Real and Virtual Water and Water Footprints: A Comparison between the Lower Fraser Valley and the Okanagan Basin

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1. Background on Blue, Green and Virtual Water and Why it is Important

The concept of virtual water was introduced by Allen in 1997 as an economic tool and an alternative means of measuring the global distribution of water through trade (Allan 1997, Allan 1998). What was unique and captivating about this new premise was that it focused not on the trade of water itself, but on the trade of water imbedded within goods and commodities. The definition of virtual water is the amount of water required to produce a given good or service (Allan, 1998, Wilchens, 2001, and Chapagain and Hoekstra, 2004a). Many authors suggest that a water crisis is imminent in many parts of the world (Rogers et al. 2006). As a result we need to improve water management, and focus on reducing demand and improving the efficiency of water use. Significant savings can be made in water use if the concept of virtual water is incorporated into water allocations, but since this is a relatively new area of research, some basic research is required to make sure that the results are credible and capable of influencing policy and the governance of water.

1.1. Blue, Green and Virtual Water

Water moves through the hydrological cycle at different rates, and most of the water that we use and manage is **blue water**, which is that component of rainwater that ends up in streams, lakes, and groundwater. However, there is also a **green water** component in the hydrological cycle, which is the rainfall that is intercepted by vegetation and by the soil, is then taken up by plants to create biomass and then evapotranspired back into the atmosphere. This part of the hydrological cycle has not been given much attention and is poorly managed. Since there is almost twice as much water in the green cycle as opposed to the blue cycle (Falkenmark and Rockstrom, 2004, Rockstrom 2005), much can be gained by improving the efficiency of green water management and biomass production. To improve biomass production is a major global challenge. There is abundant evidence to suggest that global food production needs to be increased by about 50% over the next 30 years (Lal et al. 2005) in order to meet the food demands by an additional 2.5 billion people, to improve the diet of 1 billion that currently face food shortages, and to meet the demands associated with changes in diets from emerging economies. Since the agricultural land base is shrinking, greater intensification is needed and this requires more water.

The concept of ***Virtual Water*** needs to be considered in all water balance calculations and it is becoming evident that some water scarce countries will likely import food that is water intensive to produce. Virtual water is the water that is needed to produce food or a commodity, and is measured in m^3 of water per ton of crop or product. To determine the virtual water use we need data on crop water requirements over the growing season, evapotranspiration rates, the annual yield and the amount of water used in processing the crop. This concept has been applied globally by UNESCO (Chapagain and Hoekstra, 2004) to determine water balances for most of the countries in the world. However, conducting virtual water calculations on a country by country basis is only useful for overall comparative purposes and for global trade studies but it does not address regional and seasonal differences. In order to conduct a global study, average crop water requirements, evapotranspiration and yield need to be used. To simplify the process the authors of the UNESCO study used the climate data for the capital city in each country. This is appropriate for small countries like Denmark and Holland where the capital city is in close proximity of the food production area and where the country wide climatic variability is relatively small. However, this is not appropriate for Canada where the capital city is far removed from the agricultural heartland and where the climatic variability across the country is large. To make the "Virtual Water" concept useful to water resource managers and decision makers requires that such calculations be made on a watershed or river basin scale. Conducting annual water balances are only viable in a watershed context because this allows us to determine water inputs (rainfall and snow) and outputs (discharge, groundwater losses, and evapotranspiration) and this forms the basis for water allocations for different uses. In calculating water balances usually no consideration is given to the amount of water that is exported and imported in and out of the watershed in the form of products. This can be a significant component in watersheds where agriculture is the dominant land use activity and where global trade is significant.

1.2. Agricultural-Urban Conflicts and Water Reallocation

Agriculture uses up to 70% of the available freshwater resources, and due to the rapid rate of urbanization (more than 50% of the world's population now lives in cities) the demands for water for cities is increasing rapidly. When water resources become scarce then water re-allocation between agriculture and urbanization will be necessary. This is already happening at a significant scale in California (Gleick et al, 2005) where some farmers sell or allocate their water rights to municipalities. Since the demands for water for food production, urbanization and industrial development are all increasing, conservation measures, demand reduction and improved efficiency in water use will become a critical component of water management. Given that 40% of all food is produced from 17% of irrigated agricultural land and given increased climatic variability, the pressure to irrigate more land is expected increase. Many people have suggested that irrigation water use efficiency in agriculture can be significantly improved (Postel, 2006). However, this should not only include the water application and management component but also the plant efficiency to use water. There are large differences in water demand between different crops and different trees, and this is an important component of green water management that needs to be taken into consideration when developing conservation water strategies. In many countries water for agriculture is subsidized and farmers hold the water rights. The urban pressure in many places is now so great that farmers are willing to sell their water rights to cities because the economic returns for the farmers for food production are lower than what they can obtain by selling water to urban centers. Arriving at a sustainable and equitable water use between urban and agricultural needs will be one of the great challenges facing the world in the next 30 years.

1.3. Water Needs for Food

For most staple crops it takes about 1,000 litres of water to produce 1 kg of grain. Rice requires 2-3 times this amount, while meat production takes 4-30 times more water per kilogram. Figure 1 shows the low and high estimates of water needed to grow one kg of food. As our diet becomes protein (meat) rich, more water is needed to produce that diet. This is illustrated in Figure 2 which shows a comparison of the water requirements for a daily diet in the different parts of the world. It takes about 5,400 L of water to maintain a North American daily diet. The water requirement for maintaining the daily diet in developing countries is about half of the North American requirement, and if the rest of the world strives towards a North American diet we would need twice as much water for food production. It is estimated that about 30% of the current food consumption is from livestock products (Greenland, 2005) and all indicators show that food habits are shifting towards a more meat based diet (Smil, 2000) as countries move up the development ladder. China is the best example, where meat consumption has increased dramatically since 1999. This is even the case in India where meat consumption has increased in spite of the cultural and religious taboos. These trends are clear indicators that water requirements for food production will increase significantly in the near future.

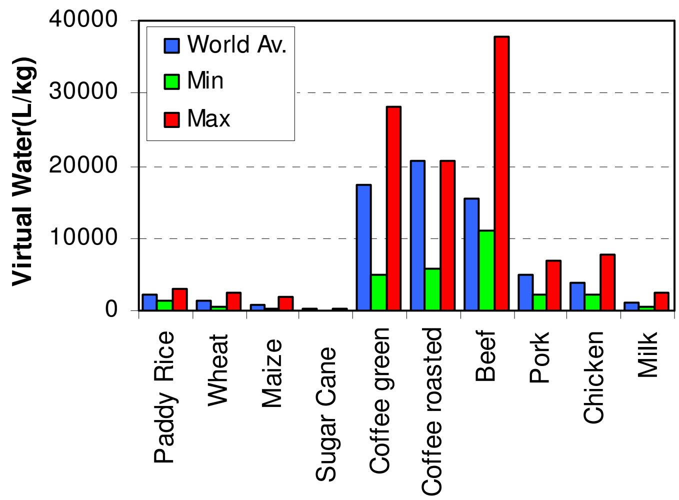


Figure 1. Global estimates of virtual water requirements to produce different crops and meat.

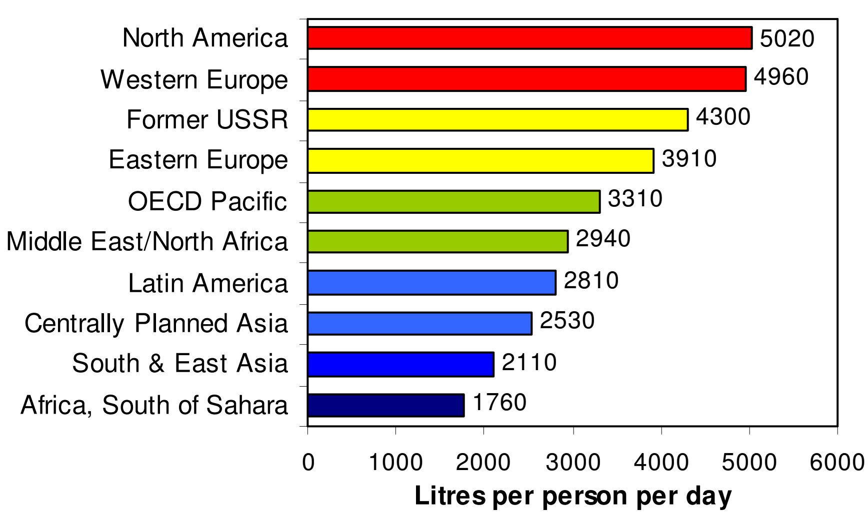
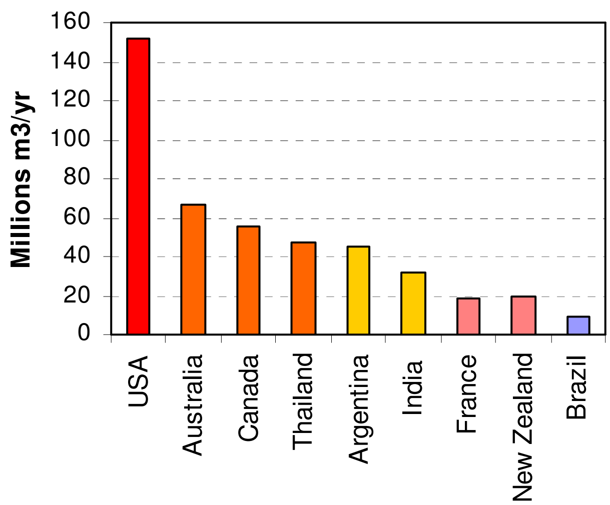


Figure 2. Water requirements to maintain different diets in the world.

1.4. Virtual Water Imports and Exports

Land rich countries with favourable climates and sufficient water resources will have the advantage to produce water intensive food and plant products, while countries with a small arable land base and scarce water resources will likely import food that is water intensive to grow. Figures 3 and 4 summarize the result of the global virtual water trade evaluation conducted by Chapagain and Hoekstra (2004). The results show that the USA, Australia and Canada are the largest virtual water exporters in the world, while Japan, Netherlands, South Korea and China are the largest virtual water importers.

Countries that have significant additional capacity to produce food (USA, Canada, Brazil and Argentina) will likely become greater water exporters particularly in the form of meat, and this will require far more water than exporting grains. China, which already has the most intensive agriculture, will likely become a major importer of meat (particularly beef and chickens), and in this way will import large amounts of virtual water. Recent evidence suggests that this is already happening; since 1999 chicken and beef imports to China far exceed exports (Figures 5 and 6).



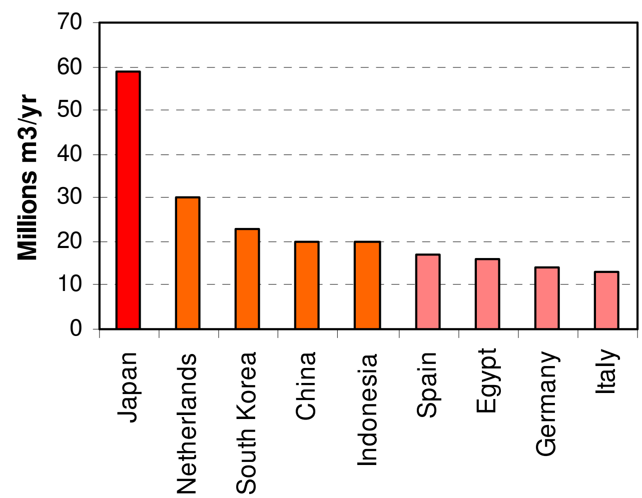


Figure 3. Virtual water exporting countries. Figure 4. Virtual water importing countries.

* (modified from Chapugain & Hoekstra 2004)

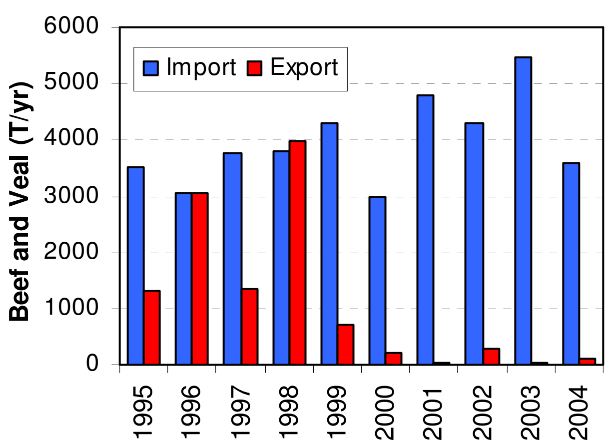


Figure 5. Historic changes in beef and veal imports and exports in China.

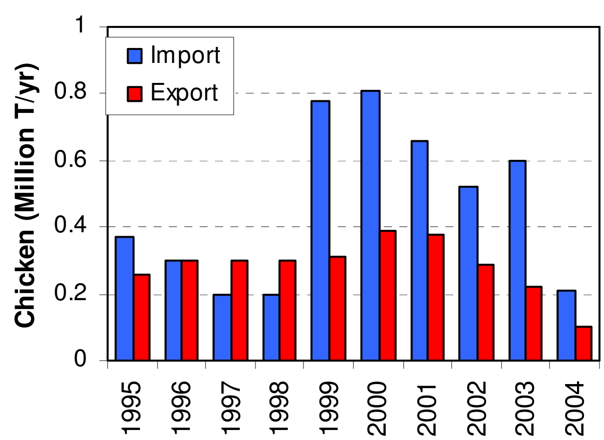


Figure 6. Historic changes in chicken imports and exports in China.

Canada has the potential to become a significant virtual water exporter, but as water resources become scarce and water pollution problems increase, decisions need to be made on how to reorganize food production. Water demanding crops should be grown in areas with surplus water and low water demanding crops should be grown in dry areas of Canada. A large proportion of the food production in Canada occurs in the semi-arid environments and with the increasing variability in climate these areas will experience higher production risks related to water shortages.

2. Aims of the project and policy relevance

The overall goal of the study was to evaluate the water use and virtual water needs between the Okanagan Basin (OK) and the Lower Fraser Valley (LFV). The Okanagan basin is the driest watershed and the Lower Fraser Valley is one of the wettest watersheds in Canada. Food production is widespread in both basins, and both areas are experiencing some of the most rapid population growth rates in the country.

The Okanagan basin is at a crossroad. Almost all surface water resources are fully allocated and questions are being raised on how to provide sufficient water to meet the continuously increasing demands from urban, recreational and agricultural activities. Agriculture alone uses up to 77% of the available freshwater resources. The annual rainfall in the area dominated by agriculture and urbanization ranges between 300 and 500 mm per year with most of it falling during the winter months. In contrast, the Lower Fraser Valley has ample water resources with annual rainfall in the lowland area ranging from 1,400 to 1,800 mm per year.

Contrasting these two areas in terms of water use and virtual water needs is of interest because of the emerging concern that short term water demands cannot be met in the Okanagan. The Okanagan has experienced rapid growth over the past 10 years, and the problem is exacerbated by increased climatic variability which is anticipated to bring higher temperatures during the summer and more unreliable snow pack in the winter.

The aims of the project are to determine the amount of water used in the production of different crops and livestock, and compare the efficiency in water requirements between the two basins. The specific objectives are:

1. Compare the water requirements and virtual water used between different crops and livestock;
2. Determine the overall water needs for food production in both basins;
3. Compare the water requirements and determine where the greatest water savings can be made by conservation and trade-offs; and
4. Compare the water needs for food with those for domestic and recreational uses.

To our knowledge this is the first time in Canada that a detailed comparison on water needs for different food produced in two river basins has been made. The study provides key information for the determination of the water balance for the Okanagan Basin. This information will provide a basis for the development of a water conservation strategy that is now being initiated by the Okanagan Basin Water Board. Decision makers can now assess in quantitative terms what activities are most water intensive and what the best trade-offs are in terms of water conservation.

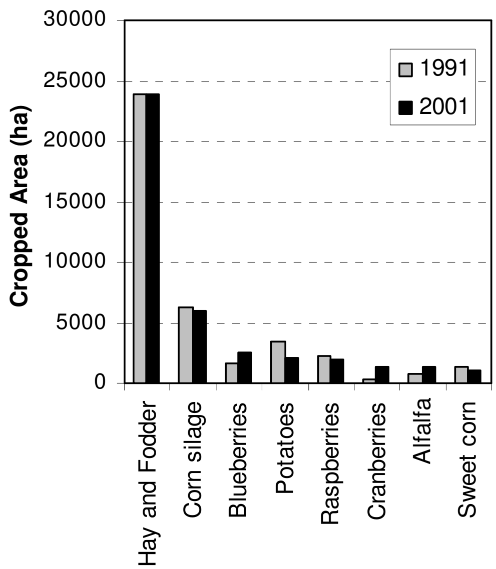
3. Crop water requirements, water use and virtual water for different crops in the Okanagan and the Lower Fraser Basins 1991-2001

Agricultural production is a significant water user in British Columbia. Agriculture is the largest water user in the Okanagan utilizing 77% of the water supplied in the summer months (Nyvall and van der Gulik, 2000). To provide a more complete picture of water use, the water footprint concept includes both the water withdrawn from surface and groundwater (blue water), and the use of soil water (green water in agricultural production).

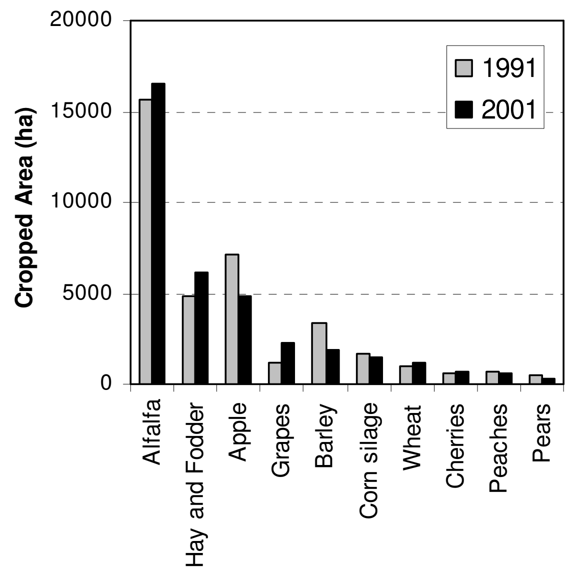
3.1. Major crops

The major crops produced in the Lower Fraser Valley and Okanagan Basin on an area (ha) and a production (T/yr) basis are show in Figures 7a to d. The Agricultural Census data (Statistics Canada 2002) was used as a basis for the crop water use and virtual water use calculations as it is the only comprehensive data available for both the Lower Fraser and Okanagan.

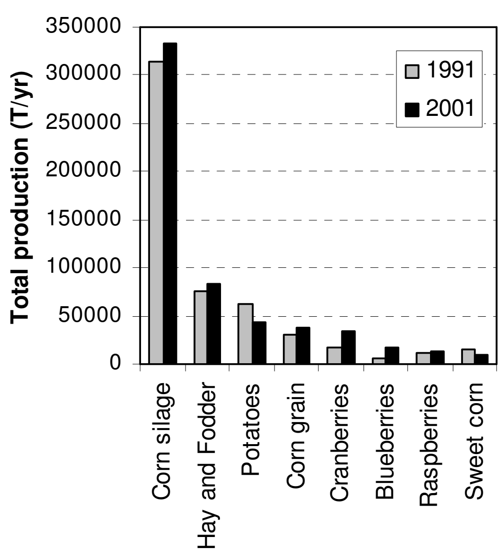
a) Lower Fraser Valley cropped area



b) Okanagan Basin cropped area



c) Lower Fraser Valley total production



d) Okanagan Basin total production

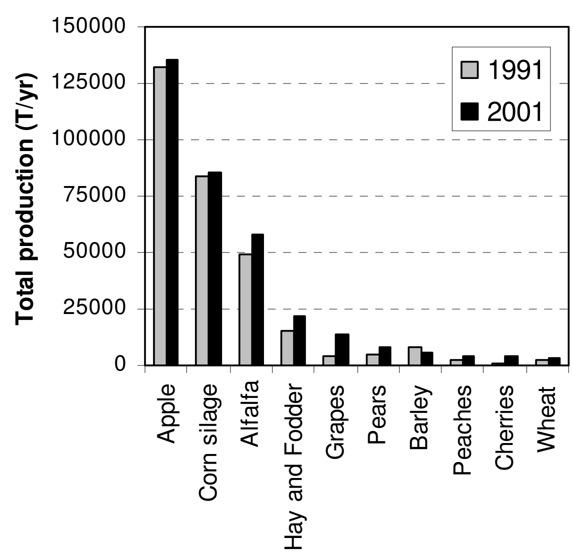


Figure 7. Cropped area and production for major crops in the Lower Fraser and Okanagan.

3.2. Crop water requirements

Estimated crop water requirements (m^3/ha) are directly related to evapotranspiration. Evapotranspiration is influenced by crop type, stage of development of the crop, and local climatic regime. The mean monthly evapotranspiration was calculated from 10 years (1995-2005) of Environment Canada data available through the Farmwest agricultural service centre (www.farmwest.com) for three stations in the Lower Fraser Valley and two stations in the Okanagan Basin. Local crop coefficients from the BC Ministry of Agriculture, Food and Fisheries (van der Gulik and Nyvall, 2001) were cross-referenced with values from the Pacific Northwest Cooperative Agricultural Weather network (USBR 2006). The resulting crop water requirements for the major crops produced in the Lower Fraser Valley and the Okanagan Basin are summarized in Figure 8a and b. High water requirement fruit crops such as apples, peaches and cherries are grown in the Okanagan Basin. The range in water requirements for crops grown in the Lower Fraser Valley is smaller, with raspberries having the highest crop water requirement (m^3/ha).

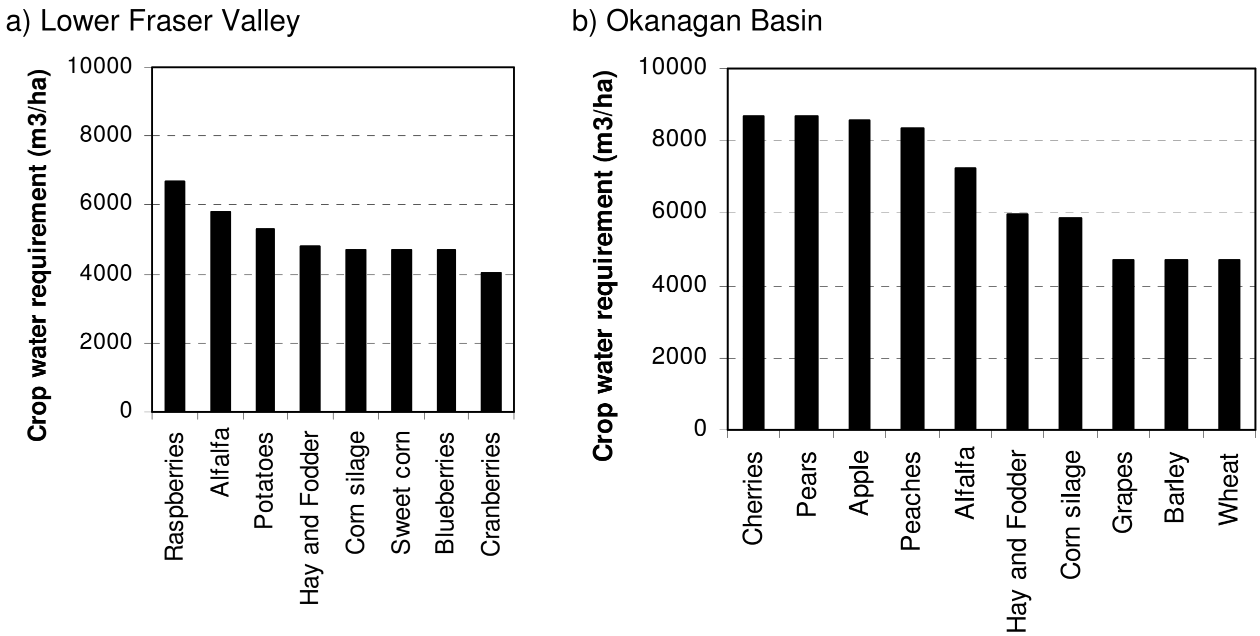
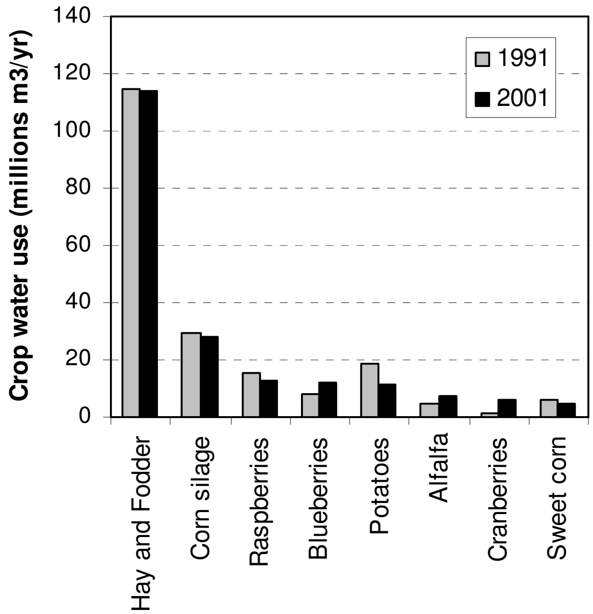


Figure 8. Crop water requirements (m^3/ha).

3.3. Crop virtual water use

Crop water use reflects the crop water requirements, the area under production and yield. Production and yield data from the 1991 and 2001 Agricultural Census (Statistics Canada, 2002) and horticultural statistics (BCMAFF, 2002) were used in the calculations, along with the crop water requirements. Crop water uses for the major crops in the two regions are presented in Figures 9a and b, and Table 1. The most water demanding crops were hay fodder in the Lower Fraser Valley, and alfalfa and apples in the Okanagan Basin. Apples have a high crop water requirement and the area under production is moderately high (3rd in the Okanagan Basin), while alfalfa is grown on over 16,000 ha of land. Apples together with alfalfa, and hay fodder make up 81% of crop water use in the Okanagan. Water use in apple production declined significantly from 1991 to 2001, in part related to a decline in cropped area. Hay and silage corn make up approximately 70% of all crop water use in the Lower Fraser, followed by raspberries and blueberries. Hay fodder has a lower crop water requirement, but the area under production in the basin is nearly 24,000 ha.

a) Lower Fraser Valley



b) Okanagan Basin

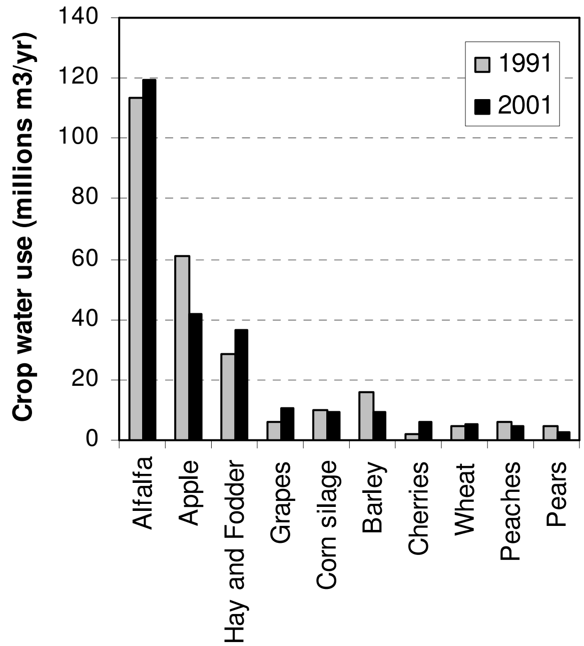
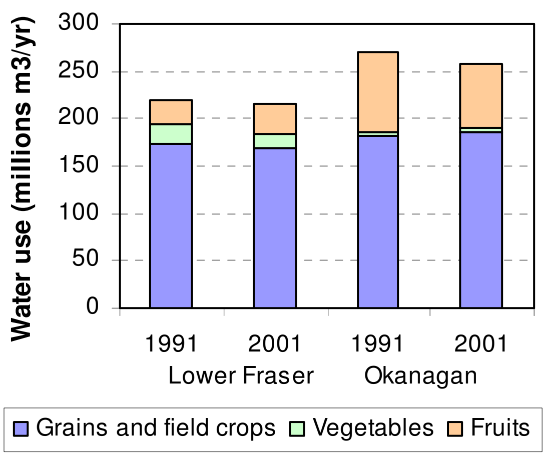


Figure 9. Crop water use (millions m^3/yr).

Overall crop water use (Figure 10a and b) in the Lower Fraser Valley has been relatively constant (-2%). Water use by fruits however did increase from 27 million m^3 in 1991 to 32 million m^3 in 2001. In the Okanagan Basin crop water use has declined by 4% with the largest change occurring in fruit production dropping from 85 million m^3 in 1991 to 69 million m^3 in 2001. Reductions can be attributed to more efficient management and higher yields.

a) Overall crop water use



b) Relative crop water use

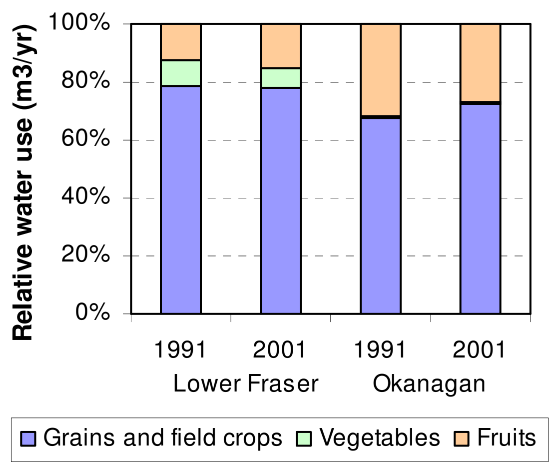


Figure 10. Changes in crop water use for grains, fruit and vegetables 1991 to 2001.

Table 1. Crop water use (CWU in m^3/yr) for different crops in the LFV and the OK, 1991-2001.

Crops	Crop Water Use (m3/yr) CWU			
Grains & Field Crops	**LFV 1991**	**LFV 2001**	**OK 1991**	**OK 2001**
Wheat	1,201,354	1,333,164	4,527,642	5,352,554
Spring wheat	891,412	990,458	2,263,821	0
Winter wheat	435,480	0	1,542,219	2,302,153
Oats	884,633	982,926	3,135,603	2,563,789
Barley	0	0	15,823,312	8,975,605
Mixed grains	118,629	131,810	1,026,453	899,904
Corn for grain	2,911,504	3,235,005	488,094	688,036
Total rye	621,535	690,594	127,972	357,132
Corn for silage	29,308,386	28,016,271	9,785,402	8,979,753
Alfalfa and alfalfa mixtures	4,603,818	7,595,426	113,225,761	119,736,477
Tame hay & fodder crops	114,738,435	114,134,549	28,855,078	36,433,782
Potatoes	18,345,344	11,418,176	1,167,412	514,453
Total Grain (m^3/yr)	174,060,531	168,528,378	181,968,769	186,803,637
Vegetables				
Sweet corn	6,022,796	4,819,497	1,077,041	564,542
Tomatoes	21,145	36,367	500,723	479,161
Cucumbers	455,998	243,563	160,558	103,175
Green peas	98,893	1,946,270	13,989	62,494
Green or wax beans	2,907,194	1,488,974	36,263	31,821
Cabbage	1,347,026	1,473,117	190,702	40,393
Cauliflower	1,636,903	230,588	115,079	32,314
Broccoli	3,251,350	473,734	52,608	32,314
Carrots	675,028	887,810	190,702	177,728
Dry onions	83,087	152,023	289,174	134,995
Lettuces	1,785,967	1,792,863	34,925	54,606
Spinach	92,443	389,370	213,703	32,312
Peppers	123,955	233,756	207,690	344,190
Squash& zucchini	890,881	1,488,256	134,614	342,775
Total Vegetables (m^3/yr)	19,392,664	15,656,184	3,217,772	2,432,820
Fruit				
Apple	55,912	52,614	61,142,764	41,949,275
Pears	na	na	4,377,769	2,470,622
Plums and prunes	na	na	1,689,792	1,007,216
Cherries (sweet)	na	na	2,238,244	5,998,844
Cherries (sour)	na	na	1,352,341	858,216
Peaches	na	na	5,702,009	4,536,635
Apricots	na	na	2,155,942	1,423,421
Strawberries	2,487,057	1,501,165	210,279	97,889
Raspberries	15,370,179	12,973,875	729,169	190,544
Blueberries	7,972,211	11,763,353	na	na
Cranberries	1,040,770	5,694,624	na	na
Grapes	164,754	105,760	5,746,585	10,785,462
Total Fruit (m^3/yr)	27,090,882	32,091,391	85,344,893	69,318,124
Overall total (m^3/yr)	220,544,076	216,275,953	270,531,434	258,554,581

3.4. Virtual water content of crops

Virtual Water Content refers to water use per ton of crop produced, and was calculated from the crop water use and production data from the Agricultural Census. Virtual Water Content is summarized Figure 11a and b, and Table 2. In the Lower Fraser Valley grain and field crops have the highest VWC with the exception of corn silage. Strawberries, raspberries and blueberries also have moderately high virtual water contents. In the Okanagan grain and fruit crops are the most water demanding in terms of m^3 of water per ton of product, specifically alfalfa, hay, wheat, barley, cherries and peaches. Significant reductions in VWC occurred in both regions from 1991 to 2001 particularly in the most water demanding fruit crops such as raspberries, blueberries, cherries and peaches. Reductions in VWC can be attributed to more efficient management and higher yields.

a) Lower Fraser Valley

b) Okanagan Basin

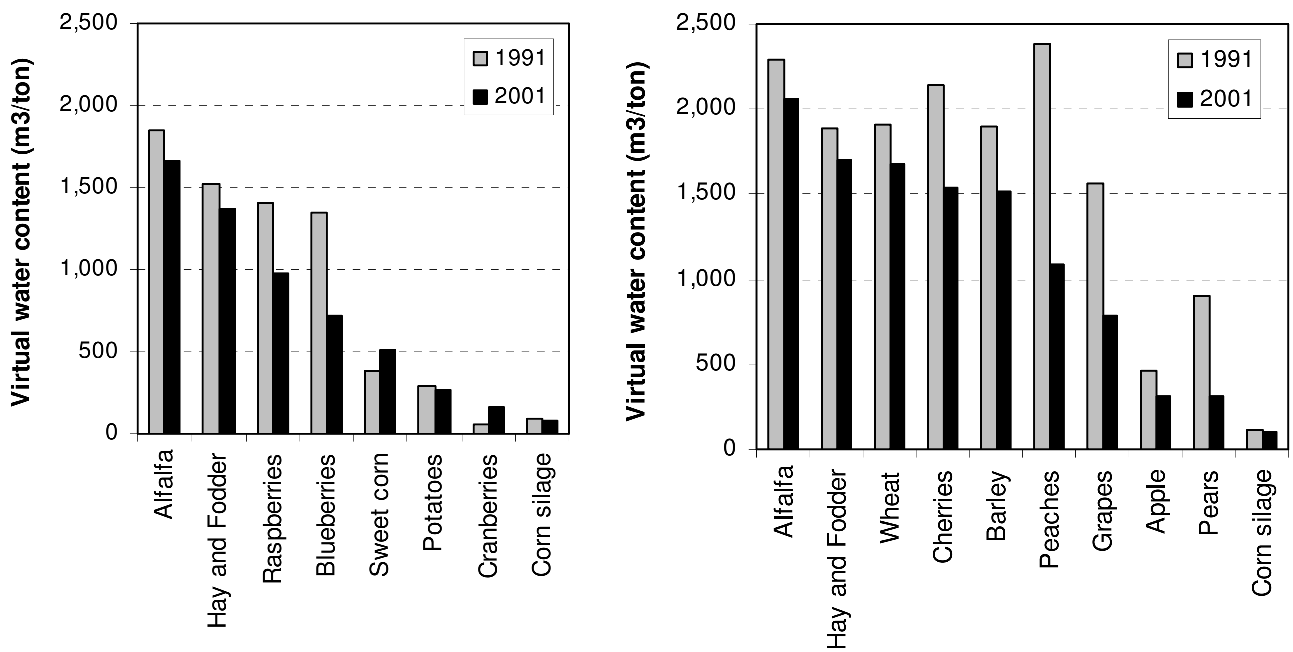


Figure 11. Virtual water content for major crops (m^3/ton).

Table 2. Virtual Water Content (VWC in m^3/ton) for different crops LFV vs. OK, 1991-2001.

Crop	LFV 1991	LFV 2001	OK 1991	OK 2001	Canada*	Global*
	Virtual Water Content (m3/ton) VWC					
Grains and Field Crops						
Wheat	1,531	1,345	1,905	1,674	1,491	1,334
Spring wheat	1,531	1,345	1,905	na		
Winter wheat	1,097	na	1,303	1,140		
Oats	1,589	1,448	1,978	1,803	1,347	1,597
Barley	na	na	1,898	1,512	44	1,388
Mixed grains	1,494	1,345	1,860	1,674	826	1,105
Corn for grain	94	84	118	105	353	909
Total rye	1,467	1,195	1,353	1,102	1,588	901
Corn for silage	93	84	117	105	84	636
Alfalfa & mixtures	1,848	1,663	2,294	2,065	na	134
Tame hay & fodder	1,522	1,369	1,891	1,702	na	167
Potatoes	294	264	122	109	106	255
Vegetables						
Sweet corn	379	513	791	593	346	509
Tomatoes	117	200	275	282	39	184
Cucumbers	375	195	562	284	59	242
Green peas	11	431	934	765	532	343
Green or wax beans	751	217	1,142	468	319	359
Cabbage	260	221	251	118	147	211
Cauliflower	732	168	488	648	169	159
Broccoli	900	178	1,932	1,187	na	na
Carrots	149	106	276	222	16	131
Dry onions	57	53	275	275	72	346
Lettuces	192	427	669	109	61	133
Spinach	189	627	393	424	148	144
Peppers	531	515	898	678	120	323
Squash& zucchini	205	192	316	151	122	234
Fruit						
Apple	308	204	463	310	169	697
Pears	na	na	906	308	287	727
Plums and prunes	na	na	624	1,300	614	1,612
Cherries (sweet)	na	na	2,146	1,534	602	1,543
Cherries (sour)	na	na	565	980	476	1,343
Peaches	na	na	2,384	1,093	288	1,194
Apricots	na	na	3,481	2,497	444	1,391
Strawberries	964	594	911	379	362	276
Raspberries	1,406	982	2,622	934	485	713
Blueberries	1,346	722	na	na	456	395
Cranberries	60	165	na	na	65	152
Grapes	967	870	1,566	787	287	655

* 2004 Chapagain and Hoekstra, UNESCO

3.5. Comparison to Canadian and Global Statistics

Figure 12 shows the virtual water contents for the major crops grown in the Lower Fraser Valley and Okanagan Basin in comparison with Canada and Global averages as determined by UNESCO (Chapagain and Hoekstra 2004). The virtual water content for fruits in the Lower Fraser Valley and Okanagan Basin were all higher than values for Canada and 50% were higher than Global VWC averages. For grain and field crops, 55% were higher than Canadian averages, and 68% were higher than Global averages (Table 2).

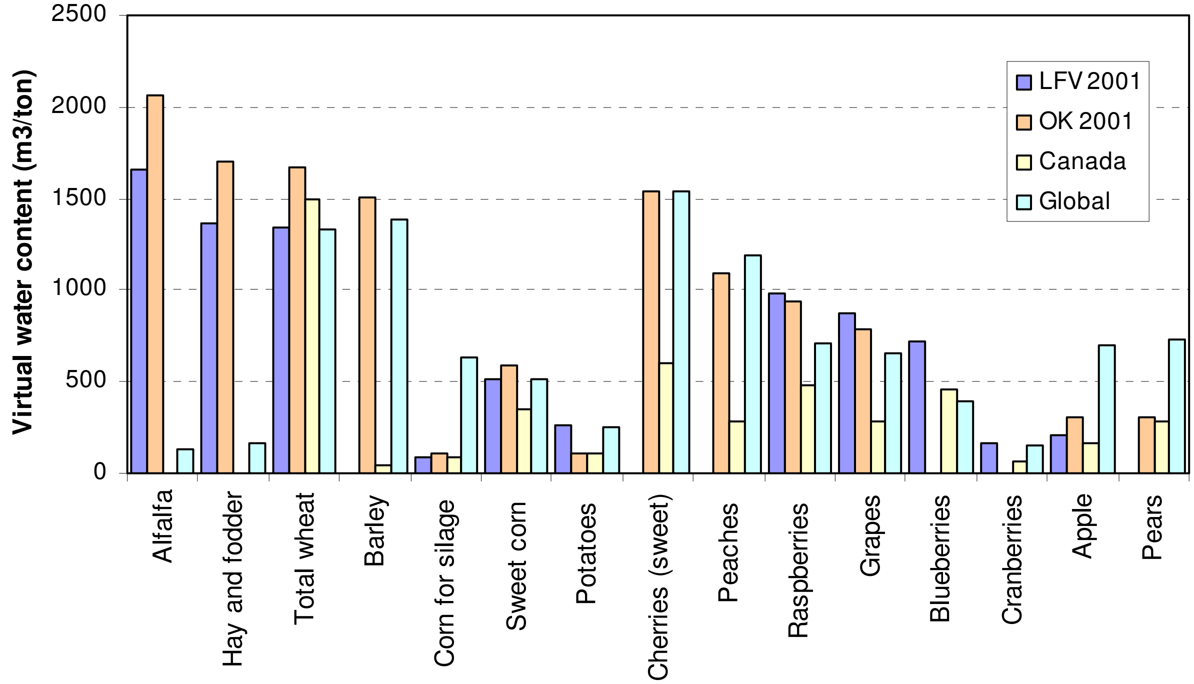


Figure 12. Comparison of virtual water content for the Lower Fraser, Okanagan, Canada and Global averages.

3.6. Virtual Water versus Value Added

The Lower Fraser Valley and Okanagan Basin are British Columbia's most important value-added agricultural regions. The Okanagan produces 25% of the total value of British Columbia's agriculture and is the province's major producer of high value tree fruits and grapes. The value of tree fruit and berry sales are summarized in Table 3 and compared to water use and virtual water content for the two regions. In the Lower Fraser, blueberries have the highest total sales on a $ basis, the 2nd highest water use (m^3) and have a relatively high virtual water content. In the Okanagan, grapes have the highest $ sales, and relatively high water use and virtual water content. Apples have a high sales quantity (kg) and a corresponding high water use, but a relatively low virtual water content.

Table 3. Quantity and value of sales for tree fruits and berries versus virtual water.

Commodity	Lower Fraser Quantity* (kg)	Value* $'000	Water use (m^3/yr)	VWC (m^3/T)	Okanagan Quantity* (kg)	Value* $'000	Water use (m^3/yr)	VWC (m^3/T)
Apples	217	273	52,614	204	121,912	28,770	41,949,275	310
Pears					5,957	2,681	2,470,622	308
Peaches					5,113	3,936	4,536,635	1093
Cherries – sweet					7,467	14,102	5,998,844	1534
Strawberries	2,464	4,754	1,501,165	594	181	800	97,889	379
Raspberries	10,560	23,850	12,973,875	982	159	1,050	190,544	934
Blueberries	20,255	70,460	11,763,353	722	231	1,148	-	-
Cranberries	38,147	33,890	5,694,624	165[1]				
Grapes	150	179	105,760	870	15,419	33,995	10,785,462	787

*2004 BCMAL Horticultural statistics
[1] Water use for flood harvesting not included

The major difference between the regions is the importance of berry versus fruit crops. The four berry crops (strawberries, blueberries, raspberries and cranberries) in the Lower Fraser Valley have a value of $133 million and use 32 million m^3 of water per year. In contrast the four major fruit crops in the Okanagan (apples, peaches, cherries and grapes) have a value of $81 million but use 63 million m^3 of water per year, more than double of that used by the four major berry crops in the Lower Fraser. Values for other crops and livestock were not easily available but similar economic evaluations and comparison with water use can be made, and this is an important research component we would like to pursue in an extended study in the future.

4. Livestock water requirements, use and virtual water, Okanagan versus the Lower Fraser Valley

Water forms 50 – 80% of an animals live weight. Livestock consume water based on the type and size of animal, level of activity, and type of diet and dry matter intake (BCMAL 2006). The virtual water content for livestock includes the virtual water content of their feed, and the volumes of drinking and service water consumed during their lifetime. As such, virtual water provides a more complete picture of water use in the livestock industry.

4.1. Land and Livestock

Calculations for livestock water use and virtual water content are based on the 1991 and 2001 Agricultural Census data (Statistics Canada, 2002). The agricultural land base in the Okanagan Basin is nearly twice that of the Lower Fraser Valley (Table 4), but there are 35% more farms in the Lower Fraser. Livestock numbers in the Lower Fraser Valley are also significantly greater, particularly poultry, pigs and dairy (Figure 13a and b). Rangeland however, is largely concentrated in the Okanagan Basin (Figure 13c and d), covering some 12,000 ha and comprising 50% of the total farm area. In contrast animal production in the Lower Fraser Valley is very intensive, and there is a concentration of production on a smaller land base.

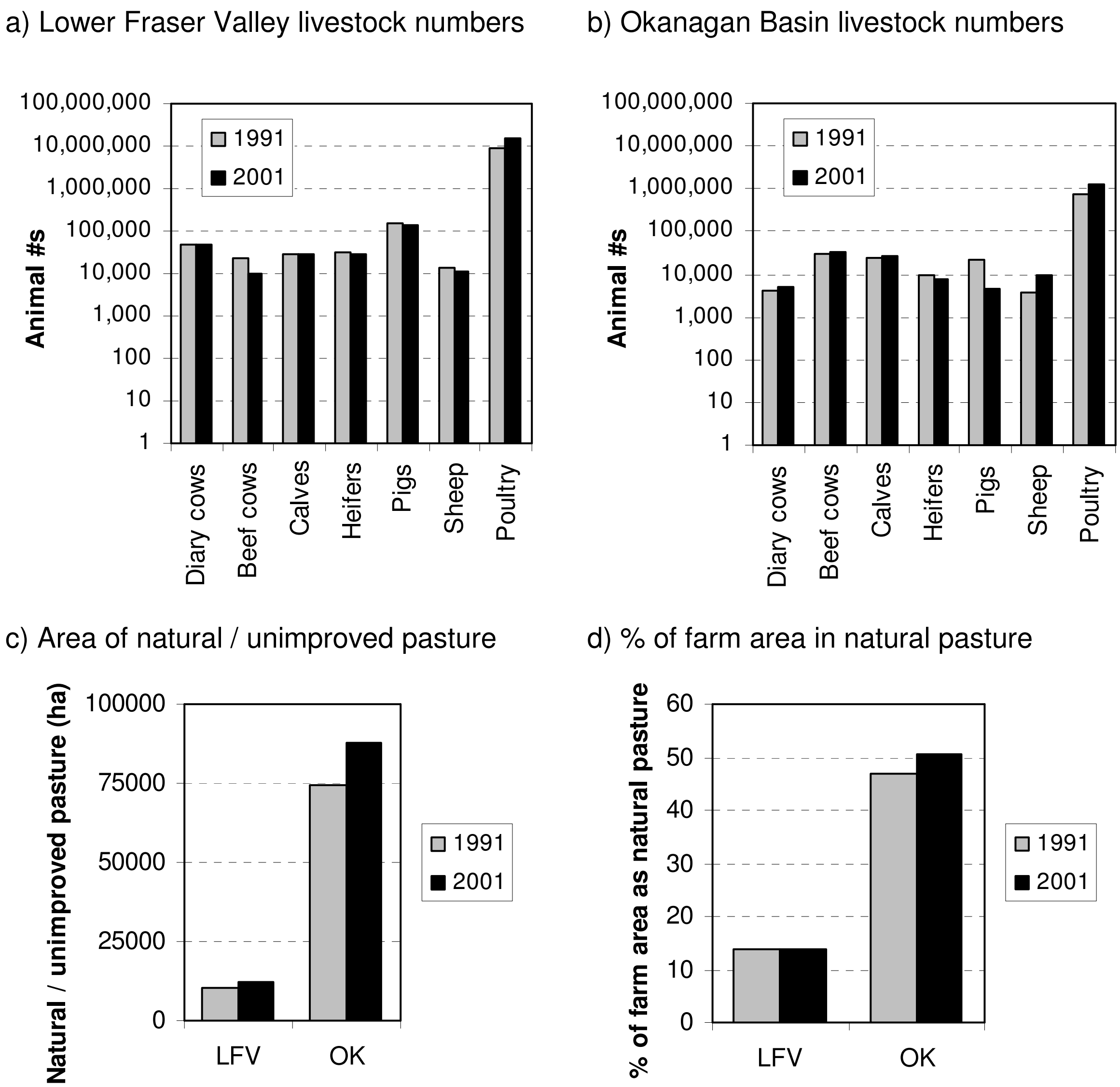


Figure 13. Animal numbers and unimproved pasture in the Lower Fraser Valley and Okanagan Basin.

4.2. Livestock Water Requirements

The virtual water content of livestock and livestock products is based on the virtual water content of the animal at the end of its lifespan (m^3 of water per ton of animal), and contains three components: the virtual water content from feed consumed, drinking water and service water (Table 5). The VWC from feed consumed includes water that is incorporated in the feed ingredients and water required to prepare the feed mix. The VWC from drinking water is based on animal water requirements. The VWC from service water includes water used to clean stables, wash animals etc.

Table 4. Comparison of virtual water use for livestock (m^3 over the lifetime of animals) between the Lower Fraser Valley and Okanagan, 1991-2001.

Summary				
	Lower Fraser Valley		**Okanagan Basin**	
General Statistics	**LFV 1991**	**LFV 2001**	**OK 1991**	**OK 2001**
Number of farms	5,542	5,262	3,863	3,888
Agric. Land (ha)	85,825	87,389	158,518	173,541
Animal Numbers				
Diary cows	48,610	48,329	4,062	5,100
Beef (bulls, cows, steers)	22,016	10,395	29,536	32,920
Calves	29,031	29,835	24,185	26,640
Heifers	31,414	28,508	9,573	7,886
Pigs	154,726	131,181	22,776	4,745
Sheep	14,233	11,254	3,616	9,324
Poultry	8,963,978	15,810,968	747,443	1,205,817
Livestock water use (m3)	**LFV 1991**	**LFV 2001**	**OK 1991**	**OK 2001**
Diary cows	1,586,047,080	1,576,878,612	132,534,936	166,402,800
Beef (bulls, cows, steers)	115,628,032	54,594,540	140,650,432	156,765,040
Calves	41,920,764	43,081,740	34,923,140	38,468,160
Heifers	103,666,200	94,076,400	31,590,900	26,023,800
Pigs	59,878,962	50,767,047	8,814,312	1,836,315
Sheep	3,216,658	2,543,404	817,216	2,107,224
Poultry	73,334,344	121,916,867	4,899,734	6,146,502
Grand totals	1,983,692,040	1,943,858,610	354,230,670	397,749,841

Table 5. Livestock water requirements (m^3/animal).

Animal type	**Water from drinking**	**Water from servicing**	**Water from feed**	**Total total**
		(m^3/animal)		
Beef (industrial)	24	7	5,221	5,252
Beef (grazing)	15	3	4744	4762
Heifers*	19	1	3,280	3,300
Dairy cows*	131	2	32,495	32,628
Calf*	5	<1	1,439	1,444
Sheep (grazing)	2	2	222	226
Pigs (industrial)	3	8	376	387
Poultry - Broiler	<0.01	<0.01	3.42	3.4
- Pullets	0.01	<0.01	4.41	4.4
-Laying	0.11	0.05	22.8	23

* based on typical livestock diets in Lower Fraser Valley

4.3. Livestock water use per animal lifetime

Census data on animal numbers combined with animal water requirements provide the basis for estimating total water use by livestock type for the life of the animal (Figure 14a and b). Livestock water use per animal lifetime in the Lower Fraser Valley is 10 times greater for dairy, 20 times greater for poultry and 30 times greater for pigs than in the Okanagan Basin. In contrast the Okanagan uses 3 times more water for beef production. Overall the Okanagan uses 5 times less water for livestock production than the Lower Fraser Valley. Dairy accounts for 40% of livestock water use and beef for 42% in the Okanagan on an animal lifetime basis, while 80% of the livestock water use in the Lower Fraser is accounted for by dairy cows.

a) Lower Fraser Valley b) Okanagan Basin

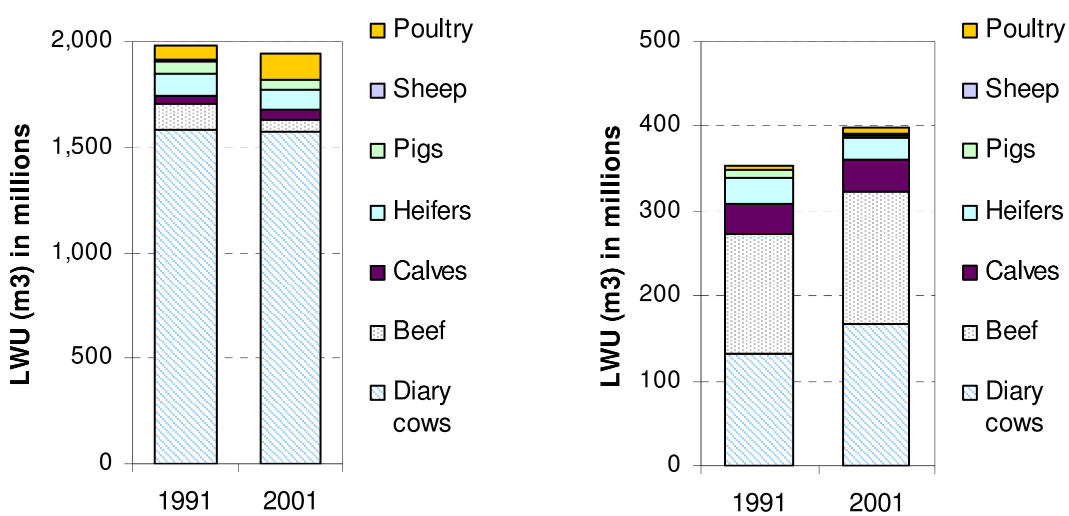


Figure 14. Livestock water use (m^3) per animal lifetime.

4.4. Livestock water use on an annual basis

The livestock water use per year was calculated from the livestock water use data per animal lifetime and typical livestock life expectancies under local management practices. The results shown in 5ure 16a and b indicate that in the Lower Fraser Valley annual livestock water use is 3.5 times greater than in the Okanagan. In the Okanagan beef make up a greater proportion of livestock water use per year, while poultry with a relatively short lifespan (6-10 weeks for broilers, 1 year for hens) are the largest livestock water user in the Lower Fraser.

The total annual water use for livestock in the Lower Fraser Valley over the lifetime of the animals was estimated at 1.9 billion m^3. This converts to an annual rate of 1 billion m^3 per year. For the Okanagan the water use over the lifetime of the animals was 404 million m^3 and converted into 244 million m^3 per year.

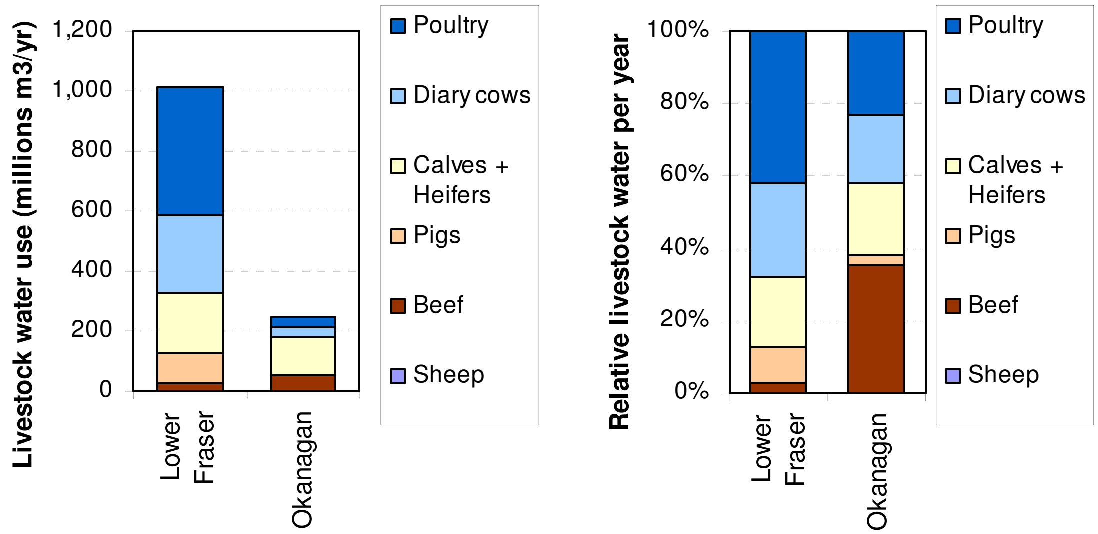


Figure 15. Livestock virtual water use per year.

4.5. Livestock virtual water content

The virtual water content of an animal at the end of its life includes the volume of water used to grow and process its feed, to provide its drinking water, and to clean it "housing". Dairy cows are the most water intensive livestock with a virtual water content > 55,000 m^3 per ton of animal. Given their high animal numbers in the Lower Fraser Valley, dairy is a significant water user. Beef cows are moderately high in their virtual water content; approximately 9,600-11,900 m^3 per ton, and contribute to their relative importance in water use in the Okanagan Basin (Table 6).

Table 6. Virtual water content for livestock (m^3/ton).

Animal type	Virtual water content (m^3/ton)	Literature* VWC (m^3/ton)
Diary cows	55,302	86,693
Beef (industrial)	9,637	9,636
Beef (grazing)	11,905	11,915
Calves	11,023	
Heifers	6,613	
Pigs	3,280	2,170 – 3,276
Sheep	5,650	5,674 - 5,648
Poultry	5,124	1,867 – 9,563

* Chapagain and Hoekstra, 2003

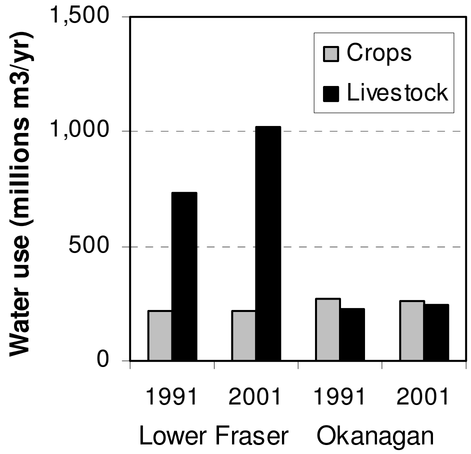
5. Comparison of crop and livestock virtual water

Virtual water use by crops and livestock are compared in Figure 16a and b. In the Lower Fraser livestock uses nearly 5 times more water per year than crops, while in Okanagan annual virtual water for crops and livestock are similar. The Lower Fraser Valley uses 2.5 times more water to produce food than the Okanagan which is comparable to the difference in rainfall between the two regions (1400-1600 mm/yr in the Lower Fraser versus 350-400 mm/yr in the Okanagan).

There has been only limited change in virtual water use for food production in the Okanagan Basin (1991-2001), while in the Lower Fraser water use for food production increased by

30%.This increase is largely due to demands for livestock production related to increases in the number poultry. The overall water use for crop production dropped slightly in both regions.

a) Comparative water use (m^3/yr)



b) Relative water use (%)

Figure 16. Comparison of water use for crops versus livestock.

There has been a decline in fruit production, with the exception of blueberries in the Lower Fraser Valley and grapes in the Okanagan. The virtual water content for stone fruits and grapes is relatively high compared to other fruits and vegetables (Table 7), and these numbers are conservative as they currently do not include the water used in processing. No reliable industrial data for water use in wine production and/or fruit products such as jam are currently available, but their addition will certainly increase the virtual water content for fruit related products.

The virtual water content for livestock is significantly greater than crops, especially dairy. Combined with the large number of animals, particularly in the Lower Fraser Valley, the water use in livestock production comprises a large proportion of the overall water use. Increases in livestock numbers in both regions have largely been in poultry, which have a relatively low virtual water content. In the Lower Fraser, all other animals with the exception of calves declined slightly between 1991 and 2001. The only other major change in livestock numbers in the Okanagan was a significant decrease in swine.

Table 7. Comparison of virtual water content for crops and livestock.

Crops	**VWC* (m^3/T)**	**Livestock**	**VWC (m^3/T)**
Apricots	2,497	Diary cows	55,302
Alfalfa	1,864	Beef	10,771
Hay and fodder	1,536	Sheep	5,650
Raspberries	982	Poultry	5,124
Grapes	787	Pigs	3,280
Blueberries	722		
Apples	310		

*2001 VWC from dominant production region (LFV or OK)
or in the case of products produced in both regions an average value was used.

6. Water used by golf courses in the Okanagan Basin

There are currently 42 turf golf courses operating in the Okanagan Basin, not including driving ranges or putting courses. These courses range from less than 9 holes to greater than 18 hole "super courses", and are primarily clustered around four main centers: Vernon, Kelowna, Penticton and Oliver (Figure 17). The Okanagan experiences an extended golf season from approximately the beginning of March to November.

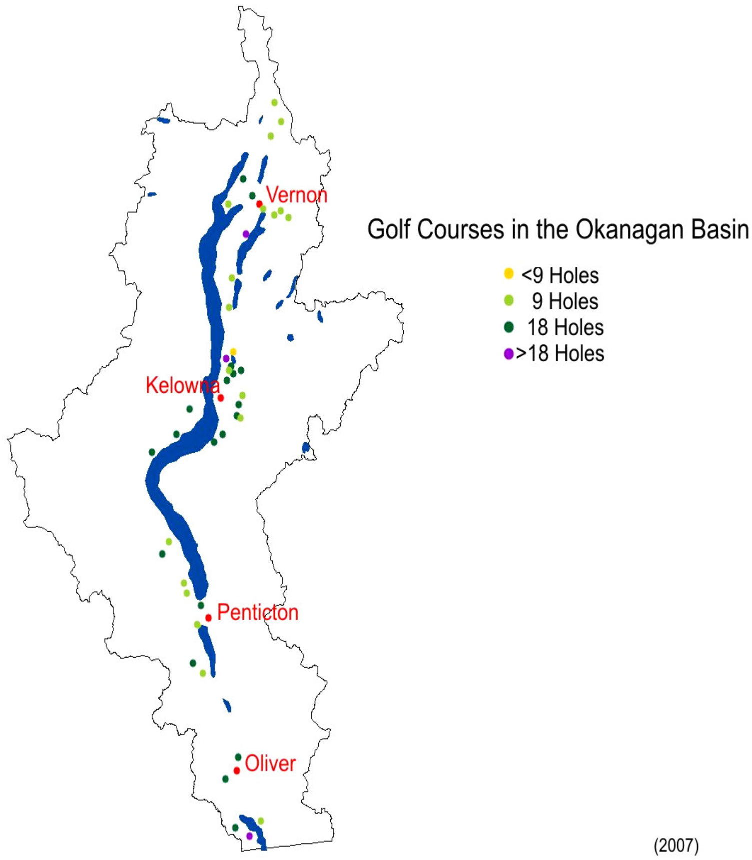


Figure 17. Map of Golf Courses in the Okanagan Basin.

The surveyed golf courses were grouped by region around the four main centers in the Okanagan Basin. An estimate of the water requirements for each golf course was determined by estimating the total managed area per course and multiplying this area by the respective rate of evapotranspiration (ET) for the region. The areas were calculated using available yardage data for each golf course and an average estimate of fairway width based the literature. Figure 18 shows the relative areas of golf courses surrounding each of the four centers.

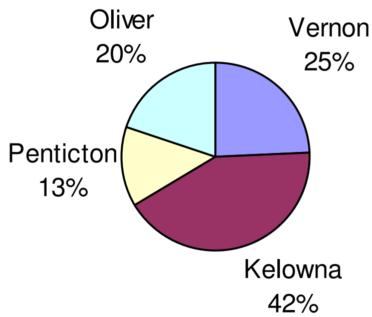


Figure 18. Percent of total golf course area by region.

Turfed area was considered separately from longer grass (or "rough") because it has a different rate of evapotranspiration (ET). The ET rate for "rough" was taken as equivalent to the reference ET for grass, and the turf crop coefficient used was 0.75 (Irrigation Industry Association of BC). Mean monthly evapotranspiration data of Environment Canada was obtained from the Farmwest agricultural services centre (www.farmwest.com) for the four centers (Oliver, Vernon, Penticton and Kelowna) for the golf season of 2006. Both the reference ET and the turf ET exceeded the precipitation during the 2006 golf season (Figure 19).

The sum of annual ET for turf and annual ET for grass applied over their respective areas gives an estimate of the "crop" water requirement for each golf course. The difference between the total ET per golf course and precipitation equals an estimate of the water deficit that must be filled by irrigation (Figure 20). This is based on the assumption that there is negligible water stored in the soil during the summer months.

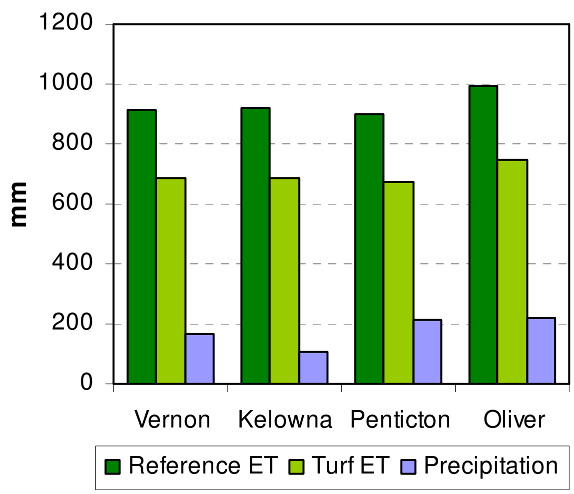


Figure 19. Evapotranspiration and precipitation for March-November 2006.

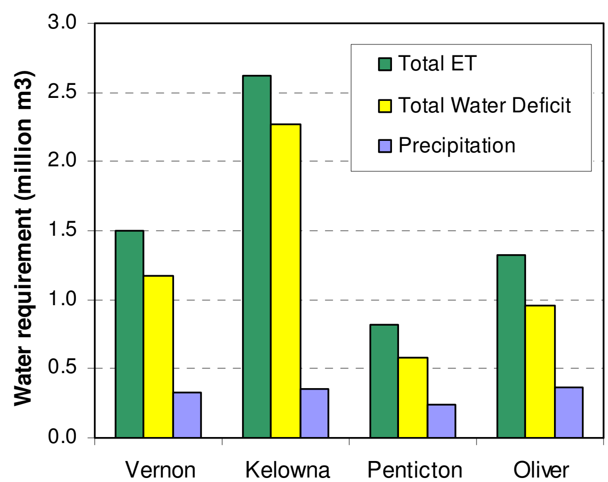


Figure 20. Precipitation, evapotranspiration and an estimate of the water amount required for irrigation (yellow) during the 2006 golf season.

From these preliminary calculations, the total estimated irrigation requirement for the golf season of 2006 in the Okanagan Basin was approximately 5 million m^3 of water. This equates to an average of approximately 6,000 m^3/ha, or to 24 m^3/ha/day throughout the season. The irrigation requirements for each region are summarized in Table 8. These values are likely conservative as they are based on minimum turf water needs and minimum managed area, and should be verified in future research using measured irrigation use for selected courses.

Table 8. Climate data and estimated irrigation water requirements (deficit) for the 2006 golf season (April-October).

Region	Precip-itation (mm)	Reference ET (mm)	Turf ET (mm)	Total Managed Golf Courses area (ha)	Total Water Deficit (m^3)	Water Deficit (m^3/ha)	Water Deficit (m^3/ha/day)
Vernon	168	914.0	685.5	198.6	1167165.8	5876.5	23.9
Kelowna	105	917.0	687.8	338.8	2269106.7	6697.5	27.3
Penticton	216	897.5	673.1	108.5	585266.1	5394.5	22.0
Oliver	223	994.0	745.5	162.0	958820.2	5917.5	24.2

Water requirements for the managed area of golf courses in the Okanagan Basin (precipitation + irrigation) is 7,755 m^3/ha which is comparable to alfalfa at 7,226 m^3/ha.

To investigate long term trends, the 42 golf courses were grouped around two stations for which climate data have been consistently collected from 1995-2005, Vernon and Summerland. Over the total area of golf courses around these two regions, average volumes of precipitation and ET were calculated. The difference between these volumes of water was calculated; a positive difference indicates a surplus of water for the “crops” (turf and rough), and a negative difference indicates a deficit (Figure 21).

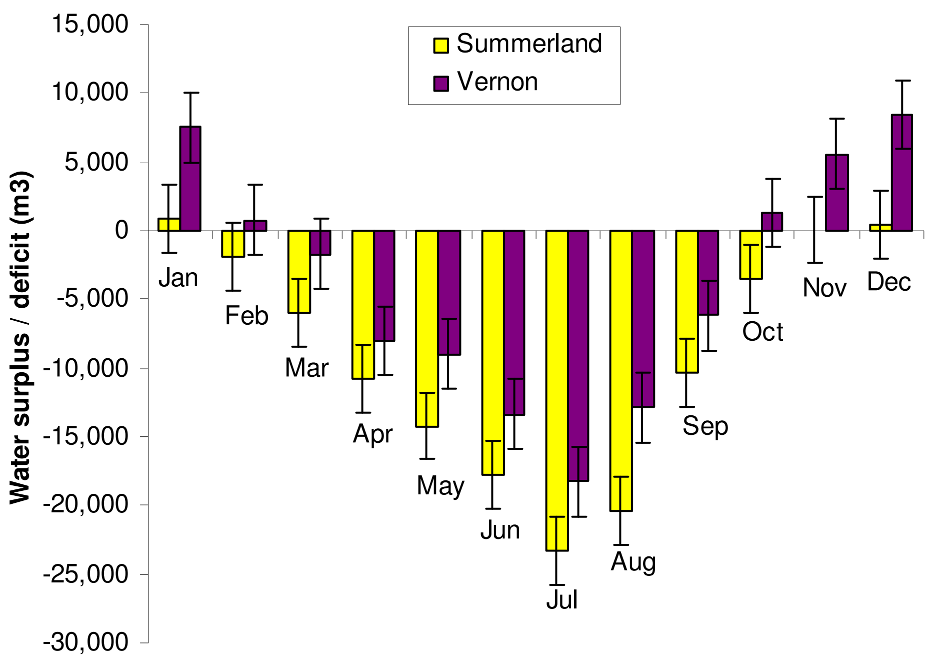


Figure 21. The average difference (± 1 S.E.) between mean volume of precipitation and mean volume ET per golf course, for 13 courses near Summerland and 29 courses near Vernon between 1995-2005. Positive values are water surpluses, negative values are water deficits.

During the golf season (March-November), the average irrigation requirement from 1995-2005 for the entire Okanagan Basin averaged approximately 2 million m^3 of water per year. This is much lower than the 5 million m^3 total calculated for the 2006 golf season. 2006 was a dry year in the Okanagan, as illustrated by the precipitation data for Vernon (Figure 22).

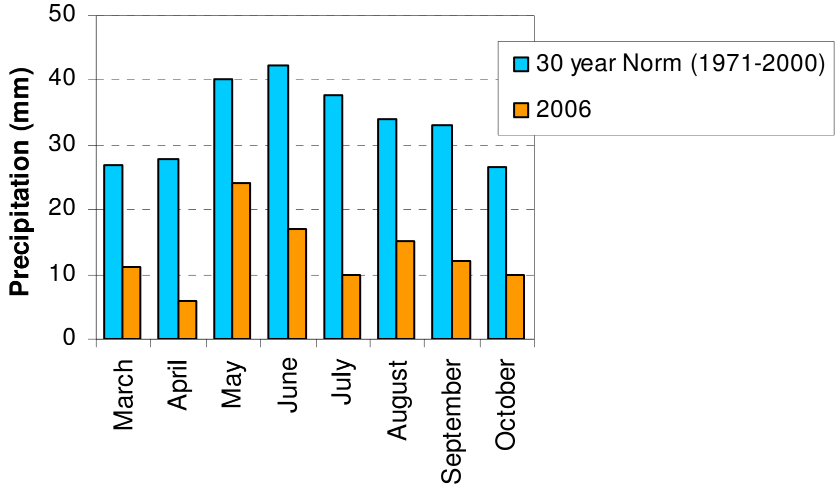


Figure 22. A comparison of 2006 precipitation to the 30 year norm for the Vernon golf season.

In summary there are 42 golf courses in the Okanagan and a conservative estimated for the irrigation requirements for the total managed area was 5 Mm^3/season or 24m3/ha/day. This represents the minimum irrigation requirements.

7. Overall Water Footprint in the Okanagan

Table 9 highlights the dramatic increases in population and changes in land use in the Okanagan since 1971.

Table 9. Growth indicators in the Okanagan Basin, 1971-2001

Growth Indicators	1971	2001
Population	115000	297601
Golf Courses	7	43
Ski Resorts	4	8
Wineries	< 12	> 82
Grape Production Area (ha)	955	2286
Water Storage Reservoirs	81	150

Domestic water use was calculated from population statistics (Statistics Canada) and average Canadian water use per capita (Brandes et al. 2006). Population and domestic water use in the Lower Fraser Valley is nearly 7.5 times greater than in the Okanagan Basin. Domestic water use in the Okanagan in 2001 was approximately 36 million m^3, and 272 million m^3 in the Lower Fraser Valley. Growth rates in both regions averaged 2.2% from 1991 to 2001.

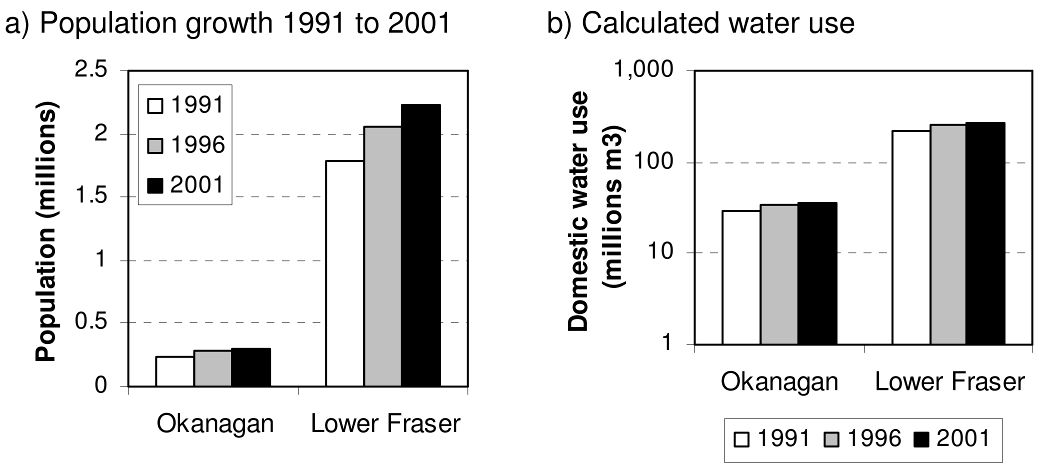


Figure 23. Population growth and related domestic water consumption.

In the watershed area draining into Okanagan Lake there are some 147 surface storage reservoirs mostly located in the headwaters of the rivers that drain into the lake. The best estimates on the cumulative storage are 180 Mm^3. For the Okanagan Lake inflow and outflow there is considerable information available. For the current calculation a volume of 1.2 m of the lake surface area was used as available blue water. Recent findings suggest that most of the stream-water systems are now fully allocated and many municipalities are trying to use more water from the lake for their needs. In addition many communities also use lake water for their needs. We determined the water needed for domestic and selective recreational uses (golf courses), and then compared these data with the crop and livestock requirements. This was then contrasted with the amount of water available from the lake.

Okanagan Lake has an average annual gross inflow of 819 Mm^3 and annual evaporation from the lake is 250-350 Mm^3 (37% of annual inflow). The average net annual outflow is 436 Million m^3. The lake volume is 26,200 Mm^3 and the surface area is 348 Mm^2. On an annual basis only about 1.2 m of the lake surface water depth can be used (418 Mm^3) because in the late winter water has to be released from the lake to prevent flooding during the snowmelt period in the spring, as many urban properties have been constructed too close the lake shore. In late summer, water has to be released to maintain a minimum stream flow for fish, environmental services and other land use activities downstream.

On the demand side we added the crop and livestock VWU to the water use for domestic and golf course uses. The results shown in Table 10 indicate that the water demand for livestock and crops are about the same on an annual basis. Also we took a very conservative approach to golf course water use and consider this a minimum amount that turf grass needs and not the actual amount that is applied. Once data for industrial and commercial use is included, it is likely that in the overall balance ¾ of all water demand is for agriculture with an equal split between crops and livestock.

When we compare the available water storage and the current demands for different uses it is evident from Table 10 that annual demands are close to the water storage capacity. Since these are average annual requirements we need to be cognizant of the fact that in dry years water conservation would be the only option in order to prevent a water crisis. However, there are serious concerns about how to satisfy future demands given the current growth rates. These results should be considered as a first rough estimate and will be refined once the water supply and demand study by the Okanagan Basin Water Board is completed.

Table 10. Water storage and demand analysis of Okanagan Lake.

Water Supply	Water Available (Mm^3/year)	Water Demand	Water Used (Mm^3/year)
Reservoir Storage*	180	Domestic Use	37
Okanagan Lake water available (1.2 m of surface)**	418	Golf Courses	6
		Crop Requirement	259
		Livestock Requirements	245
Total Blue Water Available	**598**	Total Water Demand	**546**
Average annual lake discharge	436	Industrial Demand	? Not available
Average rainfall over agricultural land per yr.	607	Water for Environmental Services	? Not available
		Estimate: 85-90% of blue water is used	

*Note: Does only include water storage in the watershed portion of Okanagan Lake
** Note: water use data was not available for the other lakes below Okanagan Lake

What we have not yet included in the discussion and calculation of a water balance is the green water component (soil moisture storage). However this is estimated to be small because the rainfall during the growing season is a small component.

A comparison of the water demands for food production in the LFV with those in the OK is provided in Table 11. In the Lower Fraser Valley crop water use is lower but the livestock water use is 4 times that of the Okanagan Basin, and the domestic water use is more than 7 times higher in the LVF.

Table 11. Comparison of water use between the LFV and the OK.

Water Use	LFV in Mm^3/yr	OK in Mm^3/yr
Crops	216	259
Livestock	1,021	245
Domestic	272	37

8. Summary, Conclusions and Future Research

The research results have shown that virtual water calculations are a new, innovative and useful tool in water management particularly in a watershed context. Since food production globally uses up to 70% of the freshwater resources it is assumed that if a region becomes water short it might be possible to import water intensive food and in this way "save" the available local water for other purposes. The food imported is the water required and imbedded in the product and represents the virtual water content.

The following conclusions can be made in this comparison between the Lower Fraser Valley and the Okanagan Basin in B.C.:

8.1. Crop water use

The greatest crop water requirement on a per ha basis in the LFV are for raspberries, alfalfa, potatoes, and hay and silage fodder. In contrast, cherries, pears, apples peaches and alfalfa have the highest water requirements on a per ha basis in the Okanagan.

When including the production figures for the crop water use in the LVF, then the greatest crop water use is for Hay and Forage (114 Mm^3/yr) followed by corn (28 Mm^3/Yr). In the Okanagan alfalfa (120 Mm^3/yr) apples (42 Mm^3/yr) and hay and fodder (36 Mm^3/yr) are the greatest crop water uses.

Grain and field crops account for 78% of overall crop water used and berry crops 15% in the LFV. In the Okanagan grain and field crops account for 72% of the crop water used and fruit production accounts for 26%.

In terms of virtual water content alfalfa, hay, fodder, raspberries and blueberries have the highest water contents on a m^3/ton basis in the LFV, and alfalfa, hay, fodder, cherries and peaches have the highest VWC in the Okanagan Basin.

Comparing water use with crop value it was found that the value of the four main berry crops produced in the LFV (raspberries, blueberries, cranberries, and strawberries) was $ 133 million and used 32 Mm^3 of water. In contrast value of the four major fruit crops in the OK (grapes, apples, cherries and peaches) was $ 81 million using 63 Mm^3 of water.

8.2. Livestock water use

The highest virtual water was determined for dairy cows (55,300 m^3/ton) followed by beef (9,600 - 11,000 m^3/ton), heifers and calves, sheep and poultry.

The virtual water use for livestock was 1.9 billion m^3 in the LFV and 404 million m^3/yr in the OK over the lifetime of the animals. This converted into a 1 billion m^3/yr virtual water use for the LFV and a 244 Mm^3/yr in the OK.

8.3. Comparison between crops and livestock

The virtual water content was significantly higher on a m^3/ton basis for most of the livestock compared to crop production.

Considering the area under production and the number of animals it was evident that the difference in water use between crops and livestock were of the same order of magnitude (259 Mm^3/y vs. 244 Mm^3/yr) for the OK but significantly different in the LFV (216 Mm^3/yr vs. 1,021 Mm^3/yr).

8.4. Golf Course Water Use

An inventory of golf courses was made for the Okanagan Basin and the preliminary results indicate that 42 courses are located in the basin. Crop water requirements were estimated to amount to 6 Mm3/yr. Subtracting precipitation yielded a minimum moisture deficit of 5 Mm^3/season for the total managed area of the golf courses or 24m^3/ha/day. Actual water use is likely much higher. A more detailed inventory of the actually managed area is required and there is a trend to over-irrigate to keep the fairways as green as possible. Actual irrigation data will be obtained from selective golf courses this summer.

8.5. Water Balance Estimates

Since the Okanagan is a water short basin a first approximation of a water balance was developed for this region. The Blue water storage was estimated at 598 Mm^3/yr (reservoir storage and available lake storage) and the water demand consisting of domestic, golf, crop and livestock requirements were estimated to be 546 Mm3/yr. This does not include groundwater and reservoir storage in the lowest part of the basin, and the industrial and commercial use for which no data was yet available. It also does not include the green water component. Assuming that these are compensating differences, approximately 90% of the blue water is currently being used.

We will compare these results with the conventional supply and demand study that is currently under way by the Okanagan Water Board, once this data becomes available.

8.6. Implications for Water Governance

This study provides a new and innovative way to examine water use. The calculations were based on census data, which was the only consistent and comprehensive dataset available at the time of the study. However, an inventory of the irrigated area and an updated census dataset will be available later this summer and it is anticipated that this will help us refine and update the information.

No previous study has examined the overall water use for the different crops and livestock in the two basins and the results provide decision makers with information related to water use efficiency for different foods produced in each basin. It also forms the basis for determining trade-offs in water requirements for growing different food, which then tells water managers how much water savings or how much more water will be required by changes in agricultural land use and management.

Given that approximately 90% of the available water is currently being used, some major decisions need to be made on how to reduce water consumption in order to accommodate anticipated future growth. The data generated is a first step in providing science based information to assist decision makers in the strategic choices of reallocation and conservation water use.

8.7. Remaining deficiencies in the analysis

- The data covers the 2001 situation and needs to be updated to 2006.
- Very limited information was available on the amount of water needed to process the crop into a product. This information is being collected with the collaboration of food processing operations and wineries.
- No food export and import data was available at the regional level, but its collection will allow the determination of the virtual water footprint.
- Very limited economic information was included (except for fruit and berry production) and this would further enhance trade of analysis.
- Additional information needs to be collected for the surface and groundwater supply storage capacity and the water demand for industrial and commercial use. This will then allow for a more refined analysis of a water balance.

9. Communication of results (Conferences, Papers and Policy Meetings)

9.1. Public Presentations

Nine public presentations were given at local, national and international Conferences on the research topic and results:

Schreier, H. **2006** Incorporating the Concept of Virtual Water. Walter and Duncan Gordon Foundation, Symposium on Protection of Our Water Resources. March 23 Toronto, March 23.

Schreier, H. **2006** Virtual water and the water footprint. Policy Research Initiative - Freshwater for the Future, National Conference Fed. Gov. of Canada . Gatineau, Quebec, May 8-10. (Invited presentation) Abstract

Schreier, H. **2006** Virtual Water and the Water Footprint. 3. Digital Earth Summit on Sustainability, Auckland, New Zealand, International Society for Digital Earth, Landcare NZ and City of Auckland. August 29-31. (Invited keynote presentation).

Schreier, H. **2006** Virtual water and the water footprint in the Western Mountains. MTCLIM Research Conference. Consortium for Integrated Climate Research on Western Mountains (CIRMOUNT), NOAA, USGS and MRI. Mt. Hood, Oregon. Sept. 19-22. The MTCLIM presentation was WEB-Casted and can be viewed as follows:
http://play.switch.ch/PLAY/Channels/0062/Archive/2006_09_22-17_34_04/OnDemand/Player/en/QuickTime/VideoHighAndSlides/000/Player.page/index.html

Schreier, H. **2006** Virtual water and the water footprint in Western Canada. Canadian Water Network, 3rd Annual CWN Conference. Bringing Water Research to Life, Montreal, Nov 20-23.

Schreier, H. **2006.** Adapting to change – Improving water management in the Okanagan. Naramata Environmental Roundtable. Naramata, B.C. Dec 11, 2006

Schreier, H. **2006**. Watershed Protection from the top to the buttom. Riparian protection, making it works in the Okanagan-Similkameen. Okanagan-Similkameen Riparian Working Group, Annual Conference, Dec. 12, 2006, Penticton B.C.

Schreier, H. **2007**. Innovative ways of managing water. Annual Conference by the Ontario Processing Vegetable Industry, London, ON. Jan 23-34 (invited Keynote address)

Schreier, H. **2007**. Measuring the water footprint in the Okanagan using the virtual water concept. Okanagan Water Stewardship Council. March 8, Kelowna, B.C. ***

***This last presentation was to the Okanagan Water Stewardship Council which is the multi-stakeholder group that gives advice and feedback on community water issues to the Okanagan Water Board. The Board is committed to develop a comprehensive water management strategy to the basin.

9.2. Research Paper:

The following Research Paper has been submitted for review in 2006 to the following Journal: Journal of Environmental Assessment Policy and Management:

K. Schendel, J. MacDonald, H. Schreier and L.M. Lavkulich. Virtual Water: A framework for comparative regional resource assessment.

The Conclusion of the paper is as follows:

The paper uses two case study areas within British Columbia, Canada to show that further refinement of the virtual water concept as proposed by UNESCO is made possible at a regional scale. Using the national and international data is not appropriate due to problems with disaggregating data to local climatic conditions. Instead, the virtual water content for smaller-scale regions is calculated for the purposes of comparison between regions and between commodities. Using the concept for this purpose provides a tool for use in regional land and water planning.

The strengths associated with using the concept at a smaller scale are in the heightened sensitivity of the variables and multi-use nature of the output. The case study shows that there is greater variability between commodities when calculated at a basin scale, and this highlights trends in local agricultural yield and productivity, as well as regional climatic differences. The use of the concept at watershed scales provides more meaningful information for regional land use planners, managers, and policy makers.

Weaknesses are associated with issues relating to natural versus political boundaries; when trade data is not captured at a small enough scale to determine trade flows, virtual water and the water footprint is not possible. Alternative means to determining the flows, and also in up-scaling the information, are necessary to overcome this issue. Geographic information systems are one option that may aid in managing this problem. GIS may also be the key were virtual water becomes the tool that integrates geo-political and ecological boundaries. For now it is an opportunity to look at land use and water use efficiencies in a new light.

In summary, the concept of virtual water may be used for commodities derived from primary photosynthesis or for goods and services requiring water. It may be employed for both policy formulation, usually at an aggregated level of data availability; or for management considerations at more specific levels of specificity of data.

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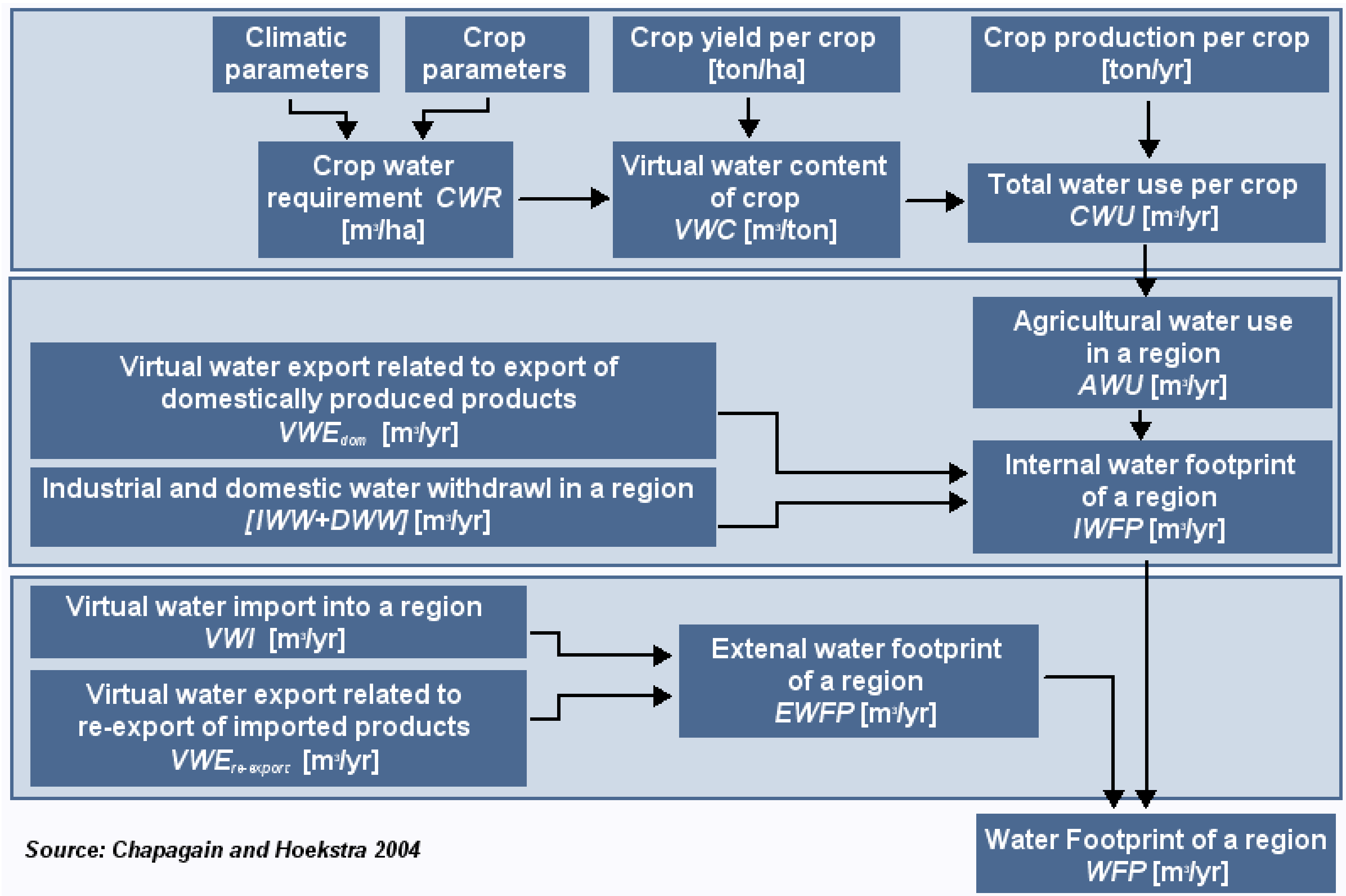
Appendix 1: Virtual Water Calculations for Crops.



Appendix 2: List of Golf Courses in the Okanagan.

Golf Course name	Address	Region	Year Opened	Yardage
Aspen Grove Golf Club	10303 Bottom Woodlake Rd, Winfield	Kelowna	1979	1597
Gallagher's Canyon Golf & Country Club	4320 Gallaghers Drive West, Kelowna	Kelowna	1980	6802
Highlands Golf (Short Game)	7961 Buchanan Rd, Coldstream	Kelowna		660
Holiday Park GC	415 Commonwealth, Winfield	Kelowna		1468
Kelowna Golf & Country Club	1297 Glenmore Drive	Kelowna	1920	6315
Kelowna Springs Golf Club	480 Penno Rd, Kelowna	Kelowna	1990	5682
Michaelbrook Ranch Golf Club	1085 Lexington Dr, Kelowna	Kelowna	1989	3750
Mission Creek Golf Club	1959 KLO Road, Kelowna	Kelowna	1980	4005
Okanagan Golf Club (Quail + Bear)	3200 Via Centrale, Kelowna	Kelowna		13791
Orchard Greens Golf Club	2777 KLO Rd, Kelowna	Kelowna		2100
Pinnacle at Gallagher's Canyon	4320 Gallaghers Drive West, Kelowna	Kelowna	1980	1984
Ponderosa Golf Club	P.O. Box 1336, Peachland	Kelowna	1979	6007
Shadow Ridge Golf Club	3770 Bulman Road, Kelowna	Kelowna	1988	6213
Shannon Lake Golf Course	2649 Shannon Lake Rd, Westbank	Kelowna	1985	5976
Sunset Ranch Golf and Country Club	5101 Upper Booth Road South, Kelowna	Kelowna	1990	6299
The Harvest Golf Club	2725 KLO Rd, Kelowna	Kelowna	<1996	7109
Vintage Hills Golf Course & Academy	3509 Carrington Rd, Westbank	Kelowna		4661
Fairview Mountain Golf Club	13105 334th Ave, P.O. Box 821, Oliver	Oliver	1925	6167
Inkameep Canyon Desert Golf Course	37041 71st St, P.O. Box 1949, Oliver	Oliver	1962	6342
Kettle Valley Golf Club	Hwy #3, Rock Creek	Oliver	1925	5892
Osoyoos Golf & Country Club	12300 Golf Course Dr, Osoyoos	Oliver	1972	19070
Sonora Dunes Golf Course	1300 Rancher Creek Rd, Osoyoos	Oliver		2600
Pentiction Golf & Country Club	600 Comox St, Box 158, Penticton	Penticton	1955	5618
Pine Hills Golf Club	3610 Pine Hills Dr, Penticton	Penticton	1973	2224
Sage Mesa Golf Club	3415 Pine Hills Dr, Penticton	Penticton	1973	2224
Skaha Meadows Golf Course	113-437 Martin St, Box 202, Penticton	Penticton	2000	2435
St Andrews by the Lake Golf Course	RR#1 S-30B, C-9, Kaleden	Penticton	1964	2070
Sumac Ridge Golf Course	RR#1 S-31A, C-41, Summerland	Penticton	1962	2202
Summerland Golf & Country Club	10120 Main St, Summerland	Penticton	1978	6135
Twin Lakes Golf Resort	RR#1 S-26B, C-8, Kaleden	Penticton	1972	6433
Birchdale Par 3*	7023 North Hwy 97a, Enderby	Vernon	1969	1257
Coldstream Golf Course	RR#2 15 Duremeadow Rd, Lumby	Vernon		2670
Hillview Golf Club	1101 - 14th Avenue, Vernon	Vernon	1986	3375
Hyde Mountain Mara Lake Golf Course	9851 Old Spallumcheen Rd, Sicamous	Vernon		6701
Lake Okanagan Resort	2751 Westside Rd, Kelowna	Vernon	1982	1160
Lakers Golf	6989 Cummings Rd, Vernon	Vernon		2202
Mabel Lake Golf & Country Club	3445 Mabel Lake Road, Enderby	Vernon		3103
Predator Ridge Golf Resort	301 Village Centre Pl, Vernon	Vernon	1991	19950
River Ridge Golf Course	RR#2 S-17A, C-18, Lumby	Vernon	1990	2650
Royal York Golf Course & R.V. Park	2440 York Ave, Armstrong	Vernon	1990	3128
Spallumcheen Golf & Country Club	9401 Hwy 97 N, Vernon	Vernon	1970	6008
Vernon Golf & Country Club	800 Kalamalka Lake Road, Vernon	Vernon	1903	6597