Groundwater Source Supply Assessment

FINAL

KGS Group 15-0122-001
March 2015

Prepared By

John Little, P.Geo
Hydrogeologist

Michael P. Smith, M.Sc. P.Geo.
Hydrogeologist

Approved By

Rob Sinclair, P.Eng.
Manager Environmental Services

KGS Group
Winnipeg, Manitoba

KGS GROUP CONSULTING ENGINEERS

Kontzamanis Graumann Smith MacMillan Inc.

3rd Floor
865 Waverley Street
Winnipeg,
Manitoba
R3T 5P4
204.896.1209
fax: 204.896.0754
www.kgsgroup.com

March 30, 2015 File No. 15-0122-001

City of Brandon
108-26th Street North
Brandon, Manitoba
R7B 1J6

ATTENTION: Ms. Alexia Stangherlin, P.Eng.
Deputy Director of Engineering Services & Water Resources
Development Services Division

RE: Groundwater Source Supply Assessment
Final Report

Dear Ms. Stangherlin:

Please find attached three (3) hard copies plus one (1) electronic copy of the Groundwater Source Supply Assessment for the City of Brandon. We have also submitted four (4) hard copies plus one (1) electronic copy of the report to Mr. Rob Matthews, P.Geo., Manager Manitoba Conservation Water Use Licensing Section on your behalf.

Completion of this report is in partial fulfillment of the requirements outlined in the letter you received from Mr. Rob Matthews, P.Geo., dated November 14, 2014, requiring a hydrogeological assessment to be completed to assess long term water level trends in the local aquifer in the vicinity of the Brandon Municipal Emergency Supply Wells and beyond.

We appreciate the opportunity to provide engineering services to the City of Brandon

Yours truly,

Rob Sinclair, P. Eng.
Manager Environmental Services

MPS/jr

EXECUTIVE SUMMARY

In response to your request, Kontzamanis, Graumann, Smith Macmillan Inc. (KGS Group) has prepared this Groundwater Source Supply Assessment report in support in fulfilling the licensing requirements of the Water Use Licensing Section, Manitoba Conservation and Water Stewardship, pursuant to the City of Brandon's (the City) authorization for withdrawal of groundwater from the Assiniboine River Valley Aquifer (ARVA) on a non-emergency basis.

The City maintains two high capacity emergency supply wells along the Assiniboine River Valley west of 18th Street North - one well is located at the Canada Games Park and the other well is located at The Turtle Crossing Park. The wells were completed in January and February 1996 in order to provide the City with a short-term emergency backup source of water supply in the event the City's main Assiniboine River source becomes temporarily interrupted, such as from a toxic spill into the river upstream from the intake. Prior to 2011, the wells had not been used since they were installed, other than for testing purposes to confirm aquifer and well capacity and operational readiness. The City expressed a desire to use the wells periodically for blending purposes during the spring runoff period, when the river water is cold and turbid with elevated suspended solids, and at times during the summer if the river water becomes turbid or the water quality is poor from elevated organic carbon. A temporary authorization to use the emergency wells for blending purposes was provided by Manitoba Conservation and Water Stewardship.

Except for 2011 when 2,049 cubic decametres of water was withdrawn due to concerns with flooding, the City's annual withdrawals have been in compliance with the regulatory requirement to pump between 1,000 cubic decametres and 1,900 cubic decametres from the wells annually.

Results of the current assessment suggest the following:

- There appears to be a direct correlation between peak seasonal river elevation and peak water levels in both the Assiniboine River Valley Aquifer (ARVA) and the Brandon Channel Aquifer (BCA). As such, the aquifer water level fluctuations are likely primarily related to pressure changes exerted by the Assiniboine River on the aquifer with recharge into the aquifer being relatively minor.

- Pumping of the City Supply Wells since 2009 shows a noticeable effect on short term water level changes within the ARVA in wells located west of 1st Street North. Water level decreases are observed in surrounding wells during pumping events, with recovery after pumping stops.

- There is no evidence that pumping the City's wells has had any effect on water levels in either the ARVA or the BCA east of 1st Street North for the full record of monitoring starting in 1996. This is obviously very important in terms of assessing local groundwater impacts noted below.

- There is a long-term trend of declining water levels evident on the provincial government observation well hydrographs completed in both the BCA and the ARVA, which may have begun prior to 1996 and continuing at present. Given this long term trend, this decrease would not be the result of any City groundwater blending programs as it starts well before City groundwater withdrawals commencing in 2011.

- The rate of water level decline observed in the hydrographs has not remained steady since 1996 a rate shift has occurred during the 2004 / 2005 period, which is unaccounted for. The rate of decline differs before and after this period of time, in both aquifers, to the west and to the east of 1st Street North. To the west, the rate of decline after 2005 appears to have increased whereas to the east, the rate of decline appears to be similar for some wells and to have decreased for others. This change in the rate of decline after 2005 predates the City's test pumping the wells that began in 2009 and therefore would not be the result of any City groundwater pumping and blending program.

- Fluctuations in water levels at observation wells near the Canada Games Park pumping well and towards the west, due to pumping effects and river flood events, have made it difficult to determine whether an increase in rate of water level decline due to blending is observed between pre-blending prior to 2011 and post blending afterwards. A longer term period of groundwater level monitoring during future withdrawals by the City would assist in determining whether a shift has occurred in the area of the supply wells.

- It is understood that the City would be comfortable with a two week supply from the Emergency Supply Wells in the event of an emergency. Previous studies estimated that a 4,000 USgpm Emergency withdrawal rate between the Canada Games Park and Turtle Crossing Park wells could be sustained on an emergency basis for between 2 weeks to 2 months, when the starting water level in the Canada Games Park well is approximately 13 m depth and the two supply wells could pumped at a combined rate.

- If a higher emergency combined pumping rate of 5,000 USgpm (315.5 L/s) is preferred, similar to current City non-emergency higher volume usage requirements, it is estimated that there would be very little if any reserve capacity in the wells at the low starting water level of 13 m, such that the pumping level would be drawn down to the pump intake in a few days or less, obvious a significant a concern for requiring 2 weeks of emergency use.

- In order to obtain 2 weeks of pumping capacity at the higher 5,000 USgpm rate, it is estimated that the starting pumping level would have to be no less than approximately 9 m below the pump motor base in the Canada Games Park well, which would leave minimal pumping capacity for ongoing blending purposes. It is understood that this would be undesirable as the City would like to retain the emergency pumping capability of the wells while still pumping them for ongoing blending purposes.

- It would improve the pumping sustainability of the wells for both emergency and blending supply if the City could call for water conservation and rationing during a loss of river supply such that the pumping withdrawals from the wells could be optimized. A mandatory city wide reduction in water use during an emergency situation could allow a lower emergency rate, closer or lower than 4,000 USgpm (252.3 L/s) to be utilized, resulting in an increased safety factor for emergency and blending supply availability.

- Long term gradual decreasing levels have been observed for many of the aquifer monitoring wells in the area, with this decrease independent of City groundwater withdrawal. If a long term gradual decrease in the ARVA aquifer continues into the future, a loss of pumping capacity in the City wells will be realized. A point may be

reached where water withdrawal for either blending or emergency use may be at significantly lower levels then require and may not be viable at all. Long term detailed monitoring of the aquifer and water levels/decreases over time would be important to further address this potential concern for the area as a whole.

Recommendations of this report include the following:

- Request to Water Use Licencing Section of Manitoba Water Stewardship Division to continue temporary authorization for the City of Brandon for an additional 5 to 10 year period.

- Due to a lack of a well-defined (recent) water level drawdown trends in the aquifer west of 18st Street North, it is recommended that another review of water levels and the City's pumping data be carried out in 5 years, after more complete long-term data base is acquired.

- During any future extended authorization period that may be issued, the City must continue to monitor water levels and water temperatures at MW4 and in the Canada Games Park well from the pressure transducers. The accuracy of the pressure transducer readings should be checked with manual readings on a routine basis. In addition, a factory calibration may be warranted to confirm accuracy of both temperature and pressure readings.

- The City's current authorization to pump the wells for non-emergency use requires the City to withdrawal a minimum of 1,000 cubic decametres annually. This limit has proved to be somewhat difficult to fulfil because this volume of water is not always required for blending in the water treatment process. It is understood that the City would prefer to be free to pump as little water as required, but to retain the upper limit of 1,900 cubic decametres annually. This licence change would allow the City to operate the wells more efficiently and conserve water for future use. Also, being able to pump at higher rates for longer periods when required provides better hydrogeologic data than a series of low capacity tests.

- The elevation of the pump motor bases in both the Canada Games Park well and the Turtle Crossing Park well should be surveyed as well as the ground elevation and top of casing of MW4. This will allow direct comparison of water elevations in these two wells with other provincial monitoring wells in the area and facilitate decisions related to raising the well casing for the two wells are well above maximum flood levels.

- There would be benefit for the City to carry out a full scale pumping test of the wells at a rate of 5,000 USgpm (315.5 L/s) when the water level in the Canada Games Park well is at or above 9.0 m depth to determine the potential for emergency pumping at the higher rate. If this test is conducted, there may be, however, short term concerns with groundwater availability for local domestic wells in the area during the pump test and immediately after the test is completed with additional potential implications on water Emergency supply availability for the recovery period, which may last a few months.

- It is recommended that the City consider a review of their master plan to determine if a form of water rationing, a water conservation bylaw, or public education could be

implemented that would specifically address an emergency loss on the river supply source. The pumping capacity of the wells is greatly reduced as the combined pumping rate increases above 3,000 USgpm (189.3 L/s). A reduced emergency requirement may allow a longer term combination of groundwater withdrawal for blending purposes, without negatively affecting a two week Emergency Supply requirement.

- It is recommended that pressure transducers be installed in the Turtle Crossing Park Well as well as the City's monitoring well that is located in the approach to the TransCanada Highway bridge over the river, 10 km west of the City. The purpose of the transducer installation near the TransCanada highway would be to monitor aquifer levels closer to the area where the aquifer begins in order to gain a better understanding of water level trends and pumping responses along the full length of the aquifer west of 18th Street North.

TABLE OF CONTENTS

PAGE

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

1.0 INTRODUCTION

In response to your request, Kontzamanis, Graumann, Smith Macmillan Inc. (KGS Group) has prepared this Groundwater Source Supply Assessment report in support in fulfilling the licensing requirements of the Water Use Licensing Section, Manitoba Conservation and Water Stewardship, pursuant to the City of Brandon's (the City) authorization for withdrawal of groundwater from the Assiniboine River Valley Aquifer (ARVA) on a non-emergency basis. The City was granted temporary authorization to continue withdrawing groundwater from the ARVA for blending purposes with Assiniboine River water on a non-emergency basis (letter dated November 14, 2014 from Robert Matthews, P.Geo., Manager, Water Use Licensing Section – Appendix A). This authorization is set to expire on May 31, 2015. Confirmation on continued use of groundwater for blending purposes past this date required the City to retain the services of a Hydrogeologist, registered with the Association of Professional Engineers and Geoscientists of Manitoba (APEGM), to assess the long-term water level and temperature trends in the aquifer both in the vicinity of the City's two supply wells and beyond.

KGS Group, in cooperation with Mr. John Little, P.Geo has prepared this report as an update to the 2011 Water Source Review report, prepared by KGS Group and the 2013 Water Level Response Review report prepared by Mr. Little. It is recommended that the KGS Group March 2011 Water Source Review report be used as reference along with this present assessment in future pumping operations.

2.0 BACKGROUND INFORMATION

A complete background summary was included in the 2013 Water Level Response Review and has been updated in this report. The City maintains two high capacity emergency supply wells along the Assiniboine River Valley west of 18th Street North - one well is located at the Canada Games Park and the other well is located at The Turtle Crossing Park (Figure 1). The wells were completed in January and February 1996 in order to provide the City with a short-term emergency backup source of water supply in the event the City's main Assiniboine River source becomes temporarily interrupted, such as from a toxic spill into the river upstream from the intake.

Prior to 2011, the wells had not been used since they were installed, other than for testing purposes to confirm aquifer and well capacity and operational readiness. The City expressed a desire to use the wells periodically for blending purposes during the spring runoff period, when the river water is cold and turbid, and at times during the summer if the river water becomes turbid or the water quality is poor from elevated organic carbon.

Aquifer Characteristics - The high capacity wells are constructed in a basal sand and gravel aquifer located in the Assiniboine River Valley, referred to as the Assiniboine River Valley Aquifer (ARVA). The aquifer is capped by approximately 13.7 to 14.3 metres (45 to 47 feet) of clay and 3 to 10 metres (10 to 30 feet) of alluvial clay, silt and sand to surface. The aquifer begins approximately 11 km (7 miles) west of 18th Street North, where the Little Saskatchewan River enters the Assiniboine River Valley, and extends east of the City.

For reference, a second aquifer, the Brandon Channel Aquifer (BCA) is present in the Brandon area. The BCA is a deeper sand and gravel aquifer, and is separated from the ARVA by a clayey till unit. The BCA is generally located immediately east of Brandon and is the primary aquifer for industrial groundwater users in the area. The City of Brandon wells do not extend into the lower BCA.

Benefits of Blending Groundwater with Surface Water - Since 2011, the use of blended water from a combined Assiniboine River surface water and ARVA groundwater source has

been highly beneficial to the City for Water Treatment operations. It is understood that blending allows:

- A reduction in the volume of chemicals required to soften water for potable use, further resulting in a decrease in the volume of sludge produced;
- A reduction in coagulation chemicals required for turbidity removal and better process control;
- Elimination of potassium permanganate use when blending;
- Reducing the amount of activated carbon required for taste and odour control;
- Reduced UV irradiation for disinfection requirements.

Supply Well Groundwater Withdrawal – Through pumping tests and blending, the City has pumped the following volumes of groundwater annually from its wells since 2009:

- 2009 – 521 megalitres;
- 2010 – 742 megalitres;
- 2011 – 2,049 megalitres;
- 2012 – 1,899 megalitres;
- 2013 – 1,552 megalitres;
- 2014 – 1544 megalitres.

Even though the City's emergency supply wells were installed in January and February 1996, the City did not begin pumping the wells aggressively until the spring of 2011. This use was coincidental to an historic flood event on the river and it is understood that more water was probably pumped for flood mitigating efforts and regulatory requirements than would generally be needed for blending purposes. At the time of the flood, surface water was observed near the Canada Games Park well. Although it was not believed that there was a connection between the observed surface water and the aquifer, the well was pumped by the City as a precautionary measure.

Water has been pumped exclusively from the Canada Games well since blending began in 2011, except for some minor pumping from the Turtle Crossing well in September 2013.

2009 to 2010 Source Assessment - In 2009 to 2010, KGS Group carried out a Water Source Review assessment that included pump testing the supply. The scope of the assessment included: determining the yield characteristics of the wells; establishing an operating criteria for each well; assessing the sustainability of the aquifer for future planned withdrawals; and identifying potential third party water level drawdown impacts from the planned withdrawals.

The KGS Group assessment found that the maximum discharge rate of the Canada Games Park well was approximately 3,300 USgpm (208.2 L/s) and the maximum discharge rate of the Turtle Crossing Park well was approximately 3,200 USgpm (201.9 L/s). The report recommended the maximum discharge rate from each well be restricted to 3,000 USgpm (189.2 L/s). The report also recommended that the Canada Games Park well should be utilized as the lead well in all pumping operations. If both supply wells were to be pumped together, at a combined withdrawal rate of 4,000 USgpm (252.3 L/s), the pumping rate ratio should be 60% capacity from the Canada Games Park well (2,400 USgpm or 151.4 L/s) and 40% capacity from the Turtle Crossing Park well (1,600 USgpm or 100.9 L/s), in order to achieve maximum drawdown efficiency between the wells.

Aquifer Recovery after Pumping - The KGS Group assessment also found that once the aquifer had been drawn down after major pumping events earlier in the year it was typically slow to recover during the winter months, and during the winters of 2009/2010 and 2010/2011 the rate of recovery of the aquifer was estimated to be in the range of 600 USgpm (37.9 L/s) and 1,500 USgpm (94.6 L/s) respectively. Winter recharge of the aquifer occurs at a time when the level and flow in the Assiniboine River is typically at a low level and there is no other source of surface water available to enter the aquifer other than the river through the overlying clay and silt.

The assessment found that a rapid melt of a heavy snowpack and/or large amounts of spring and summer rainfall augmented recharge to the aquifer and increased the amount of water that could be withdrawn during the year. These spring recharge observations raised the possibility of secondary recharge pathways to the aquifer via “windows” through the sediments along the base of the valley slopes. One potential such “window” was identified in the KGS Group report as being approximately 0.8 km (0.5 mile) west of the entrance road to the Turtle Crossing Park along the Grand Valley Road, where 5 private wells are directly affected by the City’s pumping.

Area Well Network - The provincial government maintains 3 water level observation wells in the ARVA along the Assiniboine River Valley west of 1st Street North and one well east of 1st Street North. The City monitors water levels in their own monitoring well MW4 located at the intersection of Grand Valley Road and the entrance road to the Turtle Crossing Park.

Pressure transducers were set as permanent installations in monitoring well MW4 on June 8, 2009 and in the Canada Games Park well on May 7, 2010 to monitor water levels and temperature in the aquifer.

There are 13 provincial government permanent observation wells in the Assiniboine River Valley and beyond that were used for this review. Four monitor water levels in the ARVA, one monitors water levels in the alluvial aquifer of the valley and the remainder monitor water levels in the lower BCA. These wells are located from west of 18th Street North to east of the City bypass route and both in the valley and south of the valley. The wells are located as follows (from west to east in the valley) – MH141, 142, 134, 143, (1st Street North), 144, 146, 139, 137, 136, and (south of the valley) – MH138 (Koch well field), 133, 148 and 151. Figure 01 shows the location of all the observation wells. Well MH142 is completed within alluvial deposits and not in the ARVA. Only MH142, 134, 143, 144 and the City's MW4 are completed in the ARVA. Observation wells MH138 and 151 are located at the Koch Fertilizer and Canexus plant sites and 133 and 148 are located between these plants. Except for MH146 and MW4, the period of record for all the wells dates from early 1996 to the present.

3.0 DATA PRESENTATION

Groundwater level hydrographs were prepared from data obtained at 13 provincial government observation wells located in the ARVA, the BCA, and in the shallow alluvial deposits of the Assiniboine River Valley west of 18th Street North. Two additional hydrographs were prepared for the City's pressure transducers in monitoring well MW4 and the Canada Games Park well Hydrographs have been prepared for all of these observation wells and are included in Appendix B - Figures B-1 to B-15. The only observation wells that are completed in the ARVA are MH142, 134, 143, 144 and MW4. Except for MH141, which is completed in the shallow alluvial deposits of the Assiniboine River, the other observation wells are completed in the deeper BCA.

Temperature data from the City's two pressure transducers is plotted on the groundwater level hydrographs for the Canada Games Park well and MW4. Figures B-1 to B-15 also includes stream flow hydrographs for the Assiniboine River (flow and elevation) as well as pumping data from the City's wells.

Both the KGS Group 2011 technical report, which analyzed the 2009 and 2010 pumping tests along with the 2013 Water Level Response Review report prepared by Mr. Little supported the current analysis of the local water level response in the ARVA to the City's pumping between 2009 and 2013.

4.0 RESULTS AND DISCUSSION

Based on a review of the long-term water level data for both the ARVA and the BCA, and the technical reports, the following observations are presented.

4.1 EFFECT OF BRANDON PUMPING ON SHORT TERM WATER LEVEL VARIATIONS

Pumping of the City Supply Wells since 2009 shows a noticeable effect on short term water level changes within the ARVA in wells located west of 1st Street North, in contrast to no noticeable effect on water levels in either the ARVA or the BCA east of 1st Street North.

Water elevation data collected from the monitoring well MW4 and Provincial Wells MH134 and MH142, and MH143 (Appendix B – Figures B-2, B-4 B-12 and B-13 respectively) show short term effects of pumping at the Canada Games Park City supply well. MW4 and MH142 are located approximately 2 km and 4.5 km west of the City supply well respectively, MW134 is located adjacent to the pumping well and MW143 is located 1 km east. For example, in periods where groundwater withdrawal is occurring, such as between January and June 2013, a gradual decrease in water level at MW4 is observed. When the pumping rate is increased in May 2013, a further decrease in MW4 water level occurs. In the period between June and September 2013, when pumping has stopped, the water level at MW4 recovers (Figure B-2). A similar pattern is observed for other wells west of 1st Street as well.

In strong contrast, there is no indication on the provincial government observation well hydrographs for the ARVA and the BCA, east of 1st Street North that the City's pumping to date has created any drawdown in either aquifer. Wells MH144 and MW146 are considered to be of significant importance to gauge drawdown effects occurring to the east of the City's wells (east of 1st Street North). MH144 is located approximately 2.3 km due east of 1st Street North on Provincial Road 457 and is completed in the ARVA at a depth of 20 m. The thickness of the aquifer at this location is from 9 m to 29.5 m, with clay above and below. There are no observation wells completed in the ARVA east of MH144. MH146 is located directly south across the valley and is completed in the deeper BCA at a depth of 41 m. The thickness of the aquifer at this location is from 39.6 m to 42.7 m, with till above and below. No pumping effect is observed in the long term hydrographs for MH144 and MH146 (Figures B-12 and B-13). This is more clearly evident on the one-year hydrographs for 2010, 2011, and 2012 for wells MH144

and MH146 shown on Figures 2 to 7 respectively, which includes hydrograph comparison to pumping data from the City wells.

South of MH146 is Provincial Well MH138. This well intercepts the BCA aquifer and long term water level fluctuations would be influenced by the neighbouring commercial industries. An additional review of long term hydrograph for MH138 indicates no observed influence related to the Brandon water withdrawal since pumping events were conducted in 2009 and 2010 and blending began in 2011.

4.2 LONG TERM AQUIFER WATER LEVEL PATTERNS

There is a long-term trend of declining water levels, evident on all the provincial government observation well hydrographs completed in both the BCA and the ARVA, which may have begun prior to 1996 and continuing at present. This decrease appears to be independent of Brandon Pumping.

A decline in water levels is shown on the aquifer water level hydrographs in Appendix B - Figures B-1 to B-15. Table 1 summarizes the long term drawdown slope estimates for all of the provincial observation wells, showing negative values for almost all locations. It is noted that declines measured in wells within the ARVA have been observed consistently since recording began in 1996, well before Brandon started withdrawal of the aquifer for blending purposes.

The rate of decline at some wells including MH137, MH139, MH144 and MH151 appears to have remained quite steady both before and after the 2004 / 2005 period (Appendix B). Interestingly, since 2004/2005, the rate of decline in some wells further west of 1st Street North appears to have increased, while the rate of decline of some wells east of 1st Street North and has lessened. The decrease in decline rate observed east of MH144 is also strongly seen in the long term hydrograph for MH133, MH138, MH146 and MH148. A further investigation in the change and the 2004 / 2005 trend change is beyond the current scope of work and may warrant future assessment.

Overall in the area, it appears the BCA (and probably the ARVA as well but no data is available) is performing more favourably to the east than the ARVA to the west, and this trend predates the City's recent pumping activities. These water level trends were established prior to the 2009

and 2010 pumping tests being carried out and also predate the City's pumping in 2011. The City's pumping does not appear to have influenced the rate of long-term drawdown at wells east of 1st Street North such as MH143 and west at MH144 and MH146. The amount of water level decline in the ARVA recorded at MH144 between January 12, 1996 (353.96) and April 11, 2014 (350.06) was 3.9 m to a water level that was only 0.75 m above the top of the ARVA. MH146 is completed in the much deeper, and geologically different, BCA. The water level elevation on September 11, 1997 was 353.29 m and the lowest water level elevation recorded occurred on April 11, 2014 (same date as MH144 lowest water level) was 347.825 m. The total drawdown during this period was 5.47 m. This drawdown occurred without any interference from operation of the City wells, with no change of drawdown slope observed between pre and post withdrawal in 2011.

It should be noted that potential changes in aquifer level trends between pre and post withdrawal in 2011 is not as easily defined west of 1st Street North for a few reasons. Firstly, water level data is missing in 2012 and 2014 from MH134 and MH142, and between July 2013 and May 2014 in the Canada Games Park well. In addition, there has been significant fluctuations in water levels observed in MH134, MH142 and MW4 caused both by the City's pumping, which temporarily affects water levels during withdrawal, and the historic flood events of 2011 and 2014, which caused aquifer levels to peak relative to the long-term decreasing trend.

Despite this, water levels measured at MH134 (adjacent to the Canada Games Park Well) recovered well after shutdown of the blending withdrawal, to a level which corresponded to the overall gradual declining water level trend, suggesting seasonal withdrawal by the City may be sustainable in the short term. Further assessment of this area over the next number of years may assist in clarifying whether Brandon pumping has increased aquifer drawdown west of 1st Street North.

4.3 CORRELATION BETWEEN RIVER FLOW AND AQUIFER WATER LEVELS IN AREA WELLS

There appears to be a direct correlation between seasonal peak river flows (and peak river level elevation) and corresponding seasonal peak water levels in the ARVA as well as in some observation wells in the BCA suggesting a hydraulic connection and pressure effect on the aquifer.

River level and river flow data was obtained for the period January 1, 2002 to January 1, 2014 from a gauging station (05MH013) located where the TransCanada Highway crosses the Assiniboine River Valley approximately 10 km west of the City. Although the elevation measured at 05MH013 would be higher than immediately within Brandon, the pattern of increases and decreases, as well as the volume of flow observed would be representative of conditions through the City. The river level hydrograph that is included on the report Figures B-1 to B-15 shows a continuous long-term rise of river level of approximately 0.75 m since 2002, the beginning of the data collection for this station.

Water levels in both aquifers typically peak at the same time as river levels and decline from peak levels in direct relationship to river levels. As such, aquifer levels appear to be responding to changes in pressure exerted by increases and decreases in river level pressure on the confined aquifers, which accounts for a significant percentage of changes observed in water levels in the aquifers. This is related to the storage effect of confined aquifers (as compared to unconfined aquifers where void space between grains is being filled with water). The response indicates the two aquifers are hydraulically closely connected and also that the confining clay layer over the shallower ARVA is quite competent, such that significant recharge is not occurring though the river sediments. If water level increases corresponding to higher river levels and flow were a result of replenishment of the aquifer, it would be expected that the water level within the aquifer would stay higher for a longer period of time after river flows have decreased. Figure 26 of the 2011 KGS Group Water Source Review report (Appendix C) shows the very slow recovery period of the ARVA (3 to 5 months) after each major pumping event of 2009 and 2010, also suggesting a low interconnection. It is expected that these river and groundwater level connections are related to loading by the river with response in the aquifer but only very minor amounts of recharge water based on the artesian storativity number. Note that some observation wells, such as wells in the BCA near the local commercial facilities may

not show as clearly any natural affects due to localized long term groundwater withdrawal near these locations.

4.4 AQUIFER TEMPERATURE AND GROUNDWATER WITHDRAWAL

Water temperature data has been collected in conjunction with water level data using transducers installed in the Canada Games Park supply well and monitoring well MW4. Temperature data is plotted on Figures B-1 and B-2, overlain with water levels in each of the wells.

Within the Canada Games Park Well, the temperature plot shows that when pumping starts, the water level declines and the temperature increases slightly and when pumping stops the water level recovers and the temperature decreases slightly.

An increase in temperature observed in the groundwater during pumping events may suggest a warmer source of water such as a river during summer periods. However in this case, the changes in temperature which are quite minor (+/- 0.2ºC) are likely the result of a sensor effect on the transducer probe, and not representing influx of river water into the aquifer. This latter possibility is supported by the understanding that the river connection to the aquifer is limited, with long term recharge timeframes and that fluctuations during pumping events would imply a strong direct connection, not supported by other locations. In addition, it would be expected that if the water temperature variations observed were due to a connection to the river that a difference between summer river temperature and winter river temperature would be noticed, which is not the case.

The water temperature at monitoring well MW4 has remained quite steady since June of 2009. The initial temperature was 6.13 ^{o}C and the temperature recorded in January 2015 was 6.43 ^{o}C. The water temperature showed the greatest rise at the time of the flood of 2011 and groundwater blending by the City.

This increase is not believed to be associated with groundwater withdrawal by the City. The location of MW4 is located on the opposite side of the river from the Canada Games pumping well, which does not support a higher water temperature river source being drawn into the well. The increase is also not believed to be related to the 2011 flood event as the water temperature

has stayed higher post flood and not returned to the original insitu ground temperature, which would have been expected after four years. It is likely the change in temperature that occurred in 2011 may have been a calibration drift. The accuracy of the transducer should be verified by the manufacturer.

4.5 LONG TERM VIABILITY OF AQUIFER USE FOR BLENDING AND/OR EMERGENCY SUPPLY

The current temporary authorization requires that the City must pump a minimum of 1,000 cubic decametres per year but not more than 1,900 cubic decametres per year, which was requested in part to evoke a stress on the local aquifer to assist in determining the effect if any of this additional withdrawal on surrounding water rights users and the local aquifer. Based on review of long term hydrographs for wells in the area, it appears that the range outlined in the temporary authorization does not result in a noticeable effect in water levels east of 1st Street North and also does not result in an increase in the rate of overall aquifer water level decline seen in the area since groundwater monitoring began in 1996. Short term influence during pumping can be seen in wells west of 1st Street North, however even then, it appears that the groundwater blending program has not resulted in an increase in the long term rate of water level decline. This last observation requires further assessment to confirm, as higher variability in water levels due to combinations of pumping, or flood events make accurate predictions in long term trends more difficult to make.

Based on discussions with the City, it is understood that the City would be comfortable with a two week supply of water during an emergency situation. The plan in an emergency situation (water in the Assiniboine River was unavailable due to a spill etc.) would be to withdrawal 100% of the required water from the ARVA for that two week period.

The distance to the top of the pump bowls in the Canada Games Park well is estimated to be approximately 17 m depth. It was previously estimated in 2011 that a 4,000 USgpm (252.3 L/s) withdrawal rate could be sustained on an emergency basis for between 2 weeks to 2 months, when the starting water level in the well (and aquifer) is approximately 13 m depth and the two supply wells at a combined rate. The period in which emergency pumping could occur at this rate would depend on the aquifer conditions leading up to the emergency pumping event. As previously mentioned in the December 2013 Water Level Response Review report, trying to

estimate the duration that the wells can be pumped during an emergency situation is a difficult task, and even more so when the water level in the aquifer is depressed. This is because the monitoring data suggests that the amount of water available from the aquifer varies according to such things as the level of the river and the amount of precipitation that has been received recently in the immediate area.

At current use, the City generally requires between 20 megalitres and 29 megalitres of raw water per day through a combination of Assiniboine River and groundwater withdrawal. These volumes equate to an average daily rates of 3,700 USgpm (233.4 L/s) and 5,300 USgpm (334.4 L/s) respectively. The KGS Group 2010 pumping tests showed that the pumping sustainability of the wells is greatly reduced at pumping rates of 4,000 USgpm and higher. If the city wanted a higher emergency combined pumping rate of 5,000 USgpm (315.5 L/s) to be similar to current City non emergency usage requirements, it is estimated that there would be very little if any reserve capacity in the wells at the low starting water level of 13 m, such that the pumping level would be drawn down to the pump intake in a few days or less, a concern for emergency use.

In order to obtain 2 weeks of pumping capacity at the higher 5,000 USgpm rate, it is estimated that the starting pumping level would have to be no less than approximately 9 m below the pump motor base in the Canada Games Park well. If this is preferred, then a trade-off is required with minimal pumping capacity for ongoing blending purposes. It is understood that this would be undesirable as the City would like to retain the emergency pumping capability of the wells while still pumping them for ongoing blending purposes.

Regardless, a full scale pumping test from a starting water level of approximately 9 m will be required to confirm how the aquifer will respond to pumping at 5,000 USgpm (315 L/s). There are 5 nearby private wells that based on past pump testing would be impacted by such a test and will have to be supplied with trucked in water (full discussion in the KGS 2010 report). The test would have to be completed during summer for this reason. The City's Groundwater Interference Complaint Response Plan will have to be implemented, which provides for such contingencies. These residents could potentially be without water for some time after the test is complete due to the slow recovery of the aquifer after a major pumping event. Also, it is possible the City's wells might not be available for use as an emergency supply for several months after

the pumping test. The observed impacts of conducting such a test may outweigh the information gained.

Due to the fact the drawdown in the wells increases appreciably at combined pumping rates above 3,000 USgpm (189.3 L/s), it would improve the pumping sustainability of the wells if the City could call for water conservation and rationing during a loss of river supply such that the pumping withdrawals from the wells could be optimized. A mandatory city wide reduction in water use during an emergency situation could allow a lower emergency rate, below 4,000 USgpm (252.3 L/s) to be potentially reached, resulting in an increased safety factor for supply availability.

In spite of the above considerations, long term gradual decreasing levels have been observed for many of the aquifer monitoring wells in the area, with this decrease independent of City groundwater withdrawal. Decreases were observed long before the 2009 and 2010 pump tests were conducted and 2011 blending program was initiated.

If a long term gradual decrease in the ARVA aquifer continues into the future, a loss of pumping capacity in the City wells will be realized because the amount of available drawdown from the static water level to the pump intake is reduced over time. A point may be reached where water withdrawal for either blending or emergency may be significantly reduced or potentially not viable at all. Water levels in the aquifer during the fall of 2014 were near 1997 high levels but could return to the long term trend line within a short period of time once pumping begins again in 2015. Long term detailed monitoring of the aquifer water levels over time would be important to further address this potential concern for the area as a whole.

5.0 CONCLUSIONS

The KGS Group pumping tests that took place in 2009 and 2010 provided important information on which to base the operation of the City's emergency supply wells. Monitoring of water levels at pumping and area monitoring wells since that time, while the wells were being used for blending purposes, have provided additional information on the response of the ARVA to pumping.

Based on the current assessment, the following conclusions can be made:

1. Except for 2011 when 2,049 cubic decametres of water was withdrawn due to concerns with flooding, the City's annual withdrawals have been in compliance with the regulatory requirement to pump between 1,000 cubic decametres and 1,900 cubic decametres from the wells annually.

2. There appears to be a direct correlation between peak seasonal river elevation and peak water levels in both the ARVA and the BCA. In addition, water levels in the aquifers appear to decrease at about the same time and at a similar rate as river flows. As such, the aquifer water level fluctuations are likely primarily related to pressure changes exerted by the Assiniboine River on the aquifer with recharge into the aquifer being relatively minor. Past reports have suggested that some recharge does occur from the Assiniboine River, with recharge at a slower rate, so a combination of both pressure and recharge are likely observed.

3. Pumping of the City Supply Wells since 2009 shows a noticeable effect on short term water level changes within the ARVA in wells located west of 1st Street North. Water level decreases are observed in surrounding wells including MW4 and MH134, MW142 and MW143 during pumping events, with recovery after pumping stops.

4. There is no evidence that pumping the City's wells has had any effect on water levels in either the ARVA or the BCA east of 1st Street North, including MH144, MH146 and MH138 for the full record of monitoring starting in 1996.

5. There is a long-term trend of declining water levels evident on the provincial government observation well hydrographs completed in both the BCA and the ARVA, which may have begun prior to 1996 and continuing at present. Given this long term trend, this decrease would not be the result of any City groundwater blending programs as it starts well before City groundwater withdrawals commencing in 2011.

6. The rate of water level decline observed in the hydrographs (Item 5 above) has not remained steady since 1996 a rate shift has occurred during the 2004 / 2005 period, which is unaccounted for. The rate of decline differs before and after this period of time, in both aquifers, to the west and to the east of 1st Street North. To the west, the rate of decline after 2005 appears to have increased whereas to the east, the rate of decline appears to be similar for some wells and to have decreased for others. This change in

the rate of decline after 2005 predates the City's test pumping the wells that began in 2009 and therefore would not be the result of any City groundwater pumping and blending program.

7. Fluctuations in water levels at observation wells near the Canada Games Park pumping well (MH134) and towards the west (MW4 and MH142), due to pumping effects and river flood events, have made it difficult to determine whether an increase in rate of water level decline due to blending is observed between pre- blending prior to 2011 and post blending afterwards. A longer term period of groundwater level monitoring during future withdrawals by the City would assist in determining whether a shift has occurred in the area of the supply wells.

8. It is understood that the City would be comfortable with a two week supply from the Emergency Supply Wells in the event of an emergency. The plan in an emergency would be to withdrawal 100% of the required water for the City of Brandon from the ARVA for that two week period. Previous studies estimated that a 4,000 USgpm Emergency withdrawal rate between the Canada Games Park and Turtle Crossing Park wells could be sustained on an emergency basis for between 2 weeks to 2 months, when the starting water level in the Canada Games Park well is approximately 13 m depth and the two supply wells could pumped at a combined rate.

9. If a higher emergency combined pumping rate of 5,000 USgpm (315.5 L/s) is preferred, similar to current City non emergency higher volume usage requirements by the City, it is estimated that there would be very little if any reserve capacity in the wells at the low starting water level of 13 m, such that the pumping level would be drawn down to the pump intake in a few days or less, obviously a significant concern for requiring 2 weeks of emergency use. In order to obtain 2 weeks of pumping capacity at the higher 5,000 USgpm rate, it is estimated that the starting pumping level would have to be no less than approximately 9 m below the pump motor base in the Canada Games Park well. If this approach is preferred, then a trade-off is required with minimal pumping capacity for ongoing blending purposes. It is understood that this would be undesirable as the City would like to retain the emergency pumping capability of the wells while still pumping them for ongoing blending purposes.

10. Due to the fact the drawdown in the wells increases appreciably at combined pumping rates above 3,000 USgpm, it would improve the pumping sustainability of the wells for both emergency and blending supply if the City could call for water conservation and rationing during a loss of river supply such that the pumping withdrawals from the wells could be optimized. A mandatory city wide reduction in water use during an emergency situation could allow a lower emergency rate, closer to 4,000 USgpm (252.3 L/s) to be utilized, resulting in an increased safety factor for emergency and blending supply availability.

11. Long term gradual decreasing levels have been observed for many of the aquifer monitoring wells in the area, with this decrease independent of City groundwater withdrawal. If a long term gradual decrease in the ARVA aquifer continues into the future, a loss of pumping capacity in the City wells will be realized. A point may be reached where water withdrawal for either blending or emergency use may be at significantly lower levels than required and may not be viable at all. Long term detailed

monitoring of the aquifer and water levels/decreases over time would be important to further address this potential concern for the area as a whole.

6.0 RECOMMENDATIONS

Based on the current assessment, the following recommendations are provided:

1. KGS Group recommends a request is made to the Province that the temporary authorization for City of Brandon groundwater withdrawals be extended for an additional 5 to 10 year period, as long term hydrographs for well locations east of 1st street do not show any evidence that the recent withdrawal has negatively affected water levels in the area to the east.

2. Due to a lack of a well-defined (recent) water level drawdown trends in the aquifer west of 18th Street North, it is recommended that another review of water levels and the City's pumping data be carried out in 5 years, after more complete long-term data base is acquired. At this stage this additional data should allow an assessment on whether the City's blending withdrawal has influenced the overall declining trend of water levels within the ARVA in the vicinity of the well field and west of 1st Street North.

3. During any future extended authorization period that may be issued, the City must continue to monitor water levels and water temperatures at MW4 and in the Canada Games Park well from the pressure transducers. The accuracy of the pressure transducer readings should be checked with manual readings on a routine basis. In addition, a factory calibration may be warranted to confirm accuracy of both temperature and pressure readings.

4. The City's current authorization to pump the wells for non-emergency use requires the City to withdrawal a minimum of 1,000 cubic decametres annually. This limit has proved to be somewhat onerous for the City because this volume of water is not always required for blending in the water treatment process. The City would prefer to be free to pump as little water as required, but to retain the upper limit of 1,900 cubic decametres annually. This licence change would allow the City to operate the wells in a more prudent manner and conserve water for future use. Also, being able to pump at higher rates for longer periods when required provides better hydrogeologic data than a series of low capacity tests.

5. The elevation of the pump motor bases in both the Canada Games Park well and the Turtle Crossing Park well should be surveyed as well as the ground elevation and top of casing of MW4. This will allow direct comparison of water elevations in these two wells with other provincial monitoring wells in the area and facilitate decisions related to raising the well casing for the two wells above maximum flood levels.

6. There would be benefit for the City to carry out a full scale pumping test of the wells at a rate of 5,000 USgpm (315.5 L/s) when the water level in the Canada Games Park well is 9.0 m depth to determine the potential for emergency pumping at the higher rate. However if this test is conducted, there may be short term concerns with groundwater availability for local domestic wells in the area during the pump test and immediately after the test is completed with additional potential implications on water Emergency supply availability for the recovery period, which may last a few months.

7. It is recommended that the City should consider review of their master plan to determine if a form of water rationing, a water conservation bylaw, or public education could be implemented that would specifically address an emergency loss of the river supply source. The pumping capacity of the wells is greatly reduced as the combined pumping rate increases above 3,000 USgpm (189.3 L/s). A reduced emergency requirement may allow a longer term combination of groundwater withdrawal for blending purposes, without negatively affecting a two week Emergency Supply requirement.

8. It is recommended that pressure transducers be installed in the Turtle Crossing Park Well as well as the City's monitoring well that is located in the approach to the TransCanada Highway bridge over the river, 10 km west of the City. The purpose of the transducer installation near the TransCanada highway would be to monitor aquifer levels closer to the area where the aquifer begins in order to gain a better understanding of water level trends and pumping responses along the full length of the aquifer west of 18th Street North.

7.0 STATEMENT OF LIMITATIONS AND CONDITIONS

7.1 THIRD PARTY USE OF REPORT

This report has been prepared for the City of Brandon to whom this report has been addressed and any use a third party makes of this report, or any reliance on or decisions made based on it, are the responsibility of such third parties. KGS Group accepts no responsibility for damages, if any, suffered by a third party as a result of decisions made or actions undertaken based on this report.

7.2 GEO-ENVIRONMENTAL STATEMENT OF LIMITATIONS

KGS Group prepared the geo-environmental conclusions and recommendations for this report in a professional manner using the degree of skill and care exercised for similar projects under similar conditions by reputable and competent environmental consultants. The information contained in this report is based on the information that was made available to KGS Group during the investigation and upon the services described, which were performed within the time and budgetary requirements of The City of Brandon. As the report is based on the available information, some of its conclusions could be different if the information upon which it is based is determined to be false, inaccurate or contradicted by additional information. KGS Group makes no representation concerning the legal significance of its findings or the value of the property investigated.

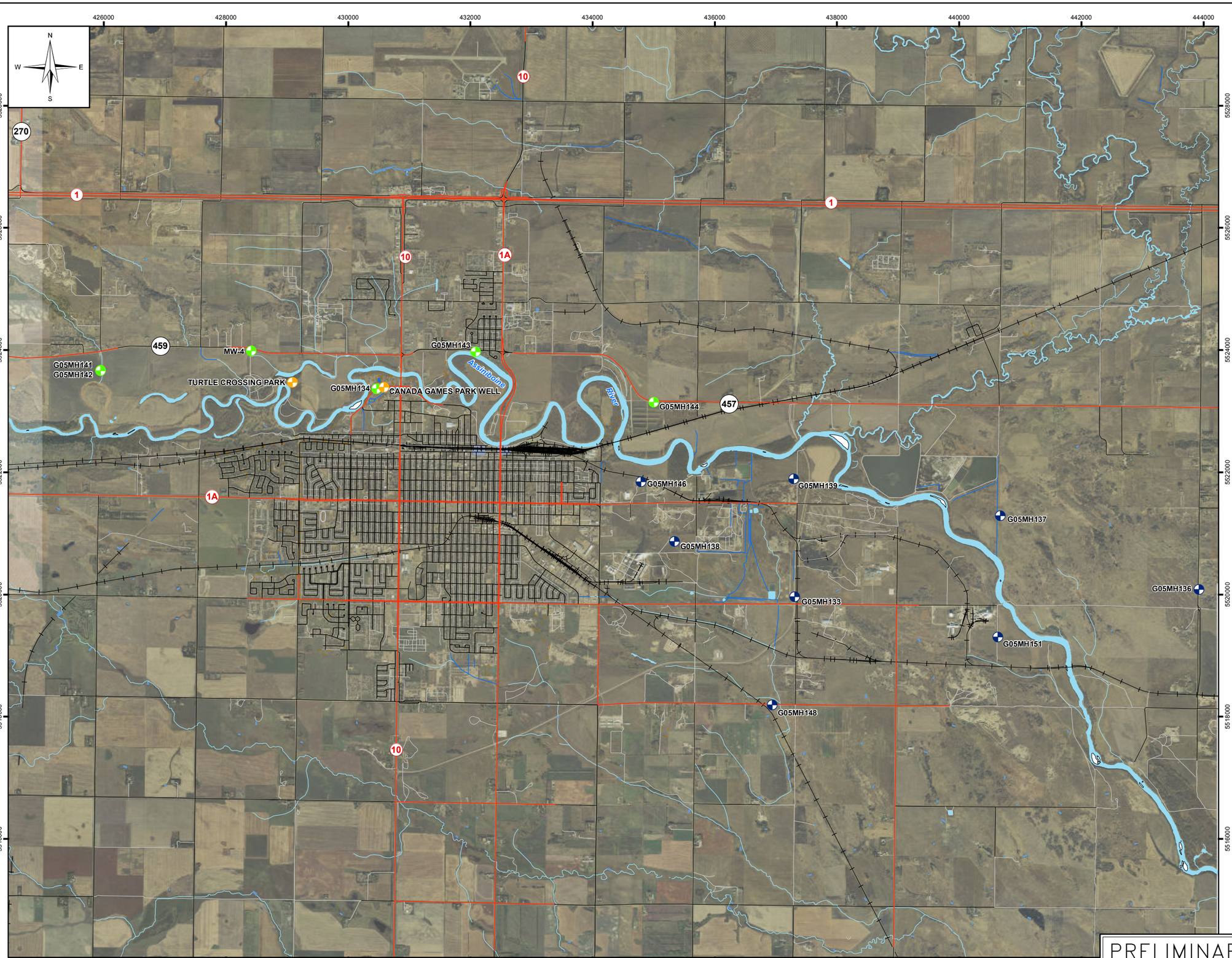
TABLES

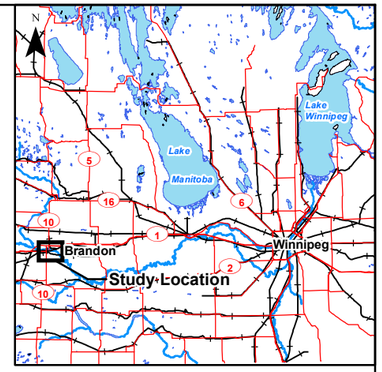
TABLE 1
RATES OF GROUNDWATER ELEVATION CHANGE IN
PROVINCIAL MONITORING WELLS

Well ID	Slope (m/year)			
	Pre-2005	Trend	Post 2005	Trend
MH-133	-0.74	Decreasing	-0.29	Decreasing
MH-134	-0.15	Decreasing	-0.44	Decreasing
MH-137	-0.20	Decreasing	-0.20	Decreasing
MH-138	-1.60	Decreasing	-0.08	Decreasing
MH-139	-0.12	Decreasing	-0.12	Decreasing
MH-141	-0.24	Decreasing	0.16	Increasing
MH-142	-0.20	Decreasing	-0.29	Decreasing
MH-143	-0.29	Decreasing	-0.39	Decreasing
MH-144	-0.29	Decreasing	-0.27	Decreasing
MH-146	-0.29	Decreasing	-0.22	Decreasing
MH-148	-1.10	Decreasing	-0.40	Decreasing
MH-151	-0.40	Decreasing	-0.40	Decreasing

Note:
River elevation has increased by approximately
0.75 m between January 2002 and January 2014.

FIGURES





LEGEND:

- Brandon Supply Wells in Assiniboine River Valley Aquifer
- Monitoring Well in Assiniboine River Valley Aquifer
- Monitoring Well in Brandon Channel Aquifer

500 0 500 1,000 1,500 2,000

Metres

SCALE: 1:60,000 METRIC 11"x17"

All units are metric and in metres unless otherwise specified.
Transverse Mercator Projection, NAD 1983, Zone 14
Elevations are in metres above sea level (MSL)

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City of BRANDON

ASSINIBOINE RIVER VALLEY AQUIFER GROUNDWATER SOURCE SUPPLY ASSESSMENT

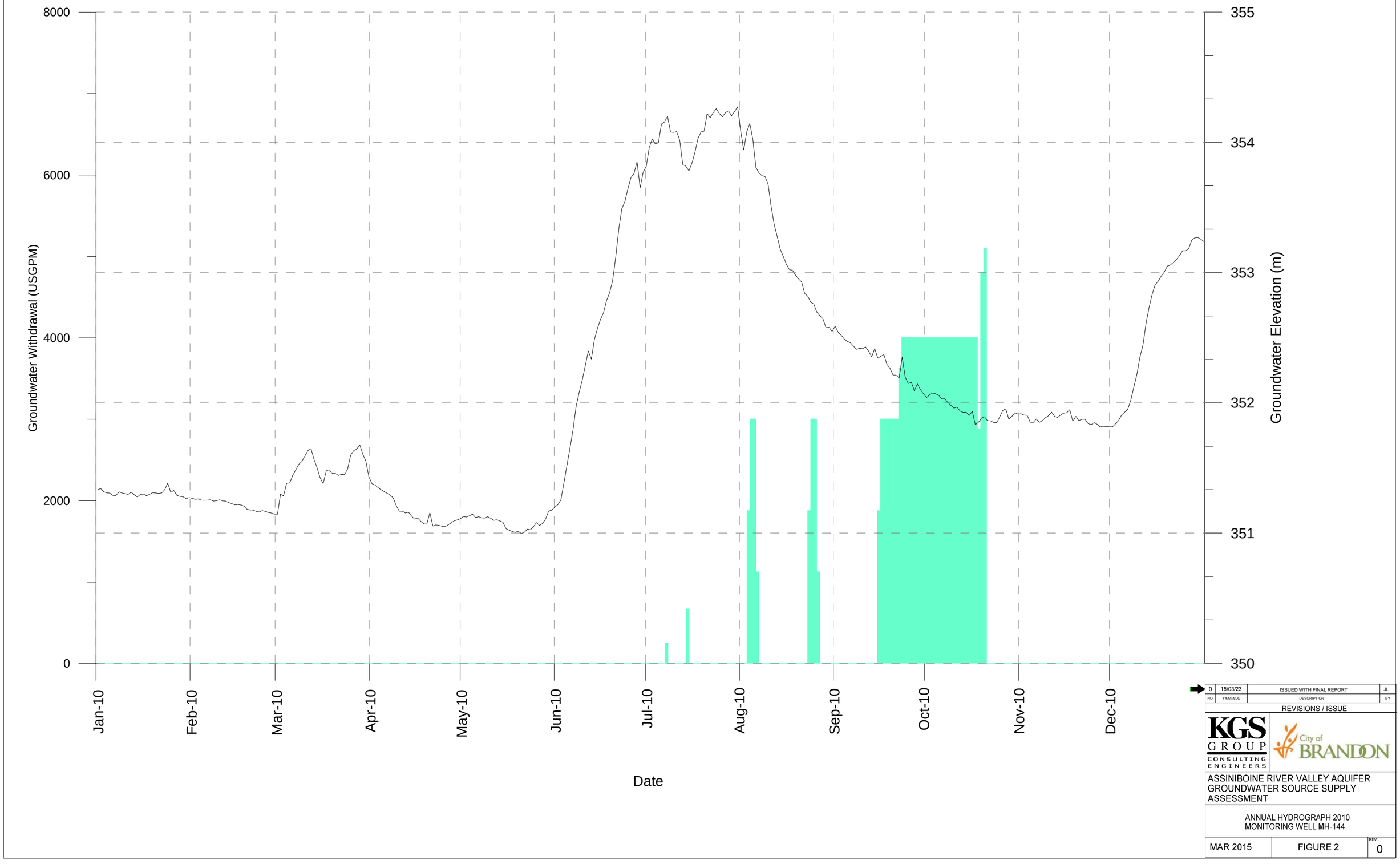
WELL LOCATION PLAN

PRELIMINARY

NOT TO BE USED FOR CONSTRUCTION

MARCH 2015 | FIGURE 01 | REV: 0

FileName: P:\Projects\2015\15-0122-001\Dwg\GIS\MXD\REV0\15-0122-001-Fig01_Rev0.mxd
11"x17" PLOT SCALE 1:1



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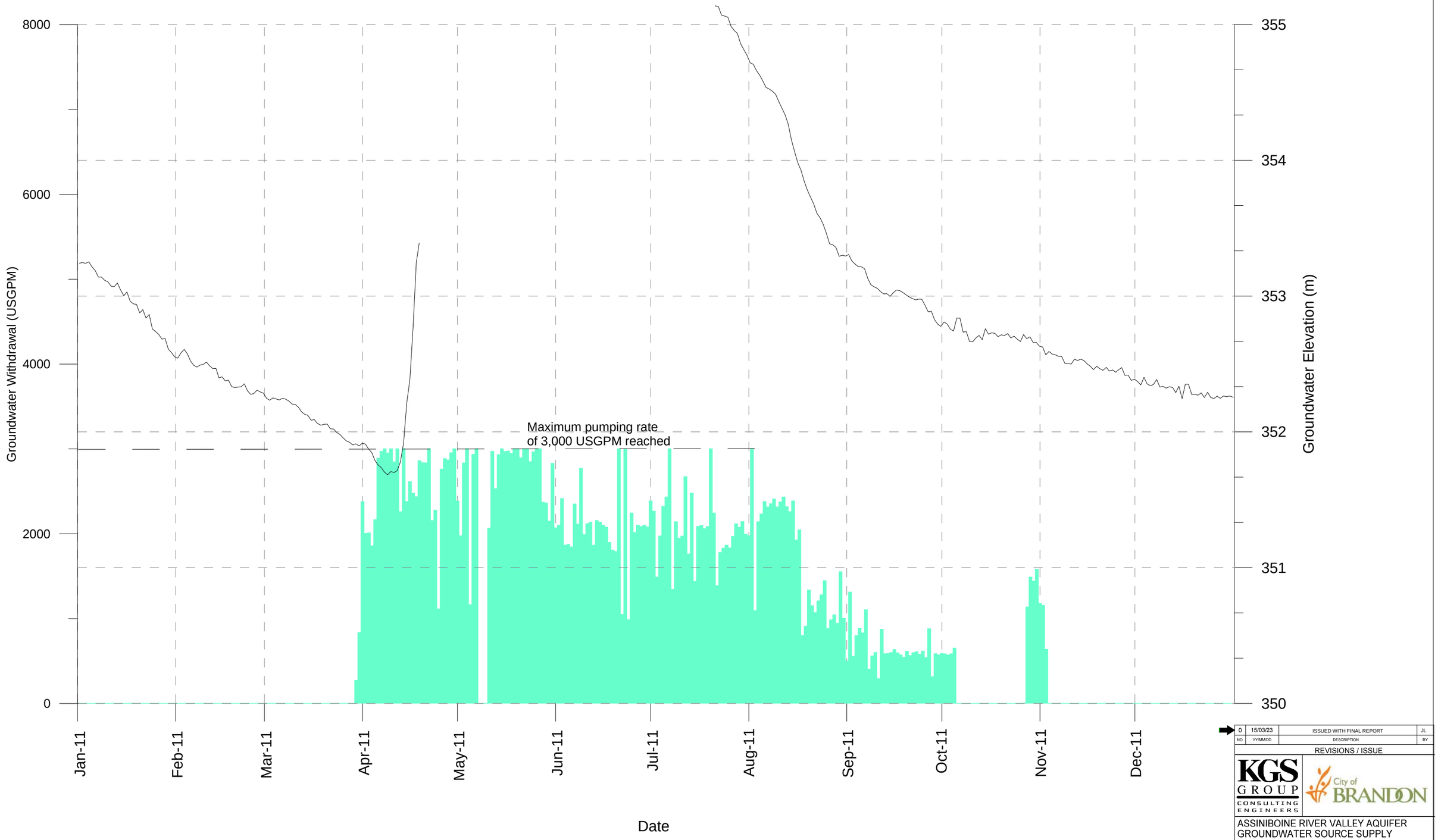
ASSINIBOINE RIVER VALLEY AQUIFER GROUNDWATER SOURCE SUPPLY ASSESSMENT

ANNUAL HYDROGRAPH 2010
MONITORING WELL MH-144

MAR 2015	FIGURE 2	REV: 0



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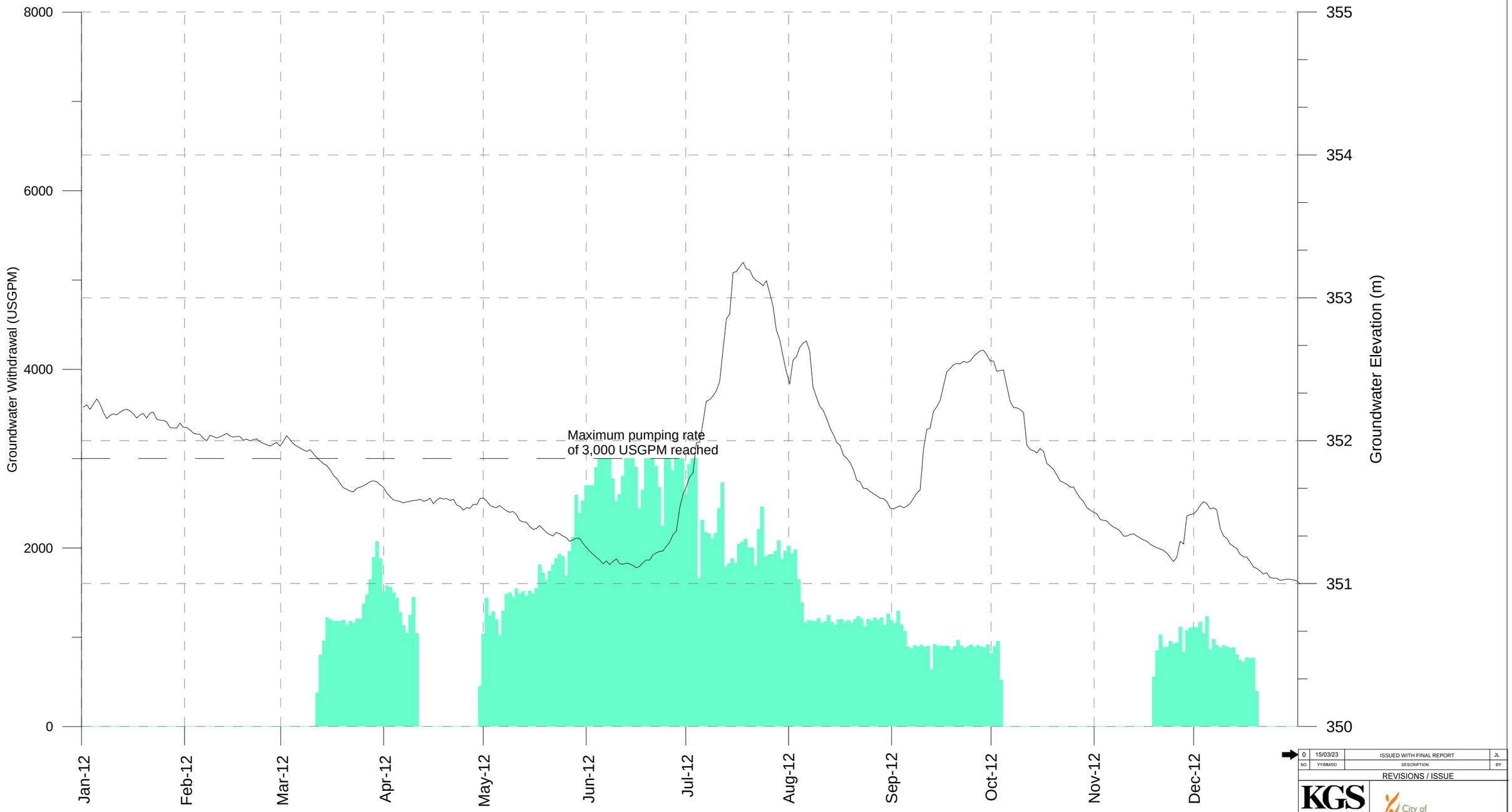
City of BRANDON

ASSINIBOINE RIVER VALLEY AQUIFER GROUNDWATER SOURCE SUPPLY ASSESSMENT

ANNUAL HYDROGRAPH 2011
MONITORING WELL MH-144

MAR 2015	FIGURE 3	REV. 0



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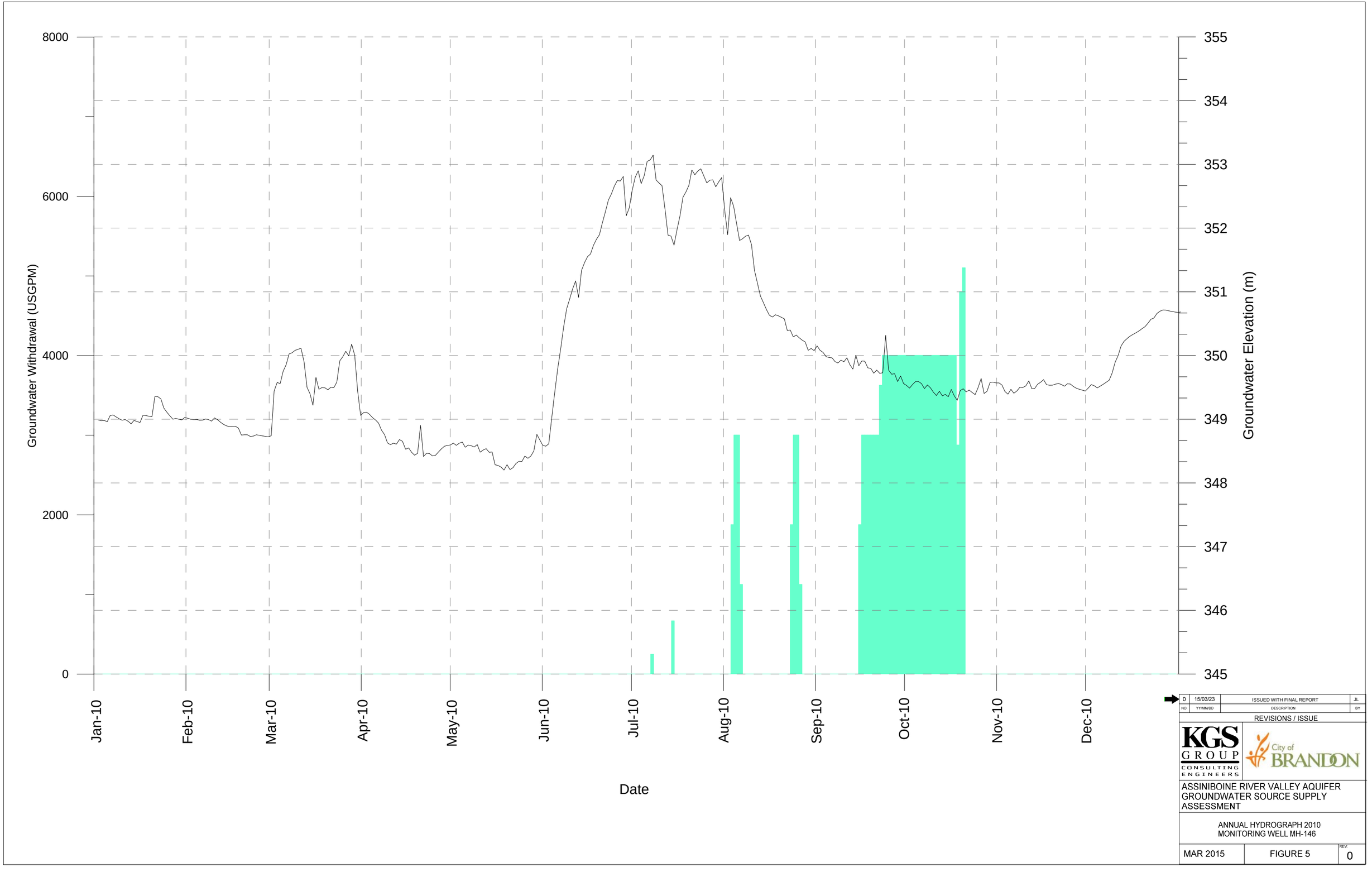
ASSINIBOINE RIVER VALLEY AQUIFER GROUNDWATER SOURCE SUPPLY ASSESSMENT

ANNUAL HYDROGRAPH 2012
MONITORING WELL MH-144

MAR 2015	FIGURE 4	REV. 0



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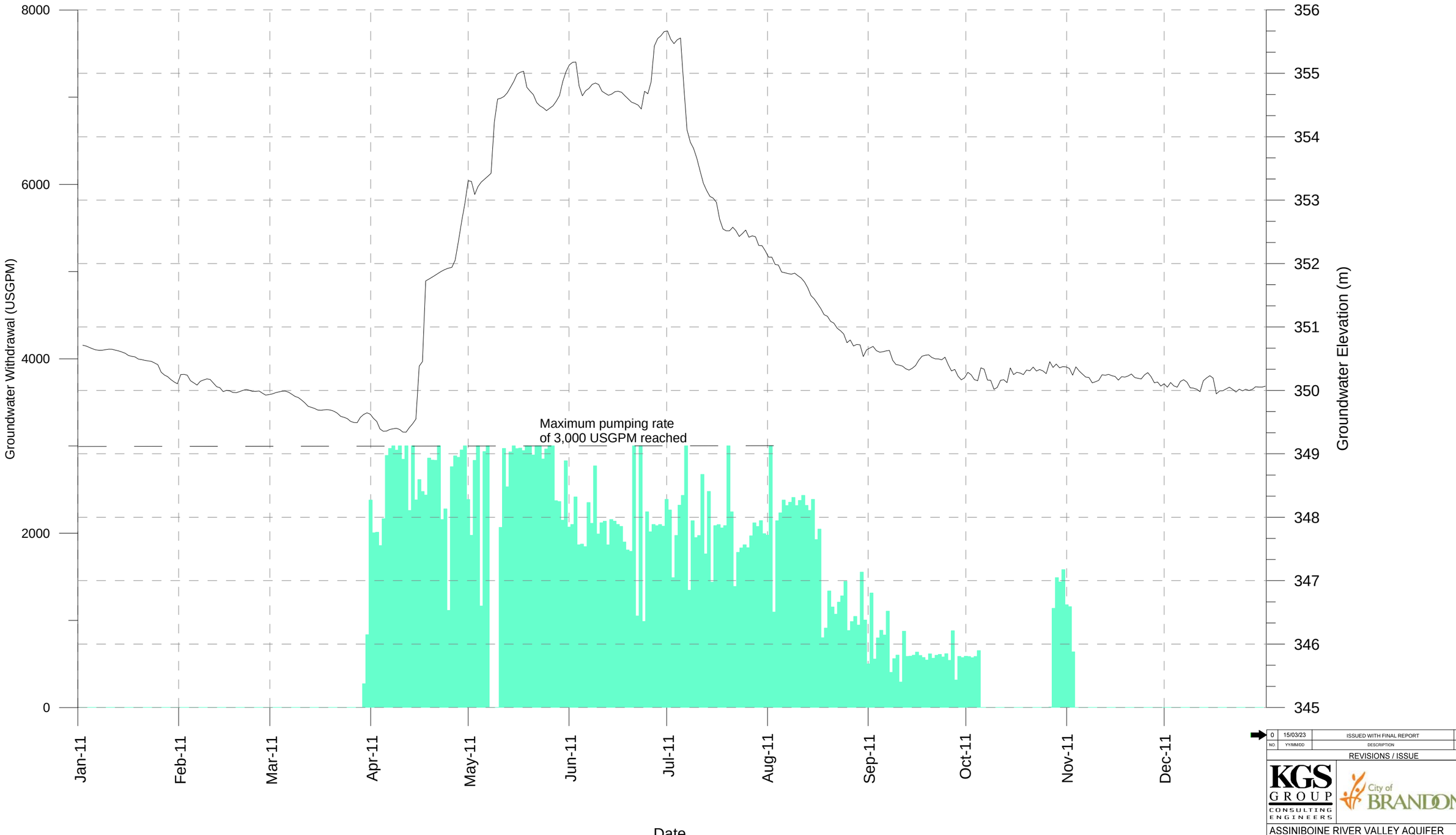
ASSINIBOINE RIVER VALLEY AQUIFER GROUNDWATER SOURCE SUPPLY ASSESSMENT

ANNUAL HYDROGRAPH 2010
MONITORING WELL MH-146

MAR 2015	FIGURE 5	REV. 0



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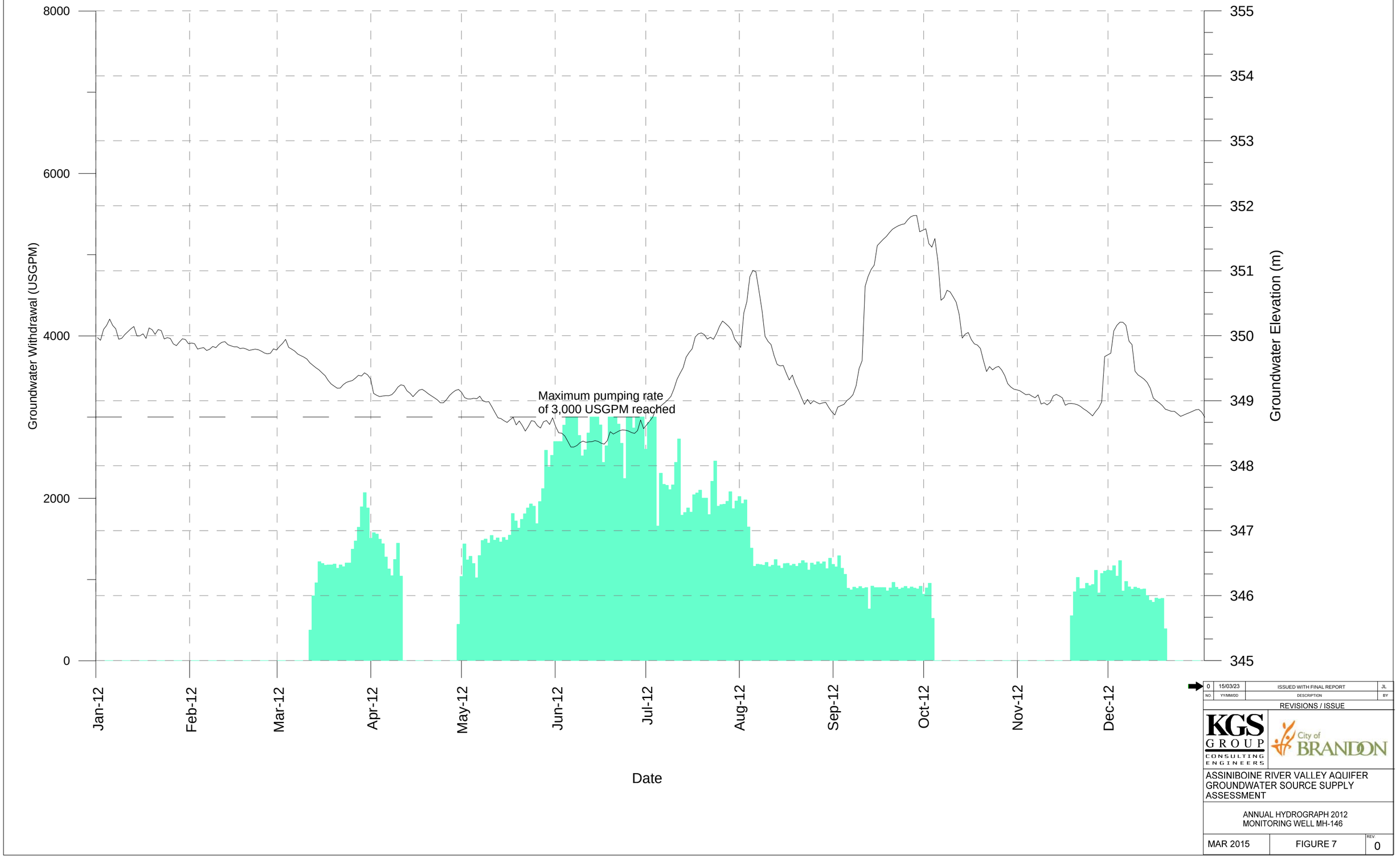
ASSINIBOINE RIVER VALLEY AQUIFER
GROUNDWATER SOURCE SUPPLY
ASSESSMENT

ANNUAL HYDROGRAPH 2011
MONITORING WELL MH-146

MAR 2015	FIGURE 6	REV. 0



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ASSINIBOINE RIVER VALLEY AQUIFER GROUNDWATER SOURCE SUPPLY ASSESSMENT

ANNUAL HYDROGRAPH 2012
MONITORING WELL MH-146

MAR 2015	FIGURE 7	REV. 0

APPENDIX A

LETTER DATED NOVEMBER 14, 2014
MANITOBA LICENSING SECTION

Manitoba
Conservation and Water Stewardship

Water Use Licensing Section
Box 16, 200 Saulteaux Crescent
Winnipeg, Manitoba, Canada R3J 3W3
T 204-945- 6009 F 204-945-7419
Rob.Matthews@gov.mb.ca

November 14, 2014

File: Brandon, City of - 5

Brad McIntosh
Water Treatment Facility Manager
Engineering Services and Water Resources
The City of Brandon
410 - 9th Street
Brandon MB R7A 6A2

Dear Mr. McIntosh:

This letter is in response to a letter from the City of Brandon (the City) dated November 3, 2014 requesting authorization to continue using groundwater on a non-emergency basis. The reasons provided for this request are as follows: (1) with the elevated levels of river water hardness, blending with groundwater reduces the amount of chemicals that are required to soften the water which in turn significantly reduces the amount of sludge produced and hauled away; (2) blending with groundwater allows a reduction in coagulation chemicals required for turbidity removal and better process control; (3) potassium permanaganate use was not required with groundwater blending which in turn reduced the amount of activated carbon required for taste and odour removal; and (4) groundwater blending reduced the amount of UV irradiation required to disinfect the potable water supply. For these reasons, the use of groundwater for blending purposes has proven to be highly beneficial for the operators to produce a high quality product for use by the City's residents and businesses.

As the Manager of the Water Use Licensing Section, I have the delegated authority on behalf of the Minister of Conservation and Water Stewardship, for administration of *The Water Rights Act*, which includes the issuance of authorizations, permits, and licences. Therefore, the City may consider this letter to be authorization under *The Water Rights Act* to divert water from the Turtle Crossing Park and Canada Games Park Wells as requested, subject to the following conditions:

1. This authorization is issued upon the express condition that it shall be subject to the provisions of *The Water Rights Act* and Regulation and all amendments thereto.

2. This authorization is not transferable or assignable to any other party.

3. **This authorization will expire on May 31, 2015.**

4. Prior to undertaking commencement of any diversion authorized by this letter, the City is required to retain the services of a hydrogeologist, registered with the Association of Professional Engineers and Geoscientists of Manitoba (APEGM).

5. The City must pump a minimum of 1,000 cubic decametres per year but not more than 1,900 cubic decametres per year.

6. The City is to maintain a pressure transducer in the permanent observation well at the intersection of the entrance road to the Turtle Crossing Park and Grand Valley Road and in the Canada Games Park Well.

7. The consulting hydrogeologist is further required to prepare and submit a technical report **by April 1, 2015** which would contain, but would not be limited to, such things as: water levels and temperature data from the two pressure transducers up until December 31, 2014. The report must include an analysis of long term water level trends in the aquifer both in the vicinity of the two supply wells and beyond.

8. The City shall assume any liability that may ensue as a result of diversion of water as authorized by this letter. The City shall further assume responsibility to correct any water supply problems or provide temporary water supply to anyone whose wells are negatively impacted as a result of the construction of pump testing.

9. Any employee of the Water Use Licensing Section, or agent designated by the Section, has the right of unrestricted access for the purpose of inspecting any works or diversion of water authorized by this letter.

10. The City shall, prior to diversion of water, acquire the necessary approvals from other relevant provincial and federal agencies.

11. The Minister or Minister's agents may, under certain conditions, instruct the City to reduce or terminate diversion of water from the well to accommodate existing senior licensed water users, domestic users, and riparian needs.

Prior to the expiry of this authorization the Section will have received and reviewed the technical report from the City, and a reassessment of the City's needs will be undertaken. An additional extension will be considered at that time.

In your letter you state a number of benefits from the use of groundwater and how your operating staff is confidant in their abilities to regulate withdraws from the aquifer. This Section feels it would be beneficial for us to meet with the Water Treatment Plant operators to learn more about this. As a result I have instructed Kylene Wiseman to contact you about arranging for such a meeting.

Please contact Kylene Wiseman at 204-945-7424 if you have any questions concerning this letter, the licensing of the proposed project, or to communicate progress of the proposed project.

Yours truly,

Rob Matthews
Manager, Water Use Licensing Section

cc: CAO, Rural Municipality of Cornwallis
CAO, Rural Municipality of Whitehead
Manager, Assiniboine Hills Conservation District
Colin Welch, Environmental Coordinator, Canexus Corporation,
Rodi Sveistrup, Compliance Team Leader, Koch Fertilizer Canada ULC
Morgan Curran-Blaney, Plant Manager, Maple Leaf
Kylene Wiseman, MCWS

APPENDIX B

LONG TERM HYDROGRAPHS

Depth to Water From Top of Pump Casing Base at Ground Surface (m)

Top of pump bowls - 17.2 m

Temperature

Water Level at Canada Games Park Pumping Well

Temperature (°C)

Flow (m^3/sec)

River Flow at Station 05MH013

River Level Elevation at Station 05MH013

River Elevation (m)

Groundwater Withdrawal (ML/day)

KGS Group Pump Tests

City of Brandon Groundwater Withdrawal

Maximum pumping rates of 3,000 USGPM reached

Groundwater Withdrawal (USGPM)

Date

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City of BRANDON

ASSINIBOINE RIVER VALLEY AQUIFER GROUNDWATER SOURCE SUPPLY ASSESSMENT

1996 - 2014 HYDROGRAPH
CANADA GAMES PARK CITY WELL
SE27-10-19W

MAR 2015 | FIGURE B-1 | REV. 0

Depth to Water From Ground Surface (m)

Top of pump bowls - 17.2 m

Temperature

Water Level at Well 4 Pumping Well

Temperature (°C)

Flow (m^3/sec)

River Level Elevation at Station 05MH013

River Flow at Station 05MH013

River Elevation (m)

Groundwater Withdrawal (ML/day)

KGS Group Pump Tests

City of Brandon Groundwater Withdrawal

Maximum pumping rates of 3,000 USGPM reached

Groundwater Withdrawal (USGPM)

Date

Depth to Top of Aquifer: 15.6 m below grade

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City of BRANDON

ASSINIBOINE RIVER VALLEY AQUIFER
GROUNDWATER SOURCE SUPPLY ASSESSMENT

1996 - 2014 HYDROGRAPH
MONITORING WELL MW-4
SE28-10-19W

MAR 2015 | FIGURE B-2 | REV. 0

Groundwater Elevation (m)

Groundwater Elevation at Well MH-133

slope = -0.74 m/yr

slope = -0.29 m/yr

Flow (m^3/sec)

River Flow at Station 05MH013

River Level Elevation at Station 05MH013

River Elevation (m)

Groundwater Withdrawal (ML/day)

KGS Group Pump Tests

City of Brandon Groundwater Withdrawal

Maximum pumping rates of 3,000 USGPM reached

Groundwater Withdrawal (USGPM)

Date

Ground Elevation MH-133: 366.339 m

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City of BRANDON

ASSINIBOINE RIVER VALLEY AQUIFER GROUNDWATER SOURCE SUPPLY ASSESSMENT

1996 - 2014 HYDROGRAPH MONITORING WELL MH-133

MAR 2015 | FIGURE B-3 | REV 0

Groundwater Elevation at Well MH-134

slope = -0.15 m/yr

slope = -0.44 m/yr

River Level Elevation at Station 05MH013

River Flow at Station 05MH013

KGS Group Pump Tests

City of Brandon Groundwater Withdrawal

Maximum pumping rates of 3,000 USGPM reached

Groundwater Elevation (m)

Flow (m^3/sec)

River Elevation (m)

Groundwater Withdrawal (ML/day)

Groundwater Withdrawal (USGPM)

Date

Ground Elevation MH-134: 358.109 m

Elevation Top of Aquifer: 343.783 m

NO.	YY/MM/DD	DESCRIPTION	BY
0	15/03/23	ISSUED WITH FINAL REPORT	JL

REVISIONS / ISSUE

KGS GROUP CONSULTING ENGINEERS

City of BRANDON

ASSINIBOINE RIVER VALLEY AQUIFER GROUNDWATER SOURCE SUPPLY ASSESSMENT

1996 - 2014 HYDROGRAPH
MONITORING WELL MH-134

MAR 2015	FIGURE B-4	REV. 0

Groundwater Elevation (m)

Groundwater Elevation at Well MH-136

Flow (m^3/sec)

River Flow at Station 05MH013

River Level Elevation at Station 05MH013

River Elevation (m)

Groundwater Withdrawal (ML/day)

KGS Group Pump Tests

City of Brandon Groundwater Withdrawal

Maximum pumping rates of 3,000 USGPM reached

Groundwater Withdrawal (USGPM)

Date

Ground Elevation MH-136: 370.640 m

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REVISIONS / ISSUE

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ASSINIBOINE RIVER VALLEY AQUIFER GROUNDWATER SOURCE SUPPLY ASSESSMENT

1996 - 2014 HYDROGRAPH MONITORING WELL MH-136

MAR 2015	FIGURE B-5	REV 0

Groundwater Elevation at Well MH-137

slope = -0.20 m/yr

slope = -0.20 m/yr

River Level Elevation at Station 05MH013

River Flow at Station 05MH013

KGS Group Pump Tests

City of Brandon Groundwater Withdrawal

Maximum pumping rates of 3,000 USGPM reached

Elevation (m)

Flow (m^3/sec)

River Elevation (m)

Groundwater Withdrawal (ML/day)

Groundwater Withdrawal (USGPM)

Date

Ground Elevation MH-137: 358.540 m

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REVISIONS / ISSUE

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City of BRANDON

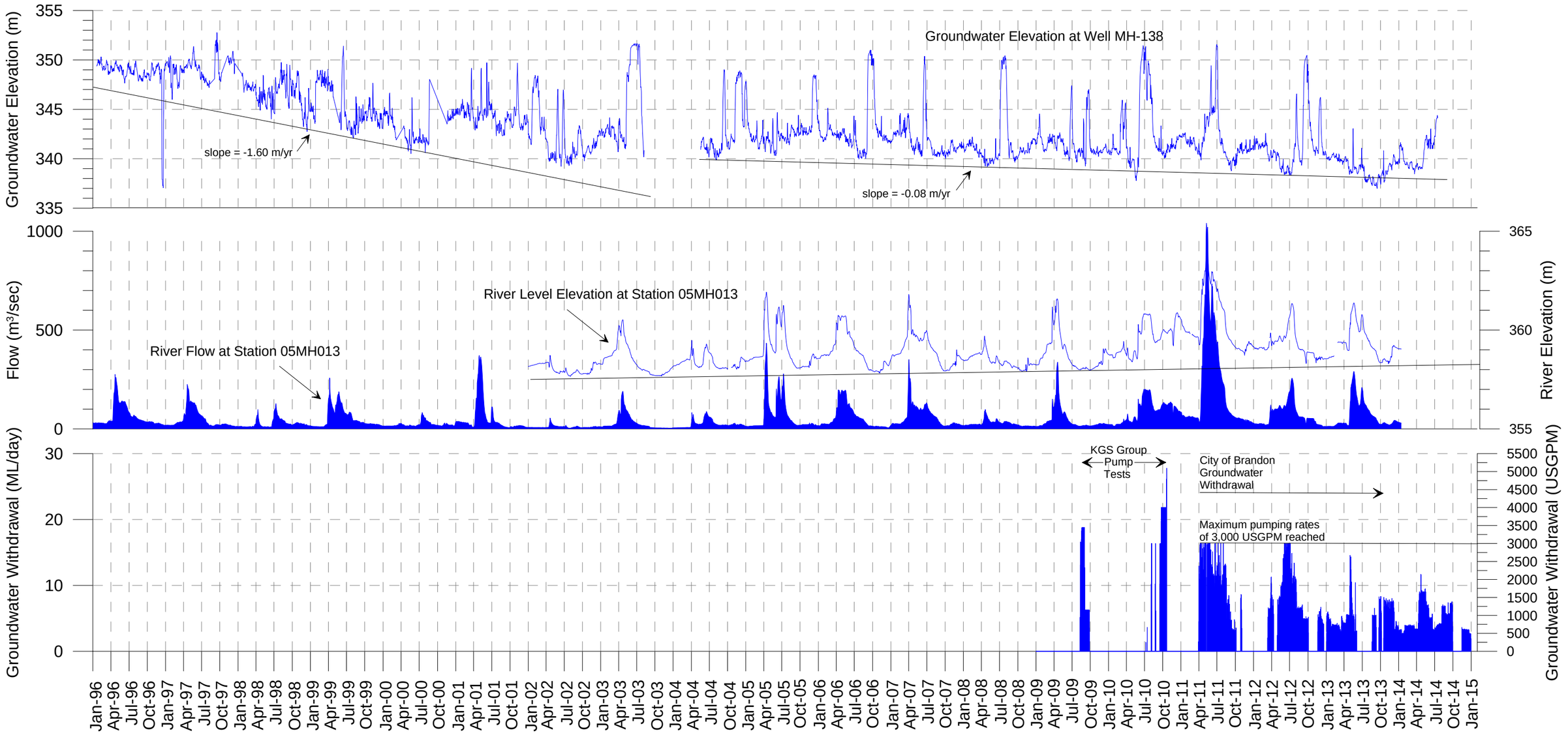
ASSINIBOINE RIVER VALLEY AQUIFER GROUNDWATER SOURCE SUPPLY ASSESSMENT

1996 - 2014 HYDROGRAPH MONITORING WELL MH-137

MAR 2015

FIGURE B-6

REV. 0



Ground Elevation MH-138: 372.619 m

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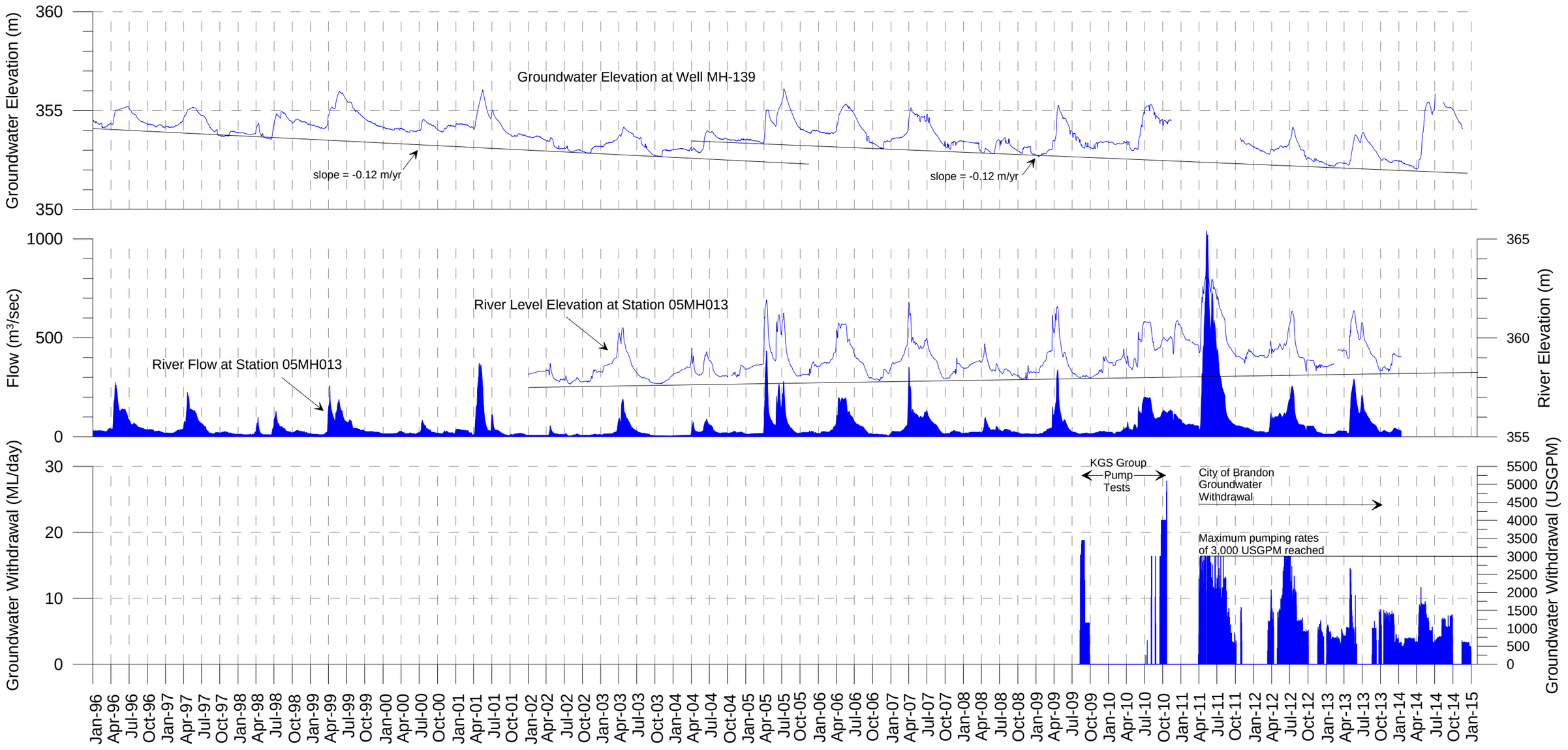
ASSINIBOINE RIVER VALLEY AQUIFER GROUNDWATER SOURCE SUPPLY ASSESSMENT

1996 - 2014 HYDROGRAPH
MONITORING WELL MH-138

MAR 2015	FIGURE B-7	REV. 0



Ground Elevation MH-139: 356.787 m

NO.	YY/MM/DD	DESCRIPTION	BY
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City of BRANDON

ASSINIBOINE RIVER VALLEY AQUIFER
GROUNDWATER SOURCE SUPPLY
ASSESSMENT

1996 - 2014 HYDROGRAPH
MONITORING WELL MH-139

MAR 2015	FIGURE B-8	REV. 0

Elevation (m)

Groundwater Elevation at Well MH-141

slope = -0.18 m/yr

slope = 0.16 m/yr

Flow (m^3/sec)

River Level Elevation at Station 05MH013

River Flow at Station 05MH013

River Elevation (m)

Groundwater Withdrawal (ML/day)

KGS Group Pump Tests

City of Brandon Groundwater Withdrawal

Maximum pumping rates of 3,000 USGPM reached

Groundwater Withdrawal (USGPM)

Date

Ground Elevation MH-141: 360.657 m

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REVISIONS / ISSUE

KGS GROUP CONSULTING ENGINEERS

City of BRANDON

ASSINIBOINE RIVER VALLEY AQUIFER GROUNDWATER SOURCE SUPPLY ASSESSMENT

1996 - 2014 HYDROGRAPH MONITORING WELL MH-141

MAR 2015 | FIGURE B-9 | REV. 0

Groundwater Elevation at Well MH-142

slope = -0.20 m/yr

slope = -0.29 m/yr

River Level Elevation at Station 05MH013

River Flow at Station 05MH013

KGS Group Pump Tests

City of Brandon Groundwater Withdrawal

Maximum pumping rates of 3,000 USGPM reached

Groundwater Elevation (m)

Flow (m^3/sec)

River Elevation (m)

Groundwater Withdrawal (ML/day)

Groundwater Withdrawal (USGPM)

Date

Ground Elevation MH-142: 360.657 m

Elevation Top of Aquifer: 344.807 m

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REVISIONS / ISSUE

KGS GROUP CONSULTING ENGINEERS

City of BRANDON

ASSINIBOINE RIVER VALLEY AQUIFER GROUNDWATER SOURCE SUPPLY ASSESSMENT

1996 - 2014 HYDROGRAPH MONITORING WELL MH-142

MAR 2015 | FIGURE B-10 | REV. 0

Groundwater Elevation (m)

Groundwater Elevation at Well MH-143

slope = -0.29 m/yr

slope = -0.39 m/yr

Flow (m^3/sec)

River Flow at Station 05MH013

River Level Elevation at Station 05MH013

River Elevation (m)

Groundwater Withdrawal (ML/day)

KGS Group Pump Tests

City of Brandon Groundwater Withdrawal

Maximum pumping rates of 3,000 USGPM reached

Groundwater Withdrawal (USGPM)

Date

Ground Elevation MH-143: 358.940 m

Elevation Top of Aquifer: 346.953 m

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REVISIONS / ISSUE

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ASSINIBOINE RIVER VALLEY AQUIFER GROUNDWATER SOURCE SUPPLY ASSESSMENT

1996 - 2014 HYDROGRAPH MONITORING WELL MH-143

MAR 2015	FIGURE B-11	REV. 0

Groundwater Elevation (m)

Groundwater Elevation at Well MH-144

slope = -0.29 m/yr

slope = -0.27 m/yr

Flow (m^3/sec)

River Flow at Station 05MH013

River Level Elevation at Station 05MH013

River Elevation (m)

Groundwater Withdrawal (ML/day)

KGS Group Pump Tests

City of Brandon Groundwater Withdrawal

Maximum pumping rates of 3,000 USGPM reached

Groundwater Withdrawal (USGPM)

Date

Ground Elevation MH-144: 358.297 m

Elevation Top of Aquifer: 349.307 m

NO.	YY/MM/DD	DESCRIPTION	BY
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REVISIONS / ISSUE

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City of BRANDON

ASSINIBOINE RIVER VALLEY AQUIFER GROUNDWATER SOURCE SUPPLY ASSESSMENT

1996 - 2014 HYDROGRAPH MONITORING WELL MH-144

MAR 2015	FIGURE B-12	REV. 0

Groundwater Elevation (m)

355
350
345

Groundwater Elevation at Well MH-146

slope = -0.29 m/yr

slope = -0.22 m/yr

Flow (m^3/sec)

1000
500
0

River Level Elevation at Station 05MH013

River Flow at Station 05MH013

River Elevation (m)

365
360
355

Groundwater Withdrawal (ML/day)

30
20
10
0

KGS Group Pump Tests

City of Brandon Groundwater Withdrawal

Maximum pumping rates of 3,000 USGPM reached

Groundwater Withdrawal (USGPM)

5500
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0

Jan-96 Apr-96 Jul-96 Oct-96 Jan-97 Apr-97 Jul-97 Oct-97 Jan-98 Apr-98 Jul-98 Oct-98 Jan-99 Apr-99 Jul-99 Oct-99 Jan-00 Apr-00 Jul-00 Oct-00 Jan-01 Apr-01 Jul-01 Oct-01 Jan-02 Apr-02 Jul-02 Oct-02 Jan-03 Apr-03 Jul-03 Oct-03 Jan-04 Apr-04 Jul-04 Oct-04 Jan-05 Apr-05 Jul-05 Oct-05 Jan-06 Apr-06 Jul-06 Oct-06 Jan-07 Apr-07 Jul-07 Oct-07 Jan-08 Apr-08 Jul-08 Oct-08 Jan-09 Apr-09 Jul-09 Oct-09 Jan-10 Apr-10 Jul-10 Oct-10 Jan-11 Apr-11 Jul-11 Oct-11 Jan-12 Apr-12 Jul-12 Oct-12 Jan-13 Apr-13 Jul-13 Oct-13 Jan-14 Apr-14 Jul-14 Oct-14 Jan-15

Date

Ground Elevation MH-146: 359.550 m

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REVISIONS / ISSUE

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City of BRANDON

ASSINIBOINE RIVER VALLEY AQUIFER GROUNDWATER SOURCE SUPPLY ASSESSMENT

1996 - 2014 HYDROGRAPH
MONITORING WELL MH-146

MAR 2015 | FIGURE B-13 | REV. 0

Groundwater Elevation (m)

Groundwater Elevation at Well MH-148

slope = -1.10 m/yr

slope = -0.40 m/yr

Flow (m^3/sec)

River Flow at Station 05MH013

River Level Elevation at Station 05MH013

River Elevation (m)

Groundwater Withdrawal (ML/day)

KGS Group Pump Tests

City of Brandon Groundwater Withdrawal

Maximum pumping rates of 3,000 USGPM reached

Groundwater Withdrawal (USGPM)

Date

Ground Elevation MH-148: 372.309 m

NO.	YY/MM/DD	DESCRIPTION	BY
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City of BRANDON

ASSINIBOINE RIVER VALLEY AQUIFER GROUNDWATER SOURCE SUPPLY ASSESSMENT

1996 - 2014 HYDROGRAPH MONITORING WELL MH-148

MAR 2015	FIGURE B-14	REV. 0

Groundwater Elevation at Well MH-151

slope = -0.40 m/yr

River Level Elevation at Station 05MH013

River Flow at Station 05MH013

KGS Group Pump Tests

City of Brandon Groundwater Withdrawal

Maximum pumping rates of 3,000 USGPM reached

Groundwater Elevation (m)

Flow (m^3/sec)

River Elevation (m)

Groundwater Withdrawal (ML/day)

Groundwater Withdrawal (USGPM)

Date

Ground Elevation MH-151: 364.485 m

NO.	YY/MM/DD	DESCRIPTION	BY
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REVISIONS / ISSUE

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City of BRANDON

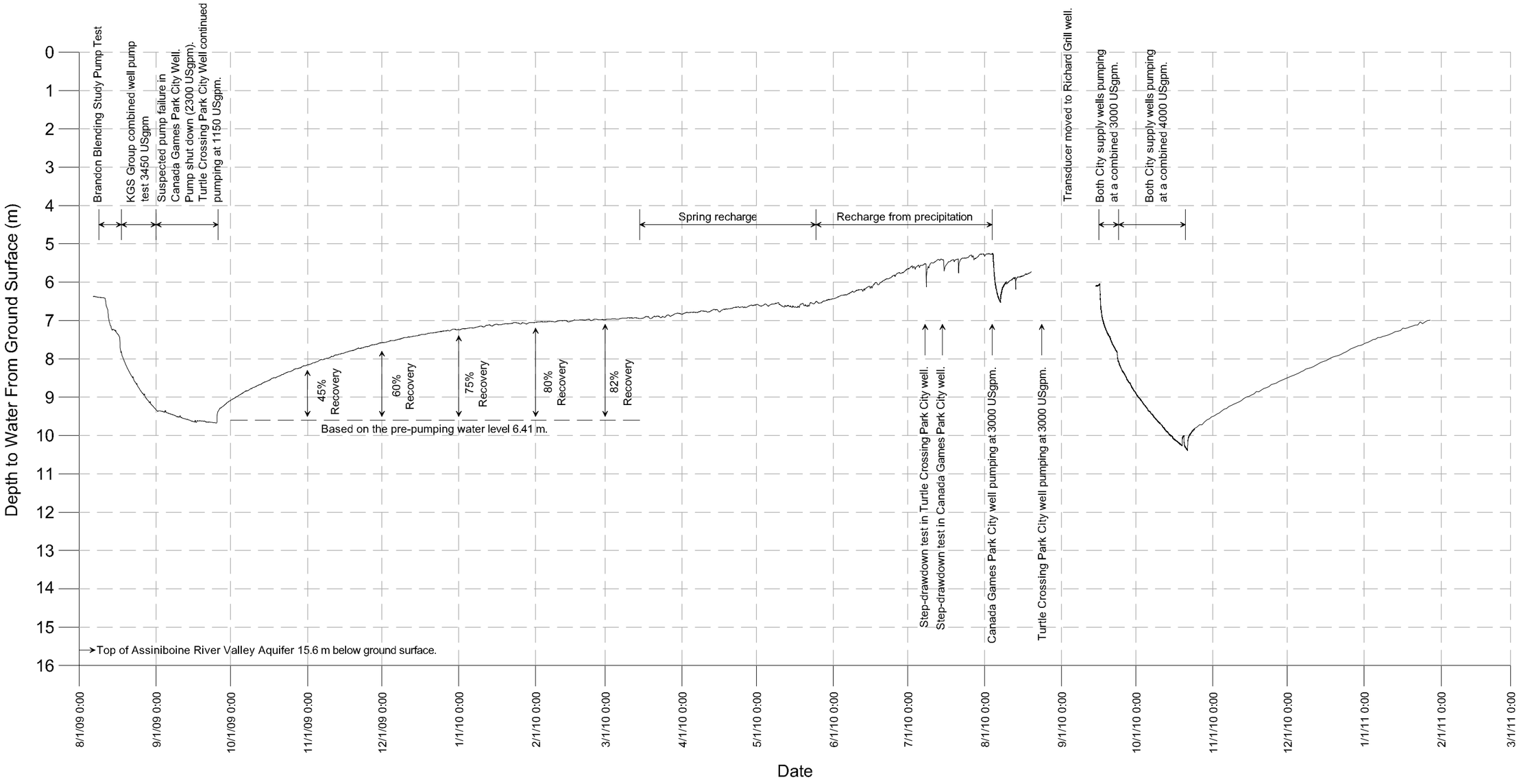
ASSINIBOINE RIVER VALLEY AQUIFER GROUNDWATER SOURCE SUPPLY ASSESSMENT

1996 - 2014 HYDROGRAPH MONITORING WELL MH-151

MAR 2015	FIGURE B-15	REV. 0

APPENDIX C

2009/2010 HYDROGRAPH MONITORING WELL MW4 FROM 2011 KGS GROUP REPORT



Notes:
1. KGS Group MW-4 is located at the intersection of Grand Valley Road and the entrance road to Turtle Crossing Park.
2. Top of aquifer 15.6 m below ground surface.
3. Bottom of aquifer 21.6 m below ground surface.
4. Casing height 0.73 m (2.4 ft) above ground surface.
4. The March 1, 2010 water level may represent a natural seasonal fully recovered water condition.
5. In 2009, approximately 520.9 megaliters (137,600,000 USgallons) of water pumped from the aquifer during testing.
6. In 2010, approximately 741.9 megaliters (195,984,000 USgallons) of water pumped from the aquifer during testing.

NO.	YY/MM/DD	DESCRIPTION	BY
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KGS GROUP CONSULTING ENGINEERS

CITY OF BRANDON, MB
WATER SOURCE REVIEW

2009/2010 HYDROGRAPH
KGS GROUP MONITORING WELL MW-4
SE28-10-19W

MARCH 2011 | FIGURE 26 | REV: 0

File Name: P:\Projects\2010\10-0422-01\Dwg\Env\Rev 0\10-0422-01 FIG 26.dwg - Tab: Model Plotted By: Rkelleher 03/14/2011 [Mon 9:12am]