-AG-197	RS	19-Jun-08	<0.0001	0.5958	0.01	<0.01	0.75
08-AG-202	RS	19-Jun-08	<0.0001	0.9723	0.03	<0.01	0.08
08-AG-203	RS	19-Jun-08	0.0001	0.3271	0.01	<0.01	0.03
08-AG-205	RS	20-Jun-08	<0.0001	0.0936	0.04	<0.01	0.08
08-AG-206	RS	20-Jun-08	0.0002	1.42	0.02	<0.01	0.26
08-AG-207	RS	20-Jun-08	<0.0001	16.1	0.27	<0.01	0.35
08-AG-208	RS	20-Jun-08	<0.0001	0.3231	0.02	<0.01	0.69
08-AG-211	**BW05**	**19-Jun-08**	**<0.0001**	**0.6857**	**0.02**	**0.01**	**0.7**
08-AG-214	RS	19-Jun-08	<0.0001	0.3012	0.08	<0.01	0.41
08-AG-215	RS	22-Jun-08	<0.0001	1.04	0.01	<0.01	0.24
08-AG-217	RSBWZ	22-Jun-08	<0.0001	0.4602	0.01	<0.01	0.33
08-AG-223	BW06	23-Jun-08	<0.0001	0.7891	0.02	<0.01	0.72
08-AG-225	RS	23-Jun-08	<0.0001	0.0272	0.01	0.03	0.02
08-AG-227	RS	23-Jun-08	<0.0001	0.087	0.02	0.02	0.11
08-AG-228	RS	24-Jun-08	0.0002	0.0951	0.02	<0.01	0.06
08-AG-231	RS	25-Jun-08	<0.0001	0.0274	0.01	<0.01	0.02
08-AG-232	RSBWZ	25-Jun-08	0.0001	0.2989	0.02	<0.01	0.04
08-AG-237	RS	26-Jun-08	<0.0001	0.0046	0.03	0.02	0.03
08-AG-242	RS	26-Jun-08	<0.0001	0.7413	0.08	<0.01	0.05
08-AG-243	RS	26-Jun-08	0.0001	5.84	0.04	<0.01	0.02
08-AG-246	RS	30-Jun-08	<0.0001	1.66	0.01	<0.01	0.09
08-AG-247	RS	30-Jun-08	<0.0001	0.6106	0.01	<0.01	0.04
08-AG-248	RS	30-Jun-08	0.0002	1.03	0.02	<0.01	0.03
08-AG-250	RS	30-Jun-08	0.0002	0.3909	0.01	<0.01	0.07
08-AG-251	RS	02-Jul-08	0.0003	0.6524	0.01	<0.01	0.09

Sample	Sample Type	Date	Tm	U	V	W	Y
			µg/L	µg/L	µg/L	µg/L	µg/L
08-AG-252	RS	02-Jul-08	0.0001	1.64	0.04	<0.01	0.26
08-AG-253	RS	02-Jul-08	<0.0001	1.59	0.56	<0.01	0.06
08-AG-254	RS	02-Jul-08	0.0005	2.2	0.01	<0.01	0.14
08-AG-255	RS	03-Jul-08	<0.0001	0.0107	0.01	0.03	0.02

* RS = Stations sampled as part of the regional study. †Stations in bold and numbered BW01-BW11 wells that were sampled as part of the local study. ‡RSBWZ – Regional wells located in the BWZ. "-" symbolizes parameter not measured. "<" symbolizes parameter is below detection limit.

Appendix R. Trace Constituents: Yb, Zn, Zr (Regional Study)

Sample	Sample Type	Date	Yb	Zn	Zr
			µg/L	µg/L	µg/L
07-AG-005	*RS	21-Jun-07	<0.001	1.2	<0.1
07-AG-006	RS	21-Jun-07	<0.001	12.1	<0.1
07-AG-008	RS	21-Jun-07	<0.001	1.5	<0.1
07-AG-011	RS	23-Jun-07	<0.001	42.2	<0.1
07-AG-014	RS	23-Jun-07	<0.001	11.7	<0.1
07-AG-016	RS	23-Jun-07	0.006	28.8	<0.1
07-AG-020	RS	24-Jun-07	<0.001	44.4	<0.1
07-AG-021	RS	24-Jun-07	<0.001	1.5	<0.1
07-AG-025	RS	26-Jun-07	<0.001	3.9	<0.1
07-AG-026	**†BW09**	**26-Jun-07**	**<0.001**	**21.3**	**<0.1**
07-AG-029	RS	26-Jun-07	<0.001	75.5	<0.1
07-AG-030	RS	26-Jun-07	<0.001	6.1	<0.1
07-AG-032	RS	26-Jun-07	<0.001	5.9	<0.1
07-AG-036	RS	27-Jun-07	<0.001	8.9	<0.1
07-AG-038	RS	27-Jun-07	<0.001	3.1	<0.1
07-AG-040	RS	28-Jun-07	<0.001	<1	<0.1
07-AG-049	RS	29-Jun-07	<0.001	5.1	<0.1
07-AG-050	RS	04-Jul-07	<0.001	2.5	<0.1
07-AG-056	RS	07-Jul-07	<0.001	<1	<0.1
07-AG-092	RS	12-Jul-07	<0.001	<1	<0.1
07-AG-094	RS	12-Jul-07	<0.001	72.7	<0.1
07-AG-109	RS	18-Jul-07	<0.001	1.6	<0.1
07-AG-125	RS	18-Jul-07	<0.001	1.3	<0.1
07-AG-145	RS	24-Jul-07	<0.001	<1	<0.1
07-AG-152	RS	24-Jul-07	<0.001	1.7	<0.1
07-AG-155	RS	26-Jul-07	<0.001	6.2	<0.1
07-AG-214	RS	05-Aug-07	<0.001	1	<0.1
08-AG-001	RS	13-May-08	<0.001	<5	<0.1
08-AG-004	RS	13-May-08	<0.001	<5	<0.1
08-AG-005	RS	13-May-08	<0.001	7	<0.1
08-AG-007	‡RSBWZ	15-May-08	<0.001	7	<0.1
08-AG-010	**BW01**	**15-May-08**	**<0.001**	**346**	**<0.1**
08-AG-012	**BW11**	**15-May-08**	**<0.001**	**668**	**<0.1**
08-AG-013	RSBWZ	15-May-08	<0.001	411	<0.1
08-AG-015	RSBWZ	15-May-08	<0.001	289.5	<0.1
08-AG-017	RS	16-May-08	<0.001	55	<0.1
08-AG-020	RSBWZ	15-May-08	<0.001	244	<0.1
08-AG-021	**BW10**	**16-May-08**	**<0.001**	**519**	**<0.1**
08-AG-023	RS	16-May-08	<0.001	31	<0.1
08-AG-025	RS	16-May-08	<0.001	11	<0.1
08-AG-030	RS	16-May-08	<0.001	<5	<0.1
08-AG-031	RS	16-May-08	<0.001	<5	<0.1
08-AG-043	RS	20-May-08	<0.001	8	<0.1
08-AG-046	RS	20-May-08	<0.001	<5	<0.1
08-AG-050	RS	20-May-08	<0.001	<5	<0.1
08-AG-053	RS	20-May-08	<0.001	18	<0.1
08-AG-060	RSBWZ	21-May-08	<0.001	749	<0.1
08-AG-062	RS	21-May-08	<0.001	57	<0.1

Sample	Sample Type	Date	Yb	Zn	Zr
			µg/L	µg/L	µg/L
08-AG-085	RS	26-May-08	<0.001	29	<0.1
08-AG-086	RSBWZ	26-May-08	<0.001	89	<0.1
08-AG-087	**BW04**	**26-May-08**	**<0.001**	**264**	**<0.1**
08-AG-100	RSBWZ	26-May-08	<0.001	46	<0.1
08-AG-102	RS	27-May-08	<0.001	65	<0.1
08-AG-103	RS	27-May-08	<0.001	58.5	<0.1
08-AG-105	**BW08**	**27-May-08**	**<0.001**	**170**	**<0.1**
08-AG-106	RS	28-May-08	<0.001	162	<0.1
08-AG-107	RS	28-May-08	<0.001	38	<0.1
08-AG-108	RS	28-May-08	<0.001	<5	<0.1
08-AG-120	RS	28-May-08	<0.001	82	<0.1
08-AG-121	RS	28-May-08	<0.001	33	<0.1
08-AG-122	RS	28-May-08	<0.001	181	<0.1
08-AG-153	RS	09-Jun-08	<0.001	<5	<0.1
08-AG-157	RS	09-Jun-08	<0.001	<5	<0.1
08-AG-162	RS	09-Jun-08	<0.001	20	<0.1
08-AG-164	RS	09-Jun-08	<0.001	19	<0.1
08-AG-165	RS	09-Jun-08	<0.001	19	<0.1
08-AG-167	**BW02**	**11-Jun-08**	**<0.001**	**393**	**<0.1**
08-AG-181	RSBWZ	11-Jun-08	<0.001	124	<0.1
08-AG-183	**BW03**	**11-Jun-08**	**<0.001**	**623**	**<0.1**
08-AG-188	RS	18-Jun-08	0.002	<5	<0.1
08-AG-190	RSBWZ	17-Jun-08	<0.001	55	<0.1
08-AG-193	RS	17-Jun-08	<0.001	14	<0.1
08-AG-194	RS	18-Jun-08	<0.001	<5	<0.1
08-AG-197	RS	19-Jun-08	<0.001	5	<0.1
08-AG-202	RS	19-Jun-08	<0.001	<5	<0.1
08-AG-203	RS	19-Jun-08	<0.001	24	<0.1
08-AG-205	RS	20-Jun-08	<0.001	<5	<0.1
08-AG-206	RS	20-Jun-08	<0.001	13	3
08-AG-207	RS	20-Jun-08	<0.001	22	<0.1
08-AG-208	RS	20-Jun-08	<0.001	<5	<0.1
08-AG-211	**BW05**	**19-Jun-08**	**<0.001**	**624**	**<0.1**
08-AG-214	RS	19-Jun-08	<0.001	<5	<0.1
08-AG-215	RS	22-Jun-08	<0.001	52	<0.1
08-AG-217	RSBWZ	22-Jun-08	<0.001	248	<0.1
08-AG-223	BW06	23-Jun-08	<0.001	247	<0.1
08-AG-225	RS	23-Jun-08	<0.001	13	<0.1
08-AG-227	RS	23-Jun-08	<0.001	23	<0.1
08-AG-228	RS	24-Jun-08	<0.001	<5	<0.1
08-AG-231	RS	25-Jun-08	<0.001	<5	<0.1
08-AG-232	RSBWZ	25-Jun-08	0.001	5	<0.1
08-AG-237	RS	26-Jun-08	<0.001	22	<0.1
08-AG-242	RS	26-Jun-08	<0.001	<5	<0.1
08-AG-243	RS	26-Jun-08	<0.001	<5	<0.1
08-AG-246	RS	30-Jun-08	<0.001	<5	<0.1
08-AG-247	RS	30-Jun-08	<0.001	9	<0.1
08-AG-248	RS	30-Jun-08	<0.001	47	<0.1
08-AG-250	RS	30-Jun-08	0.002	6	<0.1
08-AG-251	RS	02-Jul-08	0.002	196	<0.1

Sample	Sample Type	Date	Yb	Zn	Zr
			µg/L	µg/L	µg/L
08-AG-252	RS	02-Jul-08	<0.001	<5	<0.1
08-AG-253	RS	02-Jul-08	<0.001	124	<0.1
08-AG-254	RS	02-Jul-08	0.001	<5	<0.1
08-AG-255	RS	03-Jul-08	<0.001	<5	<0.1

* RS = Stations sampled as part of the regional study. †Stations in bold and numbered BW01-BW11 wells that were sampled as part of the local study. ‡RSBWZ – Regional wells located in the BWZ. "-" symbolizes parameter not measured. “<” symbolizes parameter is below detection limit.

Appendix S. Field Parameters (Local Study)

Station	Sample	Date	Temperature (°C)	pH	Conductivity (µS/cm)	Oxidation Reduction Potential (mV Ag-AgCl)	Dissolved Inorganic Carbon (mg/L)	Dissolved Organic Carbon (mg/L)
BW01	09-AG-238	29-Jul-09	-	-	-	-	-	-
BW01	09-BW01-01	19-Nov-09	-	-	-	-	-	-
BW01	09-BW01-02	18-Dec-09	-	-	-	-	-	-
BW01	10-BW01-03	5-Feb-10	-	-	-	-	-	-
BW01	10-BW01-04	26-Mar-10	-	-	-	-	-	-
BW01	10-BW01-05	23-Apr-10	-	-	-	-	-	-
BW01	10-BW01-06	14-May-10	-	-	-	-	-	-
BW01	10-BW01-07	15-Jun-10	10.55	7.3	1141	-71.0	59.4	0.5
BW01	10-BW01-07B	24-Jun-10	-	-	-	-	-	-
BW01	10-BW01-08	10-Jul-10	11.26	7.1	1158	170.3	-	-
BW01	10-BW01-10	11-Aug-10	10.41	-	1154	99.4	-	-
BW01	10-BW01-11	24-Sep-10	11.40	7.5	-	-45.0	-	-
BW01	10-AG-251	19-Oct-10	10.30	-	12	-35.7	-	-
BW02	09-BW02-00	29-Jul-09	-	-	-	-	-	-
BW02	09-BW02-01	19-Nov-09	-	-	-	-	-	-
BW02	09-BW02-02	18-Dec-09	-	-	-	-	-	-
BW02	10-BW02-03	5-Feb-10	-	-	-	-	-	-
BW02	10-BW02-04	26-Mar-10	-	-	-	-	-	-
BW02	10-BW02-05	23-Apr-10	-	-	-	-	-	-
BW02	10-BW02-06	14-May-10	-	-	-	-	-	-
BW02	10-BW02-07	15-Jun-10	11.27	7.2	1006	-229.0	66.6	0.5
BW02	10-BW02-07B	24-Jun-10	-	-	-	-	-	-
BW02	10-BW02-08	9-Jul-10	11.29	7.2	979	-80.3	-	-
BW02	10-BW02-10	11-Aug-10	11.40		1029	-47.6	-	-
BW02	10-BW02-11	24-Sep-10	11.90	7.5		-148.0	-	-
BW02	10-AG-274	20-Oct-10	-	-	-	-	-	-
BW03	09-BW03-00	30-Jun-09	-	-	-	-	-	-
BW03	09-BW03-01	19-Nov-09	-	-	-	-	-	-
BW03	09-BW03-02	19-Dec-09	-	-	-	-	-	-
BW03	10-BW03-04	26-Mar-10	-	-	-	-	-	-
BW03	10-BW03-05	23-Apr-10	-	-	-	-	-	-
BW03	10-BW03-06	14-May-10	-	-	-	-	-	-
BW03	10-BW03-07	15-Jun-10	11.03	7.4	539	-224.3	58.8	0.4
BW03	10-BW03-07B	24-Jun-10	-	-	-	-	-	-
BW03	10-BW03-08	9-Jul-10	10.55	7.4	535	-110.4	-	-
BW03	10-BW03-10	11-Aug-10	11.01	-	542	-61.0	-	-
BW03	10-BW03-11	24-Sep-10	11.60	7.7	-	-33.0	-	-
BW03	10-AG-254	20-Oct-10	9.96	-	542	-140.6	-	-
BW04	09-BW04-00	30-Jul-09	-	-	-	-	-	-
BW04	09-BW04-01	19-Nov-09	-	-	-	-	-	-
BW04	09-BW04-02	18-Dec-09	-	-	-	-	-	-
BW04	10-BW04-03	5-Feb-10	-	-	-	-	-	-
BW04	10-BW04-04	26-Mar-10	-	-	-	-	-	-
BW04	10-BW04-05	23-Apr-10	-	-	-	-	-	-
BW04	10-BW04-06	14-May-10	-	-	-	-	-	-
BW04	10-BW04-07	15-Jun-10	9.10	7.1	645	-116.6	64.2	0.4
BW04	10-BW04-07B	24-Jun-10	-	-	-	-	-	-
BW04	10-BW04-08	9-Jul-10	9.09	7.2	641	22.6	-	-
BW04	10-BW04-10	11-Aug-10	10.15	-	645	64.3	-	-
BW04	10-BW04-11	24-Sep-10	9.90	7.6	-	90.0	-	-
BW04	10-AG-271	20-Oct-10	9.11	7.5	454	-89.8	-	-
BW05	09-BW05-00	30-Jul-09	-	-	-	-	-	-
BW05	09-BW05-01	18-Nov-09	-	-	-	-	-	-
BW05	10-BW05-03	5-Feb-10	-	-	-	-	-	-
BW05	10-BW05-04	26-Mar-10	-	-	-	-	-	-
BW05	10-BW05-05	23-Apr-10	-	-	-	-	-	-

Station	Sample	Date	Temperature	pH	Conductivity	Oxidation Reduction Potential	Dissolved Inorganic Carbon	Dissolved Organic Carbon
			(°C)		(μS/cm)	(mV Ag-AgCl)	(mg/L)	(mg/L)
BW05	10-BW05-06	14-May-10	-	-	-	-	-	-
BW05	10-BW05-07	15-Jun-10	10.14	7.0	2215	-238.4	67.5	0.5
BW05	10-BW05-07B	24-Jun-10	-	-	-	-	-	-
BW05	10-BW05-08	9-Jul-10	10.42	7.2	2237	-112.4	-	-
BW05	10-BW05-10	11-Aug-10	10.54	-	2268	-100.0	-	-
BW05	10-BW05-11	24-Sep-10	11.40	7.6	-	-71.0	-	-
BW05	10-AG-268	20-Oct-10	9.97	7.5	2233	-169.1	-	-
BW06	09-BW06-00	30-Jul-09	-	-	-	-	-	-
BW06	09-BW06-01	19-Nov-09	-	-	-	-	-	-
BW06	09-BW06-02	18-Dec-09	-	-	-	-	-	-
BW06	10-BW06-03	5-Feb-10	-	-	-	-	-	-
BW06	10-BW06-04	26-Mar-10	-	-	-	-	-	-
BW06	10-BW06-05	23-Apr-10	-	-	-	-	-	-
BW06	10-BW06-06	14-May-10	-	-	-	-	-	-
BW06	10-BW06-07	15-Jun-10	10.65	7.1	756	-114.3	76.1	0.6
BW06	10-BW06-07B	24-Jun-10	-	-	-	-	-	-
BW06	10-BW06-08	9-Jul-10	10.66	7.1	757	73.1	-	-
BW06	10-BW06-10	11-Aug-10	10.54	-	751	88.7	-	-
BW06	10-BW06-11	24-Sep-10	10.80	7.5	-	69.0	-	-
BW06	10-AG-267	20-Oct-10	10.03	7.4	547	-71.1	-	-
BW08	09-BW08-00	31-Jul-09	-	-	-	-	-	-
BW08	09-BW08-01	19-Nov-09	-	-	-	-	-	-
BW08	09-BW08-02	18-Dec-09	-	-	-	-	-	-
BW08	10-BW08-03	5-Feb-10	-	-	-	-	-	-
BW08	10-BW08-04	26-Mar-10	-	-	-	-	-	-
BW08	10-BW08-05	23-Apr-10	-	-	-	-	-	-
BW08	10-BW08-06	14-May-10	-	-	-	-	-	-
BW08	10-BW08-07	15-Jun-10	11.00	7.2	1472	-264.3	48.0	0.8
BW08	10-BW08-07B	24-Jun-10	-	-	-	-	-	-
BW08	10-BW08-08	11-Jul-10	10.77	7.2	1485	-135.7	-	-
BW08	10-BW08-10	11-Aug-10	11.24	-	1498	-128.6	-	-
BW08	10-BW08-11	24-Sep-10	11.70	7.6	-	-96.0	-	-
BW08	10-AG-273	20-Oct-10	10.72	7.5	1497	-170.7	-	-
BW09	09-BW09-00	31-Jul-09	-	-	-	-	-	-
BW09	09-BW09-01	18-Nov-09	-	-	-	-	-	-
BW09	09-BW09-02	18-Dec-09	-	-	-	-	-	-
BW09	10-BW09-03A	1-Jan-10	-	-	-	-	-	-
BW09	10-BW09-03	1-Feb-10	-	-	-	-	-	-
BW09	10-BW09-04	1-Mar-10	-	-	-	-	-	-
BW09	10-BW09-05	23-Apr-10	-	-	-	-	-	-
BW09	10-BW09-06	14-May-10	-	-	-	-	-	-
BW09	10-BW09-07	15-Jun-10	11.64	7.3	732	-116.2	60.6	1.2
BW09	10-BW09-07B	24-Jun-10	-	-	-	-	-	-
BW09	10-BW09-08	12-Jul-10	11.13	7.2	776	150.0	-	-
BW09	10-BW09-10	11-Aug-10	12.93	-	747	80.7	-	-
BW09	10-BW09-11	24-Sep-10	11.60	7.5	-	50.0	-	-
BW09	10-AG-252	20-Oct-10	12.02		758	-70.5	-	-
BW10	09-BW10-00	6-Jul-09	-	-	-	-	-	-
BW10	09-BW10-01	18-Nov-09	-	-	-	-	-	-
BW10	09-BW10-02	19-Dec-09	-	-	-	-	-	-
BW10	10-BW10-03	5-Feb-10	-	-	-	-	-	-
BW10	10-BW10-04	26-Mar-10	-	-	-	-	-	-
BW10	10-BW10-05	23-Apr-10	-	-	-	-	-	-
BW10	10-BW10-06	14-May-10	-	-	-	-	-	-
BW10	10-BW10-07	15-Jun-10	12.28	7.2	608	-96.1	56.0	0.5
BW10	10-BW10-07B	24-Jun-10	-	-	-	-	-	-
BW10	10-BW10-08	13-Jul-10	13.37	7.3	596	161.1	-	-
BW10	10-BW10-10	11-Aug-10	14.13	-	613	140.6	-	-

Station	Sample	Date	Temperature	pH	Conductivity	Oxidation Reduction Potential	Dissolved Inorganic Carbon	Dissolved Organic Carbon
			(°C)		(µS/cm)	(mV Ag-AgCl)	(mg/L)	(mg/L)
BW10	10-BW10-11	24-Sep-10	14.50	7.6	-	50.0	-	-
BW10	10-AG-253	20-Oct-10	12.90		677	-59.4	-	-
BW11	09-BW11-01	19-Nov-09	-	-	-	-	-	-
BW11	09-BW11-02	19-Dec-09	-	-	-	-	-	-
BW11	10-BW11-03	5-Feb-10	-	-	-	-	-	-
BW11	10-BW11-04	26-Mar-10	-	-	-	-	-	-
BW11	10-BW11-05	23-Apr-10	-	-	-	-	-	-
BW11	10-BW11-06	14-May-10	-	-	-	-	-	-
BW11	10-BW11-07	15-Jun-10	16.07	7.1	1931	-246.2	51.2	0.5
BW11	10-BW11-07B	24-Jun-10	-	-	-	-	-	-
BW11	10-BW11-08	14-Jul-10	-	-	-	-	-	-
BW11	10-AG-250	19-Oct-10	12.31	-	2032	-134.9	-	-

"-" symbolizes parameter not measured. “<” symbolizes parameter is below detection limit.

Appendix T. Bacteriological Parameters (Local Study)

Station	Sample	Date	Total Coliform	Fecal Coliform
			counts/100mL	counts/100mL
BW01	09-AG-238	29-Jul-09	-	-
BW01	09-BW01-01	19-Nov-09	-	-
BW01	09-BW01-02	18-Dec-09	-	-
BW01	10-BW01-03	5-Feb-10	-	-
BW01	10-BW01-04	26-Mar-10	-	-
BW01	10-BW01-05	23-Apr-10	-	-
BW01	10-BW01-06	14-May-10	-	-
BW01	10-BW01-07	15-Jun-10	0.0	0.0
BW01	10-BW01-07B	24-Jun-10	-	-
BW01	10-BW01-08	10-Jul-10	-	-
BW01	10-BW01-10	11-Aug-10	-	-
BW01	10-BW01-11	24-Sep-10	-	-
BW01	10-AG-251	19-Oct-10	-	-
BW02	09-BW02-00	29-Jul-09	-	-
BW02	09-BW02-01	19-Nov-09	-	-
BW02	09-BW02-02	18-Dec-09	-	-
BW02	10-BW02-03	5-Feb-10	-	-
BW02	10-BW02-04	26-Mar-10	-	-
BW02	10-BW02-05	23-Apr-10	-	-
BW02	10-BW02-06	14-May-10	-	-
BW02	10-BW02-07	15-Jun-10	0.0	0.0
BW02	10-BW02-07B	24-Jun-10	-	-
BW02	10-BW02-08	9-Jul-10	-	-
BW02	10-BW02-10	11-Aug-10	-	-
BW02	10-BW02-11	24-Sep-10	-	-
BW02	10-AG-274	20-Oct-10	-	-
BW03	09-BW03-00	30-Jun-09	-	-
BW03	09-BW03-01	19-Nov-09	-	-
BW03	09-BW03-02	19-Dec-09	-	-
BW03	10-BW03-04	26-Mar-10	-	-
BW03	10-BW03-05	23-Apr-10	-	-
BW03	10-BW03-06	14-May-10	-	-
BW03	10-BW03-07	15-Jun-10	0.0	0.0
BW03	10-BW03-07B	24-Jun-10	-	-
BW03	10-BW03-08	9-Jul-10	-	-
BW03	10-BW03-10	11-Aug-10	-	-
BW03	10-BW03-11	24-Sep-10	-	-
BW03	10-AG-254	20-Oct-10	-	-
BW04	09-BW04-00	30-Jul-09	-	-
BW04	09-BW04-01	19-Nov-09	-	-
BW04	09-BW04-02	18-Dec-09	-	-
BW04	10-BW04-03	5-Feb-10	-	-
BW04	10-BW04-04	26-Mar-10	-	-
BW04	10-BW04-05	23-Apr-10	-	-
BW04	10-BW04-06	14-May-10	-	-
BW04	10-BW04-07	15-Jun-10	0.0	0.0
BW04	10-BW04-07B	24-Jun-10	-	-
BW04	10-BW04-08	9-Jul-10	-	-
BW04	10-BW04-10	11-Aug-10	-	-
BW04	10-BW04-11	24-Sep-10	-	-
BW04	10-AG-271	20-Oct-10	-	-
BW05	09-BW05-00	30-Jul-09	-	-
BW05	09-BW05-01	18-Nov-09	-	-
BW05	10-BW05-03	5-Feb-10	-	-
BW05	10-BW05-04	26-Mar-10	-	-
BW05	10-BW05-05	23-Apr-10	-	-

Station	Sample	Date	Total Coliform	Fecal Coliform
			counts/100mL	counts/100mL
BW05	10-BW05-06	14-May-10	-	-
BW05	10-BW05-07	15-Jun-10	0.0	0.0
BW05	10-BW05-07B	24-Jun-10	-	-
BW05	10-BW05-08	9-Jul-10	-	-
BW05	10-BW05-10	11-Aug-10	-	-
BW05	10-BW05-11	24-Sep-10	-	-
BW05	10-AG-268	20-Oct-10	-	-
BW06	09-BW06-00	30-Jul-09	-	-
BW06	09-BW06-01	19-Nov-09	-	-
BW06	09-BW06-02	18-Dec-09	-	-
BW06	10-BW06-03	5-Feb-10	-	-
BW06	10-BW06-04	26-Mar-10	-	-
BW06	10-BW06-05	23-Apr-10	-	-
BW06	10-BW06-06	14-May-10	-	-
BW06	10-BW06-07	15-Jun-10	0.0	0.0
BW06	10-BW06-07B	24-Jun-10	-	-
BW06	10-BW06-08	9-Jul-10	-	-
BW06	10-BW06-10	11-Aug-10	-	-
BW06	10-BW06-11	24-Sep-10	-	-
BW06	10-AG-267	20-Oct-10	-	-
BW08	09-BW08-00	31-Jul-09	-	-
BW08	09-BW08-01	19-Nov-09	-	-
BW08	09-BW08-02	18-Dec-09	-	-
BW08	10-BW08-03	5-Feb-10	-	-
BW08	10-BW08-04	26-Mar-10	-	-
BW08	10-BW08-05	23-Apr-10	-	-
BW08	10-BW08-06	14-May-10	-	-
BW08	10-BW08-07	15-Jun-10	0.0	0.0
BW08	10-BW08-07B	24-Jun-10	-	-
BW08	10-BW08-08	11-Jul-10	-	-
BW08	10-BW08-10	11-Aug-10	-	-
BW08	10-BW08-11	24-Sep-10	-	-
BW08	10-AG-273	20-Oct-10	-	-
BW09	09-BW09-00	31-Jul-09	-	-
BW09	09-BW09-01	18-Nov-09	-	-
BW09	09-BW09-02	18-Dec-09	-	-
BW09	10-BW09-03A	1-Jan-10	-	-
BW09	10-BW09-03	1-Feb-10	-	-
BW09	10-BW09-04	1-Mar-10	-	-
BW09	10-BW09-05	23-Apr-10	-	-
BW09	10-BW09-06	14-May-10	-	-
BW09	10-BW09-07	15-Jun-10	0.0	0.0
BW09	10-BW09-07B	24-Jun-10	-	-
BW09	10-BW09-08	12-Jul-10	-	-
BW09	10-BW09-10	11-Aug-10	-	-
BW09	10-BW09-11	24-Sep-10	-	-
BW09	10-AG-252	20-Oct-10	-	-
BW10	09-BW10-00	6-Jul-09	-	-
BW10	09-BW10-01	18-Nov-09	-	-
BW10	09-BW10-02	19-Dec-09	-	-
BW10	10-BW10-03	5-Feb-10	-	-
BW10	10-BW10-04	26-Mar-10	-	-
BW10	10-BW10-05	23-Apr-10	-	-
BW10	10-BW10-06	14-May-10	-	-
BW10	10-BW10-07	15-Jun-10	0.0	0.0
BW10	10-BW10-07B	24-Jun-10	-	-
BW10	10-BW10-08	13-Jul-10	-	-
BW10	10-BW10-10	11-Aug-10	-	-
BW10	10-BW10-11	24-Sep-10	-	-

Station	Sample	Date	Total Coliform	Fecal Coliform
			counts/100mL	counts/100mL
BW10	10-AG-253	20-Oct-10	-	-
BW11	09-BW11-01	19-Nov-09	-	-
BW11	09-BW11-02	19-Dec-09	-	-
BW11	10-BW11-03	5-Feb-10	-	-
BW11	10-BW11-04	26-Mar-10	-	-
BW11	10-BW11-05	23-Apr-10	-	-
BW11	10-BW11-06	14-May-10	-	-
BW11	10-BW11-07	15-Jun-10	-	-
BW11	10-BW11-07B	24-Jun-10	-	-
BW11	10-BW11-08	14-Jul-10	-	-
BW11	10-AG-250	19-Oct-10	-	-

"-" symbolizes parameter not measured. "<" symbolizes parameter is below detection limit.

Appendix U. Dissolved Gas Parameters (Local Study)

Station	Sample	Date	Dissolved Oxygen (DO)	Dissolved Methane (CH_4)	Dissolved Hydrogen Sulphide (H_2S)
			% saturation	% saturation	mg/L S^{2-}
BW01	09-AG-238	29-Jul-09	-	-	-
BW01	09-BW01-01	19-Nov-09	30.1	-	-
BW01	09-BW01-02	18-Dec-09	35.4	-	-
BW01	10-BW01-03	05-Feb-10	12.4	-	-
BW01	10-BW01-04	26-Mar-10	29.2	-	-
BW01	10-BW01-05	23-Apr-10	-	-	-
BW01	10-BW01-06	14-May-10	29.2	-	-
BW01	10-BW01-07	15-Jun-10	44.3	0.004	-
BW01	10-BW01-07B	24-Jun-10	-	-	-
BW01	10-BW01-08	10-Jul-10	46	-	-
BW01	10-BW01-10	11-Aug-10	21	-	-
BW01	10-BW01-11	24-Sep-10	35.4	-	-
BW01	10-AG-251	19-Oct-10	40.1	-	-
BW02	09-BW02-00	29-Jul-09	-	-	-
BW02	09-BW02-01	19-Nov-09	7.1	-	-
BW02	09-BW02-02	18-Dec-09	-	-	-
BW02	10-BW02-03	05-Feb-10	1.8	-	-
BW02	10-BW02-04	26-Mar-10	-	-	-
BW02	10-BW02-05	23-Apr-10	-	-	-
BW02	10-BW02-06	14-May-10	-	-	-
BW02	10-BW02-07	15-Jun-10	0.4	0.018	0.11
BW02	10-BW02-07B	24-Jun-10	-	-	-
BW02	10-BW02-08	09-Jul-10		-	0.25
BW02	10-BW02-10	11-Aug-10	0	-	-
BW02	10-BW02-11	24-Sep-10	0	-	-
BW02	10-AG-274	20-Oct-10	-	-	-
BW03	09-BW03-00	30-Jun-09	-	-	-
BW03	09-BW03-01	19-Nov-09	0	-	-
BW03	09-BW03-02	19-Dec-09	-	-	-
BW03	10-BW03-04	26-Mar-10	-	-	-
BW03	10-BW03-05	23-Apr-10	-	-	-
BW03	10-BW03-06	14-May-10	3.5	-	-
BW03	10-BW03-07	15-Jun-10	1.8	0.005	-
BW03	10-BW03-07B	24-Jun-10	-	-	-
BW03	10-BW03-08	09-Jul-10	3.1	-	-
BW03	10-BW03-10	11-Aug-10	1.4	-	-
BW03	10-BW03-11	24-Sep-10	0	-	-
BW03	10-AG-254	20-Oct-10	1.7	-	-
BW04	09-BW04-00	30-Jul-09	-	-	-
BW04	09-BW04-01	19-Nov-09	-	-	-
BW04	09-BW04-02	18-Dec-09	15.1	-	-
BW04	10-BW04-03	05-Feb-10	13.3	-	-

Station	Sample	Date	Dissolved Oxygen (DO)	Dissolved Methane (CH_4)	Dissolved Hydrogen Sulphide (H_2S)
			% saturation	% saturation	mg/L S^{2-}
BW04	10-BW04-04	26-Mar-10	10.6	-	-
BW04	10-BW04-05	23-Apr-10	-	-	-
BW04	10-BW04-06	14-May-10	11.5	-	-
BW04	10-BW04-07	15-Jun-10	11.8	0	-
BW04	10-BW04-07B	24-Jun-10	-	-	-
BW04	10-BW04-08	09-Jul-10	12.8	-	-
BW04	10-BW04-10	11-Aug-10	4.8	-	-
BW04	10-BW04-11	24-Sep-10	7.4	-	-
BW04	10-AG-271	20-Oct-10	11.6	-	-
BW05	09-BW05-00	30-Jul-09	-	-	-
BW05	09-BW05-01	18-Nov-09	0	-	-
BW05	10-BW05-03	05-Feb-10	1.8	-	-
BW05	10-BW05-04	26-Mar-10	-	-	-
BW05	10-BW05-05	23-Apr-10	-	-	-
BW05	10-BW05-06	14-May-10	0	-	-
BW05	10-BW05-07	15-Jun-10	-	0.006	0.37
BW05	10-BW05-07B	24-Jun-10	-	-	-
BW05	10-BW05-08	09-Jul-10	0.7	-	0.11
BW05	10-BW05-10	11-Aug-10	2.2	-	0.06
BW05	10-BW05-11	24-Sep-10	0	-	-
BW05	10-AG-268	20-Oct-10	0	-	0.21
BW06	09-BW06-00	30-Jul-09	-	-	-
BW06	09-BW06-01	19-Nov-09	6.2	-	-
BW06	09-BW06-02	18-Dec-09	12.4	-	-
BW06	10-BW06-03	05-Feb-10	7.1	-	-
BW06	10-BW06-04	26-Mar-10	-	-	-
BW06	10-BW06-05	23-Apr-10	-	-	-
BW06	10-BW06-06	14-May-10	18.6	-	-
BW06	10-BW06-07	15-Jun-10	30.2	0.004	-
BW06	10-BW06-07B	24-Jun-10	-	-	-
BW06	10-BW06-08	09-Jul-10	11.5	-	-
BW06	10-BW06-10	11-Aug-10	12.3	-	-
BW06	10-BW06-11	24-Sep-10	13.5	-	-
BW06	10-AG-267	20-Oct-10	20.7	-	-
BW08	09-BW08-00	31-Jul-09	-	-	-
BW08	09-BW08-01	19-Nov-09	0	-	-
BW08	09-BW08-02	18-Dec-09	-	-	-
BW08	10-BW08-03	05-Feb-10	1.8	-	-
BW08	10-BW08-04	26-Mar-10	-	-	-
BW08	10-BW08-05	23-Apr-10	-	-	-
BW08	10-BW08-06	14-May-10	-	-	-
BW08	10-BW08-07	15-Jun-10	-	0.004	0.12
BW08	10-BW08-07B	24-Jun-10	-	-	-
BW08	10-BW08-08	11-Jul-10	-	-	0.2
BW08	10-BW08-10	11-Aug-10	2.3	-	0.17

Station	Sample	Date	Dissolved Oxygen (DO)	Dissolved Methane (CH_4)	Dissolved Hydrogen Sulphide (H_2S)
			% saturation	% saturation	mg/L S^{2-}
BW08	10-BW08-11	24-Sep-10	0	-	-
BW08	10-AG-273	20-Oct-10	0	-	0.4
BW09	09-BW09-00	31-Jul-09	-	-	-
BW09	09-BW09-01	18-Nov-09	5.3	-	-
BW09	09-BW09-02	18-Dec-09	4.4	-	-
BW09	10-BW09-03A	01-Jan-10	-	-	-
BW09	10-BW09-03	01-Feb-10	-	-	-
BW09	10-BW09-04	01-Mar-10	-	-	-
BW09	10-BW09-05	23-Apr-10	-	-	-
BW09	10-BW09-06	14-May-10	14.2	-	-
BW09	10-BW09-07	15-Jun-10	9.2	0.007	-
BW09	10-BW09-07B	24-Jun-10	-	-	-
BW09	10-BW09-08	12-Jul-10	15.8	-	-
BW09	10-BW09-10	11-Aug-10	8.6	-	-
BW09	10-BW09-11	24-Sep-10	9.4	-	-
BW09	10-AG-252	20-Oct-10	-	-	-
BW10	09-BW10-00	06-Jul-09	-	-	-
BW10	09-BW10-01	18-Nov-09	21.3	-	-
BW10	09-BW10-02	19-Dec-09	11.5	-	-
BW10	10-BW10-03	05-Feb-10	6.2	-	-
BW10	10-BW10-04	26-Mar-10	-	-	-
BW10	10-BW10-05	23-Apr-10	-	-	-
BW10	10-BW10-06	14-May-10	12.4	-	-
BW10	10-BW10-07	15-Jun-10	7.8	0	-
BW10	10-BW10-07B	24-Jun-10	-	-	-
BW10	10-BW10-08	13-Jul-10	7.8	-	-
BW10	10-BW10-10	11-Aug-10	2.4	-	-
BW10	10-BW10-11	24-Sep-10	3.5	-	-
BW10	10-AG-253	20-Oct-10	16.3	-	-
BW11	09-BW11-01	19-Nov-09	0	-	-
BW11	09-BW11-02	19-Dec-09	0	-	-
BW11	10-BW11-03	05-Feb-10	0	-	-
BW11	10-BW11-04	26-Mar-10	0	-	-
BW11	10-BW11-05	23-Apr-10	-	-	-
BW11	10-BW11-06	14-May-10	0	-	-
BW11	10-BW11-07	15-Jun-10	1.2	0.021	-
BW11	10-BW11-07B	24-Jun-10	-	-	-
BW11	10-BW11-08	14-Jul-10	1.8	-	-
BW11	10-AG-250	19-Oct-10	0.5	-	-

"-" symbolizes parameter not measured. “<” symbolizes parameter is below detection limit.

Appendix V. Exhaled Gas Parameters (Local Study)

Station	Sample	Date	Oxygen (g) Field O_2 (%)	Carbon Dioxide (g) Field CO_2 (%)	Oxygen and Argon (g) Laboratory O_2 + Ar (v/v)	Carbon Dioxide (g) Laboratory $CO_{2\,(v/v)}$	Nitrogen (g) Laboratory $N_{2\,(v/v)}$
BW01	09-AG-238	29-Jul-09	18.2	0.6	-	-	-
BW01	09-BW01-01	19-Nov-09	18.4	0.7	-	-	-
BW01	09-BW01-02	18-Dec-09	-	-	-	-	-
BW01	10-BW01-03	05-Feb-10	-	-	-	-	-
BW01	10-BW01-04	26-Mar-10	-	-	-	-	-
BW01	10-BW01-05	23-Apr-10	-	-	-	-	-
BW01	10-BW01-06	14-May-10	-	-	-	-	-
BW01	10-BW01-07	15-Jun-10	-	-	-	-	
BW01	10-BW01-07B	24-Jun-10	18.3	0.7	19.3	0.8	79.9
BW01	10-BW01-08	10-Jul-10	-	-	-	-	-
BW01	10-BW01-10	11-Aug-10	-	-	-	-	-
BW01	10-BW01-11	24-Sep-10	-	-	-	-	-
BW01	10-AG-251	19-Oct-10	18	0.8	-	-	-
BW02	09-BW02-00	29-Jul-09	1.7	3.4	-	-	-
BW02	09-BW02-01	19-Nov-09	19.9	0.1	-	-	-
BW02	09-BW02-02	18-Dec-09	-	-	-	-	-
BW02	10-BW02-03	05-Feb-10	-	-	-	-	-
BW02	10-BW02-04	26-Mar-10	-	-	-	-	-
BW02	10-BW02-05	23-Apr-10	-	-	-	-	-
BW02	10-BW02-06	14-May-10	-	-	-	-	-
BW02	10-BW02-07	15-Jun-10	-	-	-	-	-
BW02	10-BW02-07B	24-Jun-10	15.6	1	17.7	0.9	81.4
BW02	10-BW02-08	09-Jul-10	18.3	0.5	-	-	-
BW02	10-BW02-10	11-Aug-10	-	-	-	-	-
BW02	10-BW02-11	24-Sep-10	-	-	-	-	-
BW02	10-AG-274	20-Oct-10	5.7	2.4	-	-	-
BW03	09-BW03-00	30-Jun-09	9.9	0.5	-	-	-
BW03	09-BW03-01	19-Nov-09	-	-	-	-	-
BW03	09-BW03-02	19-Dec-09	-	-	-	-	-
BW03	10-BW03-04	26-Mar-10	-	-	-	-	-
BW03	10-BW03-05	23-Apr-10	-	-	-	-	-
BW03	10-BW03-06	14-May-10	-	-	-	-	-
BW03	10-BW03-07	15-Jun-10	-	-			
BW03	10-BW03-07B	24-Jun-10	18	0.2	18.3	0.3	81.4
BW03	10-BW03-08	09-Jul-10	-	-	-	-	-
BW03	10-BW03-10	11-Aug-10	-	-	-	-	-
BW03	10-BW03-11	24-Sep-10	-	-	-	-	-
BW03	10-AG-254	20-Oct-10	16.5	0.3	-	-	-
BW04	09-BW04-00	30-Jul-09	18.3	0.2	-	-	-
BW04	09-BW04-01	19-Nov-09	18.4	0.3	-	-	-
BW04	09-BW04-02	18-Dec-09	-	-	-	-	-
BW04	10-BW04-03	05-Feb-10	-	-	-	-	-
BW04	10-BW04-04	26-Mar-10	-	-	-	-	-
BW04	10-BW04-05	23-Apr-10	-	-	-	-	-

Station	Sample	Date	Oxygen (g) Field O_2 (%)	Carbon Dioxide (g) Feild CO_2 (%)	Oxygen and Argon (g) Laboratory O_2 + Ar (v/v)	Carbon Dioxide (g) Laboratory $CO_{2\,(v/v)}$	Nitrogen (g) Laboratory $N_{2\,(v/v)}$
BW04	10-BW04-06	14-May-10	-	-	-	-	-
BW04	10-BW04-07	15-Jun-10	-	-	19.4	0.4	80.3
BW04	10-BW04-07B	24-Jun-10	-	-	-	-	-
BW04	10-BW04-08	09-Jul-10	18.4	0.2	-	-	-
BW04	10-BW04-10	11-Aug-10	-	-	-	-	-
BW04	10-BW04-11	24-Sep-10	-	-	-	-	-
BW04	10-AG-271	20-Oct-10	17.6	0.4	-	-	-
BW05	09-BW05-00	30-Jul-09	12.4	0.3	-	-	-
BW05	09-BW05-01	18-Nov-09	-	-	-	-	-
BW05	10-BW05-03	05-Feb-10	-	-	-	-	-
BW05	10-BW05-04	26-Mar-10	-	-	-	-	-
BW05	10-BW05-05	23-Apr-10	-	-	-	-	-
BW05	10-BW05-06	14-May-10	-	-	-	-	-
BW05	10-BW05-07	15-Jun-10	-	-	10.9	0.6	88.6
BW05	10-BW05-07B	24-Jun-10	-	-	-	-	-
BW05	10-BW05-08	09-Jul-10	8.9	0.5	-	-	-
BW05	10-BW05-10	11-Aug-10	-	-	-	-	-
BW05	10-BW05-11	24-Sep-10	-	-	-	-	-
BW05	10-AG-268	20-Oct-10	8.1	0.5	-	-	-
BW06	09-BW06-00	30-Jul-09	4.2	1.6	-	-	-
BW06	09-BW06-01	19-Nov-09	6.6	1.3	-	-	-
BW06	09-BW06-02	18-Dec-09	-	-	-	-	-
BW06	10-BW06-03	05-Feb-10	-	-	-	-	-
BW06	10-BW06-04	26-Mar-10	-	-	-	-	-
BW06	10-BW06-05	23-Apr-10	-	-	-	-	-
BW06	10-BW06-06	14-May-10	-	-	-	-	-
BW06	10-BW06-07	15-Jun-10	-	-	11	1.3	87.7
BW06	10-BW06-07B	24-Jun-10	-	-	-	-	-
BW06	10-BW06-08	09-Jul-10	-	-	-	-	-
BW06	10-BW06-10	11-Aug-10	8.9	1	-	-	-
BW06	10-BW06-11	24-Sep-10	-	-	-	-	-
BW06	10-AG-267	20-Oct-10	8.2	1.4	-	-	-
BW08	09-BW08-00	31-Jul-09	-	-	-	-	-
BW08	09-BW08-01	19-Nov-09	-	-	-	-	-
BW08	09-BW08-02	18-Dec-09	-	-	-	-	-
BW08	10-BW08-03	05-Feb-10	-	-	-	-	-
BW08	10-BW08-04	26-Mar-10	-	-	-	-	-
BW08	10-BW08-05	23-Apr-10	-	-	-	-	-
BW08	10-BW08-06	14-May-10	-	-	-	-	-
BW08	10-BW08-07	15-Jun-10	-	-	-	-	-
BW08	10-BW08-07B	24-Jun-10	-	-	17.1	0.2	82.7
BW08	10-BW08-08	11-Jul-10	-	-	-	-	-
BW08	10-BW08-10	11-Aug-10	20.9	0.04	-	-	-
BW08	10-BW08-11	24-Sep-10	-	-	-	-	-
BW08	10-AG-273	20-Oct-10	-	-	-	-	-

Station	Sample	Date	Oxygen (g) Field O_2 (%)	Carbon Dioxide (g) Feild CO_2 (%)	Oxygen and Argon (g) Laboratory O_2 + Ar (v/v)	Carbon Dioxide (g) Laboratory $CO_{2\ (v/v)}$	Nitrogen (g) Laboratory $N_{2\ (v/v)}$
BW09	09-BW09-00	31-Jul-09	-	-	-	-	-
BW09	09-BW09-01	18-Nov-09	-	-	-	-	-
BW09	09-BW09-02	18-Dec-09	-	-	-	-	-
BW09	10-BW09-03A	01-Jan-10	-	-	-	-	-
BW09	10-BW09-03	01-Feb-10	-	-	-	-	-
BW09	10-BW09-04	01-Mar-10	-	-	-	-	-
BW09	10-BW09-05	23-Apr-10	-	-	-	-	-
BW09	10-BW09-06	14-May-10	-	-	-	-	-
BW09	10-BW09-07	15-Jun-10	-	-			
BW09	10-BW09-07B	24-Jun-10	-	-	20.7	0.5	78.8
BW09	10-BW09-08	12-Jul-10	-	-	-	-	-
BW09	10-BW09-10	11-Aug-10	17.9	1.22	-	-	-
BW09	10-BW09-11	24-Sep-10	-	-	-	-	-
BW09	10-AG-252	20-Oct-10	-	-	-	-	-
BW10	09-BW10-00	06-Jul-09	-	-	-	-	-
BW10	09-BW10-01	18-Nov-09	-	-	-	-	-
BW10	09-BW10-02	19-Dec-09	-	-	-	-	-
BW10	10-BW10-03	05-Feb-10	-	-	-	-	-
BW10	10-BW10-04	26-Mar-10	-	-	-	-	-
BW10	10-BW10-05	23-Apr-10	-	-	-	-	-
BW10	10-BW10-06	14-May-10	-	-	-	-	-
BW10	10-BW10-07	15-Jun-10	-	-	20.2	0.9	78.9
BW10	10-BW10-07B	24-Jun-10	17.9	1.2	-	-	-
BW10	10-BW10-08	13-Jul-10	-	-	-	-	-
BW10	10-BW10-10	11-Aug-10	-	-	-	-	-
BW10	10-BW10-11	24-Sep-10	-	-	-	-	-
BW10	10-AG-253	20-Oct-10	17.4	1.3	-	-	-
BW11	09-BW11-01	19-Nov-09	16.6	0.1	-	-	-
BW11	09-BW11-02	19-Dec-09	-	-	-	-	-
BW11	10-BW11-03	05-Feb-10	-	-	-	-	-
BW11	10-BW11-04	26-Mar-10	-	-	-	-	-
BW11	10-BW11-05	23-Apr-10	-	-	-	-	-
BW11	10-BW11-06	14-May-10	-	-	-	-	-
BW11	10-BW11-07	15-Jun-10	-	-	18.6	0.3	81.1
BW11	10-BW11-07B	24-Jun-10	17.5	0.1	-	-	-
BW11	10-BW11-08	14-Jul-10	17.8	0.2	-	-	-
BW11	10-AG-250	19-Oct-10	10.5	0.5	-	-	-

"-" symbolizes parameter not measured. “<” symbolizes parameter is below detection limit.

Appendix W. Isotopic Parameters (Local Study)

Station	Sample	Date	$\delta^{18}O$ (H_2O)	$\delta^{2}H$(H_2O)	E^3H	$\delta^{18}O$ (SO_4)	$\delta^{34}S$(SO_4)
			‰VSMOW	‰VSMOW	TU	‰VSMOW	‰VCDT
BW01	09-AG-238	29-Jul-09	-	-	-	-	-
BW01	09-BW01-01	19-Nov-09	-11.5	-76	-	-	-
BW01	09-BW01-02	18-Dec-09	-11.5	-74	-	-	-
BW01	10-BW01-03	5-Feb-10	-11.4	-76	-	-	-
BW01	10-BW01-04	26-Mar-10	-11.5	-75	-	-	-
BW01	10-BW01-05	23-Apr-10	-11.3	-75	-	-	-
BW01	10-BW01-06	14-May-10	-11.4	-75	1.2	-	-
BW01	10-BW01-07	15-Jun-10	-11.3	-75	-	-	-
BW01	10-BW01-07B	24-Jun-10	-	-	-	-	-
BW01	10-BW01-08	10-Jul-10	-11.5	-75	-	14.1	27.0
BW01	10-BW01-10	11-Aug-10	-11.3	-75	-	-	-
BW01	10-BW01-11	24-Sep-10	-11.4	-74	-	-	-
BW01	10-AG-251	19-Oct-10	-11.4	-75	-	14.4	26.9
BW02	09-BW02-00	29-Jul-09	-	-	-	-	-
BW02	09-BW02-01	19-Nov-09	-11.3	-76	-	-	-
BW02	09-BW02-02	18-Dec-09	-11.5	-75	-	-	-
BW02	10-BW02-03	5-Feb-10	-11.5	-76	-	-	-
BW02	10-BW02-04	26-Mar-10	-11.3	-76	-	-	-
BW02	10-BW02-05	23-Apr-10	-11.4	-75	-	-	-
BW02	10-BW02-06	14-May-10	-11.2	-75	0.8	-	-
BW02	10-BW02-07	15-Jun-10	-11.2	-75	-	-	-
BW02	10-BW02-07B	24-Jun-10	-	-	-	-	-
BW02	10-BW02-08	9-Jul-10	-11.4	-76	-	2.0	-1.5
BW02	10-BW02-10	11-Aug-10	-11.2	-75	-	-	-
BW02	10-BW02-11	24-Sep-10	-11.3	-75	-	-	-
BW02	10-AG-274	20-Oct-10	-11.6	-76	-	1.0	-1.5
BW03	09-BW03-00	30-Jun-09	-	-	-	-	-
BW03	09-BW03-01	19-Nov-09	-12.1	-80	-	-	-
BW03	09-BW03-02	19-Dec-09	-12.0	-80	-	-	-
BW03	10-BW03-04	26-Mar-10	-11.9	-81	-	-	-
BW03	10-BW03-05	23-Apr-10	-12.0	-80	-	-	-
BW03	10-BW03-06	14-May-10	-12.0	-79	0.8	-	-
BW03	10-BW03-07	15-Jun-10	-11.9	-79	-	-	-
BW03	10-BW03-07B	24-Jun-10	-	-	-	-	-
BW03	10-BW03-08	9-Jul-10	-12.1	-80	-		
BW03	10-BW03-10	11-Aug-10	-12.0	-80	-	-	-
BW03	10-BW03-11	24-Sep-10	-12.0	-79	-	-	-
BW03	10-AG-254	20-Oct-10	-12.1	-80	-	16.0	20.4
BW04	09-BW04-00	30-Jul-09	-	-	-	-	-
BW04	09-BW04-01	19-Nov-09	-12.0	-80	-	-	-
BW04	09-BW04-02	18-Dec-09	-11.9	-79	-	-	-
BW04	10-BW04-03	5-Feb-10	-11.9	-79	-	-	-
BW04	10-BW04-04	26-Mar-10	-11.8	-79	-	-	-
BW04	10-BW04-05	23-Apr-10	-11.7	-78	-	-	-
BW04	10-BW04-06	14-May-10	-11.6	-77	4.5	-	-
BW04	10-BW04-07	15-Jun-10	-11.4	-77	-	-	-
BW04	10-BW04-07B	24-Jun-10	-	-	-	-	-
BW04	10-BW04-08	9-Jul-10	-11.9	-77	-	11.1	16.1
BW04	10-BW04-10	11-Aug-10	-11.5	-77	-	-	-
BW04	10-BW04-11	24-Sep-10	-11.6	-78	-	-	-
BW04	10-AG-271	20-Oct-10	-11.7	-77		10.6	15.0
BW05	09-BW05-00	30-Jul-09	-	-	-	-	-
BW05	09-BW05-01	18-Nov-09	-11.8	-79	-	-	-
BW05	10-BW05-03	5-Feb-10	-11.7	-78	-	-	-
BW05	10-BW05-04	26-Mar-10	-11.9	-79	-	-	-
BW05	10-BW05-05	23-Apr-10	-11.5	-78	-	-	-
BW05	10-BW05-06	14-May-10	-11.9	-77	0.8	-	-
BW05	10-BW05-07	15-Jun-10	-11.7	-78	-	-	-

Station	Sample	Date	$\delta^{18}O$ (H_2O)	δ^2H(H_2O)	E^3H	$\delta^{18}O$ (SO_4)	$\delta^{34}S$(SO_4)
			‰VSMOW	‰VSMOW	TU	‰VSMOW	‰VCDT
BW05	10-BW05-07B	24-Jun-10	-	-	-	-	-
BW05	10-BW05-08	9-Jul-10	-11.9	-78	-	13.1	25.3
BW05	10-BW05-10	11-Aug-10	-11.5	-78	-	-	-
BW05	10-BW05-11	24-Sep-10	-11.8	-78	-	-	-
BW05	10-AG-268	20-Oct-10	-11.8	-78	-	12.9	24.7
BW06	09-BW06-00	30-Jul-09	-	-	-	-	-
BW06	09-BW06-01	19-Nov-09	-11.7	-78	-	-	-
BW06	09-BW06-02	18-Dec-09	-11.8	-78	-	-	-
BW06	10-BW06-03	5-Feb-10	-11.8	-78	-	-	-
BW06	10-BW06-04	26-Mar-10	-11.7	-78	-	-	-
BW06	10-BW06-05	23-Apr-10	-11.6	-77	-	-	-
BW06	10-BW06-06	14-May-10	-11.6	-75	6.1	-	-
BW06	10-BW06-07	15-Jun-10	-11.6	-78	-	-	-
BW06	10-BW06-07B	24-Jun-10	-	-	-	-	-
BW06	10-BW06-08	9-Jul-10	-11.9	-78	-	5.6	4.2
BW06	10-BW06-10	11-Aug-10	-11.3	-76	-	-	-
BW06	10-BW06-11	24-Sep-10	-11.8	-77	-	-	-
BW06	10-AG-267	20-Oct-10	-11.8	-77	-	4.8	3.3
BW08	09-BW08-00	31-Jul-09	-	-	-	-	-
BW08	09-BW08-01	19-Nov-09	-11.6	-77	-	-	-
BW08	09-BW08-02	18-Dec-09	-	-	-	-	-
BW08	10-BW08-03	5-Feb-10	-11.6	-78	-	-	-
BW08	10-BW08-04	26-Mar-10	-11.7	-79	-	-	-
BW08	10-BW08-05	23-Apr-10	-11.7	-77	-	-	-
BW08	10-BW08-06	14-May-10	-11.7	-77	2.0	-	-
BW08	10-BW08-07	15-Jun-10	-11.6	-77	-	-	-
BW08	10-BW08-07B	24-Jun-10	-	-	-	-	-
BW08	10-BW08-08	11-Jul-10	-11.8	-77	-	-	-
BW08	10-BW08-10	11-Aug-10	-11.3	-76	-	-	-
BW08	10-BW08-11	24-Sep-10	-11.6	-77	-	-	-
BW08	10-AG-273	20-Oct-10	-11.8	-77	-	13.0	26.8
BW09	09-BW09-00	31-Jul-09	-	-	-	-	-
BW09	09-BW09-01	18-Nov-09	-11.0	-72	-	-	-
BW09	09-BW09-02	18-Dec-09	-11.0	-73	-	-	-
BW09	10-BW09-03A	1-Jan-10	-10.7	-73	-	-	-
BW09	10-BW09-03	1-Feb-10	-10.9	-72	-	-	-
BW09	10-BW09-04	1-Mar-10	-10.7	-73	-	-	-
BW09	10-BW09-05	23-Apr-10	-11.1	-72	-	-	-
BW09	10-BW09-06	14-May-10	-11.0	-72	5.4	-	-
BW09	10-BW09-07	15-Jun-10	-10.8	-71	-	-	-
BW09	10-BW09-07B	24-Jun-10	-	-	-	-	-
BW09	10-BW09-08	12-Jul-10	-10.9	-72	-	13.3	23.4
BW09	10-BW09-10	11-Aug-10	-10.6	-71	-	-	-
BW09	10-BW09-11	24-Sep-10	-11.0	-72	-	-	-
BW09	10-AG-252	20-Oct-10	-10.9	-71	-	13.7	23.3
BW10	09-BW10-00	6-Jul-09	-	-	-	-	-
BW10	09-BW10-01	18-Nov-09	-11.7	-78	-	-	-
BW10	09-BW10-02	19-Dec-09	-11.7	-78	-	-	-
BW10	10-BW10-03	5-Feb-10	-11.9	-78	-	-	-
BW10	10-BW10-04	26-Mar-10	-11.8	-78	-	-	-
BW10	10-BW10-05	23-Apr-10	-11.6	-78	-	-	-
BW10	10-BW10-06	14-May-10	-11.6	-78	0.8	-	-
BW10	10-BW10-07	15-Jun-10	-11.7	-77	-	-	-
BW10	10-BW10-07B	24-Jun-10	-	-	-	-	-
BW10	10-BW10-08	13-Jul-10	-11.7	-77	-	4.1	3.9
BW10	10-BW10-10	11-Aug-10	-11.3	-77	-	-	-
BW10	10-BW10-11	24-Sep-10	-11.7	-78	-	-	-
BW10	10-AG-253	20-Oct-10	-11.8	-78	-	0.3	-1.5
BW11	09-BW11-01	19-Nov-09	-11.3	-75	-	-	-
BW11	09-BW11-02	19-Dec-09	-11.0	-75	-	-	-

Station	Sample	Date	$\delta^{18}O$ (H_2O)	$\delta^{2}H$(H_2O)	E^3H	$\delta^{18}O$ (SO_4)	$\delta^{34}S$(SO_4)
			‰VSMOW	‰VSMOW	TU	‰VSMOW	‰VCDT
BW11	10-BW11-03	5-Feb-10	-11.4	-75	-	-	-
BW11	10-BW11-04	26-Mar-10	-11.2	-76	-	-	-
BW11	10-BW11-05	23-Apr-10	-11.2	-75	-	-	-
BW11	10-BW11-06	14-May-10	-11.3	-74	0.8	-	-
BW11	10-BW11-07	15-Jun-10	-11.0	-74	-	-	-
BW11	10-BW11-07B	24-Jun-10	-	-	-	-	-
BW11	10-BW11-08	14-Jul-10	-11.2	-74	-	16.8	26.3
BW11	10-AG-250	19-Oct-10	-11.5	-75	-	16.5	25.9

"-" symbolizes parameter not measured. “<” symbolizes parameter is below detection limit.

Appendix X. Major Constituents (Local Study)

Station	Sample	Date	Ca^{2+}	Mg^{2+}	K^{+}	Na^{+}	HCO_3^{-}	SO_4^{2-}	Cl^{-}	F^{-}
			mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
BW01	09-AG-238	29-Jul-09	-	-	-	-	-	-	-	-
BW01	09-BW01-01	19-Nov-09	172.5	55.2	0.7	9.3	-	458.4	3.8	1.8
BW01	09-BW01-02	18-Dec-09	170.2	52.8	0.8	7.4	-	433.5	4.3	1.8
BW01	10-BW01-03	5-Feb-10	157.1	50.0	0.8	7.5	-	430.4	4.4	1.4
BW01	10-BW01-04	26-Mar-10	166.2	53.3	0.8	8.3	-	456.3	4.1	1.5
BW01	10-BW01-05	23-Apr-10	186.3	58.3	0.8	8.6	-	455.4	4.4	1.5
BW01	10-BW01-06	14-May-10	177.5	54.7	0.8	8.6	311.0	424.7	4.8	1.5
BW01	10-BW01-07	15-Jun-10	173.1	51.3	0.8	8.6	241.0	413.1	4.9	1.5
BW01	10-BW01-07B	24-Jun-10	-	-	-	-	-	-	-	-
BW01	10-BW01-08	10-Jul-10	160.9	51.2	0.8	7.3	252.0	432.1	4.5	1.5
BW01	10-BW01-10	11-Aug-10	173.3	53.7	0.8	8.9	266.0	441.8	4.3	1.6
BW01	10-BW01-11	24-Sep-10	171.6	53.6	0.8	9.0	284.0	482.8	4.6	1.7
BW01	10-AG-251	19-Oct-10	173.2	53.8	0.9	9.4	335.0	444.3	4.8	1.6
BW02	09-BW02-00	29-Jul-09	-	-	-	-	-	-	-	-
BW02	09-BW02-01	19-Nov-09	118.6	48.6	0.9	14.4	-	341.5	7.3	1.4
BW02	09-BW02-02	18-Dec-09	119.7	47.2	1.0	13.4	-	302.2	8.1	1.4
BW02	10-BW02-03	5-Feb-10	124.1	48.8	0.9	14.6	-	306.8	7.9	1.1
BW02	10-BW02-04	26-Mar-10	123.1	48.1	0.9	13.5	-	316.6	7.7	1.3
BW02	10-BW02-05	23-Apr-10	136.0	51.8	1.0	16.0	-	313.3	7.9	1.3
BW02	10-BW02-06	14-May-10	136.7	52.2	0.9	16.4	338.0	316.8	8.0	1.3
BW02	10-BW02-07	15-Jun-10	136.7	50.9	1.1	17.1	282.0	335.9	7.6	1.3
BW02	10-BW02-07B	24-Jun-10	-	-	-	-	-	-	-	-
BW02	10-BW02-08	9-Jul-10	122.6	48.1	1.0	13.9	286.0	317.3	7.8	1.3
BW02	10-BW02-10	11-Aug-10	133.4	51.0	1.1	17.1	300.0	325.9	7.5	1.3
BW02	10-BW02-11	24-Sep-10	128.6	49.5	1.0	16.3	281.0	340.5	8.2	1.3
BW02	10-AG-274	20-Oct-10	134.0	51.5	1.2	17.4	-	351.4	8.4	1.3
BW03	09-BW03-00	30-Jun-09	-	-	-	-	-	-	-	-
BW03	09-BW03-01	19-Nov-09	31.4	20.3	0.5	5.0	-	60.7	0.4	1.8
BW03	09-BW03-02	19-Dec-09	29.1	20.3	0.5	4.8	-	60.9	0.4	1.8
BW03	10-BW03-04	26-Mar-10	61.8	19.6	0.5	5.1	-	57.7	0.3	1.7
BW03	10-BW03-05	23-Apr-10	69.5	21.7	0.5	5.6	-	58.0	0.3	1.6
BW03	10-BW03-06	14-May-10	69.9	21.6	0.6	6.0	261.0	58.3	0.3	1.0
BW03	10-BW03-07	15-Jun-10	70.9	19.7	0.6	6.2	232.0	58.0	0.3	1.6
BW03	10-BW03-07B	24-Jun-10	-	-	-	-	-	-	-	-
BW03	10-BW03-08	9-Jul-10	63.2	19.7	0.6	5.9	263.0	58.1	0.3	1.4
BW03	10-BW03-10	11-Aug-10	54.9	20.4	0.6	5.8	292.0	58.0	0.4	1.6
BW03	10-BW03-11	24-Sep-10	55.9	20.1	0.6	5.9	296.0	61.3	0.5	1.7
BW03	10-AG-254	20-Oct-10	55.8	20.0	0.7	6.3	286.0	60.6	0.5	1.7
BW04	09-BW04-00	30-Jul-09	-	-	-	-	-	-	-	-
BW04	09-BW04-01	19-Nov-09	82.4	22.9	0.8	8.8	-	38.7	6.2	0.8
BW04	09-BW04-02	18-Dec-09	78.7	20.6	1.0	7.8	-	45.0	8.2	0.8
BW04	10-BW04-03	5-Feb-10	91.4	22.3	0.8	10.0	-	58.4	12.7	0.7
BW04	10-BW04-04	26-Mar-10	90.6	22.5	0.8	10.4	-	61.6	13.5	0.8
BW04	10-BW04-05	23-Apr-10	93.8	25.6	0.8	10.7	-	64.3	14.2	0.8
BW04	10-BW04-06	14-May-10	93.2	25.5	0.8	10.6	254.0	64.8	14.4	0.8
BW04	10-BW04-07	15-Jun-10	89.1	23.3	0.8	11.0	304.0	64.3	14.4	0.8
BW04	10-BW04-07B	24-Jun-10	-	-	-	-	-	-	-	-
BW04	10-BW04-08	9-Jul-10	94.2	24.9	0.9	35.2	273.0	77.0	36.3	0.8
BW04	10-BW04-10	11-Aug-10	81.0	24.4	0.8	10.4	273.0	62.1	13.7	0.8
BW04	10-BW04-11	24-Sep-10	81.1	23.5	0.8	10.5	297.0	64.7	14.5	0.9
BW04	10-AG-271	20-Oct-10	83.0	23.7	0.9	11.3	285.0	65.6	15.0	0.9
BW05	09-BW05-00	30-Jul-09	-	-	-	-	-	-	-	-
BW05	09-BW05-01	18-Nov-09	88.7	42.3	1.2	275.6	-	246.8	419.4	1.8
BW05	10-BW05-03	5-Feb-10	-	-	-	-	-	-	-	-
BW05	10-BW05-04	26-Mar-10	102.6	40.3	1.2	276.0	-	244.9	405.1	0.9
BW05	10-BW05-05	23-Apr-10	120.8	45.5	1.2	305.0	-	247.8	405.4	1.6
BW05	10-BW05-06	14-May-10	120.2	45.3	1.2	310.0	354.0	247.6	404.5	1.6

Station	Sample	Date	Ca^{2+}	Mg^{2+}	K^{+}	Na^{+}	HCO_3^{-}	SO_4^{2-}	Cl^{-}	F^{-}
			mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
BW05	10-BW05-07	15-Jun-10	114.7	41.4	1.3	315.0	371.0	240.4	391.5	1.2
BW05	10-BW05-07B	24-Jun-10	-	-	-	-	-	-	-	-
BW05	10-BW05-08	9-Jul-10	107.0	41.4	1.3	314.0	297.0	246.2	404.6	1.0
BW05	10-BW05-10	11-Aug-10	98.7	42.3	1.5	308.0	316.0	244.9	403.7	0.9
BW05	10-BW05-11	24-Sep-10	99.1	42.2	1.4	339.0	334.0	245.7	425.3	1.7
BW05	10-AG-268	20-Oct-10	111.8	41.7	1.5	340.0	332.0	248.1	432.5	1.6
BW06	09-BW06-00	30-Jul-09	-	-	-	-	-	-	-	-
BW06	09-BW06-01	19-Nov-09	74.0	34.1	0.8	5.2	-	95.0	14.0	1.8
BW06	09-BW06-02	18-Dec-09	72.2	33.8	1.0	6.4	-	92.0	17.5	1.7
BW06	10-BW06-03	5-Feb-10	97.4	32.0	1.0	7.2	-	84.0	18.2	1.4
BW06	10-BW06-04	26-Mar-10	97.8	32.6	1.1	7.6	-	84.0	18.9	1.4
BW06	10-BW06-05	23-Apr-10	99.8	35.7	1.0	7.5	-	82.5	20.1	1.4
BW06	10-BW06-06	14-May-10	100.7	35.7	1.1	8.0	318.0	80.0	22.3	1.4
BW06	10-BW06-07	15-Jun-10	93.7	32.4	1.0	7.0	328.0	84.7	17.3	1.5
BW06	10-BW06-07B	24-Jun-10	-	-	-	-	-	-	-	-
BW06	10-BW06-08	9-Jul-10	95.2	33.5	0.8	5.1	314.0	102.3	5.6	1.7
BW06	10-BW06-10	11-Aug-10	85.5	34.0	1.2	7.2	318.0	84.4	18.8	1.5
BW06	10-BW06-11	24-Sep-10	85.4	33.8	1.0	5.7	337.0	98.3	13.1	1.7
BW06	10-AG-267	20-Oct-10	87.2	33.6	1.2	7.2	415.0	92.7	18.2	1.6
BW08	09-BW08-00	31-Jul-09	-	-	-	-	-	-	-	-
BW08	09-BW08-01	19-Nov-09	241.7	51.9	0.8	26.2	-	685.5	21.9	2.0
BW08	09-BW08-02	18-Dec-09	-	-	-	-	-	-	-	-
BW08	10-BW08-03	5-Feb-10	-	-	-	-	-	-	-	-
BW08	10-BW08-04	26-Mar-10	224.6	50.2	0.9	25.7	-	677.9	20.9	1.6
BW08	10-BW08-05	23-Apr-10	253.8	55.7	0.9	31.3	-	616.0	21.0	1.8
BW08	10-BW08-06	14-May-10	252.7	55.4	0.9	31.2	205.0	617.8	20.9	1.8
BW08	10-BW08-07	15-Jun-10	235.5	49.5	0.9	32.2	241.0	658.7	20.4	1.7
BW08	10-BW08-07B	24-Jun-10	-	-	-	-	-	-	-	-
BW08	10-BW08-08	11-Jul-10	220.6	49.7	0.9	28.1	232.0	661.0	20.4	1.7
BW08	10-BW08-10	11-Aug-10	238.6	51.9	1.0	33.0	219.0	662.8	20.4	1.7
BW08	10-BW08-11	24-Sep-10	230.1	50.6	0.9	32.4	219.0	671.7	22.0	1.8
BW08	10-AG-273	20-Oct-10	233.6	50.7	0.9	31.7	223.0	677.6	22.4	1.8
BW09	09-BW09-00	31-Jul-09	-	-	-	-	-	-	-	-
BW09	09-BW09-01	18-Nov-09	93.1	24.9	1.3	26.3	-	123.4	13.9	1.1
BW09	09-BW09-02	18-Dec-09	76.2	22.3	1.3	47.3	-	127.9	14.0	1.1
BW09	10-BW09-03A	1-Jan-10	90.0	26.7	1.3	28.0	-	121.4	13.0	0.9
BW09	10-BW09-03	1-Feb-10	92.6	25.8	1.2	30.3	-	114.5	12.9	1.0
BW09	10-BW09-04	1-Mar-10	90.0	26.7	1.2	29.5	-	122.2	12.9	1.0
BW09	10-BW09-05	23-Apr-10	95.4	28.2	1.2	29.4	-	138.0	14.0	1.0
BW09	10-BW09-06	14-May-10	93.0	27.3	1.3	28.9	251.0	128.9	13.4	1.1
BW09	10-BW09-07	15-Jun-10	88.0	24.9	1.3	28.9	282.0	130.3	13.7	1.0
BW09	10-BW09-07B	24-Jun-10	-	-	-	-	-	-	-	-
BW09	10-BW09-08	12-Jul-10	94.7	24.2	1.3	32.4	306.0	125.0	13.3	0.9
BW09	10-BW09-10	11-Aug-10	87.4	26.6	1.3	28.2	327.0	134.8	0.7	1.1
BW09	10-BW09-11	24-Sep-10	88.4	26.4	1.3	32.0	282.0	145.1	15.7	1.0
BW09	10-AG-252	20-Oct-10	88.6	26.2	1.3	33.6	271.0	144.2	15.4	1.0
BW10	09-BW10-00	6-Jul-09	-	-	-	-	-	-	-	-
BW10	09-BW10-01	18-Nov-09	69.8	30.9	0.6	7.3	-	160.4	0.9	1.0
BW10	09-BW10-02	19-Dec-09	60.8	26.5	0.6	6.0	-	146.0	1.0	1.0
BW10	10-BW10-03	5-Feb-10	78.7	23.9	0.5	5.0	-	116.2	0.8	1.0
BW10	10-BW10-04	26-Mar-10	89.4	28.0	0.6	7.0	-	138.7	0.6	0.8
BW10	10-BW10-05	23-Apr-10	93.4	32.0	0.6	8.1	-	130.5	0.5	0.9
BW10	10-BW10-06	14-May-10	95.7	29.6	0.6	7.6	275.0	160.4	0.6	0.9
BW10	10-BW10-07	15-Jun-10	82.6	22.4	0.5	5.4	263.0	93.2	0.5	1.0
BW10	10-BW10-07B	24-Jun-10	-	-	-	-	-	-	-	-
BW10	10-BW10-08	13-Jul-10	73.0	22.5	0.6	5.5	273.0	94.2	0.5	1.0
BW10	10-BW10-10	11-Aug-10	65.4	24.1	0.6	5.7	252.0	101.0	0.5	1.0
BW10	10-BW10-11	24-Sep-10	65.1	23.3	0.7	5.6	241.0	107.8	0.7	1.0
BW10	10-AG-253	20-Oct-10	76.3	27.2	0.7	7.8	357.0	137.6	0.9	0.9
BW11	09-BW11-01	19-Nov-09	239.3	129.3	1.1	23.4	-	982.6	9.3	2.5

Station	Sample	Date	Ca^{2+}	Mg^{2+}	K^{+}	Na^{+}	HCO_3^{-}	SO_4^{2-}	Cl^{-}	F^{-}
			mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
BW11	09-BW11-02	19-Dec-09	250.3	133.5	1.2	23.3	-	1036.3	10.1	2.7
BW11	10-BW11-03	5-Feb-10	228.6	133.5	1.0	25.7	-	928.3	10.1	2.0
BW11	10-BW11-04	26-Mar-10	224.7	130.8	1.0	25.1	-	974.2	10.2	1.8
BW11	10-BW11-05	23-Apr-10	244.0	140.3	1.1	27.8	-	949.3	9.9	1.9
BW11	10-BW11-06	14-May-10	253.4	143.7	1.1	27.0	265.0	972.3	10.4	2.0
BW11	10-BW11-07	15-Jun-10	245.3	132.7	1.1	30.1	256.0	999.7	10.3	1.7
BW11	10-BW11-07B	24-Jun-10	-	-	-	-	-	-	-	-
BW11	10-BW11-08	14-Jul-10	222.0	130.5	1.1	25.3	269.0	963.8	10.0	1.8
BW11	10-AG-250	19-Oct-10	245.7	139.4	1.2	30.6	278.0	1098.8	11.1	2.2

"-" symbolizes parameter not measured. "<" symbolizes parameter is below detection limit.

Appendix Y. Trace Constituents: Fe^{2+}, Sr^{2+}, Si, Br^-, I^-, PO_4^{2-} (Local Study)

Station	Sample	Date	Fe^{2+}	Sr^{2+}	Si	Br^-	I^-	PO_4^{2-}
			mg/L	mg/L	mg/L	mg/L	µg/L	mg/L
BW01	09-AG-238	29-Jul-09	-	-	-	-	-	-
BW01	09-BW01-01	19-Nov-09	0.032	14.6	4.5	<0.03	-	<0.05
BW01	09-BW01-02	18-Dec-09	0.019	13.9	4.5	<0.03	-	<0.05
BW01	10-BW01-03	05-Feb-10	0.04	12.9	4.7	<0.02	-	<0.04
BW01	10-BW01-04	26-Mar-10	0.06	12.9	4.8	<0.02	-	<0.04
BW01	10-BW01-05	23-Apr-10	0.04	13.7	5	<0.02	-	<0.04
BW01	10-BW01-06	14-May-10	<0.003	13.2	4.9	<0.02	-	<0.04
BW01	10-BW01-07	15-Jun-10	<0.003	13	4.8	0.03	<5	<0.04
BW01	10-BW01-07B	24-Jun-10	-	-	-	-	-	-
BW01	10-BW01-08	10-Jul-10	<0.003	12	4.7	<0.02	-	<0.04
BW01	10-BW01-10	11-Aug-10	<0.003	13.3	4.5	0.01	-	<0.04
BW01	10-BW01-11	24-Sep-10	<0.003	15.2	4.5	0.02	-	<0.04
BW01	10-AG-251	19-Oct-10	<0.003	15.2	4.6	<0.02	-	<0.04
BW02	09-BW02-00	29-Jul-09	-	-	-	-	-	-
BW02	09-BW02-01	19-Nov-09	0.691	20.8	3.3	<0.03	-	<0.05
BW02	09-BW02-02	18-Dec-09	0.685	20.9	3.3	<0.03	-	<0.05
BW02	10-BW02-03	05-Feb-10	0.643	20.1	3.4	<0.02	-	<0.04
BW02	10-BW02-04	26-Mar-10	0.513	19.2	3.5	<0.02	-	<0.04
BW02	10-BW02-05	23-Apr-10	0.757	20.2	3.5	0.03	-	<0.04
BW02	10-BW02-06	14-May-10	0.586	21.3	3.6	0.03	-	<0.04
BW02	10-BW02-07	15-Jun-10	0.395	20.9	3.6	0.05	<5	<0.04
BW02	10-BW02-07B	24-Jun-10	-	-	-	-	-	-
BW02	10-BW02-08	09-Jul-10	0.654	18.6	3.5	0.03	-	<0.04
BW02	10-BW02-10	11-Aug-10	0.621	20.7	3.2	0.03	-	<0.04
BW02	10-BW02-11	24-Sep-10	0.843	22.7	3.3	0.04	-	<0.04
BW02	10-AG-274	20-Oct-10	0.048	22.9	3.3	<0.02	-	<0.04
BW03	09-BW03-00	30-Jun-09	-	-	-	-	-	-
BW03	09-BW03-01	19-Nov-09	0.399	48.1	5.5	<0.03	-	<0.05
BW03	09-BW03-02	19-Dec-09	0.661	48.8	5.5	<0.03	-	<0.05
BW03	10-BW03-04	26-Mar-10	0.477	42.3	5.6	<0.02	-	<0.04
BW03	10-BW03-05	23-Apr-10	0.366	47.1	5.8	<0.02	-	<0.04
BW03	10-BW03-06	14-May-10	0.222	48.1	5.9	<0.02	-	<0.04
BW03	10-BW03-07	15-Jun-10	0.188	42.1	5.8	<0.02	<5	<0.04
BW03	10-BW03-07B	24-Jun-10	-	-	-	-	-	-
BW03	10-BW03-08	09-Jul-10	0.128	43.8	5.7	<0.02	-	<0.04
BW03	10-BW03-10	11-Aug-10	0.27	46.1	5.3	<0.02	-	<0.04
BW03	10-BW03-11	24-Sep-10	0.307	51.8	5.4	<0.02	-	<0.04
BW03	10-AG-254	20-Oct-10	0.591	51.5	5.4	<0.02	-	<0.04
BW04	09-BW04-00	30-Jul-09	-	-	-	-	-	-
BW04	09-BW04-01	19-Nov-09	0.019	9.9	3.7	<0.03	-	<0.05
BW04	09-BW04-02	18-Dec-09	0.018	5.8	3.7	<0.03	-	<0.05
BW04	10-BW04-03	05-Feb-10	0.01	11.3	4	<0.02	-	<0.04
BW04	10-BW04-04	26-Mar-10	0.011	11.8	3.9	<0.02	-	<0.04
BW04	10-BW04-05	23-Apr-10	0.01	14.5	4.1	<0.02	-	<0.04
BW04	10-BW04-06	14-May-10	0.01	13.9	4.1	<0.02	-	<0.04

Station	Sample	Date	Fe^{2+}	Sr^{2+}	Si	Br^-	I^-	PO_4^{2-}
			mg/L	mg/L	mg/L	mg/L	µg/L	mg/L
BW04	10-BW04-07	15-Jun-10	0.007	14	4.1	0.03	<5	<0.04
BW04	10-BW04-07B	24-Jun-10	-	-	-	-	-	-
BW04	10-BW04-08	09-Jul-10	0.032	15.3	4.1	<0.02	-	<0.04
BW04	10-BW04-10	11-Aug-10	<0.003	13.1	3.6	0.01	-	<0.04
BW04	10-BW04-11	24-Sep-10	<0.003	14.5	3.7	0.03	-	<0.04
BW04	10-AG-271	20-Oct-10	0.003	14.9	3.8	0.02	-	<0.04
BW05	09-BW05-00	30-Jul-09	-	-	-	-	-	-
BW05	09-BW05-01	18-Nov-09	1.287	41.5	4.7	0.09	-	<0.05
BW05	10-BW05-03	05-Feb-10	-	-	-	-	-	-
BW05	10-BW05-04	26-Mar-10	1.95	36.1	4.9	0.08	-	<0.04
BW05	10-BW05-05	23-Apr-10	1.11	41.8	4.9	0.08	-	<0.04
BW05	10-BW05-06	14-May-10	1.04	41	4.9	0.08	-	<0.04
BW05	10-BW05-07	15-Jun-10	0.75	40.7	4.8	0.12	15	<0.04
BW05	10-BW05-07B	24-Jun-10	-	-	-	-	-	-
BW05	10-BW05-08	09-Jul-10	1.12	38.5	4.8	0.08	-	<0.04
BW05	10-BW05-10	11-Aug-10	1.124	39.4	4.5	0.05	-	<0.04
BW05	10-BW05-11	24-Sep-10	1.169	43.4	4.6	0.09	-	<0.04
BW05	10-AG-268	20-Oct-10	0.962	43.6	4.6	0.09	-	<0.04
BW06	09-BW06-00	30-Jul-09	-	-	-	-	-	-
BW06	09-BW06-01	19-Nov-09	0.012	40.3	5.5	<0.03	-	<0.05
BW06	09-BW06-02	18-Dec-09	0.025	39.2	5.9	0.05	-	<0.05
BW06	10-BW06-03	05-Feb-10	0.062	27.6	6.6	0.05	-	<0.04
BW06	10-BW06-04	26-Mar-10	0.024	29.6	6.5	0.05	-	<0.04
BW06	10-BW06-05	23-Apr-10	0.038	28.4	6.8	0.05	-	<0.04
BW06	10-BW06-06	14-May-10	0.054	27.3	6.9	0.05	-	<0.04
BW06	10-BW06-07	15-Jun-10	0.01	32.1	6.2	0.09	<5	<0.04
BW06	10-BW06-07B	24-Jun-10	-	-	-	-	-	-
BW06	10-BW06-08	09-Jul-10	0.076	47.3	5.2	<0.02	-	<0.04
BW06	10-BW06-10	11-Aug-10	<0.003	29.2	5.9	0.05	-	<0.04
BW06	10-BW06-11	24-Sep-10	<0.003	48.8	5.3	0.04	-	<0.04
BW06	10-AG-267	20-Oct-10	<0.003	40.8	5.8	0.05	-	<0.04
BW08	09-BW08-00	31-Jul-09	-	-	-	-	-	-
BW08	09-BW08-01	19-Nov-09	2.051	16.6	4.2	0.03	-	<0.05
BW08	09-BW08-02	18-Dec-09	-	-	-	-	-	-
BW08	10-BW08-03	05-Feb-10	-	-	-	-	-	-
BW08	10-BW08-04	26-Mar-10	1.596	15.3	4.4	<0.02	-	<0.04
BW08	10-BW08-05	23-Apr-10	1.894	16.8	4.5	0.03	-	<0.04
BW08	10-BW08-06	14-May-10	1.828	16.8	4.5	0.03	-	<0.04
BW08	10-BW08-07	15-Jun-10	1.226	16.6	4.4	0.05	6	<0.04
BW08	10-BW08-07B	24-Jun-10	-	-	-	-	-	-
BW08	10-BW08-08	11-Jul-10	1.311	15.5	4.4	0.02	-	<0.04
BW08	10-BW08-10	11-Aug-10	1.454	16.3	4.2	0.02	-	<0.04
BW08	10-BW08-11	24-Sep-10	1.59	18.5	4.2	0.04	-	<0.04
BW08	10-AG-273	20-Oct-10	1.738	18.4	4.3	0.04	-	<0.04
BW09	09-BW09-00	31-Jul-09	-	-	-	-	-	-
BW09	09-BW09-01	18-Nov-09	0.007	3	4	<0.03	-	<0.05
BW09	09-BW09-02	18-Dec-09	0.01	2.5	3.9	<0.03	-	<0.05
BW09	10-BW09-03A	01-Jan-10	0.085	2.8	4.3	0.03	-	<0.04

Station	Sample	Date	Fe^{2+}	Sr^{2+}	Si	Br^-	I^-	PO_4^{2-}
			mg/L	mg/L	mg/L	mg/L	µg/L	mg/L
BW09	10-BW09-03	01-Feb-10	0.033	2.7	4.2	0.03	-	<0.04
BW09	10-BW09-04	01-Mar-10	0.241	2.7	4.3	0.03	-	<0.04
BW09	10-BW09-05	23-Apr-10	0.052	3	4.3	0.03	-	<0.04
BW09	10-BW09-06	14-May-10	0.035	2.9	4.3	0.04	-	<0.04
BW09	10-BW09-07	15-Jun-10	0.063	2.8	4.2	0.05	<5	<0.04
BW09	10-BW09-07B	24-Jun-10	-	-	-	-	-	-
BW09	10-BW09-08	12-Jul-10	0.043	2.7	4.2	<0.02	-	<0.04
BW09	10-BW09-10	11-Aug-10	0.026	2.8	3.8	0.02	-	<0.04
BW09	10-BW09-11	24-Sep-10	0.05	3.3	4	0.04	-	<0.04
BW09	10-AG-252	20-Oct-10	0.054	3.3	4	0.04	-	<0.04
BW10	09-BW10-00	06-Jul-09	-	-	-	-	-	-
BW10	09-BW10-01	18-Nov-09	0.019	42	5.4	<0.03	-	<0.05
BW10	09-BW10-02	19-Dec-09	2.638	44.1	5.7	<0.03	-	<0.05
BW10	10-BW10-03	05-Feb-10	0.023	40	5.5	<0.02	-	<0.04
BW10	10-BW10-04	26-Mar-10	0.034	37.9	5.7	<0.02	-	<0.04
BW10	10-BW10-05	23-Apr-10	0.046	42.1	6.1	<0.02	-	<0.04
BW10	10-BW10-06	14-May-10	0.037	44.4	5.9	<0.02	-	<0.04
BW10	10-BW10-07	15-Jun-10	0.02	41.4	5.6	<0.02	<5	<0.04
BW10	10-BW10-07B	24-Jun-10	-	-	-	-	-	-
BW10	10-BW10-08	13-Jul-10	0.021	42.8	5.5	<0.02	-	<0.04
BW10	10-BW10-10	11-Aug-10	0.021	44.4	5.1	<0.02	-	<0.04
BW10	10-BW10-11	24-Sep-10	<0.003	50.5	5.2	<0.02	-	<0.04
BW10	10-AG-253	20-Oct-10	0.039	46.5	5.4	<0.02	-	<0.04
BW11	09-BW11-01	19-Nov-09	0.505	18.4	4	0.33	-	<0.05
BW11	09-BW11-02	19-Dec-09	<0.003	18.2	4	<0.03	-	<0.05
BW11	10-BW11-03	05-Feb-10	4.61	17.4	4.2	<0.02	-	<0.04
BW11	10-BW11-04	26-Mar-10	3.91	17.1	4.1	<0.02	-	<0.04
BW11	10-BW11-05	23-Apr-10	5.27	17.7	3.9	0.02	-	<0.04
BW11	10-BW11-06	14-May-10	4.48	17.7	4.2	0.02	-	<0.04
BW11	10-BW11-07	15-Jun-10	2.77	17.7	4.2	0.04	5	<0.04
BW11	10-BW11-07B	24-Jun-10	-	-	-	-	-	-
BW11	10-BW11-08	14-Jul-10	3.82	16.3	4	0.03	-	<0.04
BW11	10-AG-250	19-Oct-10	3.972	19.4	3.9	0.03	-	<0.04

"-" symbolizes parameter not measured. “<” symbolizes parameter is below detection limit.

Appendix Z. Trace Constituents: NO_3^-, NO_2^-, $NH_3^+NH_4^+$, Organic N, TKN (Local Study)

Station	Sample	Date	NO_3^-	NO_2^-	$NH_3^+NH_4^+$	Organic N	TKN
			mg/L_as_N	mg/L_as_N	mg/L_as_N	mg/L_as_N	mg/L_as_N
BW01	09-AG-238	29-Jul-09	-	-	-	-	-
BW01	09-BW01-01	19-Nov-09	2.008	<0.003	-	-	-
BW01	09-BW01-02	18-Dec-09	2.778	<0.003	-	-	-
BW01	10-BW01-03	05-Feb-10	2.783	<0.003	-	-	-
BW01	10-BW01-04	26-Mar-10	2.096	<0.003	-	-	-
BW01	10-BW01-05	23-Apr-10	2.202	0.015	-	-	-
BW01	10-BW01-06	14-May-10	3.022	<0.003	-	-	-
BW01	10-BW01-07	15-Jun-10	2.61	<0.005	0.11	0.08	<0.05
BW01	10-BW01-07B	24-Jun-10	-	-	-	-	-
BW01	10-BW01-08	10-Jul-10	2.763	0.009	-	-	-
BW01	10-BW01-10	11-Aug-10	2.506	0.001	-	-	-
BW01	10-BW01-11	24-Sep-10	1.763	0.003	-	-	-
BW01	10-AG-251	19-Oct-10	2.716	0.006	-	-	-
BW02	09-BW02-00	29-Jul-09	-	-	-	-	-
BW02	09-BW02-01	19-Nov-09	<0.002	<0.003	-	-	-
BW02	09-BW02-02	18-Dec-09	<0.002	<0.003	-	-	-
BW02	10-BW02-03	05-Feb-10	<0.002	<0.003	-	-	-
BW02	10-BW02-04	26-Mar-10	<0.002	<0.003	-	-	-
BW02	10-BW02-05	23-Apr-10	<0.002	<0.003	-	-	-
BW02	10-BW02-06	14-May-10	<0.002	<0.0030	-	-	-
BW02	10-BW02-07	15-Jun-10	<0.013	<0.005	0.06	0.06	<0.05
BW02	10-BW02-07B	24-Jun-10	-	-	-	-	-
BW02	10-BW02-08	09-Jul-10	<0.002	<0.003	-	-	-
BW02	10-BW02-10	11-Aug-10	<0.002	<0.003	-	-	-
BW02	10-BW02-11	24-Sep-10	-	<0.0030	-	-	-
BW02	10-AG-274	20-Oct-10	-	<0.0030	-	-	-
BW03	09-BW03-00	30-Jun-09	-	-	-	-	-
BW03	09-BW03-01	19-Nov-09	<0.002	<0.003	-	-	-
BW03	09-BW03-02	19-Dec-09	<0.002	<0.003	-	-	-
BW03	10-BW03-04	26-Mar-10	<0.002	<0.003	-	-	-
BW03	10-BW03-05	23-Apr-10	0.003	<0.003	-	-	-
BW03	10-BW03-06	14-May-10	0.003	<0.003	-	-	-
BW03	10-BW03-07	15-Jun-10	<0.013	<0.005	0.07	0.13	0.06
BW03	10-BW03-07B	24-Jun-10	-	-	-	-	-
BW03	10-BW03-08	09-Jul-10	<0.002	<0.003	-	-	-
BW03	10-BW03-10	11-Aug-10	0.009	<0.0030	-	-	-
BW03	10-BW03-11	24-Sep-10	-	<0.0030	-	-	-
BW03	10-AG-254	20-Oct-10	-	<0.0030	-	-	-
BW04	09-BW04-00	30-Jul-09	-	-	-	-	-
BW04	09-BW04-01	19-Nov-09	1.348	<0.003	-	-	-
BW04	09-BW04-02	18-Dec-09	1.451	<0.003	-	-	-
BW04	10-BW04-03	05-Feb-10	1.842	<0.003	-	-	-
BW04	10-BW04-04	26-Mar-10	1.867	<0.0030	-	-	-
BW04	10-BW04-05	23-Apr-10	1.958	<0.003	-	-	-
BW04	10-BW04-06	14-May-10	2.062	<0.0030	-	-	-
BW04	10-BW04-07	15-Jun-10	1.92	<0.005	<0.04	<0.05	<0.05

Station	Sample	Date	NO_3^-	NO_2^-	$NH_3^+NH_4^+$	Organic N	TKN
			mg/L_as_N	mg/L_as_N	mg/L_as_N	mg/L_as_N	mg/L_as_N
BW04	10-BW04-07B	24-Jun-10	-	-	-	-	-
BW04	10-BW04-08	09-Jul-10	1.942	<0.0030	-	-	-
BW04	10-BW04-10	11-Aug-10	2.071	<0.003	-	-	-
BW04	10-BW04-11	24-Sep-10	1.802	0.003	-	-	-
BW04	10-AG-271	20-Oct-10	1.803	0.004	-	-	-
BW05	09-BW05-00	30-Jul-09	-	-	-	-	-
BW05	09-BW05-01	18-Nov-09	<0.002	<0.003	-	-	-
BW05	10-BW05-03	05-Feb-10	-	-	-	-	-
BW05	10-BW05-04	26-Mar-10	<0.002	<0.003	-	-	-
BW05	10-BW05-05	23-Apr-10	<0.002	<0.003	-	-	-
BW05	10-BW05-06	14-May-10	0.003	<0.003	-	-	-
BW05	10-BW05-07	15-Jun-10	<0.013	<0.005	0.07	<0.05	<0.05
BW05	10-BW05-07B	24-Jun-10	-	-	-	-	-
BW05	10-BW05-08	09-Jul-10	<0.002	<0.003	-	-	-
BW05	10-BW05-10	11-Aug-10	0.001	<0.003	-	-	-
BW05	10-BW05-11	24-Sep-10	-	<0.0030	-	-	-
BW05	10-AG-268	20-Oct-10	-	<0.0030	-	-	-
BW06	09-BW06-00	30-Jul-09	-	-	-	-	-
BW06	09-BW06-01	19-Nov-09	0.695	<0.003	-	-	-
BW06	09-BW06-02	18-Dec-09	0.792	<0.003	-	-	-
BW06	10-BW06-03	05-Feb-10	0.792	<0.003	-	-	-
BW06	10-BW06-04	26-Mar-10	0.822	<0.0030	-	-	-
BW06	10-BW06-05	23-Apr-10	0.883	<0.0030	-	-	-
BW06	10-BW06-06	14-May-10	0.926	<0.003	-	-	-
BW06	10-BW06-07	15-Jun-10	0.38	<0.005	<0.04	0.05	<0.05
BW06	10-BW06-07B	24-Jun-10	-	-	-	-	-
BW06	10-BW06-08	09-Jul-10	0.065	<0.003	-	-	-
BW06	10-BW06-10	11-Aug-10	0.675	<0.003	-	-	-
BW06	10-BW06-11	24-Sep-10	0.454	<0.0030	-	-	-
BW06	10-AG-267	20-Oct-10	0.646	0.007	-	-	-
BW08	09-BW08-00	31-Jul-09	-	-	-	-	-
BW08	09-BW08-01	19-Nov-09	<0.002	<0.003	-	-	-
BW08	09-BW08-02	18-Dec-09	-	-	-	-	-
BW08	10-BW08-03	05-Feb-10	-	-	-	-	-
BW08	10-BW08-04	26-Mar-10	<0.002	<0.003	-	-	-
BW08	10-BW08-05	23-Apr-10	<0.002	<0.003	-	-	-
BW08	10-BW08-06	14-May-10	<0.002	<0.003	-	-	-
BW08	10-BW08-07	15-Jun-10	<0.013	<0.005	0.1	0.32	0.22
BW08	10-BW08-07B	24-Jun-10	-	-	-	-	-
BW08	10-BW08-08	11-Jul-10	<0.002	<0.0030	-	-	-
BW08	10-BW08-10	11-Aug-10	<0.002	0.001	-	-	-
BW08	10-BW08-11	24-Sep-10	-	<0.0030	-	-	-
BW08	10-AG-273	20-Oct-10	-	<0.0030	-	-	-
BW09	09-BW09-00	31-Jul-09	-	-	-	-	-
BW09	09-BW09-01	18-Nov-09	1.322	0.023	-	-	-
BW09	09-BW09-02	18-Dec-09	1.097	0.006	-	-	-
BW09	10-BW09-03A	01-Jan-10	0.751	0.023	-	-	-
BW09	10-BW09-03	01-Feb-10	0.613	<0.003	-	-	-

Station	Sample	Date	NO_3^-	NO_2^-	$NH_3^+NH_4^+$	Organic N	TKN
			mg/L_as_N	mg/L_as_N	mg/L_as_N	mg/L_as_N	mg/L_as_N
BW09	10-BW09-04	01-Mar-10	0.598	0.005	-	-	-
BW09	10-BW09-05	23-Apr-10	1.089	<0.003	-	-	-
BW09	10-BW09-06	14-May-10	0.86	<0.003	-	-	-
BW09	10-BW09-07	15-Jun-10	0.874	<0.005	0.13	0.32	0.19
BW09	10-BW09-07B	24-Jun-10	-	-	-	-	-
BW09	10-BW09-08	12-Jul-10	1.043	0.003	-	-	-
BW09	10-BW09-10	11-Aug-10	1.168	<0.0030	-	-	-
BW09	10-BW09-11	24-Sep-10	-	<0.0030	-	-	-
BW09	10-AG-252	20-Oct-10	0.923	0.003	-	-	-
BW10	09-BW10-00	06-Jul-09	-	-	-	-	-
BW10	09-BW10-01	18-Nov-09	<0.002	<0.003	-	-	-
BW10	09-BW10-02	19-Dec-09	0.041	<0.003	-	-	-
BW10	10-BW10-03	05-Feb-10	0.05	<0.003	-	-	-
BW10	10-BW10-04	26-Mar-10	<0.002	<0.003	-	-	-
BW10	10-BW10-05	23-Apr-10	0.043	<0.003	-	-	-
BW10	10-BW10-06	14-May-10	0.043	<0.003	-	-	-
BW10	10-BW10-07	15-Jun-10	0.073	<0.005	0.15	0.11	<0.05
BW10	10-BW10-07B	24-Jun-10	-	-	-	-	-
BW10	10-BW10-08	13-Jul-10	<0.002	<0.003	-	-	-
BW10	10-BW10-10	11-Aug-10	0.055	<0.003	-	-	-
BW10	10-BW10-11	24-Sep-10	-	0.023	-	-	-
BW10	10-AG-253	20-Oct-10	-	<0.0030	-	-	-
BW11	09-BW11-01	19-Nov-09	<0.002	<0.003	-	-	-
BW11	09-BW11-02	19-Dec-09	<0.002	<0.003	-	-	-
BW11	10-BW11-03	05-Feb-10	<0.002	<0.003	-	-	-
BW11	10-BW11-04	26-Mar-10	<0.002	<0.003	-	-	-
BW11	10-BW11-05	23-Apr-10	<0.002	<0.003	-	-	-
BW11	10-BW11-06	14-May-10	<0.002	<0.003	-	-	-
BW11	10-BW11-07	15-Jun-10	<0.013	<0.005	0.1	0.11	<0.05
BW11	10-BW11-07B	24-Jun-10	-	-	-	-	-
BW11	10-BW11-08	14-Jul-10	<0.002	<0.003	-	-	-
BW11	10-AG-250	19-Oct-10	-	<0.0030	-	-	-

"-" symbolizes parameter not measured. "<" symbolizes parameter is below detection limit.

Appendix AA. Compositional Ratios (Local Study)

Station	Sample	Date	Sr/Ca	Mg/Ca	Na/Cl	Cl/Br
			ratio	ratio	ratio	ratio
BW01	09-AG-238	29-Jul-09	-	-	-	-
BW01	09-BW01-01	19-Nov-09	0.08	0.32	2.44	-
BW01	09-BW01-02	18-Dec-09	0.08	0.31	1.72	-
BW01	10-BW01-03	5-Feb-10	0.08	0.32	1.69	-
BW01	10-BW01-04	26-Mar-10	0.08	0.32	2.02	-
BW01	10-BW01-05	23-Apr-10	0.07	0.31	1.97	-
BW01	10-BW01-06	14-May-10	0.07	0.31	1.79	-
BW01	10-BW01-07	15-Jun-10	0.07	0.30	1.76	174.08
BW01	10-BW01-07B	24-Jun-10	-	-	-	-
BW01	10-BW01-08	10-Jul-10	0.07	0.32	1.60	
BW01	10-BW01-10	11-Aug-10	0.08	0.31	2.06	380.47
BW01	10-BW01-11	24-Sep-10	0.09	0.31	1.95	216.05
BW01	10-AG-251	19-Oct-10	0.09	0.31	1.95	-
BW02	09-BW02-00	29-Jul-09	-	-	-	-
BW02	09-BW02-01	19-Nov-09	0.18	0.41	1.99	-
BW02	09-BW02-02	18-Dec-09	0.17	0.39	1.65	-
BW02	10-BW02-03	5-Feb-10	0.16	0.39	1.84	-
BW02	10-BW02-04	26-Mar-10	0.16	0.39	1.74	-
BW02	10-BW02-05	23-Apr-10	0.15	0.38	2.02	315.76
BW02	10-BW02-06	14-May-10	0.16	0.38	2.05	306.69
BW02	10-BW02-07	15-Jun-10	0.15	0.37	2.26	164.02
BW02	10-BW02-07B	24-Jun-10	-	-	-	-
BW02	10-BW02-08	9-Jul-10	0.15	0.39	1.78	311.73
BW02	10-BW02-10	11-Aug-10	0.15	0.38	2.27	255.51
BW02	10-BW02-11	24-Sep-10	0.18	0.38	1.98	217.18
BW02	10-AG-274	20-Oct-10	0.17	0.38	2.08	-
BW03	09-BW03-00	30-Jun-09	-	-	-	-
BW03	09-BW03-01	19-Nov-09	1.53	0.65	12.60	-
BW03	09-BW03-02	19-Dec-09	1.68	0.70	11.23	-
BW03	10-BW03-04	26-Mar-10	0.69	0.32	14.96	-
BW03	10-BW03-05	23-Apr-10	0.68	0.31	16.17	-
BW03	10-BW03-06	14-May-10	0.69	0.31	18.11	-
BW03	10-BW03-07	15-Jun-10	0.59	0.28	19.18	-
BW03	10-BW03-07B	24-Jun-10	-	-	-	-
BW03	10-BW03-08	9-Jul-10	0.69	0.31	18.87	-
BW03	10-BW03-10	11-Aug-10	0.84	0.37	15.88	-
BW03	10-BW03-11	24-Sep-10	0.93	0.36	11.36	-
BW03	10-AG-254	20-Oct-10	0.92	0.36	12.56	-
BW04	09-BW04-00	30-Jul-09	-	-	-	-
BW04	09-BW04-01	19-Nov-09	0.12	0.28	1.42	-
BW04	09-BW04-02	18-Dec-09	0.07	0.26	0.95	-
BW04	10-BW04-03	5-Feb-10	0.12	0.24	0.79	-
BW04	10-BW04-04	26-Mar-10	0.13	0.25	0.77	-
BW04	10-BW04-05	23-Apr-10	0.15	0.27	0.75	-
BW04	10-BW04-06	14-May-10	0.15	0.27	0.74	-
BW04	10-BW04-07	15-Jun-10	0.16	0.26	0.76	446.83
BW04	10-BW04-07B	24-Jun-10	-	-	-	-
BW04	10-BW04-08	9-Jul-10	0.16	0.26	0.97	-
BW04	10-BW04-10	11-Aug-10	0.16	0.30	0.76	1033.71
BW04	10-BW04-11	24-Sep-10	0.18	0.29	0.72	563.85
BW04	10-AG-271	20-Oct-10	0.18	0.29	0.75	656.25
BW05	09-BW05-00	30-Jul-09	-	-	-	-
BW05	09-BW05-01	18-Nov-09	0.47	0.48	0.66	4859.78
BW05	10-BW05-03	5-Feb-10	-	-	-	-
BW05	10-BW05-04	26-Mar-10	0.35	0.39	0.68	5062.52
BW05	10-BW05-05	23-Apr-10	0.35	0.38	0.75	5193.89
BW05	10-BW05-06	14-May-10	0.34	0.38	0.77	5216.91
BW05	10-BW05-07	15-Jun-10	0.35	0.36	0.80	3242.64

Station	Sample	Date	Sr/Ca	Mg/Ca	Na/Cl	Cl/Br
			ratio	ratio	ratio	ratio
BW05	10-BW05-07B	24-Jun-10	-	-	-	-
BW05	10-BW05-08	9-Jul-10	0.36	0.39	0.78	5033.76
BW05	10-BW05-10	11-Aug-10	0.40	0.43	0.76	8706.76
BW05	10-BW05-11	24-Sep-10	0.44	0.43	0.80	4645.04
BW05	10-AG-268	20-Oct-10	0.39	0.37	0.79	4797.22
BW06	09-BW06-00	30-Jul-09	-	-	-	-
BW06	09-BW06-01	19-Nov-09	0.54	0.46	0.37	-
BW06	09-BW06-02	18-Dec-09	0.54	0.47	0.37	357.59
BW06	10-BW06-03	5-Feb-10	0.28	0.33	0.40	383.38
BW06	10-BW06-04	26-Mar-10	0.30	0.33	0.40	352.20
BW06	10-BW06-05	23-Apr-10	0.28	0.36	0.37	388.49
BW06	10-BW06-06	14-May-10	0.27	0.35	0.36	426.43
BW06	10-BW06-07	15-Jun-10	0.34	0.35	0.40	200.52
BW06	10-BW06-07B	24-Jun-10	-	-	-	-
BW06	10-BW06-08	9-Jul-10	0.50	0.35	0.91	-
BW06	10-BW06-10	11-Aug-10	0.34	0.40	0.38	397.25
BW06	10-BW06-11	24-Sep-10	0.57	0.40	0.44	326.76
BW06	10-AG-267	20-Oct-10	0.47	0.39	0.40	360.05
BW08	09-BW08-00	31-Jul-09	-	-	-	-
BW08	09-BW08-01	19-Nov-09	0.07	0.21	1.19	721.90
BW08	09-BW08-02	18-Dec-09	-	-	-	-
BW08	10-BW08-03	5-Feb-10	-	-	-	-
BW08	10-BW08-04	26-Mar-10	0.07	0.22	1.23	-
BW08	10-BW08-05	23-Apr-10	0.07	0.22	1.49	783.13
BW08	10-BW08-06	14-May-10	0.07	0.22	1.49	786.23
BW08	10-BW08-07	15-Jun-10	0.07	0.21	1.58	395.78
BW08	10-BW08-07B	24-Jun-10	-	-	-	-
BW08	10-BW08-08	11-Jul-10	0.07	0.23	1.38	840.58
BW08	10-BW08-10	11-Aug-10	0.07	0.22	1.62	1140.58
BW08	10-BW08-11	24-Sep-10	0.08	0.22	1.47	607.10
BW08	10-AG-273	20-Oct-10	0.08	0.22	1.42	620.35
BW09	09-BW09-00	31-Jul-09	-	-	-	-
BW09	09-BW09-01	18-Nov-09	0.03	0.27	1.89	-
BW09	09-BW09-02	18-Dec-09	0.03	0.29	3.39	-
BW09	10-BW09-03A	1-Jan-10	0.03	0.30	2.15	468.87
BW09	10-BW09-03	1-Feb-10	0.03	0.28	2.34	495.89
BW09	10-BW09-04	1-Mar-10	0.03	0.30	2.30	505.69
BW09	10-BW09-05	23-Apr-10	0.03	0.30	2.10	503.57
BW09	10-BW09-06	14-May-10	0.03	0.29	2.16	374.72
BW09	10-BW09-07	15-Jun-10	0.03	0.28	2.10	275.08
BW09	10-BW09-07B	24-Jun-10	-	-	-	-
BW09	10-BW09-08	12-Jul-10	0.03	0.26	2.44	-
BW09	10-BW09-10	11-Aug-10	0.03	0.30	41.14	27.82
BW09	10-BW09-11	24-Sep-10	0.04	0.30	2.04	425.87
BW09	10-AG-252	20-Oct-10	0.04	0.30	2.18	399.73
BW10	09-BW10-00	6-Jul-09	-	-	-	-
BW10	09-BW10-01	18-Nov-09	0.60	0.44	8.01	-
BW10	09-BW10-02	19-Dec-09	0.73	0.44	6.13	-
BW10	10-BW10-03	5-Feb-10	0.51	0.30	5.98	-
BW10	10-BW10-04	26-Mar-10	0.42	0.31	12.01	-
BW10	10-BW10-05	23-Apr-10	0.45	0.34	14.91	-
BW10	10-BW10-06	14-May-10	0.46	0.31	12.54	-
BW10	10-BW10-07	15-Jun-10	0.50	0.27	11.65	-
BW10	10-BW10-07B	24-Jun-10	-	-	-	-
BW10	10-BW10-08	13-Jul-10	0.59	0.31	11.43	-
BW10	10-BW10-10	11-Aug-10	0.68	0.37	11.54	-
BW10	10-BW10-11	24-Sep-10	0.77	0.36	8.25	-
BW10	10-AG-253	20-Oct-10	0.61	0.36	8.54	-
BW11	09-BW11-01	19-Nov-09	0.08	0.54	2.51	28.19

Station	Sample	Date	Sr/Ca	Mg/Ca	Na/Cl	Cl/Br
			ratio	ratio	ratio	ratio
BW11	09-BW11-02	19-Dec-09	0.07	0.53	2.31	-
BW11	10-BW11-03	5-Feb-10	0.08	0.58	2.55	-
BW11	10-BW11-04	26-Mar-10	0.08	0.58	2.46	-
BW11	10-BW11-05	23-Apr-10	0.07	0.57	2.82	455.17
BW11	10-BW11-06	14-May-10	0.07	0.57	2.59	452.97
BW11	10-BW11-07	15-Jun-10	0.07	0.54	2.93	263.86
BW11	10-BW11-07B	24-Jun-10	-	-	-	-
BW11	10-BW11-08	14-Jul-10	0.07	0.59	2.52	339.35
BW11	10-AG-250	19-Oct-10	0.08	0.57	2.77	344.77

"-" symbolizes parameter not measured. "<" symbolizes parameter is below detection limit.

Appendix BB. Trace Constituents: Ag, Al, As, B, Ba, Be, Bi (Local Study)

Station	Sample	Date	Ag µg/L	Al µg/L	As µg/L	B mg/L	Ba µg/L	Be µg/L	Bi µg/L
BW01	09-AG-238	29-Jul-09	-	-	-	-	-	-	-
BW01	09-BW01-01	19-Nov-09	0.013	<5	0.11	0.07	46.50	<0.01	<0.05
BW01	09-BW01-02	18-Dec-09	0.010	<5	0.10	0.06	47.00	<0.01	<0.05
BW01	10-BW01-03	5-Feb-10	0.015	<5	0.09	0.06	45.30	<0.01	<0.05
BW01	10-BW01-04	26-Mar-10	0.012	<5	0.07	0.07	47.00	<0.01	<0.05
BW01	10-BW01-05	23-Apr-10	0.010	<5	0.07	0.07	44.80	<0.01	<0.05
BW01	10-BW01-06	14-May-10	0.010	<5	0.11	0.07	48.20	<0.01	<0.05
BW01	10-BW01-07	15-Jun-10	0.010	<5	0.11	0.06	47.10	<0.01	<0.05
BW01	10-BW01-07B	24-Jun-10	-	-	-	-	-	-	-
BW01	10-BW01-08	10-Jul-10	0.010	<5	0.08	0.06	48.10	<0.01	<0.05
BW01	10-BW01-10	11-Aug-10	0.013	<5	0.10	0.07	44.40	<0.01	<0.05
BW01	10-BW01-11	24-Sep-10	0.014	<5	0.10	0.07	44.70	<0.01	<0.05
BW01	10-AG-251	19-Oct-10	0.017	<5	0.11	0.06	46.00	<0.01	<0.05
BW02	09-BW02-00	29-Jul-09	-	-	-	-	-	-	-
BW02	09-BW02-01	19-Nov-09	0.016	<5	0.18	0.08	87.80	<0.01	<0.05
BW02	09-BW02-02	18-Dec-09	0.018	<5	0.19	0.08	90.50	<0.01	<0.05
BW02	10-BW02-03	5-Feb-10	0.021	<5	0.17	0.09	86.80	<0.01	<0.05
BW02	10-BW02-04	26-Mar-10	0.017	<5	0.17	0.09	88.40	<0.01	<0.05
BW02	10-BW02-05	23-Apr-10	0.015	<5	0.14	0.09	86.10	<0.01	<0.05
BW02	10-BW02-06	14-May-10	0.019	<5	0.18	0.10	85.95	<0.01	<0.05
BW02	10-BW02-07	15-Jun-10	0.017	<5	0.18	0.09	81.90	<0.01	<0.05
BW02	10-BW02-07B	24-Jun-10	-	-	-	-	-	-	-
BW02	10-BW02-08	9-Jul-10	0.018	<5	0.16	0.09	87.10	<0.01	<0.05
BW02	10-BW02-10	11-Aug-10	0.016	<5	0.16	0.09	82.50	<0.01	<0.05
BW02	10-BW02-11	24-Sep-10	0.020	<5	0.18	0.09	84.10	<0.01	<0.05
BW02	10-AG-274	20-Oct-10	0.023	<5	0.10	0.08	82.50	<0.01	<0.05
BW03	09-BW03-00	30-Jun-09	-	-	-	-	-	-	-
BW03	09-BW03-01	19-Nov-09	0.039	<5	1.33	0.02	155.20	<0.01	<0.05
BW03	09-BW03-02	19-Dec-09	0.042	<5	1.29	0.03	153.30	<0.01	<0.05
BW03	10-BW03-04	26-Mar-10	0.032	<5	1.56	0.02	155.00	<0.01	<0.05
BW03	10-BW03-05	23-Apr-10	0.034	<5	1.30	0.03	148.00	<0.01	<0.05
BW03	10-BW03-06	14-May-10	0.037	<5	1.76	0.03	148.00	<0.01	<0.05
BW03	10-BW03-07	15-Jun-10	0.034	<5	1.78	0.02	146.00	<0.01	<0.05
BW03	10-BW03-07B	24-Jun-10	-	-	-	-	-	-	-
BW03	10-BW03-08	9-Jul-10	0.033	<5	1.78	0.02	148.00	<0.01	<0.05
BW03	10-BW03-10	11-Aug-10	0.037	<5	1.78	0.03	147.00	<0.01	<0.05
BW03	10-BW03-11	24-Sep-10	0.041	<5	2.13	0.02	149.00	<0.01	<0.05
BW03	10-AG-254	20-Oct-10	0.045	<5	1.83	0.02	152.00	<0.01	<0.05
BW04	09-BW04-00	30-Jul-09	-	-	-	-	-	-	-
BW04	09-BW04-01	19-Nov-09	0.009	<5	0.05	0.02	249.20	<0.01	<0.05
BW04	09-BW04-02	18-Dec-09	0.005	<5	0.05	0.02	202.50	<0.01	<0.05
BW04	10-BW04-03	5-Feb-10	0.014	<5	0.06	0.02	265.00	<0.01	<0.05
BW04	10-BW04-04	26-Mar-10	0.010	<5	0.07	0.01	274.00	<0.01	<0.05
BW04	10-BW04-05	23-Apr-10	0.013	<5	0.05	0.02	286.00	<0.01	<0.05
BW04	10-BW04-06	14-May-10	0.014	<5	0.07	0.02	272.00	<0.01	<0.05
BW04	10-BW04-07	15-Jun-10	0.010	<5	0.08	0.02	275.00	<0.01	<0.05
BW04	10-BW04-07B	24-Jun-10	-	-	-	-	-	-	-
BW04	10-BW04-08	9-Jul-10	0.009	<5	0.27	0.02	264.00	<0.01	<0.05
BW04	10-BW04-10	11-Aug-10	0.011	<5	0.05	0.02	274.00	<0.01	<0.05
BW04	10-BW04-11	24-Sep-10	0.016	<5	0.04	0.02	279.00	<0.01	<0.05
BW04	10-AG-271	20-Oct-10	0.018	<5	0.09	0.01	283.00	<0.01	<0.05
BW05	09-BW05-00	30-Jul-09	-	-	-	-	-	-	-
BW05	09-BW05-01	18-Nov-09	0.034	<5	2.79	0.11	122.10	<0.01	<0.05
BW05	10-BW05-03	5-Feb-10	-	-	-	-	-	-	-
BW05	10-BW05-04	26-Mar-10	0.032	<5	4.30	0.11	117.00	<0.01	<0.05

Station Sample Date Ag Al As B Ba Be Bi

			µg/L	µg/L	µg/L	mg/L	µg/L	µg/L	µg/L
BW05	10-BW05-05	23-Apr-10	0.035	<5	4.70	0.12	117.00	<0.01	<0.05
BW05	10-BW05-06	14-May-10	0.041	<5	4.40	0.12	118.00	<0.01	<0.05
BW05	10-BW05-07	15-Jun-10	0.030	<5	3.10	0.11	115.00	<0.01	<0.05
BW05	10-BW05-07B	24-Jun-10	-	-	-	-	-	-	-
BW05	10-BW05-08	9-Jul-10	0.083	<5	3.70	0.11	118.00	<0.01	<0.05
BW05	10-BW05-10	11-Aug-10	0.033	<5	3.15	0.11	114.00	<0.01	<0.05
BW05	10-BW05-11	24-Sep-10	0.041	<5	3.25	0.11	116.00	<0.01	<0.05
BW05	10-AG-268	20-Oct-10	0.042	<5	2.80	0.10	117.00	<0.01	<0.05
BW06	09-BW06-00	30-Jul-09	-	-	-	-	-	-	-
BW06	09-BW06-01	19-Nov-09	0.034	<5	0.23	0.02	109.80	<0.01	<0.05
BW06	09-BW06-02	18-Dec-09	0.029	<5	0.35	0.02	110.40	<0.01	<0.05
BW06	10-BW06-03	5-Feb-10	0.023	<5	0.33	0.02	131.00	<0.01	<0.05
BW06	10-BW06-04	26-Mar-10	0.024	<5	0.33	0.02	125.00	<0.01	<0.05
BW06	10-BW06-05	23-Apr-10	0.020	<5	0.28	0.02	130.00	<0.01	<0.05
BW06	10-BW06-06	14-May-10	0.020	<5	0.38	0.02	126.00	<0.01	<0.05
BW06	10-BW06-07	15-Jun-10	0.023	<5	0.26	0.02	122.00	<0.01	<0.05
BW06	10-BW06-07B	24-Jun-10	-	-	-	-	-	-	-
BW06	10-BW06-08	9-Jul-10	0.033	<5	0.25	0.02	91.50	<0.01	<0.05
BW06	10-BW06-10	11-Aug-10	0.021	<5	0.31	0.02	126.00	<0.01	<0.05
BW06	10-BW06-11	24-Sep-10	0.042	<5	0.30	0.02	108.00	<0.01	<0.05
BW06	10-AG-267	20-Oct-10	0.038	<5	0.27	0.02	100.00	<0.01	<0.05
BW08	09-BW08-00	31-Jul-09	-	-	-	-	-	-	-
BW08	09-BW08-01	19-Nov-09	0.013	6	3.36	0.17	26.37	<0.01	<0.05
BW08	09-BW08-02	18-Dec-09	-	-	-	-	-	-	-
BW08	10-BW08-03	5-Feb-10	-	-	-	-	-	-	-
BW08	10-BW08-04	26-Mar-10	0.014	<5	3.17	0.17	26.60	<0.01	<0.05
BW08	10-BW08-05	23-Apr-10	0.013	<5	3.10	0.19	25.80	<0.01	<0.05
BW08	10-BW08-06	14-May-10	0.013	<5	3.11	0.19	26.00	<0.01	<0.05
BW08	10-BW08-07	15-Jun-10	0.010	<5	3.50	0.18	25.90	<0.01	<0.05
BW08	10-BW08-07B	24-Jun-10	-	-	-	-	-	-	-
BW08	10-BW08-08	11-Jul-10	0.013	<5	3.36	0.17	27.50	<0.01	<0.05
BW08	10-BW08-10	11-Aug-10	0.013	<5	3.56	0.17	25.40	<0.01	<0.05
BW08	10-BW08-11	24-Sep-10	0.020	<5	3.98	0.17	26.20	<0.01	<0.05
BW08	10-AG-273	20-Oct-10	0.019	<5	3.67	0.17	26.80	<0.01	<0.05
BW09	09-BW09-00	31-Jul-09	-	-	-	-	-	-	-
BW09	09-BW09-01	18-Nov-09	<0.005	<5	0.17	0.09	88.20	<0.01	<0.05
BW09	09-BW09-02	18-Dec-09	0.006	<5	0.12	0.10	72.30	<0.01	<0.05
BW09	10-BW09-03A	1-Jan-10	0.006	<5	0.18	0.11	84.00	<0.01	<0.05
BW09	10-BW09-03	1-Feb-10	<0.005	<5	0.12	0.11	82.45	<0.01	<0.05
BW09	10-BW09-04	1-Mar-10	0.006	<5	0.23	0.11	87.50	<0.01	<0.05
BW09	10-BW09-05	23-Apr-10	<0.005	<5	0.19	0.10	92.40	<0.01	<0.05
BW09	10-BW09-06	14-May-10	<0.005	<5	0.20	0.10	87.80	<0.01	<0.05
BW09	10-BW09-07	15-Jun-10	<0.005	<5	0.19	0.10	85.30	<0.01	<0.05
BW09	10-BW09-07B	24-Jun-10	-	-	-	-	-	-	-
BW09	10-BW09-08	12-Jul-10	<0.005	<5	0.19	0.11	87.00	<0.01	<0.05
BW09	10-BW09-10	11-Aug-10	<0.005	<5	0.17	0.09	83.40	<0.01	<0.05
BW09	10-BW09-11	24-Sep-10	0.006	<5	0.19	0.10	87.30	<0.01	<0.05
BW09	10-AG-252	20-Oct-10	0.009	<5	0.19	0.10	85.80	<0.01	<0.05
BW10	09-BW10-00	6-Jul-09	-	-	-	-	-	-	-
BW10	09-BW10-01	18-Nov-09	0.035	<5	0.05	0.03	90.90	<0.01	<0.05
BW10	09-BW10-02	19-Dec-09	0.036	<5	0.04	0.03	92.00	<0.01	<0.05
BW10	10-BW10-03	5-Feb-10	0.033	<5	0.04	0.02	93.70	<0.01	<0.05
BW10	10-BW10-04	26-Mar-10	0.031	<5	0.03	0.03	90.00	<0.01	<0.05
BW10	10-BW10-05	23-Apr-10	0.030	<5	0.03	0.03	91.20	<0.01	<0.05
BW10	10-BW10-06	14-May-10	0.035	<5	0.05	0.03	91.10	<0.01	<0.05
BW10	10-BW10-07	15-Jun-10	0.032	<5	0.05	0.02	92.90	<0.01	<0.05
BW10	10-BW10-07B	24-Jun-10	-	-	-	-	-	-	-
BW10	10-BW10-08	13-Jul-10	0.032	<5	0.04	0.02	97.10	<0.01	<0.05
BW10	10-BW10-10	11-Aug-10	0.033	<5	0.05	0.02	95.00	<0.01	<0.05
BW10	10-BW10-11	24-Sep-10	0.039	<5	0.04	0.02	97.70	<0.01	<0.05
Station	Sample	Date	Ag	Al	As	B	Ba	Be	Bi

			µg/L	µg/L	µg/L	mg/L	µg/L	µg/L	µg/L
BW10	10-AG-253	20-Oct-10	0.044	<5	0.04	0.03	96.40	<0.01	<0.05
BW11	09-BW11-01	19-Nov-09	0.014	<5	0.11	0.19	9.62	<0.01	<0.05
BW11	09-BW11-02	19-Dec-09	0.015	<5	0.12	0.20	9.87	<0.01	<0.05
BW11	10-BW11-03	5-Feb-10	0.016	<5	0.15	0.23	9.75	<0.01	<0.05
BW11	10-BW11-04	26-Mar-10	0.017	<5	0.10	0.22	9.61	<0.01	<0.05
BW11	10-BW11-05	23-Apr-10	0.015	<5	0.10	0.24	9.20	<0.01	0.13
BW11	10-BW11-06	14-May-10	0.014	<5	0.08	0.24	9.74	<0.01	<0.05
BW11	10-BW11-07	15-Jun-10	0.016	<5	0.13	0.23	9.17	<0.01	<0.05
BW11	10-BW11-07B	24-Jun-10	-	-	-	-	-	-	-
BW11	10-BW11-08	14-Jul-10	0.014	<5	0.12	0.22	9.94	<0.01	<0.05
BW11	10-AG-250	19-Oct-10	0.021	<5	0.14	0.22	9.31	<0.01	<0.05

"-" symbolizes parameter not measured. “<” symbolizes parameter is below detection limit.

Appendix CC. Trace Constituents: Cd, Ce, Co, Cr, Cs, Cu, Dy (Local Study)

Station	Sample	Date	Cd	Ce	Co	Cr	Cs	Cu	Dy
			µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
BW01	09-AG-238	29-Jul-09	-	-	-	-	-	-	-
BW01	09-BW01-01	19-Nov-09	0.06	<0.002	<0.005	0.03	0.001	5.85	<0.001
BW01	09-BW01-02	18-Dec-09	0.05	<0.002	<0.005	0.05	0.001	4.95	<0.001
BW01	10-BW01-03	5-Feb-10	0.05	<0.002	<0.005	<0.02	0.002	3.80	<0.001
BW01	10-BW01-04	26-Mar-10	0.05	<0.002	<0.005	<0.02	0.002	4.10	<0.001
BW01	10-BW01-05	23-Apr-10	0.05	0.004	<0.005	<0.02	0.002	2.60	<0.001
BW01	10-BW01-06	14-May-10	0.05	<0.002	<0.005	<0.02	0.002	2.30	0.001
BW01	10-BW01-07	15-Jun-10	0.04	<0.002	<0.005	<0.02	0.002	2.30	0.002
BW01	10-BW01-07B	24-Jun-10	-	-	-	-	-	-	-
BW01	10-BW01-08	10-Jul-10	0.04	<0.002	<0.005	<0.02	0.002	1.80	<0.001
BW01	10-BW01-10	11-Aug-10	0.05	<0.002	<0.005	<0.02	0.001	2.50	<0.001
BW01	10-BW01-11	24-Sep-10	0.05	<0.002	<0.005	<0.02	0.002	2.40	<0.001
BW01	10-AG-251	19-Oct-10	0.05	<0.002	<0.005	<0.02	0.002	2.80	<0.001
BW02	09-BW02-00	29-Jul-09	-	-	-	-	-	-	-
BW02	09-BW02-01	19-Nov-09	0.02	<0.002	<0.005	0.03	0.003	0.78	<0.001
BW02	09-BW02-02	18-Dec-09	0.02	<0.002	<0.005	<0.02	0.002	1.73	<0.001
BW02	10-BW02-03	5-Feb-10	0.01	<0.002	0.022	<0.02	0.005	0.60	<0.001
BW02	10-BW02-04	26-Mar-10	0.01	<0.002	0.024	<0.02	0.004	0.40	<0.001
BW02	10-BW02-05	23-Apr-10	<0.01	<0.002	<0.005	<0.02	0.005	0.40	<0.001
BW02	10-BW02-06	14-May-10	<0.01	<0.002	<0.005	<0.02	0.004	0.95	<0.001
BW02	10-BW02-07	15-Jun-10	0.01	0.003	0.010	0.03	0.004	0.80	<0.001
BW02	10-BW02-07B	24-Jun-10	-	-	-	-	-	-	-
BW02	10-BW02-08	9-Jul-10	0.01	<0.002	0.032	0.02	0.004	0.90	<0.001
BW02	10-BW02-10	11-Aug-10	0.02	<0.002	<0.005	<0.02	0.004	0.70	<0.001
BW02	10-BW02-11	24-Sep-10	0.02	<0.002	0.012	<0.02	0.003	0.50	<0.001
BW02	10-AG-274	20-Oct-10	0.02	<0.002	0.029	<0.02	0.005	15.70	<0.001
BW03	09-BW03-00	30-Jun-09	-	-	-	-	-	-	-
BW03	09-BW03-01	19-Nov-09	0.01	<0.002	0.103	<0.02	<0.0005	0.32	<0.001
BW03	09-BW03-02	19-Dec-09	0.01	<0.002	0.233	0.02	0.001	0.39	<0.001
BW03	10-BW03-04	26-Mar-10	0.01	<0.002	0.093	<0.02	0.002	<0.2	<0.001
BW03	10-BW03-05	23-Apr-10	0.02	<0.002	0.080	0.24	0.003	0.40	<0.001
BW03	10-BW03-06	14-May-10	<0.01	0.003	0.085	<0.02	0.003	0.50	<0.001
BW03	10-BW03-07	15-Jun-10	0.02	<0.002	0.094	<0.02	0.004	0.20	<0.001
BW03	10-BW03-07B	24-Jun-10	-	-	-	-	-	-	-
BW03	10-BW03-08	9-Jul-10	0.01	<0.002	0.109	<0.02	0.003	0.30	<0.001
BW03	10-BW03-10	11-Aug-10	0.01	<0.002	0.096	<0.02	0.004	0.30	<0.001
BW03	10-BW03-11	24-Sep-10	0.02	<0.002	0.100	<0.02	0.004	0.30	<0.001
BW03	10-AG-254	20-Oct-10	0.01	<0.002	0.102	<0.02	0.004	<0.2	<0.001
BW04	09-BW04-00	30-Jul-09	-	-	-	-	-	-	-
BW04	09-BW04-01	19-Nov-09	0.06	<0.002	<0.005	0.09	0.001	7.20	<0.001
BW04	09-BW04-02	18-Dec-09	0.03	0.005	<0.005	0.11	0.001	6.96	<0.001
BW04	10-BW04-03	5-Feb-10	0.02	<0.002	<0.005	0.10	0.002	4.00	<0.001
BW04	10-BW04-04	26-Mar-10	0.02	0.002	0.015	0.12	0.002	3.70	<0.001
BW04	10-BW04-05	23-Apr-10	0.02	0.014	<0.005	0.14	0.003	2.90	<0.001
BW04	10-BW04-06	14-May-10	0.03	<0.002	<0.005	0.09	0.002	3.10	<0.001
BW04	10-BW04-07	15-Jun-10	0.02	<0.002	<0.005	0.10	0.002	2.80	<0.001
BW04	10-BW04-07B	24-Jun-10	-	-	-	-	-	-	-
BW04	10-BW04-08	9-Jul-10	0.02	0.002	0.028	0.10	0.002	3.40	<0.001
BW04	10-BW04-10	11-Aug-10	0.02	0.012	<0.005	<0.02	0.002	4.70	0.003
BW04	10-BW04-11	24-Sep-10	0.03	0.002	<0.005	<0.02	0.003	5.30	<0.001
BW04	10-AG-271	20-Oct-10	0.02	<0.002	<0.005	0.05	0.002	3.85	<0.001
BW05	09-BW05-00	30-Jul-09	-	-	-	-	-	-	-
BW05	09-BW05-01	18-Nov-09	0.03	<0.002	0.082	0.05	0.001	0.49	<0.001
BW05	10-BW05-03	5-Feb-10	-	-	-	-	-	-	-
BW05	10-BW05-04	26-Mar-10	0.03	<0.002	0.076	0.20	0.004	<0.2	<0.001
BW05	10-BW05-05	23-Apr-10	0.02	<0.002	0.088	<0.02	0.004	0.30	<0.001

Station	Sample	Date	Cd	Ce	Co	Cr	Cs	Cu	Dy
			µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
BW05	10-BW05-06	14-May-10	0.03	0.002	0.073	<0.02	0.004	0.40	<0.001
BW05	10-BW05-07	15-Jun-10	0.03	<0.002	0.079	<0.02	0.005	0.30	<0.001
BW05	10-BW05-07B	24-Jun-10	-	-	-	-	-	-	-
BW05	10-BW05-08	9-Jul-10	0.04	<0.002	0.087	<0.02	0.003	0.30	<0.001
BW05	10-BW05-10	11-Aug-10	0.03	<0.002	0.082	<0.02	0.004	0.60	<0.001
BW05	10-BW05-11	24-Sep-10	0.02	0.003	0.084	0.03	0.004	0.30	<0.001
BW05	10-AG-268	20-Oct-10	0.03	0.002	0.078	<0.02	0.005	0.40	<0.001
BW06	09-BW06-00	30-Jul-09	-	-	-	-	-	-	-
BW06	09-BW06-01	19-Nov-09	0.06	<0.002	<0.005	<0.02	0.003	2.43	<0.001
BW06	09-BW06-02	18-Dec-09	0.06	<0.002	<0.005	0.04	0.003	1.48	<0.001
BW06	10-BW06-03	5-Feb-10	0.04	<0.002	0.007	0.03	0.003	1.60	<0.001
BW06	10-BW06-04	26-Mar-10	0.04	0.006	0.010	0.05	0.006	1.60	<0.001
BW06	10-BW06-05	23-Apr-10	0.03	0.002	<0.005	0.02	0.004	1.30	<0.001
BW06	10-BW06-06	14-May-10	0.03	<0.002	<0.005	0.06	0.005	1.60	<0.001
BW06	10-BW06-07	15-Jun-10	0.04	<0.002	0.005	<0.02	0.005	1.10	<0.001
BW06	10-BW06-07B	24-Jun-10	-	-	-	-	-	-	-
BW06	10-BW06-08	9-Jul-10	0.06	0.007	0.035	0.11	0.005	1.30	<0.001
BW06	10-BW06-10	11-Aug-10	0.05	<0.002	<0.005	<0.02	0.005	1.20	<0.001
BW06	10-BW06-11	24-Sep-10	0.07	<0.002	0.013	<0.02	0.006	0.90	<0.001
BW06	10-AG-267	20-Oct-10	0.06	<0.002	0.011	<0.02	0.005	0.90	<0.001
BW08	09-BW08-00	31-Jul-09	-	-	-	-	-	-	-
BW08	09-BW08-01	19-Nov-09	0.02	0.016	<0.005	0.03	0.001	1.31	<0.001
BW08	09-BW08-02	18-Dec-09	-	-	-	-	-	-	-
BW08	10-BW08-03	5-Feb-10	-	-	-	-	-	-	-
BW08	10-BW08-04	26-Mar-10	0.02	<0.002	0.125	0.03	0.003	0.80	<0.001
BW08	10-BW08-05	23-Apr-10	0.02	0.010	0.072	0.36	0.004	0.80	<0.001
BW08	10-BW08-06	14-May-10	0.02	<0.002	0.068	<0.02	0.003	0.70	<0.001
BW08	10-BW08-07	15-Jun-10	0.02	<0.002	0.055	0.10	0.003	0.80	<0.001
BW08	10-BW08-07B	24-Jun-10	-	-	-	-	-	-	-
BW08	10-BW08-08	11-Jul-10	0.03	<0.002	0.127	0.05	0.003	0.50	<0.001
BW08	10-BW08-10	11-Aug-10	0.03	<0.002	0.100	<0.02	0.003	0.90	<0.001
BW08	10-BW08-11	24-Sep-10	0.03	0.002	0.160	<0.02	0.004	0.70	<0.001
BW08	10-AG-273	20-Oct-10	0.03	0.002	0.120	<0.02	0.003	0.70	<0.001
BW09	09-BW09-00	31-Jul-09	-	-	-	-	-	-	-
BW09	09-BW09-01	18-Nov-09	0.04	<0.002	<0.005	<0.02	0.002	12.29	<0.001
BW09	09-BW09-02	18-Dec-09	0.05	<0.002	0.044	<0.02	0.003	137.22	<0.001
BW09	10-BW09-03A	1-Jan-10	0.05	<0.002	0.037	0.06	0.003	7.30	<0.001
BW09	10-BW09-03	1-Feb-10	0.05	<0.002	<0.005	0.04	0.003	10.25	<0.001
BW09	10-BW09-04	1-Mar-10	0.06	<0.002	0.031	0.03	0.002	8.80	<0.001
BW09	10-BW09-05	23-Apr-10	0.05	<0.002	0.013	0.02	0.003	6.90	<0.001
BW09	10-BW09-06	14-May-10	0.04	<0.002	0.013	0.03	0.002	7.10	<0.001
BW09	10-BW09-07	15-Jun-10	0.04	0.005	0.021	0.29	0.003	6.00	<0.001
BW09	10-BW09-07B	24-Jun-10	-	-	-	-	-	-	-
BW09	10-BW09-08	12-Jul-10	0.04	<0.002	0.042	0.02	0.002	8.40	<0.001
BW09	10-BW09-10	11-Aug-10	0.04	<0.002	0.006	0.02	0.002	9.20	<0.001
BW09	10-BW09-11	24-Sep-10	0.05	<0.002	0.025	0.19	0.003	6.80	<0.001
BW09	10-AG-252	20-Oct-10	0.06	<0.002	0.043	<0.02	0.002	5.70	<0.001
BW10	09-BW10-00	6-Jul-09	-	-	-	-	-	-	-
BW10	09-BW10-01	18-Nov-09	0.29	<0.002	0.229	<0.02	0.003	112.96	<0.001
BW10	09-BW10-02	19-Dec-09	0.02	<0.002	<0.005	<0.02	0.004	5.22	<0.001
BW10	10-BW10-03	5-Feb-10	0.02	<0.002	0.009	<0.02	0.007	3.20	<0.001
BW10	10-BW10-04	26-Mar-10	0.02	<0.002	0.010	<0.02	0.006	4.90	<0.001
BW10	10-BW10-05	23-Apr-10	0.03	<0.002	<0.005	0.03	0.008	4.90	<0.001
BW10	10-BW10-06	14-May-10	0.03	<0.002	<0.005	<0.02	0.007	3.80	<0.001
BW10	10-BW10-07	15-Jun-10	0.01	<0.002	<0.005	<0.02	0.007	2.20	<0.001
BW10	10-BW10-07B	24-Jun-10	-	-	-	-	-	-	-
BW10	10-BW10-08	13-Jul-10	0.01	<0.002	0.031	0.08	0.005	1.90	<0.001
BW10	10-BW10-10	11-Aug-10	0.01	<0.002	<0.005	<0.02	0.005	1.85	<0.001
BW10	10-BW10-11	24-Sep-10	0.01	0.009	0.010	<0.02	0.006	1.80	<0.001
BW10	10-AG-253	20-Oct-10	0.02	0.006	0.017	<0.02	0.006	9.00	<0.001

Station	Sample	Date	Cd	Ce	Co	Cr	Cs	Cu	Dy
			µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
BW11	09-BW11-01	19-Nov-09	<0.01	<0.002	<0.005	0.10	0.005	1.35	<0.001
BW11	09-BW11-02	19-Dec-09	0.02	<0.002	<0.005	<0.02	0.003	1.47	<0.001
BW11	10-BW11-03	5-Feb-10	0.01	<0.002	<0.005	<0.02	0.005	0.90	<0.001
BW11	10-BW11-04	26-Mar-10	<0.01	<0.002	<0.005	<0.02	0.004	1.00	<0.001
BW11	10-BW11-05	23-Apr-10	0.02	<0.002	<0.005	<0.02	0.004	1.00	<0.001
BW11	10-BW11-06	14-May-10	0.01	0.002	<0.005	<0.02	0.005	0.70	<0.001
BW11	10-BW11-07	15-Jun-10	0.01	<0.002	0.050	<0.02	0.005	1.70	<0.001
BW11	10-BW11-07B	24-Jun-10	-	-	-	-	-	-	-
BW11	10-BW11-08	14-Jul-10	<0.01	<0.002	<0.005	<0.02	0.005	0.70	<0.001
BW11	10-AG-250	19-Oct-10	0.02	<0.002	0.070	<0.02	0.006	0.80	<0.001

"-" symbolizes parameter not measured. “<” symbolizes parameter is below detection limit.

Appendix DD. Trace Constituents: Er, Eu, Ga, Gd, Hf, Hg, Ho (Local Study)

Station	Sample	Date	Er	Eu	Ga	Gd	Hf	Hg	Ho
			µg/L	µg/L	µg/L	µg/L	µg/L	ng/L	µg/L
BW01	09-AG-238	29-Jul-09	-	-	-	-	-	-	-
BW01	09-BW01-01	19-Nov-09	<0.001	<0.0004	<0.002	0.001	<0.004		0.0006
BW01	09-BW01-02	18-Dec-09	<0.001	<0.0004	0.002	<0.001	<0.004		<0.0001
BW01	10-BW01-03	5-Feb-10	<0.001	<0.0004	<0.002	<0.001	<0.004		<0.0001
BW01	10-BW01-04	26-Mar-10	<0.001	<0.0004	0.003	<0.001	<0.004		<0.0001
BW01	10-BW01-05	23-Apr-10	<0.001	<0.0004	<0.002	<0.001	<0.004		0.0002
BW01	10-BW01-06	14-May-10	<0.001	<0.0004	<0.002	0.002	<0.004		0.0002
BW01	10-BW01-07	15-Jun-10	<0.001	<0.0004	0.002	<0.001	<0.004	<1.5	0.0003
BW01	10-BW01-07B	24-Jun-10	-	-	-	-	-	-	-
BW01	10-BW01-08	10-Jul-10	<0.001	<0.0004	<0.002	<0.001	<0.004		0.0003
BW01	10-BW01-10	11-Aug-10	<0.001	<0.0004	<0.002	<0.001	<0.004		<0.0001
BW01	10-BW01-11	24-Sep-10	<0.001	<0.0004	<0.002	0.001	<0.004		0.0003
BW01	10-AG-251	19-Oct-10	<0.001	<0.0004	0.003	0.001	<0.004		0.0002
BW02	09-BW02-00	29-Jul-09	-	-	-	-	-	-	-
BW02	09-BW02-01	19-Nov-09	<0.001	<0.0004	0.002	0.001	<0.004		0.0002
BW02	09-BW02-02	18-Dec-09	<0.001	<0.0004	0.003	0.001	<0.004		<0.0001
BW02	10-BW02-03	5-Feb-10	<0.001	<0.0004	0.002	0.001	<0.004		<0.0001
BW02	10-BW02-04	26-Mar-10	<0.001	<0.0004	<0.002	<0.001	<0.004		0.0001
BW02	10-BW02-05	23-Apr-10	<0.001	<0.0004	0.003	<0.001	<0.004		<0.0001
BW02	10-BW02-06	14-May-10	<0.001	<0.0004	0.002	<0.001	<0.004		0.0001
BW02	10-BW02-07	15-Jun-10	<0.001	<0.0004	0.002	<0.001	<0.004	<1.5	<0.0001
BW02	10-BW02-07B	24-Jun-10	-	-	-	-	-	-	-
BW02	10-BW02-08	9-Jul-10	<0.001	<0.0004	<0.002	0.002	<0.004		<0.0001
BW02	10-BW02-10	11-Aug-10	<0.001	0.0006	0.003	<0.001	<0.004		<0.0001
BW02	10-BW02-11	24-Sep-10	<0.001	<0.0004	0.002	0.001	<0.004		0.0001
BW02	10-AG-274	20-Oct-10	<0.001	<0.0004	0.006	<0.001	<0.004		0.0002
BW03	09-BW03-00	30-Jun-09	-	-	-	-	-	-	-
BW03	09-BW03-01	19-Nov-09	<0.001	<0.0004	0.006	<0.001	<0.004		<0.0001
BW03	09-BW03-02	19-Dec-09	<0.001	<0.0004	0.006	0.001	<0.004		<0.0001
BW03	10-BW03-04	26-Mar-10	<0.001	<0.0004	0.006	0.003	<0.004		<0.0001
BW03	10-BW03-05	23-Apr-10	<0.001	<0.0004	0.005	0.002	<0.004		<0.0001
BW03	10-BW03-06	14-May-10	<0.001	<0.0004	0.006	0.002	<0.004		0.0001
BW03	10-BW03-07	15-Jun-10	<0.001	<0.0004	0.007	0.003	<0.004	<1.5	<0.0001
BW03	10-BW03-07B	24-Jun-10	-	-	-	-	-	-	-
BW03	10-BW03-08	9-Jul-10	<0.001	<0.0004	0.003	<0.001	<0.004		<0.0001
BW03	10-BW03-10	11-Aug-10	<0.001	<0.0004	0.006	0.001	<0.004		0.0002
BW03	10-BW03-11	24-Sep-10	<0.001	<0.0004	0.010	0.002	<0.004		0.0002
BW03	10-AG-254	20-Oct-10	<0.001	<0.0004	0.007	0.002	<0.004		<0.0001
BW04	09-BW04-00	30-Jul-09	-	-	-	-	-	-	-
BW04	09-BW04-01	19-Nov-09	<0.001	<0.0004	<0.002	0.002	<0.004		<0.0001
BW04	09-BW04-02	18-Dec-09	<0.001	<0.0004	<0.002	0.002	<0.004		<0.0001
BW04	10-BW04-03	5-Feb-10	<0.001	<0.0004	0.002	0.002	<0.004		<0.0001
BW04	10-BW04-04	26-Mar-10	<0.001	<0.0004	<0.002	0.003	<0.004		0.0002
BW04	10-BW04-05	23-Apr-10	<0.001	<0.0004	0.004	0.001	<0.004		<0.0001
BW04	10-BW04-06	14-May-10	<0.001	<0.0004	0.002	0.002	<0.004		0.0001
BW04	10-BW04-07	15-Jun-10	<0.001	<0.0004	0.002	0.002	<0.004	<1.5	<0.0001
BW04	10-BW04-07B	24-Jun-10	-	-	-	-	-	-	-
BW04	10-BW04-08	9-Jul-10	<0.001	<0.0004	0.004	0.003	<0.004		0.0002
BW04	10-BW04-10	11-Aug-10	<0.001	<0.0004	<0.002	0.002	<0.004		0.0006
BW04	10-BW04-11	24-Sep-10	<0.001	<0.0004	0.003	0.002	<0.004		0.0002
BW04	10-AG-271	20-Oct-10	<0.001	<0.0004	<0.002	0.003	<0.004		0.0002
BW05	09-BW05-00	30-Jul-09	-	-	-	-	-	-	-
BW05	09-BW05-01	18-Nov-09	<0.001	<0.0004	0.007	0.001	<0.004		0.0002
BW05	10-BW05-03	5-Feb-10	-	-	-	-	-	-	-
BW05	10-BW05-04	26-Mar-10	<0.001	<0.0004	0.005	<0.001	<0.004		0.0001
BW05	10-BW05-05	23-Apr-10	<0.001	<0.0004	0.007	0.003	<0.004		<0.0001

Station	Sample	Date	Er	Eu	Ga	Gd	Hf	Hg	Ho
			µg/L	µg/L	µg/L	µg/L	µg/L	ng/L	µg/L
BW05	10-BW05-06	14-May-10	<0.001	<0.0004	0.007	0.003	<0.004		0.0002
BW05	10-BW05-07	15-Jun-10	<0.001	<0.0004	0.008	0.001	<0.004	<1.5	<0.0001
BW05	10-BW05-07B	24-Jun-10	-	-	-	-	-	-	-
BW05	10-BW05-08	9-Jul-10	<0.001	<0.0004	0.006	0.001	<0.004		0.0002
BW05	10-BW05-10	11-Aug-10	<0.001	0.0011	0.008	0.002	<0.004		0.0003
BW05	10-BW05-11	24-Sep-10	<0.001	<0.0004	0.008	0.002	<0.004		0.0003
BW05	10-AG-268	20-Oct-10	<0.001	<0.0004	0.006	0.002	<0.004		0.0003
BW06	09-BW06-00	30-Jul-09	-	-	-	-	-	-	-
BW06	09-BW06-01	19-Nov-09	<0.001	<0.0004	0.003	0.002	<0.004		<0.0001
BW06	09-BW06-02	18-Dec-09	<0.001	<0.0004	0.003	0.001	<0.004		<0.0001
BW06	10-BW06-03	5-Feb-10	<0.001	<0.0004	<0.002	0.001	<0.004		<0.0001
BW06	10-BW06-04	26-Mar-10	<0.001	<0.0004	<0.002	0.001	<0.004		0.0001
BW06	10-BW06-05	23-Apr-10	0.001	<0.0004	0.003	0.002	<0.004		<0.0001
BW06	10-BW06-06	14-May-10	<0.001	<0.0004	<0.002	<0.001	0.007		<0.0001
BW06	10-BW06-07	15-Jun-10	<0.001	<0.0004	0.002	0.002	<0.004	<1.5	0.0001
BW06	10-BW06-07B	24-Jun-10	-	-	-	-	-	-	-
BW06	10-BW06-08	9-Jul-10	<0.001	<0.0004	0.003	0.002	<0.004		<0.0001
BW06	10-BW06-10	11-Aug-10	<0.001	<0.0004	0.004	0.001	<0.004		<0.0001
BW06	10-BW06-11	24-Sep-10	<0.001	<0.0004	0.004	0.002	<0.004		<0.0001
BW06	10-AG-267	20-Oct-10	<0.001	<0.0004	0.002	0.002	<0.004		0.0002
BW08	09-BW08-00	31-Jul-09	-	-	-	-	-	-	-
BW08	09-BW08-01	19-Nov-09	<0.001	<0.0004	0.004	0.002	<0.004		0.0003
BW08	09-BW08-02	18-Dec-09	-	-	-	-	-	-	-
BW08	10-BW08-03	5-Feb-10	-	-	-	-	-	-	-
BW08	10-BW08-04	26-Mar-10	<0.001	<0.0004	0.003	<0.001	<0.004		0.0001
BW08	10-BW08-05	23-Apr-10	<0.001	<0.0004	0.003	<0.001	<0.004		0.0001
BW08	10-BW08-06	14-May-10	<0.001	<0.0004	0.003	0.002	<0.004		0.0002
BW08	10-BW08-07	15-Jun-10	<0.001	<0.0004	0.004	<0.001	<0.004	<1.5	<0.0001
BW08	10-BW08-07B	24-Jun-10	-	-	-	-	-	-	-
BW08	10-BW08-08	11-Jul-10	<0.001	<0.0004	0.004	<0.001	<0.004		<0.0001
BW08	10-BW08-10	11-Aug-10	<0.001	<0.0004	0.004	<0.001	<0.004		<0.0001
BW08	10-BW08-11	24-Sep-10	<0.001	<0.0004	0.005	<0.001	<0.004		<0.0001
BW08	10-AG-273	20-Oct-10	<0.001	0.0007	0.005	0.002	<0.004		<0.0001
BW09	09-BW09-00	31-Jul-09	-	-	-	-	-	-	-
BW09	09-BW09-01	18-Nov-09	<0.001	<0.0004	<0.002	<0.001	<0.004		<0.0001
BW09	09-BW09-02	18-Dec-09	<0.001	<0.0004	0.004	0.001	<0.004		<0.0001
BW09	10-BW09-03A	1-Jan-10	<0.001	<0.0004	0.003	0.003	<0.004		<0.0001
BW09	10-BW09-03	1-Feb-10	<0.001	<0.0004	<0.002	<0.001	<0.004		0.0001
BW09	10-BW09-04	1-Mar-10	<0.001	<0.0004	<0.002	<0.001	<0.004		0.0001
BW09	10-BW09-05	23-Apr-10	0.001	<0.0004	<0.002	<0.001	<0.004		<0.0001
BW09	10-BW09-06	14-May-10	<0.001	<0.0004	0.003	<0.001	<0.004		0.0001
BW09	10-BW09-07	15-Jun-10	<0.001	<0.0004	<0.002	0.001	<0.004	<1.5	0.0001
BW09	10-BW09-07B	24-Jun-10	-	-	-	-	-	-	-
BW09	10-BW09-08	12-Jul-10	<0.001	<0.0004	<0.002	<0.001	<0.004		0.0002
BW09	10-BW09-10	11-Aug-10	<0.001	<0.0004	<0.002	<0.001	<0.004		<0.0001
BW09	10-BW09-11	24-Sep-10	<0.001	<0.0004	0.003	<0.001	<0.004		0.0001
BW09	10-AG-252	20-Oct-10	<0.001	<0.0004	0.003	<0.001	<0.004		0.0002
BW10	09-BW10-00	6-Jul-09	-	-	-	-	-	-	-
BW10	09-BW10-01	18-Nov-09	<0.001	<0.0004	0.005	<0.001	<0.004		<0.0001
BW10	09-BW10-02	19-Dec-09	<0.001	<0.0004	0.003	<0.001	<0.004		<0.0001
BW10	10-BW10-03	5-Feb-10	<0.001	<0.0004	0.003	<0.001	<0.004		<0.0001
BW10	10-BW10-04	26-Mar-10	<0.001	<0.0004	<0.002	<0.001	<0.004		<0.0001
BW10	10-BW10-05	23-Apr-10	<0.001	<0.0004	0.002	<0.001	<0.004		0.0001
BW10	10-BW10-06	14-May-10	<0.001	<0.0004	0.003	<0.001	<0.004		<0.0001
BW10	10-BW10-07	15-Jun-10	<0.001	<0.0004	0.006	<0.001	<0.004	<1.5	<0.0001
BW10	10-BW10-07B	24-Jun-10	-	-	-	-	-	-	-
BW10	10-BW10-08	13-Jul-10	<0.001	<0.0004	0.004	0.001	<0.004		<0.0001
BW10	10-BW10-10	11-Aug-10	<0.001	<0.0004	0.005	<0.001	<0.004		<0.0001
BW10	10-BW10-11	24-Sep-10	<0.001	<0.0004	0.003	0.002	<0.004		<0.0001
BW10	10-AG-253	20-Oct-10	<0.001	<0.0004	0.003	<0.001	<0.004		0.0002

Station	Sample	Date	Er	Eu	Ga	Gd	Hf	Hg	Ho
			µg/L	µg/L	µg/L	µg/L	µg/L	ng/L	µg/L
BW11	09-BW11-01	19-Nov-09	<0.001	<0.0004	0.005	<0.001	<0.004		<0.0001
BW11	09-BW11-02	19-Dec-09	<0.001	<0.0004	0.006	<0.001	<0.004		<0.0001
BW11	10-BW11-03	5-Feb-10	<0.001	<0.0004	0.005	<0.001	<0.004		<0.0001
BW11	10-BW11-04	26-Mar-10	<0.001	<0.0004	0.005	<0.001	<0.004		<0.0001
BW11	10-BW11-05	23-Apr-10	<0.001	<0.0004	0.003	<0.001	<0.004		<0.0001
BW11	10-BW11-06	14-May-10	<0.001	<0.0004	0.005	<0.001	<0.004		<0.0001
BW11	10-BW11-07	15-Jun-10	<0.001	<0.0004	0.005	<0.001	<0.004	<1.5	<0.0001
BW11	10-BW11-07B	24-Jun-10	-	-	-	-	-	-	-
BW11	10-BW11-08	14-Jul-10	<0.001	<0.0004	0.003	0.001	<0.004		<0.0001
BW11	10-AG-250	19-Oct-10	<0.001	<0.0004	0.010	<0.001	<0.004		<0.0001

"-" symbolizes parameter not measured. “<” symbolizes parameter is below detection limit.

Appendix EE. Trace Constituents: La, Li, Lu, Mn, Mo, Nb, Nd (Local Study)

Station	Sample	Date	La	Li	Lu	Mn	Mo	Nb	Nd
			µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
BW01	09-AG-238	29-Jul-09	-	-	-	-	-	-	-
BW01	09-BW01-01	19-Nov-09	0.003	5.7	<0.0001	5	4.0	0.001	<0.003
BW01	09-BW01-02	18-Dec-09	0.004	5.3	0.0001	4	3.8	<0.001	<0.003
BW01	10-BW01-03	5-Feb-10	0.003	4.5	<0.0001	6	3.6	<0.001	0.004
BW01	10-BW01-04	26-Mar-10	0.002	4.5	<0.0001	25	2.9	<0.001	<0.003
BW01	10-BW01-05	23-Apr-10	0.003	5.3	<0.0001	6	3.8	0.003	<0.003
BW01	10-BW01-06	14-May-10	0.004	5.2	0.0002	2	3.6	0.001	<0.003
BW01	10-BW01-07	15-Jun-10	0.005	5.1	<0.0001	2	3.6	<0.001	0.004
BW01	10-BW01-07B	24-Jun-10	-	-	-	-	-	-	-
BW01	10-BW01-08	10-Jul-10	0.004	4.5	<0.0001	5	3.5	0.001	0.003
BW01	10-BW01-10	11-Aug-10	0.004	5.9	<0.0001	4	3.6	<0.001	0.003
BW01	10-BW01-11	24-Sep-10	0.003	5.5	0.0001	3	3.6	<0.001	<0.003
BW01	10-AG-251	19-Oct-10	0.004	5.4	<0.0001	2	3.7	<0.001	0.003
BW02	09-BW02-00	29-Jul-09	-	-	-	-	-	-	-
BW02	09-BW02-01	19-Nov-09	0.002	4.4	<0.0001	13	4.5	<0.001	<0.003
BW02	09-BW02-02	18-Dec-09	0.002	4.6	<0.0001	13	4.4	0.001	<0.003
BW02	10-BW02-03	5-Feb-10	0.001	3.7	<0.0001	14	4.6	<0.001	<0.003
BW02	10-BW02-04	26-Mar-10	0.002	3.5	<0.0001	12	4.4	<0.001	<0.003
BW02	10-BW02-05	23-Apr-10	0.002	4.2	<0.0001	15	4.3	<0.001	<0.003
BW02	10-BW02-06	14-May-10	0.002	4.4	0.0001	14	4.5	<0.001	<0.003
BW02	10-BW02-07	15-Jun-10	0.002	5.6	<0.0001	20	4.6	0.001	0.005
BW02	10-BW02-07B	24-Jun-10	-	-	-	-	-	-	-
BW02	10-BW02-08	9-Jul-10	0.001	3.7	<0.0001	15	4.2	<0.001	<0.003
BW02	10-BW02-10	11-Aug-10	<0.001	4.4	<0.0001	12	4.3	<0.001	<0.003
BW02	10-BW02-11	24-Sep-10	0.001	4.0	<0.0001	14	4.3	<0.001	<0.003
BW02	10-AG-274	20-Oct-10	0.001	4.5	<0.0001	5	4.6	<0.001	<0.003
BW03	09-BW03-00	30-Jun-09	-	-	-	-	-	-	-
BW03	09-BW03-01	19-Nov-09	0.002	3.5	<0.0001	14	3.5	<0.001	<0.003
BW03	09-BW03-02	19-Dec-09	0.002	3.6	<0.0001	17	3.4	<0.001	<0.003
BW03	10-BW03-04	26-Mar-10	0.002	2.8	<0.0001	14	3.3	<0.001	<0.003
BW03	10-BW03-05	23-Apr-10	0.002	3.2	<0.0001	15	3.4	<0.001	<0.003
BW03	10-BW03-06	14-May-10	0.003	3.5	<0.0001	14	3.4	<0.001	<0.003
BW03	10-BW03-07	15-Jun-10	0.002	3.5	<0.0001	13	3.5	<0.001	<0.003
BW03	10-BW03-07B	24-Jun-10	-	-	-	-	-	-	-
BW03	10-BW03-08	9-Jul-10	0.001	3.6	<0.0001	11	3.4	<0.001	<0.003
BW03	10-BW03-10	11-Aug-10	0.002	3.3	<0.0001	15	3.3	<0.001	<0.003
BW03	10-BW03-11	24-Sep-10	0.002	3.1	<0.0001	12	3.5	<0.001	<0.003
BW03	10-AG-254	20-Oct-10	0.003	3.5	<0.0001	13	3.5	<0.001	<0.003
BW04	09-BW04-00	30-Jul-09	-	-	-	-	-	-	-
BW04	09-BW04-01	19-Nov-09	0.002	2.2	<0.0001	<2	0.6	<0.001	<0.003
BW04	09-BW04-02	18-Dec-09	0.005	2.2	<0.0001	<2	0.5	<0.001	<0.003
BW04	10-BW04-03	5-Feb-10	0.003	2.1	<0.0001	<2	0.6	<0.001	<0.003
BW04	10-BW04-04	26-Mar-10	0.004	2.0	<0.0001	<2	0.6	0.001	<0.003
BW04	10-BW04-05	23-Apr-10	0.006	2.0	0.0001	<2	0.6	<0.001	0.006
BW04	10-BW04-06	14-May-10	0.003	2.2	<0.0001	<2	0.6	<0.001	<0.003
BW04	10-BW04-07	15-Jun-10	0.003	2.6	<0.0001	6	0.6	<0.001	<0.003
BW04	10-BW04-07B	24-Jun-10	-	-	-	-	-	-	-
BW04	10-BW04-08	9-Jul-10	0.004	2.9	<0.0001	5	1.0	0.002	0.005
BW04	10-BW04-10	11-Aug-10	0.013	2.2	0.0001	3	0.6	<0.001	0.007
BW04	10-BW04-11	24-Sep-10	0.004	1.9	<0.0001	<2	0.6	<0.001	<0.003
BW04	10-AG-271	20-Oct-10	0.003	2.2	<0.0001	<2	0.6	<0.001	<0.003
BW05	09-BW05-00	30-Jul-09	-	-	-	-	-	-	-
BW05	09-BW05-01	18-Nov-09	0.004	9.4	<0.0001	14	5.6	0.001	<0.003
BW05	10-BW05-03	5-Feb-10	-	-	-	-	-	-	-
BW05	10-BW05-04	26-Mar-10	0.002	8.5	<0.0001	20	5.1	<0.001	<0.003
BW05	10-BW05-05	23-Apr-10	0.002	10.2	0.0001	11	5.4	0.001	<0.003
BW05	10-BW05-06	14-May-10	0.003	12.9	0.0002	13	5.3	0.002	<0.003
BW05	10-BW05-07	15-Jun-10	0.002	9.8	<0.0001	8	5.1	<0.001	<0.003

Station	Sample	Date	La	Li	Lu	Mn	Mo	Nb	Nd
			µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
BW05	10-BW05-07B	24-Jun-10	-	-	-	-	-	-	-
BW05	10-BW05-08	9-Jul-10	0.003	9.8	0.0002	10	5.1	<0.001	0.003
BW05	10-BW05-10	11-Aug-10	0.005	9.5	<0.0001	9	5.0	0.003	<0.003
BW05	10-BW05-11	24-Sep-10	0.005	9.6	0.0002	9	5.1	0.001	<0.003
BW05	10-AG-268	20-Oct-10	0.004	10.1	0.0002	8	5.2	0.002	0.004
BW06	09-BW06-00	30-Jul-09	-	-	-	-	-	-	-
BW06	09-BW06-01	19-Nov-09	0.002	6.8	<0.0001	5	17.2	<0.001	<0.003
BW06	09-BW06-02	18-Dec-09	0.003	7.2	<0.0001	3	17.4	0.001	<0.003
BW06	10-BW06-03	5-Feb-10	0.002	7.0	<0.0001	3	12.9	<0.001	<0.003
BW06	10-BW06-04	26-Mar-10	0.004	7.9	0.0001	3	13.8	<0.001	0.005
BW06	10-BW06-05	23-Apr-10	0.002	7.2	<0.0001	4	12.9	<0.001	<0.003
BW06	10-BW06-06	14-May-10	0.003	7.8	<0.0001	6	12.6	<0.001	<0.003
BW06	10-BW06-07	15-Jun-10	0.001	7.0	<0.0001	4	13.8	<0.001	<0.003
BW06	10-BW06-07B	24-Jun-10	-	-	-	-	-	-	-
BW06	10-BW06-08	9-Jul-10	0.005	6.0	<0.0001	4	19.9	<0.001	0.004
BW06	10-BW06-10	11-Aug-10	0.003	6.9	<0.0001	6	13.2	<0.001	<0.003
BW06	10-BW06-11	24-Sep-10	0.002	6.0	<0.0001	3	18.3	0.001	<0.003
BW06	10-AG-267	20-Oct-10	<0.001	7.3	<0.0001	4	16.0	0.001	<0.003
BW08	09-BW08-00	31-Jul-09	-	-	-	-	-	-	-
BW08	09-BW08-01	19-Nov-09	0.018	6.9	<0.0001	26	7.7	0.002	0.011
BW08	09-BW08-02	18-Dec-09	-	-	-	-	-	-	-
BW08	10-BW08-03	5-Feb-10	-	-	-	-	-	-	-
BW08	10-BW08-04	26-Mar-10	0.001	5.7	<0.0001	25	7.1	<0.001	<0.003
BW08	10-BW08-05	23-Apr-10	0.006	6.6	<0.0001	31	7.5	0.002	0.003
BW08	10-BW08-06	14-May-10	<0.001	6.8	<0.0001	30	7.3	0.002	<0.003
BW08	10-BW08-07	15-Jun-10	<0.001	6.8	<0.0001	27	7.7	0.001	<0.003
BW08	10-BW08-07B	24-Jun-10	-	-	-	-	-	-	-
BW08	10-BW08-08	11-Jul-10	0.001	5.8	<0.0001	22	7.3	<0.001	<0.003
BW08	10-BW08-10	11-Aug-10	0.001	7.0	<0.0001	22	7.4	0.002	<0.003
BW08	10-BW08-11	24-Sep-10	0.001	6.6	0.0001	22	7.5	0.001	<0.003
BW08	10-AG-273	20-Oct-10	0.001	6.5	<0.0001	24	7.3	<0.001	<0.003
BW09	09-BW09-00	31-Jul-09	-	-	-	-	-	-	-
BW09	09-BW09-01	18-Nov-09	0.001	4.4	<0.0001	<2	4.3	<0.001	<0.003
BW09	09-BW09-02	18-Dec-09	0.002	6.2	<0.0001	9	4.3	<0.001	<0.003
BW09	10-BW09-03A	1-Jan-10	0.002	3.9	<0.0001	7	4.2	<0.001	<0.003
BW09	10-BW09-03	1-Feb-10	0.001	4.2	<0.0001	<2	5.1	<0.001	<0.003
BW09	10-BW09-04	1-Mar-10	0.001	4.1	<0.0001	8	4.6	<0.001	<0.003
BW09	10-BW09-05	23-Apr-10	0.001	4.4	<0.0001	3	4.1	<0.001	<0.003
BW09	10-BW09-06	14-May-10	0.001	4.3	<0.0001	4	4.1	<0.001	<0.003
BW09	10-BW09-07	15-Jun-10	0.003	4.5	<0.0001	5	3.9	<0.001	<0.003
BW09	10-BW09-07B	24-Jun-10	-	-	-	-	-	-	-
BW09	10-BW09-08	12-Jul-10	0.001	4.2	<0.0001	<2	5.2	<0.001	<0.003
BW09	10-BW09-10	11-Aug-10	0.002	7.8	<0.0001	3	3.7	<0.001	<0.003
BW09	10-BW09-11	24-Sep-10	0.002	4.5	<0.0001	2	4.3	<0.001	<0.003
BW09	10-AG-252	20-Oct-10	0.001	4.7	<0.0001	3	4.8	<0.001	<0.003
BW10	09-BW10-00	6-Jul-09	-	-	-	-	-	-	-
BW10	09-BW10-01	18-Nov-09	0.002	2.7	<0.0001	33	3.8	<0.001	<0.003
BW10	09-BW10-02	19-Dec-09	0.002	2.7	<0.0001	4	3.3	<0.001	<0.003
BW10	10-BW10-03	5-Feb-10	0.002	2.0	<0.0001	4	2.7	0.001	<0.003
BW10	10-BW10-04	26-Mar-10	0.003	2.3	0.0001	4	3.1	<0.001	<0.003
BW10	10-BW10-05	23-Apr-10	0.001	2.6	<0.0001	5	3.4	<0.001	<0.003
BW10	10-BW10-06	14-May-10	0.002	2.6	<0.0001	5	3.0	<0.001	<0.003
BW10	10-BW10-07	15-Jun-10	<0.001	2.1	<0.0001	4	2.5	<0.001	<0.003
BW10	10-BW10-07B	24-Jun-10	-	-	-	-	-	-	-
BW10	10-BW10-08	13-Jul-10	0.001	2.2	<0.0001	3	2.5	<0.001	<0.003
BW10	10-BW10-10	11-Aug-10	0.002	2.3	<0.0001	4	2.4	<0.001	<0.003
BW10	10-BW10-11	24-Sep-10	0.005	3.2	<0.0001	5	2.5	0.002	0.005
BW10	10-AG-253	20-Oct-10	0.004	2.6	<0.0001	6	3.0	<0.001	<0.003
BW11	09-BW11-01	19-Nov-09	<0.001	11.5	<0.0001	32	2.8	<0.001	<0.003
BW11	09-BW11-02	19-Dec-09	<0.001	11.5	<0.0001	49	2.7	<0.001	<0.003

Station	Sample	Date	La	Li	Lu	Mn	Mo	Nb	Nd
			µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
BW11	10-BW11-03	5-Feb-10	<0.001	9.8	<0.0001	60	2.9	<0.001	<0.003
BW11	10-BW11-04	26-Mar-10	<0.001	10.3	<0.0001	64	2.5	0.002	<0.003
BW11	10-BW11-05	23-Apr-10	0.002	11.4	<0.0001	96	2.8	<0.001	<0.003
BW11	10-BW11-06	14-May-10	0.002	11.1	<0.0001	67	2.5	0.001	<0.003
BW11	10-BW11-07	15-Jun-10	<0.001	12.3	<0.0001	60	2.7	<0.001	<0.003
BW11	10-BW11-07B	24-Jun-10	-	-	-	-	-	-	-
BW11	10-BW11-08	14-Jul-10	<0.001	9.8	<0.0001	68	2.5	<0.001	<0.003
BW11	10-AG-250	19-Oct-10	<0.001	11.7	<0.0001	71	2.3	0.001	<0.003

"-" symbolizes parameter not measured. "<" symbolizes parameter is below detection limit.

Appendix FF. Trace Constituents: Ni, Pb, Pr, Rb, Sb, Sc, Se (Local Study)

Station	Sample	Date	Ni	Pb	Pr	Rb	Sb	Sc	Se
			µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
BW01	09-AG-238	29-Jul-09	-	-	-	-	-	-	-
BW01	09-BW01-01	19-Nov-09	0.5	0.134	0.0008	0.6	0.01	<0.1	<0.2
BW01	09-BW01-02	18-Dec-09	0.2	0.114	0.0004	0.6	0.01	<0.1	<0.2
BW01	10-BW01-03	5-Feb-10	<0.1	0.141	0.0005	0.6	0.02	<0.1	<0.2
BW01	10-BW01-04	26-Mar-10	<0.1	0.160	0.0005	0.6	0.02	<0.1	<0.2
BW01	10-BW01-05	23-Apr-10	1.5	0.039	0.0008	0.6	0.01	0.1	<0.2
BW01	10-BW01-06	14-May-10	1.7	0.042	0.0005	0.6	0.02	<0.1	<0.2
BW01	10-BW01-07	15-Jun-10	1.8	0.023	0.0004	0.6	0.01	<0.1	<0.2
BW01	10-BW01-07B	24-Jun-10	-	-	-	-	-	-	-
BW01	10-BW01-08	10-Jul-10	<0.1	0.026	<0.0004	0.5	0.01	<0.1	<0.2
BW01	10-BW01-10	11-Aug-10	1.8	0.033	<0.0004	0.6	0.01	<0.1	<0.2
BW01	10-BW01-11	24-Sep-10	1.9	0.055	0.0006	0.6	0.01	0.2	<0.2
BW01	10-AG-251	19-Oct-10	4.2	0.033	0.0005	0.6	0.01	0.1	<0.2
BW02	09-BW02-00	29-Jul-09	-	-	-	-	-	-	-
BW02	09-BW02-01	19-Nov-09	2.3	0.007	<0.0004	0.8	<0.01	<0.1	<0.2
BW02	09-BW02-02	18-Dec-09	2.9	0.018	<0.0004	0.8	<0.01	<0.1	<0.2
BW02	10-BW02-03	5-Feb-10	3.4	0.003	<0.0004	0.7	<0.01	<0.1	<0.2
BW02	10-BW02-04	26-Mar-10	3.2	0.003	<0.0004	0.7	<0.01	<0.1	<0.2
BW02	10-BW02-05	23-Apr-10	2.3	<0.002	0.0005	0.7	<0.01	0.1	<0.2
BW02	10-BW02-06	14-May-10	2.7	0.006	<0.0004	0.8	<0.01	<0.1	<0.2
BW02	10-BW02-07	15-Jun-10	3.8	0.046	<0.0004	0.8	<0.01	<0.1	<0.2
BW02	10-BW02-07B	24-Jun-10	-	-	-	-	-	-	-
BW02	10-BW02-08	9-Jul-10	3.3	0.008	<0.0004	0.7	<0.01	<0.1	<0.2
BW02	10-BW02-10	11-Aug-10	2.8	0.002	<0.0004	0.7	<0.01	0.1	<0.2
BW02	10-BW02-11	24-Sep-10	1.9	0.002	<0.0004	0.7	<0.01	0.2	<0.2
BW02	10-AG-274	20-Oct-10	3.9	0.093	<0.0004	0.8	0.02	<0.1	<0.2
BW03	09-BW03-00	30-Jun-09	-	-	-	-	-	-	-
BW03	09-BW03-01	19-Nov-09	0.8	0.051	0.0005	0.6	<0.01	<0.1	<0.2
BW03	09-BW03-02	19-Dec-09	1.0	0.035	<0.0004	0.6	0.01	<0.1	<0.2
BW03	10-BW03-04	26-Mar-10	0.6	0.048	<0.0004	0.6	<0.01	<0.1	<0.2
BW03	10-BW03-05	23-Apr-10	0.4	0.101	<0.0004	0.6	0.02	<0.1	<0.2
BW03	10-BW03-06	14-May-10	0.4	0.069	0.0007	0.7	0.01	0.1	<0.2
BW03	10-BW03-07	15-Jun-10	0.8	0.019	0.0004	0.7	0.01	<0.1	<0.2
BW03	10-BW03-07B	24-Jun-10	-	-	-	-	-	-	-
BW03	10-BW03-08	9-Jul-10	0.8	0.039	<0.0004	0.6	<0.01	<0.1	<0.2
BW03	10-BW03-10	11-Aug-10	0.4	0.052	<0.0004	0.6	<0.01	<0.1	<0.2
BW03	10-BW03-11	24-Sep-10	0.4	0.052	<0.0004	0.6	0.01	0.2	<0.2
BW03	10-AG-254	20-Oct-10	0.4	0.030	<0.0004	0.7	<0.01	<0.1	<0.2
BW04	09-BW04-00	30-Jul-09	-	-	-	-	-	-	-
BW04	09-BW04-01	19-Nov-09	0.5	1.058	<0.0004	0.6	0.04	<0.1	0.3
BW04	09-BW04-02	18-Dec-09	<0.1	0.325	0.0005	0.6	0.02	<0.1	<0.2
BW04	10-BW04-03	5-Feb-10	0.5	0.256	<0.0004	0.5	0.02	<0.1	<0.2
BW04	10-BW04-04	26-Mar-10	0.4	0.240	0.0005	0.5	0.02	<0.1	<0.2
BW04	10-BW04-05	23-Apr-10	<0.1	0.262	0.0005	0.6	0.02	<0.1	<0.2
BW04	10-BW04-06	14-May-10	<0.1	0.307	<0.0004	0.6	0.02	<0.1	<0.2
BW04	10-BW04-07	15-Jun-10	0.5	0.258	<0.0004	0.6	0.02	<0.1	<0.2
BW04	10-BW04-07B	24-Jun-10	-	-	-	-	-	-	-
BW04	10-BW04-08	9-Jul-10	51.9	0.438	<0.0004	0.6	0.03	<0.1	<0.2
BW04	10-BW04-10	11-Aug-10	0.3	0.385	0.0021	0.5	0.02	<0.1	<0.2
BW04	10-BW04-11	24-Sep-10	<0.1	0.353	<0.0004	0.5	0.02	0.1	0.2
BW04	10-AG-271	20-Oct-10	0.3	0.207	<0.0004	0.6	0.02	<0.1	0.0
BW05	09-BW05-00	30-Jul-09	-	-	-	-	-	-	-
BW05	09-BW05-01	18-Nov-09	1.1	0.110	0.0008	1.1	0.02	<0.1	<0.2
BW05	10-BW05-03	5-Feb-10	-	-	-	-	-	-	-
BW05	10-BW05-04	26-Mar-10	1.0	0.046	0.0006	1.0	0.02	<0.1	<0.2
BW05	10-BW05-05	23-Apr-10	1.7	0.056	0.0011	1.1	0.04	<0.1	<0.2
BW05	10-BW05-06	14-May-10	1.2	0.051	0.0006	1.1	0.05	<0.1	<0.2
BW05	10-BW05-07	15-Jun-10	1.6	0.018	<0.0004	1.0	0.05	<0.1	<0.2

Station	Sample	Date	Ni	Pb	Pr	Rb	Sb	Sc	Se
			µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
BW05	10-BW05-07B	24-Jun-10	-	-	-	-	-	-	-
BW05	10-BW05-08	9-Jul-10	1.7	0.061	0.0006	1.0	0.04	<0.1	<0.2
BW05	10-BW05-10	11-Aug-10	1.5	0.025	0.0011	1.0	0.03	<0.1	<0.2
BW05	10-BW05-11	24-Sep-10	1.1	0.148	0.0009	1.0	0.03	<0.1	<0.2
BW05	10-AG-268	20-Oct-10	1.2	0.049	0.0006	1.1	0.03	<0.1	<0.2
BW06	09-BW06-00	30-Jul-09	-	-	-	-	-	-	-
BW06	09-BW06-01	19-Nov-09	1.0	0.159	<0.0004	0.7	0.08	<0.1	<0.2
BW06	09-BW06-02	18-Dec-09	0.9	0.089	0.0004	0.7	0.05	<0.1	<0.2
BW06	10-BW06-03	5-Feb-10	0.8	0.227	<0.0004	0.6	0.05	<0.1	<0.2
BW06	10-BW06-04	26-Mar-10	1.1	0.108	0.0012	0.7	0.09	<0.1	<0.2
BW06	10-BW06-05	23-Apr-10	0.7	0.077	0.0005	0.7	0.05	<0.1	<0.2
BW06	10-BW06-06	14-May-10	0.7	0.091	0.0004	0.7	0.05	<0.1	<0.2
BW06	10-BW06-07	15-Jun-10	1.0	0.052	<0.0004	0.6	0.09	<0.1	<0.2
BW06	10-BW06-07B	24-Jun-10	-	-	-	-	-	-	-
BW06	10-BW06-08	9-Jul-10	1.7	0.116	0.0019	0.8	0.07	<0.1	<0.2
BW06	10-BW06-10	11-Aug-10	0.9	0.069	<0.0004	0.6	0.08	<0.1	<0.2
BW06	10-BW06-11	24-Sep-10	0.7	0.072	0.0004	0.7	0.07	<0.1	<0.2
BW06	10-AG-267	20-Oct-10	0.7	0.048	0.0004	0.7	0.05	<0.1	<0.2
BW08	09-BW08-00	31-Jul-09	-	-	-	-	-	-	-
BW08	09-BW08-01	19-Nov-09	<0.1	0.021	0.0037	0.9	<0.01	<0.1	<0.2
BW08	09-BW08-02	18-Dec-09	-	-	-	-	-	-	-
BW08	10-BW08-03	5-Feb-10	-	-	-	-	-	-	-
BW08	10-BW08-04	26-Mar-10	1.6	0.012	<0.0004	0.8	<0.01	<0.1	<0.2
BW08	10-BW08-05	23-Apr-10	0.6	0.020	0.0007	0.9	<0.01	<0.1	<0.2
BW08	10-BW08-06	14-May-10	0.5	0.009	<0.0004	0.8	<0.01	0.1	<0.2
BW08	10-BW08-07	15-Jun-10	1.8	0.003	<0.0004	0.8	<0.01	<0.1	<0.2
BW08	10-BW08-07B	24-Jun-10	-	-	-	-	-	-	-
BW08	10-BW08-08	11-Jul-10	1.5	0.003	<0.0004	0.8	<0.01	<0.1	<0.2
BW08	10-BW08-10	11-Aug-10	1.2	0.007	<0.0004	0.8	<0.01	<0.1	<0.2
BW08	10-BW08-11	24-Sep-10	2.2	0.013	<0.0004	0.8	<0.01	0.2	<0.2
BW08	10-AG-273	20-Oct-10	2.2	0.005	<0.0004	0.8	<0.01	<0.1	<0.2
BW09	09-BW09-00	31-Jul-09	-	-	-	-	-	-	-
BW09	09-BW09-01	18-Nov-09	1.3	0.839	<0.0004	0.7	0.12	<0.1	0.3
BW09	09-BW09-02	18-Dec-09	2.0	1.917	<0.0004	0.7	0.15	<0.1	0.4
BW09	10-BW09-03A	1-Jan-10	1.5	0.161	<0.0004	0.7	0.11	<0.1	<0.2
BW09	10-BW09-03	1-Feb-10	1.5	0.207	<0.0004	0.7	0.11	<0.1	<0.2
BW09	10-BW09-04	1-Mar-10	1.6	0.266	<0.0004	0.7	0.12	<0.1	0.2
BW09	10-BW09-05	23-Apr-10	1.7	0.482	<0.0004	0.7	0.12	<0.1	0.3
BW09	10-BW09-06	14-May-10	1.6	0.408	<0.0004	0.7	0.10	<0.1	0.2
BW09	10-BW09-07	15-Jun-10	1.9	0.311	<0.0004	0.7	0.11	<0.1	<0.2
BW09	10-BW09-07B	24-Jun-10	-	-	-	-	-	-	-
BW09	10-BW09-08	12-Jul-10	2.2	0.282	<0.0004	0.6	0.09	<0.1	0.3
BW09	10-BW09-10	11-Aug-10	1.6	0.312	<0.0004	0.6	0.07	<0.1	0.3
BW09	10-BW09-11	24-Sep-10	1.8	0.343	<0.0004	0.7	0.09	<0.1	0.3
BW09	10-AG-252	20-Oct-10	2.0	0.281	<0.0004	0.7	0.09	<0.1	0.3
BW10	09-BW10-00	6-Jul-09	-	-	-	-	-	-	-
BW10	09-BW10-01	18-Nov-09	60.5	2.625	0.0004	0.4	0.41	<0.1	<0.2
BW10	09-BW10-02	19-Dec-09	2.4	0.181	<0.0004	0.4	0.01	<0.1	<0.2
BW10	10-BW10-03	5-Feb-10	1.9	0.164	<0.0004	0.4	0.02	<0.1	<0.2
BW10	10-BW10-04	26-Mar-10	2.7	0.197	0.0004	0.4	0.02	<0.1	<0.2
BW10	10-BW10-05	23-Apr-10	2.3	0.269	<0.0004	0.4	0.02	<0.1	<0.2
BW10	10-BW10-06	14-May-10	1.9	0.127	<0.0004	0.4	0.02	<0.1	<0.2
BW10	10-BW10-07	15-Jun-10	1.5	0.036	<0.0004	0.4	0.01	<0.1	<0.2
BW10	10-BW10-07B	24-Jun-10	-	-	-	-	-	-	-
BW10	10-BW10-08	13-Jul-10	1.3	0.033	<0.0004	0.4	<0.01	<0.1	<0.2
BW10	10-BW10-10	11-Aug-10	1.0	0.038	<0.0004	0.4	<0.01	<0.1	<0.2
BW10	10-BW10-11	24-Sep-10	1.1	0.040	0.0014	0.4	0.01	<0.1	<0.2
BW10	10-AG-253	20-Oct-10	1.7	0.025	0.0005	0.4	0.01	<0.1	<0.2
BW11	09-BW11-01	19-Nov-09	1.4	0.024	<0.0004	1.1	0.02	<0.1	<0.2
BW11	09-BW11-02	19-Dec-09	0.5	0.027	<0.0004	1.1	0.02	<0.1	<0.2

Station	Sample	Date	Ni	Pb	Pr	Rb	Sb	Sc	Se
			µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
BW11	10-BW11-03	5-Feb-10	1.5	0.051	<0.0004	1.1	0.02	<0.1	<0.2
BW11	10-BW11-04	26-Mar-10	2.0	0.031	<0.0004	1.0	0.01	<0.1	<0.2
BW11	10-BW11-05	23-Apr-10	2.2	0.071	<0.0004	1.1	0.02	0.2	<0.2
BW11	10-BW11-06	14-May-10	2.9	0.055	<0.0004	1.0	0.01	0.2	<0.2
BW11	10-BW11-07	15-Jun-10	22.1	0.028	<0.0004	1.1	0.02	<0.1	<0.2
BW11	10-BW11-07B	24-Jun-10	-	-	-	-	-	-	-
BW11	10-BW11-08	14-Jul-10	1.8	0.013	<0.0004	1.0	<0.01	<0.1	<0.2
BW11	10-AG-250	19-Oct-10	5.5	0.023	<0.0004	1.1	0.01	0.2	<0.2

"-" symbolizes parameter not measured. “<” symbolizes parameter is below detection limit.

Appendix GG. Trace Constituents: Sm, Sn, Ta, Tb, Th, Ti, Tl (Local Study).

Station	Sample	Date	Sm	Sn	Ta	Tb	Th	Ti	Tl
			µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
BW01	09-AG-238	29-Jul-09	-	-	-	-	-	-	-
BW01	09-BW01-01	19-Nov-09	<0.001	0.01	0.0009	0.0006	0.006	0.2	0.074
BW01	09-BW01-02	18-Dec-09	<0.001	<0.01	0.0004	<0.0001	0.002	0.2	0.071
BW01	10-BW01-03	5-Feb-10	<0.001	0.02	<0.0003	<0.0001	<0.001	<0.1	0.064
BW01	10-BW01-04	26-Mar-10	0.001	0.02	<0.0003	<0.0001	<0.001	<0.1	0.078
BW01	10-BW01-05	23-Apr-10	<0.001	<0.01	0.0003	0.0002	<0.001	<0.1	0.072
BW01	10-BW01-06	14-May-10	0.002	<0.01	<0.0003	0.0002	<0.001	<0.1	0.071
BW01	10-BW01-07	15-Jun-10	<0.001	<0.01	<0.0003	<0.0001	<0.001	<0.1	0.072
BW01	10-BW01-07B	24-Jun-10	-	-	-	-	-	-	-
BW01	10-BW01-08	10-Jul-10	0.002	<0.01	<0.0003	<0.0001	0.001	<0.1	0.070
BW01	10-BW01-10	11-Aug-10	0.001	<0.01	0.0011	0.0001	0.006	0.2	0.067
BW01	10-BW01-11	24-Sep-10	<0.001	<0.01	0.0007	0.0002	0.010	0.4	0.069
BW01	10-AG-251	19-Oct-10	<0.001	<0.01	0.0007	0.0002	0.005	0.6	0.069
BW02	09-BW02-00	29-Jul-09	-	-	-	-	-	-	-
BW02	09-BW02-01	19-Nov-09	<0.001	<0.01	0.0010	0.0001	0.001	0.2	0.001
BW02	09-BW02-02	18-Dec-09	<0.001	<0.01	0.0008	<0.0001	<0.001	0.2	0.001
BW02	10-BW02-03	5-Feb-10	0.001	0.01	<0.0003	<0.0001	<0.001	<0.1	<0.001
BW02	10-BW02-04	26-Mar-10	<0.001	<0.01	<0.0003	<0.0001	<0.001	<0.1	<0.001
BW02	10-BW02-05	23-Apr-10	0.001	<0.01	<0.0003	<0.0001	<0.001	<0.1	<0.001
BW02	10-BW02-06	14-May-10	<0.001	<0.01	<0.0003	<0.0001	<0.001	<0.1	<0.001
BW02	10-BW02-07	15-Jun-10	0.001	0.03	<0.0003	<0.0001	<0.001	0.1	0.001
BW02	10-BW02-07B	24-Jun-10	-	-	-	-	-	-	-
BW02	10-BW02-08	9-Jul-10	<0.001	0.02	<0.0003	<0.0001	<0.001	<0.1	0.001
BW02	10-BW02-10	11-Aug-10	0.001	<0.01	0.0009	<0.0001	0.002	0.2	<0.001
BW02	10-BW02-11	24-Sep-10	<0.001	<0.01	0.0006	0.0002	0.011	0.3	<0.001
BW02	10-AG-274	20-Oct-10	<0.001	0.01	0.0006	<0.0001	0.003	0.4	0.004
BW03	09-BW03-00	30-Jun-09	-	-	-	-	-	-	-
BW03	09-BW03-01	19-Nov-09	<0.001	<0.01	0.0009	<0.0001	<0.001	0.1	0.032
BW03	09-BW03-02	19-Dec-09	<0.001	0.01	0.0005	<0.0001	<0.001	<0.1	0.025
BW03	10-BW03-04	26-Mar-10	<0.001	<0.01	<0.0003	<0.0001	<0.001	<0.1	0.029
BW03	10-BW03-05	23-Apr-10	<0.001	<0.01	<0.0003	<0.0001	<0.001	<0.1	0.030
BW03	10-BW03-06	14-May-10	<0.001	0.03	<0.0003	0.0002	<0.001	<0.1	0.032
BW03	10-BW03-07	15-Jun-10	0.001	<0.01	<0.0003	0.0001	<0.001	<0.1	0.032
BW03	10-BW03-07B	24-Jun-10	-	-	-	-	-	-	-
BW03	10-BW03-08	9-Jul-10	<0.001	<0.01	<0.0003	0.0001	<0.001	<0.1	0.034
BW03	10-BW03-10	11-Aug-10	<0.001	0.01	0.0012	<0.0001	<0.001	<0.1	0.032
BW03	10-BW03-11	24-Sep-10	<0.001	0.01	0.0007	0.0002	0.005	<0.1	0.033
BW03	10-AG-254	20-Oct-10	0.001	<0.01	<0.0003	0.0002	0.004	<0.1	0.030
BW04	09-BW04-00	30-Jul-09	-	-	-	-	-	-	-
BW04	09-BW04-01	19-Nov-09	<0.001	<0.01	0.0007	<0.0001	<0.001	0.1	0.013
BW04	09-BW04-02	18-Dec-09	<0.001	<0.01	<0.0003	<0.0001	<0.001	<0.1	0.012
BW04	10-BW04-03	5-Feb-10	<0.001	<0.01	<0.0003	<0.0001	<0.001	<0.1	0.013
BW04	10-BW04-04	26-Mar-10	0.001	<0.01	<0.0003	<0.0001	<0.001	<0.1	0.012
BW04	10-BW04-05	23-Apr-10	<0.001	<0.01	<0.0003	0.0002	<0.001	<0.1	0.014
BW04	10-BW04-06	14-May-10	0.002	<0.01	<0.0003	<0.0001	<0.001	<0.1	0.013
BW04	10-BW04-07	15-Jun-10	0.002	<0.01	<0.0003	<0.0001	<0.001	<0.1	0.015
BW04	10-BW04-07B	24-Jun-10	-	-	-	-	-	-	-
BW04	10-BW04-08	9-Jul-10	<0.001	0.02	<0.0003	<0.0001	<0.001	<0.1	0.013
BW04	10-BW04-10	11-Aug-10	0.003	<0.01	0.0011	0.0004	<0.001	<0.1	0.014
BW04	10-BW04-11	24-Sep-10	0.002	<0.01	<0.0003	<0.0001	0.002	0.1	0.014
BW04	10-AG-271	20-Oct-10	0.000	<0.01	0.0001	0.0000	0.000	<0.1	0.014
BW05	09-BW05-00	30-Jul-09	-	-	-	-	-	-	-
BW05	09-BW05-01	18-Nov-09	<0.001	0.05	0.0007	0.0002	<0.001	0.4	0.005
BW05	10-BW05-03	5-Feb-10	-	-	-	-	-	-	-
BW05	10-BW05-04	26-Mar-10	<0.001	<0.01	<0.0003	<0.0001	<0.001	<0.1	0.006
BW05	10-BW05-05	23-Apr-10	0.001	0.02	<0.0003	0.0002	<0.001	<0.1	0.004
BW05	10-BW05-06	14-May-10	0.002	0.02	<0.0003	0.0001	<0.001	<0.1	0.007
BW05	10-BW05-07	15-Jun-10	0.002	0.02	<0.0003	<0.0001	0.001	<0.1	0.012

Station	Sample	Date	Sm	Sn	Ta	Tb	Th	Ti	Tl
			µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
BW05	10-BW05-07B	24-Jun-10	-	-	-	-	-	-	-
BW05	10-BW05-08	9-Jul-10	<0.001	0.01	<0.0003	<0.0001	<0.001	<0.1	0.007
BW05	10-BW05-10	11-Aug-10	0.002	0.07	0.0010	0.0002	<0.001	0.2	0.010
BW05	10-BW05-11	24-Sep-10	0.001	0.03	0.0015	0.0003	0.007	0.4	0.009
BW05	10-AG-268	20-Oct-10	<0.001	0.03	0.0008	0.0002	0.004	0.4	0.008
BW06	09-BW06-00	30-Jul-09	-	-	-	-	-	-	-
BW06	09-BW06-01	19-Nov-09	<0.001	<0.01	0.0009	<0.0001	<0.001	<0.1	0.032
BW06	09-BW06-02	18-Dec-09	<0.001	<0.01	0.0004	<0.0001	<0.001	<0.1	0.029
BW06	10-BW06-03	5-Feb-10	<0.001	<0.01	<0.0003	<0.0001	<0.001	<0.1	0.024
BW06	10-BW06-04	26-Mar-10	0.001	0.02	<0.0003	0.0002	<0.001	<0.1	0.023
BW06	10-BW06-05	23-Apr-10	<0.001	<0.01	<0.0003	<0.0001	<0.001	<0.1	0.021
BW06	10-BW06-06	14-May-10	<0.001	<0.01	<0.0003	<0.0001	<0.001	<0.1	0.023
BW06	10-BW06-07	15-Jun-10	<0.001	<0.01	<0.0003	<0.0001	<0.001	<0.1	0.027
BW06	10-BW06-07B	24-Jun-10	-	-	-	-	-	-	-
BW06	10-BW06-08	9-Jul-10	0.002	0.03	<0.0003	0.0001	<0.001	<0.1	0.033
BW06	10-BW06-10	11-Aug-10	0.001	<0.01	0.0006	<0.0001	<0.001	<0.1	0.019
BW06	10-BW06-11	24-Sep-10	<0.001	0.01	0.0014	0.0001	0.002	<0.1	0.026
BW06	10-AG-267	20-Oct-10	<0.001	<0.01	<0.0003	<0.0001	0.002	<0.1	0.024
BW08	09-BW08-00	31-Jul-09	-	-	-	-	-	-	-
BW08	09-BW08-01	19-Nov-09	0.002	<0.01	0.0010	0.0004	0.009	0.6	<0.001
BW08	09-BW08-02	18-Dec-09	-	-	-	-	-	-	-
BW08	10-BW08-03	5-Feb-10	-	-	-	-	-	-	-
BW08	10-BW08-04	26-Mar-10	<0.001	0.01	<0.0003	<0.0001	<0.001	<0.1	0.004
BW08	10-BW08-05	23-Apr-10	0.001	0.03	<0.0003	<0.0001	<0.001	0.1	0.005
BW08	10-BW08-06	14-May-10	<0.001	<0.01	<0.0003	<0.0001	<0.001	0.1	0.004
BW08	10-BW08-07	15-Jun-10	<0.001	0.01	<0.0003	<0.0001	<0.001	0.1	0.003
BW08	10-BW08-07B	24-Jun-10	-	-	-	-	-	-	-
BW08	10-BW08-08	11-Jul-10	<0.001	<0.01	<0.0003	<0.0001	<0.001	<0.1	0.006
BW08	10-BW08-10	11-Aug-10	<0.001	<0.01	0.0009	0.0002	<0.001	0.5	0.006
BW08	10-BW08-11	24-Sep-10	<0.001	0.02	0.0010	0.0001	0.011	0.8	0.003
BW08	10-AG-273	20-Oct-10	0.002	<0.01	0.0013	0.0002	0.015	0.9	0.002
BW09	09-BW09-00	31-Jul-09	-	-	-	-	-	-	-
BW09	09-BW09-01	18-Nov-09	<0.001	<0.01	0.0004	<0.0001	<0.001	<0.1	0.107
BW09	09-BW09-02	18-Dec-09	<0.001	0.03	0.0003	<0.0001	<0.001	<0.1	0.093
BW09	10-BW09-03A	1-Jan-10	<0.001	0.01	<0.0003	<0.0001	<0.001	<0.1	0.124
BW09	10-BW09-03	1-Feb-10	<0.001	<0.01	<0.0003	<0.0001	<0.001	<0.1	0.133
BW09	10-BW09-04	1-Mar-10	<0.001	0.01	<0.0003	0.0002	<0.001	<0.1	0.136
BW09	10-BW09-05	23-Apr-10	<0.001	<0.01	<0.0003	<0.0001	<0.001	<0.1	0.112
BW09	10-BW09-06	14-May-10	<0.001	0.02	<0.0003	<0.0001	<0.001	<0.1	0.113
BW09	10-BW09-07	15-Jun-10	<0.001	0.01	<0.0003	<0.0001	<0.001	<0.1	0.107
BW09	10-BW09-07B	24-Jun-10	-	-	-	-	-	-	-
BW09	10-BW09-08	12-Jul-10	0.002	<0.01	<0.0003	<0.0001	<0.001	<0.1	0.107
BW09	10-BW09-10	11-Aug-10	0.001	0.01	0.0012	<0.0001	0.001	<0.1	0.102
BW09	10-BW09-11	24-Sep-10	<0.001	0.02	0.0006	<0.0001	0.002	0.2	0.116
BW09	10-AG-252	20-Oct-10	0.001	<0.01	0.0007	0.0002	0.002	<0.1	0.115
BW10	09-BW10-00	6-Jul-09	-	-	-	-	-	-	-
BW10	09-BW10-01	18-Nov-09	<0.001	0.03	0.0004	<0.0001	<0.001	<0.1	0.046
BW10	09-BW10-02	19-Dec-09	<0.001	0.01	0.0004	<0.0001	<0.001	<0.1	0.022
BW10	10-BW10-03	5-Feb-10	<0.001	<0.01	<0.0003	<0.0001	<0.001	<0.1	0.022
BW10	10-BW10-04	26-Mar-10	<0.001	0.01	<0.0003	<0.0001	<0.001	<0.1	0.022
BW10	10-BW10-05	23-Apr-10	<0.001	0.01	<0.0003	<0.0001	<0.001	<0.1	0.021
BW10	10-BW10-06	14-May-10	0.001	<0.01	<0.0003	<0.0001	<0.001	<0.1	0.018
BW10	10-BW10-07	15-Jun-10	<0.001	0.01	<0.0003	<0.0001	<0.001	<0.1	0.017
BW10	10-BW10-07B	24-Jun-10	-	-	-	-	-	-	-
BW10	10-BW10-08	13-Jul-10	<0.001	<0.01	<0.0003	<0.0001	<0.001	<0.1	0.016
BW10	10-BW10-10	11-Aug-10	<0.001	<0.01	0.0005	<0.0001	<0.001	<0.1	0.013
BW10	10-BW10-11	24-Sep-10	0.002	0.01	0.0003	0.0002	0.002	<0.1	0.014
BW10	10-AG-253	20-Oct-10	<0.001	<0.01	0.0014	0.0001	0.002	0.1	0.017
BW11	09-BW11-01	19-Nov-09	<0.001	<0.01	0.0012	<0.0001	<0.001	0.4	0.033
BW11	09-BW11-02	19-Dec-09	<0.001	<0.01	0.0005	<0.0001	<0.001	0.3	0.005

Station	Sample	Date	Sm	Sn	Ta	Tb	Th	Ti	Tl
			µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
BW11	10-BW11-03	5-Feb-10	0.001	<0.01	<0.0003	<0.0001	0.004	0.2	0.007
BW11	10-BW11-04	26-Mar-10	<0.001	0.01	<0.0003	<0.0001	<0.001	0.1	0.004
BW11	10-BW11-05	23-Apr-10	<0.001	0.02	<0.0003	<0.0001	<0.001	0.3	0.004
BW11	10-BW11-06	14-May-10	<0.001	<0.01	<0.0003	<0.0001	<0.001	0.3	0.005
BW11	10-BW11-07	15-Jun-10	<0.001	0.02	<0.0003	<0.0001	<0.001	0.2	0.006
BW11	10-BW11-07B	24-Jun-10	-	-	-	-	-	-	-
BW11	10-BW11-08	14-Jul-10	<0.001	<0.01	<0.0003	<0.0001	<0.001	0.1	0.004
BW11	10-AG-250	19-Oct-10	<0.001	<0.01	0.0009	<0.0001	0.016	1.4	0.004

"-" symbolizes parameter not measured. "<" symbolizes parameter is below detection limit.

Appendix HH. Trace Constituents: Tm, U, V, W, Y, Yb, Zn, Zr (Local Study)

Station	Sample	Date	Tm	U	V	W	Y	Yb	Zn	Zr
			µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
BW01	09-AG-238	29-Jul-09	-	-	-	-	-	-	-	-
BW01	09-BW01-01	19-Nov-09	<0.0001	1.7750	0.05	<0.01	0.07	<0.001	567.0	<0.1
BW01	09-BW01-02	18-Dec-09	<0.0001	1.6930	0.06	<0.01	0.07	<0.001	385.0	<0.1
BW01	10-BW01-03	5-Feb-10	<0.0001	1.4000	0.07	<0.01	0.07	<0.001	930.0	<0.1
BW01	10-BW01-04	26-Mar-10	<0.0001	1.4000	0.06	<0.01	0.07	<0.001	581.0	<0.1
BW01	10-BW01-05	23-Apr-10	0.0001	1.6000	0.05	<0.01	0.07	<0.001	479.0	<0.1
BW01	10-BW01-06	14-May-10	<0.0001	1.5400	0.09	<0.01	0.07	<0.001	264.0	<0.1
BW01	10-BW01-07	15-Jun-10	<0.0001	1.5500	0.05	<0.01	0.06	<0.001	289.0	<0.1
BW01	10-BW01-07B	24-Jun-10	-	-	-	-	-	-	-	-
BW01	10-BW01-08	10-Jul-10	0.0001	1.4100	0.08	<0.01	0.06	<0.001	309.0	<0.1
BW01	10-BW01-10	11-Aug-10	<0.0001	1.6400	0.08	<0.01	0.08	<0.001	302.0	<0.1
BW01	10-BW01-11	24-Sep-10	<0.0001	1.6300	0.08	<0.01	0.09	<0.001	320.0	<0.1
BW01	10-AG-251	19-Oct-10	<0.0001	1.6500	0.06	<0.01	0.10	<0.001	303.0	<0.1
BW02	09-BW02-00	29-Jul-09	-	-	-	-	-	-	-	-
BW02	09-BW02-01	19-Nov-09	<0.0001	4.0000	0.01	<0.01	0.09	<0.001	384.0	<0.1
BW02	09-BW02-02	18-Dec-09	<0.0001	3.8200	0.01	<0.01	0.09	<0.001	326.0	<0.1
BW02	10-BW02-03	5-Feb-10	<0.0001	3.9000	0.01	<0.01	0.09	<0.001	330.0	<0.1
BW02	10-BW02-04	26-Mar-10	<0.0001	3.5900	0.01	<0.01	0.09	<0.001	204.0	<0.1
BW02	10-BW02-05	23-Apr-10	0.0001	3.6300	0.01	<0.01	0.09	<0.001	253.0	<0.1
BW02	10-BW02-06	14-May-10	<0.0001	4.1150	0.02	<0.01	0.09	<0.001	208.0	<0.1
BW02	10-BW02-07	15-Jun-10	<0.0001	4.3400	0.02	<0.01	0.09	<0.001	169.0	<0.1
BW02	10-BW02-07B	24-Jun-10	-	-	-	-	-	-	-	-
BW02	10-BW02-08	9-Jul-10	0.0001	3.4200	0.01	<0.01	0.08	<0.001	166.0	<0.1
BW02	10-BW02-10	11-Aug-10	<0.0001	3.9700	0.04	<0.01	0.12	<0.001	161.0	<0.1
BW02	10-BW02-11	24-Sep-10	<0.0001	3.7600	<0.003	<0.01	0.13	<0.001	191.0	<0.1
BW02	10-AG-274	20-Oct-10	<0.0001	4.7100	<0.003	<0.01	0.13	<0.001	525.5	<0.1
BW03	09-BW03-00	30-Jun-09	-	-	-	-	-	-	-	-
BW03	09-BW03-01	19-Nov-09	<0.0001	0.2000	0.01	0.01	0.20	<0.001	752.5	<0.1
BW03	09-BW03-02	19-Dec-09	0.0001	0.1793	<0.003	<0.01	0.22	<0.001	689.0	<0.1
BW03	10-BW03-04	26-Mar-10	<0.0001	0.1660	<0.003	0.01	0.20	<0.001	718.0	<0.1
BW03	10-BW03-05	23-Apr-10	<0.0001	0.1900	0.00	0.01	0.21	<0.001	714.0	<0.1
BW03	10-BW03-06	14-May-10	<0.0001	0.2130	0.00	<0.01	0.23	<0.001	547.0	<0.1
BW03	10-BW03-07	15-Jun-10	0.0001	0.2120	0.01	<0.01	0.21	<0.001	451.0	<0.1
BW03	10-BW03-07B	24-Jun-10	-	-	-	-	-	-	-	-
BW03	10-BW03-08	9-Jul-10	<0.0001	0.2100	0.01	<0.01	0.21	<0.001	378.0	<0.1
BW03	10-BW03-10	11-Aug-10	<0.0001	0.2120	<0.003	0.01	0.25	<0.001	426.0	<0.1
BW03	10-BW03-11	24-Sep-10	<0.0001	0.2110	<0.003	<0.01	0.28	<0.001	355.5	<0.1
BW03	10-AG-254	20-Oct-10	0.0001	0.2080	0.05	0.01	0.31	<0.001	439.0	<0.1
BW04	09-BW04-00	30-Jul-09	-	-	-	-	-	-	-	-
BW04	09-BW04-01	19-Nov-09	<0.0001	0.7090	0.09	<0.01	0.05	<0.001	611.0	<0.1
BW04	09-BW04-02	18-Dec-09	<0.0001	0.6820	0.04	<0.01	0.03	<0.001	179.0	<0.1
BW04	10-BW04-03	5-Feb-10	<0.0001	0.6690	0.11	<0.01	0.06	<0.001	118.0	<0.1
BW04	10-BW04-04	26-Mar-10	<0.0001	0.6780	0.12	<0.01	0.06	<0.001	118.0	<0.1
BW04	10-BW04-05	23-Apr-10	<0.0001	0.7570	0.14	<0.01	0.07	<0.001	117.0	<0.1
BW04	10-BW04-06	14-May-10	<0.0001	0.7730	0.13	<0.01	0.07	<0.001	134.0	<0.1
BW04	10-BW04-07	15-Jun-10	<0.0001	0.7510	0.15	<0.01	0.07	<0.001	105.0	<0.1
BW04	10-BW04-07B	24-Jun-10	-	-	-	-	-	-	-	-
BW04	10-BW04-08	9-Jul-10	0.0001	0.7400	0.11	0.02	0.07	<0.001	104.0	<0.1
BW04	10-BW04-10	11-Aug-10	0.0003	0.7400	0.10	<0.01	0.09	<0.001	162.0	<0.1
BW04	10-BW04-11	24-Sep-10	<0.0001	0.7500	0.16	<0.01	0.08	<0.001	177.0	<0.1
BW04	10-AG-271	20-Oct-10	<0.0001	0.7618	0.12	<0.01	0.09	<0.001	159.5	<0.1
BW05	09-BW05-00	30-Jul-09	-	-	-	-	-	-	-	-
BW05	09-BW05-01	18-Nov-09	<0.0001	0.5255	0.01	0.01	0.18	<0.001	308.0	<0.1
BW05	10-BW05-03	5-Feb-10	-	-	-	-	-	-	-	-
BW05	10-BW05-04	26-Mar-10	<0.0001	0.4120	<0.003	0.01	0.17	<0.001	353.0	<0.1
BW05	10-BW05-05	23-Apr-10	0.0001	0.7580	0.06	0.01	0.19	<0.001	264.0	<0.1
BW05	10-BW05-06	14-May-10	<0.0001	0.8220	0.03	0.01	0.19	<0.001	235.0	<0.1
BW05	10-BW05-07	15-Jun-10	0.0001	0.9500	0.10	<0.01	0.18	<0.001	201.0	<0.1

Station	Sample	Date	Tm	U	V	W	Y	Yb	Zn	Zr
			µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
BW05	10-BW05-07B	24-Jun-10	-	-	-	-	-	-	-	-
BW05	10-BW05-08	9-Jul-10	<0.0001	0.7680	0.06	<0.01	0.18	<0.001	262.0	<0.1
BW05	10-BW05-10	11-Aug-10	0.0001	0.7910	0.03	0.02	0.23	<0.001	227.0	<0.1
BW05	10-BW05-11	24-Sep-10	<0.0001	0.7660	0.05	<0.01	0.25	<0.001	228.0	<0.1
BW05	10-AG-268	20-Oct-10	0.0002	0.8300	0.09	<0.01	0.25	<0.001	188.5	<0.1
BW06	09-BW06-00	30-Jul-09	-	-	-	-	-	-	-	-
BW06	09-BW06-01	19-Nov-09	<0.0001	1.0490	0.01	<0.01	0.17	<0.001	349.0	<0.1
BW06	09-BW06-02	18-Dec-09	<0.0001	0.8565	0.02	<0.01	0.17	<0.001	224.0	<0.1
BW06	10-BW06-03	5-Feb-10	<0.0001	0.8420	0.02	<0.01	0.12	<0.001	308.0	<0.1
BW06	10-BW06-04	26-Mar-10	0.0001	0.8960	0.03	<0.01	0.13	<0.001	246.5	<0.1
BW06	10-BW06-05	23-Apr-10	<0.0001	0.9180	0.02	<0.01	0.13	<0.001	288.0	<0.1
BW06	10-BW06-06	14-May-10	0.0001	0.9430	0.03	<0.01	0.13	<0.001	315.5	0.3
BW06	10-BW06-07	15-Jun-10	<0.0001	1.0800	0.02	<0.01	0.14	<0.001	220.0	<0.1
BW06	10-BW06-07B	24-Jun-10	-	-	-	-	-	-	-	-
BW06	10-BW06-08	9-Jul-10	<0.0001	0.8650	0.02	<0.01	0.22	<0.001	193.0	<0.1
BW06	10-BW06-10	11-Aug-10	0.0001	0.9630	0.04	<0.01	0.16	<0.001	227.0	<0.1
BW06	10-BW06-11	24-Sep-10	<0.0001	0.8860	<0.003	<0.01	0.27	<0.001	178.0	<0.1
BW06	10-AG-267	20-Oct-10	<0.0001	0.8640	0.04	<0.01	0.25	<0.001	225.0	<0.1
BW08	09-BW08-00	31-Jul-09	-	-	-	-	-	-	-	-
BW08	09-BW08-01	19-Nov-09	<0.0001	0.5410	0.01	<0.01	0.08	<0.001	28.0	<0.1
BW08	09-BW08-02	18-Dec-09	-	-	-	-	-	-	-	-
BW08	10-BW08-03	5-Feb-10	-	-	-	-	-	-	-	-
BW08	10-BW08-04	26-Mar-10	<0.0001	0.4490	0.01	<0.01	0.07	<0.001	47.0	<0.1
BW08	10-BW08-05	23-Apr-10	<0.0001	0.4990	0.01	<0.01	0.08	<0.001	67.0	<0.1
BW08	10-BW08-06	14-May-10	<0.0001	0.4960	0.00	<0.01	0.08	<0.001	92.0	<0.1
BW08	10-BW08-07	15-Jun-10	0.0002	0.5330	0.01	<0.01	0.07	<0.001	83.0	<0.1
BW08	10-BW08-07B	24-Jun-10	-	-	-	-	-	-	-	-
BW08	10-BW08-08	11-Jul-10	<0.0001	0.4860	0.01	<0.01	0.07	<0.001	36.0	<0.1
BW08	10-BW08-10	11-Aug-10	<0.0001	0.5300	<0.003	<0.01	0.10	<0.001	28.0	<0.1
BW08	10-BW08-11	24-Sep-10	<0.0001	0.5520	<0.003	<0.01	0.11	<0.001	23.0	<0.1
BW08	10-AG-273	20-Oct-10	<0.0001	0.5190	<0.003	<0.01	0.11	<0.001	27.0	<0.1
BW09	09-BW09-00	31-Jul-09	-	-	-	-	-	-	-	-
BW09	09-BW09-01	18-Nov-09	<0.0001	0.5480	0.05	0.02	0.02	<0.001	41.0	<0.1
BW09	09-BW09-02	18-Dec-09	<0.0001	0.4800	0.05	0.02	0.02	<0.001	49.0	<0.1
BW09	10-BW09-03A	1-Jan-10	0.0002	0.5240	0.07	0.02	0.02	<0.001	52.0	<0.1
BW09	10-BW09-03	1-Feb-10	<0.0001	0.5325	0.05	0.01	0.02	<0.001	50.5	<0.1
BW09	10-BW09-04	1-Mar-10	<0.0001	0.5560	0.07	0.02	0.02	<0.001	55.0	<0.1
BW09	10-BW09-05	23-Apr-10	<0.0001	0.5160	0.06	0.01	0.02	<0.001	51.0	<0.1
BW09	10-BW09-06	14-May-10	<0.0001	0.5150	0.05	0.01	0.02	<0.001	44.0	<0.1
BW09	10-BW09-07	15-Jun-10	<0.0001	0.4950	0.07	0.02	0.02	<0.001	46.0	<0.1
BW09	10-BW09-07B	24-Jun-10	-	-	-	-	-	-	-	-
BW09	10-BW09-08	12-Jul-10	<0.0001	0.4710	0.05	0.01	0.02	<0.001	43.5	<0.1
BW09	10-BW09-10	11-Aug-10	<0.0001	0.4780	0.04	0.02	0.02	<0.001	36.0	<0.1
BW09	10-BW09-11	24-Sep-10	<0.0001	0.5080	0.07	0.02	0.02	<0.001	40.0	<0.1
BW09	10-AG-252	20-Oct-10	<0.0001	0.5040	0.06	0.02	0.02	<0.001	41.0	<0.1
BW10	09-BW10-00	6-Jul-09	-	-	-	-	-	-	-	-
BW10	09-BW10-01	18-Nov-09	<0.0001	0.7180	0.00	0.04	0.18	<0.001	1742.0	<0.1
BW10	09-BW10-02	19-Dec-09	<0.0001	0.5990	<0.003	0.04	0.19	<0.001	244.0	<0.1
BW10	10-BW10-03	5-Feb-10	<0.0001	0.4250	0.00	0.03	0.19	<0.001	172.0	<0.1
BW10	10-BW10-04	26-Mar-10	<0.0001	0.6180	0.01	0.04	0.17	<0.001	306.0	<0.1
BW10	10-BW10-05	23-Apr-10	<0.0001	0.6970	0.01	0.04	0.20	<0.001	301.0	<0.1
BW10	10-BW10-06	14-May-10	<0.0001	0.6130	0.01	0.04	0.21	<0.001	214.0	<0.1
BW10	10-BW10-07	15-Jun-10	<0.0001	0.3880	0.01	0.03	0.20	<0.001	125.0	<0.1
BW10	10-BW10-07B	24-Jun-10	-	-	-	-	-	-	-	-
BW10	10-BW10-08	13-Jul-10	<0.0001	0.3630	0.02	0.03	0.20	<0.001	94.0	<0.1
BW10	10-BW10-10	11-Aug-10	<0.0001	0.3940	0.01	0.03	0.26	<0.001	94.0	<0.1
BW10	10-BW10-11	24-Sep-10	0.0002	0.3810	<0.003	0.03	0.29	<0.001	103.0	<0.1
BW10	10-AG-253	20-Oct-10	<0.0001	0.5690	<0.003	0.04	0.28	<0.001	178.0	<0.1
BW11	09-BW11-01	19-Nov-09	<0.0001	1.0320	0.00	<0.01	0.08	<0.001	1049.0	<0.1
BW11	09-BW11-02	19-Dec-09	<0.0001	1.0030	<0.003	<0.01	0.08	<0.001	1281.0	<0.1

Station	Sample	Date	Tm	U	V	W	Y	Yb	Zn	Zr
			µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
BW11	10-BW11-03	5-Feb-10	<0.0001	0.7990	<0.003	<0.01	0.08	<0.001	1299.5	<0.1
BW11	10-BW11-04	26-Mar-10	<0.0001	0.6680	<0.003	<0.01	0.08	<0.001	1916.0	<0.1
BW11	10-BW11-05	23-Apr-10	<0.0001	0.6850	0.04	<0.01	0.08	<0.001	1789.0	<0.1
BW11	10-BW11-06	14-May-10	<0.0001	0.6890	0.03	<0.01	0.08	<0.001	1765.0	<0.1
BW11	10-BW11-07	15-Jun-10	<0.0001	0.7650	<0.003	<0.01	0.08	<0.001	1546.5	<0.1
BW11	10-BW11-07B	24-Jun-10	-	-	-	-	-	-	-	-
BW11	10-BW11-08	14-Jul-10	<0.0001	0.6510	<0.003	<0.01	0.07	<0.001	1521.0	<0.1
BW11	10-AG-250	19-Oct-10	<0.0001	0.8440	<0.003	<0.01	0.11	<0.001	977.0	<0.1

"-" symbolizes parameter not measured. “<” symbolizes parameter is below detection limit.

Curriculum Vitae

Name:	Candace N. Freckelton
Post-secondary Education and Degrees:	The University of Western Ontario London, Ontario, Canada 2002-2008 H.B.Sc. in Geology with a major in Psychology
	The University of Western Ontario London, Ontario, Canada 2009-2012 M.Sc. in Geology
Related Work Experience	Surficial Geochemist Ministry of Northern Development and Mines Ontario Geological Survey 2012- current
	Teaching Assistant The University of Western Ontario 2009-2010
	Senior Field Assistant Ministry of Northern Development and Mines Ontario Geological Survey 2009-2011
	Geological Assistant Ministry of Northern Development and Mines Ontario Geological Survey 2008-2009
	Research Assistant The University of Western Ontario 2007-2008
	Data Entry Operator Ministry of Natural Resources Oil, Gas, Salt Resources Library 2006
Volunteer Experience	UWO Laboratory for Stable Isotope Science Committee Organizer The University of Western Ontario 2010-2011

UWO Earth Sciences London Gem and Mineral Show Committee
The University of Western Ontario
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Publications & Abstracts

Freckelton, C.N., Hamilton, S.M., Longstaffe, F.J. 2012. Spatial and Temporal Hydrogeochemical Study of Southwestern Ontario's Breathing Well Region. International Association of Hydrogeologists, Niagara Falls, Canada.

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