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Bear Mountain Golf Courses

Golf Irrigation Water Balance Study

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1. Introduction

Ecoasis owns, operates, and maintains the Mountain and Valley golf courses at Bear Mountain. An integral part of operating the golf courses is managing the supply of irrigation water. Ecoasis has retained Colquitz Engineering Ltd. (CQZ) to review water supply and demands associated with the irrigation of the golf courses and prepare a water balance to provide a better understanding of the water management.

This document builds upon the irrigation planning work previously completed by Kerr Wood Leidal (KWL) and utilizes monitoring data from the summer of 2016.

1.1 Scope of Work

The scope of work for this assignment is summarized as follows:

- Obtain and review relevant background information;
- Complete a system water balance based on the data for the summer of 2016;
- Summarize the groundwater extraction for the summer of 2016;
- Access potential climate change implications;
- Summarize water use observation, and;
- Provide recommendations regarding water use.

1.2 Background

The Mountain and Valley golf courses at Bear Mountain have been in operation since 2003 and 2008, respectively. The courses were constructed within the Bear Mountain Development which straddles the City of Langford (CoL) and District of Highlands (DoH) municipal boundaries.

Ponds were specifically constructed as reservoirs to store and supply irrigation water for the two courses. The Mountain Course ponds, adjacent to hole 10, and holes 11 and 12 (upper ponds), supply irrigation water to the Mountain Course. Osborn Pond supplies irrigation water to the Valley Course.

Inflow of water to the ponds comes from precipitation and groundwater wells. During the summer months, the primary source of inflow to the ponds are the wells as there is little surface runoff.

The upper ponds and Osborn Pond have usable detention volumes of approximately 37,000 m^3 and 65,000 m^3, respectively. A schematic of the irrigation infrastructure for the Bear Mountain golf courses is illustrated in Figure 1-1 below.

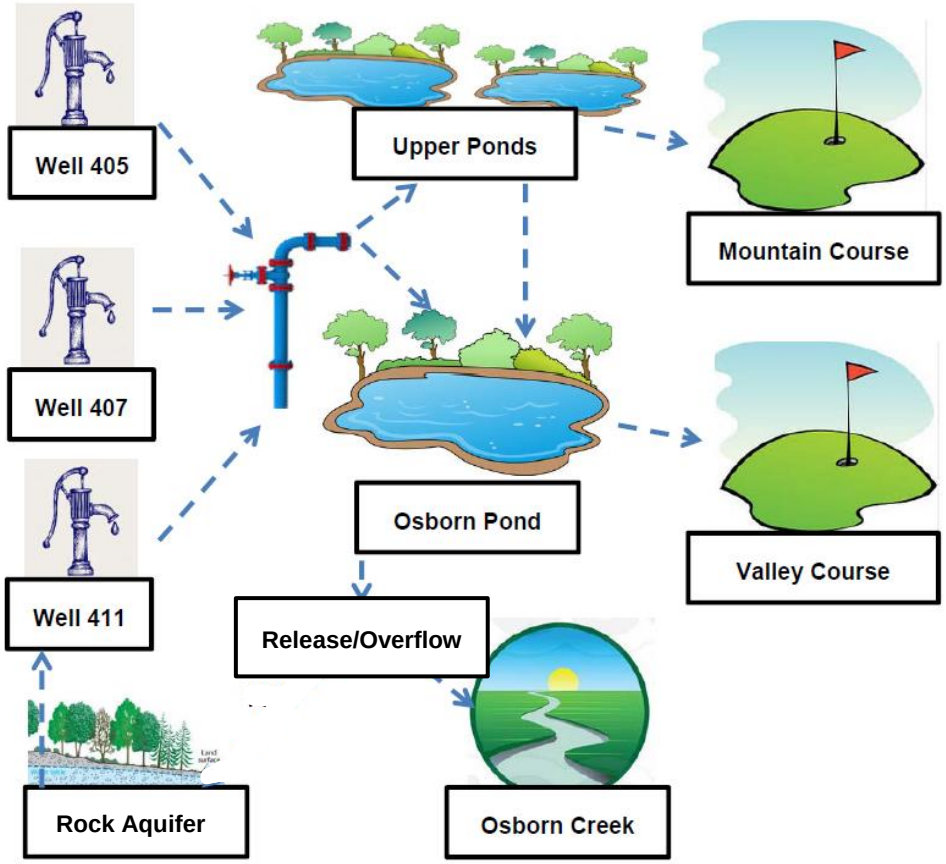


Figure 1-1: Schematic of Irrigation System

2. Water Balance

A water balance has been prepared to tally supply and demand for the Bear Mountain irrigation system.

This water balance is used to determine unaccounted for losses (leakage) from the system and to evaluate options for the irrigation system (e.g. additional supply, reduced demand, increased storage).

The water balance accounts for:

- Inflows – catchment runoff, groundwater from wells, irrigation return;
- Demands - irrigation, evaporation, and fish release;
- Change in storage – Osborn and upper ponds, and;
- Pond leakage - used to balance inputs, outputs and change in storage

2.1 Water Monitoring

There are a number of parameters that are key to the water balance analysis. The source data for these inputs are summarized as follows:

- Precipitation and temperature are recorded at the Bear Mountain climate stations located at the reservoir on Skirt Mountain.
- Water levels in the Upper Ponds (supply to the Mountain Course irrigation system) are manually recorded by golf course operation station.
- Water levels in Osborn Pond are recorded using radar telemetry and logged on a 1-hour time step. This is an improvement on the water level data from previous years which was manually recorded. A photo of the type of radar equipment used for the Osborn Pond level monitoring is provided in Figure 2-1 below.
- Irrigation demands are recorded by four meters (two for each course) located in the irrigation pump houses.
- Well supply volumes are recorded by electromagnetic flow meters (magmeters) on the well supply mains to both the Valley and Mountain irrigation ponds. This is an improvement in measurement accuracy from previous years. A photo of one of the Sensus magmeters is provided in Figure 2-2 below.

Figure 2-1: Osborn Pond Radar Water Level Monitoring Device

Figure 2-2: Well Water Supply Meter

2.2 Inflows

2.2.1 Catchment Runoff

The Mountain and Valley courses are primarily contained within the Osborn Pond watershed which is approximately 240 ha in size. The upper ponds are located in the upper most reach of the watershed and have a sub-catchment area of approximately 14.9 ha. In addition to catchment runoff, direct precipitation to the ponds was also calculated based on surface area of the ponds.

Runoff estimates from the Osborn Pond watershed area were prepared using the precipitation data and catchment yield factors. The catchment yield factors account for loss of flow to groundwater, transpiration and evaporation. Yield factors used in previous KWL analysis are as follows:

Table 2-1: Previous Analysis Catchment Yield Factors

	May	June	July	August	September
Catchment Yield	0.30	0.20	0.12	0.10	0.19

Notes:
- A catchment yield factor of 1.0 would indicate that 100% of the precipitation in the catchment results in runoff to the pond, and a catchment yield factor of 0.0 would indicate that none of the precipitation in the catchment results in runoff to the pond.

In 2016, continuous 1-hour increment water level measurements of Osborn Pond were recorded for the first time. This data allows for a review of Osborn Pond's response to precipitation. This review indicates that very little precipitation during the late spring and summer months results in runoff to the Osborn Pond.

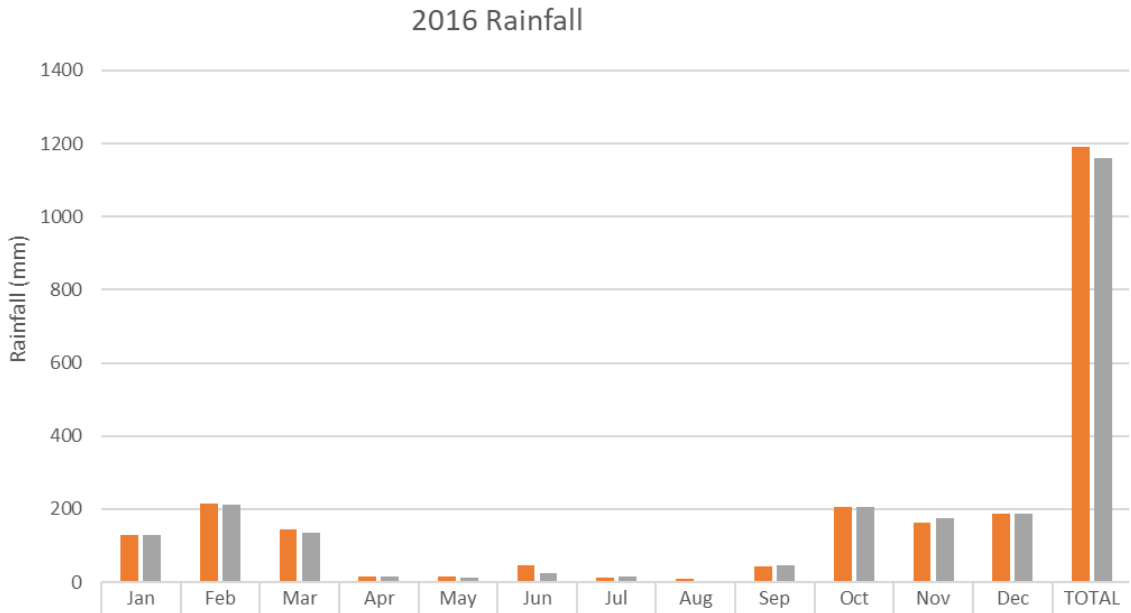
The catchment yield factors used in the water balance analysis were adjusted for both Osborn Pond and the upper ponds, as follows:

Table 2-2: Adjusted Analysis Catchment Yield Factors

	May	June	July	August	September
Catchment Yield	0.06	0.04	0.02	0.02	0.04

In addition to the rainfall runoff from the catchment, the precipitation that falls directly on the irrigation ponds was included with a runoff factor of 1.0.

The precipitation used in the analysis came from the Bear Mountain tipping bucket rain gauge, supplemented by the Langford City Hall rain gauge in times when the gauge was not functional. The monthly rainfall totals for the Bear Mountain and Langford City Hall rain gauges are summarized in Figure 2-1 below.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	TOTAL
Bear Mountain	130	214	145	16	15	47	13	10	45	206	164	189	1192
Langford City Hall	130	211	135	15	12	24	16	5	46	206	175	189	1162

Figure 2-3: 2016 Rainfall Data

It should be noted that the Bear Mountain and Langford City Hall rain gauges are not heated and only record snow that naturally melts into the collection funnel, therefore underestimating snow precipitation.

2.2.2 Groundwater from Wells

Thurber and now Western Water Associates has been involved with the development and ongoing monitoring of water wells for the Bear Mountain development since 1996. During this time, a total of 14 water wells have been drilled on the site. Of these wells, three wells (405, 407, and 411) are being utilized for the supply of irrigation water to the Mountain and Valley Courses. Since 2010, Thurber has monitored ground water usage, groundwater levels, and groundwater quality.

Wells 405 and 407 pump to the upper ponds for irrigation of the Mountain Course, and well 411 pumps to Osborn Pond for irrigation of the Valley Course. In 2016, the well pumps were in operation from May 4th to September 27th.

In 2014, the flow meters on the well supply system were checked by KWL with a temporary clamp-on flow meter. This clamp-on meter indicated that the flow from well 411 was being significantly under estimated by the inline meter. In order to improve flow measurement accuracy, prior to the 2016 summer season Ecoasis installed electromagnetic flow meters (magmeters) on the well supply mains to both the Valley and Mountain irrigation ponds. Magmeters are the modern standard for accurate flow measurement of water and typically have measurement errors of less than +/-1%.

The water balance results prior to the installation of the magmeters in 2016 are suitable for review from a general trend perspective, however the volumes should only be considered as rough estimates.

2.2.3 Irrigation Return

In previous year water balance analysis, it was assumed that 8.5% of the irrigation volume returned to the ponds as runoff. Considering that very little precipitation results in runoff to Osborn Pond given the improved water level measurement data (see Catchment Runoff subsection above), the irrigation return volume is now assumed to be zero.

2.3 Water Demands

2.3.1 Irrigation

Bear Mountain golf course irrigation typically occurs in the months of May through to September. The irrigation demands are actively adjusted by golf course maintenance staff. The primary climate conditions which impact irrigation demands are temperature, precipitation and wind.

Ecoasis has engaged Landscapes Unlimited to undertake a review of the irrigation usage for the golf courses. We understand that once recommendations are completed and maintained, the irrigation demands of the golf courses will be reduced as compared with the current situation. The Landscapes Unlimited memorandum is included in Appendix A.

For each of the golf courses there is an irrigation supply pump station that draws water from the irrigation pond(s) which pressurizes and feeds the golf course irrigation system. At each of the irrigation pump stations there are two separate systems; a high-pressure system and a low-pressure system. There are flow meters on each of the systems which are manually recorded by staff on approximately a monthly basis.

In 2014 the irrigation pump flow meters were calibrated by KWL. Based on this work by KWL, calibration factors have been applied to the 2016 irrigation meter data of 0.90 and 0.93 for the high-pressure and low-pressure systems, respectively.

The irrigation system was in operation in 2016 from May 4th until September 30th.

2.3.2 Evaporation

Estimates of monthly potential loss due to evaporation from the irrigation ponds were determined using the Thornthwaite's formula. The Thornthwaite's formula calculates monthly evaporation potential based on precipitation rates, average temperature, and sunlight hours.

$$PE_m = 16N_m\left(\frac{10\bar{T}_m}{I}\right)^a$$

Where:

- **PE_m** is the monthly potential evaporation,
- **N_m** is a monthly factor (a value of 1.0 is equivalent to a 30-day month with 12 hours of sunlight per day
- **T_m** is the average monthly temperature
- **I** is an index encompassing the annual climate
- **a** is a function of the annual climate index

Evaporation rates using the above formula is based on information available from the Bear Mountain climate station.

2.3.3 Fish Release

Bear Mountain golf course operations provided a fish release from Osborn Pond up until May 31, 2016, at which time the fish release valve was closed. Based on a review of the continuous Osborn Pond water level data, the fish release is estimated to be 3 L/s.

2.4 Change in Storage

The amount of stored water used for irrigation in the water balance calculations is based on the water level recordings, and a comparison with the elevation / volume curves for each of the ponds. These curves are illustrated on the following figures.

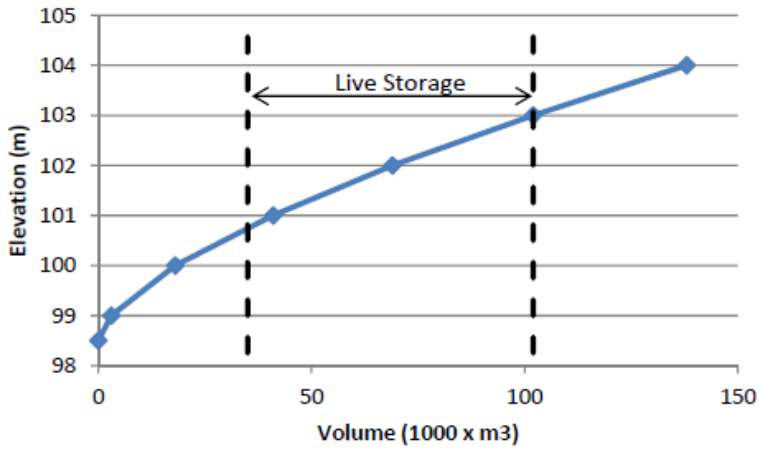


Figure 2-4: Osborn Pond Irrigation Storage

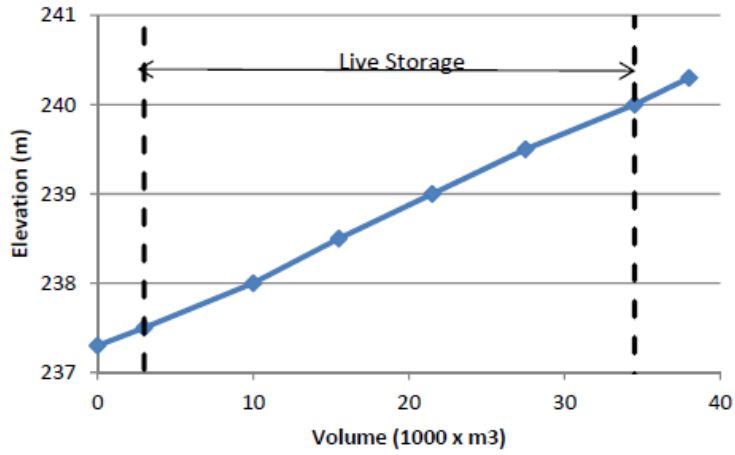


Figure 2-5: Upper Pond (Main Only) Irrigation Storage

Note: There is approximately an additional 5,000 m^3 of live storage available for the upper ponds at the adjacent smaller hole 10 pond.

2.5 Water Balance Summary

The 2016 water balance has been developed for May to September (inclusive) to cover the entire period of groundwater extraction through the wells. The water balance is summarized in the following Table 2-3.

Table 2-3: May to September, 2016 - Water Balance Summary

Inflows (m3)	Mountain	Valley	Notes
Well Inflow	140,057	204,473	
Precipitation Runoff	2,951	14,708	
CRD Water[1]	18,961	-	
Change in Storage	2,929	54,067	
Irrigation Return	-	-	Assumes no irrigation return
TOTAL INFLOW	164,897	273,247	
Outflows (m3)			
Irrigation Demands	110,154	95,463	
Evaporation	11,064	18,448	
Release	-	7,258	Fish Release of 3 L/s until May 31st
TOTAL OUTFLOW	121,218	121,169	
Net Losses			
Losses (m3)	43,680	152,079	
Losses (m3/day)	299	1,042	
Losses (L/s)	3	12	

Notes:
1 – CRD water was used to fill the upper ponds for aesthetic purposes for the PGA TOUR Champions golf tournament in September 2016.

2.5.1 Pond Losses

Leakage from Osborn Pond was previously considered in the *Osborn Pond – Water Licence Application Development Report, Focus, July 12, 2007*. This report estimated that the leakage from the Osborn Pond berm could be up to 1.0 L/s.

As part of the water balance analysis for this project, we have assumed the deficit between inputs and outputs is lost to pond leakage. As indicated above the estimated average pond leakage for the upper ponds is 3 L/s (Mountain Course), and 12 L/s for Osborn Pond (Valley Course).

The leakage rate was also checked by applying the season water balance parameters to an hourly water balance model for the Valley Course, and comparing the model predicted Osborn Pond volume with the volume based on the continuous measurement data.

The results of the modelled and measured water Osborn Pond volumes are illustrated on the following Figure 2-4.

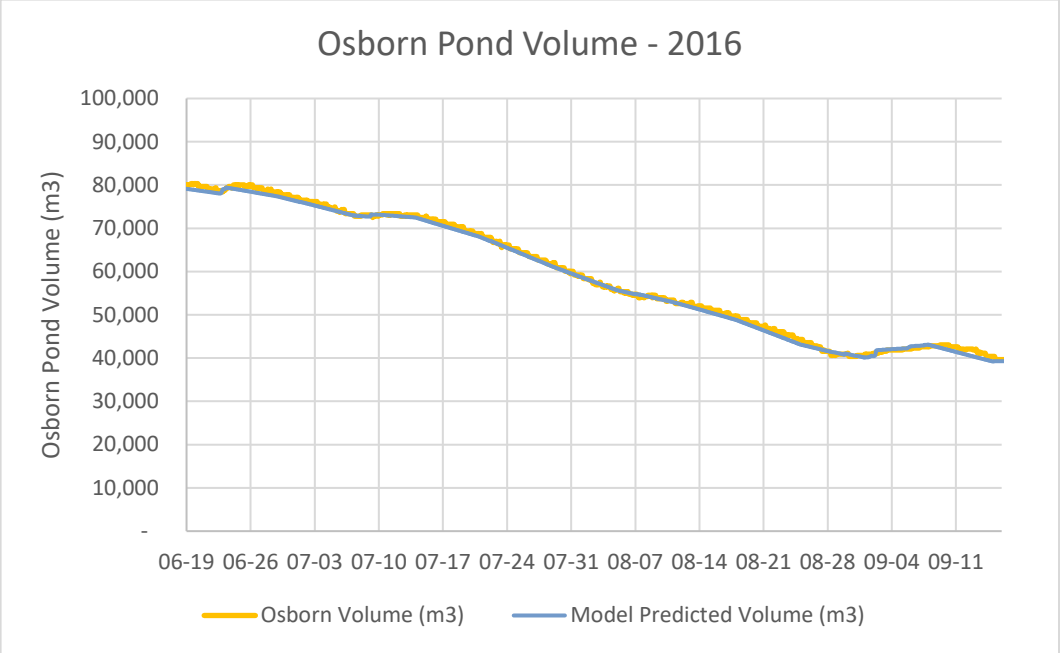


Figure 2-6: Osborn Pond Modelled and Observed Volumes

As illustrated above, the model closely matches the observed water volumes for Osborn Pond, confirming the accuracy of the water balance model on a daily time step basis and supporting the leakage rates from the seasonal water balance.

3. Groundwater Extraction

3.1 Groundwater Monitoring

Consultants have been monitoring annual groundwater use for the development since 2007. This groundwater monitoring was completed by Western Water Associates in 2016, and is summarized in the reports *Bear Mountain 2015-2016 Annual Groundwater Monitoring Report, October 19, 2017* and *Bear Mountain Groundwater Supply Assessment Report, October 17, 2017*.

The monitoring of the supply wells indicates that there is significant drawdown over the pumping season. Well 411 dropped by approximately 80 m with wells 405 and 407 dropping by approximately 50 to 43 m. The groundwater monitoring indicates that the groundwater levels in the monitoring wells only fluctuate by approximately 3 to 5 m seasonally.

3.2 Net Groundwater Extraction

As indicated above, it is estimated that Osborn Pond is leaking at a rate significantly higher than originally assumed. From May to September 2016, the estimated leakage from the pond is in the range of 150,000 m^3. The measured groundwater inflow to Osborn Pond over this period is 205,000 m^3. Therefore, leakage is approximately 74% of the total groundwater extracted over the same period.

A field inspection in May of 2014 observed that leakage through the dam is not occurring at a significant rate. This indicates that the water leaking from Osborn Pond is from the bottom of the pond.

It is not known what is happening to the water leaking from the pond. This leaked water could be contributing to the following:

- To groundwater that discharges to a marine environment (deep groundwater);
- To groundwater that discharges to surface water bodies (e.g. wetlands, Osborn Creek, Millstream Creek) in DoH or neighbouring jurisdictions (shallow groundwater), and/or;
- To the Bear Mountain groundwater wells that recirculate the water to the irrigation ponds.

The flow between the pond, groundwater, and wells is illustrated in Figure 3-1 below.

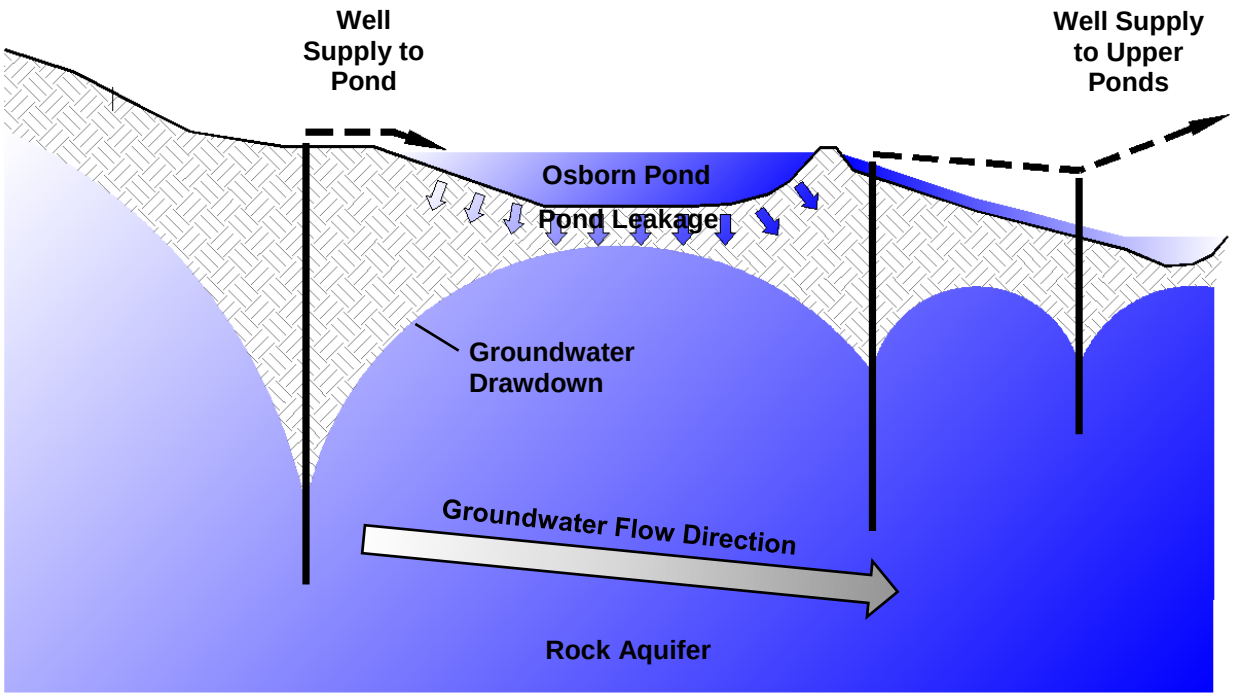


Figure 3-1: Osborn Pond Leakage

The net groundwater extraction for the Mountain and Valley golf courses (difference between what is withdrawn from the aquifer by wells 411 and what is leaked from ponds) is summarized in the following table.

Table 3-1: 2016 Net Groundwater Extraction

	Volume (m3)		Percentage (%)	
	Mountain	**Valley**	**Mountain**	**Valley**
Gross Well Supply to Detention	140,057	204,473	100%	100%
Estimated Leakage Loss	43,680	152,079	31%	74%
Net Groundwater Extraction	96,377	52,394	69%	26%

The net groundwater extraction for the period of May to September 2016 is equal to approximately 660 m^3/day and 360 m^3/day for the Mountain and Valley golf courses, respectively.

4. Climate Change

The CRD has recently published the report *Climate Projections for the Capital Region, April 2017*. This report provides a number of climate projections for the capital region based on the results of global climate models. The projections are for the 2050s (average of 2041–2070 model results) and 2080s (2071-2100).

The report provides the following regarding general climate projections.

> *The capital region can expect noticeable changes to our climate in the coming decades. At a high level, the region can expect:*
> - *Warmer winter temperatures*
> - *Fewer days below freezing*
> - *More extreme hot days in summers*
> - *Longer dry spells in summer months*
> - *More precipitation in fall, winter, and spring*
> - *More intense extreme events*

Climate change impacts that are particularly relevant to the irrigation of the Bear Mountain golf courses are as follows:

- Summer temperature/summer precipitation – changes to irrigation demands
- Annual precipitation – changes to aquifer supply

4.1 Spring/Summer Temperature

A change in summer temperature/precipitation could result in changes in irrigation demands.

The CRD report projects spring/summer daytime high temperatures will increase as follows:

Table 4-1: Change in Average Daytime High Temperature (°C)

Season	2050s	2080s
Spring	2.7 (range 1.6 to 4.5)	4.3 (range 2.7 to 7.0)
Summer	3.3 (range 2.1 to 4.2)	5.2 (range 3.7 to 7.0)
Notes: - The range provides the 10th percentile and 90th percentile values		

The CRD report projects the number of summer days in the region where the temperature will exceed 25°C will increase from 12 historically to 36 (range 28 to 46) and 59 (range 43 to 78) for the 2050s and 2080s, respectively.

Considering the above increase in spring/summer temperatures and duration of hot days, it is anticipated that golf course irrigation demands will increase as a result of climate change.

4.2 Precipitation

The aquifer in the Highlands is primarily supplied by rainfall and changes in rainfall could result in changes to the aquifer supply volume.

Precipitation has been recorded at the Bear Mountain climate station since 2010 and at the Langford City Hall climate station since 2008. The annual precipitation values climate values are summarized below:

Table 4-2: Annual Precipitation (mm)

Climate Station	2008	2009	2010	2011	2012	2013	2014	2015	2016
Bear Mountain	-	-	1094	1206	1123	836	1238	1294	1192
Langford Hall	861	1249	1069	1204	1168	803	1255	1307	1162

Notes:
- The Bear Mountain and Langford City Hall rain gauges are not heated and only record snow that naturally melts into the collection funnel, therefore underestimating snow precipitation.
- The Bear Mountain rain gauge did not function properly for the following months and the data from the Langford Hall gauge was used: 2010/01, 2010/12, 2012/04, 2013/09-11, 2015/02, 2015/12, 2016/01, 2016/10, 2016/12

The CRD report projects a net increase in the annual precipitation by 5% (range of 1% to 10%) and 12% (range of 4% to 17%) for the 2050s and 2080s, respectively. The precipitation in the summer is projected to decrease with the precipitation in all other seasons projected to increase.

The CRD report also states, “The relatively modest projected increase in precipitation in the wet season should increase the likelihood that surface water supply reservoirs will fill and groundwater supplies replenish. However, this increase in precipitation will likely be delivered during more extreme events.”

Considering the above, it is anticipated that climate change will not result in a reduction in the supply to the aquifer which is the irrigation system groundwater source.

5. Water Use Observations and Recommendations

5.1 Observations

For the 2016 irrigation season, Ecoasis improved the monitoring accuracy with the installation of magmeters on the well supply lines and continuous water levels measurements of Osborn Pond. With this more accurate information, there is now increased confidence in the water balance model results.

Key findings from the monitoring and water balance model for 2016 are as follows:

- For the Mountain Course the total volume of groundwater extracted is estimated at 140,000 m^3 and the total irrigation volume is estimated at 110,000 m^3. The net groundwater extraction for the Mountain Course was approximately 96,000 m^3.
- For the Valley Course the total volume of groundwater extracted is estimated at 205,000 m^3 and the total irrigation volume is estimated at 96,000 m^3. The net groundwater extraction for the Valley Course was approximately 52,000 m^3.
- Osborn Pond is leaking at a rate significantly higher than was anticipated in the design and planning of the irrigation system. The estimated volume leaked from Osborn Pond from May to September is 152,000 m^3. Therefore, the net volume of groundwater extracted during this time approximately 53,000 m^3, or 26% of the gross volume extracted.

Despite the higher than originally anticipated leakage rate from Osborn Pond, the well and storage system appears to have an adequate supply of water to irrigate the Bear Mountain golf courses due to the continuous well pumping throughout the summer. A supplemental supply of water (CRD water) may be required in the late summer if having the ponds near full is an aesthetic requirement (e.g. for the PGA golf tournament).

Golf course irrigation demands may increase in the future as a result of climate change. However, it is anticipated that climate change will not result in a reduction in the supply to the aquifer. A reduction in irrigation demands, as outlined by Landscapes Unlimited, will assist in offsetting potential increased irrigation demands as a result of climate change.

As reported by Western Water Associates, Bear Mountain is fortunate to have high producing irrigation wells located in a fractured zone of the regional bedrock aquifer. This aquifer is recharged by percolation over the aquifer during the wet season. Western Water Associates states, “the extent of drawdown due to operation of the Bear Mountain irrigation wells likely remains within the property limits.” and “Both golf courses have been using groundwater since 2008 and there have been no indications of impacts to neighbouring wells to date.” Additionally, the monitoring also indicates that the water levels in the irrigation wells recover quickly following well pumping shut-down.

At this time, the current aquifer-based irrigation supply appears to provide adequate supply to meet the irrigation demands. Specifically, the irrigation wells and irrigation ponds are sized adequately for the current demands of the Bear Mountain golf courses. However, should there be a trend of insufficient irrigation supply in the future, the following contingency strategies should be considered:

1. CRD Water (temporary or emergency supply shortfall) – CRD water could be supplied to the Mountain storage pond to augment the Mountain Course irrigation system, thereby limiting the aquifer well demand to the Valley Course only. It is likely not acceptable for the CRD water, which contains chloramines, to directly discharge to Osborn Pond due to potential impacts on fish. The CRD option is likely only feasible as a temporary or emergency supply measure due to the high expense to

purchase the water and potential limited supply as the development approaches full residential build-out.

2. Osborn Pond Lining – A pond liner would limit leakage and therefore effectively increase the surface-level storage. This pond liner could either be a contiguous polyethylene liner or a clay liner. This work should occur during the late summer months when the pond level is lowest.
3. Osborn Dam Raising - The dam creating Osborn Pond could likely be raised by approximately 1.0 metre without a full rebuild of the dam, which would increase the storage volume by approximately 36,000 m^3. Preliminary calculations indicate that there is sufficient runoff from the watershed to fill this expanded Osborn Pond. This option is only sensible once Osborn Pond has been made more water-tight through the installation of a pond liner.
4. Increase Well Supply – The well supply to the irrigation system could be increased by adding additional wells or increasing the depth of the existing wells. The feasibility of this contingency strategy should be reviewed by a hydrogeologist before it considered further.

5.2 Recommendations

5.2.1 Monitoring

The following are recommendation related to the monitoring of the irrigation systems for the Bear Mountain golf courses:

- It is recommended that Ecoasis continue with well and water quality monitoring as recommended by Western Water Associated and environmental monitoring recommended by WSP.
- Continue to monitor water levels in Osborn Pond and the upper ponds through the irrigation season to ensure that irrigation demands are not exceeding the available supply from the wells and storage.
- Continue to monitor well supply volumes and irrigation system demand volumes.
- Compare yearly monitoring results to determine if there is a trend of increased irrigation demands or reduced aquifer supply that suggest a contingency strategy may need to be considered.

5.2.2 Irrigation System

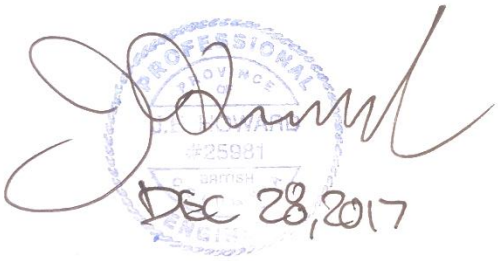
The following are recommendations related to the irrigation system:

- Consider starting well pumping earlier in the Spring to ensure Osborn Pond and the upper ponds are full in the late Spring. This will have the secondary benefit of increasing available fish flows in Osborn Creek in late Spring and potentially early Summer.
- Undertake and maintain the recommendations received from Landscapes Unlimited which will reduce irrigation demand.

5.3 Report Submission

Prepared by:

COLQUITZ ENGINEERING LTD.



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Water Resources Engineer

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Revision History

Revision #	Date	Status	Revisions	Author
-	December 28, 2017	FINAL		J. Howard

Appendix A

LANDSCAPES UNLIMITED MEMORANDUM

BEAR MOUNTAIN GOLF OPERATION – BEST INDUSTRY PRACTICES FOR WATER MANAGEMENT

Background

Landscapes Unlimited, LLC engaged in an agronomic operations advisory role with The Westin Bear Mountain Golf Resort and Spa in January 2014. The primary purposes of the engagement are to improve the health of the turfgrass and golf course playability, support the grounds maintenance team with project management, and enhance the environmental responsibility of the maintenance department. Landscapes Unlimited, LLC performs golf course construction, renovation, and management services around the world. The 41 year old company has completed over 1700 golf course construction and renovation projects and has over 40 golf course management clients.

Recommendation

Growing medium:
All of the golf course turfgrass growing areas are capped with sand. Over time, an undesirable organic build-up (thatch) has developed on top of the sand. Thatch inhibits water infiltration into the sand. The combination of the shallow-rooting of the Annual Bluegrass (P*oa annua*) and the thatch build-up creates a very challenging growing situation. The thatch holds moisture and stays too moist in wet conditions, and it dries extremely hard in dry conditions. The thatch must be removed/diluted/managed while keeping the course open for play. **Bear Mountain has excessive thatch conditions, with 4" build-up on the Mountain Course, and 2" build-up on the Valley Course. It is inferred that no fairway aeration had ever occurred on either Bear Mountain course since their inception, in an environment (shorter Northern summers) that promotes high thatch build-up.**

Management Practices

The first remedial action is management of the thatch. The solution to thatch infestation is dilution - physical removal and soil amending. In an extreme situation like the condition at Bear Mountain, a multi-year program will be required to fix the problem. This program does not have an end. It must be continued every year during the lifespan of the golf course, or the thatch will continue to develop. The first strategy is to work on the thatch in two ways. First, core aeration is performed as a means of physical removal. Second, sand is applied to the surface and worked into the canopy as a means of amending the soil. The programs in 2015 were acceptable, but can be steadily improved as operational efficiencies increase every year so that all fairways can ideally be fully aerated twice a year (once in spring, and once in autumn). There are also many inputs required. Key inputs during this root zone remediation program are soil wetting agents. Wetting agents have a number of benefits. In the case at Bear Mountain, the primary needs are soil penetration to break the surface, followed by moisture holding enhancement in the root zone area.

To actualize a proper dethatching and aeration program, Bear Mountain procured additional equipment in spring 2015 and reorganized their operational team to prioritize the necessary work tasks. **It is estimated that it will take a minimum of 5 to 10 years to successfully break up and remove the built-up thatch such that optimum turfgrass growing conditions have been reinstated.**

Landscapes Unlimited identified the following 5 point plan in spring 2015, and are in process of indoctrinating the required elements into the Bear Mountain operating routines.

5 Point Water Management Plan for Westin Bear Mountain Golf Resort & Spa

1. **Develop a written water management (conservation) plan**
   Establish a water allocation program based on prioritized allocation (greens as highest priority, tees, fairways and roughs as lowest)
   Eliminate water applications in dry seasons (i.e. defer Driving Range irrigation)
   Enhance the current record-keeping process
2. **Add scientific variables (ET rates and moisture readings) to the irrigation decision making process**
   Weather station installation and operation
   Perform daily moisture meter readings from April to September
   Enhance the central controller programming operation with hand-held interfaces
   Study potential new technology (permanent sensors with remote access, water treatment devices, etc.)
3. **Irrigation system audit and programming documentation**
   Individual field satellite controller walk-through audit
   Individual controller programming and inventory sheets
   Immediate attention to system deficiencies (specific to individual head operation)
   Study of water distribution with future head spacing adjustments and relocation changes
4. **Study the pump station(s) and well flow meters for accuracy and reliability**
   Pump station flow tests and comparison to central programmer projected flows
   Well flow tests
5. **Introduction of turfgrass cultural practices to enhance overall plant health and the interface between the turfgrass and the soil**
   Solid tine and core aeration for compaction relief and thatch removal
   Sand topdressing to dilute the thatch and create a firmer playing surface
   Strategic applications of wetting agents and surfactants to improve water use efficiency

ECOASIS Golf Water Use Target & Trending Result

Pre: Landscapes Unlimited - 2014 Water Use Mountain & Valley Golf Courses: Metered - 61,600,000 USG / 233,000 cubic meter

Dethatching Program of all Fairways, plus the introduction of additional water management systems.
Ecoasis Targeted Water Use – Reduce over 10 years overall water use 20% to 50,000,000 USG / 189,000 cubic meters

2016 Water Use: 54,500,000 USG / 205,617 cubic meters
2017 Water Use : 51,900,000 USG / 195,849 cubic meters (Partial reduction due to a directive from PGA Champions Tour representatives requiring firm playing conditions for their event in September.)