Yukon Wide Long-Term Groundwater Monitoring Program
Community of Whitehorse Wells
2001-2010 Monitoring Data Analysis

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Water Resources Branch
Environment Yukon
Government of Yukon
Box 2703 (V-310)
Whitehorse, Yukon
Canada Y1A 2C6

Phone: 867-667-3171
Fax: 867-667-3195
Email: water.resources@gov.yk.ca

Summary

Climate change is, and will continue, altering the hydrologic cycle in Yukon. In order to adapt to changes affecting communities, decision-makers, water users and Yukoners need to have better access to data and information about Yukon's water resources.

Groundwater is of great importance to Whitehorse community water supply, for both the municipal water system and in country residential subdivisions. Thus, understanding changes to our groundwater resources over time from natural processes and human consumption is important to the proper management of these resources.

Previous studies of groundwater in the Whitehorse area have relied on well logs and groundwater exploration programs to better establish hydrogeological conditions in the region. To date, the absence of long-term groundwater monitoring records has precluded more detailed assessments of groundwater resources and their fluctuations over time.

Since 2001, four long-term monitoring wells have been established in the community of Whitehorse. The Yukon Wide Long-Term Groundwater Monitoring Program was initiated with an observation well constructed in the Wolf Creek subdivision (Gartner Lee Ltd, 2001b), and two additional wells were instrumented in 2008, in the Selkirk well field and the Whitehorse Copper subdivision, respectively (Gartner Lee Ltd, 2008). An additional well was added to the program as part of the Whitehorse Community Adaptation Project in 2011, in an undeveloped area in the McRae Creeks watershed, to provide baseline conditions for southern Whitehorse.

This report presents results from these wells in the community of Whitehorse. Data collected at the Wolf Creek well for the period from 2001 to 2010 are presented; a description of Whitehorse Copper well data collected between 2008 and 2010 is also provided. Considerable missing data has precluded discussion of Selkirk well data.

Seasonal discharge and recharge periods are observed yearly in the Wolf Creek well. The primary recharge period tends to begin around the end of April and end between July and August, coinciding with the spring snowmelt period and continued spring and summer infiltration. The discharge period begins in late fall and continues through the winter, likely due to groundwater discharges to Wolf Creek. A similar pattern is observed in the Whitehorse Copper well however the maximum aquifer recovery appears to occur earlier, between late June and late July. Water levels begin to drop in early fall and continue declining over the winter period.

The Denali Fault earthquake on November 3rd, 2002 resulted in a rapid decrease in aquifer level in the Wolf Creek well, which over 2 days resulted in a 0.6 m water level drop. Recharge over a 3-year period led to water levels returning to pre-earthquake levels in late 2005.

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Introduction

Climate change is, and will continue, altering the hydrologic cycle in Yukon. Precipitation, snowmelt, glacier melt, runoff, and flooding are changing as a result of a warming climate. In order to adapt to these changes, decision-makers, water users and Yukoners need to have better access to data and information about Yukon's water resources.

Groundwater is a vital resource to Yukon communities. In the community of Whitehorse, the municipal drinking water supply is made up entirely of groundwater pumped from the Selkirk aquifer in Riverdale, while country residential subdivisions in and outside the city depend almost exclusively on groundwater sources for drinking water supply.

Despite the importance of this subsurface water supply, the groundwater regimes associated with community water supplies are still poorly understood (Jacobson, 2003). For the community of Whitehorse, the development of wells in the Selkirk aquifer, and subsequent exploration for other possible groundwater sources during subdivision development over the last 50 years have provided information on the surficial geology, aquifer potential, and sustainable yields in some areas (i.e. Stanley, 1979, Gartner Lee Ltd, 2002). As part of a 2000 Department of Indian and Northern Affairs (INAC) Water Resource Division water resource inventory project for the upper Yukon River, a water well database was built for the Wolf Creek and Pineridge subdivisions area (and later expanded to the rest of the territory), and a groundwater usage study was undertaken in the Wolf Creek and Pineridge subdivisions (Gartner Lee Ltd, 2001a). The study found that groundwater extraction utilized a large portion of the annual infiltration flow available for Wolf Creek base flow. The absence of long-term groundwater level data in this area, and that of other developed aquifers, precluded the determination of whether these groundwater usages were negatively impacting groundwater levels.

In 2001, as follow-up, a long-term monitoring well was constructed in the Wolf Creek subdivision (Gartner Lee Ltd, 2001b). Four additional long-term monitoring wells were instrumented in 2008; two of these in Whitehorse, in the Selkirk well field and Whitehorse Copper subdivision respectively (Gartner Lee Ltd, 2008). The objective of these long-term monitoring wells is to collect information on long-term trends in groundwater in areas where there is infrastructure (e.g., country residential sub-divisions).

This report presents results from the long-term monitoring wells in the community of Whitehorse, which are part of the Yukon Wide Long-Term Groundwater Monitoring Program. The report begins with a review of previous groundwater studies undertaken in the Whitehorse area, presents the Whitehorse long-term monitoring wells and data collection methods, discusses the resulting groundwater levels recorded, and finishes with the study's conclusions.

This work has been funded by the Whitehorse Community Adaptation Project (WhiteCAP) and undertaken in Yukon Environment's Water Resources Branch.

Background

Groundwater is water located in the spaces between soil particles and in the fractures of rock formations underground. As part of the hydrologic cycle, groundwater results from the infiltration of water through the subsurface into the saturated zone, the upper portion of which makes up the groundwater table. Groundwater moves underground depending on existing hydraulic gradients and the porosity and permeability of the medium through which is it moving, among other factors. An aquifer is an underground layer holding water, which can yield a usable quantity of water. Aquifer layers range from granular deposits such as sands and gravels within glaciofluvial deposits to fractured bedrock layers.

Whitehorse Groundwater Studies

Early explorations of groundwater in Yukon and permafrost regions of Canada focused on surface evidence of groundwater flow systems such as springs, aufeis, open-water reaches in rivers in winter, groundwater contributions to baseflow, and community use for drinking water supply. These suggested that alluvial and glaciofluvial deposits provided an adequate source of groundwater for community water supply in the discontinuous permafrost zone (van Everdingen, 1974), including in the city of Whitehorse. In the discontinuous zone, groundwater can be found in unfrozen sand and gravel underlying thick alluvial deposits in valleys. It can also be obtained in permeable bedrock below or unaffected by the permafrost (DIAND, 1975). Aquifers in Yukon tend to be either sand and gravel layers within or below thick glaciolacustrine and glacial sediments, or floodplain sand and gravel deposits along the modern rivers of the territory (Intera Environmental Consultants Ltd, 1975).

In Whitehorse, knowledge about groundwater sources, including warm groundwater, has been gained through successive studies to expand city groundwater infrastructure to meet increased demand and identify groundwater potential during subdivision development. Groundwater development in the city of Whitehorse began in 1956 with the completion of production wells in the shallow groundwater of the Selkirk area. In the 1970s, additional wells were drilled in the Selkirk aquifer, including one deep test production well. Details for these wells are given in Stanley (1979). Exploration in other areas began in the late 1970’s. This included exploration in northern parts of the city (Hydrogeological Consultants Ltd, 1976), Hillcrest (Stanley Associates Engineering, 1978), and Selkirk areas (Stanley Associates Engineering, 1980). More recent subdivision expansions have resulted in further groundwater exploration in the Wolf Creek area (EBA Engineering Consultants Ltd, 1990, Gartner Lee Ltd, 2002).

In 2000, INAC Water Resources, the Government of Yukon and the City of Whitehorse contracted Gartner Lee Ltd to undertake the Upper Yukon River Surface and Groundwater Inventory (Gartner Lee Ltd, 2001a&b). Water well records collected in Wolf Creek and Pineridge subdivisions were used in a groundwater usage study (Gartner Lee Ltd, 2001a).

This study concluded that groundwater consumption constituted a very small percentage of water in the water budget, however represented ~18% of the available infiltration that could be potentially increasing baseflow to Wolf Creek. Without long-term water level data, however, it was not possible to determine if consumption rates were causing a reduction in base flows in the creek or a long-term reduction of aquifer storage. Subsequently, a long-term monitoring well was initiated in the Wolf Creek subdivision, and a preliminary groundwater inventory of Whitehorse was prepared (Gartner Lee Ltd, 2001b). This project assembled a large amount of information pertaining to groundwater in the Whitehorse area.

Documentation and assessment of Yukon community water systems, including Whitehorse, was undertaken in 2001. The reporting outlined water system information, including water source, water pumping, storage and treatment facilities, water distribution, operation and maintenance, water licences, and recommendations (Jacobson, 2003). For the City of Whitehorse, which now relies entirely on the Selkirk Aquifer for its drinking water, the watershed management plan identifies areas of recharge and potential risks to the aquifer, as well as water modelling activities that were undertaken to determine the feasibility of complete reliance on groundwater (UMA, 2003).

As these studies corroborate, the availability of long-term groundwater monitoring records, drilling and water well records, and usage rates are integral to better understanding of our groundwater supplies.

Long-Term Groundwater Monitoring Program

The Yukon Wide Long-Term Groundwater Monitoring Program was initiated in 2001 with the installation of Long Term Monitoring Well No. 1 in the Wolf Creek subdivision. Four more wells were added to the program in 2008, two in Whitehorse – in the Selkirk well field and in the Whitehorse Copper subdivision – in addition to two wells in Dawson and Faro, respectively. The objective of these long-term monitoring wells is to collect information on both short- and long-term trends in groundwater in areas where there is infrastructure (e.g., country residential sub-divisions).

An additional well has been added to the program as part of WhiteCAP in an undeveloped area between Mount Sima and the Wolf Creek subdivision, in the McRae Creeks watershed. This newest well, set away from high use areas, has been chosen to provide baseline conditions that can be compared with the Wolf Creek and Whitehorse Copper long-term monitoring wells.

Wells

There are currently three long-term monitoring wells in the community of Whitehorse. One additional well has been instrumented as part of WhiteCAP.

Wolf Creek Well

The Wolf Creek well was drilled and instrumented in 2001. The well is located on Dawson Road (Lot #117) in the Wolf Creek subdivision, approximately 14 km south of downtown Whitehorse, near the southern city limit (Gartner Lee Ltd, 2001b). It is an open-hole observation well 48.8 m below ground level, completed in Miles Canyon Basalt (bedrock). A description of the physiography, surficial geology, and stratigraphy of the well is given by Gartner Lee Ltd (2001b).

The well was initially instrumented with a Thalamedes OTT shaft encoder system. In 2008 the instrumentation was changed to a Solinst pressure transducer system: a level logger records from below the water surface, while a barologger provides above water pressure compensation.

Whitehorse Copper Well

The Whitehorse Copper well was instrumented in 2008. The well is located on Serac Court (Lot #61) in the Whitehorse Copper subdivision, approximately 11 km from downtown Whitehorse. The well is 27.4 m below the top of casing (with the well cap removed). A Solinst Levelogger and Barologger system provide the water level measurements.

Selkirk Well

The Selkirk well was instrumented in 2008. The well is located off Selkirk Street in Riverdale. A Solinst Levelogger and Barologger system provide the water level measurements.

McRae Creeks Well

The McRae Creeks well was added to the program as part of WhiteCAP in June 2011. This well is approximately 1 km west southwest of the Wolf Creek subdivision, accessible on foot or by all-terrain vehicle. A Solinst Levelogger and Barologger system provide the water level measurements.

Well information for community of Whitehorse wells is given in Table 1, while Figure 1 shows well locations.

Table 1: Long-term monitoring well information for Whitehorse wells

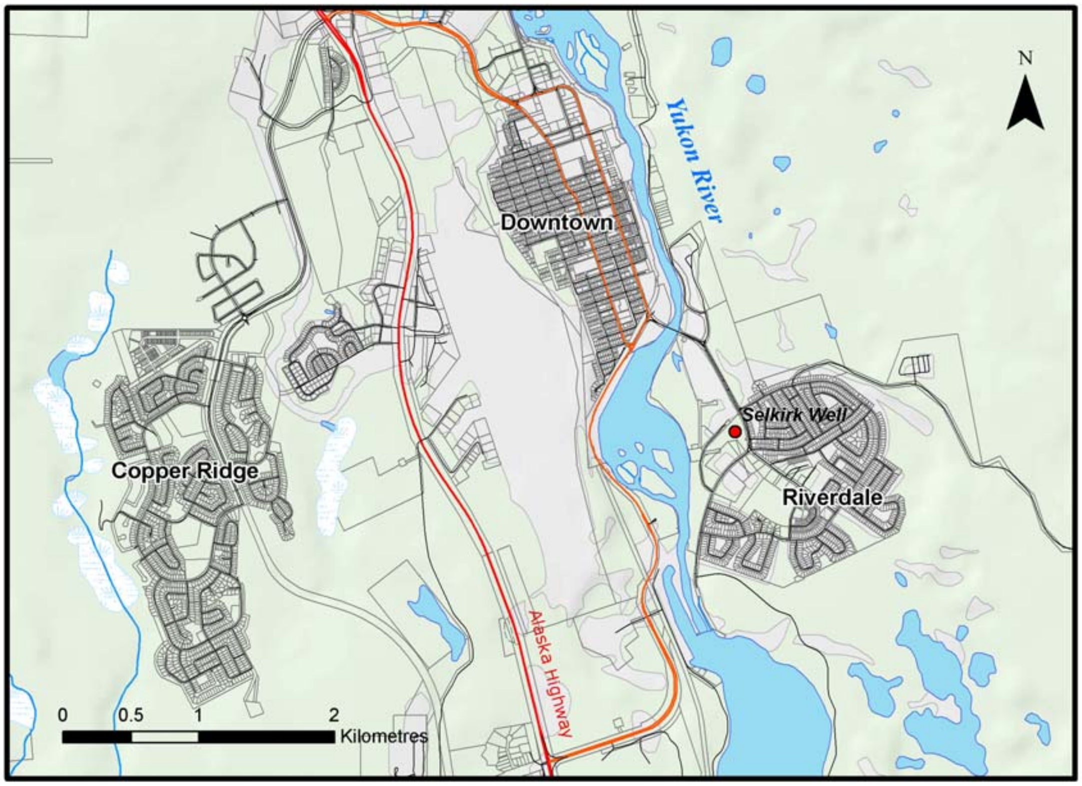
Site Code	Well Name	Site State	Start Year	Latitude	Longitude
YGWLT-0101	Wolf Creek well	Other	2001	60º36’24.9	-134º57’45.8
YGWLT-0801	Whitehorse Copper well	Other	2008	60º37’19.2	-135º0’31.6
YGWLT-0804	Selkirk well	Other	2008	60º 42’26.2	-135º2’10.5
YGWLT-1101	McRae Creeks well	Natural	2011	60º36’23.7	-135º0’24.6

Data collection & rendering

Data was collected from 2001 to 2008 in the Wolf Creek well using an OTT float shaft encoder level logger. This logger recorded water level every hour. The resulting data for this period is step-like in quality. In comparison, the Solinst system that has been used since 2008 in the Wolf Creek well and in all other wells, records data every 15 minutes, and water level measurements tend to be noisier with this instrumentation. Once initialized, the loggers provide continuous data collection for up to 6 months, and observations visits are made regularly to ensure optimal data collection. During site visits technicians download the stored data and validate logger function – water sensing tape is used to ground truth instrument-recorded water levels. Lineal corrections are applied between manual observations where an offset cannot be attributed to a known event.

A well data summary for the Whitehorse wells is provided in Appendix A. As a result of short records and missing data, only the Wolf Creek well data is analysed in detail, while general trends are discussed for the Whitehorse Copper well. Considerable missing data has precluded discussion of Selkirk well data.

All sub-hourly water levels have been averaged to daily levels for analysis in this report.



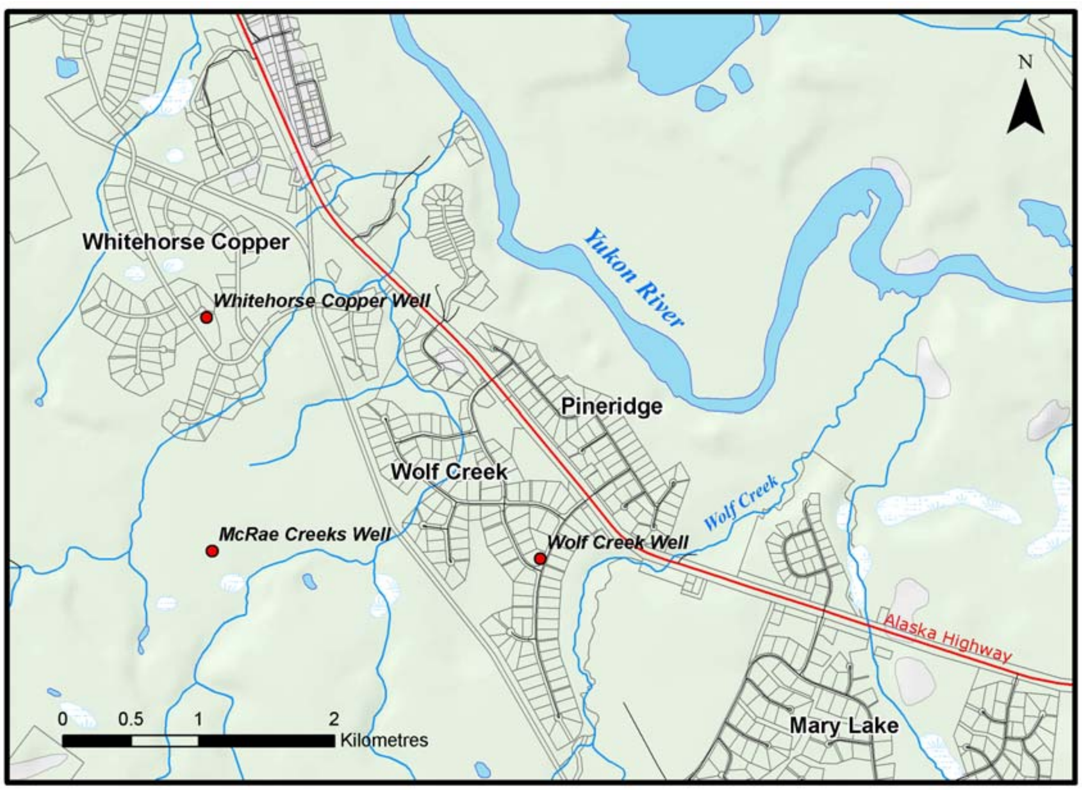


Figure 1: a) Selkirk Well in Riverdale, b) Whitehorse Copper, Wolf Creek and McRae Creeks Wells in southern Whitehorse

Monitoring Results

Analysis of the Wolf Creek well monitoring data from 2001 to 2010 is provided below. A discussion of general trends for the Whitehorse Copper well follows.

Wolf Creek Well

Daily water levels measured at the Wolf Creek well from 2001 to 2010 are shown in Figure 2. While seasonal fluctuations in water levels are apparent, most visible is a considerable drop in water level between November 3rd and 4th 2002 from ~16.6 to 17.2 m below the top of the casing (shown also in Figure 3a). This drop coincided with the Denali Fault earthquake, which occurred at 2:12pm Whitehorse time on November 3rd 2002. The 7.9 magnitude earthquake had an epicentre 145 km east southeast of Denali National Park in Alaska (USGS, 2003). The hourly data record in the Wolf Creek well shows a rapid decrease in aquifer level initiated during the earthquake, and continuing for the following 2 days (Figure 3b). Similar earthquake disturbances to the water table and aquifers have been documented, for example in Alaska after the great Alaska earthquake in 1964 (National Research Council, 1968). As shown in Figure 3c, recharge over a 3-year period finally resulted in water levels returning to pre-earthquake levels in late 2005.

A yearly hydrograph of water levels for Wolf Creek well is shown in Figure 4 for several years of record considered unaffected by the Denali Fault earthquake. As noted by Gartner Lee Ltd (2001b), there is an observed increased in water level during the spring. Over the 10-year record, this period has tended to begin around the end of April (day 110 to 120, ie April 20th to April 30th). The end of the recharge period is less clear, as water levels increase until the end of June in some years (ie 2001) and until November in other (ie 2009), however in general the recharge period appears to end between July and August. This timing coincides with the spring snowmelt period, and continued spring and summer infiltration. Similar recharge timing was observed from a monthly and annual water balance developed for the upper Wolf Creek basin using the Cold Regions Hydrological Model (Janowicz *et al*., 2004). While the well is at a lower elevation than the upper Wolf Creek study area, continued melt, runoff and infiltration from the upper part of the basin could contribute to extended aquifer recharge timing.

Also visible in Figure 4, a decline in water levels begins late in the fall and continues through the winter in the Wolf Creek well. With dropping levels in Wolf Creek in this period, declining groundwater level is likely due to groundwater discharges to the stream.

Whitehorse Copper Well

A similar seasonal trend is visible in the Whitehorse Copper well for data collected between 2008 and 2010. Recharge begins in the spring around the end of April and ends in late June/early July. Water levels begin to drop in early fall and continue declining over the winter period.

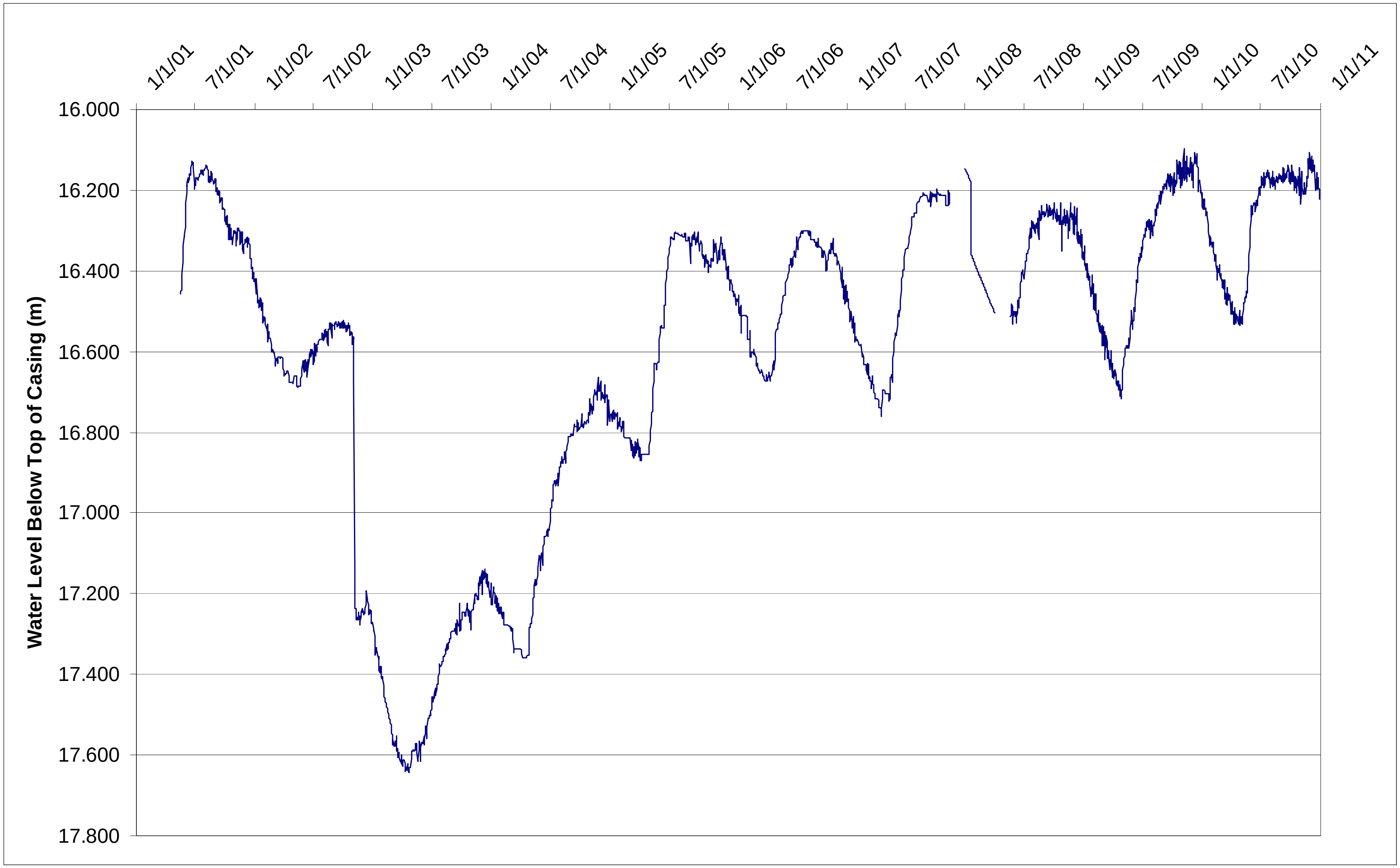


Figure 2: Wolf Creek well water levels, May 2001 to December 2010

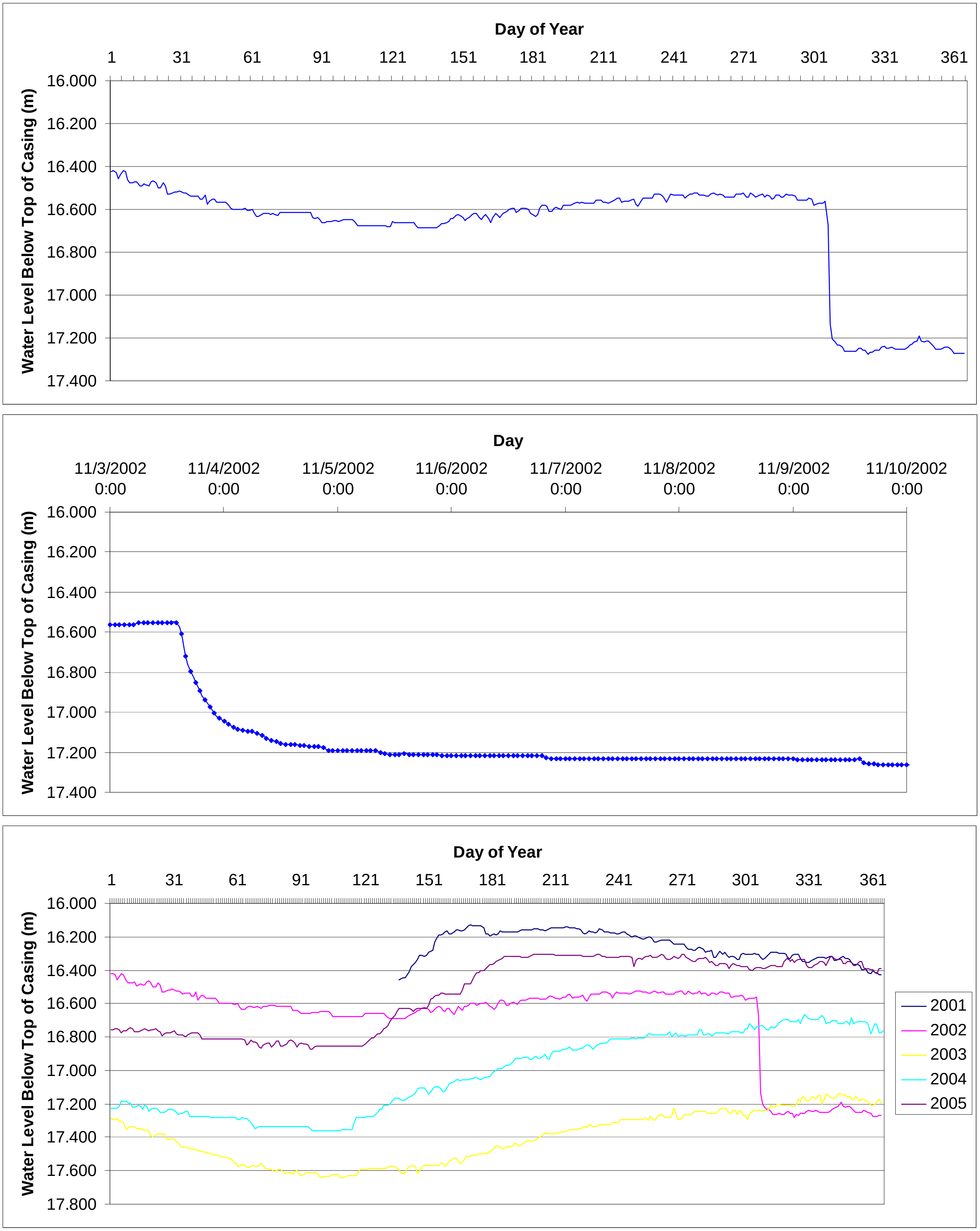


Figure 3: a) Daily water level for 2002, b) Hourly water level prior to, during, and after the 2002 earthquake event, c) Water level recovery after the earthquake

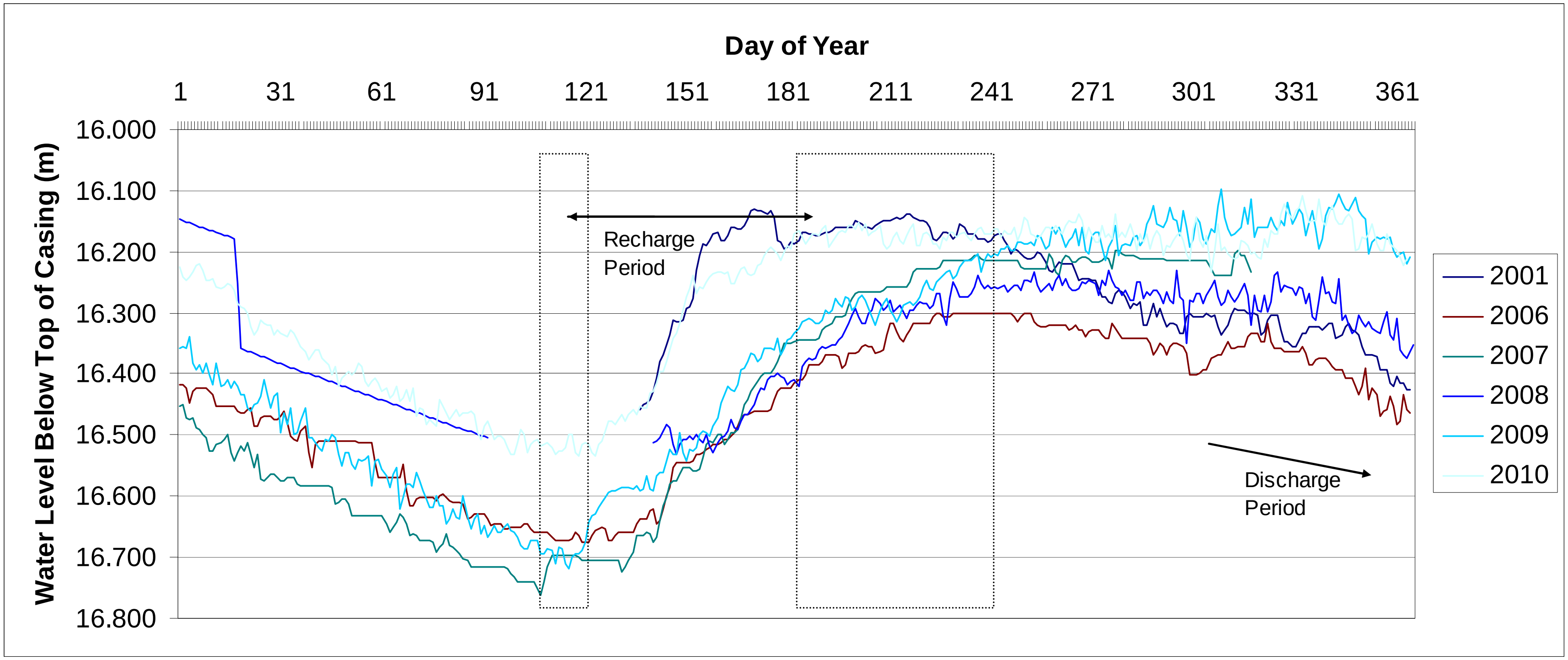


Figure 4: Hydrograph of water levels for Wolf Creek well

Conclusion

Groundwater is of great importance to Whitehorse community water supply, for both the municipal water system and in country residential subdivisions. Thus, understanding changes to our groundwater resources over time from natural processes and human consumption is important to the proper management of these resources. Long-term monitoring of groundwater in areas with groundwater extraction infrastructure, can improve understanding of how usages are impacting groundwater levels. Monitoring in natural areas provides a baseline of water level change over time.

In 2001, the Yukon Wide Long-Term Groundwater Monitoring Program was initiated with the construction of the Wolf Creek well. Four additional wells were instrumented in 2008, of which two are in Whitehorse: in the Selkirk well field and the Whitehorse Copper subdivision. An additional well was added to the program as part of WhiteCAP in 2011 in an undeveloped area in the McRae Creeks watershed to provide baseline conditions for southern Whitehorse.

Previous studies of groundwater in the Whitehorse area have relied on well logs and groundwater exploration programs to better establish hydrogeological conditions in the region. To date, the absence of long-term groundwater monitoring records has precluded more detailed assessments of groundwater resources and their fluctuations over time.

Data collected at the Wolf Creek well for the period from 2001 to 2010 are presented in this report; a description of Whitehorse Copper well data collected between 2008 and 2010 is also provided. Considerable missing data has precluded discussion of Selkirk well data.

Seasonal discharge and recharge periods are observed yearly in the Wolf Creek well. The primary recharge period tends to begin around the end of April and end between July and August, coinciding with the spring snowmelt period, and continued spring and summer infiltration. The discharge period begins in late fall and continues through the winter, likely due to groundwater discharges to Wolf Creek. A similar pattern is observed in the Whitehorse Copper well, however the maximum aquifer recovery appears to occur earlier, between late June and July. Water levels begin to drop in early fall and continue declining over the winter period.

The Denali Fault earthquake on November 3rd, 2002 resulted in a rapid decrease in aquifer level in the Wolf Creek well, which over 2 days resulted in a 0.6m water level drop. Recharge over a 3-year period led to water levels returning to pre-earthquake levels in late 2005.

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Appendix A

Whitehorse - Well Data Summary
Yukon Wide Long-Term Groundwater Monitoring Program

Introduction
This document is produced by Water Resources Branch- Hydrology Section. The content of this document provides a general summary of recorded well data and specific details concerning monitoring and installation for the following groundwater wells- Wolf Creek Subdivision, Whitehorse Copper Subdivision and Selkirk Subdivision.

Well No. 1 - Wolf Creek Subdivision

Table 1 – Summary of Well Data Collection, Wolf Creek Subdivision

Record Period		***Comment***
May 17 2001	December 31 2001	Complete
January 1 2002	December 31 2002	Complete
January 1 2003	December 31 2003	Complete
January 1 2004	December 31 2004	Complete
January 1 2005	December 31 2005	Complete
January 1 2006	December 31 2006	Complete
January 1 2007	December 31 2007	Complete
January 1 2008	December 31 2008	Missing Data (April 2- May 20)
January 1 2009	December 31 2009	Complete
January 1 2010	December 31 2010	Complete

Table 2 – Summary of Well Elevation Details

Well ID	***Northing***	***Easting***	***Elevation of TOC (masl)***	***Groundwater Elevation (masl)***	***Elevation of Well Bottom (masl)***
YGWLT-0101	Unknown	Unknown	738.0 e	721.52 e	689.20 e

e- estimate from Gartner Lee Ltd 2001 borehole log

Table 3 – Summary of Logger Installation Details

Logger Install Date	***Water Level (mb TOC)***	***Depth of Levelogger (mb TOC)***	***Levelogger Serial Number***	***Barologger Serial Number***
17-May-2001	16.48	Unknown	1028542	1030004

Special Notation

Well data for Wolf Creek Subdivision was recorded using the following instrument(s) or logger(s) during the periods noted:

- May 17 2001 to November 14 2007 (Thalamedes OTT- shaft encoder)
- November 14 2007 to May 19 2008 (unaccounted)
- May 20 2008 to November 26 2010 (present) (Solinst- Pressure Transducer)

Well No. 2 - Whitehorse Copper Subdivision

Table 4 – Summary of Well Data Collection, Whitehorse Copper Subdivision

Record Period		***Comment***
March 20 2008	December 31 2008	Missing Data- (December 21- December 31)
January 1 2009	December 31 2009	Missing Data- (January 1- April 19)
January 1 2010	December 31 2010	Missing Data- (January 24- December 31)

Table 5 – Summary of Well Elevation Details

Well ID	***Northing***	***Easting***	***Elev. of TOC (masl)***	***Groundwater Elev. (masl)***	***Elev. of Well Bottom (masl)***
YGWLT-0801	6720687.2	499514.6	778.3	771.4	750.9

Table 6 – Summary of Logger Installation Details

Logger Install Date	***Water Level (mb TOC)***	***Depth of Levelogger (mbTOC)***	***Levelogger Serial Number***	***Barologger Serial Number***
20-Mar-08	6.91	11.0	310029592	11029407

Special Notation

Well data for Whitehorse Copper Subdivision was recorded using the following instrument(s) or logger(s) during the periods noted:

- 2008 20 March to 2010 23 November (present) (Solinst- Pressure Transducer)

Well No. 3 - Selkirk Subdivision

Table 7 – Summary of Well Data Collection, Selkirk Subdivision

Record Period		***Comment***
August 13 2008	December 31 2008	Missing Data- (October 31- December 11)
January 1 2009	December 31 2009	Missing Data- (April 1 – December 31)
January 1 2010	December 31 2010	Missing Data-(January 1- July 19)

Table 8 – Summary of Well Elevation Details

Well ID	*Northing*	*Easting*	*Elevation of TOC (masl)*	*Groundwater Elevation (masl)*	*Elevation of Well Bottom (masl)*
YGWLT-0804	Unknown	Unknown			

Table 9 – Summary of Logger Installation Details

Logger Install Date	*Water Level (mb TOC)*	*Depth of Levelogger (mbTOC)*	*Levelogger Serial Number*	*Barologger Serial Number*
11-Dec-2008	8.21	Unknown	1030722	1029995 1018962

Special Notation

Well data for Selkirk Subdivision was recorded using the following instrument(s) or logger(s) during the periods noted:

- 2008 11 December to 2011 05 November (present) (Solinst- Pressure Transducer)