

18 January 2017

Project No. 1314350010-008-L-Rev1

Laura Beckett, Municipal Planner, Approving Officer  
District of Highlands  
1980 Millstream Road  
Victoria, BC  
V9B 6H1

## **RESULTS OF 2015 GROUNDWATER LEVEL MONITORING PROGRAM, DISTRICT OF HIGHLANDS, BC**

Dear Ms. Beckett,

As requested by the District of Highlands (the District), Golder Associates Ltd. (Golder) conducted a groundwater level monitoring program in the District of Highlands, BC (the Highlands). Golder conducted the work in accordance with our proposal titled "Work Plan and Cost Estimate for 2015 Groundwater Level Monitoring Program, District of Highlands, BC" (Golder Reference No. 1314350010-003-WP-Rev0) and dated 29 June 2015.

Our letter should be interpreted and used in accordance with the limitations and considerations set out in Golder Associate Ltd.'s *Study Limitations*, provided at the end of this letter.

### **1.0 BACKGROUND AND OBJECTIVE**

The Highlands is one of 13-member municipalities of the Capital Regional District (CRD), encompassing approximately 37 square km and located northwest of Victoria, BC. The majority of the residential population<sup>1</sup> of approximately 2,120 obtains potable water from private, individual water wells. Commercial groundwater use is limited to the southern portion of the Highlands. The Hanington Estates subdivision, located along the southern portion of the Highlands, obtains water from a water system ("Hanington Estates Water System") that is supplied by two communal supply wells. Irrigation water for the Bear Mountain Golf Course (Bear Mountain) is sourced from groundwater wells located within the Highlands. Some businesses within the Millstream Industrial Park, located in the Highlands and Langford, also use groundwater for commercial purposes.

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<sup>1</sup> BC Stat, 2011. 2011 Census Total Population Results, Municipalities by Regional District. Available on-line at: <http://www.bcstats.gov.bc.ca/StatisticsBySubject/Census/2011Census/PopulationHousing/MunicipalitiesByRegionalDistrict.aspx>



## 1.1 Aquifer Description

Groundwater supplies within the Highlands are derived primarily from drilled wells completed in the Wark-Colquitz Aquifer. This bedrock aquifer is identified as Aquifer No. 680 by the BC Ministry of Environment (MoE) and is categorized as class IIB under the BC Aquifer Classification System, indicating moderate demand relative to aquifer productivity and moderate vulnerability of the aquifer to contamination from surface sources. Sewage servicing within the Highlands is by individual septic systems.

## 1.2 Highlands Monitoring Program

Golder has conducted groundwater level monitoring in the Highlands since 2009 in support of the District's Groundwater Protection Study. The water-level information was used to assess seasonal water-level variations and, in 2012, to refine the Highland's numerical groundwater model, which was in turn used to develop groundwater conservation and protection measures. At the completion of the study, Golder recommended that the District continue to monitor groundwater conditions in the Highlands to assess long term trends. If trends were to be observed, the results would provide the basis for guiding implementation of management strategies including the conservation and groundwater protection measures, and public education efforts. Further details are provided in Golder's report titled "Phase 3: Groundwater Protection Study District of Highlands, District of Highlands Victoria, BC" (Golder Report No. 0714140014-501-R-Rev2-3000) and dated 18 December 2012.

At present, electronic data loggers (i.e., pressure transducers) are present in six monitoring wells located across the Highlands to collect continuous water-level data, and one additional pressure transducer (a "barologger") is present to monitor changes in barometric (i.e., atmospheric) pressure. The locations of monitoring wells DOH-01, DOH-02A, DOH-03, DOH-04B, DOH-07B and DOH-09A are presented on attached Figure 1.

Monitoring wells DOH-1, DOH-02A, DOH-07B and DOH-09A are unused wells that are not equipped with pumps (i.e., are not in operation); therefore, the water levels in these wells are generally considered to be representative of static groundwater levels in the aquifer in the vicinity of the wells. DOH-03 and DOH-04B are equipped with pumps and operated as supply wells for non-potable uses (i.e., not for drinking water) and, therefore, the water levels in these wells during operation may not be representative of the water levels in the surrounding aquifer.

## 1.3 Objective

The objective of the 2015 groundwater level monitoring program was to compile and analyse data from the Highlands and stakeholder monitoring programs to assess regional groundwater conditions and potential long-term trends.

## 2.0 METHODS

### 2.1 Groundwater Level Monitoring

The transducers that are installed in the Highlands monitoring wells, including the barologger that is deployed at monitoring location DOH-02A, are programmed to collect data every twelve hours. Golder conducted downloaded pressure transducer data and collected a manual depth-to-water measurement at each monitoring location in the Highlands on 31 March, 8 to 9 July, 20 October and 18 December 2015.

## 2.2 Data Compilation and Analysis

In addition to the District's monitoring program, Golder also obtained data from other stakeholder monitoring programs in the Highlands including:

- BC Ministry of Environment (MoE) Observation Well Network: water-level data available on-line from the MoE for Observation Well No. 372, located in the western portion of the Highlands.
- Hanington Estates Water System: flow data available from Island Flow Control Water Solutions Ltd. for the Hanington Estates Water System, in the southern portion of the Highlands.
- Bear Mountain Monitoring Program: water-level and flow data available from Ecoasis Developments LLP for the Bear Mountain Golf and Country Club in the southern portion of the Highlands.
- University of Victoria (UVic) School-Based Weather Station Network: data available on-line for four UVic weather stations, located at various areas of the Highlands

The locations of the monitoring wells and weather stations from the various stakeholder monitoring programs are also presented on Figure 1.

Golder compiled the raw pressure data from the Highlands monitoring wells and corrected the data for variations in barometric pressure, as recorded by the barologger, to calculate groundwater levels for each Highlands monitoring well. Golder also compiled data available from MoE Observation Well No. 372, Environment Canada's Highland Weather Station and the UVic weather stations. Golder plotted the data from the Highlands and stakeholder monitoring programs and analysed the results to assess seasonal and long-term trends.

Golder reviewed flow data for the Hanington Estates Water System and the results from the Bear Mountain Monitoring Program presented in the report prepared by Thurber Engineering Ltd. (Thurber) titled "Bear Mountain 2014-2015 Annual Groundwater Monitoring Report" (Thurber File No. 19-3713-5) and dated 17 August 2016. Golder did not conduct a detailed review of the data presented in Thurber's report. Rather, Golder assessed the results from the Bear Mountain Monitoring Program in the context of the regional groundwater system.

## 3.0 RESULTS AND DISCUSSION

### 3.1 District of Highlands Monitoring Program

Detailed water-level data for monitoring wells DOH-01, DOH-02A, DOH-03, DOH-04B, DOH-07B and DOH-09A for the period from 1 January 2011 through 18 December 2015, together with daily precipitation data from nearby weather stations are presented on Figures 2 through 7.

Water levels recorded in the majority of the Highlands monitoring wells in 2015 were generally consistent with the seasonal patterns that have been observed in previous years. Water levels are generally highest and stable in the wet winter season (December to April), decline to a seasonal low during the summer months (approximately May to September) and then increase in response to precipitation (October and November). The seasonal responses observed in 2015 were generally consistent with those observed in previous years and greatest in monitoring wells located at higher elevations, in areas of inferred groundwater recharge. Seasonal responses in 2015 ranged from approximately 15 m in DOH-02A, located in an upland area at an elevation of over 260 m above sea level (asl), to less than 5 m in DOH-03, DOH-07B and DOH-09A, located at lower elevations in inferred groundwater discharge areas adjacent to wetlands.

The groundwater levels that were observed in the Highlands monitoring wells at the end of the dry season of 2015 were consistent with precipitation patterns and generally within the range of those observed during previous years. The total precipitation recorded for the West Highlands District Firehall weather station from 1 May through 31 August 2015 was 52.7 mm, compared to values that ranged from 44.2 mm to 135.1 mm for the same period in 2012 and 2013, respectively. In 2015, seasonal precipitation increased beginning in late August, whereas the wet season began in mid-October in 2012 and mid-September in 2013.

The seasonal low water level in DOH-02A was reported to be approximately 29.4 m below top of (well) casing (btoc) in late August 2015, within the range of dry season levels that have ranged from 29.9 mbtoc to 27.7 mbtoc in 2012 and 2013, respectively. Similarly, the dry season water levels reported in 2015 for DOH-04B (8.8 mbtoc) and DOH-09A (5.1 mbtoc) were also within the ranges of 8.0 – 9.5 mbtoc and 5.0 – 5.2 mbtoc that were reported for these wells, respectively, during previous years.

In 2015, the water levels in DOH-01, DOH-03 and DOH-07B were also generally consistent with previous years. These monitoring wells continued to be influenced by pumping of the well (DOH-03) or nearby well(s) (DOH-01 and DOH-07B); however, less pumping-induced drawdown was observed in these wells compared to previous years. For example, the lowest isolated (i.e., pumping induced) water level of 20.7 mbtoc that was observed for DOH-01 in 2015, was higher than values of up to 28.2 mbtoc that have been observed in previous years. The low water level observed in DOH-03 was consistent with 2014, but lower than those observed from 2011 to 2013. The low water level in DOH-07B was slightly lower than previous years; further monitoring is required to determine if this is a discernable trend and represents a long term decline in dry season water levels.

Following the onset of the wet season, water levels in the Highlands monitoring wells responded rapidly to precipitation, increasing from early September of 2015. The isolated periods of rapid water level increases observed in monitoring wells are consistent with groundwater recharge during periods of greater precipitation. The seasonal high water levels observed in December 2015 were consistent with previous years.

### **3.2 BC Ministry of Environment Observation Well**

Water-level data for MoE Observation Well No. 372 (MoE Well No. 372) are plotted with precipitation data from nearby West Highlands District Firehall weather station on Figure 8.

The water level patterns observed in MoE Well No. 372 were generally consistent with those observed in the Highlands monitoring wells. The seasonal low water level of 61.1 mbtoc that was reported for the dry season of 2015 was slightly higher than the low of 61.5 mbtoc that was reported in the summer of 2012. The fairly consistent water level of 61.1 mbtoc that was observed from early September to late October of 2015 may reflect a stable water level, or an error in the dataset that was provided for the well. The high water level of 47 mbtoc that was observed in November 2015 is consistent with those observed late in 2014 and higher than those observed during the late winter months of previous years.

### 3.3 Hanington Estates Water System

Water supply for the Hanington Estates Water System is sourced from two groundwater supply wells. Well 409 (Well Tag No. 85183) is operated as the primary water supply for the Hanington System and Well 500 (Well Tag No. 85184) is operated periodically as a backup supply. The total flows from wells 409 and 500 were reported to be 18,803 cubic metres (m<sup>3</sup>) and 4,847 m<sup>3</sup>, respectively, for a combined flow of 23,650 m<sup>3</sup> for the period 13 February 2015 to 4 December 2015. The average groundwater use for the Hanington Estates Water System during this period was 80.4 m<sup>3</sup>/day and anticipated to be higher during the drier, hotter summer season. This 2015 estimate is higher than the values of 76.1 m<sup>3</sup>/day and 77.0 m<sup>3</sup>/day that were reported for 2013 and 2014, respectively; however, the population in Hanington Estates is also estimated to have increased from 161 residents in 2013 to 182 in 2015<sup>2</sup>. Based on population data, the average water use at Hanington Estates is calculated to be approximately 442 litres per person per day (L/p/d) for the period February to December of 2015. This value is lower than the values of 473 L/p/d and 448 L/p/d that were estimated for 2013 and 2014, respectively.

Water level data were not provided for Well 409 and Well 500 for 2015.

### 3.4 Bear Mountain Monitoring Program

The results of the Bear Mountain Groundwater Monitoring Program for 2014-2015 were reported by Thurber (2016). Continuous water level data were collected with dedicated pressure transducers that were deployed in irrigation (i.e., pumping) wells 405, 407 and 411, and monitoring wells 413 and 414. Irrigation wells 405, 407 and 411 are each equipped with a flow meter to measure flow rates. Thurber (2016) reported that, in addition to the groundwater monitoring program, KWL was retained to conduct a water balance study for the Bear Mountain operations; however, the results of the water balance study were not yet available.

Bear Mountain pumped a total groundwater volume of approximately 238,050 cubic metres (m<sup>3</sup>) from 12 May to 5 October 2015 at intermittent pumping rates of approximately 1.3 – 2.8 litres per second (L/s) from well 405, 2.5 – 10.1 L/s from well 407 and 8.5 – 11.7 L/s from well 411. The total volume extracted in 2015 was less than the 265,950 m<sup>3</sup> that was reported to have been pumped from these irrigation wells from 29 April to 23 September 2014.

During the pumping period, maximum drawdown in the irrigation wells was reported to be approximately 47 m in wells 405 and 407, and 82 m in well 411. Relatively less drawdown was reported for the irrigation wells in 2015 when compared to 2014, with maximum drawdown values of 50 m being reported for wells 405 and 407 and 90 m being reported for well 411 at the end of the dry season in 2014. In the fall of 2015, the water levels in the irrigation wells recovered to 100% of the pre-pumping groundwater levels within approximately five weeks compared to recovery periods of approximately six weeks in 2014, 10 days in 2013 and two weeks in 2012. Thurber attributed the relatively slower recovery periods in 2014 and 2015 to longer dry seasons in these years.

In 2015, the static water levels in observation wells 413 and 414 were reported to be similar to those observed in previous years, exhibiting a seasonal fluctuation of approximately 5 m. Thurber interpreted these results as indicating that the observation wells are hydraulically separate from the lineament (i.e., fault/fracture zone) in which the irrigation wells are completed. Thurber noted that there are currently no monitoring wells upgradient (north) from the irrigation wells and, therefore, the extent of the drawdown from operation of the irrigation wells is not known.

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<sup>2</sup> Population information, as provided by the District of Highlands in June 2016, based on Stats Canada 2011 Census data and number of developed properties.

Thurber (2016) recommended that water level monitoring equipment be removed from wells 413 and 414 and transferred to wells 408 and 412 to gather detailed water level data at other locations. These wells were drilled during previous groundwater exploration programs for Bear Mountain. Thurber further recommended that remaining unused wells at Bear Mountain, including wells 400, 401, 402 and 410, be closed in accordance with the BC Ground Water Protection Regulation.

## **4.0 CONCLUSIONS AND RECOMMENDATIONS**

### **4.1 Conclusions**

The results from the 2015 groundwater monitoring program were generally consistent with the seasonal patterns reported for previous years. Water levels in the Highlands monitoring wells during the dry season of 2015 were within the range of those observed in previously monitored years (2010 – 2014). Low water levels observed in monitoring well DOH-07B, which is interpreted to be slightly influenced by pumping of an adjacent well, were marginally lower in 2015 compared to previous years; further monitoring is required to determine if this is a discernable trend and represents a long term decline in dry season water levels at this location.

The average water use at Hanington Estates was estimated to be approximately 80.4 m<sup>3</sup>/day for the period February to December of 2015, higher than the average values of 76.1 m<sup>3</sup>/day and 77.0 m<sup>3</sup>/day that were calculated for 2013 and 2014, respectively. However, the population in Hanington Estates also increased between 2013 and 2015. When calculated on a per capita basis, groundwater use in Hanington Estates is estimated to have decreased to 442 L/p/d in 2015 compared to values of 473 L/p/d in 2013 and 448 L/p/d in 2014.

A total volume of 238,050 m<sup>3</sup> of groundwater was reported to have been pumped from Bear Mountain irrigation wells 405, 407 and 411 during the dry season of 2015, less than the volume of 265,950 m<sup>3</sup> that was extracted in 2014. Relatively less pumping-induced drawdown was observed in the irrigation wells in 2015 compared to 2014. In 2015, the water levels in the irrigation wells recovered to 100% of the pre-pumping levels within approximately five weeks, compared to six weeks in 2014, 10 days in 2013 and two weeks in 2012.

### **4.2 Recommendations**

Golder recommends that the groundwater monitoring program continue in 2016 to assess seasonal patterns and long term trends in groundwater levels across the Highlands, particularly for DOH-07B, which exhibited slightly lower water levels in 2015 compared to previous years. The results of stakeholder programs should also continue to be reviewed on an annual basis to monitor groundwater conditions in the southern portion of the Highlands where production wells are operated.

It is recommended that the District request detailed groundwater flow and water level data for the Hanington Estates wells. Flow and water level data should be collected on a monthly to quarterly basis to support assessment of seasonal patterns associated with the Hanington supply wells. It is also recommended that the data be collected according to a consistent schedule to generate a dataset that is comparable year over year.


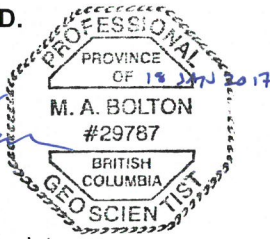
Once available, the water balance study for Bear Mountain should be reviewed to understand groundwater extraction and water use at the golf course. As recommended by Thurber (2016), transfer of the water level monitoring equipment from observation wells 413 and 414 to unused wells 408 and 413 would provide detailed data at other locations in the vicinity of the Bear Mountain irrigation wells.

## 5.0 CLOSURE

We trust the above information meets your current needs. If you have any questions or require additional information, please do not hesitate to contact the undersigned.

Yours truly,

**GOLDER ASSOCIATES LTD.**

Mark Bolton, MSc, PGeo  
Associate, Senior Hydrogeologist



Jillian Sacré, MSc, PGeo  
Principal, Senior Hydrogeologist

MAB/JPS/smh

- Attachments:
- Figure 1: Monitoring Locations District of Highlands
  - Figure 2: Depth to Groundwater Monitoring Well DOH-01 and Precipitation in Southern Highlands
  - Figure 3: Depth to Groundwater Monitoring Well DOH-02A and Precipitation in Western Highlands
  - Figure 4: Depth to Groundwater Monitoring Well DOH-03 and Precipitation in Southern Highlands
  - Figure 5: Depth to Groundwater Monitoring Well DOH-04B and Precipitation in Western Highlands
  - Figure 6: Depth to Groundwater Monitoring Well DOH-07B and Precipitation in Northern Highlands
  - Figure 7: Depth to Groundwater Monitoring Well DOH-09A and Precipitation in Eastern Highlands
  - Figure 8: Depth to Groundwater Monitoring Well MoE Observation Well 372 and Precipitation in Western Highlands

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## 6.0 STUDY LIMITATIONS

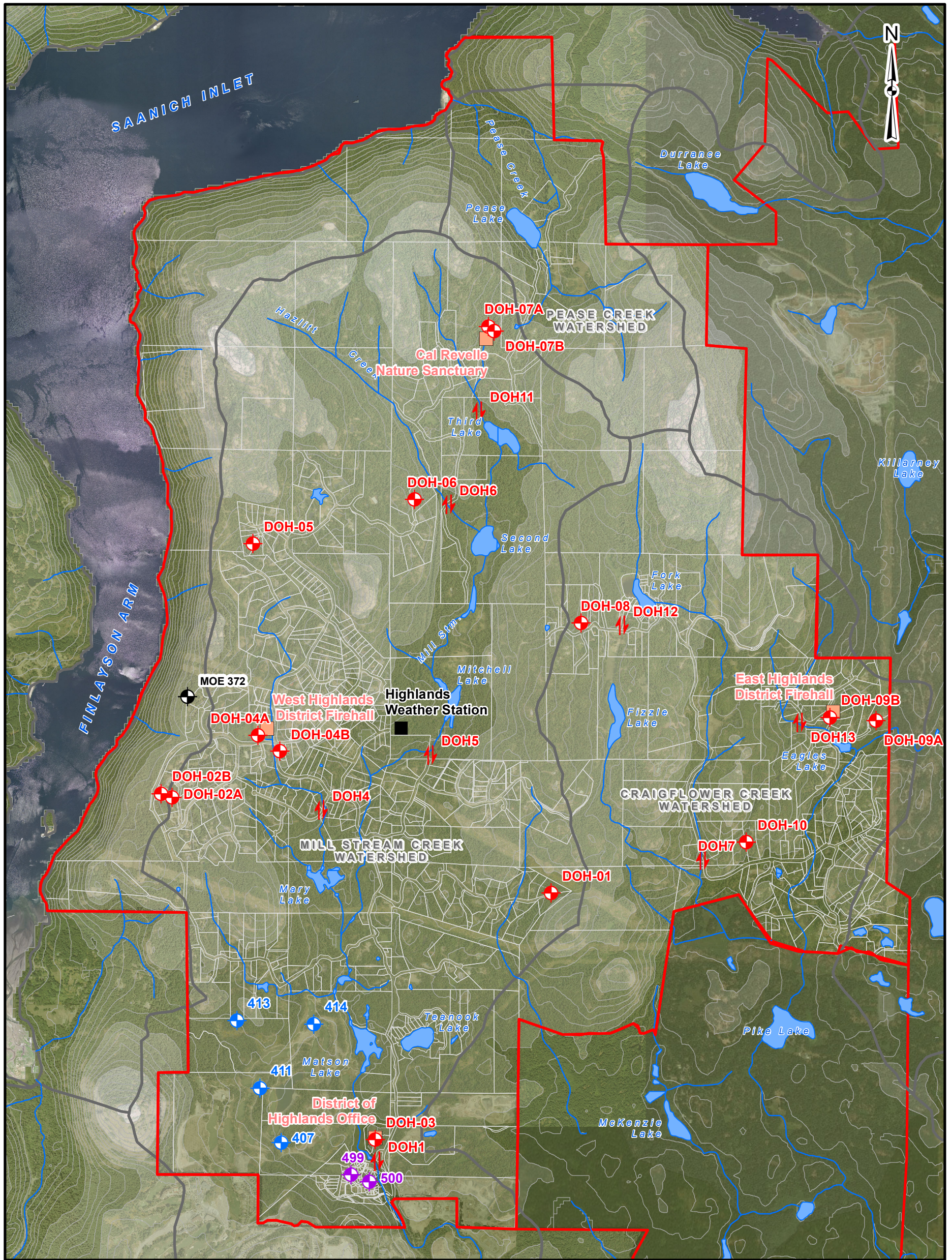
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**LEGEND**

- District of Highlands Monitoring Well Location
- Stream Flow Measurement Location (2010)
- Hanington Creek Estates Well
- Bear Mountain Monitoring Well
- Ministry of Environment Observation Well No. 372
- Environment Canada Weather Station
- University of Victoria Weather Station
- Contour (20m Interval)
- Watercourse
- Waterbody
- Cadastre Information
- Major Watershed Boundary
- Municipality Boundary
- Elevation - metres above sea level (masl)**
- 0 - 100
- 101 - 200
- 201 - 300
- 301 - 400
- 401 - 500

**REFERENCE**

Data provided by the District of Highland and BC ILMB.  
 Base data provided by the Ministry of Environment, WMS.  
 Hydrology obtained from Canvec© Department of Natural Resources Canada. All Rights Reserved.  
 Projection: Transverse Mercator Datum: NAD 83 Coordinate System: UTM Zone 10



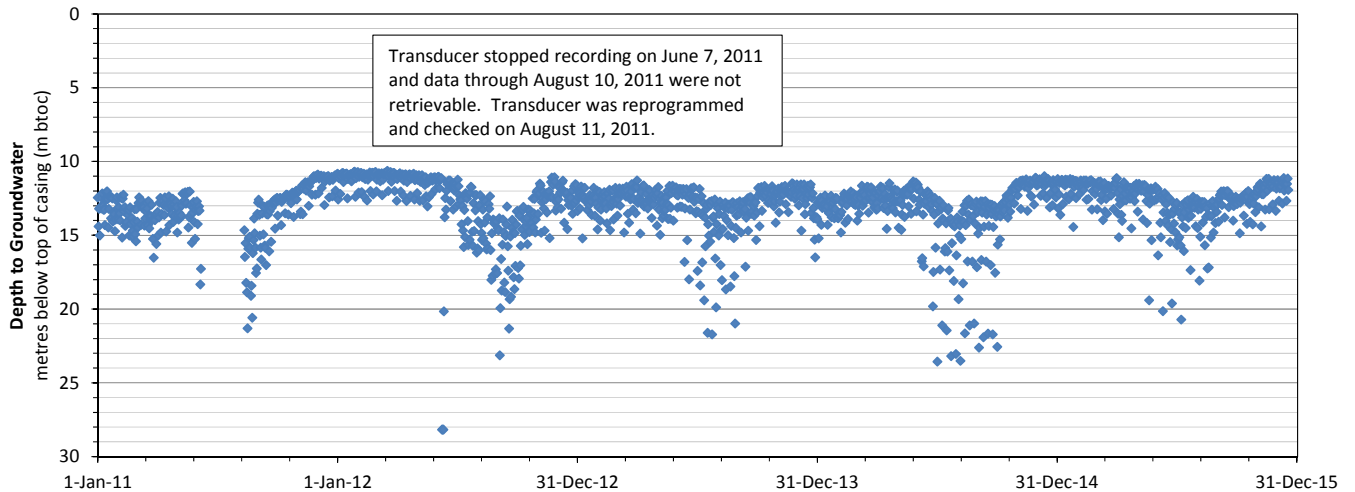
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 GROUNDWATER PROTECTION STUDY  
 HIGHLANDS, B.C.

TITLE  
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 DISTRICT OF HIGHLANDS**

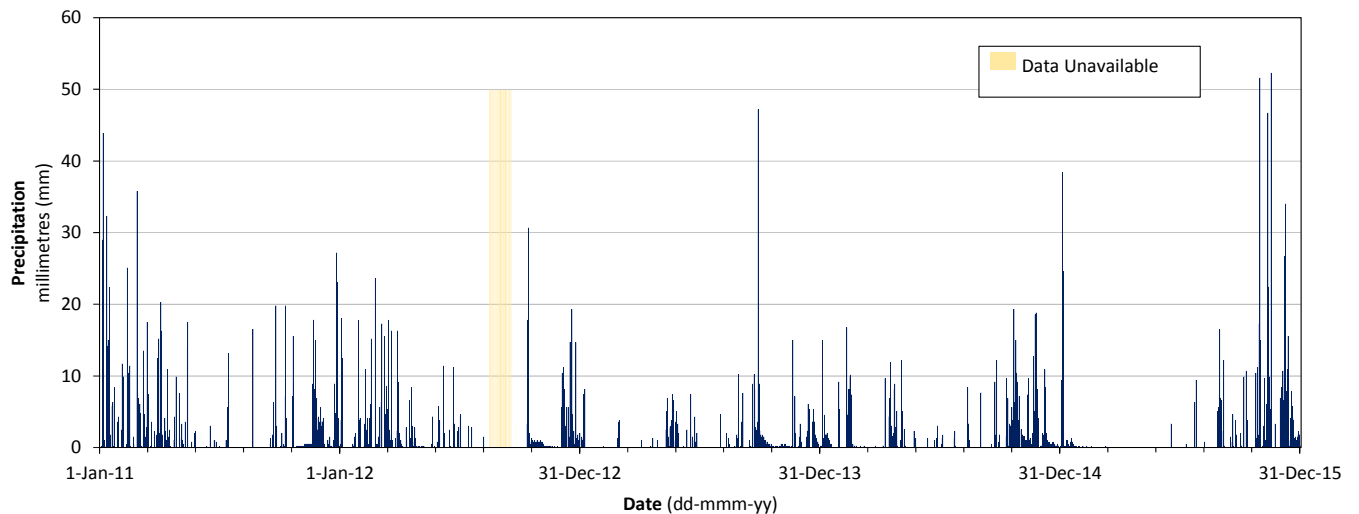


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REVIEW	JPS	5 Nov. 2015	

**District of Highlands Monitoring Well DOH-01**



**District of Highlands Office Weather Station**



**Notes**

Water level data collected under the District of Highlands Groundwater Monitoring Program.

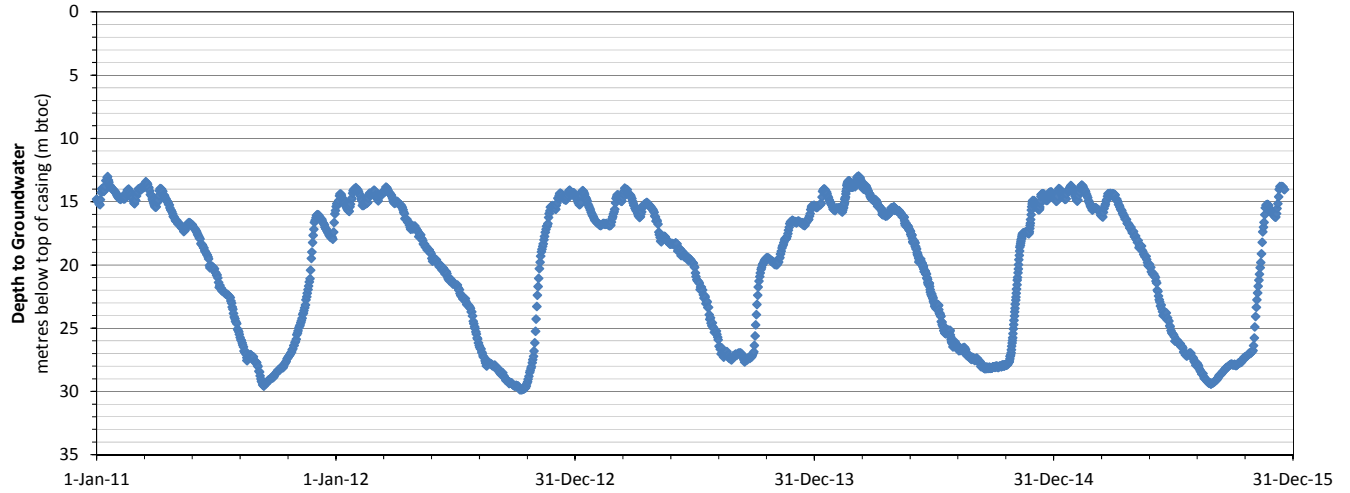
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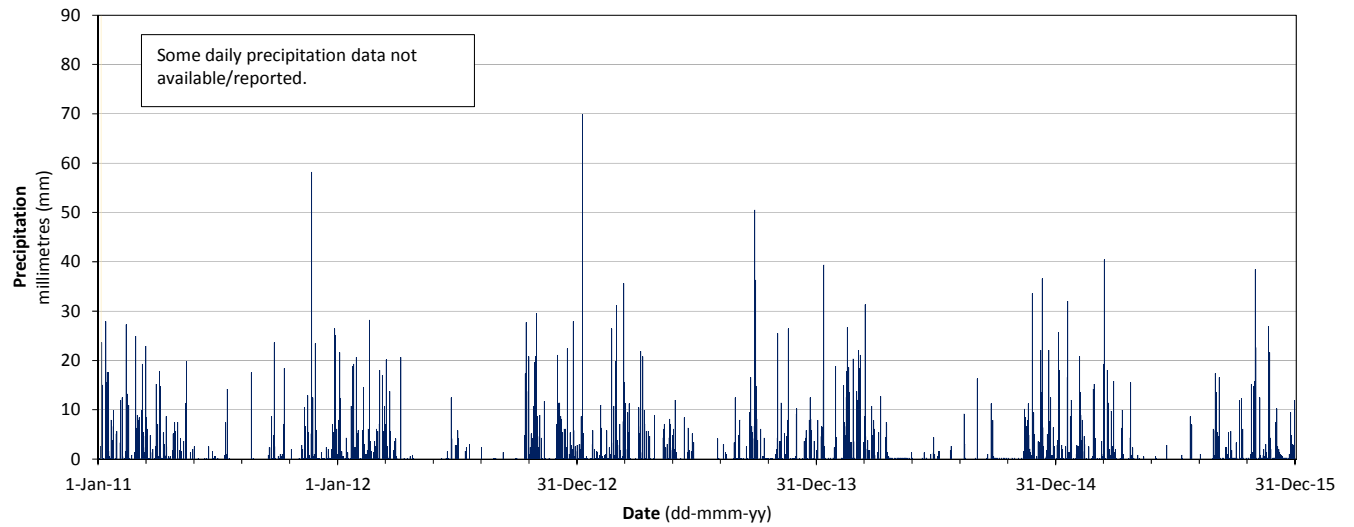


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**District of Highlands Monitoring Well DOH-02A**



**West Highlands District Firehall Weather Station**



**Notes**

Water level data collected under the District of Highlands Groundwater Monitoring Program.

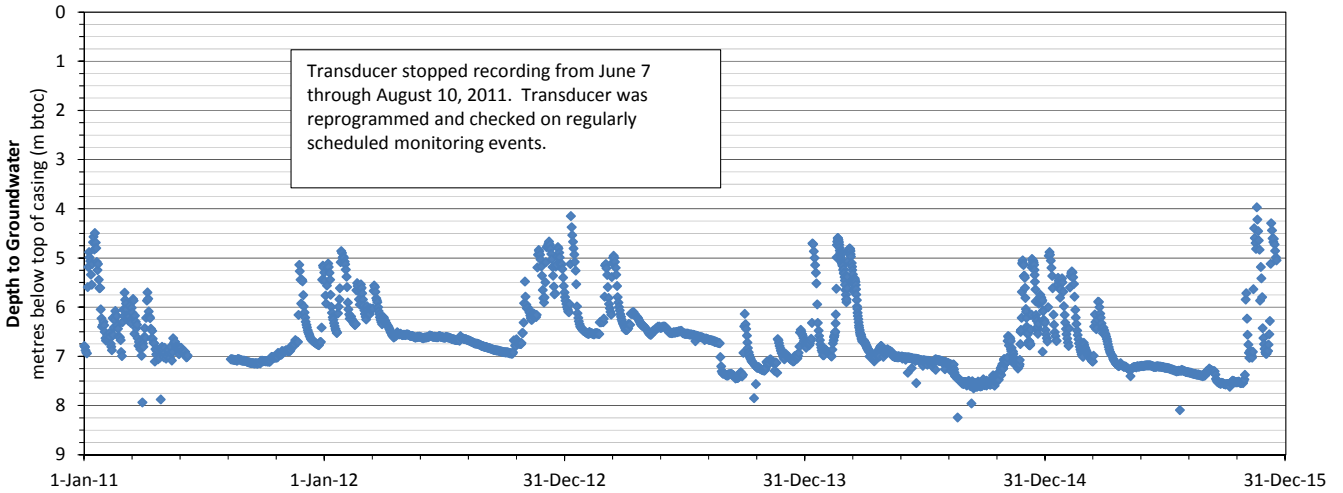
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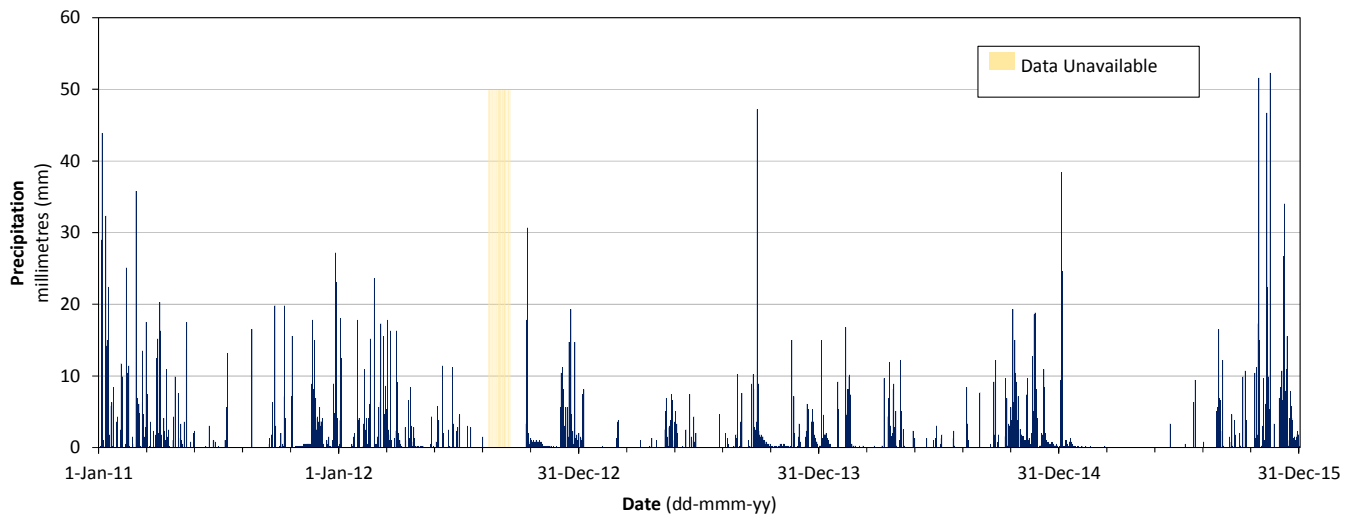
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**District of Highlands Monitoring Well DOH-03**



**District of Highlands Office Weather Station**



**Notes**

Water level data collected under the District of Highlands Groundwater Monitoring Program.

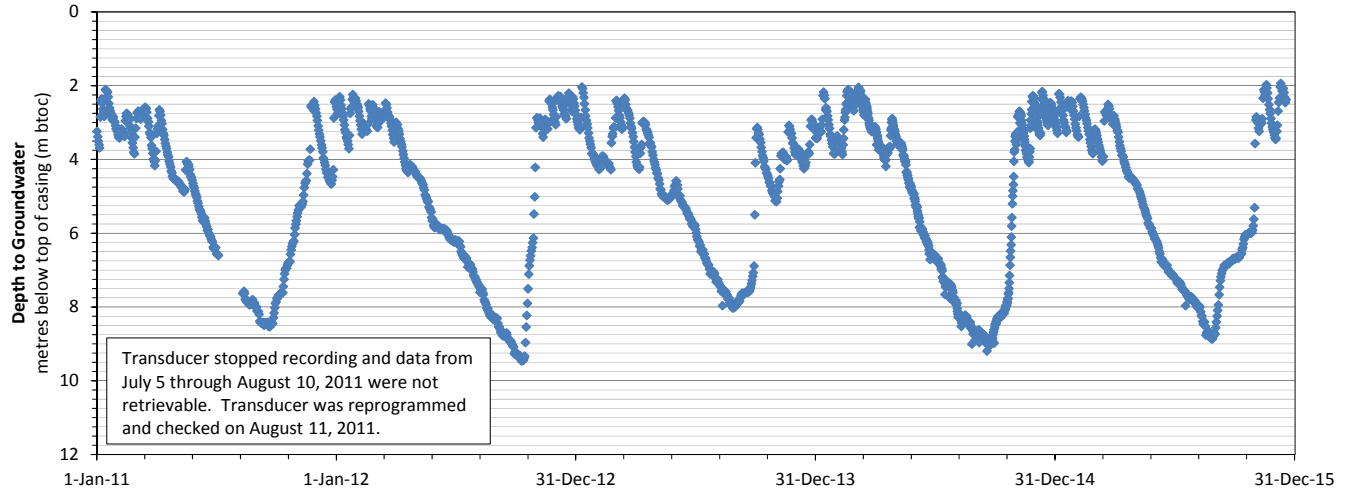
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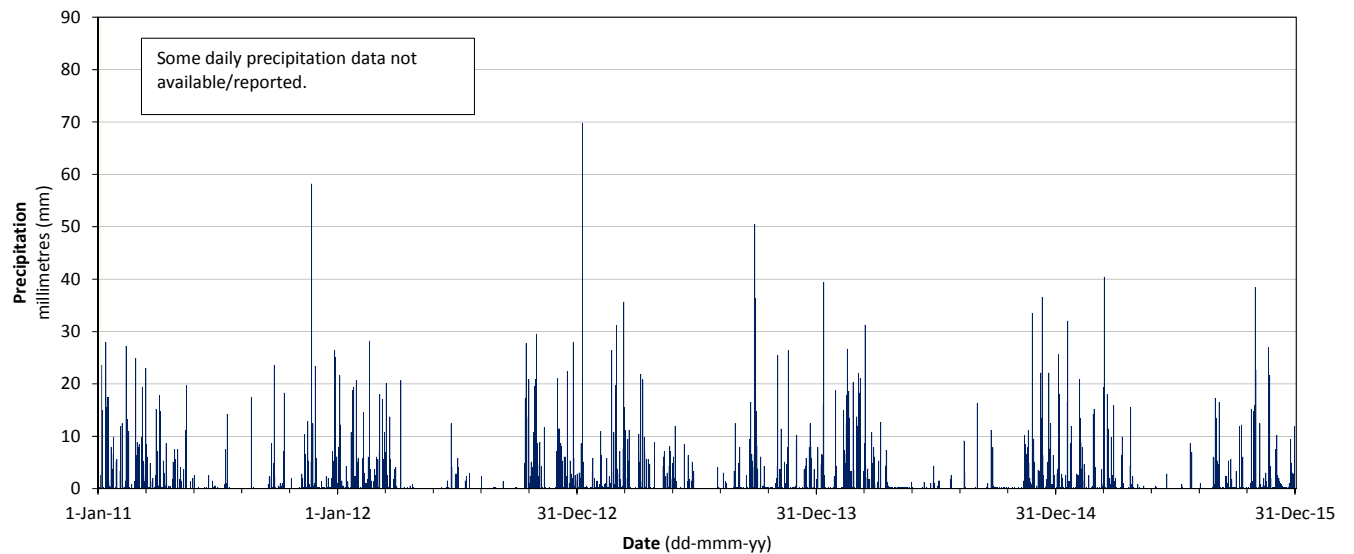


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**District of Highlands Monitoring Well DOH-04B**



**West Highlands District Firehall Weather Station**



**NOTES**

Water level data collected under the District of Highlands Groundwater Monitoring Program.

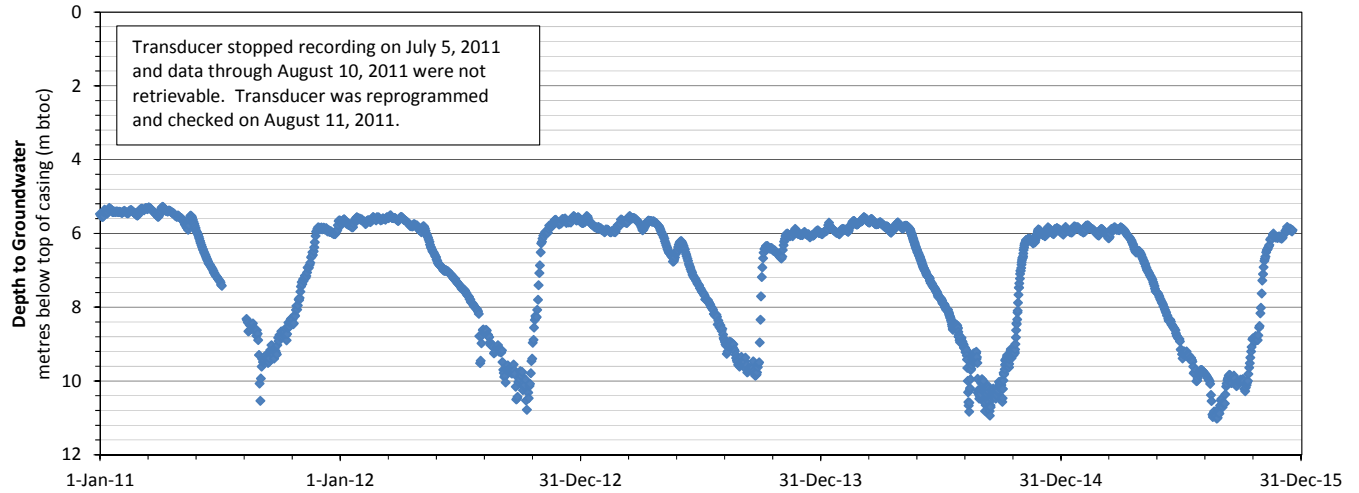
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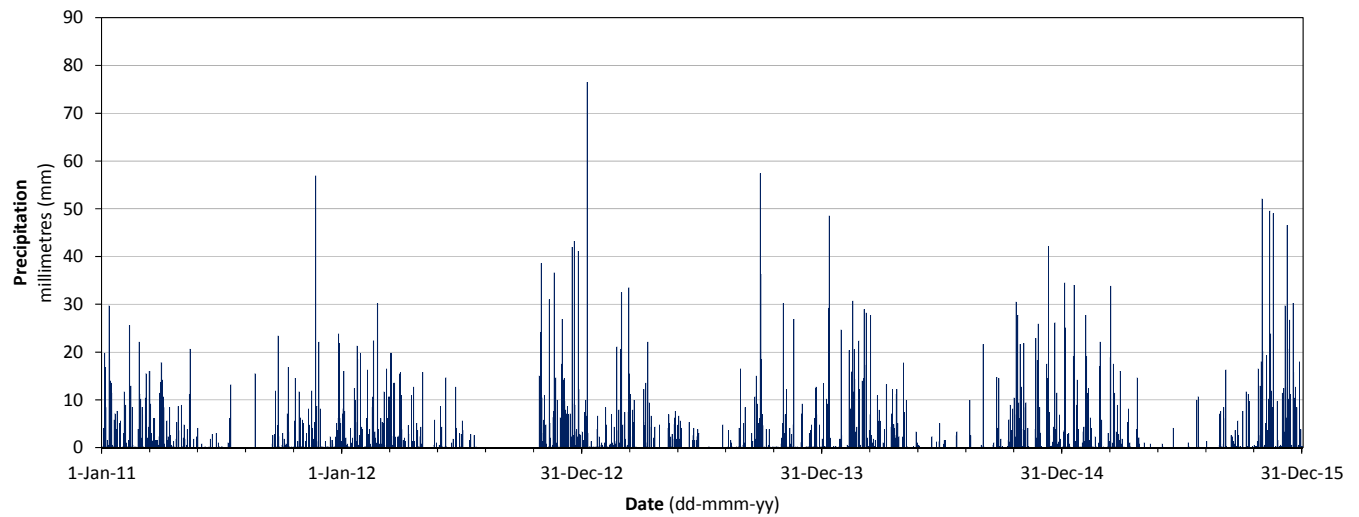
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**District of Highlands Monitoring Well DOH-07B**



**Calle Revelle Nature Sanctuary Weather Station**



**Notes**

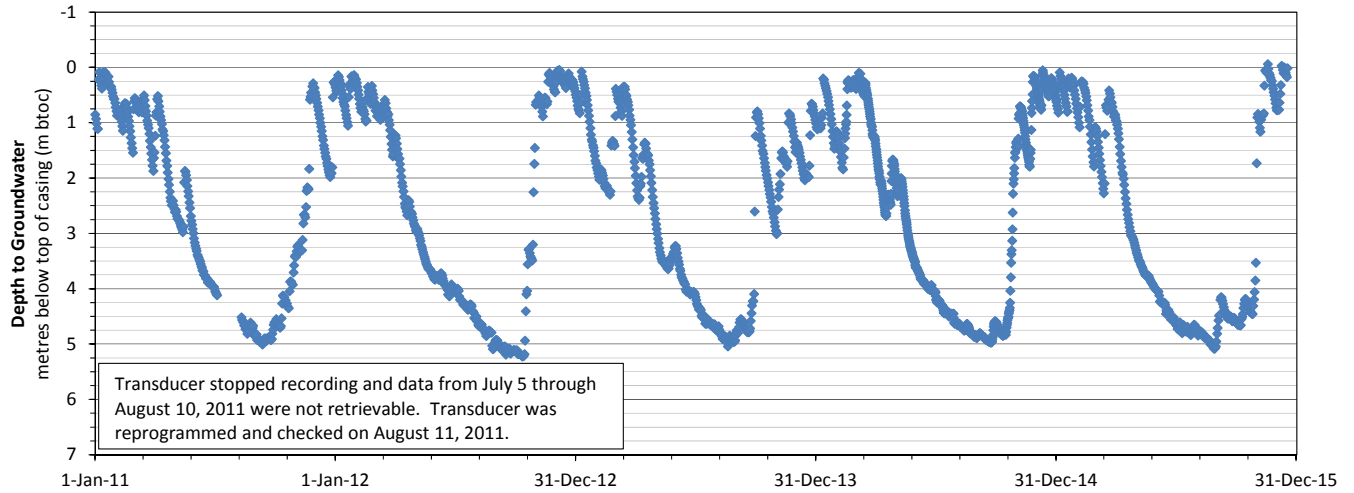
Water level data collected under the District of Highlands Groundwater Monitoring Program.

Precipitation data obtained online from the University of Victoria School-Based Weather Station Network.  
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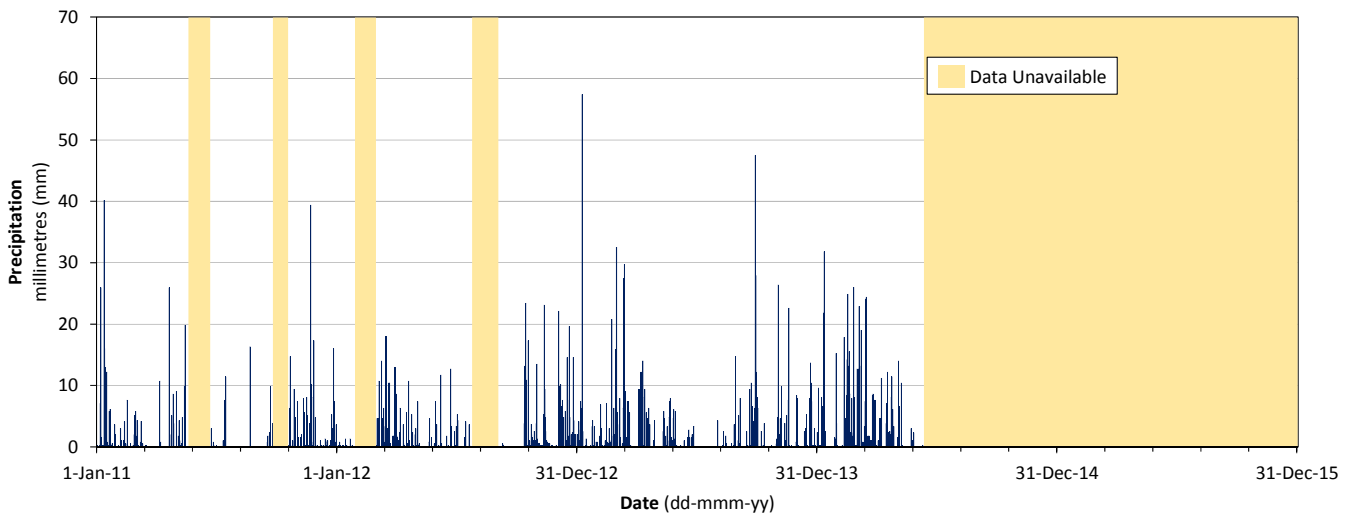
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REVIEW	JPS	15OCT28		

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**District of Highlands Monitoring Well DOH-09A**



**East Highlands District Firehall Weather Station**



**Notes**

Water level data collected under the District of Highlands Groundwater Monitoring Program.

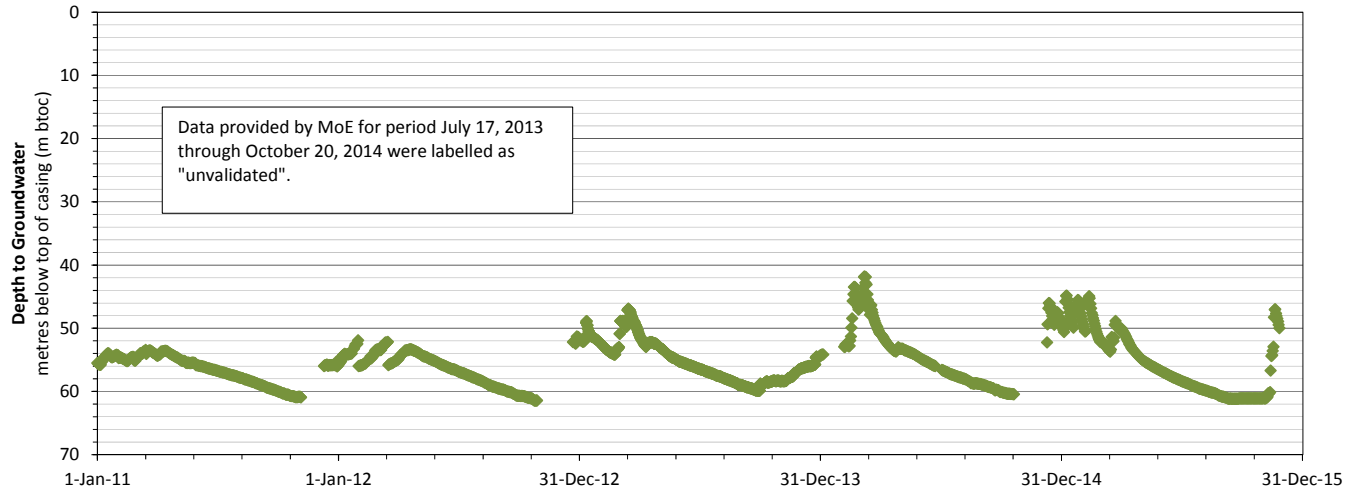
Precipitation data obtained online from the University of Victoria School-Based Weather Station Network.  
<http://www.victoriaweather.ca/>

PROJECT		<b>DISTRICT OF HIGHLANDS 2015 GROUNDWATER MONITORING PROGRAM HIGHLANDS, BC</b>		
TITLE		<b>DEPTH TO GROUNDWATER MONITORING WELL DOH-09A AND PRECIPITATION IN EASTERN HIGHLANDS</b>		
PROJECT No.		13-1435-0010	FILE No. ----	
DESIGN	CB	14NOV06	SCALE	NTS REV.
CADD	CB	15JAN16	<b>FIGURE 7</b>	
CHECK	MAB	15OCT28		
REVIEW	JPS	15OCT28		

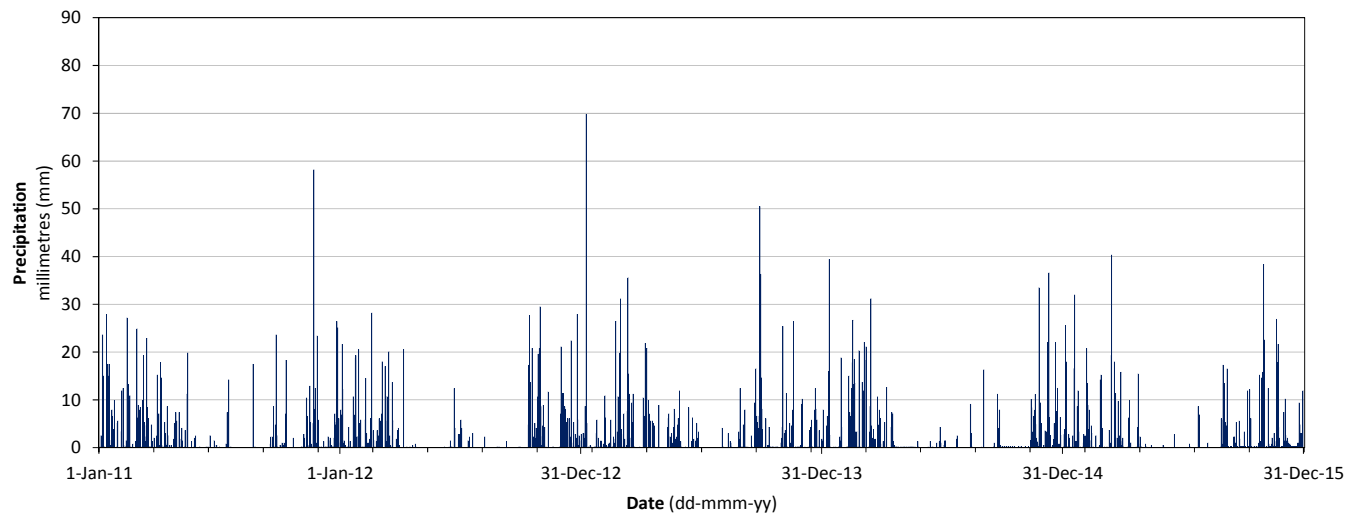


REVISION DATE: BY: FILE:

**BC Ministry of Environment Observation Well No. 372**



**West Highlands District Firehall Weather Station**



**Notes**

Water level data obtained online from the Ministry of Environment British Columbia Groundwater Observation Network.  
[http://www.env.gov.bc.ca/wsd/data\\_searches/obsWell/map/obsWells.html](http://www.env.gov.bc.ca/wsd/data_searches/obsWell/map/obsWells.html)

Precipitation data obtained online from the University of Victoria School-Based Weather Station Network.  
<http://www.victoriaweather.ca/>

PROJECT		<b>DISTRICT OF HIGHLANDS 2015 GROUNDWATER MONITORING PROGRAM HIGHLANDS, BC</b>		
TITLE		<b>DEPTH TO GROUNDWATER MOE OBSERVATION WELL 372 AND PRECIPITATION IN WESTERN HIGHLANDS</b>		
PROJECT No.		13-1435-0010	FILE No. ----	
DESIGN	CB	14NOV06	SCALE	NTS REV.
CADD	CB	15JAN16	<b>FIGURE 8</b>	
CHECK	MAB	15OCT28		
REVIEW	JPS	15OCT28		

