Comox Valley
REGIONAL DISTRICT

Staff report

**DATE:** November 13, 2015

**FILE**: 5620-02

**TO:** Chair and Directors
Black Creek Oyster Bay Services Committee

**FROM:** Debra Oakman, CPA, CMA
Chief Administrative Officer

**RE:** Black Creek/Oyster Bay groundwater asset characterization

**Purpose**
To bring forward a hydrogeological report that details an assessment on the Black Creek-Oyster Bay (BCOB) supply wells.

**Policy analysis**
Bylaw No. 1557, being the "Black Creek – Oyster Bay Water Local Service Area Conversion and Establishment Bylaw, 1993" converts the specified area for the purpose of providing water service to a local service area.

Bylaw No. 5, being the "Black Creek / Oyster Bay Water Service Regulation, Fees and Charges Bylaw, 2008" regulates the fees and charges, terms and conditions under which water may be supplied and used in the BCOB water service area.

At the June 15, 2015 BCOB services committee meeting, staff informed the committee that a report would be brought forward to a subsequent BCOB committee meeting that identifies the current capacity of the BCOB water system.

**Executive summary**
The BCOB water system is supplied by water from two different water sources. The first are ground water wells (two in the Oyster River Nature Park) and the second is an infiltration gallery in the Oyster River. These water sources are typically rotated seasonally depending on system demand and turbidity.

The BCOB system experienced reduced source water flows in 2014 and 2015 due to dry summers and minimal winter snow pack. The Comox Valley Regional District (CVRD) operated both well #4 and the Oyster River infiltration gallery at the same time in the summer of 2015 in order to keep up with the system demand.

The historical operating strategy has been to have only one source in service at a time, however the BCOB system has seen a decline in source water capacity over the last couple of years that has required the CVRD to operate multiple water sources concurrently.

The CVRD engaged the services of a GW Solutions, a hydrogeological consulting firm, to investigate the existing supply wells in order to determine what kind of capacity the BCOB water system can sustain over the long term.

Pump testing was conducted on well#4 while monitoring of the effects of two nearby test wells, the Evans farm well, the Oyster River infiltration gallery and well#1.

It was concluded that the two groundwater wells have a significant hydraulic connection between one another and they should not be operated at the same time in order to maximize the well supply. At the same time, well #4 was found to have very little interference with either the Oyster River infiltration gallery or the Evans farm well. Therefore pumping from both these sources at the same will have little to no effect on the water sources.

Findings of the testing were that well#4 does not have the long term capacity to meet wintertime daily demands or the summer maximum daily demand on its own.

Similar testing of well #1 and the Oyster River infiltration gallery is required to determine if the BCOB supply wells have the long term capacity to meet the maximum day demands of the system.

**Recommendation from the chief administrative officer:**
THAT the 2016-2020 preliminary financial plan for the Black Creek/Oyster Bay water service, function 313, include $27,000 funding to complete further evaluation of groundwater well #1 and the Oyster River infiltration gallery.

AND FURTHER THAT staff report back on the findings on this work in the fall of 2016.

Respectfully:

***D. Oakman***

Debra Oakman, CPA, CMA
Chief Administrative Officer

**History/background factors**
The CVRD owns and operates the BCOB water system. The water system consists of two sources of water supply. One is a ground water well (two wells #1 and #4 located in the Oyster River Nature Park). These wells have been historically used from October to May when demands are moderate. The other is an infiltration gallery in the Oyster River, which has been historically used in the summer when water demands are higher and turbidity is generally low.

The current operating strategy has been to have only one source in service at a time. Switching between sources is relatively simple, however mixing the two sources requires the addition of chemicals to raise the PH level as the well water is more acidic than the river water. For that reason we have not historically run the two sources at the same time.

The summer of 2014 was historically the driest summer in 50 years along with an almost negligible winter snow pack. Flows in the Oyster River were very low from late August through September and the amount of water the CVRD was able to draw through the infiltration gallery was not enough to keep up with system demand. The Oyster River had all but dried up over top of the infiltration gallery forcing the implementation of stringent watering restrictions and the mixing of the two water sources in order to keep up with demand and ensure adequate storage for fire flows. Several factors contributed to the reduced river flows such as sediment blinding of the infiltration gallery and possibly the river flowing along an alternate route.

In 2015 the CVRD faced a similar situation as the winter snow pack was virtually non-existent, river flow in the oyster river was low and up until late August the summer was very hot and dry. As a precautionary move, the CVRD implemented stage 3 watering restrictions for the BCOB water system very early in the summer of 2015 that helped ensure there was adequate water supply for domestic use and fire protection throughout the summer.

The CVRD has experienced a number of challenges in recent years to the BCOB water source supply and as a result engaged the services of a GW Solutions, a hydrogeological consulting firm, to investigate the existing wells, the surrounding aquifer and the infiltration gallery in order to determine what kind of capacity the BCOB water system can sustain over the long term.

In June 2015 GW Solutions provided a report on the supply dynamics of the BCOB groundwater wells that identified a number of environmental variables that are likely influencing the amount of available water to the system. The report recommended pump testing on the production wells to assess the capacity of the wells and aquifer that surrounds the wells.

In July 2015 GW Solutions conducted a pump test on the primary groundwater well, (well #4), while monitoring water levels in the production wells, two test wells in the Oyster Park, the Oyster River infiltration gallery and the Evans farm well. Testing of the well was conducted at the height of the summer and dry season to best determine the ultimate capacity of the well.

The results of the pump testing and groundwater monitoring were that the capacity of well #4 has declined since it was put into service and cannot on its own provide the maximum day demand required by the system. As well as the changes in climate that have resulted in reduced source water supply, bio-fowling of the wells has contributed to a slow decline in their production capacity.

While there was no appreciable interference between the production wells and the farm well, a small but measurable connection with the Oyster River infiltration gallery was observed.
As a result of the testing, it was discovered that pumping both production wells, (#1 and #4) at the same time actually reduces the net amount of water that can be pumped from the wells as compared to just pumping from well #4.

The current maximum day demand for the BCOB system is approximately 2,000 cubic metres a day. Based on the data collected during the pump test of well #4 and projecting that analysis forward using well #1, the two wells can only supply 40 per cent of the maximum day demand for the BCOB water system.

In order to meet the demand needs of the BCOB system during the summer months it will be necessary to combine the water from well #4 with the surface water from the Oyster River infiltration gallery at the same time.

The Oyster River infiltration gallery has not yet been evaluated to assess its capacity. The evaluation criteria for a surface water river intake is slightly different than a groundwater well and capacity/yield assumptions for the Oyster River intake cannot be projected using the information from the well #4 pump test.

In order to determine the current capacity of the BCOB water system, a pump test and assessment report of the Oyster River infiltration gallery and well# 1 will need to be completed. Findings from this testing will better enable the CVRD to understand what supply deficiencies if any we have in the system.

GW Solutions provided the following recommendations in an effort to maximum the capacity of the current system, regain additional capacity within the current wells, and explore additional source water supplies:

1) Pump test well #1 and the Oyster River infiltration gallery.
2) Rehabilitate wells #1 and #4 by way of scrubbing and water jetting to regain some of the capacity within the wells that has been lost over the years.
3) Conduct a ground penetrating radar (GPR) survey within the Oyster River Regional Park to identify areas best suitable for well drilling locations.
4) Drill two new wells based on locations identified in the GPR survey.

It is also felt that a better understanding of the capacity of the infiltration gallery is essential in determining the total future water capacity for the system.

**Options**

The committee has the following options:

1. Proceed with tasks 1-2 as described above.
2. Proceed with tasks 1-4 as described above.
3. Not proceed with any further testing or well development.

In order to ensure long term adequate supply of safe drinking water for both domestic and fire protection purposes and maintain the current rate structure, option 1 is recommended.

**Financial factors**

Effective July 2015, an increase to both the user fees and parcel tax rates was adopted by the CVRD board at the March 24, 2015 meeting. There are no available funds in the 2015 BCOB budget to complete any further hydrogeological testing this year, however $27,000 of funding for this work will be included in the preliminary 2016-2020 financial plan.

**Legal factors**

If an increase to rates is required, Bylaw No. 5 will require an amendment in order to change the water rates in the service area and/or Bylaw No. 93 will require an amendment to change the parcel tax rate in 2016.

**Sustainability implications**

Water conservation measures are in line with the goals and objectives of the Comox Valley sustainability strategy which includes goals for addressing water conservation and efficiency and targets for reducing household consumption.

**Intergovernmental factors**

Water conservation bylaws with watering restrictions have been developed and implemented by the City of Courtenay, the Town of Comox and all remaining CVRD water local services areas.

**Interdepartmental involvement**

Staff from the engineering department have been leading this work with assistance from the communications department promoting water awareness and conservation throughout the BCOB community.

**Citizen/public relations**

There has been significant feedback from residents in the BCOB community about water issues and the recent decline in our source water. The CVRD recognizes the need to gain public support in order to be successful in protecting water resources and achieving conservation goals.

Prepared by:

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Dave Leitch, AScT
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Concurrence:

***M. Rutten***

Marc Rutten, P.Eng.
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Attachment: Appendix A – "Black Creek - Oyster Bay Water System – Groundwater Asset Characterization"

# MEMO

FROM: Dr. Gilles Wendling
TO: David Leitch, Senior Manager of Water and Wastewater & Mike Hershmiller, Manager of Water Services
DATE: September 21, 2015
SUBJECT: Black Creek - Oyster Bay Water System – Groundwater Asset Characterization

As part of the work plan proposed by GW Solutions Inc. (GW Solutions) and approved by the client, GW Solutions has designed and supervised 24-hour pumping test on CVRD Well #4 of the Black Creek-Oyster Bay (BCOB) water system, located in Oyster River Regional Park.

## Black Creek - Oyster Bay Water System Wells and Locations

The goal of this work was to establish a baseline for the water table, and to assess the 2015 well performance and aquifer conditions using a 24-hour pumping test. During the pumping test, water levels were measured at five locations, including two BCOB production wells (PW1 and PW 2), two test wells (TW07-1 and TW07-2), and the Oyster River intake (River Station) (Figure 1).

**Table 1 - Well names and monitoring locations during test.**

| CVRD Name | Test Name | Test Role |
|---|---|---|
| Well #1 | PW1 | Monitoring |
| **Well #4** | **PW2** | **Pumping** |
| Well #2 | River Station | Monitoring |
| 2007 Test Well #1 | TW07-1 | Monitoring |
| 2007 Test Well #2 | TW07-2 | Monitoring |

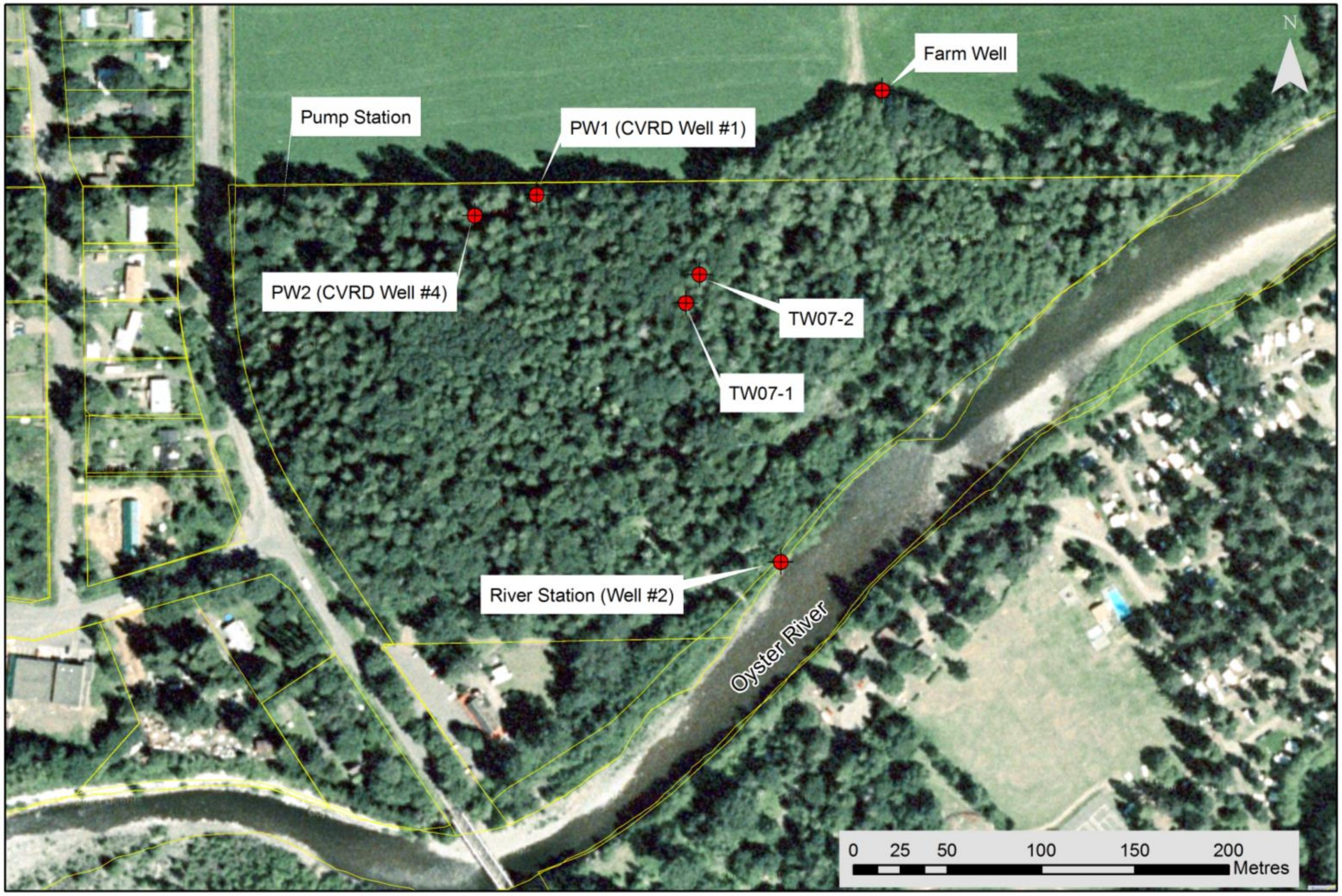


**Figure 1. - Well locations and names at the Black Creek - Oyster Bay water production area at Oyster River Regional Park**

## Constant rate pumping test

The 24-hour pumping test was commenced on July 15th, 2015 at 14:00. For the duration of the test, PW2 was pumped at a rate of 80 $m^3$ per hour (352 USgpm), which is slightly less than the peak demand of the BCOB water system recorded in recent years of approximately 2000 $m^3$ per day (367 USgpm). All of the water produced during the pumping test was stored in the CVRD reservoir.

**Table 2 - Black Creek-Oyster Bay water system daily demand and pumping rates.**

| **Daily Demand ($m^3$/day)** *(Rounded to neared 10)* | **Pump Setting ($m^3$/hour)** | **Equivalent L/s** | **Equivalent USgpm** | **Pumping** | **Rating for:** |
|---|---|---|---|---|---|
| 840 | 34.9 | 9.7 | 154 | PW1 + PW2 | PW2 - 2004 safe yield if pumped in conjunction with PW1 (CVRD Well #4) (EBA, 2004) |
| 1280 | 53.3 | 14.8 | 235 | PW2 | PW2 when pumping alone (EBA, 2004) |
| 1570 | 65.5 | 18.2 | 289 | PW1 | PW1 - 2004 safe yield if pumped in conjunction with PW2 (CVRD Well #4) (EBA, 2004) |
| 2400 | 100 | 18.2 + 9.7= 27.9 | 442 | PW1 + PW2 | Combined rate when pumping PW1 and PW2 (EBA, 2004) |
| 2000 | 83.3 | 23.1 | 367 | - | Maximum daily demand (2013-2014) |
| **1920** | **80** | **22.2** | **352** | **PW2** | **PW2 pumping rate for this test** |

Groundwater levels were monitored in the pumping well (PW2) as well as three other nearby wells (PW1, TW07-1, and TW07-2). Oyster River levels were monitored at the Oyster River intake (River Station) (Figure 2). The pumping of PW2 during the test affected all other wells monitored, and the drawdown measured at each of the monitoring locations decreased with distance from the pumping well. Pumping of PW2 created 1.5 m of induced drawdown in PW1, whereas induced drawdown at TW07-1 and TW07-2 was 28 cm and 35 cm, respectively. After 24 hours, water levels in PW2 had dropped 4.3 m below the initial, pre-test level.

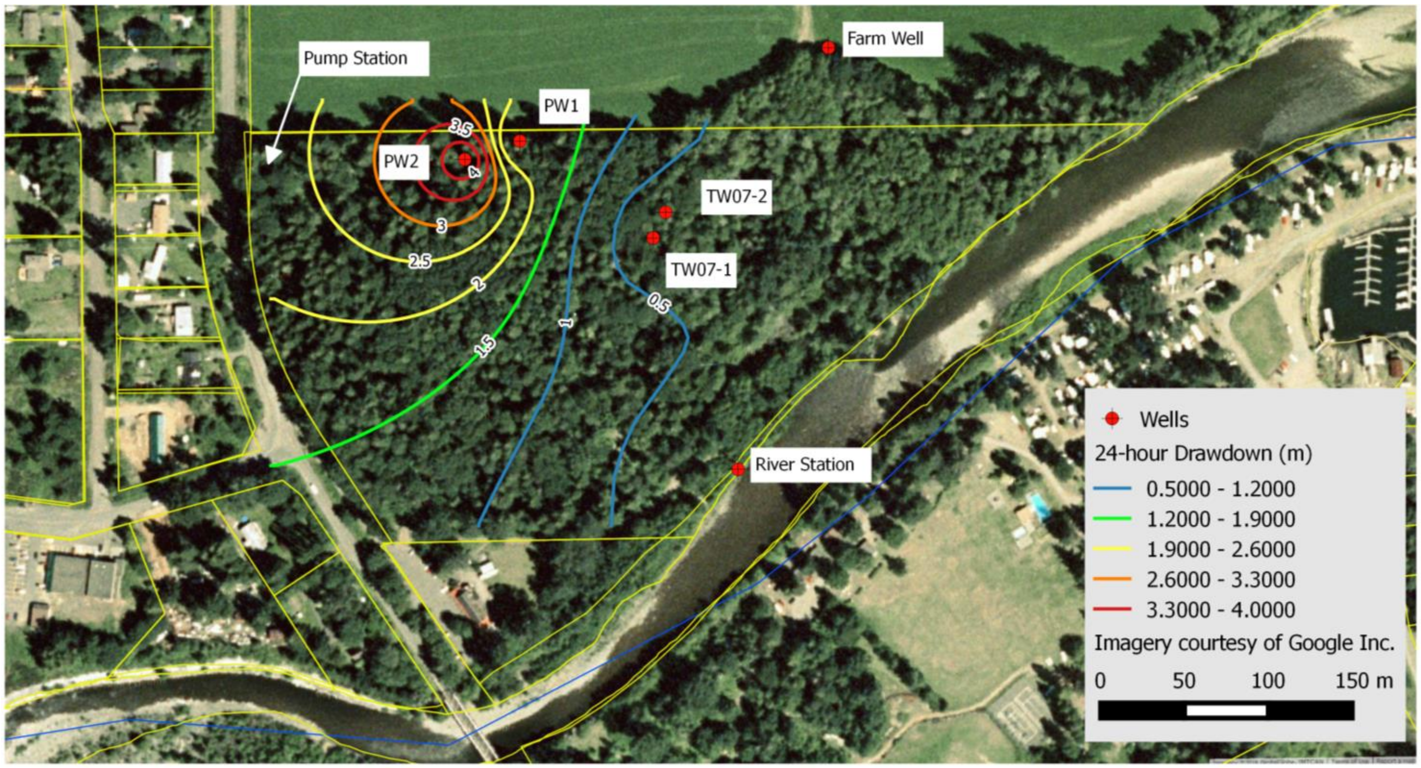


**Figure 2. Drawdown contours interpolated from water level data recorded during 24 hour pumping test.**

An hydraulic connection between PW2 and the river is indicated by a slight decrease in water levels at the river intake during the pumping of PW2, followed by an increase in river levels concurrent with pump shut-off (Figure 3). After pump shut-off, recovery was monitored in PW2. Although initially rapid, the recovery rate slowed considerably after one hour, and the well took approximately 6 hours to reach stable water levels, close to full recovery (100% recovery compared to pre-test water levels was not reached since the background water table was observed to be dropping over the time frame of the test and recovery period).

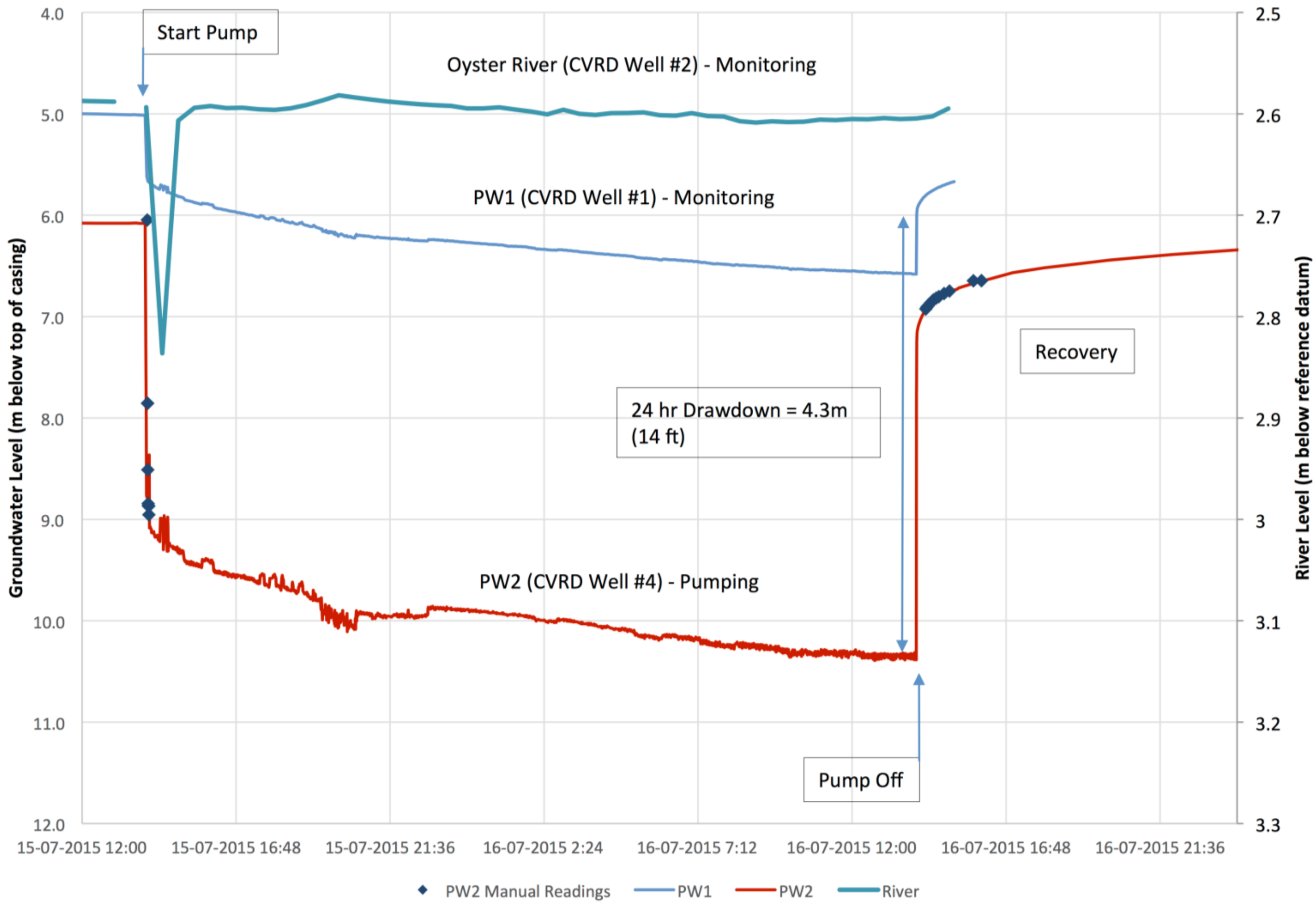


Figure 3 – 24-hour pumping test and recovery data.

## Well Interaction & Induced Drawdown

Water level data from the various monitoring stations illustrate the hydraulic connection between the various wells completed in the aquifer, as well as the connection between the aquifer and the Oyster River (Figure 4). A background trend of dropping water levels was observed at the river station and all wells. During the monitoring period of July 13$^{th}$ to July 21$^{st}$, 2015, water levels decreased by approximately 10 cm per week in the wells.

A pattern of daily drawdown and recovery was seen in water levels at TW07-1 and TW07-2 that was not seen in any of the other wells, or the river intake (Figure 4.). This pattern is likely indicative of localized interaction with the adjacent farm pumping well, located approximately 110 m to the northeast of TW07-1 and TW07-2 (Figure 2). The timing and frequency of the drawdown-recovery pattern in TW07-1 and TW07-2 is consistent with daily pumping and night time recovery of water levels. Induced drawdown in TW07-1 and TW07-2 from the farm well pumping over this period was on the order of 10 cm. Although the exact timing and pumping rates of the farm well were not investigated, the well is regularly pumped at rates in the order of 500 USgpm (2725 $m^3$/day, P. Evans, personal communication July 13, 2015)

These findings highlight the shared nature of the water resource in the vicinity of Oyster River Park. There is no appreciable interference between the adjacent well operated by the farm and those currently operated by the CVRD. Should the CVRD choose to drill additional wells in the area, it will be a challenge to choose a site that is outside of the radius of influence of either their existing production wells, or that of their neighbours.

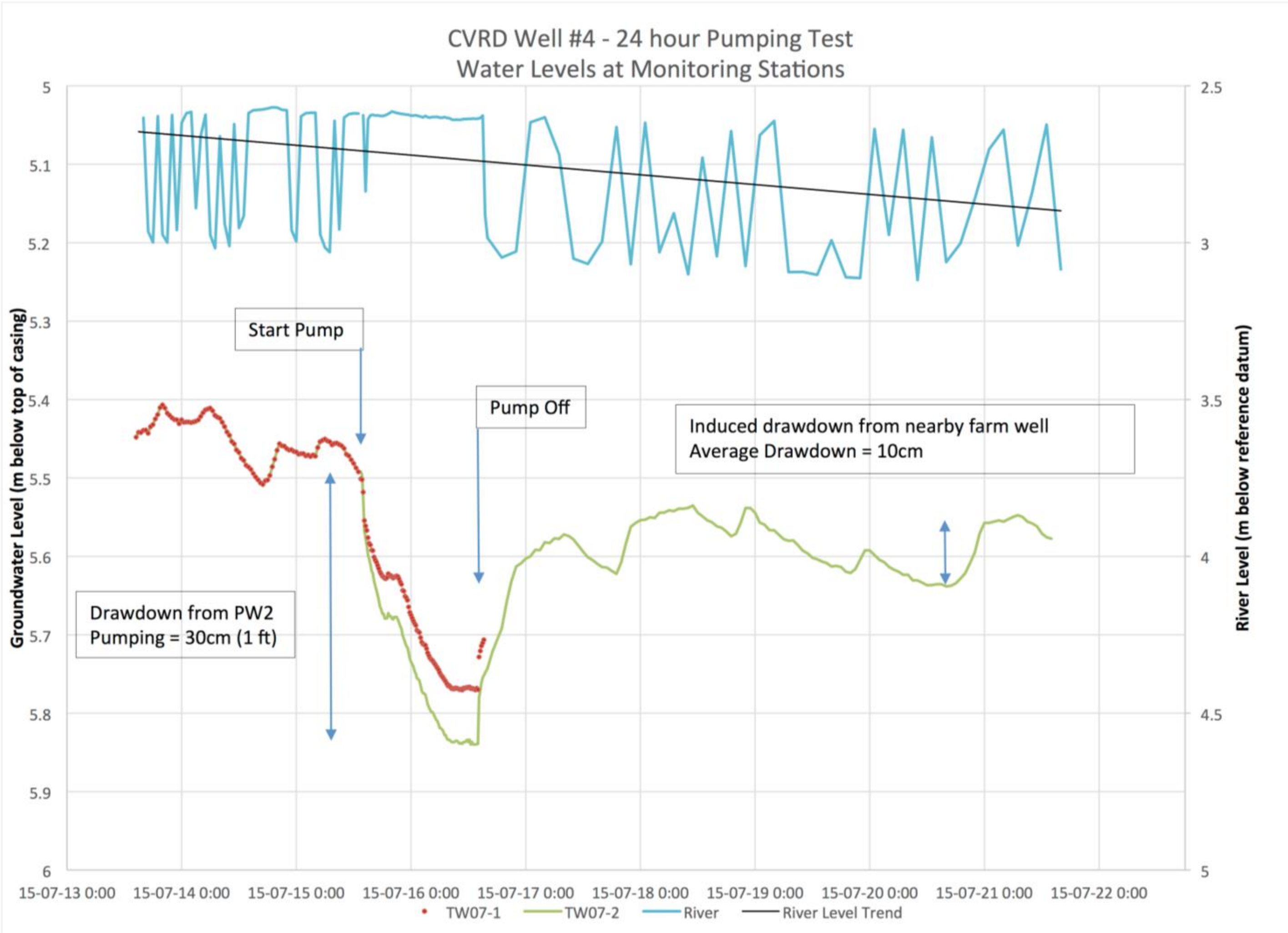


**Figure 4 - Water levels and monitoring stations during 24-hour pumping test and recovery.**

## Well Yield Rating

Wells in BC are rated following the "*Evaluating Long-term Well Capacity for a Certificate of Public Convenience and Necessity*" guidelines. In overburden wells, a pumping test of at least 24 hours is required. The method consists of projecting the time versus drawdown data to 100 days – a period of time over which it is assumed that no recharge will occur. Figure 5 shows the drawdown for the 2003 and 2015 testing of PW2, together with pumping rates and extrapolated 100-day drawdown values for each test.

Using July 2015 drawdown data from the pumping well (PW2) and induced drawdown data from PW1, aquifer parameters of transmissivity and storativity were computed using AquiferTest software (Schlumberger, 2015).

During the July 15-16 2015 pumping test on PW2, the pumping rate of 352 USgpm (80$m^3$ per hour) produced the following drawdown thresholds:

- Within 10 minutes of the pump start, the water level dropped below the screen intake;
- After 24 hours, drawdown had reached 4.3 m, i.e. 40 cm above the pump assembly;
- Projecting forward, the top of the pump assembly would have been reached after 67 hours (2 days, 18 hours);
- The 100-day drawdown for PW2 pumped at 352 USgpm (80 $m^3$/hour) is projected to be 5.7 m.
- The induced drawdown in PW1 after 100-days of pumping PW2 at the above rate is projected to be 3.4 m

The specific capacity of a well is expressed as the discharge rate per meter of drawdown and is a reflection of the hydrological performance of the well and aquifer system. The specific capacity calculated from the 2003 and 2015 pumping tests of PW2, along with the percentage difference that has occurred over that time period are presented in Table 3. The calculated change and loss in specific capacity over the last 9 years is calculated to be -33%

**Table 3**

| Parameter | Unit | PW2 2003 | PW2 2015 | PW2 2015* |
|---|---|---|---|---|
| Pumping rate | USgpm | 275 | 352 | 275 |
| Drawdown (100 days) | m | 3.2 | 5.7 | 4.8 |
| Projected specific capacity (100 days) | USgpm/m | 85.9 | 61.8 | 57.3 |
| Specific capacity (metric) | L/s/m | 5.4 | 3.9 | 3.6 |

* Results using analytical model based on pumping at the higher rate of 352 USgpm.

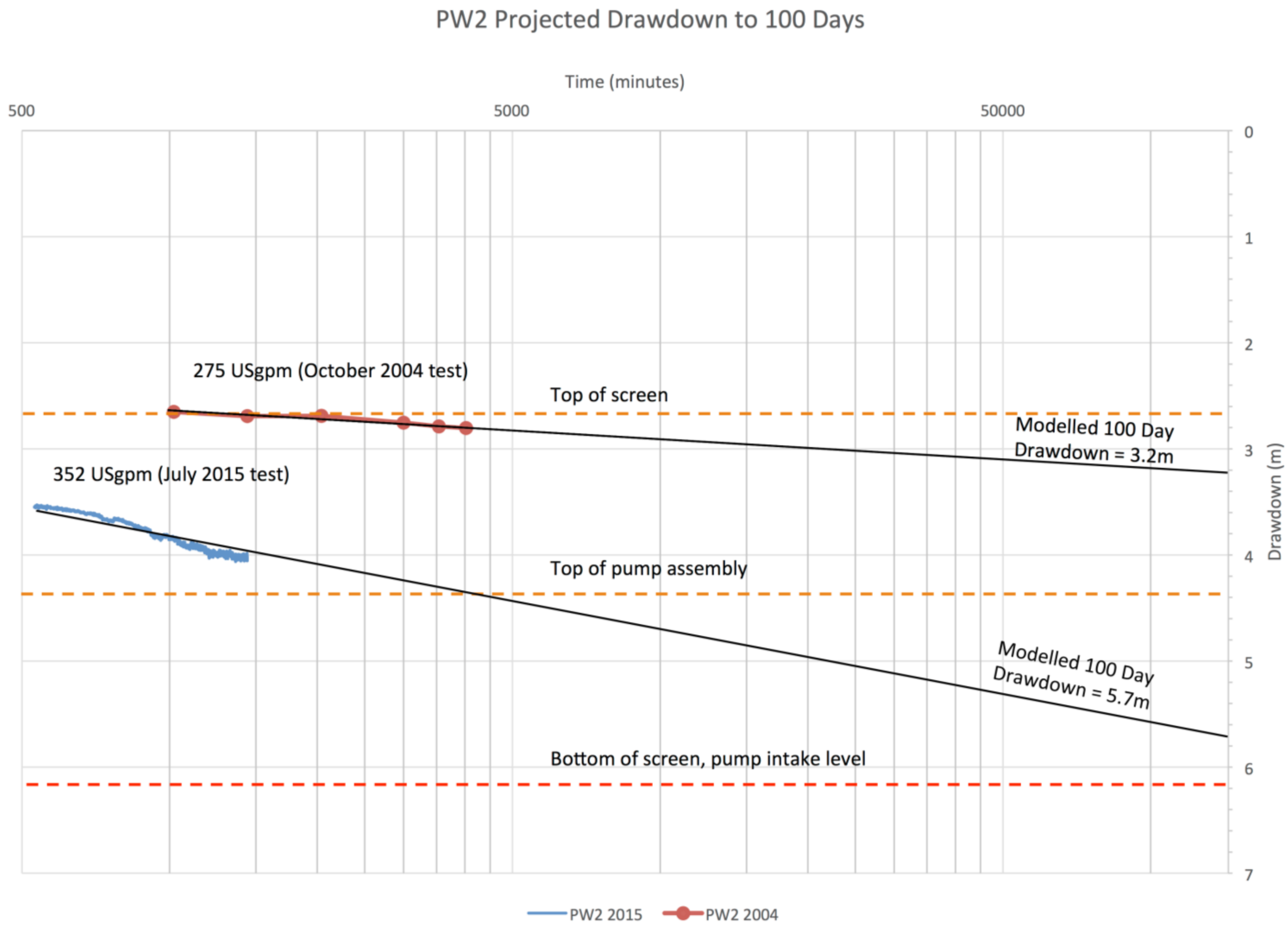


**Figure 5. Extrapolated 100-day drawdown in PW2 with pumping rates of 275 USgpm (EBA 2004) and 352 USgpm (GWS 2015)**

**Table 4. Yield calculations for PW1 and PW2 with no safety factor.**

| No Safety Factor | | | | | Pumped Together | |
|---|---|---|---|---|---|---|
| **Parameter** | **Unit** | **Key** | **PW2 Only** | **PW1 Only** | **PW2** | **PW1** |
| Specific capacity (metric) | L/s/m | a | 3.9 | 6.5 | 3.6 | 6.5 |
| Depth to top of screen (unconfined) | m | b | 7.47 | 9.11 | 7.47 | 9.11 |
| Stickup | m | c | 0 | 0 | 0 | 0 |
| "Static" water level (July average) | mbTOC | d | 4.71 | 5.03 | 4.71 | 5.03 |
| Seasonal impact | m | e | 1 | 1 | 1 | 1 |
| Impact from nearby wells | m | f | 0 | 0 | 1 | 1 |
| Safety factor (0%) | | g | 1 | 1 | 1 | 1 |
| Available drawdown | m | h = b+c-d-e | 1.76 | 3.08 | 0.76 | 2.08 |
| Available drawdown | m | i = g x h | 1.76 | 3.08 | 0.76 | 2.08 |
| Estimated sustainable yield | L/s | j = a x i | 6.9 | 20.0 | 2.7 | 13.5 |
| Aquifer estimated sustainable yield | USgpm | | 109 | 317 | 44 | 214 |
| Maximum recommended yield | $m^3$/hour | | 25 | 72 | 10 | 49 |
| Daily Demand | $m^3$/day | | 588 | 1728 | 1404 | |
| Peak Demand Shortfall | | | 1412 | 272 | 596 | |

Note that the rating listed in Table 4 (for each individual well, column 4 and 5) does not take into account any safety factor for the water column and assumes that the pumping level corresponds to the top of the screen.

### Table 5. Yield calculations for PW1 and PW2 with a 30% Safety Factor

| | | | | | Pumped Together | |
|---|---|---|---|---|---|---|
| **Parameter** | **Unit** | **Key** | **PW2 Only** | **PW1 Only** | **PW2** | **PW1** |
| Pumping rate | Usgpm | | 352 | 350 | 275 | 350 |
| Drawdown (100 days) | m | | 5.7 | 3.4 | 4.8 | 3.4 |
| Projected specific capacity (100 days) | Usgpm/m | | 61.8 | 102.9 | 57.3 | 102.9 |
| Specific capacity (metric) | L/s/m | a | 3.9 | 6.5 | 3.6 | 6.5 |
| Depth to top of screen (unconfined) | m | b | 7.47 | 9.11 | 7.47 | 9.11 |
| Stickup | m | c | 0 | 0 | 0 | 0 |
| "Static" water level (July average) | mbTOC | d | 4.71 | 5.03 | 4.71 | 5.03 |
| Seasonal impact | m | e | 1 | 1 | 1 | 1 |
| Impact from nearby wells | m | f | 0 | 0 | 1 | 1 |
| Safety factor (30%) | | g | 0.7 | 0.7 | 0.7 | 0.7 |
| Available drawdown | m | h = b+c-d-e | 1.76 | 3.08 | 0.76 | 2.08 |
| Safe available drawdown | m | i = g x h | 1.23 | 2.16 | 0.53 | 1.46 |
| Safe estimated sustainable yield | L/s | j = a x i | 4.8 | 14.0 | 1.9 | 9.5 |
| Safe aquifer estimated sustainable yield | USgpm | | 76 | 222 | 30 | 150 |
| Maximum recommended yield | $m^3$/hour | | 18 | 51 | 7 | 34 |
| Daily Demand | $m^3$/day | | 420 | 1212 | 984 | |
| Peak Demand Shortfall | | | 1580 | 788 | 1016 | |

**Table 6. Yield calculations for PW1 and PW2 with a 33% drop in PW1 specific capacity and no safety factor.**

| Parameter | Unit | Key | PW2 Only | PW1 Only | Pumped Together PW2 | Pumped Together PW1 |
|---|---|---|---|---|---|---|
| Specific capacity (metric) | L/s/m | a | 3.9 | 4.4 | 3.6 | 4.4 |
| Depth to top of screen (unconfined) | m | b | 7.47 | 9.11 | 7.47 | 9.11 |
| Stickup | m | c | 0 | 0 | 0 | 0 |
| "Static" water level (July average) | mbTOC | d | 4.71 | 5.03 | 4.71 | 5.03 |
| Seasonal impact | m | e | 1 | 1 | 1 | 1 |
| Impact from nearby wells | m | f | 0 | 0 | 1 | 1 |
| Safety factor (0%) | | g | 1 | 1 | 1 | 1 |
| Available drawdown | m | h = b+c-d-e | 1.76 | 3.08 | 0.76 | 2.08 |
| Available drawdown | m | i = g x h | 1.76 | 3.08 | 0.76 | 2.08 |
| Estimated sustainable yield | L/s | j = a x i | 6.9 | 13.4 | 2.7 | 9.1 |
| Aquifer estimated sustainable yield | USgpm | | 109 | 212 | 44 | 143 |
| Maximum recommended yield | $m^3$/hour | | 25 | 48 | 10 | 33 |
| Daily Demand | $m^3$/day | | 588 | 1152 | 1020 | |
| Peak Demand Shortfall | | | 1412 | 848 | 980 | |

**Table 7. Yield calculations for PW1 and PW2 with a 33% drop in PW1 specific capacity and a 30% safety factor.**

| | | | | | Pumped Together | |
|---|---|---|---|---|---|---|
| **Parameter** | **Unit** | **Key** | **PW2 Only** | **PW1 Only** | **PW2** | **PW1** |
| Specific capacity (metric) | L/s/m | a | 3.9 | 4.4 | 3.6 | 4.4 |
| Depth to top of screen (unconfined) | m | b | 7.47 | 9.11 | 7.47 | 9.11 |
| Stickup | m | c | 0 | 0 | 0 | 0 |
| "Static" water level (July average) | mbTOC | d | 4.71 | 5.03 | 4.71 | 5.03 |
| Seasonal impact | m | e | 1 | 1 | 1 | 1 |
| Impact from nearby wells | m | f | 0 | 0 | 1 | 1 |
| Safety factor (30%) | | g | 0.7 | 0.7 | 0.7 | 0.7 |
| Available drawdown | m | h = b+c-d-e | 1.76 | 3.08 | 0.76 | 2.08 |
| Safe available drawdown | m | i = g x h | 1.23 | 2.16 | 0.53 | 1.46 |
| Safe estimated sustainable yield | L/s | j = a x i | 4.8 | 9.4 | 1.9 | 6.3 |
| Safe aquifer estimated sustainable yield | USgpm | | 76 | 149 | 30 | 100 |
| Maximum recommended yield | $m^3$/hour | | 18 | 34 | 7 | 23 |
| Daily Demand | $m^3$/day | | 420 | 816 | 720 | |
| Peak Demand Shortfall | | | 1580 | 1184 | 1280 | |

## Well Efficiency

As a well is pumped, the water level (available head) in the well drops as a result of head loss in the aquifer (aquifer losses), and head loss in the aquifer near the well screen (radius of typically less than 2 m), and through the screen itself (well losses), due to higher flow velocity in this zone . Higher pumping rates increase the velocity of water entering the well screen, thereby producing higher velocity flow, resulting in even greater well losses.

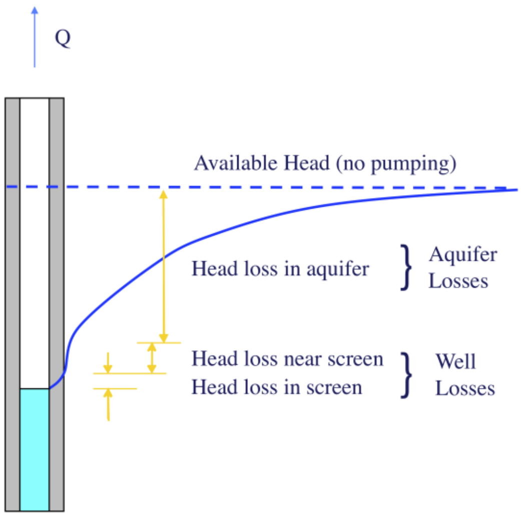


**Figure 6. Available head loss in a pumping well is the result of aquifer losses and well losses.**

The efficiency of a well is a measure of the percentage of aquifer head losses to total head losses (measured drawdown). Well efficiency is calculated using the following equation:

$$well\ efficiency\ (\%) = \frac{aquifer\ head\ loss}{aquifer\ head\ loss + well\ head\ loss} \times 100$$

Aquifer losses can be determined using drawdown data obtained from three or more steps of varying pumping rates. Using the aquifer parameters of transmissivity and storativity computed from the 2015 drawdown data of PW2 and PW1, we modeled the projected 100-day drawdown that would likely be obtained under different pumping rates (Figure 7). The results were used to calculate the coefficients for well losses and aquifer losses for PW2 and PW1 under different pumping rates. From this, we determined that PW2 is operating at an efficiency higher than 63% when pumping at a rate lower than its original rating of 275 USgpm (63 $m^3$/hour) (Figure 8). When pumped at the test rate of 352 USgpm, the drawdown observed in PW2 is due 57% to the aquifer material (aquifer losses) and 43% related to well construction and/or completion. Well losses increase significantly in PW2 at pumping rates greater than 200 USgpm (45 $m^3$/hour), i.e. rates capable of meeting a daily demand above approximately 1,100 $m^3$.

PW1 is operating at an efficiency higher than 66% when pumping at a rate lower than 300 USgpm (68 $m^3$/hour) (Figure 9). However, well losses increase significantly (and well efficiency decreases) in PW1 at pumping rates greater than 250 USgpm (57 $m^3$/hour), i.e. rates capable of meeting a daily demand above approximately 1,400 $m^3$.

From this analysis, we conclude that neither PW1 nor PW2 is capable of meeting peak summer demand of 2,000 $m^3$/day.

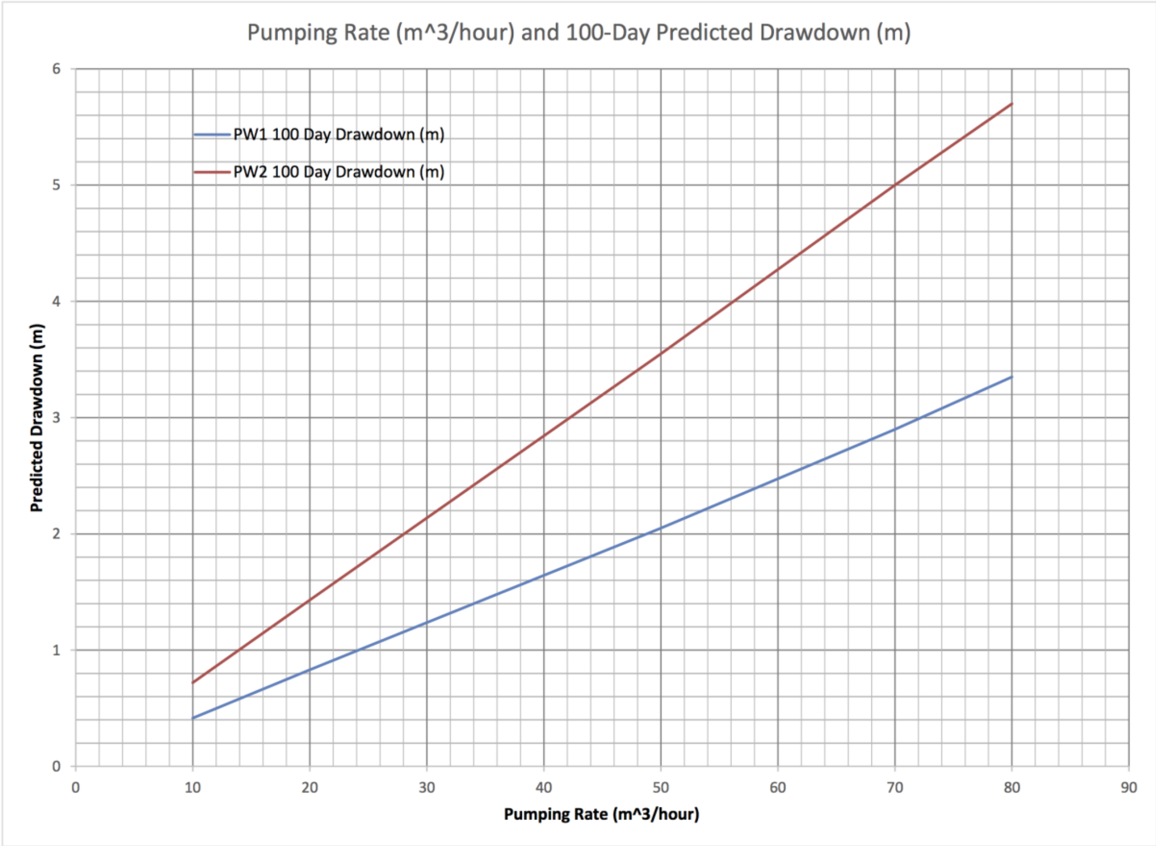


**Figure 7. Pumping rates and 100-day predicted drawdown for PW1 and PW2.**

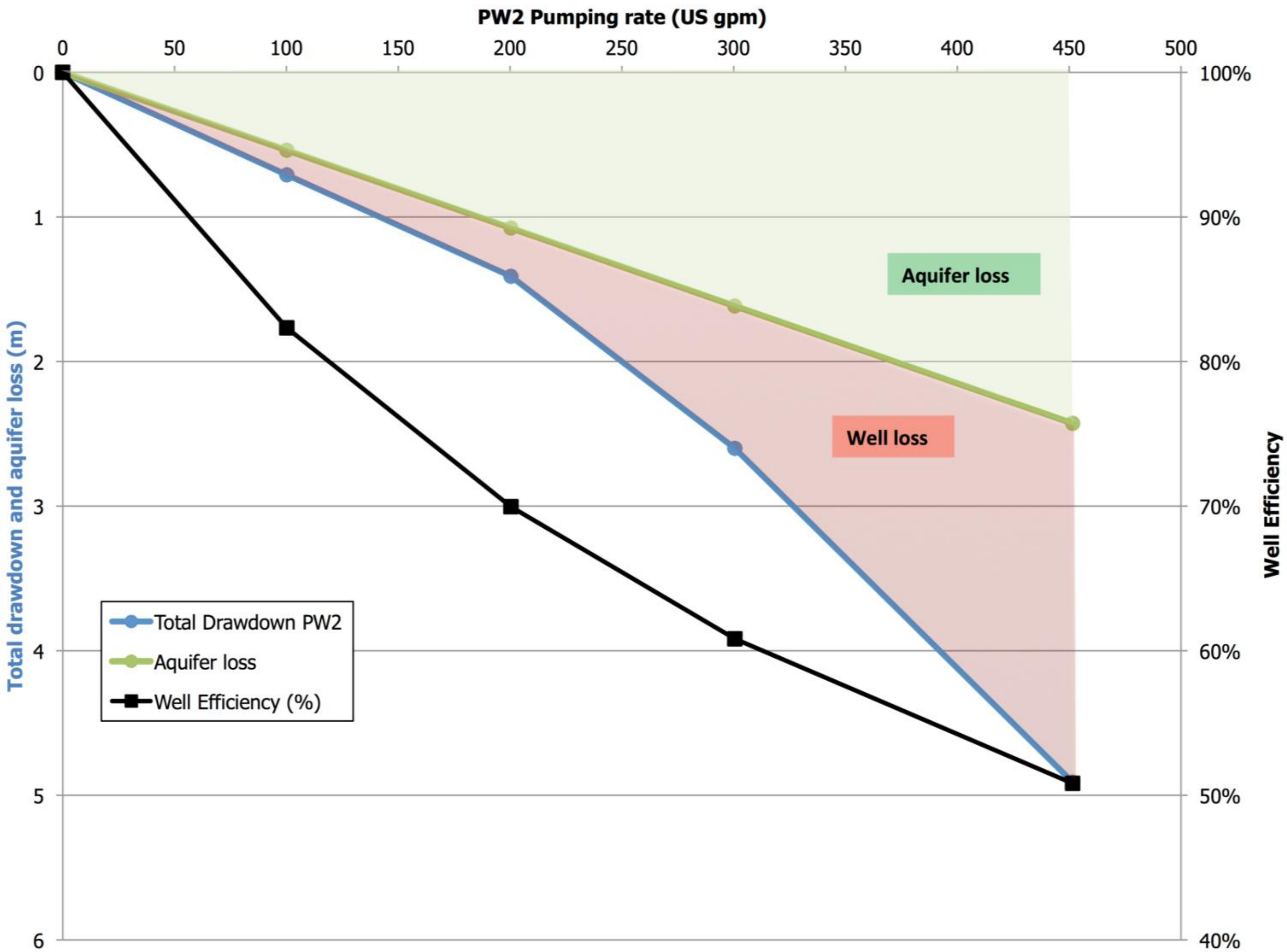


Figure 8. PW2 aquifer losses, well losses and well efficiency.

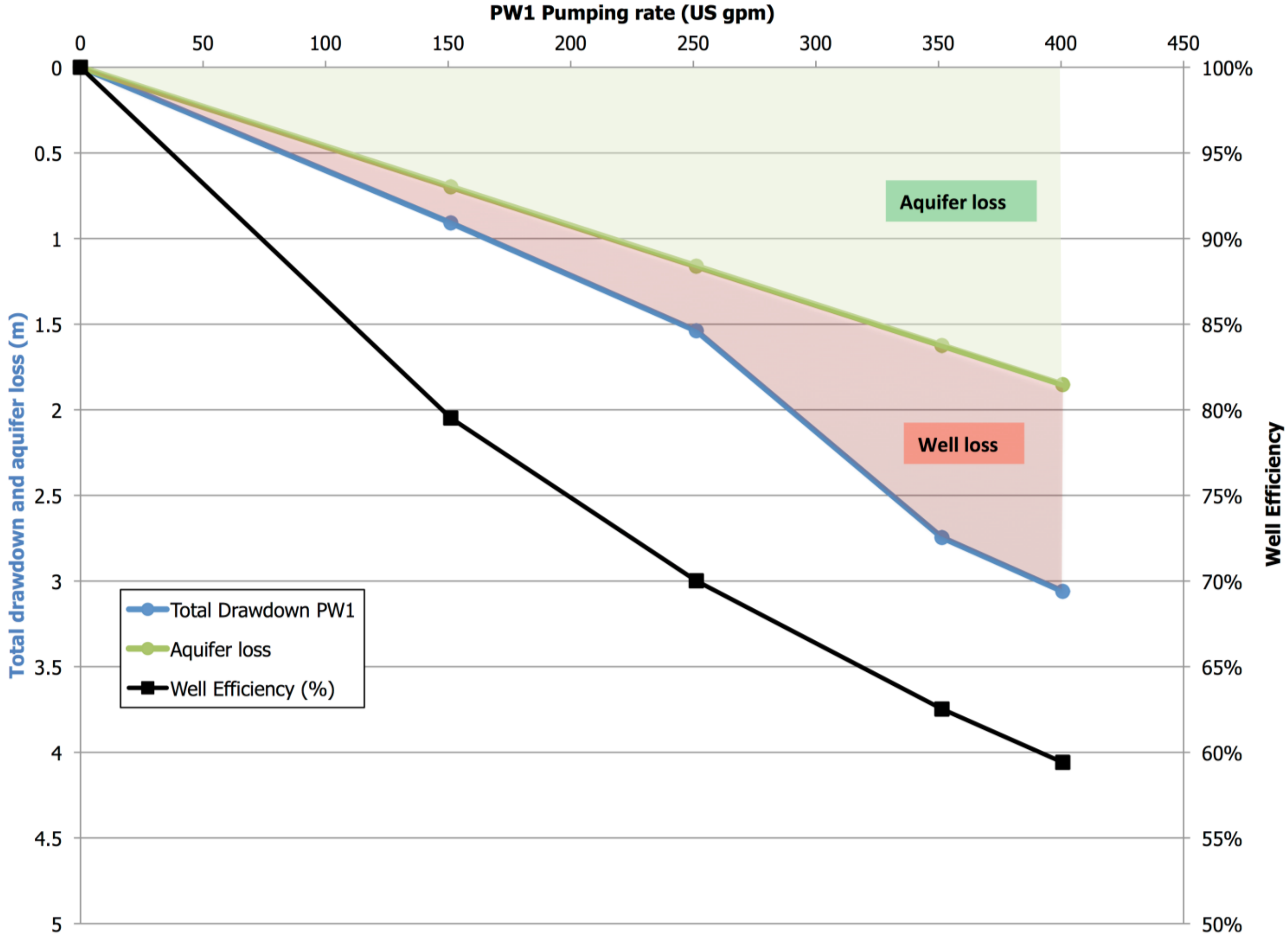


**Figure 9. PW1 aquifer losses, well losses and well efficiency**

## Conclusions

**Operational Water Levels**

Biological incrustation (“bio-fouling”) resulting from bacteria growth can reduce the pore spaces in both the well screen and surrounding aquifer material. In turn, reduced pore spaces will increase groundwater entrance velocity, turbulence and therefore increase drawdown in the well. Regular cycling of water levels to levels below the top of screen can increase the likelihood of biological incrustation in a well. Moderate levels of encrustation was observed in the video inspection of PW1, conducted June 1, 2015 by Drillwell Entreprises Ltd.

> **In order to minimize negative potential impacts to the screen and adjacent aquifer material during regular pumping, water levels in PW1 and PW2 should always be maintained above the top of their screen.**

The wells have likely been operated at rates that generate drawdown to within the screened section. This should be avoided since it will result in a lower available yield from the well.

**Yield Ratings**

The sustainable well yield ratings for PW2 have been downgraded in 2015 from the original 2004 rating of 63 $m^3$/hour (275 USgpm) to approximately 18 $m^3$/hour (90 USgpm), taking into account a 30% safety factor.

The sustainable well yield ratings for PW1 is estimated at 51 $m^3$/hour (242 USgpm), taking into account a 30% safety factor, and based on 2003 pumping test data. A pumping test should be completed on this well to estimate its efficiency loss since the last time it was tested (2003).

Taking into account well interference (estimated at 1 m), the maximum combined yield of the wells is 1400 $m^3$/d, the estimated peak demand for the system being approximately 2,000 $m^3$/d. This does not take into account any safety factor and assumes the drawdowns extend to the top of the screens. The combined estimated yield of the wells (safe yield) drops to 980 $m^3$/d if a 30% safety factor is applied.

**Table 8. Recommended yields and operational assumptions for PW1 and PW2.**

| Operational Assumptions | Parameter | Unit | PW2 Only | PW1 Only | Pumped Together PW2 | Pumped Together PW1 |
|---|---|---|---|---|---|---|
| No Safety Factor | Maximum recommended yield | $m^3$/hour | 25 | 72 | 10 | 49 |
| | Daily Demand | $m^3$/day | 588 | 1728 | 1404 | |
| 30% Safety Factor | Maximum recommended yield | $m^3$/hour | 18 | 51 | 7 | 34 |
| | Daily Demand | $m^3$/day | 420 | 1212 | 984 | |
| 33% Drop in Well Specific Capacity (PW1) and No Safety Factor | Maximum recommended yield | $m^3$/hour | 25 | 48 | 10 | 33 |
| | Daily Demand | $m^3$/day | 588 | 1152 | 1020 | |
| 33% Drop in Well Specific Capacity (PW1) and 30% Safety Factor | Maximum recommended yield | $m^3$/hour | 18 | 34 | 7 | 23 |
| | Daily Demand | $m^3$/day | 420 | 816 | 720 | |

As of summer 2015, even without the applied safety factors, the BCOB wells are not expected to meet maximum daily demand from the water system of 2,000 $m^3$ per day. A low water table during the dry season reduces the available water column above the screened interval, thereby significantly reducing the available drawdown and recommended pumping rates of both wells. Since well-to-well interference further reduces the available drawdown, pumping both wells during the dry season conditions actually results in a diminished sustainable, combined yield.

> **If it is deemed necessary to pump groundwater during the dry season (June 1 to November 1), we recommend operating PW1 alone, never in concert with PW2.**

Well interference is likely less of a factor during the wet season, when the water table is high and demand is less. The current pumping well configuration of 2 wells in close proximity, while evidently adequate in design to meet wet season demand, is not recommended for combined pumping under dry season conditions. To meet BCOB summertime demand from groundwater, an additional well will have to be drilled that is outside of the effective radii of influence of the two CVRD pumping wells PW1 and PW2, as well as that of the farm well.

**Baseline Water Levels**
Water levels monitored throughout Oyster River Park before, during and after the July 15th pumping test of PW2 indicate that groundwater levels were dropping by approximately 10 cm per week. Water levels in PW1 and PW2 measured in July 2015 were very close to levels recorded at the end of the dry season in October 2003 -the only historical water level data available at the time of writing. Should drought conditions continue in 2015, we can anticipate lower static levels by the end of the 2015 dry season, with levels up to approximately 1 m below those recorded in recent years. This will reduce even more the capacity of the wells as their rating is a function of the available water column (Item “d” in Tables 4 through 7).

**Well Interaction**
GW Solutions could find no appreciable interference between the adjacent farm well and the wells currently operated by the CVRD. Well interference was observed at TW07-1 and TW07-2 resulting from pumping of PW2 and pumping at the farm well. Should the CVRD decide to drill additional production wells at Oyster River Park, areas outside of the zone of influence of their existing production wells and of the adjacent farm well should be targeted.

**Oyster River Interaction**
River water levels recorded during the pumping test of PW2 indicate that there is a small but measureable connection between pumping of PW2 and the Oyster River.

## Recommendations

As of writing, the CVRD had installed a new pump in PW1, purchased and installed water level probes in each production well, and purchased a manual water level meter for operations staff to periodically monitor groundwater levels. Completing the pumping test of PW1 and the River Well should be conducted before the winter (wet season). In addition, both wells (PW1 and PW2) should be rehabilitated. GW Solutions proposes the following actions be taken:

1. Conduct a 24-hour pumping test on both PW1 (Well #1) and the River Well infiltration gallery. This will provide a 2015 specific capacity and safe yield for PW1, and an estimated efficiency rating for the infiltration gallery. Monitoring of Oyster River levels during pumping test of PW1, as was done during the pumping test of PW2, will assist the CVRD in meeting the new Groundwater Licensing requirements under the Water Act by assessing the hydraulic connection between groundwater and surface water. Total cost for testing, data interpretation and reporting is approximately $8,000.
2. Rehabilitate the BCOB production wells using standard techniques of scrubbing and water jetting through the well screen. This work would be completed by a drilling contractor with suitable equipment. Well rehabilitation will help diminish the biofouling that has accumulated in the wells, as observed in the video inspection of PW1 conducted June 1, 2015. Biofouling is likely contributing the drop in specific capacity observed in PW2. Projected cost of remediation of both production wells is approximately $19,000.

The Black Creek-Oyster Bay water system currently cannot meet peak demand from groundwater alone. GW Solutions recommends that the CVRD secure a new production well as early as fall 2015. Groundwater Licensing requirements under the BC Water Sustainability Act will take effect early in 2016. All existing non-residential groundwater users will be required to assess, among other things, the potential impacts of their groundwater use on environmental flow needs, other groundwater users, and evaluate potential hydraulic connectivity to surface water. Any work completed before the implementation of the new regulations should represent less effort and cost. Therefore, we are recommending the following:

3. Use geophysical methods to delineate coarser-grained aquifer materials in the subsurface ahead of drilling any new test wells. Given the heterogeneity of the coarser-grained aquifer material at the Oyster River site, and the expense of targeting the aquifer by drilling test wells, conducting geophysical survey in advance of drilling will increase the likelihood of successfully targeting areas suitable for new production wells. GW Solutions recommends a one-day survey of the site using ground-penetrating radar (GPR), which will be tied to existing wells with known hydrogeological properties. Projected cost of the GPR survey and data interpretation is approximately $6,000.
4. Based on the results of the GPR survey, identify drilling locations that offer high aquifer potential and minimal interference with existing production wells, and the adjacent farm well. Target locations will be reviewed with respect to the new Groundwater At Risk of Pathogens (GARP) guidelines developed through the Drinking Water Protection Regulations and the BC the Ministry of Health.

5. GW Solutions proposes to supervise and drill two 6-inch test wells based on locations evaluated in the preceding steps. If the aquifer conditions encountered in the test wells are deemed to be sufficiently productive, we will supervise the drilling of a new 10-inch production well for the Black Creek Oyster Bay water system. Costs associated with drilling and completing new wells are projected to be approximately $ 10,000 each for the 6-inch test wells and $ 24,000 for the 10-inch production well. The cost of the pumping test will be determined once the location and design of the production well are known.
6. GW Solutions recommends that the results of the work completed to date, as well as what is recommended, be presented through a series of slides to the CVRD board of directors, during a delegation. GW Solutions would be happy to present and this will be complimentary.

## Closure

Conclusions and recommendations presented herein are based on available information at the time of the study. The work has been carried out in accordance with generally accepted engineering practice. No other warranty is made, either expressed or implied. Engineering judgment has been applied in producing this memo. This memo was prepared by personnel with professional experience in the fields covered. Reference should be made to the General Conditions and Limitations attached in Appendix 1.

GW Solutions was pleased to produce this document. If you have any questions, please contact me.

Yours truly,
**GW Solutions Inc.**

Gilles Wendling, Ph.D., P.Eng.
**President**

Matt Vardal, MSc.,
**Project Hydrogeologist**

# Appendix 1: Black Creek-Oyster Bay Groundwater Asset – Projected Costs Table
## Testing, rehabilitation and new groundwater resource development

| Task | GW 215 | MV 140 | Fees | Expenses | Contractors | Total Cost |
|---|---|---|---|---|---|---|
| **Production Well Rating and Rehabilitation** | | | | | | |
| Task 1 – Update Production Well Ratings | | | | | | |
| Task 1b - 24-hour pumping test on Production Well 1 | 1 | 16 | $2,455 | $100 | TBD | $2,555 |
| Task 1b - 24-hour pumping test on River Well | 1 | 16 | $2,455 | $100 | TBD | $2,555 |
| Task 1c - Data interpretation and Reporting on Specific Capacity and Safe Yield | 4 | 15 | $2,960 | | | $2,960 |
| Task 2 - Well Rehabilitation | | | | | | |
| Task 2a - Jetting, scrubbing and cleaning production wels PW1 and PW2 | 2 | 16 | $2,670 | | $16,000 | $18,670 |
| **Groundwater Resource Development** | | | | | | |
| Task 3 - Groundwater Exploration: Subsurface Mapping | | | | | | |
| Task 3a - Geophysical Survey (GPR) | | 10 | $1,400 | $100 | $3,400 | $4,900 |
| Task 3b - Model Optimal Well locations | | 6 | $840 | | | $840 |
| Task 4 - Drilling Program | | | | | | |
| Task 4a - Drill 6" Test Well 1 (20m deep) | 2 | 8 | $1,550 | $400 | $6,770 | $8,720 |
| Task 4b - Drill 6" Test Well 2 (20m deep) | 2 | 8 | $1,550 | $400 | $6,770 | $8,720 |
| Task 4c - Drill 10" Production Well 3 (20m deep) * | 2 | 12 | $2,110 | $400 | $18,665 | $21,175 |
| Task 5 - Well Testing Program | | | | | | |
| Task 5a - Step Test Production Well 3 ** | 1 | 10 | $1,615 | $100 | TBD | $1,715 |
| Task 5b - 24-hour Pumping Test Production Well 3 ** | 1 | 16 | $2,455 | $150 | TBD | $2,605 |
| Task 6 - Water Quality and Screen Design | | | | | | |
| Task 6a - Water Quality/Grain-Size Analysis Test Well 1 | 1 | 2 | $495 | $200 | $750 | $1,445 |
| Task 6b - Water Quality/Grain-Size Analysis Test Well 2 | 1 | 2 | $495 | $200 | $750 | $1,445 |
| Task 6c - Water Quality/Grain-Size Analysis Production Well 3 ** | 2 | 4 | $990 | $700 | $850 | $2,540 |
| Task 7 - Data interpretation and reporting | 6 | 24 | $4,650 | | | $4,650 |
| Project Management and Communication | 8 | 12 | $3,400 | | | $3,400 |
| | | | | | | |
| Subtotal | | | | | | $88,895 |
| Contingency (10%) | | | | | | $8,890 |
| **Total** | | | | | | $97,785 |

* Drilling of Production Well 3 contingent on aquifer conditions encountered in subsurface drilling of Test Well 1 and 2 (Tasks 4a and 4b)

** Contingent on Task 4c

## Appendix 2: GW Solutions Inc. – General Conditions and Limitations

This report incorporates and is subject to these “General Conditions and Limitations”.

**1.0 USE OF REPORT**
This report pertains to a specific area, a specific site, a specific development, and a specific scope of work. It is not applicable to any other sites, nor should it be relied upon for types of development other than those to which it refers. Any variation from the site or proposed development would necessitate a supplementary investigation and assessment. This report and the assessments and recommendations contained in it are intended for the sole use of GW SOLUTIONS’s client. GW SOLUTIONS does not accept any responsibility for the accuracy of any of the data, the analysis or the recommendations contained or referenced in the report when the report is used or relied upon by any party other than GW SOLUTIONS’s client unless otherwise authorized in writing by GW SOLUTIONS. Any unauthorized use of the report is at the sole risk of the user. This report is subject to copyright and shall not be reproduced either wholly or in part without the prior, written permission of GW SOLUTIONS. Additional copies of the report, if required, may be obtained upon request.

**2.0 LIMITATIONS OF REPORT**
This report is based solely on the conditions which existed within the study area or on site at the time of GW SOLUTIONS’s investigation. The client, and any other parties using this report with the express written consent of the client and GW SOLUTIONS, acknowledge that conditions affecting the environmental assessment of the site can vary with time and that the conclusions and recommendations set out in this report are time sensitive. The client, and any other party using this report with the express written consent of the client and GW SOLUTIONS, also acknowledge that the conclusions and recommendations set out in this report are based on limited observations and testing on the area or subject site and that conditions may vary across the site which, in turn, could affect the conclusions and recommendations made. The client acknowledges that GW SOLUTIONS is neither qualified to, nor is it making, any recommendations with respect to the purchase, sale, investment or development of the property, the decisions on which are the sole responsibility of the client.

**2.1 INFORMATION PROVIDED TO GW SOLUTIONS BY OTHERS**
During the performance of the work and the preparation of this report, GW SOLUTIONS may have relied on information provided by persons other than the client. While GW SOLUTIONS endeavours to verify the accuracy of such information when instructed to do so by the client, GW SOLUTIONS accepts no responsibility for the accuracy or the reliability of such information which may affect the report.

**3.0 LIMITATION OF LIABILITY**
The client recognizes that property containing contaminants and hazardous wastes creates a high risk of claims brought by third parties arising out of the presence of those materials. In consideration of these risks, and in consideration of GW SOLUTIONS providing the services requested, the client agrees that GW SOLUTIONS’s liability to the client, with respect to any issues relating to contaminants or other hazardous wastes located on the subject site shall be limited as follows:
(1) With respect to any claims brought against GW SOLUTIONS by the client arising out of the provision or failure to provide services hereunder shall be limited to the amount of fees paid by the client to GW SOLUTIONS under this Agreement, whether the action is based on breach of contract or tort;
(2) With respect to claims brought by third parties arising out of the presence of contaminants or hazardous wastes on the subject site, the client agrees to indemnify, defend and hold harmless GW SOLUTIONS from and against any and all claim or claims, action or actions, demands, damages, penalties,

fines, losses, costs and expenses of every nature and kind whatsoever, including solicitor-client costs, arising or alleged to arise either in whole or part out of services provided by GW SOLUTIONS, whether the claim be brought against GW SOLUTIONS for breach of contract or tort.

**4.0 JOB SITE SAFETY**

GW SOLUTIONS is only responsible for the activities of its employees on the job site and is not responsible for the supervision of any other persons whatsoever. The presence of GW SOLUTIONS personnel on site shall not be construed in any way to relieve the client or any other persons on site from their responsibility for job site safety.

**5.0 DISCLOSURE OF INFORMATION BY CLIENT**

The client agrees to fully cooperate with GW SOLUTIONS with respect to the provision of all available information on the past, present, and proposed conditions on the site, including historical information respecting the use of the site. The client acknowledges that in order for GW SOLUTIONS to properly provide the service, GW SOLUTIONS is relying upon the full disclosure and accuracy of any such information.

**6.0 STANDARD OF CARE**

Services performed by GW SOLUTIONS for this report have been conducted in a manner consistent with the level of skill ordinarily exercised by members of the profession currently practicing under similar conditions in the jurisdiction in which the services are provided. Engineering judgement has been applied in developing the conclusions and/or recommendations provided in this report. No warranty or guarantee, express or implied, is made concerning the test results, comments, recommendations, or any other portion of this report.

**7.0 EMERGENCY PROCEDURES**

The client undertakes to inform GW SOLUTIONS of all hazardous conditions, or possible hazardous conditions which are known to it. The client recognizes that the activities of GW SOLUTIONS may uncover previously unknown hazardous materials or conditions and that such discovery may result in the necessity to undertake emergency procedures to protect GW SOLUTIONS employees, other persons and the environment. These procedures may involve additional costs outside of any budgets previously agreed upon. The client agrees to pay GW SOLUTIONS for any expenses incurred as a result of such discoveries and to compensate GW SOLUTIONS through payment of additional fees and expenses for time spent by GW SOLUTIONS to deal with the consequences of such discoveries.

**8.0 NOTIFICATION OF AUTHORITIES**

The client acknowledges that in certain instances the discovery of hazardous substances or conditions and materials may require that regulatory agencies and other persons be informed and the client agrees that notification to such bodies or persons as required may be done by GW SOLUTIONS in its reasonably exercised discretion.

**9.0 OWNERSHIP OF INSTRUMENTS OF SERVICE**

The client acknowledges that all reports, plans, and data generated by GW SOLUTIONS during the performance of the work and other documents prepared by GW SOLUTIONS are considered its professional work product and shall remain the copyright property of GW SOLUTIONS.

**10.0 ALTERNATE REPORT FORMAT**

Where GW SOLUTIONS submits both electronic file and hard copy versions of reports, drawings and other project-related documents and deliverables (collectively termed GW SOLUTIONS's instruments of professional service), the Client agrees that only the signed and sealed hard copy versions shall be considered final and legally binding. The hard copy versions submitted by GW SOLUTIONS shall be the original documents for record and working purposes, and, in the event of a dispute or discrepancies, the hard copy versions shall govern over the electronic versions. Furthermore, the Client agrees and waives all future right of dispute that the original hard copy signed version archived by GW SOLUTIONS shall be deemed to be the overall original for the Project. The Client agrees that both electronic file and hard copy versions of GW SOLUTIONS's instruments of professional service shall not, under any circumstances, no matter who owns or uses them, be altered by any party except GW SOLUTIONS. The Client warrants that GW SOLUTIONS's instruments of professional service will be used only and exactly as submitted by GW SOLUTIONS. The Client recognizes and agrees that electronic files submitted by GW SOLUTIONS have been prepared and submitted using specific software and hardware systems. GW SOLUTIONS makes no representation about the compatibility of these files with the Client's current or future software and hardware systems