Golf Course Water Reuse Pilot Study

Phase II Report

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Phase II - 2008 Soil, Water, and Turfgrass Tissue Sampling and Analysis and Turfgrass Quality Evaluation at Two City of Spokane Golf Courses

Objective:

To determine the long-term (2 year) effect of irrigation with reuse water compared to non-effluent city/pond water, on soil chemical and physical properties and turfgrass tissue and quality parameters at two City of Spokane golf courses under conditions of routine management and play.

Phase II Tasks and Materials & Methods:

Details of Phase II tasks and protocol were previously outlined (September 2008 City of Spokane Golf Course Water Reuse Pilot Study – Phase II). During Phase II soil, plant, water quality, and turfgrass parameters were evaluated throughout the 2008 turfgrass growing season. Sampling was performed at two City of Spokane golf courses: Downriver and The Creek at Qualchan Golf Courses. This Pilot Study is a demonstration study that will identify numerical, but not statistical, differences and trends among treatments. This is due to the lack of replication of experimental units in the experimental design, which was developed prior to WSU's involvement in the project, and new construction and reconstruction of two sites; therefore, statistical comparison cannot be made among treatments.

Task 1. Soil sampling and analysis (Basic soil test, SAR, and CEC).

Soil samples were obtained from each golf course three times (May 15, July 15, and October 15, 2008) during the 2008 turfgrass growing season. A basic soil test, sodium adsorption ratio (SAR), and soil cation exchange capacity (CEC) (October 15 only), a measure of the amount of exchangeable cations in the soil, were performed on each sample by Kuo Testing Labs, Inc. Due to the extremely rocky soil at the Downriver #7 rough site, soil was sampled to a

depth of approximately 2 in. and not to the typical turfgrass soil sampling depth of 4 in., which was the sampling depth at all the other golf course sites.

Laboratory: Kuo Testing Labs, Inc.
337 South 1st
Othello, WA 99344
509-488-0112

Results.

Soil test (Downriver).

Downriver #7 rough basic soil test (Table 1) indicated little difference between sites receiving reuse water and city water irrigation. Soil test parameters outside the optimum range were consistently high or low between reuse or city water. Also, there was little change in parameters over time, i.e., parameters in the optimum range remained there and those outside the optimum range remained outside the optimum range, except for sulfate-S (SO_4-S) and boron, which fell off precipitously at the October 15, 2008 sampling date. In 2009, sulfate-S (SO_4-S) and boron will be closely monitored to see if this trend continues.

At Downriver #7 rough, the electrical conductivity (EC) was slightly above the optimum for reuse water sampled on July 15, 2008 and reuse and city irrigation water on July 15 and October 15. One possible reason for these elevated EC measurements may be attributed to the shallow sampling depth (2 in.), which was due to the rocky nature of the soil at Downriver.

EC, or soluble salts (SS), is a measure of the salt content (salinity) of the soil. Elevated salt levels (especially sodium salts) can cause poor soil structure, water drainage, and plant growth. Soil salinity should be monitored regularly since salt levels are often high in reuse water (Harivandi, 2004).

Downriver #7 rough soil test CEC was quite high for both irrigation water sources. CEC was twice as high in the area irrigated with city water compared to the reuse water irrigated area. The difference in these two CEC values is hard to determine, since each has roughly the same percentage of organic matter (OM) present in the soil.

Downriver #6 tee results were similar to those for the #7 rough, i.e., there was little effect of reuse water, compared to city water, over time. Boron at 0.52 ppm in the reuse irrigation water area was marginally above the optimum range (0.3-0.5 ppm). Boron is of concern because small amounts can be phytotoxic to plants; however, more so to ornamentals than turfgrasses. The CEC for the #6 tee are much lower than those measured for the #7 rough due to the high sand content and lower percentage of OM of the tee. There was essentially no difference in CEC between irrigation water sources on #6 tee.

Soil test (Qualchan).

At Qualchan (Table 2), the reconstruction of #15 green (sod from the old green was reused and put back in the same area of the new green) and a newly constructed #16 back tee (back tee site received reuse irrigation water) make comparisons over time difficult. These data will become more meaningful in 2009 as the two sites become mature. That being said, #15 green, prior to reconstruction, showed similar soil pH, OM content, and nutrient levels, except for nitrate-N (NO_3-N) and ammonium-N (NH_4-N) levels on July 15, 2008, which were higher where reuse irrigation water was applied to the green as opposed to where pond water was applied.

Immediately after the #15 green was reconstructed, in the fall 2008, there was essentially no difference in soil test data between the reuse or pond water irrigation treatments, as one would expect.

Making comparisons between the new #16 back tee, which was planted in mid-June 2008, and the older, established #16 forward tee will be very difficult. In any event, overall the new #16 tee irrigated with reuse water showed nutrient levels lower than the older #16 tee irrigated with pond water. This was most likely due to the high sand content and very low percentage of OM in the newly constructed #16 tee, which resulted in a low nutrient holding capacity. Surprisingly, the CEC of the #16 reuse water site was quite high (30.23 meq/100g). The nutrient holding capacity of the new #16 tee should increase over time, but still may not be as high as the older #16 tee (pond water irrigation) by the conclusion of the study.

The #16 fairway, reuse or pond water irrigation, sites were not rebuilt during 2008. There were only minor differences between reuse and pond water on soil test results. Overall, if anything, the #16 fairway site receiving reuse irrigation water had fewer (only potassium, which was slightly high) soil test parameters outside the optimum range.

At Qualchan, EC at all locations and irrigation treatments were at satisfactory levels throughout the growing season.

In 2009, basic soil tests will be conducted by Harris Labs instead of Kuo Testing Labs for better interpretation of results.

Task 2. Soil sampling and analysis (Trace Element Screen [heavy metals], Mercury, and Soil Physical Properties).

Soil samples taken in 2008 to determine the baseline soil heavy metal levels (trace element screen and mercury) were analyzed by the Analytical Sciences Laboratory (ASL) at the University of Idaho.

Laboratory: University of Idaho Analytical Sciences Laboratory
Holm Research Center
PO Box 442203
Moscow, ID 83844-2203
208-885-7081

Results.

Initial soil heavy metals:

The initial soil heavy metal levels prior to the application of reuse water are presented in Tables 3 and 4 for Downriver and Qualchan, respectively. The initial baseline samples from #6 tee and #7 rough at Downriver were taken on May 15, 2008. At Qualchan, the baseline samples were taken on May 15, 2008 for the #16 fairway treatments and #16 tee for the pond water irrigation treatment. Due to reconstruction of the #15 green and a new #16 back tee, baseline data was collected June 17, 2008 for the #16 tee reuse water and October 15, 2008 for both irrigation treatments on the #15 green.

According to the Model Toxics Control Act (MTCA) standards, most initial soil heavy metal levels at Downriver and Qualchan do not pose a problem. There were two exceptions. Chromium was slightly elevated (3 ppm > MTCA cleanup regulation) at the Downriver #7 rough city water site and arsenic was slightly high (4 ppm > MTCA cleanup regulation) at the Qualchan #16 tee reuse irrigation water site (Tables 3 and 4). It is interesting that the newly constructed sand-based #16 tee at Qualchan had an elevated level of arsenic on June 17, 2008, which was prior to the application of reuse irrigation water (Table 4). Soil heavy metals will be sampled for and analyzed at the end of 2009.

Initial soil physical properties:

Prior to the application of reuse irrigation water, initial soil physical properties were determined on an undisturbed soil core taken on May 15, 2008 from the Downriver tee #6 receiving city water, Downriver tee #6 receiving reuse water, Qualchan fairway #16 receiving pond water, and Qualchan fairway #16 receiving reuse water. ISTRC SYSTEM^{TM} BenchMarking of an undisturbed core sample was performed by the International Sports Turf Research Center (ISTRC), Inc. Discussions of the results of soil physical properties were provided by ISTRC (minor editing by WSU).

Laboratory: International Sports Turf Research Center, Inc.
11372 Strang Line Road
Lenexa, KS 66215
913-829-8873

Downriver #6 tee City Water:

The sand content in this rootzone is fairly high with the higher content in the 2 to 3 inch and 3 to 4 inch strata (Table 5). The silt and clay contents aggregate between 10 and 12% with the fine sand and another 10 to 12% when the organic material is added to the "fines" (silt, clay, and fine sand). The resulting rootzone mix is one that is highly susceptible to compaction.

The rootzone is one that holds water. The sealed off condition (infiltration rate of less than an inch of water per hour) is consistent with the drying time as are the water porosity and water holding properties. In spite of the sealed off condition and relatively low air porosity (12.16%) the turf had deep and dense root structure.

Downriver #6 tee Reuse Water:

This sample has a different sand composition in its top inch, which is probably attributable to topdressing (Table 5). If this area has been topdressed, the topdressing sand/mix is a poor choice. Even though the silt and clay percentages are low, the fine sand component is too high.

The soil below the top inch is similar to the Downriver #6 tee City Water site above, except that it has a silt and clay content that is in the 12 to 13% range. Water retention (as measured by the water porosity and water holding properties) remains very high to excessive. The infiltration and air porosity properties are higher at this site but root density is not as good.

Qualchan #16 fairway Pond Water:

The amount of organic material in the top 2 inches at this site was extremely high (Table 6). This site is best described as "thatchy". The impact of buried material (thatch) is manifested

in the bulk density of 0.71 g/cc. By definition the bulk density of water is 1.0 g/cc. Even though soil comprises the 2 to 3 inch and 3 to 4 inch strata, the light weight of the plant matter results in the low bulk density.

Qualchan #16 fairway Reuse Water:

This site does not have the same amount of thatch as the Qualchan #16 fairway Pond Water site in the top 2 inches (Table 6). The top inch however is similar.

The soil is higher in silt/clay and lower in fine sand components. The organic contents inherent in the soil are also lower.

The top 1.5 inches are "gummed up" (ISTRC terminology) with too much organic material. The 2nd inch's 4.56% is concentrated in the 1 to 1.5 inch depth. The air porosity is fairly good at 16.99%, it is deceiving. A significant portion of the air porosity is in the buried thatch/biomass that is clearly visible in the top inch. Water is not able to efficiently drain through the profile because the air porosity is not evenly distributed through the soil.

The above soil samples are of concern for turfgrass growth and management due to their low leaching potential, and will pose a problem if salts (especially sodium) accumulate from the prolonged use of reuse water and can not be leached below the rootzone. This will be much less of a problem on sand-based greens and tees with adequate subsurface drainage. Therefore, evaluation of soil physical properties will be important in late 2009.

Task 3. Water sampling and analysis.

The irrigation water samples were: Downriver city water, Qualchan pond water, and reuse water (from the City of Spokane water treatment plant) obtained from irrigation systems established at Qualchan and the Downriver golf courses. The analysis of these water samples for irrigation suitability was conducted by Harris Laboratories.

Laboratory: Harris Laboratories
300 Speedway Circle, Suite 2
Lincoln, NE 68502
402-476-0300

An extended heavy metal screen and mercury analysis on reuse and city and pond water was conducted by the University of Idaho Analytical Sciences Laboratory.

Laboratory: University of Idaho Analytical Sciences Laboratory
Holm Research Center
PO Box 442203
Moscow, ID 83844-2203
208-885-7081

Water samples for heavy metals were taken on May 15, July 15, and October 15, 2008. The water samples were: Downriver city water and reuse water and Qualchan pond water and reuse water.

Results.

Irrigation suitability:

Downriver.

The irrigation suitability samples of reuse and city water at Downriver were taken once in the summer and once in the fall in 2008. The water characteristics of reuse water and city water were quite similar, except, for an unknown reason, there were no carbonates measured in the reuse water (Table 7). Both had elevated levels for water hardness with city water hardness on October 15, 2008 at levels that could be a probable problem. Both water sources had similar pH levels, which were high and could pose possible problems. Although still within satisfactory levels, reuse water had several times higher levels of total soluble salts, EC, sodium, chloride, SAR, and many of the plant nutrients compared to city water.

Qualchan.

The irrigation suitability samples of reuse and pond water at Qualchan were taken once in the summer and once in the fall in 2008. Water characteristics, July 15, 2008, showed elevated water hardness and bicarbonate levels in both reuse and pond water and indicated a possible problem (Table 8). As seen at Downriver, no carbonates were detected in the reuse water on July 15, 2008. Carbonate levels in reuse water were detected on October 15 and were satisfactory. On October 15, 2008, the reuse water had a high hardness level and was listed as a probable problem.

Overall, it is quite clear that several other irrigation suitability parameters (sodium, chloride, SAR, and NO_3-N) from the reuse water sample taken at Qualchan on October 15, 2008 were elevated and indicated a probable problem. Also, including the four parameters mentioned above, total soluble salts showed a several fold increase compared to the reuse water samples taken July 15, 2008. It is possible that some sampling error occurred in the reuse water sample for October 15, 2008. This sample was taken directly from the reuse water storage building located at The Creek at Qualchan Golf Course. In 2009, careful attention will be paid to the water sampling technique. Both water sources had similar pH levels, which were high and could pose possible problems. Pond water at Qualchan and the reuse water on July 15, 2008, for the most part, had irrigation suitability parameters in the satisfactory range. In addition, as seen at Downriver, the reuse water had several times higher levels of total soluble salts, EC, sodium, chloride, SAR, and many of the plant nutrients compared to pond water.

Extended heavy metal screen and mercury analysis:

The heavy metal and mercury analysis for Downriver and Qualchan are presented in Tables 9 and 10, respectively. At both Downriver and Qualchan, the reuse water and the city or pond water were well below EPA recommended limits for heavy metals in reuse water for irrigation. With respect to heavy metals, these water sources do not pose an apparent irrigation problem. However, it will still be important to continue monitoring for heavy metals in the reuse water during 2009.

Task 4. Tissue testing.

June 17, August 15, September 15, and October 15, 2008 during the turfgrass growing season turfgrass leaf tissue samples were taken from the ten golf course sites (except for the #15 green at Qualchan on October 15 when an application of topdressing sand to the green prevented tissue sampling). Tissue samples were obtained from the mower basket following mowing of tees and greens by golf course personnel and from hand clipped samples obtained by WSU personnel from golf course fairway and rough sites. The samples were air dried and foreign debris and any fertilizer prills were removed by hand from the sample prior to shipping to Harris Laboratories for tissue analysis.

Laboratory: Harris Laboratories
300 Speedway Circle, Suite 2
Lincoln, NE 68502
402-476-0300

Results.

The effect of reuse water or city or pond water on leaf tissue analysis at Downriver and Qualchan are given in Tables 11 and 12, respectively. Throughout this discussion of turfgrass tissue analysis, nutrients were not discussed if both water sources (reuse and city/pond) indicated high levels. Differences due to levels below the normal range were minor and probably can be ignored, as low nutrient levels can be supplemented with fertilizers if warranted. Also, additional data needs to be collected from the golf course superintendents as to when fertilization occurred at each site relative to sampling date.

Tissue tests (Downriver).

Downriver #7 rough leaf tissue samples indicated only minor differences due to type of irrigation water source. Compared to city irrigation water tissue samples, tissue samples from the reuse water area were slightly high in sulfur on August 15, 2008. Plants growing in the rough, regardless of water source, tended to be high (above the normal range) in iron. Copper and boron levels were low. Levels above the normal range are not inherently detrimental to plants. Also, they may reflect a recent application of fertilizer if consistent between water sources.

Downriver #6 tee leaf tissue samples indicated only minor differences due to irrigation water source. Compared to city water, the reuse water tissue samples were slightly above the normal range for nitrogen on October 15 and sulfur on August 15, 2008. As with the #7 rough samples, plants were high in iron and low in copper. Tissue levels of manganese were also high for both irrigation water sources on #6 tee.

Tissue tests (Qualchan).

Qualchan #15 green tissue samples were fairly consistent between irrigation water sources. On June 17 and September 15, 2008, nitrogen was above the normal range in the reuse water area. Regardless of water source leaf tissue samples tended to be high in iron and low in boron.

Qualchan #16 fairway reuse water tissue samples were above the normal range for sulfur on August 15 and zinc on August 15 and October 15, 2008. The #16 fairway tissue samples, regardless of water source, were below the normal range for copper and boron. Interestingly,

tissue samples from the reuse water area generally had nitrogen levels in the normal range while tissue samples from the pond water irrigation area tended to be below normal.

Qualchan #16 tee reuse water leaf tissue samples had more values above the normal range (when pond water samples were not outside the normal range) than the rough or fairway samples. This may be due to the #16 tee reuse water site being a newly constructed sand-based tee compared to the older #16 tee that received pond water. Phosphorus on September 15, sodium on August 15, zinc on August 15, and manganese on August 15 and September 15, 2008 were above the normal range. Phosphorous, sulfur, and manganese are likely high due to fertilizer applications by golf course personnel to stimulate rapid turfgrass growth during grow-in of the new #16 back tee. Above normal sodium levels from leaf tissue off the new #16 tee are most likely related to the high soil sodium levels (51.3 ppm), as indicated in the basic soil test (Table 2).

Task 5. Turfgrass evaluation.

The golf course sites were evaluated monthly (mid-May through mid-October, 2008) for turfgrass parameters by Washington State University turfgrass personnel.

The monthly turfgrass evaluations were:

Turfgrass quality visually evaluated 1-9; 9 = excellent turfgrass quality (Table 13).

Turfgrass color visually evaluated 1-9; 9 = healthy, dark green color (Table 14).

Chlorophyll index was measured with a CM1000 Chlorophyll Meter (Spectrum Technologies) in the field as a further indication of turfgrass color and health (Table 15).

Collection of data on additional turfgrass parameters, e.g., phytotoxicity, disease, etc. were not warranted during 2008.

Results.

Turfgrass quality (Downriver).

At Downriver, turfgrass quality of the #6 tee showed no irrigation water treatment differences throughout the season (Table 13). The visual turfgrass quality of the tee was highly consistent, receiving a quality rating of 7 throughout the season.

At Downriver #7 rough, early in the season there was no difference in visual turfgrass quality due to source of irrigation water. However, from July 15 through October 15, 2008 the area of the #7 rough receiving reuse water was consistently better than the area receiving city water. The magnitude of the difference was 1 unit greater, so the turfgrass quality difference would probably not be noticeable without side-by-side areas to visually compare.

Turfgrass quality (Qualchan).

The newly constructed #16 back tee receiving reuse irrigation water generally had a visual quality rating that was higher than the older #16 tee receiving pond water (Table 13). This was especially noticeable late in the growing season. This difference could be due to factors other than irrigation source, e.g., the new #16 tee probably received additional fertility and irrigation during grow-in. Also, the soil physical properties are most likely better on the newly constructed sand-based tee compared to the older more mature #16 tee. Furthermore, the older #16 tee is a

mixture of bentgrass (*Agrostis stolonifera* L.), annual bluegrass (*Poa annua* L.), and perennial ryegrass (*Lolium perenne* L.), which gives it a mottled appearance as opposed to the newly established #16 tee, which is a uniform stand of Kentucky bluegrass (*Poa pratensis* L.) and perennial ryegrass.

The #15 green was reconstructed in the fall 2008. Visual turfgrass quality ratings on the old #15 green, prior to reconstruction, showed no differences between irrigation water source. Likewise, the newly reconstructed green in the late fall 2008 also showed no differences between irrigation water sources.

The Qualchan #16 fairway sites performed similar to the Downriver #7 rough sites. Late in the growing season the reuse irrigation water area received a higher quality rating than the pond water irrigated area. As at Downriver, visual turfgrass quality differences were not major.

Turfgrass color (Downriver).

Turfgrass color of the #7 rough (Table 14), which was evaluated from July through October 2008, showed a similar trend as turfgrass quality ratings discussed above (Table13). The area of the #7 rough receiving reuse irrigation water was consistently a darker green color than the area receiving city water. Again the differences, while consistent, were minor.

Downriver #6 tee showed no color differences during the rating period due to irrigation water source.

Turfgrass color (Qualchan).

At Qualchan, the new #16 back tee receiving reuse irrigation water was lower in color rating than the older #16 tee during the summer (Table 14). This may have been due to higher water applications needed during the establishment period of the newly constructed tee, which potentially flushed nutrients beyond the rootzone. However, later in the growing season the new #16 tee receiving reuse irrigation water had color rating higher than the older #16 tee receiving pond water.

Qualchan #15 green showed no difference in turfgrass color between irrigation water sources throughout the season.

Qualchan #16 fairway turfgrass color was slightly higher late in the season for the fairway area that received reuse irrigation water. Again differences were small and would not be noticeable unless side-by-side comparisons of the turfgrass areas could be made.

Turfgrass chlorophyll index (Downriver).

Downriver #6 tee showed only minor differences, and inconsistent trends, due to irrigation water source for chlorophyll index throughout the season (Table 15).

Downriver #7 rough had chlorophyll index values that were consistently higher throughout the growing season for the rough area receiving reuse water (Table 15). This was similar to the visual rating for turfgrass color (Table 14). Overall the #7 rough area receiving reuse irrigation water had better color and probably healthier plants throughout the season as indicated by chlorophyll index and color ratings.

Turfgrass chlorophyll index (Qualchan).

Qualchan #16 tee chlorophyll index was higher in the area receiving pond water irrigation early in the season and higher in the reuse irrigation water later in the season (Table 15). The

chlorophyll index results (Table 15) are consistent with the visual ratings for turfgrass color (Table 14).

Qualchan #15 green chlorophyll index was somewhat higher for the reuse irrigation water area (Table 15). Differences were not major and were not detected in the visual ratings for turfgrass color (Table 14).

Qualchan #16 fairway chlorophyll index was consistently higher for the area receiving reuse irrigation water, which would indicate a slightly darker green and healthier turfgrass (Table 15).

Task 6. Fertilizer program nutrient balance.

Our original rationale was that a potential exists for nutrients to be added to the turfgrass areas receiving reuse irrigation water, therefore, it might be necessary to adjust the amount of nutrients (fertilizer) being applied by golf course personnel so that each site received the same amount of nutrients. Since the nutrient balance was to be based on data collected during 2008, balancing of nutrients would only occur during the 2009 fertilizer applications. So, if needed, this task could still be accomplished in 2009.

Results.

We have reconsidered this task and have decided it is not best to adjust fertility levels across water source treatment areas. The objectives of the study are to determine the effect of irrigation with reuse or city/pond water on several soil and turfgrass parameters under normal golf course maintenance and play. If supplemental nutrient applications were added, the long term effect and comparison of reuse to city/pond irrigation water would be masked by these additional applications. Also, since numerous elements were measured, balancing nutrients by golf course personnel would be extremely difficult, as most of these elements are not applied by golf course superintendents during routine golf course maintenance.

Task 7. Phase II data analysis and 2008 report.

Results.

Completed.

References:

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Table 1. The effect of reuse and city water, used to irrigate turfgrass, on basic soil test results at Downriver Golf Course in 2008.

		Basic soil test (Downriver GC)													Interpretation			
		7 Rough						6 Tee										
		Reuse Water			City Water			Reuse Water			City Water			Analysis	Below Optimum	Optimum	Above Optimum	Unsatis-
	Units	5/15	7/15	10/15	5/15	7/15	10/15	5/15	7/15	10/15	5/15	7/15	10/15	Method	Range	Range	Range	factory
pH		6.3	6.7	6.8	6.1	6.6	6.6	6.7	6.9	7.2	6.5	6.9	7.0			5.5 - 7.0		< 4.5 & > 8.5
Organic Matter	%	6.14	5.48	6.42	6.36	6.06	7.04	2.08	2.72	3.33	1.91	2.46	2.37			1 - 10		< 1 & > 10
NO_3-N	ppm	10.3	43.8	65.3	16.3	27.8	40.5	1.5	1.0	11.0	0.5	0.8	13.8					
NH_4-N	ppm	8.5	18.5	9.3	14.8	19.3	15.3	4.5	5.8	3.3	3.5	3.0	3.0					
Phosphorous	ppm	20	28	22	22	30	26	78	78	63	72	36	65	Bicarb		12 - 15		
Potassium	ppm	210	230	392	227	282	622	170	177	215	138	142	203	Bicarb		165 - 200		
SO_4-S	ppm	17	28	<1	16	30	<1	20	34	41	23	38	21			14 - 20		
Boron	ppm	0.97	0.66	0.02	0.88	0.05	<.01	0.38	0.16	0.52	0.38	0.15	0.41			0.3 - 0.5		
EC (SS)	mmho/cm	0.25	0.60	0.86	0.32	0.88	1.06	0.38	0.40	0.45	0.42	0.26	0.26	Sat. Ext.		< 0.75		> 2.5
Zinc	ppm	11.0	4.8		10.8	9.5		5.0	4.4		5.0	4.2		DPTA		0.8 - 1.5		
Calcium	ppm	15.7	98.2		19.4	81.7		44.6	149.7		31.0	168.8		Sat. Ext.				
Magnesium	ppm	21.2	37.2		29.7	34.6		17.0	20.6		18.9	26.9		Sat. Ext.				
Sodium	ppm	10.8	35.9		8.5	9.7		7.9	67.5		9.1	14.4		Sat. Ext.				
SAR	meq/L	0.42	0.78		0.28	0.23		0.25	1.37		0.32	0.27				< 4.0		> 9.0
CEC	meq/100g			23.98			48.23			8.06			7.24					

Table 2. The effect of reuse and pond water, used to irrigate turfgrass, on basic soil test results at The Creek at Qualchan Golf Course in 2008.

		Basic soil test (The Creek at Qualchan GC)																		Interpretation			
		15 Green						16 fairway						16Tee									
		Reuse water			Pond water			Reuse water			Pond water			Reuse water			Pond water			Analysis	Below Optimum	Optimum	Above Optimum	Unsatis-
	Units	5/15	7/15	10/15*	5/15	7/15	10/15*	5/15	7/15	10/15	5/15	7/15	10/15	5/15**	7/15	10/15	5/15	7/15	10/15	Method	Range	Range	Range	factory
pH		7.2	7.1	8.1	7.0	7.0	8.3	6.7	6.7	7.1	6.3	6.4	6.6		7.2	7.7	6.4	6.6	6.9			5.5 - 7.0		< 4.5 & > 8.5
Organic Matter	%	1.47	3.52	1.02	1.54	3.09	0.58	2.43	3.78	2.32	1.40	3.11	5.36		0.42	0.3	2.25	3.42	3.42			1 - 10		< 1 & > 10
NO_3-N	ppm	1.3	5.3	32.5	1.8	3.0	11.8	0.5	1.5	34.0	0.5	3.8	32.3		0.8	2.5	0.5	2	12.8					
NH_4-N	ppm	2.3	6.8	0.5	2.3	3.3	0.5	8.0	6.0	3.5	5.3	4.5	13.8		0.5	0.3	5.5	12.3	4.5					
Phosphorous	ppm	28	24	7	34	22	3	8	14	12	16	22	19		11	10	22	20	21	Bicarb		12 - 15		
Potassium	ppm	99	89	101	78	74	91	182	117	246	178	197	266		31	44	168	165	177	Bicarb		165 - 200		
SO_4-S	ppm	19	59	81	17	74	35	9	12	18	12	13	<1		9	11	13	11	26			14 - 20		
Boron	ppm	0.27	0.25	0.09	0.33	0.21	0.07	0.22	0.07	0.37	0.28	0.12	0.01		0.01	0.13	0.25	0.06	0.32			0.3 - 0.5		
EC (SS)	mmho/cm	0.26	0.29	0.58	0.23	0.35	0.29	0.21	0.26	0.44	0.18	0.20	0.57		0.12	0.13	0.17	0.21	0.31	Sat. Ext.		< 0.75		> 2.5
Zinc	ppm	1.2	2.6	0.4	1.8	2.0	0.2	2.0	2.4	1.4	1.8	1.8			0.4		3.6	3.6		DPTA		0.8 - 1.5		
Calcium	ppm	60.1	175.5		38.1	241.2		33.4	66.0		19.2	54.0			35.6		31.8	72.3		Sat. Ext.				
Magnesium	ppm	12.0	27.0		10.9	31.0		20.4	33.0		12.9	28.3			12.1		13.1	23.1		Sat. Ext.				
Sodium	ppm	3.3	39.5		5.8	11.6		5.0	36.3		7.3	11.1			51.3		5.5	8.7		Sat. Ext.				
SAR		0.10	0.73		0.21	0.19		0.17	0.91		0.32	0.30			1.90		0.21	0.23				< 4.0		> 9.0
CEC	meq/100g			8.17			9.54			11.43			15.08			30.23			38.54					

*Green reconstructed in Fall 2008 with a new sand base and sod from the old green. Soil test reflects the new sand that was used to construct the green.

**Reuse water tee finished construction in June 2008.

Table 3. Initial soil heavy metal levels at Downriver Golf Course 5/15/08.

	Soil heavy metal levels (ppm) Downriver				MTCA Cleanup Regulations* (Ecological Indicator Soil Concentrations for Protection of Terrestrial Plants)	Detect Limit	Analysis	Prep
	7 Rough		6 Tee					
Analyte	Reuse	City	Reuse	City	(ppm)	(ppm)	Method	Method
Beryllium	0.71	0.60	0.47	0.49	10	0.02	ICP-MS	3050B Digest
Chromium	21	45	13	14	42	0.38	ICP-MS	3050B Digest
Cobalt	6.8	5.5	4.0	4.3	20	0.02	ICP-MS	3050B Digest
Nickel	12.0	12.0	8.4	8.9	30	0.06	ICP-MS	3050B Digest
Copper	14	14	18	16	100	0.06	ICP-MS	3050B Digest
Arsenic	6.7	7.0	12.0	13.0	10	0.38	ICP-MS	3050B Digest
Selenium	< 0.38	< 0.38	< 0.38	< 0.38	1	0.38	ICP-MS	3050B Digest
Molybdenum	0.51	1.00	0.38	0.37	2	0.02	ICP-MS	3050B Digest
Silver	0.63	0.70	1.20	0.96	2	0.08	ICP-MS	3050B Digest
Cadmium	0.19	0.59	0.10	0.11	4	0.04	ICP-MS	3050B Digest
Antimony	< 0.38	< 0.38	< 0.38	< 0.38	5	0.38	ICP-MS	3050B Digest
Barium	140	130	88	94	500	0.04	ICP-MS	3050B Digest
Thallium	0.21	0.19	0.15	0.16	1	0.06	ICP-MS	3050B Digest
Lead	33	41	10	11	50	0.04	ICP-MS	3050B Digest
Mercury	0.074	0.270	0.033	0.042	0.3	0.008	CVAFS	Nitric/HCl Digest

*Model Toxics Control Act (MTCA) compiled by the Washington State Department of Ecology Toxics Cleanup Program. (WAC 173-340-900). Oct 12, 2007. Page 247.
Website: http://www.ecy.wa.gov/pubs/9406.pdf

Exceeds MTCA levels for cleanup.

Table 4. Initial soil heavy metal levels at The Creek at Qualchan Golf Course in 2008.

	Soil heavy metal levels (ppm) Qualchan						*** MTCA Cleanup Regulations (Ecological Indicator Soil Concentrations for Protection of Terrestrial Plants) (ppm)	Detect Limit (ppm)	Analysis Method	Prep Method
	15 Green (10/15)*		16 Fairway (5/15)		16 Tee (6/17)**	(5/15)				
Analyte	Reuse	Pond	Reuse	Pond	Reuse	Pond				
Beryllium	0.28	0.30	0.54	0.59	0.77	0.54	10	0.02	ICP-MS	3050B Digest
Chromium	7.8	8.1	14.0	15.0	16.0	14.0	42	0.38	ICP-MS	3050B Digest
Cobalt	5.2	5.0	6.8	6.6	4.6	6.7	20	0.02	ICP-MS	3050B Digest
Nickel	5.6	5.6	12.0	12.0	10.0	12.0	30	0.06	ICP-MS	3050B Digest
Copper	9.0	8.8	11.0	12.0	12.0	11.0	100	0.06	ICP-MS	3050B Digest
Arsenic	1.1	1.3	7.1	7.0	14.0	8.9	10	0.38	ICP-MS	3050B Digest
Selenium	< 0.38	< 0.38	< 0.38	< 0.38	<0.38	< 0.38	1	0.38	ICP-MS	3050B Digest
Molybdenum	0.17	0.18	0.31	0.29	0.25	0.26	2	0.02	ICP-MS	3050B Digest
Silver	<0.08	<0.08	0.58	0.53	0.097	0.47	2	0.08	ICP-MS	3050B Digest
Cadmium	<0.04	0.044	0.057	0.110	0.086	0.130	4	0.04	ICP-MS	3050B Digest
Antimony	< 0.38	< 0.38	< 0.38	< 0.38	<0.38	< 0.38	5	0.38	ICP-MS	3050B Digest
Barium	32	36	100	110	85	97	500	0.04	ICP-MS	3050B Digest
Thallium	<0.06	<0.06	0.15	0.17	0.16	0.15	1	0.06	ICP-MS	3050B Digest
Lead	2.3	1.6	8.4	9.1	8.7	8.6	50	0.04	ICP-MS	3050B Digest
Mercury	<0.008	0.01	0.0098	0.013	0.013	0.0082	0.3	0.008	CVAFS	Nitric/HCl Digest

*Green reconstructed Fall 2008 with a new sand base and sod from the old green. Green was resampled for heavy metals on 10/15/08.

**Sample taken 6/17/08 after tee was constructed and before effluent water applied.

***Model Toxics Control Act (MTCA) compiled by the Washington State Department of Ecology Toxics Cleanup Program. (WAC 173-340-900). Oct 12, 2007. Page 247.
Website: http://www.ecy.wa.gov/pubs/9406.pdf

Exceeds MTCA levels for cleanup.

Table 5. Initial soil physical properties, May 15, 2008, prior to reuse water application at #6 tee at Downriver. Interpretations in brackets are primarily those provided by ISTRC.

Property	Downriver #6 tee Reuse Water	Downriver #6 tee City Water
Infiltration rate (in./hr)	1.23 [very low]	0.27 [sealed off]
Subsurface air capacity (air porosity)	13.47% [very low]	12.16% [very low]
Water porosity (capillary)	37.22% [very high to excessive]	37.47% [very high to excessive]
Bulk density (g/cc)	1.38 [ok]	1.42 [ok]
Water holding	27.01% [very high]	26.36% [very high]
Organic content (1/4 to 1 in.)	2.58% [a little high]	3.00% [high]
Organic content (1 to 2 in.)	2.58% [high]	2.59% [high]
Organic content (2 to 3 in.)	3.12% [very high]	2.40% [high]
Organic content (3 to 4 in.)	2.87% [very high]	2.44% [high]
Root mass	½ in.	½ in. [rooting in buried thatch]
Feeder roots	Sparse at 3 in.	Medium at 3 in. [very good]

Table 6. Initial soil physical properties, May 15, 2008, prior to reuse water application at Qualchan #16 fairway. Interpretations in brackets are primarily those provided by ISTRC.

Property	Qualchan #16 fairway Reuse Water	Qualchan #16 fairway Pond Water
Infiltration rate (in./hr))	0.81 [sealed off]	0.15 [sealed off]
Subsurface air capacity (air porosity)	16.99% [fairly good]	10.41% [low]
Water porosity (capillary)	48.09% [excessive]	65.98% [2/3 of sample holds water]
Bulk density (g/cc)	1.02 [very low, high thatch content]	0.71 [thatch]
Water holding	47.21% [excessive]	92.37% [excessive water]
Organic content (1/4 to 1 in.)	6.68% [past excessive]	7.92% [past excessive]
Organic content (1 to 2 in.)	4.56% [excessive]	6.76% [thatch]
Organic content (2 to 3 in.)	1.59% [ok]	2.94% [very high]
Organic content (3 to 4 in.)	0.98% [ok]	0.89% [ok]
Root mass	5/8 in.	5/8 in.
Feeder roots	Sparse at 3 in.	Sparse at 3 in.

Table 7. Irrigation suitablity of reuse water from the Spokane waste water treatment plant and city water at Downriver Golf Course in 2008.

			Irrigation suitability (Downriver GC)				Interpretation		
			Reuse water		City water				
		Units	7/15	10/15	7/15	10/15	Satisfactory	Possible problem	Probable problem
Water Characteristics	pH		7.60	8.10	7.90	8.10	5.5 - 7.5	4.5 - 5.5 & 7.5 - 8.5	< 4.5 & > 8.5
	Hardness		196.60	226.35	101.66	321.43	0 - 125	126- 245	>245
	Bicarbonate	ppm	85.40	85.40	92.72	117.12	0 - 111	112 - 525	>525
	Carbonate	ppm	0.00	0.00	4.80	7.20	0 - 12	13 - 62	>62
Impact on general growth	EC	mmhos/cm	0.72	0.69	0.22	0.32	0 - 0.75	0.75 - 3.0	>3.0
	Total Soluble Salts	ppm	460.80	441.60	140.80	204.80	0 - 480	481 - 1950	>1950
Impact from root contact	Sodium	meq/l	2.05	2.63	0.17	0.51	0 - 2.9	3.0 - 9.0	>9.0
	Chloride	ppm	37.00	68.40	3.88	4.86	0 - 140	141 - 360	>360
	Boron	ppm	0.18	0.19	0.04	0.07	0 - 0.5	0.6 - 2.0	>2.0
Impact from foliage contact	Sodium	ppm	47.23	60.44	3.96	11.67	0 - 70	71 - 210	>210
	Chloride	ppm	37.00	68.40	3.88	4.86	0 - 100	101 - 350	>350
Impact on soil structure	SAR	meq/l	2.35	2.91	0.25	0.56	0 - 6.0	6.1 - 9.0	> 9.0
	EC	mmhos/cm	0.72	0.69	0.22	0.32	> 0.51	< 0.50	
	Total Soluble Salts	ppm	460.80	441.60	140.80	204.80			
Plant Nutrients	Nitrate (NO_3-N)	ppm	22.20	23.40	0.78	14.10			
	Phosphate (PO_4)	ppm	0.40	0.29	0.00	0.00			
	Potassium (K)	ppm	7.54	11.67	1.78	3.39			
	Magnesium (Mg)	ppm	25.28	24.27	10.90	19.56			
	Calcium (Ca)	ppm	37.18	50.74	22.79	96.49			
	Sulfate (SO_4)	ppm	64.62	66.68	10.80	20.52			
	Manganese (Mn)	ppm	0.08	0.00	0.05	0.01			
	Iron (Fe)	ppm	0.01	0.00	0.00	0.00			
	Boron (B)	ppm	0.18	0.19	0.04	0.07			

Table 8. Irrigation suitablity of reuse water from the Spokane waste water treatment plant and water pumped from an irrigation pond at The Creek at Qualchan Golf Course in 2008.

			Irrigation suitability (The Creek at Qualchan GC)				Interpretation		
			Reuse water		Pond water				
		Units	7/15	10/15	7/15	10/15	Satisfactory	Possible problem	Probable problem
Water Characteristics	pH		7.60	8.10	8.20	8.20	5.5 - 7.5	4.5 - 5.5 & 7.5 - 8.5	< 4.5 & > 8.5
	Hardness		197.04	432.71	147.10	197.42	0 - 125	126- 245	>245
	Bicarbonate	ppm	124.44	122.00	131.76	122.00	0 - 111	112 - 525	>525
	Carbonate	ppm	0.00	7.20	7.20	7.20	0 - 12	13 - 62	>62
Impact on general growth	EC	mmhos/cm	0.72	2.21	0.30	0.32	0 - 0.75	0.75 - 3.0	>3.0
	Total Soluble Salts	ppm	460.80	1414.00	192.00	204.80	0 - 480	481 - 1950	>1950
Impact from root contact	Sodium	meq/l	2.01	15.22	0.16	0.20	0 - 2.9	3.0 - 9.0	>9.0
	Chloride	ppm	88.70	376.00	5.28	4.24	0 - 140	141 - 360	>360
	Boron	ppm	0.20	0.24	0.03	0.04	0 - 0.5	0.6 - 2.0	>2.0
Impact from foliage contact	Sodium	ppm	46.15	350.10	3.69	4.63	0 - 70	71 - 210	>210
	Chloride	ppm	88.70	376.00	5.28	4.24	0 - 100	101 - 350	>350
Impact on soil structure	SAR	meq/l	2.53	14.71	0.23	0.26	0 - 6.0	6.1 - 9.0	> 9.0
	EC	mmhos/cm	0.72	2.21	0.30	0.32	> 0.51	< 0.50	
	Total Soluble Salts	ppm	460.80	1414.40	192.00	204.80			
Plant Nutrients	Nitrate (NO_3-N)	ppm	24.20	284.00*	0.33	10.60			
	Phosphate (PO_4)	ppm	0.07	0.00	0.00	0.00			
	Potassium (K)	ppm	7.43	12.60	1.84	2.40			
	Magnesium (Mg)	ppm	25.07	23.68	18.70	19.59			
	Calcium (Ca)	ppm	37.70	134.26	28.17	46.85			
	Sulfate (SO_4)	ppm	64.59	66.63	17.81	19.65			
	Manganese (Mn)	ppm	0.01	0.00	0.03	0.01			
	Iron (Fe)	ppm	0.00	0.03	0.00	0.00			
	Boron (B)	ppm	0.20	0.24	0.03	0.04			

* Very high nitrate levels.

Table 9. Heavy metal levels in irrigation water at Downriver Golf Course in 2008.

	Irrigation water heavy metal levels (ppb) Downriver						EPA* Recommended Limits for Heavy Metals in Reuse Water for Irrigation	EPA* Recommended Limits for Heavy Metals in Reuse Water for Irrigation	Detect		
	Reuse water			City water			**Long term use**	**Short term use**	Limit	Analysis	Prep
Analyte	5/15	7/15	10/15	5/15	7/15	10/15	(ppb)	(ppb)	(ppb)	Method	Method
Beryllium	< 0.13	< 0.13	< 0.13	< 0.13	< 0.13	< 0.13	100	500	0.13	ICP-MS	
Chromium	< 1	< 1	< 1	< 1	< 1	< 1	100	1000	1	ICP-MS	
Cobalt	< 0.25	< 0.25	< 0.25	< 0.25	< 0.25	< 0.25	50	5000	0.25	ICP-MS	
Nickel	1.3	1.7	1.5	< 0.5	< 0.5	< 0.5	200	2000	0.5	ICP-MS	
Copper	7.8	5.3	9.6	< 0.25	< 0.5	6.8	200	5000	0.5	ICP-MS	
Arsenic	1	1.1	0.88	2.4	2.8	2.1	100	2000	0.5	ICP-MS	
Selenium	< 1	< 1	< 1	< 1	< 1	< 1	20	20	1	ICP-MS	
Molybdenum	2.3	2.4	2.8	1.1	< 1	1.7	10	50	1	ICP-MS	
Silver	< 0.25	< 0.25	< 0.25	3.1	< 0.25	< 0.25			0.25	ICP-MS	
Cadmium	< 0.25	< 0.25	< 0.25	< 0.25	< 0.25	0.52	10	50	0.25	ICP-MS	
Barium	12	16	17	23	1.9	26			0.5	ICP-MS	
Lead	0.37	< 0.25	0.30	0.35	< 0.25	0.51	5000	10000	0.25	ICP-MS	
Mercury	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05			0.05	CVAFS	BrCl Digest
Vanadium	0.42	0.43	0.27	< 0.25	< 0.25	< 0.25	100	1000	0.25	ICP-MS	
Manganese	8.8	8.7	< 0.25	< 0.25	< 0.25	0.26	200	10000	0.25	ICP-MS	
Zinc	67	67	110	170	5.8	810	2000	10000	2.5	ICP-MS	

*EPA Guidelines for Water Reuse. EPA/625/R-04/108. Sept. 2004. Page 25.
Website: http://www.epa.gov/ord/NRMRL/pubs/625r04108/625r04108.pdf

Table 10. Heavy metal levels in irrigation water at The Creek at Qualchan Golf Course in 2008.

	Irrigation water heavy metal levels (ppb) Qualchan						EPA* Recommended Limits for Heavy Metals in Reuse Water for Irrigation	EPA* Recommended Limits for Heavy Metals in Reuse Water for Irrigation	Detect		
	Reuse water			Pond water			**Long term use**	**Short term use**	Limit	Analysis	Prep
Analyte	5/15	7/15	10/15	5/15	7/15	10/15	(ppb)	(ppb)	(ppb)	Method	Method
Beryllium	< 0.13	< 0.13	< 0.13	< 0.13	< 0.13	< 0.13	100	500	0.13	ICP-MS	
Chromium	< 1	< 1	4.4	< 1	< 1	< 1	100	1000	1	ICP-MS	
Cobalt	< 0.25	< 0.25	6.8	< 0.25	< 0.25	< 0.25	50	5000	0.25	ICP-MS	
Nickel	1.3	1.8	2.4	< 0.5	< 0.5	< 0.5	200	2000	0.5	ICP-MS	
Copper	7.8	5.2	7	2.5	< 0.25	5.7	200	5000	0.5	ICP-MS	
Arsenic	1	1.1	1.2	2.2	3.1	3.1	100	2000	0.5	ICP-MS	
Selenium	< 1	< 1	<1	< 1	< 1	< 1	20	20	1	ICP-MS	
Molybdenum	2.3	2.3	2.8	1	1.5	1.8	10	50	1	ICP-MS	
Silver	< 0.25	< 0.25	< 0.25	< 0.25	< 0.25	< 0.25			0.25	ICP-MS	
Cadmium	< 0.25	< 0.25	< 0.25	< 0.25	< 0.25	< 0.25	10	50	0.25	ICP-MS	
Barium	12	16	17	22	25	29			0.5	ICP-MS	
Lead	0.37	< 0.25	0.79	1.2	< 0.25	0.36	5000	10000	0.25	ICP-MS	
Mercury	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05			0.05	CVAFS	BrCl Digest
Vanadium	0.42	0.43	0.48	< 0.25	< 0.25	< 0.25	100	1000	0.25	ICP-MS	
Manganese	8.8	11	6.8	8.3	< 0.25	< 0.25	200	10000	0.25	ICP-MS	
Zinc	67	76	85	18	6.3	200	2000	10000	2.5	ICP-MS	

*EPA Guidelines for Water Reuse. EPA/625/R-04/108. Sept. 2004. Page 25.
Website: http://www.epa.gov/ord/NRMRL/pubs/625r04108/625r04108.pdf

Table 11. The effect of reuse and city water on leaf tissue analysis of turfgrass at Downriver Golf Course in 2008.

Leaf tissue analysis of turfgrass (Downriver GC)

		7 Rough								6 Tee								Below		Above
		Reuse water				City water				Reuse water				City water				Normal	Normal	Normal
	Units	6/17	8/15	9/15	10/15	6/17	8/15	9/15	10/15	6/17	8/15	9/15	10/15	6/17	8/15	9/15	10/15	Range	Range	Range
Nitrogen	%	3.49	4.39	4.06	3.90	2.63	4.31	4.25	3.16	3.66	4.25	3.54	4.95	3.65	3.96	3.98	4.50		3.91 - 4.50	
Phosphorous	%	0.25	0.44	0.37	0.36	0.23	0.49	0.32	0.28	0.42	0.53	0.45	0.43	0.43	0.53	0.44	0.43		0.30 - 0.50	
Potassium	%	2.07	2.93	2.84	2.65	1.77	2.71	2.76	2.38	2.14	2.89	2.15	2.68	2.08	2.82	2.11	2.55		2.50 - 3.50	
Magnesium	%	0.23	0.30	0.32	0.28	0.21	0.25	0.30	0.27	0.16	0.27	0.34	0.24	0.14	0.26	0.32	0.23		0.25 - 0.50	
Calcium	%	0.39	0.53	0.53	0.52	0.33	0.42	0.55	0.53	0.39	0.44	0.42	0.44	0.37	0.51	0.43	0.51		0.50 - 0.75	
Sodium	%	0.04	0.14	0.15	0.12	0.01	0.10	0.02	0.02	0.03	0.13	0.10	0.12	0.01	0.04	0.02	0.03		0.01 - 0.16	
Sulfur	%	0.28	0.42	0.45	0.38	0.25	0.39	0.45	0.34	0.30	0.46	0.34	0.36	0.29	0.39	0.29	0.33		0.26 - 0.40	
Zinc	ppm	30	40	39	40	26	52	45	41	36	60	52	54	33	50	43	49		41 - 60	
Manganese	ppm	31	65	41	37	25	144	23	33	139	164	167	99	146	155	150	134		41 - 80	
Copper	ppm	6	11	10	9	5	14	12	8	9	13	12	9	7	12	11	11		16 - 20	
Iron	ppm	242	324	560	470	93	883	202	411	564	869	3379	1214	500	997	3083	1684		126 - 175	
Boron	ppm	10	12	10	12	8	16	7	7	18	25	29	18	16	16	14	14		21 - 40	
Molybdenum	ppm	11.41	0.01	0.01		13.26	0.01	2.10		14.78	0.01	0.01		3.66	0.01	9.48				
Aluminum	ppm	223	279	571	453	51	571	139	321	366	454	2155	1010	276	666	1990	1043			

Table 12. The effect of reuse and pond water on leaf tissue analysis of turfgrass at The Creek at Qualchan Golf Course in 2008.

Leaf tissue analysis of turfgrass (The Creek at Qualchan GC)

		15 Green								16 fairway								16 Tee								Below		Above
		Reuse water				Pond water				Reuse water				Pond water				Reuse water				Pond water				Normal	Normal	Normal
	Units	6/17	8/15	9/15	10/15*	6/17	8/15	9/15	10/15*	6/17	8/15	9/15	10/15	6/17	8/15	9/15	10/15	7/15**	8/15	9/15	10/15	6/17	8/15	9/15	10/15	Range	Range	Range
Nitrogen	%	4.87	4.50	5.25	No Data	4.92	3.79	4.39	No Data	3.00	4.28	4.06	4.14	2.46	3.67	3.47	3.42	3.41	4.48	4.36	3.41	4.01	4.00	4.12	3.18		3.91 - 4.50	
Phosphorous	%	0.45	0.61	0.64	No Data	0.45	0.55	0.59	No Data	0.36	0.42	0.46	0.44	0.34	0.51	0.54	0.40	0.40	0.54	0.55	0.40	0.37	0.53	0.49	0.36		0.30 - 0.50	
Potassium	%	2.09	2.85	2.75	No Data	2.08	2.41	2.39	No Data	1.75	2.93	2.53	2.80	1.87	2.49	2.69	2.35	2.89	3.17	3.03	2.89	1.88	2.67	2.55	2.15		2.50 - 3.50	
Magnesium	%	0.18	0.26	0.26	No Data	0.20	0.24	0.32	No Data	0.25	0.34	0.31	0.28	0.26	0.33	0.35	0.32	0.31	0.48	0.31	0.31	0.24	0.33	0.27	0.32		0.25 - 0.50	
Calcium	%	0.43	0.51	0.38	No Data	0.44	0.52	0.52	No Data	0.40	0.44	0.38	0.47	0.40	0.44	0.51	0.44	0.63	0.58	0.43	0.63	0.36	0.51	0.42	0.61		0.50 - 0.75	
Sodium	%	0.02	0.11	0.11	No Data	0.01	0.03	0.03	No Data	0.02	0.08	0.04	0.13	0.01	0.01	0.02	0.01	0.16	0.18	0.08	0.16	0.01	0.02	0.02	0.02		0.01 - 0.16	
Sulfur	%	0.41	0.45	0.45	No Data	0.40	0.42	0.40	No Data	0.25	0.50	0.41	0.43	0.24	0.39	0.50	0.32	0.36	0.72	0.44	0.36	0.32	0.53	0.46	0.36		0.26 - 0.40	
Zinc	ppm	42	60	58	No Data	41	53	48	No Data	28	72	52	63	27	46	33	55	50	68	46	50	33	56	40	46		41 - 60	
Manganese	ppm	49	73	62	No Data	52	67	74	No Data	60	44	41	60	93	38	23	72	98	329	137	98	158	53	43	280		41 - 80	
Copper	ppm	12	18	17	No Data	12	16	14	No Data	5	12	13	10	5	13	13	6	14	16	15	14	7	15	13	11		16 - 20	
Iron	ppm	399	336	539	No Data	319	565	1911	No Data	307	172	199	587	652	134	147	179		1230	569	576	177	237	271	541		126 - 175	
Boron	ppm	15	13	10	No Data	14	12	10	No Data	10	14	11	10	10	7	10	6		25	21	14	9	9	6	9		21 - 40	
Molybdenum	ppm	11.17	0.01	0.03	No Data	8.26	0.01	0.01	No Data	2.51	0.01	0.01		14.92	0.01	0.01			0.01	0.01		6.55	0.01	4.61				
Aluminum	ppm	188	143	321	No Data	91	186	1271	No Data	203	99	121	434	418	68	100	112		899	238	411	81	130	134	447			

*Green reconstructed in Fall 2008. A tissue sample was not taken due to the large amount of topdress sand on the green.

**First tissue sample taken after newly constructed tee was planted mid-June 2008.

Table 13. The effect of reuse and conventional irrigation water on visual turfgrass quality at The Creek at Qualchan and Downriver Golf Courses in 2008.

Golf Course	Area	Irrigation Source	Turfgrass quality*					
			5/15	6/17	7/15	8/15	9/17	10/15
Qualchan	16 Tee	Reuse	**	**	6	6	7	7
	16 Tee	Pond	6	6	5	6	5	5
	15 Green	Reuse	6	6	7	7	7	6***
	15 Green	Pond	6	6	7	7	7	6***
	16 Fairway	Reuse	6	6	6	7	7	7
	16 Fairway	Pond	6	6	5	6	6	6
Downriver	6 Tee	Reuse	7	7	7	7	7	7
	6 Tee	City	7	7	7	7	7	7
	7 Rough	Reuse	7	7	7	7	8	7
	7 Rough	City	7	7	6	6	7	6

*Turfgrass quality rated on a scale of 1 to 9 with 9 = excellent turf quality.

**16 Tee not finished construction and planted until mid-June 2008.

*** 15 Green was reconstructed in fall 2008.

Table 14. The effect of reuse and conventional irrigation water on visual turfgrass color at The Creek at Qualchan and Downriver Golf Courses in 2008.

Golf Course	Area	Irrigation Source	Turfgrass color*			
			7/15	8/15	9/17	10/15
Qualchan	16 Tee	Reuse	5	5	7	7
	16 Tee	Pond	6	6	6	6
	15 Green	Reuse	7	7	7	7**
	15 Green	Pond	7	7	7	7**
	16 Fairway	Reuse	7	7	8	8
	16 Fairway	Pond	7	7	7	7
Downriver	6 Tee	Reuse	8	7	7	8
	6 Tee	City	8	7	7	8
	7 Rough	Reuse	8	7	8	8
	7 Rough	City	7	6	7	7

*Turfgrass color visually rated on a scale of 1 to 9 with 9 = dark green.

**15 Green was reconstructed in fall 2008.

Table 15. The effect of reuse and conventional irrigation water on chlorophyll index readings at The Creek at Qualchan and Downriver Golf Courses in 2008.

Golf Course	Area	Irrigation Source	Chlorophyll index*			
			7/15	8/15	9/17	10/15
Qualchan	16 Tee	Reuse	290	217	375	319
	16 Tee	Pond	402	403	358	284
	15 Green	Reuse	362	399	392	166**
	15 Green	Pond	363	341	331	158**
	16 Fairway	Reuse	463	537	528	354
	16 Fairway	Pond	375	446	461	324
Downriver	6 Tee	Reuse	323	333	400	385
	6 Tee	City	331	320	404	357
	7 Rough	Reuse	417	429	602	404
	7 Rough	City	405	392	453	374

*Chlorophyll index readings on a scale of 0 to 999 with 999 = very high chlorophyll content.

**15 Green was reconstructed in fall 2008.